UNIVERSITY OF NOVI SAD
Technical faculty "Mihajlo Pupin"
Zrenjanin, Republic of Serbia

In cooperation with partners

Industrial Engineering and Environmental Protection

IIZS conference

PROCEEDINGS

V International Conference – Industrial Engineering And Environmental Protection (IIZS 2015)

Zrenjanin, 15-16th October 2015.

University of Novi Sad
Technical faculty “Mihajlo Pupin”
Zrenjanin, Republic of Serbia

V International Conference Industrial Engineering and Environmental Protection (IIZS 2015)

Proceedings

Zrenjanin, 15 - 16th October 2015.

IN COOPERATION WITH PARTNERS:

UNIVERSITY OF AGRICULTURE, FACULTY OF AGRICULTURAL ENGINEERING , KRAKOW, POLAND

TECHNICAL UNIVERSITY-SOFIA, PLOVDIV BRANCH, THE FACULTY OF MECHANICAL ENGINEERING, PLOVDIV, BULGARIA

UNIVERSITY «St. KLIMENT OHRIDSKI«, TECHNICAL FACULTY, BITOLA, MACEDONIA

UNIVERSITY POLITEHNICA TIMISOARA, FACULTY OF ENGINEERING, HUNEDOARA, ROMANIA

UNIVERSITY OF EAST SARAJEVO, FACULTY OF MECHANICAL ENGINEERING EAST SARAJEVO, B&H, REPUBLIC OF SRPSKA

„AUREL VLAICU” UNIVERSITY OF ARAD, FACULTY OF ENGINEERING, ARAD, ROMANIA

UNIVERSITY OF NIŠ, FACULTY OF MECHANICAL ENGINEERING, NIŠ, SERBIA

V International Conference - Industrial Engineering and Environmental Protection (IIZS 2015)

Organizer of the Conference:
Technical faculty “Mihajlo Pupin”, Zrenjanin, University of Novi Sad, Republic of Serbia

Reviewers:
Ph.D James G. Speight, CD&W Inc., Laramie,Wyoming, USA
Ph.D Slawomir Kurpaska, Professor, University of Agriculture in Krakow Institute of Agricultural, Engineering and Informatics
Ph.D Dragiša Tolmač, Professor, Technical faculty “Mihajlo Pupin”, Zrenjanin, Republic of Serbia
Ph.D Miroslav Lambić, Professor, Technical faculty “Mihajlo Pupin”, Zrenjanin, Republic of Serbia

Publisher:
Technical faculty “Mihajlo Pupin”, Zrenjanin, University of Novi Sad

For publisher:
Ph.D Milan Pavlović, Dean of Technical faculty “Mihajlo Pupin”, Zrenjanin

Proceedings Editorial Board:
MSc. Ivan Palinkaš, Technical faculty “Mihajlo Pupin”, Zrenjanin, Republic of Serbia
Ph.D Eleonora Desnica, Technical faculty “Mihajlo Pupin”, Zrenjanin, Republic of Serbia
Ph.D Ljiljana Radovanović, Technical faculty “Mihajlo Pupin”, Zrenjanin, Republic of Serbia
Ph.D Jasmina Pekez, Technical faculty “Mihajlo Pupin”, Zrenjanin, Republic of Serbia
MSc. Jasna Tolmač, Technical faculty “Mihajlo Pupin”, Zrenjanin, Republic of Serbia

Design:
MSc. Stanislava Sinđelić, Technical faculty “Mihajlo Pupin”, Zrenjanin, Republic of Serbia

Lecturer:
MSc. Dragica Ivin, Technical faculty “Mihajlo Pupin”, Zrenjanin, Republic of Serbia

Printed by:
Sajnos doo, Novi Sad
Circulation: 15
ISBN: 978-86-7672-264-8

CIP - Каталогизација у публикацији
Библиотека Матице српске, Нови Сад

62:005.3(082)
502/504(082)

INTERNATIONAL Conference Industrial Engineering and Environmental Protection (5 ; 2015 ; Zrenjanin)
Proceedings / V International Conference Industrial Engineering and Environmental Protection (IIZS 2015), Zrenjanin, 15-16th October 2015 ; [proceedings editorial board Ivan Palinkaš ... et al.]. - Zrenjanin : Technical faculty "Mihajlo Pupin", 2016 (Novi Sad : Sajnos). - 504 str. : ilustr. ; 30 cm

Tiraž 15. - Bibliografija uz svaki rad.

ISBN 978-86-7672-264-8

a) Индустријски инжењеринг - Зборници b) Животна средина - Заштита - Зборници
COBISS.SR-ID 303661831

INTRODUCTION

Departments of Mechanical engineering at Technical Faculty "Mihajlo Pupin", Zrenjanin, organized four international conferences:
1. »PTEP 2011 - Process Technology and Environmental Protection»,
2. «IIZS 2012 - Industrial Engineering and Environmental Protection»,
3. «IIZS 2013 - Industrial Engineering and Environmental Protection»,
4. «IIZS 2014 - Industrial Engineering and Environmental Protection».

Industrial engineering is a field of technique, which includes the processes and procedures, plants, machinery and equipment used in manufacturing final products in different industries. The task of industrial engineers is that on the basis of theoretical and practical knowledge, solve specific problems in engineering practice, and the development of technology in the field of industrial production process.

The theme of scientific conference «IIZS 2015», covers the fields of industrial engineering, which are defined in the program of the conference, such as: Process technology and Energy efficiency, Engineering environmental protection and safety at work, Manufacturing technology and materials, Maintenance, Design and maintenance of process plants, Basic operations, machinery and processes, Oil and gas industry, Computer technologies and engineering education, Biotechnology, Reengineering and project management, Process management.

The main goals of the conference can be indentified here: innovation and expansion of knowledge engineers in industry and environmental protection; support to researchers in presenting the actual results of research projects, establishing new contacts with leading national and international institutions and universities; popularization of the faculty and its leading role in our society and the immediate environment, in order to attract quality young population for studing at our faculty, cooperation with other organizations, public companies and industry; initiative for collecting ideas in solving specific practical problems; interconnection and business contacts; introducing professional and business organizations with results of scientific and technical research; presentation of scientific knowledge and exchange of experiences in the field of industrial engineering.

We express gratitude to:

- The pratners of the conference – University of agriculture, Faculty of agricultural engineering, Krakow, Poland; Technical university-Sofia, Plovdiv branch**,** Faculty of mechanical engineering, Plovdiv, Bulgaria; University «St. Kliment Ohridski«, Technical faculty, Bitola, Macedonia; University Politehnica Timisoara, Faculty of engineering, Hunedoara, Romania; University of East Sarajevo, Faculty of mechanical engineering East Sarajevo, B&H, Republic of Srpska; „Aurel Vlaicu” University of Arad, Faculty of engineering, Arad, Romania; University of Niš, Faculty of mechanical engineering, Niš, Serbia,
- Zrenjanin Town Hall,
- Regional Chamber of Commerce,
- The management of Technical Faculty «Mihajlo Pupin», University of Novi Sad,

for supporting the organization of the conference «IIZS 2015». We are also grateful to all the authors who have contributed with their works to the organization of the scientific meeting «IIZS 2015».

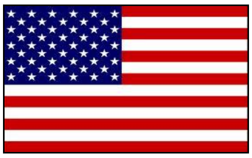
We would like our Conference to become a traditional meeting of researchers, every year. We are open and thankful for all useful suggestions which could contribute that the next, International Conference - Industrial Engineering and Environmental Protection, become better in organizational and program sense.

President of the Organizing Committee
Prof. Ph.D Dragiša Tolmač

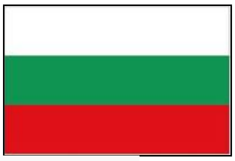
Zrenjanin, 15 - 16th October 2015.

Conference participants are from the following countries:

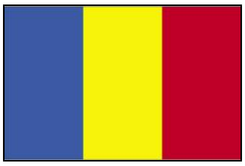
Serbia



United States of America



Republic of Bulgaria



Romania

Libya

Republic of India

Republic of Turkey

Iran

Croatia

Montenegro

FYR Macedonia

Egypt

Bosnia and Herzegovina

CONTENTS

Session 1. Process technology and Energy efficiency

Session 2. Engineering environmental protection and safety at work

Session 3. Manufacturing technologies and materials

Session 4. Maintenance

Session 5. Design and maintenance of process plants

Session 6. Basic operations, machinery and processes

Session 7. Oil and gas industry

Session 8. Computer technologies and engineering education

Session 9. Biotechnology

Session 10. Reengineering and project management

Session 11. Process management

Session 12. Student papers

Session 1.

Process technology and Energy efficiency

A COMPARATIVE ANALYSIS OF SOLAR RESOURCE DATABASES AND GROUND OBSERVATIONS FOR DIFFERENT LOCATIONS IN SERBIA

Snežana Dragićević
University of Kragujevac, Faculty of Technical Sciences in Čačak, Serbia
e-mail: snezana.dragicevic@ftn.kg.ac.rs

Abstract: Renewable energy offers a promising prospect for meeting the power needs of both developing and developed countries as it available in all parts of the world. As the use of solar energy expands, with more and more commercial and residential users investing on solar energy systems around the globe, there is substantial demand for relatively simple, easy-to-use software packages for the planning and performance estimation of solar installations. This paper presents a review of a comparative analysis of different free internet solar databases and ground observations for two locations in Serbia. Results show that the use of solar RETScreen database can obtain precise data on the intensity of the global solar radiation for analyzed locations.
Key words: solar energy, comparative analysis, internet solar database

INTRODUCTION

Solar energy can have an important place in the energy sector of a country as a renewable and inexhaustible energy resource. It is interesting that energy technologies based on the use of solar energy are developed in the most technologically and economically powerful countries, because a number of reasons of which the most important strategic, economic and ecological factors. Solar energy is clean form of energy whose application does not pollute the environment. Solar energy could simply transform directly into heat, and directly or indirectly into electricity, thereby enabling speedy implementation in all energy processes. Use of solar energy in all aspects of energy consumption increase in many countries and offers various possibilities for application. Modern solar systems enable utilization of solar energy throughout the year and at the same time, significantly reduce emissions of harmful gases into the atmosphere.
Solar energy technology is expected to play an important role in attaining the 10 % renewable energy target by 2020. Solar radiation is highly variable in time and space. The annual sum of incoming solar radiation can change significantly from year to year and the variability patterns are quite different each year. The successful and effective utilization of solar energy systems and devices largely depend on the availability of information on solar radiation characteristics of the location in which the system is to be situated. Accurate data of solar radiation is preferably measured at the ground level. Due to high equipment and installation costs often is not financially feasible to install measuring stations. In that case, where ground-measured data is not readily available other solar radiation databases could be used, [1]. This paper shows the assessment of the accuracy of various methods for determining the solar radiation data on the horizontal surface at two different locations in the Republic of Serbia (Belgrade and Zlatibor) and comparing the results of these methods with the values that are at these locations measured over a longer period.

MATERIAL AND METHODS

Internet solar radiation databases

Concerning solar energy sources, there are varieties of databases worldwide today. Free internet solar radiation databases which are mainly used are: PVGIS, ESPA, SoDa, NASA, RETScreen and Meteonorm. In this paper, we analyze the data obtained from PVGIS, RETScreen and SoDa databases.
PVGIS (Photovoltaic Geographical Information System) is the part SOLAREC initiative that aims to contribute to the implementation of renewable energy in the European Union. PVGIS as one of the bases of solar radiation has an advantage compared to other similar databases because the software and the database is open source and available for free public use, [2]. In addition, PVGIS system is made in a

very high geographical resolution of 1x1 km with a simple user interface based on maps. It is estimated that the overall accuracy of the calculations is very high. Detailed geographical, climatic and other data make PVGIS web calculator ideal not only for initial assessment of the systems, but also for serious planning of photovoltaic systems on precisely chosen locations in Europe and Africa.

In this paper we used version PVGIS -3. This version of the software uses a set of data based on measurements carried out on the ground from 1981 to 1990, and which are then interpolated between geographical locations where they performed physical measurements to obtain values for any geographic point. Recently, a new version of this software, PVGIS-CMSAF, which uses a new database for the values of solar radiation provided with the Climate Monitoring Satellite Application Facility (CMSAF) for the period from 1998 to 2010. Taking into account the possible inaccuracies in the earlier measurement instruments on the ground, and the fact that the intensity of solar radiation now slightly higher than 30 years ago when measurements were performed for PVGIS-3, there are indications that PVGIS-CMSAF gives a slightly higher solar radiation.

The RETScreen Clean Energy Project Analysis Software is a decision support tool developed with the contribution of numerous experts from governments, industries and academia. RETScreen is an Excel-based clean energy project analysis provided free-charge, helps decision makers determine the technical and financial viability of potential renewable energy, energy efficiency and cogeneration projects, [3]. The RETScreen Climate Database includes meteorological data and climate data from ground monitoring stations and/or from NASA's global satellite/analysis data. If climate data is not available from a specific ground monitoring stations, data is provided from NASA's satellite data. NASA satellite data within the RETSCreen Climate Database contains a full dataset and maps available from NASA and covers the entire surface of the planet.

SoDa Service is a web-application designed to answer the needs of industry and research for information on several solar resources, [4]. The SoDa Service is a broker to a list of services and web services, i.e. it offers a one-stop access to a large set of information relating to solar radiation and its use. This service itself is not a warehouse. The innovation is that it is made of an Intelligent System that builds links to other resources that are located in various countries. To answer a request, the SoDa service invokes several resources to elaborate the appropriate answer and ensures the flow and exchange of information between the services and itself, as well as with the customer.

The database used was from the free services section and the data was given from HelioCam-1 (HC-1) and HelioCam-3 (HC-3) services, [5]. HC-1 service provides time series of monthly, weekly and daily Global Solar Irradiation values over a horizontal plane, as well as monthly irradiation received by a plane normal to sunrays. The geographical coverage corresponds to the Meteosat satellite field of view, i.e. covers Europe, Africa, Atlantic Ocean, Middle East and the time coverage of data is from 1985 to 2005. HC-3 service provides time series of the radiation components over a horizontal, fix-tilted and normal plane for the actual weather conditions as well as clear-sky conditions. Those databases are based on surface solar radiation estimation from Meteosat Second Generation satellite images. This satellite base method provides an alternative to interpolation methods used by other databases that are based on meteorological ground stations. It enables a better spatial and temporal coverage of data.

Solar resources comparison

The measurement of solar energy radiation over the territory of the former Yugoslavia was organized extent of in 1957, with a network of 13 measuring stations. For the measurement of global, diffuse, and reflected solar radiation were used Second-class pyranometers Moll-Gorezynski, while Linke-Feussner pyrheliometer, class two, was used for measurement of direct solar radiation. The duration of solar radiation was measured by Campbell-Stokes heliograph.

According to the decision of the World Meteorological Organization (WMO) in 1967, Yugoslavia joined the World program monitoring of solar radiation data. Those data are available on World Radiation Data Center Online Archive site. After the abolition of the Yugoslav national center of solar radiation in 1988, the network of measuring stations are gradually extinguished, and in 1991 were completely stopped measurements of solar radiation. Hydro meteorological Service of the Republic of Serbia again started measurement of solar radiation data at the end of 2009.

Serbian energy measurement of global solar radiation during the year is carried out in a small number of meteorological stations, for practical use of solar radiation for production of heat and electricity are

also used data from different solar databases. Given that there are sometimes significant variations in different solar databases, the question arises from the source of data on the energy of solar radiation is the most reliable, or that the database contains data that is closest to the measured values of solar radiation in the local meteorological stations, [6]. This paper present compared of measured energy values of global solar radiation collected by the Yugoslav National Center for solar radiation (now Republic Hydro - Meteorological Service of Serbia) in the period from 1964 to 1991 with data obtained from the Soda HC-1, SoDa HC-3, RETScreen and PVGIS solar databases.
Ground-measured monthly-daily average global solar radiation from databases of the Republic Hydro Meteorological Service of Serbia (RHMS) and the aforementioned Internet database of solar radiation for analyzed location Belgrade and Zlatibor, are shown in Table 1 and Table 2.

Table 1. Monthly average daily solar radiation on a horizontal surface for Belgrade in $\mathrm{kWh/m^2/day}$

Location	Month	RHMS	SoDa HC-1	SoDa HC-3	RETScreen	PVGIS
Belgrade Latitude 44.783 Longitude 20.533	Jan	1.49	1.18	1.58	1.39	1.25
	Feb	2.24	1.97	2.02	2.15	2.00
	Mar	3.47	3.62	3.55	3.38	3.17
	Apr	4.72	4.34	4.75	4.50	4.36
	May	5.80	5.67	5.78	5.59	5.53
	Jun	6.19	6.05	6.45	6.12	5.98
	Jul	6.27	6.38	6.34	6.29	6.30
	Avg	5.59	5.70	5.33	5.53	5.55
	Sep	4.26	4.02	4.11	4.19	4.14
	Oct	2.92	2.99	2.89	2.88	2.71
	Nov	1.74	1.61	1.91	1.54	1.50
	Dec	1.06	1.10	1.16	1.10	1.06
Annual Mean		3.81	3.72	3.82	3.73	3.63

Global annual energy of solar radiation per square meter of horizontal surface on the territory of Belgrade for different bases was calculated with data from the Table 1 and amounts for SoDaHC-1 1358 kWh/m^2, SoDaHC-3 1394 kWh/m^2, RETScreen 1362 kWh/m^2 and PVGIS 1325 kWh/m^2. Ground-measured monthly-daily average global solar radiation from RHMS databases (measuring location Green Hill) was 1391 kWh/m^2. The analysis of the obtained results shows that the deviation is slightly higher in the winter months and lower in the summer months between May and September, when the average daily values of global solar radiation significantly higher than other months.

Table 2. Monthly average daily solar radiation on a horizontal surface for Zlatibor in $\mathrm{kWh/m^2/day}$

Location	Month	RHMS	SoDa HC-1	SoDa HC-3	RETScreen	PVGIS
Zlatibor Latitude 43.733 Longitude 19.717	Jan	1.53	1.52	1.65	1.68	1.38
	Feb	2.35	2.22	1.87	2.48	1.97
	Mar	3.36	3.62	3.34	3.49	3.21
	Apr	4.37	4.35	4.59	4.40	4.44
	May	5.31	5.48	5.31	5.29	5.32
	Jun	5.58	5.88	6.26	5.79	5.99
	Jul	5.80	6.35	6.08	6.00	6.08
	Avg	5.34	5.76	5.33	5.42	5.36
	Sep	4.08	4.16	4.05	4.22	3.72
	Oct	2.98	3.15	3.16	3.04	2.64
	Nov	1.98	1.76	1.89	1.88	1.65
	Dec	1.34	1.33	1.39	1.39	1.16
Annual Mean		3.67	3.80	3.74	3.76	3.58

Global annual energy of solar radiation per square meter of horizontal surface on the Zlatibor for different bases was calculated from the Table 2 and amounts for SoDaHC-1 1387 kWh/m^2, SoDaHC-3

1365 kWh/m^2, RETScreen 1372 kWh/m^2 and PVGIS 1307 kWh/m^2. Ground-measured monthly-daily average global solar radiation from databases of the RHMS was 1340 kWh/m^2.

RESULTS AND DISCUSSION

The performance of the models was evaluated based on the statistical indicators: the mean bias error (MBE), the root mean square error (RMSE), and the mean percentage error (MPE), [7]. These tests are the ones that are the most commonly applied in comparing the models of solar radiation estimations and they are given as:

$$MPE = \frac{1}{N}\sum_{i=1}^{N}\left(\frac{G_{ipred}-G_{iobs}}{G_{iobs}} \times 100\right) \tag{1}$$

$$RMSE = \frac{1}{N}\sum_{i=1}^{N}\sqrt{\left(G_{ipred} - G_{iobs}\right)^2} \tag{2}$$

$$MBE = \frac{1}{N}\sum_{i=1}^{N}\left(G_{ipred} - G_{iobs}\right) \tag{3}$$

where G_{iobs} is the i_{th} observed ground measured value of monthly global radiation on a horizontal surface, G_{ipred} is the i_{th} computed value monthly global radiation on the same surface, and N is the total number of observation.

The MPE is the percentage deviation of the calculated and measured monthly average daily global solar radiation data. A positive MPE values provides the averages amount of overestimation in the calculated values, while the negative value gives underestimation. A low value of MPE is desirable. The RMSE provides information on the short-term performance of the correlations by allowing a term-by-term comparison of the deviation between the calculated and measured values. Lower RMSE values reflect a better model in terms of its absolute deviation, but a few large errors in the sum can produce a significant increase in the indicator. The MBE reveals whether a given model has a tendency to under or over predict. A positive value of MBE shows an over-estimate while a negative value represents an under-estimate by the model, with MBE values closest to zero being desirable. It is possible to have large RMSE values at the same time a small MBE or vice versa. The use of RMSE and MBE statistical indicator is not adequate for the evaluation of models performance but usage MPE in addition to RMSE and MBE give results that are more reliable. To analyze the comparison in detail, statistical equation (1-3) were used to calculated values of MPE, RMSE and MBE of the selected data. Ground measured data was used as the reference in this analysis.

Table 3. Comparison of various statistical methods for global radiation data

Data	MPE (%)	RMSE (kWh/m^2)	MBE (kWh/m^2)
BELGRADE			
SoDa HC-1	-3.69	0.20	-0.09
SoDa HC-3	2.18	0.15	0.11
RETScreen	-1.85	0.12	-0.09
PVGIS	-6.27	0.22	-0.18
ZLATIBOR			
SoDa HC-1	1.90	0.25	0.13
SoDa HC-3	2.10	0.27	0.09
RETScreen	1.70	0.12	0.08
PVGIS	-5.54	0.26	-0.08

From Table 3, it is observed that the best results of statistical indicators were obtained from RETScreen data, for both analyzed locations. MPE values calculated showed an underestimation throughout the entire PVGIS database, and overestimation throughout the entire SoDa HC-3 database. Results shows that of the data compared with the ground measured data, RETScreen is more reliable and can be used for most solar energy applications. SoDa HC-3 free database has the highest error margins in this analysis.

The findings in this paper go in line with the findings of Remund and Muller where they recorded MPEs of between 2-10 % for worldwide data, [8]. Also, those findings are strongly in-line with the works of Moujaled where he recorded the best results of statistical indicators from RETScreen database, [1].

CONCLUSION

Information about solar resources and the intensity of solar radiation is necessary in all phases of development projects for the use of solar systems. The ability to identify differences in values measured / estimated at various solar insulation databases for a particular site may represent a valuable contribution to the planning and decision-making, since the differences in precision estimates may have a significant impact on performance prediction of solar systems. The importance of research precision databases of solar radiation is particularly pronounced in areas where there is no active network of systematic measurement of solar radiation, such as Serbia.

According to obtained results, we can conclude that data from RETScreen database has the least deviation of the mean annual energy values of global solar radiation during the day gets on one square meter of horizontal surface on the ground in relation to RHMS solar database. This result stems from the fact that RETScreen and RHMS solar databases have very similar periods in which measurements of solar radiation were performed. RETScreen database has data of 24 years of measurement and RHMS has collection of 27 years of ground-measured data.

As a slightly worse, the results of SoDa HC-3 solar database are shown. It should be noted that in this study a free version of SoDa HC-3 base is used, which has a very short period in which the information was collected. However, this is one of the most modern methods and it is very unlikely that a commercial version also yielded very good results.

REFERENCES

[1] Moujaled, J.K., A Comparative assessment of solar resources databases, simulations and ground observation for Kumasi, Master thesis, Department of Mechanical Engineering, College of Engineering, Kwame Nkrumah University of Science and Technology, Ghana, 2014.

[2] Axaopoulos, P.J, Fylladitakis, E.D., Gkarakis, K., Accuracy analysis of software for the estimation and planning of photovoltaic installations, International Journal of Energy and Environmental Engineering, 5:1, 2014. doi:10.1186/2251-6832-5-1

[3] Pavlović, T., Milosavljević, D., Piršl, D., Simulation of photovoltaic systems electricity generation using Homer software in specific locations in Serbia, Thermal Science, Vol.17, No.2, pp. 333-347, 2012.

[4] Gschwind, B., Ménard, L., Ranchin, T., Wald, L., Stackhouse, P., A proposal for a thesaurus for web services in solar radiation, In Proceedings EnviroInfo 2007, Vol.1, pp. 135-142, 2007.

[5] Cros, S., Albuisson, M., Lefevre, M., Rigollier, C., Wald, L., HelioClim: a long-term database on solar radiation for Europe and Africa, Proceedings of Eurosun 2004, PSE GmbH Freiburg, Germany, pp. 916-920, 2004.

[6] Dragićević, S., Estimation of global solar radiation in Serbia, Procedings of IV International Conference Industrial Engineering And Environmental Protection, October 15th, 2014, Zrenjanin, Serbia, pp. 40-45, 2014.

[7] Katiyar, A.K., Kumar, A., Pandey, C.K., Das, B., A comparative study of monthly mean daily clear sky radiation over India, International Journal of Energy and Environment, Vol.1, No.1, pp.177-182, 2010.

[8] Remund, J., Muller, S.C., Solar radiation and uncertainty informatipn of Meteornom 7, 26th European Photovoltaic Solar Energy Conference and Exhibition, pp. 4388-4390, 2011.

SOLAR IRRADIATION ON THE PV MODULES WITH ORIENTATION 0° AND 40° - AND INCLINATION β_{OPT}, 0°, 45° AND 90°

Miroslav Lambić
University of Novi Sad, Technical Faculty "Mihajlo Pupin", Zrenjanin, Serbia
e-mail: lambicmiroslav@yahoo.com

Abstract: In practice it is often the dilemma of designers and users of solar installations, in particular regarding the orientation of PV modules to the building. Therefore, in different buildings - especially those who do not have suitable oriented (South) area setting PV modules done in supporting structures that are more complex, more expensive, less accessible, worse visual effect and other. It is often not justified, especially when it comes to deviations up to a maximum of 40° South orientation.
The paper presents data on the value of solar irradiance at the surface with an orientation of 0° and 40° - in optimal angle and angle of 0°, 45° and 90°.
Key words: Solar irradiation, PV moduls, orientation and inclination angle

INTRODUCTION

Orientation and inclination of the receiving surface of the solar radiation for different locations, are described in detail a large number of current literature on solar energy. Derived (build) solar plants with photovoltaic modules are located on different objects or surfaces - under different slopes and different orientations of receiving surface in relation to the South. It directly affects the value of useful amounts received electricity energy from solar radiation. The widest use of solar systems in urban and rural areas where the PV modules are installed on different residential, commercial, industrial and other facilities. At such facilities are set smaller photovoltaic systems to generate electricity. As for the locations of larger systems (systems with higher power), mainly solar power - they are commonly performed in supporting structures placed on the ground, rather than on functional parts of different objects. In these - predominantly - a number of cases are easy and always ensures south facing solar PV module, wherein they are placed under optimum annual inclination for obtaining maximum amounts of energy from such immovable surface - solar PV modules. The specific situations, it is when the receiving surface are not under the annual optimal slope, but under a different slope which is suitable for a seasonal system. In this case, at such inclinations in the respective periods of the year receives the maximum energy effect, while in other periods of the year this effect is much smaller. But often, favorably oriented (and the optimum angle) of the surface for installation of solar PV modules are not available in practice.

OVERVIEW OF REFERENCE LITERATURE

In lit. [1-4] there is data provided on the value of solar irradiation on a horizontal surface [1] and the surface at an angle of 35, 45 and 55 [2,3,4]. Cited literature [1-4] contains a number of data, diagrams and figures which are essential for proper evaluation, assessment and dimensioning of solar installations (thermal and photovoltaic). Data relating to the selection of the solar system, determining the size of the receiving surface and energy monthly and yearly effects. The present energy effects relating to thermal collectors and photovoltaic modules that are located in the cities of Serbia and under different slopes (0°, 30°, 45° and under optimum slope). However, apart from the aforementioned literature sources and other sources - domestic and foreign do not provide precise data on irradiation at the surface whose orientation differs from the south. The above references are given tabular data to determine the values of incident energy at different inclined surfaces whose orientation deviates from south orientation. In this regard, program PVGIS provides data, except for the different slopes of the gripping surfaces and to their different orientations.
For solar plants and irradiations conditions in Vojvodina a study has been done on the potential use of solar energy - lit. [1] where they are tabulated, for many cities, the data for the values of incident energy with the reception areas under different slopes and clear southern exposure.

In lit. [2, 3] there is information about the values of solar energy under different slopes and clear southern exposure reception area for larger cities in the Republic of Serbia. The research results related to the value produced useful electrical energy for PV modules with orientations: vertically Southern, vertically - Eastern, vertical - Western, horizontal and inclined surfaces optimally are given in lit. [4]. It was found that in a measurement period from August 1 to December 1 (2014 yr.) With PN module surface of 0.407 m^2 - energy obtained:

- To the south oriented modules at an angle of inclination from 90° - gained 11.45 kWh,
- The south-oriented module, the angle is 0° - gained 12.58 kWh and
- To the south oriented modules at an angle of 33° - received 15.7 kWh.

The aim is to show through a concrete example to indicate to the designers of solar systems that the values of incident energy at different oriented surfaces are important, but their value is so small that it must resort to constructive concepts of support structures in order to ensure a fully south facing PV - modules. This provides less investment in the support structure, better adjustment to the fields of solar PV module geometry object, better visual effects, etc. ii. Of course, this does not imply performing solution in which there is a substantial deviation from South orientation, because then the energy effects are significantly lower. In drafting and making decisions on the orientation of solar PV modules it is necessary to perform optimization analysis of energy effects and conditions set, and especially keep in mind the daily cycle of energy consumption in a particular house.

THE SOLAR IRRADIATION

Tables 1 to 3 give information about values 1 solar energy for the following cases (according PVGIS program - Photovoltaic Geographical Information System - JRC - European Commission - http://re.jrc.ec.europa.eu/pvgis/apps3/pvest .php). Data is given for the city of Kikinda - Serbia (Location: 45°48'20 "North, 20°28'22" East):

- Tilt: 0°, 45°, 90° and optimal slope,
- Orientation: 0° and 40° - Southwest.

Table 1. Monthly Solar Irradiation: orientation = 0°, inclination = 0°, optimall angle = 34°, 45° and 90° (PVGIS Estimates of long-term monthly averages; Location: 45°48'20" North, 20°28'22" East)

Month	H_h	H_{opt}	H(45)	H(90)
Jan	1070	1630	1730	1620
Feb	1790	2510	2610	2270
Mar	3520	4470	4540	3500
Apr	4900	5470	5360	3420
May	5740	5780	5480	2940
Jun	6310	6060	5670	2740
Jul	6420	6320	5950	2960
Aug	5710	6200	6010	3490
Sep	3980	4880	4900	3540
Oct	2730	3930	4100	3510
Nov	1510	2450	2630	2490
Dec	865	1330	1420	1350
Year	3720	4260	4210	2820

H_h: Irradiation on horizontal plane (Wh/m^2/day)
H_{opt}: Irradiation on optimally inclined plane (Wh/m^2/day) - Optimal inclination angle is: 34 degrees
H(45): Irradiation on plane at angle: 45deg. (Wh/m^2/day)
H(90): Irradiation on plane at angle: 90deg. (Wh/m^2/day)

Table 2. The optimum slope of receiving surface. Orientation receiving surface: South and 40° - deviations from the south (PVGIS Estimates of long-term monthly averages; Location: 45°48'20" North, 20°28'22" East)

Month	H_d	H_m	H_d	H_m
	inclination=34° orientation=0°	inclination=34° orientation=0°	inclination=31° orientation=40°	inclination=31° orientation=40°
Jan	1.63	50.5	1.46	45.1
Feb	2.51	70.2	2.28	63.8
Mar	4.47	138	4.18	130
Apr	5.47	164	5.32	160
May	5.78	179	5.78	179
Jun	6.06	182	6.15	184
Jul	6.32	196	6.36	197
Aug	6.20	192	6.07	188
Sep	4.88	146	4.60	138
Oct	3.93	122	3.56	110
Nov	2.45	73.5	2.16	64.8
Dec	1.33	41.3	1.18	36.7
Yearly average	**4.26**	**130**	**4.10**	**125**
Total for year		**1560**		**1500**

H_d: Average daily sum of global irradiation per square meter received by the modules of the given system (kWh/m^2)
H_m: Average monthly sum of global irradiation per square meter received by the modules of the given system (kWh/m^2)

Table 3. Average sum of global irradiation per square meter received by the modules of the given system (kWh/m^2): inclination=90°, 45°, 0°; orientation=0°, 40° (PVGIS estimates of solar electricity generation; Location: 45°48'20" North, 20°28'22" East)

Month	H_m inclination=90°, orientation=40°	H_m inclination=45°, orientation=0°	H_m inclination=45°, orientation=40°	H_m inclination=0°, orientation=0°
Jan	41.7	56.7	50.1	33.3
Feb	53.8	79.3	71.5	50.1
Mar	97.6	144	134	109
Apr	103	162	157	147
May	101	173	173	178
Jun	96.9	173	176	189
Jul	106	187	189	199
Aug	114	187	183	177
Sep	97.7	151	142	119
Oct	92.5	132	119	84.7
Nov	61.4	81.7	71.7	45.4
Dec	34.6	47.3	41.9	26.8
Yearly average	**83.3**	**131**	**126**	**113**
Total for year	**1000**	**1570**	**1510**	**1360**

COMPARATIVE VALUES OF INCIDENT ENERGY

The diagrams - Figure 1 shows a comparative view average daily solar radiation on:

a) an inclined surface 45° and a southern orientation - for the month of January,
b) an inclined surface 45° and a southern orientation - for the month of July,
c) an inclined surface 45° and the orientation of the surface to 40° departs from the South - for the month of January and
d) an inclined surface 45° and the orientation of the surface to 40° departs from the South - for the month of July.

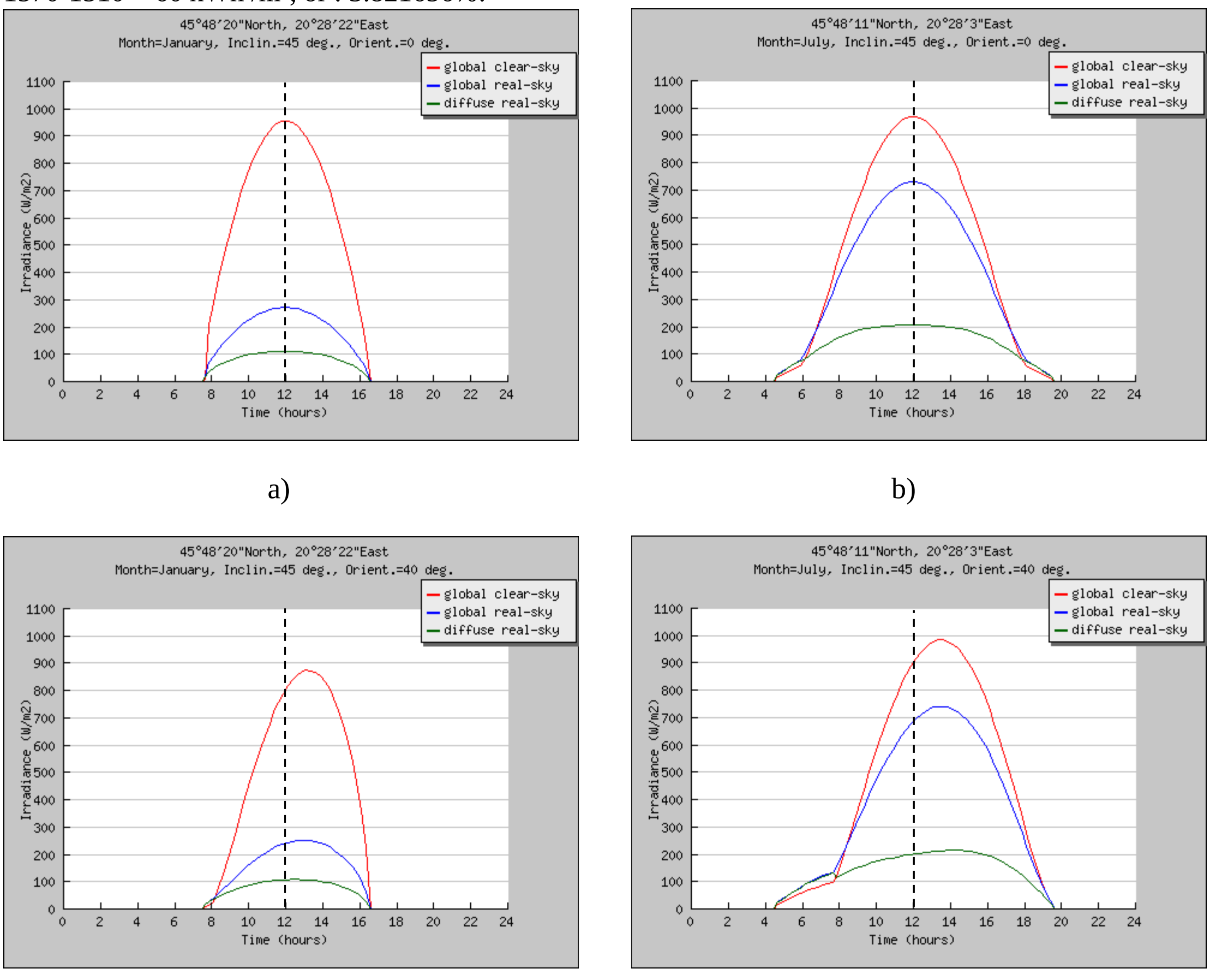
Figure 1 shows that the total radiated energy to a receiving surface - greater in south orientated area compared to the one that is south oriented. Radiated energy to the surface oriented toward the southwest, with deviation from the south to 40°, the greater the afternoon (after 12 hours) compared to the value of incident energy (after 12 hours) to the south oriented surface (under the same pitch). To a certain extent reduces the overall reduction of incident energy so orientated area in relation to the south oriented surface.

Average daily radiation during the year (for the location) in comparison to the optimum slope of 34° less:

- The slope of the 0°: 4260-3720 = 540 Wh /m^2 / day, respectively: 12,676 %
- The slope of the 45°: 4260-4210 = 50 Wh / m^2 /day, respectively: 1.11734 %
- The slope of the 90°: 4260-2820 = 1440 Wh /m^2 / day, respectively: 33.8028 %.

Average annual energy radiated to the optimal inclined surface oriented toward the South with respect to optimally tilted surface whose orientation differs from the South for 40° - to the Southwest - is lower: 1560-1500 = 60 kWh / m^2, respectively: 3.846%!

Average annual energy radiated to the surface at an angle of 45° - oriented towards the South to the surface tilted at the same angle (45°), whose orientation differs from the South for 40° -by Southwest - is lower: 1570-1510 = 60 kWh /m^2, or : 3.821656%!



a) b)

c) d)

Figure 1. Average daily sum irradiance: a) Januar, inclination: 45°, orientation: 0°; b) July, inclination: 45°, orientation: 0°; c) Januar, inclination: 45°, orientation: 40°; d) July, inclination: 45°, orientation: 40°

CONCLUSION

In practice, there is often a situation when setting PV modules on buildings (roof or façade) whose orientation or configuration is not suitable for direct placement and orientation of PV modules to the South. In such cases, setting up PV module with an orientation which more or less deviates from the South should not be avoided. At the same time decreased energy yield is not very pronounced if these aberrations to 40°. The deviation from South orientation higher - investment in the supporting structure may (not must) be greater. For each specific case of pronounced deviations from the possible orientations of modules from the South it is necessary to carry out technical and economic feasibility of implementation of such solutions. The analysis refers to the cost of increased investment in the system (including, possibly, greater investment in supporting the construction and installation) and the value of decreased energy effects.
The paper shows that the energetic effects declined by about 4% in systems in which the PV modules are placed so that their orientation varies from the south to 40° (at an inclination of 45° - for a given location).

Acknowledgements

This work was supported by the Serbian Ministry of Education, Science and Technological Development, project number TR 33009.

REFERENCES

[1] Lambić, M. et all: Study on the estimation of overall solar potential - solar atlas and the possibility of "production" and use of solar energy on the territory of AP Vojvodina, - studies, the Executive Council of AP Vojvodina, Provincial Secretariat for Energy and min. Resources, Novi Sad, 2011.
[2] Lambic, M.: The solar technology - Heat and photoelectric systems, "AGM book", Belgrade, 2013.
[3] Lambic, M.: Solar energy, Zavod za udžbenike, Belgrade, 2015.
[4] Pavlović, T.; Tripanagnostopoulos, Y.; Mirjanić, D.; D. Milosavljević: Solar Energy in Serbia, Greece and the Republic of Srpska, Academy of Sc. And Arts of the R. of Srpska, Banja Luka, 2015.
[5] Radosavljevic, J .; Pavlovic, M .; Lambic, M .: Solar Energy and Sustainable Development, Građevinska knjiga, Belgrade, 2004.
[6] Weiss, W. Mauthner, F .: Solar Heat Worldwide, SHC, International Energy Agency, 2014.
[7] Lambic, M.: The basic concept of supporting structures of PV modules, Proceedings of Scientific Forum: Energy Technology – 2012, Vrnjačka Banja, May, 2012, (p. 8 / 1-5).
[8] Lambic, M.: DESIGN AND FINANCING OF THE CONSTRUCTION OF SOLAR INSTALLATIONS, Proceedings of the scientific conference: Energy Technology - 2011, Vrnjačka Banja, June, 2011, (p. 3 / 1-6).

ENERGY SYSTEMS BASED ON THE USE OF ALTERNATIVE ENERGY SOURCES IN THE DEGRADED AREA OF MINING AND ENERGY COMPLEXES AS THE ALTERNATIVE OF ENERGY EFFICIENCY AND SUSTAINABLE DEVELOPMENT

Jelena Malenovic Nikolić[1], Jasmina Radosavljević[1], Dejan Vasović[1]
[1]University of Niš, Faculty of occupational safety, Niš, Serbia
e-mail: jasmina.radosavljevic@znrfak.ni.ac.rs

Abstract: Increased energy efficiency and implementation of the principles of sustainable development in the energy industry is based on concurrent use of alternative and classical energy sources. Integration of modern methods of environmental management allows simultaneous use of solar and wind energy in deserted and degraded surface mines. This paper discusses the integration of the Balanced Scorecard for the purpose of creating a basis for the elimination of any shortcomings in the development of alternative and classical energy sources.
Key words: energy systems, alternative energy, mining and energy complexes, sustainable development

INTRODUCTION

Exploitation of non-renewable energy resources is a major problem, especially if one considers that non-renewable energy source reserves are decreasing and that renewable sources are insufficiently utilised. Energy issues and energy crises do not result in energy conservation, even though that would be an acceptable solution from the environmental perspective, as well. Human need for a more comfortable life grows daily, so the available primary environmental elements are of a lower quality – by wasting energy, people breathe polluted air, drink water from the rivers into which they released wastewater, and eat food grown in contaminated soil.

MATERIAL AND METHODS

Environmental issues

The impact of surface mining on environmental quality depends on the capacity of mining machinery, productivity, and weather conditions. Formation of a number of benches on stepped walls, which are drained by precipitation, accumulates wastewater in the surface mine. Surface coal mining [1] is characterised by dust dispersion in every stage of the technological process. Air quality is also affected by emission of exhausts from mining machinery and transport vehicles. To a greater or smaller extent, dust emission accompanies every stage of coal mining. Disposal of tailings is the second or final stage of the technological process of coal mining, and it is accompanied by dust and exhaust emissions. Recultivation and remediation of the tailings pond is the final stage of the disposal of tailings, which is often overlooked in our country, resulting in unnecessary loss of arable land, dust emissions, and wastewater due to tailings pond drainage.
Whether it is done within or outside the surface mine [2,3], the transport of coal and tailings reduces environmental quality. Transport depends on weather conditions, arrangement of mining machinery, and road quality. Weather conditions affect air pollution during increased wind activity, which scatters dust from the roads and coal particles from vehicles; they also affect soil quality during the rainy season, when dust is washed off the roads.
Coal combustion in thermal power stations causes emissions of gaseous and solid pollutants, which are often emitted into the atmosphere without sufficient filtration, thus endangering human health.
The impact of coal mining and combustion on environmental quality is shown in Figure 1 and Figure 2.

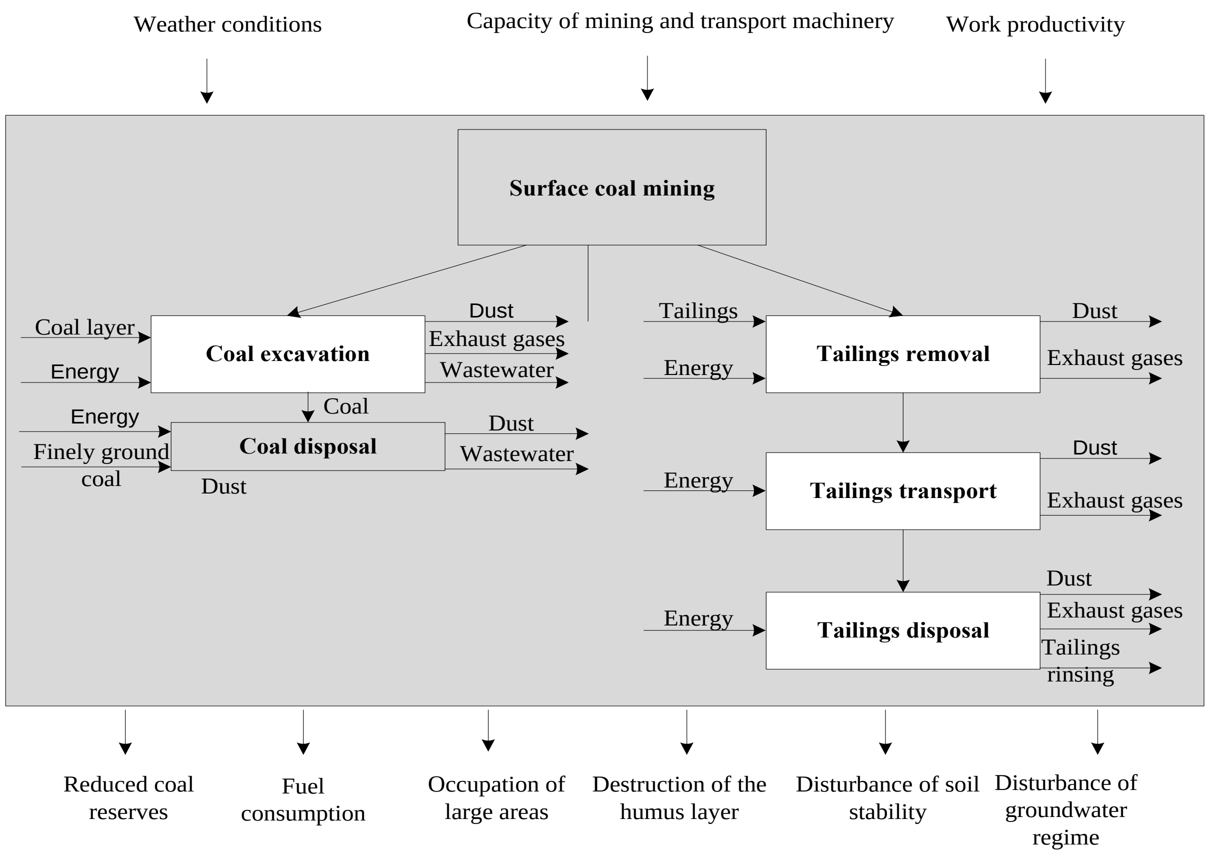


Figure 1 Environmental issues due to surface mining

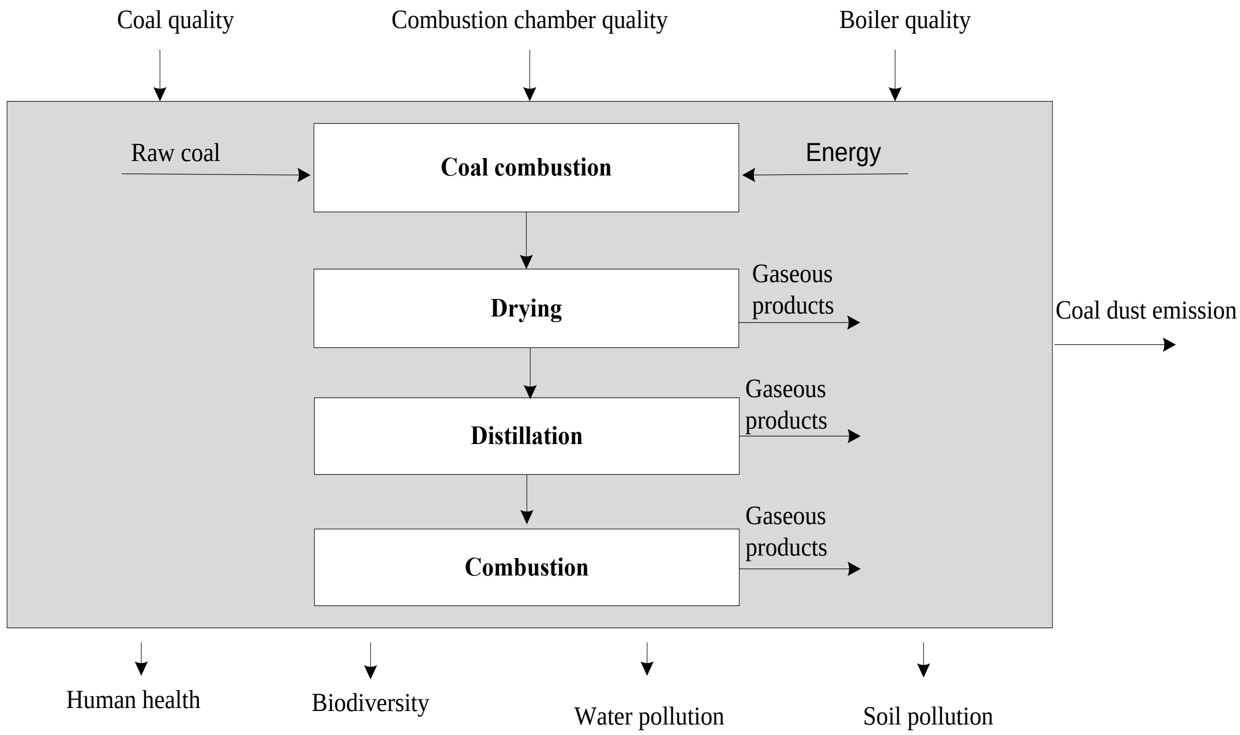


Figure 2 Environmental issues due to coal combustion

Ecological aspects of environmental protection and strategic prospects of the Balanced Scorecard

The standard framework of Balanced Scorecard (BSC) implementation is based on the key strategic perspectives [6-1], which include finance (F), users (U), internal processes (IP), and learning and development (LD). The energy industry is among the more profitable branches of economy, so strategic perspectives concerning finance are very important. Sustainability Balanced scorecard (SBSC) is aimed towards defining the relevant strategic environmental and social goals by focusing on the provision of finances, environmental protection, and social development.
The BSC enables the use of modern environmental management systems based on concurrent development of alternative and classical energy sources. This method allows the unification of energy transformation procedures for the purpose of enabling environmental quality preservation. Definition of parallel energy transformation processes leads to higher energy efficiency [4] and lower pollutant emissions in relation to the amount of distributed energy.

RESULTS AND DISCUSSION

The most complex mode of SBSC [5] use in energy industry is the introduction of renewable energy sources, as a market-oriented environmental perspective. The proposed solution can provide additional economic benefit, while reducing the need for remediation. Transversal SBSC will allow profit increase and harmonization of business operations with the principles of sustainable development accompanied by the use of alternative energy sources and compliance with the principles of sustainable development. The proposal of BSC strategy implementation is given in Table 1.

Table 1 Implementation of progressive BSC strategy in energy systems

<table>
<tr><td>Implementation goal</td><td colspan="2">Strategy planning of mining and energy complexes aimed at developing the existing market and enable the development of Serbian energy industry and environmental quality</td></tr>
<tr><td>Implementation proposal</td><td colspan="2">Renewable energy sources, recultivation of old and addition of new park areas, remediation and allotment of space for the placement of solar and wind energy technology</td></tr>
<tr><td rowspan="5">SBSC Type</td><td>Total SBSC</td><td>Integration of all environmental and social aspects (ESA) into every strategic perspective</td></tr>
<tr><td>ESA-F</td><td>Financial investment in the development of alternative energy according to the financial ability of the mining and energy complex</td></tr>
<tr><td>ESA-U</td><td>Provision of additional amounts of electricity for users mitigates the difficult electric energy situation in the country and helps stabilize the electrical grid</td></tr>
<tr><td>ESA-IP</td><td>Selection of suitable locations for the use of solar and wind energy and creation of a basis for the generation of higher profit</td></tr>
<tr><td>ESA-LD</td><td>Prediction of economic benefits of using alternative energy sources and familiarization with the manner and duration of the return on investment</td></tr>
</table>

	Additive SBSC	**Integration of new environmental and social aspects (ESA) as a separate perspective**
	ESA	Use of alternative energy sources with the government's help through assets allocated for the improvement of energy efficiency, while reducing the energy industry's impact on environmental pollution and raising the country's status on the environmental maps of Europe
	Transversal SBSC	**Integration of environmental and social aspects (ESA) as the leading principles for all strategic perspectives**
	ESA-F	Financial investment that is oriented towards the development of alternative energy sources and generation of higher profit through increased flexibility in terms of selecting the most suitable development opportunities
	ESA-U	Connection to the electrical grid; substantial contribution to the development of alternative energy sources; and favourable impact on the energy source structure in the country's energy balance
	ESA-IP	Use of solar and wind energy in every suitable location of the mining and energy complex
	ESA-LD	Personnel training for using alternative sources; equipment selection; and designation of locations within the mining and energy complex for expanding capacities and increasing energy conversion efficiency
Implementation results	**Development of management strategy for the mining and energy complex towards developing the environmental market**	

CONCLUSION

Use of alternative energy sources as a new environmental aspect can contribute to both financial stability and preservation of environmental quality. The total structure implies giving priority to environmental aspects during the planning of financial investment, customer relations, internal processes, and employee training. The conditions in the Serbian electricity sector warrant the implementation of transversal SBSC, but also require considerable government support.

REFERENCES

[1] Study on Environmental Impact Assessment for the Construction Project of a New Block (B3) at TE "Kostolac B", Faculty of Mechanical Engineering and Faculty of Mining and Geology, Belgrade, 2013

[2] N. R. Grujic, M. Trifunovic, Z. Pesic, Electrical Energy Production from Coal and its impacts on Environment, Journal of Environmental Protection and EcologyVol. 15, No 1, 2014, pp. 16–22

[3] A.-D. Gheorghiu, Z. Torok, A. Ozunu, How Can Existing Risk Assessment Methodologies be bsed in a systematic maner, in the extractive mining industry?, Journal of Environmental Protection and Ecology 14, No 4, 2013, pp.1597–1607

[4] M.A. Uyterlinde,.W.G. Arkel, H.Burger, A.W.N. Dril, H.Jeeninga, P.Kroon, Monitoring Enery Efficiency Indikators, Dutch contribution to the project 'Cross country comparison on energy efficiency- Phase 6, 2000

[5] I. Dias, L. Rejinders, P. Antunes, From environmental Performance Evaluation to Eco-Efficiency and Sustainability Balanced Scorecard, Wiley InterScience, 2003

CONCEPTUAL DESIGN SOLUTION OF HEATING THE TOWN OF ZRENJANIN ENERGY FROM BIOMASS

Dragiša Tolmač[1], Jasna Tolmač[1], Slavica Prvulović[1], Sanja Stankov[1], Zlatko Košut[2]
[1]University of Novi Sad, Technical faculty "Mihajlo Pupin", Zrenjanin, Serbia
[2]Victoria Starch, Zrenjanin, Serbia
e-mail: dragisatolmac@gmail.com

Abstract: This paper considers the possibility of heating of Zrenjanin, using energy from biomass. Fuel wood pellets, derived from cereal straw. Victoria Starch Company, has two steam boilers of 2x16, 25 MW = 32.5 MW, and used as fuel pellets from biomass. This paper provides an overview of the available materials and the analysis of the cost of investments.
Key words: project, heating, biomass

INTRODUCTION

Consumer supply heat to the Zrenjanin was started in 1970. Year. Implementation of the "Jug" was conducted in 1971. The construction of the exchanger stations steam-hot water heat power of 12.5 MW and the main hot water line DN 400, which connected the "power plants" the existing consumers of thermal energy village 4 july and Little America. With the connection of new customers and increased power stations (steam-hot water) to 45 MW. Heating program from the city of Zrenjanin in 1976. was completed in 1981. construction exchanger stations power 90 MW. Of the heating season 2010/11., Started operating a new production plant with 70 MW of heat supply in the city of Zrenjanin, since due to the economic crisis, a lot of customers off the heat network. For the supply of heat to raspoladganju are 2 hot water boilers each with a capacity of 35 MW with fuel-natural gas.

MATERIAL AND METHODS

Victoria Starch has two boilers for steam production capacity of 50 tons per hour (2 x 25 tons) pressure 12 bar and temperature of 180 ° C, the motor fuel to biomass - pellets of straw cereals. Translated into thermal power is the max . 2x16 , 25 = 32.5 MW.
So Victoria Starch , a capacity that can provide about 50 % of the existing heat production in Zrenjanin , with a very good business for the parameters in Victoria Starch and in city Zrenjanin . This startup of biomass boilers , it is possible to train and organize the work process steam production and pre-construction and commissioning of the plant for the production of starch .
The energy value of a cubic meter of natural gas is theoretically 33.338.35 kJ/m^3 . (source Novi Sad gas http://www.novisadgas.rs/korisnici/ official website)
The energy value of straw pellet weight is 16.500 kJ / kg (European Committee for Standardization, CEN TC335 committee under published 27 technical specifications (preliminary standards) for solid fuels during the 2003-2006 year (Alakangas , 2010) . These specifications are supplemented and adopted as European standards (ENplus) 2010. .) http://www.poljoprivrednatehnika.org.rs
The above data show that the two koligram enough pellets to replace 1 m^3 of natural gas , and with the current price of 40,48 dinars. Production price of straw pellets is currently around 8 dinars / kg.
Based on this, we have the following balance :
1m^3 gas = 2 kg pellets: 33.000 kJ/m^3= 2 x 16.500 kJ / kg, 40,48 dinars (=) 16 dinars.
These data indicate that for the same amount of energy is required to extract 2.5 times less money.
In Figure 1, which is attached hereto , owned by Victoria Starch are most necessary mechanical and technological equipment which would allow heating of the town .

<u>Mechanical technological equipment and documentation that exists</u>

1. Boilers for steam production with equipment located in Victoria Starch company in Zrenjanin, capacity 2x25 t / h, of steam , which is 32,5 MW.

2. Projekti boiler construction are completed.
3. Heat exchangers, steam - heat hot water are located in Zrenjanin (in the old sugar mill) and requires repair . Surface heat is about 330 m^2, which fully meets capacity.
4. Object for installation of boilers also exists but is in need of renovation - raising the roof on the existing design.
5. Pump for hot water circulation and the associated pumps also exist in the old sugar refinery
6. Well water supply and there is also a fully equipped.
7. Supply electricity is provided - were repaired and put into operation the appropriate substation.
8. Drainage also trained and ready for use.

Mechanical technological equipment to be purchased

1. Boilers service elements for which projects are part of the boiler (chimney , filters, ash handling , transport- introduction of pellets)
2. Chemical treatment boiler water treatment capacity of 10 m^3 / h
3. Pipelines to connect boiler and heat exchanger as well as connecting with the city heating plant.

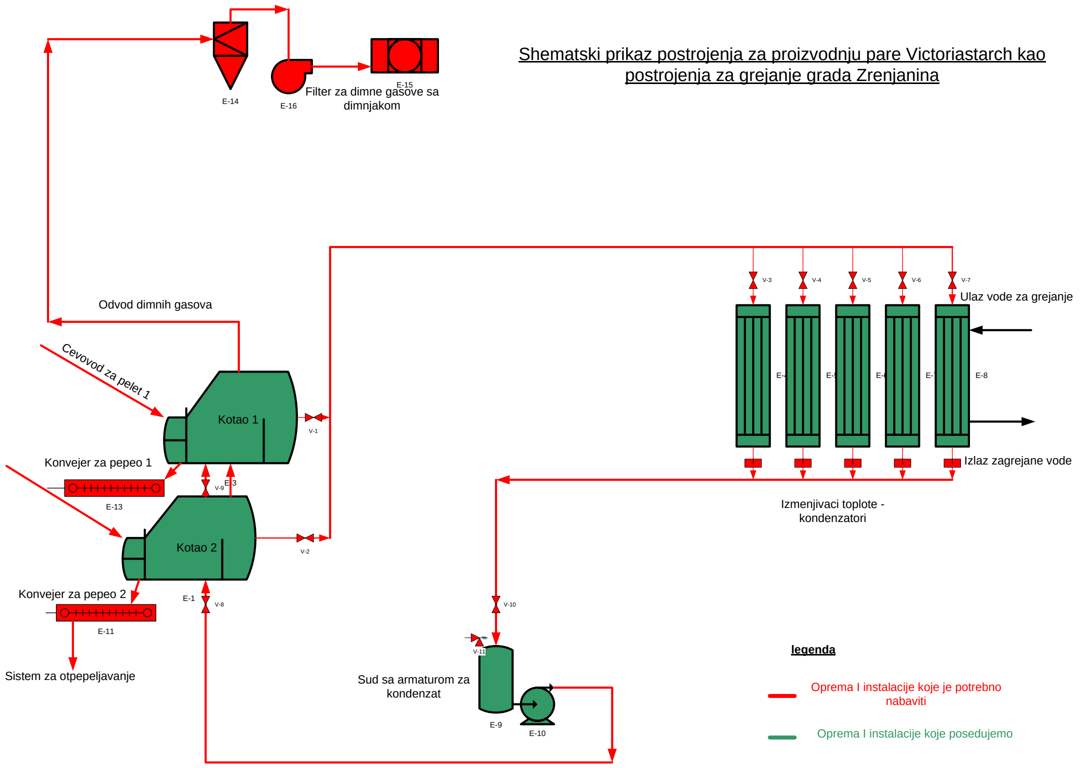


Figure 1. Technological scheme of plant steam production Victoriastarch and heating town of Zrenjanin.

ANALYSIS OF INVESTMENT IN PLANT CITY HEATING

Based on the data we PUC - District Heating delivers heat from October 15 until April 15, which means 183 days, on average, 14 hours (07.00 and 21.00), except for the cold days, on average, 20 days a year when the heat is supplied 24 hours a day.
These data indicate that the boilers operate 2282 + 480 = 2762 hours per year. The data available to indicate that if the boiler is operating at full capacity - consumes about 3545 m^3 / h, of natural gas as the current gas price 40,72 dinars/m^3, is 144.352 dinars / h, if you count that one of the boilers to be

leading in this case, the priority is heat produced in Victoriastarch-in, we get: 8 RSD / kilo of pellets (two pounds an energy equivalent to 1 m^3 of natural gas), heat per hour is 64.000 3542 x 8 x 2 = 56.720 RSD / h.

At the level of the heating season gas heating costs 398 700 224 dinars, or € 3,591,894

At the level of the heating season heating with pellets is 156 660 640 dinars, or € 1,411,357

On the difference in price of about 2,180,537 € / year. - One heating season, it is necessary economic analysis to the PUC District Heating, entered into cooperation with Victorijastarch included, but estimates show that for nearly two heating season comes to a complete repayment of investments so that the investment in the production of starch had fully repaid the boiler room .

PRODUCTION PRICE OF ENERGY

Based on the information we have, the JKP - District Heating, delivers thermal energy of 15 October through 15 April, which means 183 days , on average, 14 hours (07.00 and 21.00) izuyev cold days , on average, 20 days a year when the heat is supplied 24 hours a day. These data indicate that the boilers operate 2282 +480 = 2762 h / year (data obtained from plants) . If you calculate the maximum production of both the boiler 50 t / h of steam for one year - the heating season produced 89.753 MWh of energy - water vapor.

1. Costs energy
For one MWh of steam needed 295 kg of pellets of standard quality . A value of energy 8 din / kg of pellets, it is annually 211. 817. 080 dinars, or 1.908.262 € / year.

2. Costs electricity
Since we found that boiler work 2762 hours a year, while the installed electrical power of 1.2 MW for each boiler so that the boiler in the heating season to spend 3,314,400 kWh at a cost of 4.2 dinars / kWh, is one of the heating season 13,920,480 dinars, or € 125,184 / year .
Power is taken as the maximum installed capacity, ie . includes all associated equipment : conveyors , ventilation, chemical treatment of water and so on. , so that electricity for one year with part of the year when boilers will not work does not exceed the sum of € 150,000 / year.

3. Costs chemical water
Condensate return should be 90 % , if it goes into the calculation of 80 % then the required amount of DI water for boilers annually in the amount of 27.620 m3/god . Tenders for HPV calculated the price of demi water of 0.25 € / m^3. If you zoom in on this price to 0.30 € / m^3 indicates that the annual cost of producing DI water € 8,286 / year.

4. Costs maintenance
Binding downtime for maintenance - cleaning boilers and maintenance recommended by the manufacturer of equipment (lubrication replacement of consumable elements) as well as regular maintenance should not exceed € 30,000 / year.

5. Costs compressed air
Recommendations for this type of boilers that cost € 0.07 / per ton of money , which is : 9000 € / year.

6. Costs workforce
Given the legal occupancy of jobs needed for the četvorosmenski 8 executor of the boiler room and 4 for HPV , whose salary with shift work and public holidays will be around 850 euros per employee for a total workforce of € 122,400 / year .
Total costs year on year
1 +2 +3 +4 +5 +6 = 2.227,948 €
The total production of 89.753 MWh of steam

Unit price of steam is 2.227.948 / 89.753 = 24,82 € / t , steam
It is necessary to consider the potential unplanned downtime and failure to maintain the boiler on max mode, so it is necessary to correct the price by about 15 %, so that the price will be 28 € / MWh
If we add to this price earnings of 25% of the price of steam heating plant to it was 35 € / MWh
Price vapor which currently produces District Heating is 47.75 €/MWh (obtained from SM)
Based on the presented calculations , the remaining income : 89.753 x (47.75-35) =
1.077.036 €/ year.

CONCLUSION

Supply of heat, JKP District Heating has 2 hot water boilers each with a capacity of 35 MW with fuel-natural gas.
Due to the economic crisis, a lot of customers off the heat, with heat networks.
Victoria Starch, has two boilers for steam production capacity (2 x 25 t / h) = 50 t / h, pressure 12 bar and temperature of 180 ° C, the motor fuel to biomass - pellets of straw cereals. Translated into thermal power is the max. 2x16, 25 = 32,5 MW.
The above data show that the two koligrama enough pellets to replace 1 m^3 of natural gas, and with the current price of 40,48 dinars. Production price of straw pellets is currently around 8 dinars / kg.
This is a production price in Victoria Starch.
The price of pellets on the market or 20 dinars / kg.
The budget cost of investment goes up with the price of pellets of 8 dinars / kg
Based on this, we have the following balance:
1m^3 gas = 2 kg pellets: 33.000 kJ/m^3 = 2x16.500 kJ / kg, 40.48 dinars (=) 16 dinars
These data indicate that for the same amount of energy is required to extract 2,5 times less money.
At the level of the heating season gas heating costs 398. 700. 224 dinars, or € 3.591.894
At the level of the heating season heating with pellets amounted to: 156. 660. 640 dinars, or € 1.411.357.
The difference in price is about 2,180,537 €/ year. - One heating season.
The total investment amounts to: € 2.340.000.
Planned cost of production of water vapor in Victoriastarch-in, which takes into account all costs (fuel prices, the cost of electricity, water treatment chemical costs, maintenance costs and labor costs) is 35 € / MWh.
Price vapor produced by the JKP - District Heating is 47.75 € / MWh.
Total potential production of water vapor in Victoriastarsh-in is: 89. 753 MWh.
Based on the presented calculations, the remaining income: 89 753 x (47.75 - 35) = 1.077.036 €/ year.
Payback time: 2.340.000 / 1.077.036 = 2,17 years.
Construction Financing: 2.000.000 € -Victoriastarch
340.000 € -JP City plant.

REFERENCES

[1] Tolmač, D. : Machinery and Apparatus, Technical Faculty "Mihajlo Pupin", Zrenjanin, 2009.
[2] Tolmač, D. : Machines and Devices - Solved assignments, Technical Faculty "Mihajlo Pupin" Zrenjanin.2006.
[3] Tolmač, D. : Design of Technology Systems - Production Systems - Faculty of Engineering "Mihajlo Pupin", Zrenjanin, 2008.
[4] Tolmač, D. : Production and Process Systems - Collection of solved problems, Technical Faculty "Mihajlo Pupin" Zrenjanin.2008.
[5] Tolmač, D., Prvulović, S., Radovanovic, LJ, Blagojević, Z. : Theory of System Design - design, investment, re-engineering, Technical Faculty "Mihajlo Pupin" Zrenjanin.2007.
[6] Tolmač, D. : Design, Technical Faculty "Mihajlo Pupin", Zrenjanin, 2009.
[7] Tolmač, D., Prvulović, S. : Process engineering and management in industrial engineering, Technical Faculty "Mihajlo Pupin", Zrenjanin, 2010.

ANALYSIS CAN BE USED IN AGRICULTURAL BIOMASS FOR HEAT PRODUCTION

Slavica Prvulović[1], Dragiša Tolmač[1], Marija Matić[1], Zlatko Košut[2]
[1]University of Novi Sad, Technical Faculty "Mihajlo Pupin", Zrenjanin, Serbia
[2]Victoria Starch, Zrenjanin, Serbia
e-mail: prvulovicslavica@yahoo.com

Abstract: The paper describes the availability of biomass in Serbia and its ability to use to produce energy, particularly heat. Based on several studies, biomass is the most significant renewable energy potential in the Republic of Serbia and Vojvodina. In the territory of AP Vojvodina, the most important potential of biomass make harvest remains, the remains of crop production, plant mass created in a vineyard and fruit production and primary processing of agricultural products.
Analysis of the structure of biomass residues from agricultural production shows that more than half of the resource lies in corn biomass, more than a quarter in the straw of small grain, primarily wheat, and the remaining 15 percent in the harvest remains of sunflower, soybean, rapeseed or residues of orchards and rezidbenim vineyards.
Key words: biomass, combustion, heat, energy

INTRODUCTION

The use of biomass as a renewable energy source for electricity and thermal energy has enormous potential in Serbia and is constantly expanding. Biomass as a fuel is available in many forms and can be obtained from various sources. The most important advantage of these fuels in comparison with fossil fuels is that their thermal achieved using CO2 neutrality, and the emission of CO and TOC (total organic carbon) is significantly lower.
Biomass as a renewable energy source represents an organic degradable matter of vegetable or animal origin as well as biodegradable fraction of industrial and municipal waste that different processes translates into energy. Most often used in the form of biomass energy for heating, cooking and water heating. In addition, all the topical use of biomass in cogeneration plants for heat and electricity [1,2,3].
As a renewable energy source, biomass includes:
Wood biomass
- Residues and waste generated by grinding, ...
- Often it is the waste that burdens the business of wood processing companies
- Serves as a fuel in their boilers, raw materials for products, briquettes, pellets
- It's cheaper and better quality fuel from forest biomass

Residues and waste from agriculture
- Straw, corn stalks, cobs, stems, pits, shells, ...
- This is a heterogeneous biomass different properties
- It has a low heating value due to the high proportion of moisture and various impurities
- Processes are pressing, baling, pelleting

The potential of wood (forest) biomass in Serbia is 40%, and agriculture 60%. Different types of agricultural biomass differ significantly, and therefore differs and their combustion, as well as problems that arise in the plants where the biomass used.

Animal waste and scrap
- Anaerobic digestion (feces - all kinds of animals + green weight)
- Incineration (litter, carcasses -živinarske farms)
- Biogas (60% methane, 35% CO2, 5% of a mixture of hydrogen, nitrogen, ammonia, hydrogen sulfide, CO, oxygen, and water vapor)

Biomass from Waste
- Green fraction of household waste
- Biomass from parks and gardens from urban areas
- Sludge from sewage collectors

MATERIAL AND METHODS

Availability of biomass in Serbia for production of energy

Biomass is the most important renewable energy source in Serbia and represents two-thirds of the total potential, or 62% of renewable energy, corresponding to 2.4 million oil equivalent. Energy potential BIMAS of forestry is estimated at around one million tonnes of oil equivalent, while the rest belongs to organic raw materials or agricultural waste and residues from farming. Instead of agricultural residues burning in the fields, which is prohibited by law, farmers should be able to take advantage of these residues for energy production.

Technically feasible, annual energy biomass potential in Serbia is approximately 2.7 Mtoe. The energy potential of biomass from forestry and wood industry (logging residues and trees produced during primary and / or industrial wood processing) is estimated at approximately 1.0 Mtoe, while about 1.7 Mtoe from agricultural biomass (agricultural waste and residues from farming, including liquid manure) [4, 5].

The use of biomass for energy purposes

Biomass is mainly used for domestic heating. There are positive experiences of the use of biomass in large plants, but major obstacles are security of supply and cost of biomass. Some companies use their own biomass (for example, residues from wood used in forest and wood-processing companies or agricultural residues on farms for heat production) [6, 7]. Prices for biomass are not clearly established and can vary considerably in different locations and time periods. At the same time, manufacturers of pellets place their products mainly to foreign markets because of the small presence of appliances for their combustion.

The use of biomass for energy purposes should be done so that it can not call into question any other possibility of its application (biomass as food, for example). At the same time, it is necessary that biomass used for energy purposes passes the criteria, to ensure fulfillment of relevant energy, environment, et al., Conditions. In order to prevent any problems in functioning, it is necessary to define all types of biomass that can be used to provide electricity and thermal energy, biogas and biofuels for transport as well as the requirements that must be met. This is also crucial in terms of sustainability criteria and fears of competition with food production and the use of crops for human consumption [3, 8, 9].

Table 1. The energy potential of biomass

Source biomass		Potencijal (toe)
Wood biomass		1.527.678
Firewood		1.150.000
Residues from wood processing		179.563
forest waste		163.760
Wood from trees outside forests		34.355
Agricultural biomass		1.670.240
Residues from agricultural crops		1.023.000
Residues from fruit growing, viticulture and fruit processing		605.000
Liquid manure for biogas production		42.240
Biofuels for transport		191.305
The total biomass	Without transport fuels	3.197.918
	With fuel for transport	3.389.223

RESULTS AND DISCUSSION

Resources biomass from agricultural grains

The total amount of crop residues in crop production is 9.55 million tons. The total available potential of biomass in Serbia is as mentioned 2.7 Mtoe, where biomass from agricultural production accounts for a significant part of the 60%
Wheat, barley, rye, corn, sunflower, soybean, canola, account for 40% -from the total arable land, of which 75% of products for small and medium-sized private farms and 25% are agricultural combines and larger companies. The lack of non-standard yields. Fruits and vegetables accounts for 16% of the total arable land. The disadvantage is the relatively high moisture content [3, 4, 6].

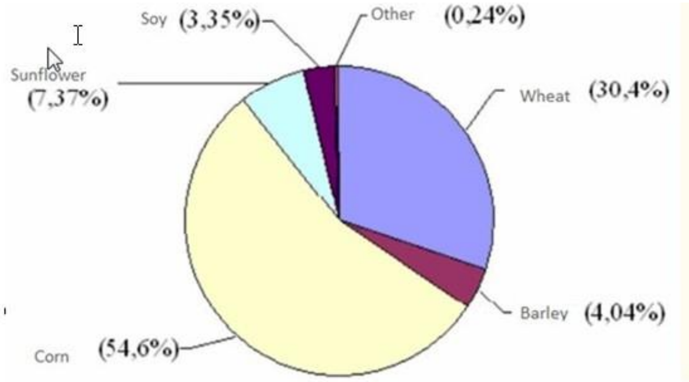


Figure 1. Resources biomass from agricultural graints

In Serbia, the government low level of use of agricultural biomass:
- Straw is mainly used as litter in stables
- The private farms often fallen biomass in the fields in spring and autumn
- It is estimated that about 50% remains with the larger and about 20% from smaller farms used to produce energy
- Use for heating houses and buildings is rare
- There is no market for biomass products
- Fragmentation of the estate-expensive collection and transportation costs of biomass

The following table provides an overview of the potential of biomass from agriculture in Serbia

Table 2. Potential of biomass from agriculture in Serbia

Serial number	Culture	Area (t/h)	Yield (t/h)	Total biomass (10^3h)
1.	corn	1300	5,5	7150
2.	sunflower	200	2	800
3.	wheat	850	3,5	2975
4.	barley	165	2,5	412,5
5.	oats	16	1,6	25,6
6.	rye	5	2	12
7.	Seed corn	25	2,3	86,25
8.	cobs *	-	-	1430
9.	sunflower Shells	-	-120	
10.	soy	80	2	320
11.	oilseed rape	60	2,5	300
12.	hop	1,5	1,6	7,92
13.	tobacco	3	1	1,05
14.	orchards	275	1,05	289,44
15.	vineyards	75	0,95	71,55
16.	S manure **	-	-	110
	TOTAL :	3055,5		12571,31

* Weight maize cobs analyzed is included in the mass of corn stalks
** Mass of liquid manure is not included in the total amount of biomass

It is estimated that the total potential of biomass from agriculture in Serbia, about 12.5 million tons per year, which in energy terms is approximately 1.7 million ten. It is known that biomass in huge quantities, that is renewed every year and that irrational use. Crop residues are usually burned directly in the field, which is forbidden by law. As a compromise solution could be adjusted to 1/4 or biomass plowed through the mat back field, 1/4 from products for animal feed, 1/4 used for heating buildings and 1/4 for other purposes (in the alcohol industry, furniture, construction materials, paper, packaging, cosmetics, etc.). In this way they would be settled all economic activity, given that the biomass residues from the agricultural production there in sufficient quantities [7, 8]. The above analysis can be seen that the total quantity of biomass residues from the agricultural production intended for heating purposes (just over 3 million tons) could save the equivalent amount of about 1317 x 103 tons of light heating oil. Identical mass of diesel fuel used in all agricultural production in Serbia.

Table 3. The energy potential of biomass residues from the agricultural production in Serbia

Serial number	biomass	Biomass combustion (25% of total) (10^3)	Lower heat power (MJ/kg)	Equivalent light heating oil (10^3t)
1.	wheat straw	743,75	14	247,92
2.	barley straw	103,13	14,2	34,87
3.	Oat straw	6,4	14,5	2,21
4.	rye straw	3	14	1
5.	Straw of soya	80	15,7	29,9
6.	Straw rapeseed	75	17,4	31,07
7.	maize	1787,5	13,5	547,55
8.	Maize seed corn	21,56	13,85	7,11
9.	cobs	357	14,7	124,95
10.	sunflower stalks	200	14,5	69,05
11.	The shell sunflower	30	17,55	12,54
12.	The stems of hops	1,98	14	0,66
13.	stalks tobacco	0,26	13,85	0,09
14.	The remains of pruning in the orchards	289,44	14,15	97,5
15.	The remains of pruning in the vineyards	71,55	14	23,85
16.	manure	110	23	60,24
	TOTAL	3880,57	14,26	1317,51

Agriculture is a production in which the investment is less than the energy obtained (produced) power. By using biomass from the rest of the agricultural production of agriculture increases the level of energy autonomy agriculture.

Biomass can be used to produce biogas. Gas occurring anaerobic process from biomass, ie. from residues in agricultural production comprises 60-80% CH4, thermal-power 8570 kcal / m3 or 9960 kWh / m3. Other CO2 (about 20%), HS. Gas of this quality can be used in the production of electricity, as fuel for boilers for industrial use boiler for space heating, direct combustion for cooking and lighting, burning to prevent pollution of the atmosphere.

Biomass can be used for direct combustion: heating rooms, facilities, greenhouses, cooking, briquetting and pelleting, the production of electricity by direct combustion or in the form of a substrate with manure.

Briquetting and pelleting biomass has advantages compared to other procedures of biomass preparation which consists in increasing the mass of biofuel per unit volume (density), reducing the cost of handling and transportation, reducing storage space, slowing the biological processes of spoilage biomass, increasing the energy efficiency installations compared to combustion plants baled mass.

Briquetting and pelleting biomass has drawbacks such as the need to prepare materials to the humidity and granulation, in some cases necessary additives (in composite briquettes from coal dust, etc.), One must invest in the necessary technology which is necessary for running process, power consumption is required for the preparation of biomass

According to current estimates, the dominant part of wood biomass could be used for the production of pellets and heat production, and agricultural biomass for cogeneration of electricity and thermal energy and biogas [8, 9].

CONCLUSION

Based on the above it can be concluded that Serbia has a huge amount of biomass, where biomass from agricultural production is an important part, as much as 60%. Biomass out of agriculture has great importance for the production of energy, particularly heat. Its application to achieve significant savings on the heated, as well as the reduction of environmental pollution, especially if this biomass can not be used for other purposes, for example. animal nutrition.

ACKNOWLEDGMENTS

This paper is part of a research project funded by the Provincial Secretariat for Science and Technological Development of AP Vojvodina, number 114-451-1510 / 2014-01

REFERENCES

[1] Gürdil, G.A.K., Selvi, K.C., Malaták, J., Pinar, Y., Biomass utilization for thermal energy, AMA, Agricultural Mechanization in Asia, Africa and Latin America, Volume 40, Issue 2, March 2009, Pages 80-85

[2] Mckentry , P. Energy production biomass (part 1): overview of biomass, Bioresource Technology, 83 (2002), pp. 37–46

[3] Brkić M, Janić T. (2000). Biomass as a source of raw materials, fertilizer, animal feed and energy, Traktori i pogonske mašine, JUMPTO, Novi Sad, 5(2): 23-28.

[4] Jovanović, B., Parović, M., Status and development of biomass in Serbia, Study, Studija, Beograd, 2009.

[5] Brkić, M, Janić, T: Possibilities of using biomass in agriculture, Proceedings of the II conferences: "Briquetting and pelleting biomass in agriculture and šmarstvu", Regional Chamber of Commerce from Sombor and "Dacom" in Apatin, Sombor, 1998, s. 5 – 9.

[6] Novaković D, Đević M, Radojević, D. (2003). Remains of biomass in crop production, the study "Energy potential and characteristics of biomass residues and technology for its preparation and use of energy in Serbia, Institute for Nuclear Sciences" Vinca", Beograd, 1-5.

[7] Dare, P. , Gifford, J. , Hooper, R.J. , Clemens, A.H. , Damiano, L.F. , Gong, D. T.W. Matheson, Combustion performance of biomass residue and purpose grown species, Biomass and Bioenergy, 21 (2001), pp. 277–287

[8] Steenari, B.-M., Lundberg, A., Pettersson, H.,Wilewska-Bien, M., Andersson, D., Investigation of ash sintering during combustion of agricultural residues and the effect of additives, Energy and Fuels, Volume 23, Issue 11, 19 November 2009, Pages 5655-5662

[9] Schmidt J, Leduc S, Dotzauer E, Kindermann G, Schmid E. Potential of biomass-fired combined heat and power plants considering the spatial distribution of biomass supply and heat demand. International Journal of Energy Research 2010; 34 (11) : 970-985

COMPARATIVE ANALYSIS OF ENERGY EFFICIENCY OF TWO INDOOR SWIMMING POOLS USING THE ENERGY BALANCE METHOD

Stefan Kocić[1], Ivana Petrović[1], Marko Mančić[1], Dragoljub Zivković[1], Milan Đorđević[2]
[1] Mašinski fakultet Univerziteta u Nišu, A.Medvedeva 14, 18000 Niš, Srbija
[2]Faculty of Technical Sciences, University of Priština, Kosovska Mitrovica, Serbia
e-mail: markomancic@yahoo.com

Abstract: The basic tool for identifying and preparing energy efficiency projects of public buildings is building energy balance. Preparation of an energy balance includes collecting, monitoring and analyzing energy performance data, which enables comparison to energy indicators and determination of efficiency of energy usage. The robustness of an energy balance may vary, classifying the balance as preliminary or detailed.
In this paper, preliminary energy balance of indoor swimming pools in two public sport and recreation centers (SRC) is performed: SRC "Dubočica" in Leskovac, and SRC "Čair" in Niš. Energy efficiency analysis is done according to the results of the performed analysis of energy balance. Energy efficiency indicators are calculated and compared to the benchmark values. According to complexity and size of the investments required for their realization, proposed measures for energy efficiency improvement are classified as: low-budget, medium-budget and high-budget measures of good housekeeping. Application of Flat Plate Solar thermal collector systems for heating is proposed for both systems. Cost Benefit Analysis is done for both solar installations. Results of the performed CBA showed impact of energy market costs in Serbia to economic feasibility of the analyzed projects..
Key words: energy efficiency, indoor swimming pool, energy balance, renewable energy sources, cost benefit analysis

INTRODUCTION

Energy balance is represented by a central database about the produced and consumed energy in a state, region, city, municipality or a company. Its main purpose is to be used by analyst professionals and decision makers as the basis for analysis, prediction of energy demand, creating future development scenarios and defining energy economic policy of an entity. Energy balance is also one of the basic elements for state monitoring and defining policy and measures for environmental protection.
On a local level, energy balance enables an overview of the structure of the supplied and consumed energy to be created in order to define measures for energy savings. Herein, two important aspects of energy savings should be brought to attention: economic aspect and environmental aspect. Energy efficiency improvement relates to lower fuel consumption followed by increased reliability and quality of the provided utility service.
In this paper, energy efficiency of indoor swimming pools in Sport and Recreation Center (SRC) " Dubocica" in Leskovac and Sport and Recreation Center "Cair" in Nis (fig. 1) was performed by measn of preliminary energy balance. Results of comparative preliminary energy balance results for the two sport centers are presented. Based on the obtained results, energy efficiency meeasures for both swimming pool buildings are proposed.

a) b)

Figure 1. a) Indoor swimming pools in SRC „Dubočica“ in Leskovac, and b) SRC „Čair“ in Niš

There are three swimming pools located in SRC „Dubočica“, with water surface areas of 1050 m^2, 330 m^2 and 100 m^2, and depths of 2 m, 1,45 m and 0,5 m respectively. Total water surface of the pool area is 1480 m^2. For the purpose of fulfillment of indoor thermal comfort conditions in the pool hall and auxiliary rooms, an energy system with heat exchangers rated at around 3.35 MW in total, is installed (tab.1) [1].

SRC Cair is equipped with three swimming pools, with the following surface areas: Olympic pool 1050m^2, recreation pool 300m^2 and children's pool 100m^2, with the swimming pool debts of 2,2 m ; 0,8-1,8m and 0,5m, respectfully. Total free water surface of the swimming pool is 1450m^2. Total installed capacity of heat exchangers designed to provide thermal comfort conditions of the building is 3,58MW.

Both indoor swimming pools are used by grownups, children and professionals, with the total annual number of 55000 swimmers in SRC Dubocica and 36783 swimmers in Cair.

According to the installed capacities of heat exchangers, it can be seen that the greatest ratio of energy is consumed for pool water heating and air heating and pool hall ventilation. Basic demand of supply air in the pool hall is determined by condensation on walls and glass surfaces. Ventilation usually accounts for 50 to 70% of total pool hall heating. The quantity of air for ventilation depends on the method of pool water treatment. Namely, if the water is treated by Ozone instead of Chlorine, the quantity of fresh ventilation supply air can be reduced.

Sanitary hot water may be heated not only by the heat exchangers, but also by the installed electric heaters with power rated at 60 kW. Both heat exchangers and electric heaters are located inside a hot water boiler, which has a total volume of 5 m^3.

Heating energy is supplied to indoor swimming pools by the heat production plant of “Zdravlje – Actavis” company, located on a distance of approximately 200m. The heat production plant of this company is equipped with calorimeters measuring consumed heating energy. The supplier of heating energy determines the costs of supplied energy according to “consumed” fuel oil with a conversion factor of 7,5l.

According to installed capacity of the heat exchangers in SRC “Cair”(tab.1) the greatest design heating load of 2193 kW can be addressed to heating and ventilation and pool heating (61%), whereas 18% can be addressed to radiative heating, and 17% to sanitary hot water heating. The sanitary hot water heating system had the capacity of 60kW according to initial design, but was increased by 524 kW, according to demands observed during daily exploitation. Heat is supplied by the local district heating network. In the summer time, sanitary hot water is heated by electricity. Heat consumption costs are calculated per unit of heated floor surface.

Table 1. Installed capacity of the heat exchangers SRC „Dubočica“[1] and SRC „Čair“

Installed capacity of the heat exchangers	SRC „Dubočica“		SRC „Čair“	
Radiator heating (90/70 °C)	276,153 kW	8,24 %	628kW	18%
Convective heating for demisting of the hall's glass surfaces (90/70 °C)	261,625 kW	7,81 %	/	/
Floor heating of the pool hall (35/45 °C)	87,457 kW	2,61 %	175kW	5%
Sanitary hot water heating (60 °C)	145,100 kW	4,33 %	524 + 60kW	17%
Pool water heating (24 do 26 °C)	1510,000 kW	45,08 %	N/A	N/A
Air heating and ventilation / *heating and ventilation and pool heating	1069,510 kW	31,93 %	*2193kW	61%
- Ventilation chamber for demisting of the pool hall glass surfaces	518,180 kW			
- Ventilation chamber for the pool hall stands	403,100 kW			
- Ventilation chamber for ventilation of lobbies	96,800 kW			
- Ventilation chamber for ventilation of cloakrooms	51,430 kW			
Total installed power of heat exchangers	3349,845 kW	100 %	3580kW	100%

ENERGY BALANCE RESULTS

Preliminary energy balance of the two indoor swimming pools was performed in three stages:

- Data acquisition and estimation of the current energy consumption,
- Calculation of the energy efficiency indicators, and
- Identification of potential possibilities for energy savings.

Table 2 . Electricity consumption in the base year 2009. SRC „Dubočica”

Electricity								CO2 Emission	1kWh=0.8 kgC02
Month	Active energy (high tariff)	Active energy (low tariff)	Reactive energy (cosφ≥0,95)	Excessive reactive energy ussage (cosφ<0,95)	Billing demand	Excessive demand consumed	Total energy	Emission CO2	Total (Din)
	[kWh]	[kWh]	[kVArh]	[kVArh]	[kW]	[din.]	[kWh]	(kg)	
Jan	78462	0	25517	69	148	377604	78462	62770	377604
Feb	67719	0	22054	225	154	339162	67719	54175	339162
Mar	73221	0	23736	354	145	355028	73221	58577	355028
Apr	67863	471	21930	552	152	355395	68334	54667	355395
May	57573	411	18714	363	146	277277	57984	46387	277277
Jun	69134	538	22376	456	119	336673	69672	55738	336673
Jul	81363	669	26038	951	165	391302	82032	65626	391302
Aug	76644	744	21958	745	159	369151	77388	61910	369151
Sep	55446	537	17878	540	177	297634	55983	44786	297634
Oct	42996	399	13851	426	136	297573	43395	34716	297573
Nov	58548	447	18893	516	136	297473	58995	47196	297473
Dec	63265	130	20657	200	112	306706	63395	50716	306706
Total	792234	4346	253602	5397		4000978	796580	637264	4000978

Data acquisition represents the preparation stage and is conducted after realization of the initial stage, when the questioners were formed. The questioners are conceived in a way they could provide as much information and relevant energy consumption data as possible [2]. In this stage, it was of utmost importance to remove any perplexities in the terms of filling out the questioner.

Collected data are organized in an electronic database (Excel software), and energy balance is done afterwards with the results presented in tables 2 to 6 and diagrams on figures 3,4,5 and 6.
The data for SRC „Dubočica" are presented for the base year 2009. since this was the year with complete energy performance data, whereas 2013 was chosen as base year„Čair". Both chosen years are considered viable for performing energy balances, since no significant energy efficiency measure was applied in neither of the two buildings since.

Table 3. Electricity consumption in the base year 2013. SRC „Čair"

Electricity							**CO2 Emission**	1kWh=0.8 kgC02
Month	Active energy (high tariff)	Active energy (low tariff)	Reactive energy (cosφ≥0,95)	Excessive reactive energy ussage (cosφ<0,95)	Billing demand	Total energy	Emission CO2	Total (Din)
	[kWh]	[kWh]	[kVArh]	[kVArh]	[kW]	[kWh]	(kg)	
Jan	174495	36525	19155	76065	510	211020	168816	1165536.375
Feb	161655	33510	15795	67740	480	195165	156132	1080923.85
Mar	139245	28305	14970	53685	360	167550	134040	898282.125
Apr	116535	21975	13320	46095	360	138510	110808	784645.275
Maj	99375	17265	13140	46605	315	116640	93312	676133.88
Jun	117195	27990	18855	63450	375	145185	116148	816929.505
Jul	131835	37080	24390	76650	330	168915	135132	878461.83
Avg	132990	54060	32385	73830	360	187050	149640	931385.82
Sep	111930	18060	12240	62745	300	129990	103992	729709.68
Okt	115905	20310	13470	61125	330	136215	108972	768321.66
Nov	130335	22245	13275	61905	390	152580	122064	869737.335
Dec	163455	27495	17085	72675	465	190950	152760	1074404.82
Total	1594950	344820	208080	762570	4575	1939770	1551816	10674472.16

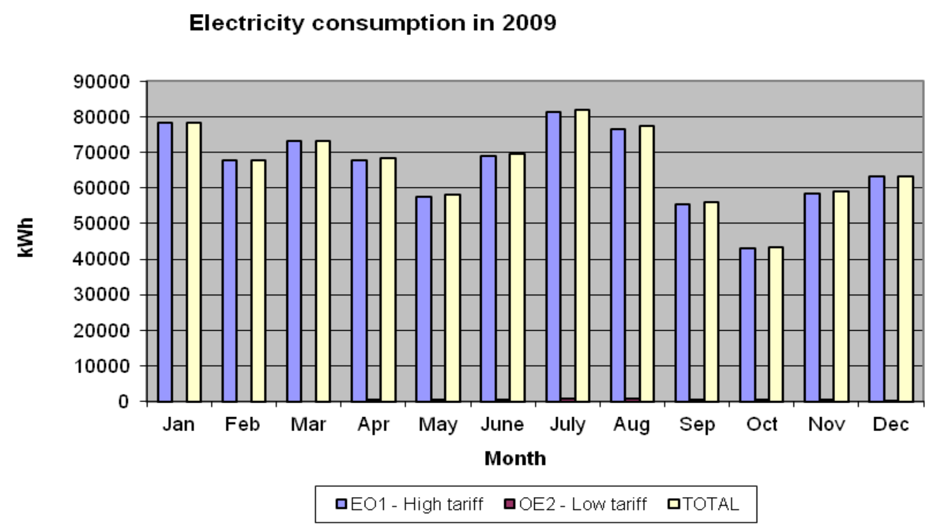


Figure 3. Diagram of electricity consumption in the base year 2009. SRC „Dubočica"

Electricity consumption in SRC „Čair" is significantly higher then the electricity consumption in SRC „Dubocica". This is caused by the equipment which operates throughout the year in SRC „Cair", and the fact that it includes electricity consumption of parts of the building oher than the pool, which is not the case in SRC „Dubocica" data.

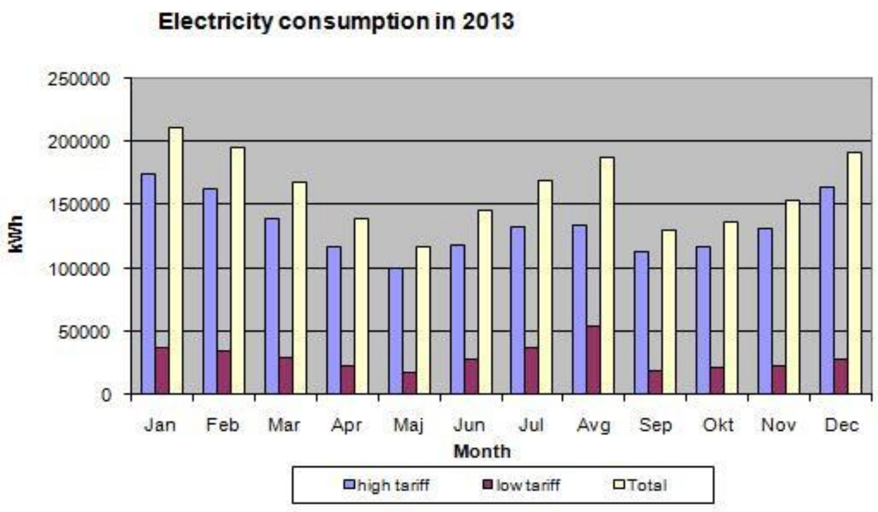


Figure 4. Diagram of electricity consumption in the base year 2013. SRC „Čair”

Electricity consumption in SRC „Dubočica” i SRC „Čair” is the highest in the summer period, which coresponds to the summer season. This is caused by the increased sanitary hot water consumption related to the increased number of swimmers in this period.

Table 4. Water consumption in 2009. SRC „Dubočica” and SRC „Čair” in 2013.

SRC	Water consumption in 2009. SRC „Dubočica”		Water consumption in 2013. SRC „Čair”	
Month	Consumption (m^3)	Total (Din)	Consumption (m^3)	Total (Din)
Jan	1.278,00	27.093,60	3004.0	218000.28
Feb	1.576,00	33.411,20	3004.0	218000.28
Mar	1.540,00	34.419,00	3004.0	218000.28
Apr	1.879,00	43.029,10	3004.0	218000.28
May	1.477,00	34.510,30	3004.0	218000.28
Jun	1.764,00	40.395,60	6594.0	478526.58
Jul	2.064,00	47.205,60	5511.0	438289.83
Aug	4.382,00	100.347,80	4156.0	330526.68
Sep	2.507,00	57.410,30	2807.0	223240.71
Oct	1.814,00	41.540,60	2316.0	184191.48
Nov	4.175,00	95.607,50	2335.0	185702.55
Dec	2.300,00	52.670,00	2357.0	187452.21
TOTAL	26.756,00	607.640,60	41096.0	3117931.44

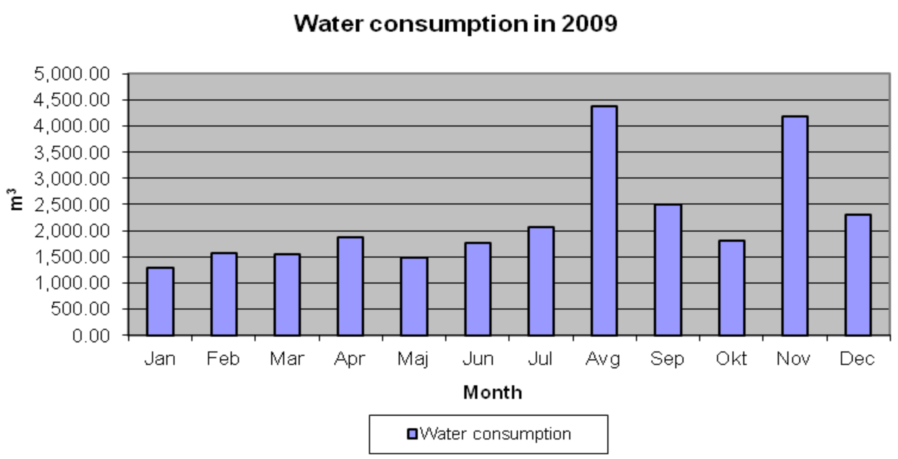


Figure 5. Diagram of water consumption during the year 2009. SRC „Dubočica”

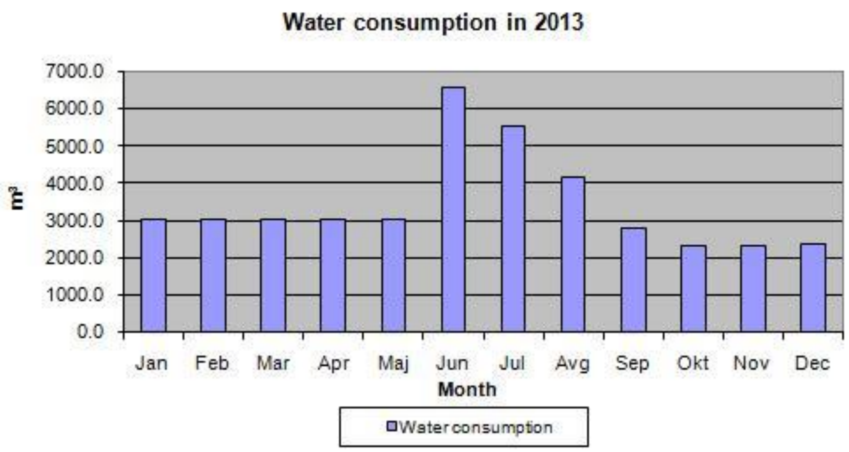


Figure 6. Diagram of water consumption during the year 2013. SRC „Čair"

An increase of water consumption in the summer period can be observed in both indoor swimming pools. The cause behind this is the same as with the electricity consumption increase – higher number of swimmers in this period. Equal ammounts of water consumption in SRC „Cair" in the first 5 months is the mallfunction of the water meeter, which was not observed and fixed on time.

Table 5. Fuel oil consumption and CO_2 emissions in the base year 2009. SRC „Dubočica"

FUEL No. 1	**Fuel oil**		Conversion factor(kWh/jm)	11,000.00
			Emission CO2 (kg/kWh)	0.28
Month, year.	Consumption t	Consumption (kWh)	Emission CO2 (kg)	Total (Din)
Jan, 2009	42.00	462,000.00	129,360.00	1,248,750.00
Feb, 2009	21.00	231,000.00	64,680.00	624,400.00
Mar, 2009	33.00	363,000.00	101,640.00	977,400.00
Apr, 2009	38.00	418,000.00	117,040.00	1,128,600.00
May, 2009	12.00	132,000.00	36,960.00	340,416.00
Jun, 2009	8.00	88,000.00	24,640.00	243,000.00
Jul, 2009	4.00	44,000.00	12,320.00	132,300.00
Aug, 2009	7.00	77,000.00	21,560.00	205,200.00
Sep, 2009	10.00	110,000.00	30,800.00	312,660.00
Oct, 2009	33.00	363,000.00	101,640.00	969,300.00
Nov, 2009	29.00	319,000.00	89,320.00	872,424.00
Dec, 2009	44.00	484,000.00	135,520.00	1,296,000.00
TOTAL 2009	281.00	3,091,000.00	865,480.00	8,350,450.00

Heat consumption in SRC „Dubočica" was measured by calirimers and represent real consumption in the base year, whereas heat supply costs were not measured in the other building, and heat supply costs are payed ber unit price per unit of heated surface.

Energy efficiency indicators

Indicators of energy efficiency represent specific energy indices used to define potentials for energy savings and determine possible effects of energy efficiency measures implementation. Their significance lies in the fact that by comparing the calculated (real) values of indicators (tab.8), acquired according to the collected data, with the usual or standard (target) values of indicators of energy efficiency (tab. 7) [2,3,4,5], the sectors with possible energy savings and efficient enough consumers can be clearly spotted.

Table 6. Monthly district heating costs in SRC „Čair“

Mesec, god.	Total (Din)	Tariff (Din/m^2)
Jan, 2013	543239.55	29.23
Feb, 2013	543240.55	29.23
Mar, 2013	543241.55	29.23
Apr, 2013	543242.55	29.23
Maj, 2013	543243.55	29.23
Jun, 2013	543244.55	29.23
Jul, 2013	543245.55	29.23
Avg, 2013	543246.55	29.23
Sep, 2013	543247.55	29.23
Okt, 2013	543248.55	29.23
Nov, 2013	543249.55	29.23
Dec, 2013	543250.55	29.23
TOTAL 2013	**6518940.6**	

Table 7. Values of energy efficiency indicators for indoor swimming pools [2-5]

Annual heating energy consumption [kWh/m^2]	1800
Annual electricity consumption [kWh/m^2]	414
Annual heating energy consumption per visitor [kWh]	9,5
Annual water consumption per visitor [m^3]	0,1 – 0,25
Maximum power of installed heat exchanger [kW/m^2]	3,0

Table 8. Calculated values of energy consumption indicators for the referent year 2009. SRC „Dubočica” and SRC „Čair” for the referent year 2013.

Calculated values of energy consumption indicators	SRC „Dubočica”	SRC „Čair“
Annual heating energy consumption [kWh/m^2]	2089	
Annual electricity consumption [kWh/m^2]	538	312.87
Annual heating energy consumption per visitor [kWh]	56,2	
Annual water consumption per visitor [m^3]	0,486	1.11
Power of installed heat exchangers [kW/m^2]	2,26	0.557

Values of indicators of energy efficiency, shown in tables 7 and 8, are given per square meter of water surface.
By comparing the calculated indicator values (Tab. 8), and benchmark values (Tab. 7), we can conclude the following:

In SRC „Dubočica

- heating energy consumption can be lowered minimum by approximately 14%,
- electricity consumption can be lowered minimum by approximately 23%, and
- water consumption can be lowered minimum by approximately 50%.

In SRC „Čair“

- electricity consumption is near to the average
- water consumption should be lowered by 77.48%.
- There is no apropriete data to compare heating consumption.

The worst parameter relates to the annual heating energy consumption per visitor/user of the pool (tab.8). Namely, the real value of annual heating energy consumption per user is 56,2 kWh (tab.8), which is almost 6 times higher than the recommended value of that parameter which is 9,5 kWh (tab.7). The only way of improving this parameter is increasing the number of pool users, which represents a task of both economic and social significance.
In addition, the parameter of water consumption in SRC„Čair“ per swimmer is 5 times higher than the benchmark. (0,1 – 0,25 m^3 per swimmer). Indicator values for heat consumption in this indoor

swimming pool was ommited from the study, since no relavant data regarding heat consumption other than real costs were available.

PROPOSAL OF MESURES FOR ENERGY EFFICIENCY IMPROOVEMENT

The goal of energy efficiency improvement is energy saving, and the consequence is improvement of economic situation and better environment protection. Typical measures for energy efficiency improvement are: introduction of combined heat and power production, improvement of building's thermal insulation, replacement of doors and windows, replacement of pipeline parts in a district heating network, application of pumps and compressors powered by variable speed electric motors, automation of energy system, usage of renewable energy sources as well as modern more efficient lighting systems, etc.

It is common practice to convey economically justified measures of energy efficiency, especially the ones which require small investments, and only then to consider implementation of new technologies based on using renewable energy sources, which may require larger initial investments.

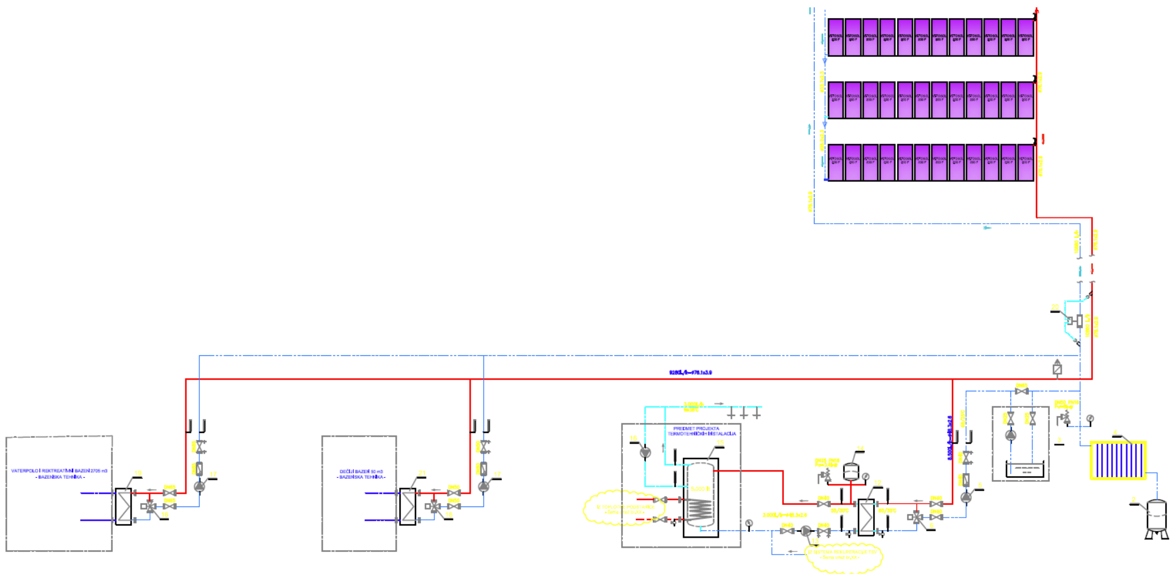


Figure 7. Representation of the new energy system solution of the indoor swimming pools

The main motive behind implementation of energy efficiency projects and utilization of renewable energy sources is economic profit. When such projects are not profitable, or lie on the edge of profitability, state or local government can influence the final decision in favor of project realization with incentive measures.

Measures for energy efficiency improvement are (tab.9):

- measures of rational energy recourse management (good housekeeping) mere – low-budget measures, based on object user motivation for rational energy usage which do not require cash assets,
- medium-budget measures of energy efficiency, implying investments in new technical solutions, equipment, installation, with a goal to optimize functionality of certain subsystems for energy transformation and distribution (this can be measuring and control equipment, equipment for monitoring and control, etc.), and
- high-budget measures of energy efficiency, implying significant internal investments in object reconstruction, equipment and installation modernization.

Table 9. Possible measures for energy savings

Measure	Concrete measures
Good housekeeping measures – low-budget measures	- building ventilation in summertime during the night in order to reduce heating and steam demand, - timing optimization of heating and hot water production, - improving of window seals, - turning lighting off in rooms when not required, - lamp cleaning, - maintenance of belts, filter purity, fans, flaps, air distribution systems, - closing water taps, - regular maintenance taps and toilet water tanks, - repairs of all locations in water piping installation of the object subjected to leakage, - lowering water flow whenever possible (washing, watering).
Medium-bufget measures	- installing thermostatic valves on heating units, - insulation of piping, valves and reservoirs, - installing efficienc hot water pumps, - using energy efficient lighting, - using systems for lighting control (presence sensors, daylight sensors, lighting control according to daylight intensity), - installing self-closing taps with sensors, - using washers with adjustable amount of wash-out water, - disjunction of technical water supply and drinking water supply for using draw-well water.
High-budget water	- construction of gas fired or biomass fired boiler rooms, - introduction of solar collectors for water heating for the purpose of heating and treating sanitary hot water, - introduction of heat pump, - adding insulation layer to external walls, - introduction of electro-motors with frequency control to power the fans.

In accordance with the measures for energy efficiency improvement, presented in table 9. the authors particularly insist that apart from low-budget measures which could be implemented immediately, high priority measures of insulation of piping, vents and reservoirs should be realized as priorities. At the same time it is necessary to lower the electricity consumed for sanitary hot water heating to minimum possible.
Additional insulation of external walls and introduction of solar collectors for the preparation of sanitary hot water [6,7] are priorities from the group of high-budget measures, followed by heat pump introduction in a later stage (fig.7)[8,9].
The decision for building its own gas or biomass fired boiler room, should be brought after additional economic analysis that should include a certain risk analysis.

COST BENEFIT ANALYSIS OF THE PROPOSED SOLAR SYSTEMS

Cost benefit analysis of the proposed solar systems was performed to investigate their financial and economic feasibility. Energy performance of the proposed solar system is estimated using TSol software. Results are presented in table 11, whereas estimated investment costs are presented in table 10.

Table 10. Viessmann solarni sistem za SRC ,,Dubočica”

SOLARNI SISTEM	No	Cost per item.	Total cost
Flat plate solar collector Vitasol 200f	144	402€	57.977€
Heat exhanger NT50X-CDL-10,200 kW	1	3770€	3770€
Heat exhanger NT50-CDH-10,86kW	1	2090€	2090€
Heat exhanger NT50X-CDH-10,200kW	1	2590€	2590€
Labor and other costs	/		26649€
Sub Total	/		93076€
20% VAT	/		18615€
Total			111.691€

It is considered that the same solar system with the same solar collector surface area can be applied to both analysed swimming pools. The intention was to investigate project profitability, since the cost of energy used to heat water in the summer period is not the same in the analysed pools: electricity is used in SRC “Cair”, whereas district heat from “Actavis” is used in SRC “Dubocica”. Main Cost benefit results are presented in Table 12. Cost of supplied heat in SRC “Dubocica” is 0.028 EUR/kWh, whereas cost of electricity used for the same purposes in the summer time in SRC “Cair” is 0.082 EUR/kWh. Cost benefit parameters are calculated for economic lifetime of 20 years, with the constant prices and average annual growth of energy costs of 2%. Cost benefit analysis is performed according to methodology presented in [10].

Table 11. Results of annual simulation

Installed collector power	295.18 kW	
Installed solar surface area (gross)	421.68 m²	
Irradiation on to collector surface (active)	590.88 MWh	1,522.56 kWh/m²
Energy delivered by collectors	335.52 MWh	864.56 kWh/m²
Energy delivered by collector loop	326.59 MWh	841.56 kWh/m²
DHW heating energy supply	179.70 MWh	
Solar contribution to DHW	79.11 MWh	
Energy swimming pool solar system	247.48 MWh	
Energy from auxiliary heating	129.0 MWh	
District heating savings	**466,561.6 kWh**	
CO2 emissions avoided	**100,777.30 kg**	
DHW solar fraction	**41.1 %**	
Swimming pool solar fraction	**94.0 %**	
Total solar fraction	**71.7 %**	
System efficiency	**55.3 %**	

Table 12. Results of the Cost Benefit Analysis

	SRC ,,Dubočica”	SRC ,,Čair“
Pay back period	**13.2**	**4.4**
FNPV	**486.85**	**201,732.61**
FRR	**5.06%**	**23.38%**
NPVq	**0.00**	**1.81**
Discount rate	5%	5%

The results of the performed Cost benefit analysis indicated that the project is feasible in SRC “Cair”, with very good profitability results, whereas the results for SRC “Dubocica” project are barely positive. The cause of such discrepancy of the results are different prices of supplied heat used to heat sanitary hot water and pool heating mainly in the summer. It should be noted that the cost of supplied heat in SRC "Dubocica" is different to typical market price of supplied heat in Serbia, however it represents the actual heating costs based on the real costs of the sport center towards the "Actavis", the heat supplier.

CONCLUSION

Using the energy balance method represents a very efficient way for analyzing energy efficiency of indoor swimming pools. In order to estimate potential possibilities for savings and energy efficiency improvements using energy efficiency indicators was necessary. According to the obtained results, potential projects were identified and concrete measures were proposed. The proposed measures are classified as low-budget, medium-budget and high-budget, and they are based on using modern energy technologies and renewable energy sources. Improvement of energy efficiency of indoor swimming pools in SRC „Dubočica" in Leskovac will contribute not only to better economic savings but also to better environmental protection. The cost of fuel used for heating can significantly affect financial and economic feasibility of solar thermal system application for heating sanitary hot water and swimming pool water in indoor swimming pool. Such projects can generally be considered financially feasible in such public buildings with typical domestic heat supply market prices.

REFERENCES

[1] Project documentation of indoor swimming pools in SRC „Dubočica", Public service „Direkcija za urbanizam i izgradnju", Leskovac, 1996.
[2] Karamarković V. i dr., Uputstvo za izradu energetskih bilansa u opštinama, Ministarstvo rudarstva i energetike Republike Srbije, Beograd, 2007.
[3] Karamarković V., Matejić M., Brdarević Lj., Stamenić M., Ramić B., Uputstvo za pripremu projekata u oblasti energetske efikasnosti u opštinama, Ministarstvo rudarstva i energetike Republike Srbije, Beograd, 2008.
[4] Technical guidelines of the Society of Engineers of Germany – VDI (Verein Deutscher Ingenieure e.V.) 3807
[5] Recknagel H., Sprenger E., Grejanje i klimatizacija, Građevinska knjiga, 1982.
[6] Lambić M., Solarna tehnika, Srbija Solar, Novi Sad, 2004.
[7] Lukić N., Babić M., Solarna energija, Mašinski fakultet u Kragujevcu, 2008.
[8] Stefanovi V. i dr. ,Studija opravdanosti primene energetski visokoefikasnog poligeneracij-skog postrojenja za proizvodnju toplotne energije za zatvoreni gradski bazen, Niš. 2007.
[9] Šamšalović S., Toplotna pumpa – Tehnologija održive proizvodnje energije, SMEITS, Beograd, 2009.
[10] Vladan Karamarković, Maja Matejić, Ljiljana Brdarević, Mirjana Stamenić, Biljana Ramić, uputstvo za pripremu projekata u oblasti energetske efikasnosti u opštinama, MINISTARSTVO RUDARSTVA I ENERGETIKE REPUBLIKE SRBIJE BEOGRAD, 2008.

ACKNOWLEDGEMENT

This paper was done in the framework of project III 42006 - "Research and development of energy and environmentally highly effective polygeneration systems based on using renewable energy sources" and project TR 33015 – "Research and development of a Serbian zero-net energy house" (2011-2014), both financed by the Republic of Serbia Ministry for Education and Science.

WASTE OIL AS A RESOURCE FOR PRODUCTION OF BIODIESEL IN THE BANAT REGION

Aleksandar Đurić[1], Jasmina Pekez[1], Ivan Palinkaš[1], Milan Pavlović[1], Miroslav Vulić[1]
[1]University of Novi Sad, Technical Faculty "Mihajlo Pupin", Zrenjanin, Serbia
e-mail: pekezjasmina@gmail.com

Abstract: Increased use of renewable energy sources today is a relevant topic in transport sector, which is responsible for 84% of total CO_2 emission. Therefore, there is a tendency to use biodiesel as an alternative fuel, with its physicochemical properties similar to diesel fuel which during combustion in diesel engines emits much smaller amount of harmful gases into the environment. Advantages of using biodiesel are multiple, which is why countries of the European Union tend to use it more. To reduce the price of biodiesel, which would have a positive impact on increasing its use, this paper considered the possibility of using waste edible oil as raw material for biodiesel production in the Banat region. Highlighted are ecological, energy and economic benefits of using waste edible oil as a resource for production of biodiesel, as well as its disadvantages.
Key words: biodiesel, waste oil

INTRODUCTION

Increased emission involved in creation of greenhouse effect (mainly due to increased demand and use of fossil fuels) and its impact on the global climate is the reason for actions that are trying to reduce emission of these gases, especially CO_2. As energy demands increase and fossil fuels are limited, research is directed towards alternative renewable fuels [1-2].The advantages of using this alternative fuel are its renewability, biodegrability and better quality exhaust gases [3]. In addition, burning of vegetable-oil based fuel does not contribute to net atmospheric CO_2 level because such fuel is made from agricultural materials which are produced via photosynthetic carbon fixation. The substitution of conventional diesel fuels with fatty acid methyl esters already comprises a commercial activity in many countries of the world [4-5]. However, the use of biodiesel has not expanded into developing countries, due to the higher prices than conventional diesel. The higher cost of biodiesel is due to its production mostly from expensive high-quality oil. Use of low-cost feedstock such as waste frying oils and non-edible oils should help to make biodiesel competitive in price with petroleum diesel [6-7].

MATERIAL AND METHODS

Biodiesel and its benefits

Within the sectors which use the final form of energy, transport sector is the most important, firstly because of its share in final consumption (over 30% of total energy consumption) and, secondly, because of its almost complete dependence on liquid fossil fuels. Transport policy is therefore a priority area in improving energy efficiency. Road traffic is of particular importance since it is responsible for 84% of total CO_2 emission from the transport sector.
Liquid biofuels are the only renewable energy source that can be used without changing the current technology of vehicles. Biodiesel (fatty acid methyl ester) is an alternative fuel similar in physical and chemical characteristics to diesel fuel [8]. Biodiesel has higher oxygen content than petroleum diesel and its use in diesel engines have shown great reduction in emission of particulate matter, carbon monoxide, sulfur, polyaromatics, hydrocarbons, smoke and noise [9-10]. It is suitable for replacing fossil diesel in engines of agricultural machinery, trucks, buses and cars without (or with minimal) modifications to the engine and engine equipment. Biodiesel is non-toxic, biodegradable, and compared to conventional diesel fuel during combustion in engines, emission of harmful compounds is significantly lower [11]. It is most commonly obtained by transesterification of triglycerides of vegetable oils or animal fats with methanol in presence of an alkali or an acid catalyst [12]. In the market of liquid fuels in some countries it is sold in pure form or mixed with mineral diesel fuel in any proportion. Interest in biodiesel production has grown rapidly in the last 10 years. The first quantities of commercially made biodiesel emerged in the EU at the beginning of 90s, and the estimated rise in

the EU in recent years has reached 35% per annum. Banat has an enormous potential to produce biodiesel. Moreover, it is very well geographically located and has a strong agricultural tradition.

Waste oil as a resource for production of biodiesel

The EU Thematic Strategy on prevention and recycling of waste, known as the EU Thematic Strategy on Waste aims to prevent waste generation, and to use waste as a resource, especially for raw material and energy. On the other hand, there is a warning that the internal market should facilitate recycling and reuse with setting high environmental standards.

One of the basic problems of both developed countries and societies in transition is the increased waste generation, especially waste vegetable oil. Waste edible oil is oil resulting from catering and tourist activities, in industry, health service, public administration and other similar activities.

It is estimated that in developed countries about 10% of the used vegetable oil can be collected compared to consumption of edible vegetable oil. In less developed countries, this percentage is lower.

According to the Mittelbach (2002) [13], it is realistic to collect about 3 liters of waste edible oil and fats per capita in Austria. Given that the consumption of edible oil in Austria is about 30 liters per capita and in Serbia about 16 liters, it is estimated that in Serbia it would be possible to collect about 1.5 liters of waste edible oils per capita.

In Serbia there is no organized system for proper collection and treatment of waste oil and almost the entire amount is spilled, polluting water and land resources, it is improperly incinerated, emitting harmful compounds into the atmosphere, and mixed with animal feed.

Waste edible oil from households and restaurants that costs two to three times less than the price of fresh pressed oil, in addition to fresh vegetable oil and animal fats, provides raw material for biodiesel production. However, waste oil from food in the total production of biodiesel is poorly represented (about 1%), for which there are several reasons:

- significantly higher content of free fatty acids in comparison to fresh oil, which requires preparation of raw materials,
- insufficient information about potential quantities of waste oil,
- additional transport costs in collecting waste oil.

Generators of waste oil in the Banat region

Generators of waste edible oil are objects in catering and tourism, industry, health service, public administration and other similar activities in which more than 20 meals per day are prepared [14].

In the Banat region 225 buildings are identified which are used for food preparation. In these facilities in some periods (during the week) less than 20 meals a day are prepared, so that they do not directly fall under impact of the Law on Waste Management and regulations regarding management of waste oil.

According to census of 2002, the Banat region has the population of about 680,000. Given that the consumption of edible oil in Banat is about 16 liters per capita, it is estimated that about 1.5 liters of waste edible oil per capita could be collected. This means that in Banat annually about 1,020 tons of waste edible oil could be collected.

In addition to households, catering facilities and all other facilities in which food is prepared (canteens, hospitals, nursing homes, spas, fish shops, etc.) also represent a great potential, and they represent a real potential for collection of waste cooking oil.

Figure 1 is a graph showing the dynamics of generating waste oil in the Banat region on a monthly basis. In addition to the values for generating waste oil the amount of consumed fresh oil in food preparation is also presented. Of the total oil used for cooking, 43% remains as waste.

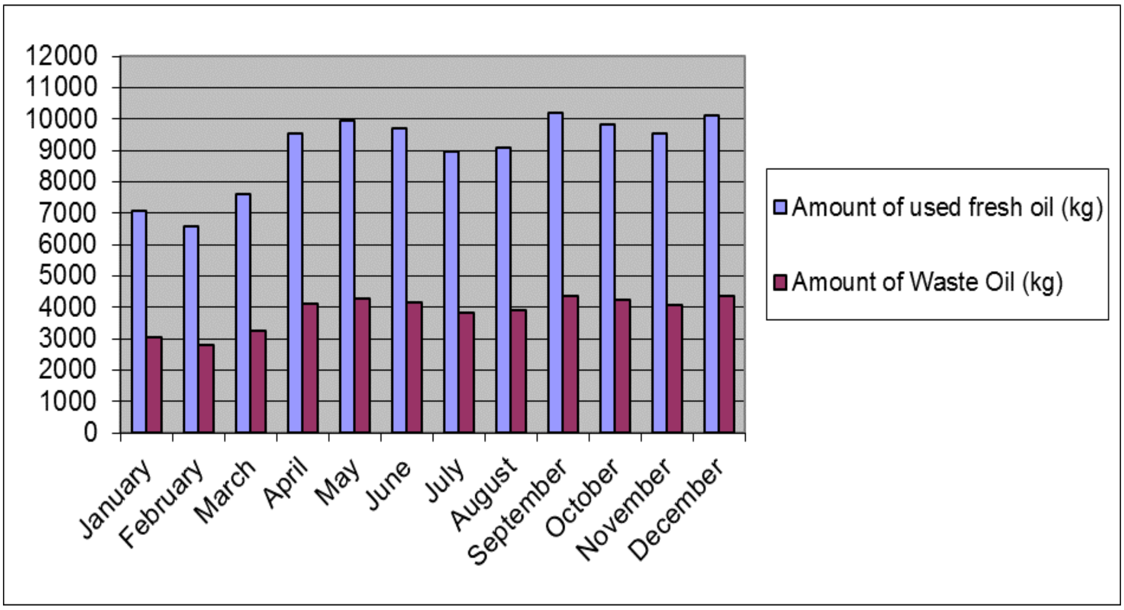


Figure 1. Dynamics of generating waste oil

RESULTS AND DISCUSSION

Ecological aspect of using waste oil for production of biodiesel

Due to lack of a system for management of waste edible oil which would include all aspects of this type of waste, more than 80% of this waste is improperly and uncontrolably spilled into waterways, discharged into sewers, mixed with communal waste and disposed of in landfills. Waste edible oil from restaurants is also used in livestock feed mixed with animal feed.

Inadequate waste disposal in unsanitary dumps leads to pollution of soil and groundwater. Rainfall filtered through the mass of deposited waste decomposes harmful substances, thereby contaminating the soil and groundwater. Additional problem is that pollution of the soil does not have only local character, but leads to pollution of soil and groundwater and surface water in the wider area and, indirectly, to the endangerment of flora and fauna on the surface.

Using waste oil as a resource for producing biodiesel has several positive effects in terms of environmental protection: to eliminate the problem of disposal of waste oil and increase the amount of biodiesel produced, the use of which globally affects the reduction in emission of greenhouse gases.

Energy aspect of biodiesel production from waste edible oil

By analysis of energy consumption for production of one ton of biodiesel, if we take into account all the necessary stages shown in Figure 2, we can conclude that to produce 1 t of biodiesel from crude oil 35 445 MJ is required.

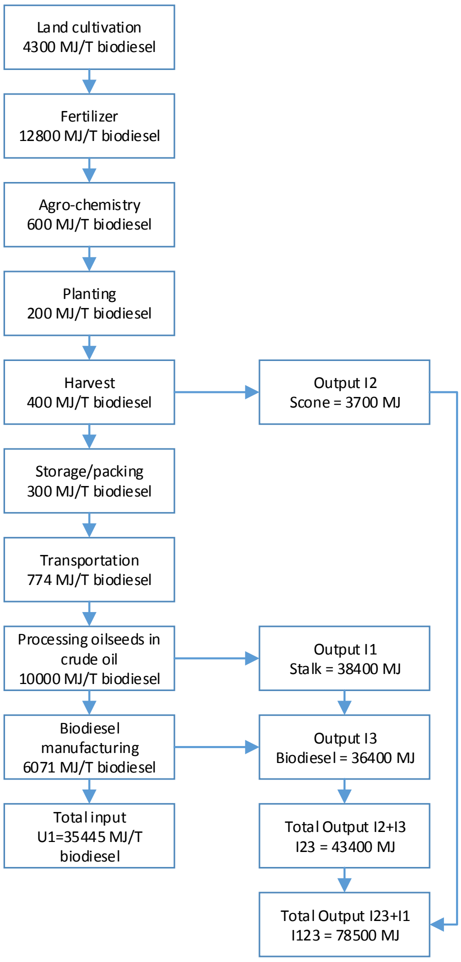


Figure 2. Energy balance in production of biodiesel from oil crops

In analysis of energy consumption of biodiesel production from waste edible oil, the most important components are transport costs in collection of waste oil. Table 1 presents energy consumption in production of biodiesel from waste oil in the Banat region. Energy required to produce one ton of biodiesel from waste edible oil is 6618.21 MJ.
In order to collect 1200 kg of waste oil in the Banat region, which is necessary to produce 1 ton of biodiesel, 53 liters of fuel are required and 1659,11 MJ of energy. If this is compared with the data that for production of crude oil from oilseeds requires 29.374 MJ / t of biodiesel, the conclusion is that energy savings achieved by collecting waste oil is 27,714.89 MJ / t of biodiesel, or 81.33%.

Table 1. Energy balance of biodiesel production from waste oil

Description of activity	Unit	Relative density kg/litre	Quantity litre	Mass kg	Energy value	Energy consumption MJ / ton biodiesel
Collecting waste oil (fuel)	litre	0,860	53	45,58	36,4 MJ/kg	1659,11
Methanol + catalyst	litar	0,795	244	202	23,65MJ/kg	4777,3
Waste oil	litar	0,913	1100	1195,7	37,3 MJ/kg	44599,61
Hot water (80°C)	kWh	-	30	-	-	108
Electric energy	kWh	-	20,5	-	-	73,8
Total energy consumption with oil (U_1)						**51217,82**
Total energy consumption without oil (U_2)						**6618,21**

Table 1 shows two values: energy consumption with oil (U1) and energy consumption without oil (U2). This is done to demonstrate full benefit of using waste oil as raw material for biodiesel production. Data on energy consumption without oil, which was almost disposed of, shows direct energy consumption for production of biodiesel from waste oil collected at the waste generator. Of course, in energy analysis of the process of biodiesel production from waste and fresh oil there must be information on the process inputs and outputs, in order to obtain information on gains or losses.

Economic aspect of biodiesel production from waste edible oil

The main reactant in production of biodiesel is vegetable oil (rarely fat), so the basic price of biodiesel depends on the price of oil (i.e. technologies for oil production), i.e. the price of raw materials. In the early 90s of the last century, when the biodiesel industry faced great initial costs, contracted price for rapeseed used in production of biodiesel was significantly lower than the rapeseed grown for human consumption.

Market price of crude sunflower, rapeseed and palm oil ranges from 950 - 1300 € / t, depending on manufacturer, the amount and the supplier or importer, regarding palm oil. The price of waste vegetable oil on the market ranges from 200 - 300 € / t, depending on the amount available and suppliers, as well as whether waste oil is collected independently or bought directly from operators. In case when it is collected, direct costs include costs of transport, i.e. collecting and costs of labour. Analyzed data shows that the price of waste oil is 4 to 5 times lower than purchase of crude oil.

The biggest problem with this raw material is that waste oil has different characteristics and is usually mixed with animal fat, organic waste, and has a significant percentage of water. Different quality of oil complicates technological process of biodiesel production. Since the most usual is a batch process of alcoholysis, it is necessary to check the quality of each batch of oil in order to make technological process of alcoholysis optimal.

Another major problem is that the market does not have a constant inflow of this type of waste. The reason is that part of this waste is used as a feed additive due to low prices, despite the fact that it is harmful to animals, lack of information about options for disposal and recycling waste edible oil, insufficiently developed awareness about environmental protection and increasing energy efficiency, use of alternative fuels and underdeveloped system for collection and disposal of waste oil.

CONCLUSION

Use of waste edible oil for biodiesel production has several advantages:

- it eliminates the problem of disposal of waste oil in landfills, watercourses and sewage systems;
- it eliminates the problem of feeding livestock with toxic waste fats;
- it increases the production of biodiesel as alternative fuel, which influences the reduced emission of greenhouse gases.

Using waste edible oil for biodiesel production also affects the decrease in prices of biodiesel due to:

- energy savings in production process of biodiesel from waste oil in relation to crude oil;
- lower prices of waste oil compared to crude oil as raw material.

In order to increase the percentage of use of waste oil for biodiesel production it is necessary to:

- perform better control of waste disposal;
- develop system for collection of waste oil;
- educate citizens about consequences of improper disposal of waste on environment and thus themselves;
- educate citizens on possibilities of increasing energy efficiency at local and global levels.

Disadvantages of using waste oil as raw material for biodiesel production in relation to crude oil are reflected in the following:

- Biodiesel produced from waste edible oil has more increased viscosity and poorer cold properties than biodiesel produced from pure vegetable oil, which is a result of changed structure of fatty acids in process of food preparation.
- Reaching better quality of biodiesel from waste edible oil is achieved by mixing it with fresh vegetable oil, because waste edible oil alone cannot meet quality requirements EN 14214th

REFERENCES

[1] Saka S, Kusdiana D. Biodiesel fuel from rapeseed oil as prepared in supercriticalmethanol. Fuel 2001;80:225–31.
[2] Xie W, Peng H, Chen L. Transesterification of soybean oil catalyzed bypotassium loaded on alumina as a solid base catalyst. ApplCatal A-Gen2006;300:67–74.
[3] Bondioli P, Gasparoli A, Lanzani A, Fedeli E, Veronese S, Sala M. Storage stabilityof biodiesel. J Am Oil ChemSoc 1995;72:699–702.
[4] Zullaikah S, Lai Chao-Chin, Vali SR, Ju Yi-Hsu. A two-step acid-catalyzedprocess for the production of biodiesel from rice bran oil. BioresourTechnol2005;96:1889–96.
[5] Murayama T. Evaluating vegetable oils as a diesel fuel. Inform 1994;5:1135–8.
[6] Bailey B, Eberhardt J, Goguen S, Erwin J. Diethyl ether (DEE) as a renewablediesel fuel. SAE Paper No. 972978, SAE, Warrendale, PA; 1997.
[7] Zhang Y, Dube´ MA, McLean DD, Kates M. Biodiesel production from nbwastecooking oil: 2. Economic assessment and sensitivity analysis. BioresourTechnol 2003;90:229–40.
[8] Mustafa, C. et al.: Performance and exhaust emissions of a biodiesel engine, Applied Energy 83, Elsevier, 2006. p. 594.
[9] Zheng S, Kates M, Dube MA, McLean DD. Acid-catalyzed production ofbiodiesel from waste frying oil. Biomass Bioenerg 2006;30:2670–2.
[10] Zhang Y, Dubé MA, McLean DD, Kates M. Biodiesel production from wastecooking oil: 1. Process design and technological assessment. BioresourTechnol, 2003;89:1–16.
[11] Barnwal, B.K., Sharma, M.P.: Prospects of biodiesel production from vegetable oils in India, Renewable and Sustainable Energy Reviews 9, Elsevier, 2005. p. 363.
[12] Zhang, Y. et al.: Biodiesel production from waste cooking oil: 2. Economic assessment and sensitivityanalysis, Bioresource Technology 90, Elsevier, 2003. p. 229.
[13] Mittelbach, M.: Experience with Biodiesel from Used Frying Oil in Austria, Institute for Chemistry, Working Group Renewable Resources, Karl-Franzens-University Graz, Graz, 2002.
[14] Uredba o upravljanju otpadnim uljima „Službeni glasnik RS”, br. 55/05, 71/05 i 101/07
[15] Zlatko Jurac, Optimiranje proizvodnje biodizela iz otpadnih jestivih ulja s obzirom na zahteve kvaliteta, Sveučilište u Rijeci, Tehnički fakultet, DOKTORSKA TEZA, RIJEKA , 2011

POSSIBILITY OF APPLICATION OF SOLAR PUMPS IN IRRIGATION

Aleksandar Ašonja[1], Danilo Mikić[1], Jasmina Pekez[2]
[1]The Association of Intellectuals for the Development of Science in Serbia, "The Serbian Academic Center", Novi Sad, Serbia,
[2]University of Novi Sad, Technical Faculty "Mihajlo Pupin", Zrenjanin, Serbia,
e-mail: aleksandar.asonja@gmail.com

Abstract: Today, is very often, especially where there is no indented city water supply network, on smaller agricultural areas, farms and the like. for irrigation use solar pumps. The paper deals with the problem of dimensioning of solar pumps in irrigation. For irrigation needs, the paper analyzed the solar pump of smaller capacity which are intended for watering of small agricultural areas, such as those in greenhouses, etc.
Key words: The solar panel, the sun, irrigation, agriculture

INTRODUCTION

In the Republic of Serbia today is about 40% of arable land, while the region of Vojvodina has 1.78 million ha of fertile arable land, of which only 28% is irrigated. [1] In stated problem lies an enormous research task, which consists of increasing the surface area that could be irrigate, and that energy that would have initiated such systems is renewable. Demand for water is greater the very sandy, particularly windy and southern positions than on the structural soils of the northern exposition [2]. Schedule of moisture on the surface of the earth is far more complex than the layout of heat and light.
Moisture, particularly in the form of water, plays an important role in the life of plant species, because it is a requirement for many the life processes who can not imagined without the participation of water. It is considered that moisture is one of the most important herbal ecological factors, far more influential than light and heat, because the diversity of flora and its a geographical layout usually depends on the just from the schedule moisture.
While the sun's rays directly receive to biomass, moisture (rain, snow) receiving himself through the land. It occurs in the form of air humidity and of atmospheric deposition [3].
Plants in themselves contain up to 95% water, but by far is higher amount of water which pass through herbal organism. The evaporation of water from plants is called transpiration, and it is of unusual importance, because it is conveyed by way of water. The relationship between taking water from the soil and allocations via the leaves called water balance of plants. It is normal that the water balance is in equilibrium, but often occur under the influence of heat, to violate this occurs and the water deficit which may be from 5 to 10 and up to 30% without any damage to the herbal organism. When this lack of exceeds a certain limit, then the plants are showing the first signs of wilting, ie. loses turgor and leaves were due to wilt wither, which can be permanently or temporary.

POSSIBILITY OF PRODUCTION ENERGY ON AGRICULTURAL OF LAND

For centuries, the sunlight is applied to produce food for humans. However, in 1970 - in those years they began to applied by solar photovoltaic panels, very often i on arable the agricultural land. This was one of the disadvantages of this form of renewable energy source, because he disturbed yields in agriculture.

Architecture and technologies of solar panels over time in sophistication, so that they used today and lands that are used agricultural production. The goal of contemporary of agricultural production is that the produce food and electricity at the same time. Such plants could provide additional sources of income for agricultural producers. By selecting of adequate of agricultural crops submitted by the of, seed, the same would be protected obscuring of: sun and high temperatures (which last year recorded an increase) heavy rainfalls, of the winds, hail and the like.

SOLAR PLANT IN IRRIGATION

In recent years, about 30% of users of solar energy in agriculture uses the sun to drive irrigation pumps, but this trend is changing rapidly in favor of those farmers who of their installation linked to the power grid in order to sell the excess electricity produced. Some of the construction of solar panels I can change their slope as the sun changes its position. This makes it possible to provide a an increase in daily gain energy by as much as 55% [4]. When designing the solar plant for irrigation of agricultural cultures, the most important task is to choose the solution which is the largest efficiency, and the investment minimum. Selection of appropriate methods of irrigation, is conditioned by a number of factors: the land, biological, climatic, relief, economic, hydrogeological technical and technological. When designing such plants, and making a decision for selection of equipment important role is played lot size to be irrigated and its need for with water. [4]

How solar photovoltaic panels produce the most energy during the summer when there is the most the sun then, in agricultural production and the greatest need for with water. The applicability of these solutions for irrigation can meet the needs of all types of agriculture production: farming, pomology and viticulture. This solar water pumps any submersible or floating, provides the water needed for the [5]:

- irrigation of agricultural cultures,
- dewatering (removal of excess water) and
- servicing households.

Depending on the types of agricultural cultures and their water needs, the size of the plot and the weather conditions, solar systems for irrigation may be:

- the fixed (Figure 1a),
- semi-mobile (Fig.1b) and
- mobile (Fig. 1c).

a)

b)

c)

Figure 1. a) Fixed solar systems for solar drive pumps and irrigation,
b) Semi mobile solar system for irrigation "pivot, center pivot",
c) Mobile solar irrigation system

When in dimensioning and the choice of abstraction, with regard to water availability and choices of solar pumps, to be distinguished:

- underground waters,
- surface water (rivers, lakes, reservoirs etc.).

Choice of water intake is the most important problem in defining a solar plant for irrigation. Here is certainly worth a take account of physical and chemical properties of water, its temperature etc. Water intakes of surface water courses are not limited to capacity, unlike underground of water courses.
For the purposes of extraction of groundwater the necessary the investments in drilling of wells [6].
In dimensioning of and selection of the device for irrigation, should consider the following:

- species of plant and its need for water,
- watering the duration (h).
- Tornus irrigations (number of days).
- firth norm (m^3/ha),
- the required amount of water during growing season (m^3),
- pedological content of the soil,
- parcel size (ha),
- configuration of plot,
- capacity solar pump (l/s),
- available pressure in the system (bar), etc.

The choice of solar pump is based primarily on the availability of the most affordable multimedia water intakes. It further pump selection is performed in accordance with the required quantity of water and the necessary efforts pumps.

MATERIALS AND METHODS

Irrigation systems in Republic of Serbia are usually driven by diesel or electric motors. The goal of of this paper is the presentation of the possibilities of small for irrigation of agricultural areas with solar pumps of small capacities, although solar pumps can be used for irrigation of agricultural areas with larger capacities than 1,500 l / h. Justification of this study lies in the fact is very fragmented holdings in the Republic of Serbia.
The paper presents justification of of solar pumps in irrigation, depending on their capacity. Were analyzed water demands to be used for watering of small of agricultural areas, that the application can be found in greenhouses, etc. The advantage of these of watering, the method especially dropwise, the small amount of water that are given plants. For this reasonthis paper analyzes three types of pumps: A to 2 l/h, B 4 l/h and C to 8 l/h, table 1. Average work time for which the observed justification of use of these pumps amounted to 10 h / day. Capacities the said solar pump on a monthly and annual basis are shown in table 1.

Table 1. Capacity of solar pumps on a monthly and annual basis

Size of the solar pump	Capacity (l/h)	The capacity on a monthly basis (m^3/mes)	The capacity on an annual basis (m^3/god)
A	2	0,6	10,80
B	4	1,2	14,40
C	8	2,4	28,80

RESULTS AND DISCUSSION

Using solar energy in agricultural production most appropriate is, since the highest energy is produced at those moments when it is most required for the growth of of agricultural cultures. For example. irrigating is carried out in the period when he has the most solar energy and when needs were for with water for agricultural culture is greatest. How would liberate the need the use of conventional energy sources in the irrigation of smaller of agricultural areas (eg. under the the greenhouses and glasshouses) can be used all year round solar pump with a capacity of 0.6 to 2.4 m^3/mes. Problems for wider application of these solar pumps in agriculture are:

- financial and economic aspects,
- a continuous supply of energy during the whole year [7],
- no informing of agricultural producers and others.

CONCLUSION

From year to year reduces the required investment for solar systems (solar pump) in irrigation and the time required for the repayment of the total investment in such systems. Due to its small investment and is very of simple of equipment today is is very economical payable application of solar pumps of small capacity of from 2 to 8 l / h. In the world investments in this equipment cost effective for a few years (2-3 years).

Because of the low price of electricity in Serbia, which is still below the average in the each region, the use of these solar plant is on the verge of profitability. But harmonization electricity prices with the prices in the region, and how there would be justification of the use of solar plants for irrigation. But by adjusting electricity prices with the prices in the region, will exist justification of use of solar plants for irrigating.

REFERENCES

[1] Petrović, P. (2008). Beogradska deklaracija ministarske konferencije „Životna sredina za Evropu", Traktori i pogonske mašine, Vol.13, No.3, 72-79.

[2] Ašonja, A. (2001). Primena fotonaponskih solarnih panela u navodnjavanju višegodišnjih zasada, Diplomski rad, Poljoprivredni fakultet, Novi Sad.

[3] Milojić, B. (1983). Ratarstvo (II izdanje), Naučna knjiga, Beograd.

[4] Ашоња. А. (2015). Могућности примене соларне енергије из агронапонских постројења, Техничка дијагностика, Vol.14, No.1, 17-23.

[5] Ашоња. А., Диховични, Ђ. (2015). Могућности примене соларне енергије у водоснабдевању, Техничка дијагностика, Vol.14, No.2, 7-13.

[6] Belić, S., Benka, P. (1996). Tehnika navodnjavanja i odvodnjavanja, Poljoprivredni fakultet, Novi Sad.

[7] Pekez, J., Radovanović, Lj., Desnica, E., Lambić, M. Increase of exploitability of renewable energy sources, Energy Sources, Part B: Economics, Planning, and Policy Article in press, Manuscript ID: UESB-2011-0031.R1, DOI number: 10.1080/15567249.2011.580318.

PROJECT CONCEPTUAL DESIGN OF TRANSPORTATION AND STORAGE OF STARCH

Dragiša Tolmač[1], Jasna Tolmač[1], Slavica Prvulović[1], Sanja Stankov[1]
[1]University of Novi Sad, Technical Faculty "Mihajlo Pupin", Zrenjanin, Serbia
e-mail: dragisatolmac@gmail.com

Abstract: This paper describes the design and technological solution of transport and storage of starch. This type of product, obtained in the industrial processing of cereals, a starting material is corn. The project was developed and implemented for the factories of the products made from corn - "IPOK", Zrenjanin.
The paper contains a description of the technological process, the scheme of technological process, energy requirements specification machine technology equipment.
Key words: starch, transport, storage

INTRODUCTION

In the main project was developed mechanical design technology facilities for transport and storage of starch. Storage starch is performed in three cell silo capacity 3x150 tons.
Newly designed line of the facility provide a very good technical solutions for the storage of starch, according to the current world technology, given the experience and knowledge to be applied in the food industry. The entire investment project included: transport and storage of starch dryer to silo, like starch and transport facilities for the finalization of the bulk transport vehicle tanks. The project includes the installation of compressed air, for machinery and equipment [2], [4, 5].

DESCRIPTION OF THE TECHNOLOGY

Plant transport and storage of starch, consisting of three cells silo capacity of 3 x 150 tons, with its machines.
Technology and mechanical design includes transport and storage of starch from the line to dry, and loaded on a tanker, and bagging plant for mixing the special starch.
The capacity of the pneumatic transport of starch dryer to silo is G_1 = 8000 kg / h, and from the silo filling in bulk tankers G_2 = 20 000 kg / h. Storage starch is carried out in three silo-cell capacity of 150 t each. Given the decision to exclude from the starch silo and transport to other production facilities.
The dried starch from the plant for drying using a rotary compressor (27) and lift-fluid dispenser (19), points (21 and 20), pneumatic pipeline (16), G_1 capacity = 8000 kg / h, the system pressure, transported to silo I, II (3), or to the bagging plant. Mentioned silos with a capacity of 150t, (300m3).
Separation of starch from the air is transported to the deposition of the free volume of the silo (minimum 30m^3) when the tank is full. Dust collection silo is done using a filter (5) the surface F = 7m2. The filters are equipped with their own fan (6) for the aspiration of silos.
At the top of the silos are opened easily with movable lids to direct any explosion. These holes also serve to open the exit of air safety at possible congestion filters.
Safe discharging of silos provides the vibratory feeder (4), 2400 mm diameter, which are included only during the discharge of silos. Closure of the silo and is performed using a manual valve (7) and screw conveyor (23), which is reversible and can be transported through the system starch worm conveyor (24, 25, 26) and filling device (12) in bulk tank filling or through fluid-lift dispensers (22) using a rotary compressor (18) and switches (20), starch can be pneumatically transported by pipeline (17) in mixers modifiers or bagging starch.
Closing the bottom of the silo II is carried out using a manual valve (7) and using the lift-fluid dispenser (8). Using a rotary compressor (14) and switch (1) through pneumatic tubes (10), cyclone (11), the rotary feeder (9) and filling device (12) is bulk charging tanks.
Silos I and II are designed for commercial starch silo while III is intended for special starch. Closing the bottom of the silo III is carried out using a manual valve (7) and fluid-lift dispensers (8). Using a

rotary compressor (14) and switch (1) through pneumatic tubes (10), cyclone (11), the rotary feeder (9) and filling device (12) is bulk charging tanks.
Based on the calculations [2], the installed power capacity and mechanical-technological equipment for the transport and storage of starch, the installed capacity of electric engine is 133 kW. For the degree of concurrency of operation 0.8 total daily demand for electricity is: $133 \cdot 0{,}8 \cdot 24 = 2560$ kWh.

CONCLUSION

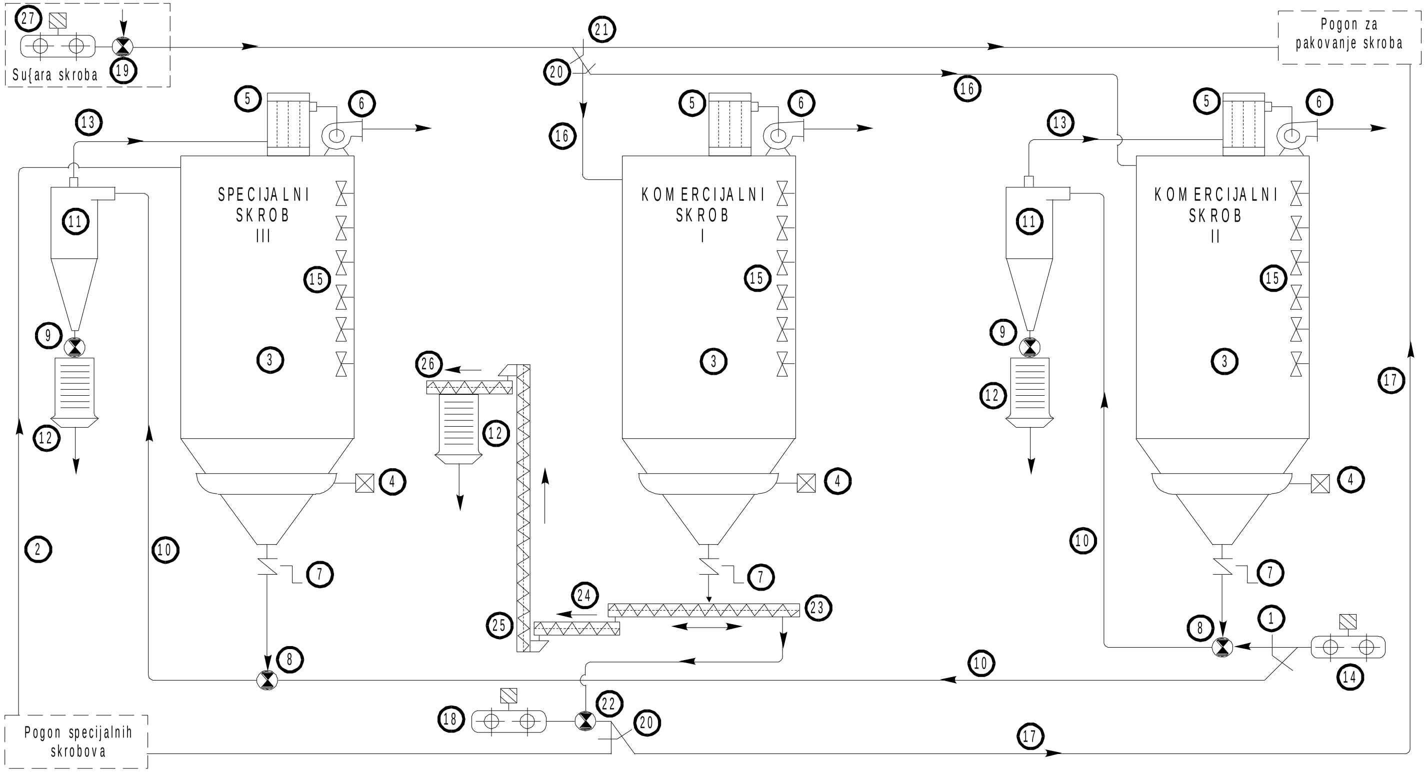
Plant transport and storage of starch, the capacity of 3 x 150 tons, built in "IPOK", Zrenjanin, to increase the production capacity of starch, with a dedicated transport system and stored in a silo capacity of 3 x 150 tons. Also provided is a better quality product - starch storage in the system, which was one of the key issues and market demand [1], [3].

REFERENCES

[1] Prvulovic, S., Tolmač, D. : Project organization and implementation of plans for construction, X International Symposium on Project Management, Proceedings, p. (160-163), YUPMA 2006.
[2] Tolmač, D., Lambic, M.: The mechanical-technological project for the starch silo capacity 3x150 tons, DD "Šinvoz", Zrenjanin, (made for "IPOK", Zrenjanin.)
[3] Tolmač, D. Prvulovic, S. : Projects of technological systems in the food industry, "SM"-Engineering, Zrenjanin, 2001.
[4] Tolmač, D. : Design, Technical Faculty "Mihajlo Pupin", Zrenjanin, 2009.
[5] Tolmač, D. : Design of Technological Systems - Production Systems -, Technical Faculty "Mihajlo Pupin", Zrenjanin, 2008.
[6] Prvulović, S., Tolmač., D., Tolmač, J. : Process systems and installations, Technical Faculty "Mihajlo Pupin", Zrenjanin, 2014.

POZICIJA	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.	13.
NAZIV	Cevna skretnica	Cevovod	Silos	Vibracioni izuzimač	Vre}asti filter	Ventilator	Ru~ni zasun	Fluid-lift dozator	Rotacioni izuzimač	Cevovod	Ciklon	Teleskopski uređaj	Kolektor
TEHNI^KI PODACI	tip 150	L = 145m	V = 300m³	D = 2400mm	F = 7m²	Q=2000m³/h	ϕ=350mm	N=2,2kW, Q=20t/h	N=2,2kW, Q=20t/h	L = 50m	ϕ600x2550mm	ϕ = 200mm	ϕ270mm, L=20m
MATERIJAL	ner|aju}i ~elik	Al cevi	^.0361				^.4572	ner|aju}i ~elik	SL	Al cevi	^.4572	ner|aju}i ~elik	pocinkovan lim

POZICIJA	14.	15.	16.	17.	18.	19.	20., 21.	22.	23.	24.	25.	26.	27.
NAZIV	Kompresioni agregat	Pokazivač nivoa	Cevovod	Cevovod	Kompresorski agregat	Fluid-lift dozator	Cevna skretnica	Fluid-lift dozator	Pužni transporter	Pužni transporter	Pužni transporter	Pužni transporter	Kompresorski agregat
TEHNI^KI PODACI	N=30kW,Q=26,4m³/min		NV120	L = 105,5m	N=22kW,Q=16,8m³/min	tip 120	tip 120	tip 120	L = 60m	L = 26m	L = 60m	L = 40m	N=30kW,Q=17m³/min
MATERIJAL			Al cevi	Al cevi					^.4572	^.4572	^.4572	^.4572	



I.2. - Tehnolo{ka {ema transporta i skladi{tenja skroba

9

MATHEMATICAL MODEL FOR ESTIMATING USEFUL ENERGY OBTAINED ON THE SOLAR COLLECTORS FOR REGION OF BELGRADE

Kristijan Vujičin[1], Miroslav Vulić[2]
[1]University of Belgrade, Faculty of Mechanical Engineering, Belgrade, Serbia
[2]University of Novi Sad, Technical Faculty "Mihajlo Pupin", Zrenjanin, Serbia
e-mail: kristijan.vujicin@gmail.com

Abstract: Aim of this paper is calculating of potential of solar radiation in region of Belgrade using mathematical model. Data for solar energy are calculated by correlation of various parametres. The data used for the global solar radioation were taken from the database of the Joint Research Centre, Institute for Energy and Transport for the period 2001-2012. Corellations are formed between data for insolation on the horizontal surface, inslolation on the vertical surface and optimal surface, and also for useful energy, which data are measured on the one solar system in Belgrade during 2012.
Key words: mathematical model, solar radiation, correlation, insolation, useful energy

INTRODUCTION

The energy of solar radiation that comes to the Earth yearly is around 170 times bigger than the energy contained in the overall reserves of coal in the world. The capacity of solar radiation on Earth is, according to available estimations, around 14000 times bigger than the overall energy consumed by human kind today [1]. The power of solar radiation that falls onto the Earth is around 175000 TW. What kind of a potential is that shows also the fact that entire world energy consumption has the power of closely 13 TW! The energy of solar radiation that reaches the Earth's surface, meaning potentially usable solar radiation, is around 1.9 · 108 TWh (190 million of TWh) yearly. Comparing to the needs of human kind for energy, that is 1.3 · 105 TWh (130 thousand TWh) yearly, we come to a derivational fact that the solar energy that reaches the Earth during only 6 hours is enough to satisfy all needs in the world on annual level. To get a better insight for these values, an average household in some of the most developed countries in the world spends yearly around 10000 kWh of electricity, and it would take 100000 years to spend 1 TWh. Around 37% of global demand for energy is satisfied with production of electricity which in 2008 was around 17000 TWh. The problem with analysing solar radiation is primarily connected with the lack of systematically recorded data in weather stations or institutes. In addition, in order to have statistical significance in analysis and to develop various estimation models it is important to have access to detailed data for a long period of time.
The average values of global solar radiation are the most significat parameters for estimating efficiency of solar energy systems. However, there are no available data about measured solar iradiation for each location, which complicates the estimation during projecting solar energy systems. For locations without measured values, the solution is to build mathematical models that will provide reliable estimation for solar iradiation.
The success in estimating the efficiency of solar systems depends solely on the data for solar radiation for the place where the implementation of the system is planned. The deficiency of data is a key issue. Even in developed countries there are very few meteorological stations that record data for solar radiation. There are no data available or similar studies for this region.
The aim of this paper is to establish the correlation between data taken from the database and data measured in the solar system in Belgrade. The established correlations are the basis for a mathematical model which can estimate the potential of solar radiation in Belgrade. The database used for the analysis is available for the period 2001 - 2012. Based on the data a typical meteorological year (TMY) with the average solar radiation per month was developed. The data available from this database are as follows: insolation on a horizontal surface (H_h), insolation on a vertical surface (H_v), insolation on the optimum surface (H_{opt}). The database of measured values and the net usable energy Q_m was obtained from a small company engaged in business in the field of solar energy. These data were measured on the solar system

which contains 40 solar panels installed in Belgrade. The measurements were conducted in 2012. The parameter used in the analysis is useful energy per square meter on the absorbing surface of collectors. The rest of the paper is structured as follows: Section 2 shows studies conducted in different parts of the world. Section 3 shows the context in which the research was conducted, i.e. climatic characteristics of the Belgrade region and basic information about the small energy firm whose project was used as a source of data for the research. Sections 4 and 5 present the data analysis and the discussion of constraints and validity of the research. The concluding remarks are given in the last section.

RELATED WORK

Solar irradiation attracts significant attention in research community because of the importance of solar energy for humans. Several studies have reported researches on solar irradiation and other relevant parameters of solar energy in different parts of the world. Some of them are briefly presented in this section.

For example, the authors [2] presented the potential of solar energy in Medina (Kingdom of Saudi Arabia) based on correlation between the different parameters of solar energy. The aim of the study is to develop estimation models for different components of solar irradiation, and to evaluate the potential of solar energy in Medina. Analysis is based on database for five years since 1998 until 2002 that is available at the National Renewable Energy Laboratory (NREL) website. The authors developed a typical meteorological year (TMY) from the database, a sunshine duration by using the global radiation data, and calculated the extraterrestrial radiation (H_0) and sunshine duration (SS) in order to obtain the clearness index ($K_t = H_G/H_0$) values. Homogenizing data eliminated seasonal effect. The authors developed the correlation model between the global radiation (H_G), diffuse irradiation (H_D) and sunshine duration (SS) over the year, and correlation model between temperature and global irradiation. In addition, the authors investigated evolution between the temperature and the global irradiation at Medina, and proposed a model of correlation between the temperature T(C deg) and the global irradiation H_G (W /m^2) received on horizontal surface. Regression models are calculated for sunrise until midday, and for midday until sunset.

Study [3] presents application of various regression analyses to estimate monthly mean solar radiation in Turkey. Data used in the analysis were obtained from observation stations in Antalya, Izmir, Ankara, Yenihisar (Aydin), and Yumurtalik (Adana), and from measurment in Elazig. The corerlations were calculated for the retios of daily insolation H to the extraterrestrial radiation (H_0), and measured sunshine duration in a day (n) to the theoretical daylength of that day (N). In addition, the authors included in the regression analysis the monthly mean sunshine duration taking into account the natural horizon of the site N_{nh}. Because athmospheric effects influence the solar radiation differently in winter and summer, the relations ($H/H_0 = f(n/N)$) and ($H/H_0 = f(n/N_{nh})$) were investigated by different regression analyses for both seasons. The study uses root mean square error (RMSE) and mean bias error (MBE), and t-statistic to evaluate the accuracy of the correlations.

In Croatia, a graduate thesis analysed the estimation of solar radiation in 2004 [4]. In the paper the global solar radiation measured at Puntijarka (Croatia) was analysed and the measurements were conducted from 1959 to 2004. It was concluded that there was an increase of radiated energy over the time. It was also observed that there are no significant deviations from the values obtained theoretically. A correlation between the parameters of global solar radiation, diffuse radiation and insolation was established and it was concluded that the values were very high, i.e. the parameters largely depend on each other. The result of this work are four empirical models which, with help of insolation data, determine values for radiant of solar radiation. In the measurements conducted from 1959 to 2004 it was observed that there were deficiencies in the data for the given period, and the deficiencies for these models were neutralised.

Study [5] shows an estimation of global solar radiation in the cities of Bulgaria: Sofia, Sandanski, Chirpan and Kardjali. For these cities the average monthly solar radiation per day on a horizontal surface is shown and it was obtained using the following parameters: the duration of solar radiation, diffuse radiation, minimum and maximum air temperature. These parameters were measured in the hydro-meteorological stations. They are an input into mathematical model that calculates the total solar radiation. The mathematical model developed in this study was also tested. The tests show that for

summer and winter different models developed in this study should be used to minimise the estimation error. The error determined in the study is about 5-8%.
Based on a thorough examination, it was concluded that there are no studies on the assessment of solar radiation in the region that is the subject of this study.

DATA ANALYSIS

The development of a model for estimation of useful solar energy involves the collection of relevant data on the sun's energy for the geographical area that is considered, the collection of empirical data that include the elements of projecting of a typical system and the development of appropriate mathematical models based on the collected data. Mathematical model is based on establishing a correlation between the useful solar energy measured on the selected plant and the data about insolation in the observed place, and then defining a linear regression that can be used to estimate the useful solar energy on the new plants.
Correlation coefficient R reflects the degree of linear association between two observed variables [6] [7]. Prediction or estimation in linear regression can be done by analysing coefficient of determination R^2 [8][9].

Data collection

Data used in this study, i.e. insolation on the horizontal surface (H_h), insolation on the vertical surface (H_v), and insolation on the optimum surface (H_{opt}) were taken from the database 'Joint Research Centure' (JRC) [10]. The collected data are for period 2001 - 2012. Based on them a typical meteorological year (TMY) was formed and used during the study.
A typical meteorological year (TMY) is based on the collation of selected weather data for a specific location, generated from a data bank much longer than a year in duration. It is specially selected so that it presents the range of weather phenomena for the location in question, while still giving annual averages that are consistent with the long-term averages for the location in question.
In table 2, the second, the third and the fourth columns, i.e. H_h, H_v and H_{opt} contain the data downloaded from the database 'Joint Research Centure', while the fifth column represents the data measured (Q_m) on the solar system which is implemented in Belgrade. The data were taken from the company that has designed the solar system, which is located in one institution in Belgrade. The strength of the solar system is Q = 44 kW, respectively 40 solar collectors, which represents 80m^2 of net surface. The solar collectors were chosen by using AHP analysis. [11]. The solar system is used to heat 4000 l of sanitary hot water, where the hot water consumption during the day amounts to 3800 l. Based on the previous results of this plant, the total saving per year is over 55% of the total energy for the heating of hot water. Data are given for each month separately and each value presents the average value measured in the particular month. Figure 1 shows a graphical representation of the measured useful energy per m^2 on the selected solar installation in Belgrade.

Table 1. Basic information about the implemented projects

Ordinal number	Location	Number of collectors	Power of plant (kW)	Year
1	Subotica I	48	52,8	2010
2	Subotica II	80	88	2009
3	Apatin	20	22	2010
4	Novi Knjževac	30	33	2011
5	Bački Petrovac	30	33	2010
6	Sombor	75	82,5	2011
7	Coka	30	33	2011
8	Kikinda I	80	88	2011

9	Kikinda II	40	44	2010
10	Kikinda III	40	44	2012
11	Kikinda IV	20	22	2012
12	Kikinda V	180	198	2012
13	Kikinda VI	18	16,5	2012
14	Zrenjanin I	200	220	2009
15	Zrenjanin II	80	88	2009
16	Zrenjanin III	80	88	2010
17	Zrenjanin IV	40	44	2010
18	Vršac	30	33	2011
19	Kovin I	40	44	2010
20	Kovin II	30	33	2011
21	Kovin III	40	44	2011
22	Smederevo I	20	22	2010
23	Smederevo II	16	17,6	2010
24	Pozarevac	200	220	2010
25	Stamnica	80	88	2010
26	Kragujevac	40	44	2010
27	Vrnjačka Banja I	75	82,5	2011
28	Vrnjačka Banja II	96	105,6	2011
29	Beograd I	30	33	2011
30	Beograd II	40	44	2012
31	Novi Sad I	180	196	2010
32	Novi Sad II	30	33	2010
33	Obrenovac I	40	44	2009
34	Obrenovac II	27	29,7	2010
35	Vrbas	80	88	2010
	Total	2.182	2.400,2	

Data analysis

The simple model for estimating the useful energy with regard to solar irradiation is based on correlation and regression analysis. Analysis uses data about useful energy calculated from the project "Plant for the heating of water by solar energy" implemented by a small company in Belgrade. Data used in the analysis are outlined in table 2. Correlation coefficients were calculated according formulas presented in [9].

Correlation analysis was performed between the values for usable energy obtained for the solar plant, and the values that are retrieved from the database for irradiation on horizontal, vertical and optimal (35 degrees) surfaces. Correlation coefficients and coefficient of determination for all three cases are presented in table 3.

The regression analysis is based on two steps: the determination of correlation between the two variables and the establishment of a linear regression for these variables [12]. The correlation analysis was performed between certain values for three different positions of the solar collectors.

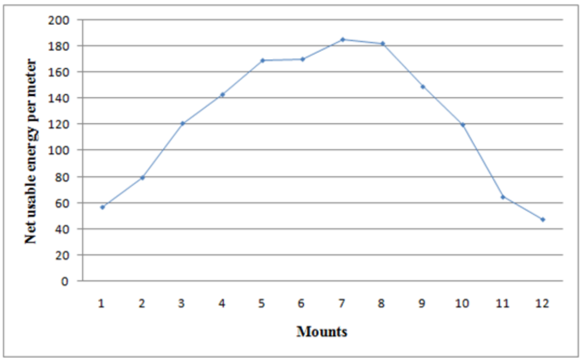


Figure 1. Net usable energy measured in the selected solar plant in Belgrade

Table 2. Data for correlation analysis

Month	H_h	H_{opt}	H_v	Q_m/m^2
January	1.190	1.870	1.880	57
February	1.970	2.830	2.580	79,5
March	3.150	3.930	3.030	121
April	4.370	4.770	2.960	143
May	5.500	5.470	2.810	169
June	6.000	5.700	2.650	170
July	6.260	6.090	2.910	185
August	5.520	5.040	3.350	182
September	4.100	3.900	3.640	149
October	2.710	2.280	3.450	120
November	1.460	1.630	2.250	64,7
December	1.000	4.120	1.680	47,6
Year	3.610		2.770	

The analysis was conducted between the following parameters: global solar radiation on a horizontal surface and the measured value on the solar system, global solar radiation on the optimum surface and measured values on the solar system and global solar radiation on a vertical surface and measured values on the solar system. This means that the correlation coefficient R was determined for all three cases, as it is shown in table 3.

The values for global solar radiation, as well as for the measured values of solar radiation, refer to the average values during a typical meteorological year (TMY) , while the data for Q_m were measured in 2012.

Table 3. Calculated correlation coefficients of determination

Analysis number	Correlation between	R	R^2
1	Q_m - H_h	0,934871	0,873984
2	Q_m - H_{opt}	0,95284	0,907904
3	Q_m - H_v	0,686578	0,47139

Model is defined with linear regression trend lines for three cases: irradiation on horizontal surface, irradiation on vertical surface and irradiation on optimal surface.

Correlation coefficient 0.934871 for horizontal surface indicates strong correlation between useful energy and irradiation on horizontal surface. In addition high value of determination coefficient 0.873984 ensures very good estimation of useful energy for horizontal surfaces determined by the regression trend line presented with equation 1.

Y = 0,326X – 113,8

Equation 1 enables estimation of useful energy on solar collectors when surfaces are horizontal. Regression line is defined as a trend line in scatter plot (see figure 2) with values for H_h and useful energy. Independant variable X for regression line is irradiation on horizontal surface, while estimated or dependant variable Y is useful energy.

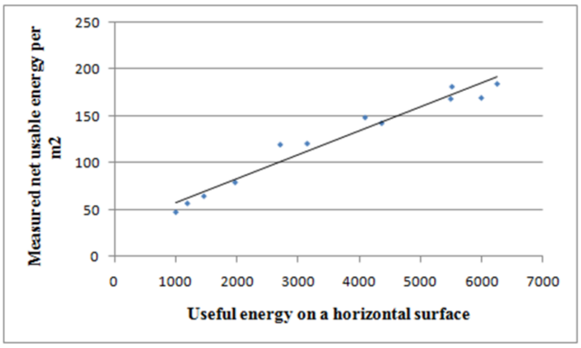


Figure 2. Sccater plot and regression line for horizontal surface

The correlation coefficient of 0.686578 for vertical surface shows a weaker correlation between useful energy and insolation on a vertical surface. In addition, a relatively low value of the coefficient of determination 0.47139 indicates that the estimation of useful energy on a vertical surface is not reliable enough. The independent variable X for regression line is irradiation on vertical surface, while the estimated or dependent variable Y is useful energy. The regression line for the case of the vertical surface is represented by the equation 2.

Y = 0,776X – 1.085

Equation 2 enables the estimate of the useful energy on the solar collectors when the collectors are placed vertically (90° angle). The regression line is defined as a trend of line on a scatter diagram, with the values for H_v and useful energy (see figure 3).

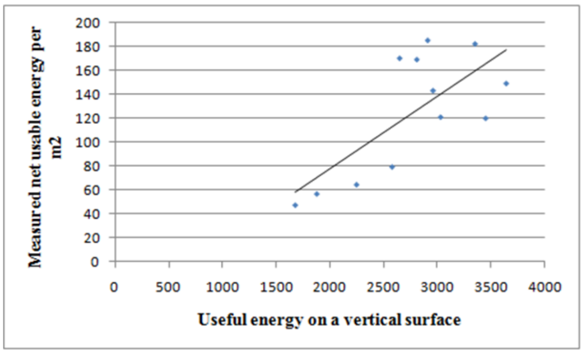


Figure 3. Sccater plot and regression line for vertical surface

The correlation coefficient of 0.95284 for optimal surface shows a very strong correlation between the useful energy and radiation on the optimum surface. In addition, a high value of coefficient of determination 0.907904 provides a very good estimation of useful energy on the optimum surface using the equation:

Y = 0,399X – 581,4

Independant variable X for regression line is irradiation on optimal surface, while estimated or dependant variable Y is useful energy. Equation 3 enables estimation of useful energy in the solar collectors when the collectors are mounted at an optimum angle which is, in this case, 35°. The regression line is defined as the trend line in the scatter diagram with values for H_{opt} and useful energy (see figure 4).

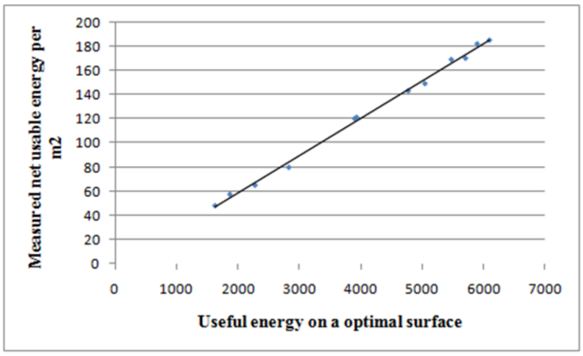


Figure 4. Sccater plot and regression line for optimal surface

Discussion of results

The estimation of useful solar energy is represented by equations 1, 2 and 3. Each equation presents the estimation of solar energy for a particular angle of solar collector. The slope of the solar collector presents the angle which sunlight falls under. The assessment is based not only on the value of the correlation coefficient R, but it also includes the analysis of the value of the coefficient of determination R^2.
The coefficients of correlations for horizontal and optimal surface are very high and indicate a strong rela- tionship between the variables for which the correlation is established. In addition, high values of determination coefficients provide a very good estimation for future projects.
Such high values of the coefficients show that the mathematical models, which are defined by equations 1, 2 and 3, can provide a very good estimaton of useful solar energy.

VALIDITY AND LIMITATIONS OF THE STUDY

Limitations and validity of any empirical study should be discussed. This discussion includes internal and external validity of the study. Internal validity refers to the analytical process and validity of data. The analytical process is based on correlation and regression analysis that are well defined and regularly used in the research practice. However, more detailed analysis that include additional parameters is welcome, and it will be the case for multivariable analysis like multiple correlation and multiple regression.
External validity refers to applicability of this estimation model in other regions. It is evident that the results are dependent of the geographical region, but the presented analysis could be used in models developed for other regions. Additional implementation of the model in nearby locations, and with data from several projects will provide the evidence about the validity of this model. This provides an opportunity for further research that will prove results of this research.

CONCLUSION

The aim of this article is development of a mathematical model that will be used for estimating the useful solar energy based on the angle of solar collectors and measured solar irradiation in selected geographical region.
The result of the paper is a mathematical model which contains three equations (equations 1, 2 and 3) that are used for the calculation of useful energy on the solar collector placed vertically, horizontally and under an optimum angle. The best value was obtained in the assessment of solar radiation on the optimum angle of the solar collectors. The models define the importance of correlation between the data for solar radiation taken from the database of 'Joint Research Centure', and the measured data for usable energy in the selected solar system in Belgrade.

This paper is of particular importance because there are no similar studies in this region, nor data for the radiant sunlight for most places in the region.
The directions for future research will include development of similar estimation models for several places, as well as the areas in which there are no data on solar radiation. Also, new parameters such as diffuse radiation, clearness index and sunshine will be included in the analysis. The planned result of long-term research is the technical solution that will enable engineers an accurate assessment of solar radiation in the places where such information does not exist.

REFERENCES

[1] Study on the estimation of overall solar potential - solar atlas and the possibility of “production” and use of solar energy on the territory of AP Vojvodina, Republic of Serbia, Autonomous Province of Vojvodina Provincal secretariat for energy and mineral resources, 2011.
[2] Benghanem, M., Joraid, A.A., A multiple correlation between different solar parameters in Medina, Renewable Energy, Vol.32, pp.2424-2435, 2007.
[3] Türk Toğrul, I., Toğrul, H., Global solar radiation over Turkey: comparasion of predicted and measured data, Renewable Energy, Vol.25, pp.55-67, 2000.
[4] Susanj, B., Analysis of the global solar radiation on the measured at Puntijarka of 1959th to 2004th, University of Zagreb, 2012.
[5] Ivancheva, V., Koleva, E., Estimation of the global solar radiation over Bulgaria, Balwois, 2008.
[6] Quirk, T., Excel 2010 for Educational and Psychologycal Statistics: A guide to Solving Practical Problems, Springer, 2010.
[7] Tompkins, C.A., Using and interpreting linear regression and correlation analyses: Some cautions and considerations, Clinical Aphasiology Conference, Vol.21, pp.35-46, 1991.
[8] Helland, I.S., On the interpretation and use of r2 in regression analysis, Biometrics, Vol.43, pp.61-69, 1987.
[9] Buglear, J., Stats means business: a guide to business statistics, Oxford, UK: Buttworth-Heinemann, 2001.
[10] Vujičin, K., Stojanov, Ž., Using AHP Method and Expert Choice Software for Deciding on Solar Collector Products, International conference on Applied Internet and Information Technologies, pp.319-323, 2012.
[11] Allen, M.P., Understading Regression Analysis, Springer, 1997.

Session 2.

Engineering environmental protection and safety at work

POSSIBILITIES OF USING SOFTWARE PACKAGE PHOENICS IN ENVIRONMENTAL PROTECTION

Aleksandar Đurić[1], Milan Pavlović[1], Miroslav Vulić[1], Bogdana Vujić[1], Una Marčeta[1]
[1]University of Novi Sad, Technical Faculty "Mihajlo Pupin", Zrenjanin, Serbia
e-mail: alekszr@yahoo.com

Abstract: Computational Fluid Dynamics (CFD) has found wide applications in science disciplines. One of the many software packages which working on principle of CFD is PHOENICS.
PHOENICS can analyse the spread of pollution and therefore ensure intelligent design to reduce emissions at the point of generation. It can also help evaluate discharge into the atmosphere, seas, lakes or rivers. Some of the possibilities of software package are shown in the following text.
Key words: Computational Fluid Dynamics (CFD), PHOENICS, environment, simulation

INTRODUCTION

Computational Fluid Dynamics (CFD) is concerned with numerical solution of differential equations governing transport of mass, momentum, and energy in moving fluids. CFD finds extensive usage in basic and applied research, [1].
CFD comprises a variety of technologies including mathematics, computer science, engineering and physics, and these disciplines have to be brought together to provide the means of modelling fluid flows. Such modelling is used many fields of science and engineering but, if it is to be useful, the results that it yields must be realistic simulation of a fluid in motion. At present this depends on the problem being simulated, the software being used and the skill of the user, [2].
Since the early 1970s, commercial software packages (or computer codes) became available, making CFD an important component of engineering practise in industrial, defence, and environmental organizations, [1].

Table 1. Some of available CFD softwares, [3], [4].

Software	Address	Purpose of use
ANSYS	http://www.ansys.com	commercial
Fluent	http://www.fluent.com/	commercial
CD-adapco	http://www.cd-adapco.com/	commercial
COMSOL	http://www.comsol.com/	commercial
FEATFLOW	http://www.featflow.de	open-source
PyFR	http://www.pyfr.org	open-source
OpenFOAM	http://www.openfoam.com	open-source
PHOENICS	http://www.cham.co.uk	commercial

In the following text will be shown some of possibilities of using software packages PHOENICS, with examples in the fields of environmental protection.

ABOUT PHOENICS

PHOENICS (Parabolic Hyperbolic or Elliptic Numerical Integration Code Series) is a single computer code which has been designed so as to permit the computer simulation of all fluid-flow processes, [5].
PHOENICS is applicable to steady or unsteady, one-dimensional, two-dimensional or three-dimensional turbulent or laminar, multi-phase, compressible or incompressible flows using Cartesian, cylindrical-polar or curvilinear coordinates. You can also look at interphase transfer processes and propreties, porosities, parabolic or eliptic formulation, interacting chemical species, combustion modelling, compressible and incompressible flows, sub, trans and supersonic flows. The code also has a spatial marching integration option to handle parabolic and hyperbolic flows, as well as transonic free jets in the absence of recirculation zones, [6].

Beside that is PHOENICS assigned for commercial use, this software can be used for academic demand. PHOENISC provides students with a “Virtual Reality (VR)” interface, which gives relative ease in setting-up flows and the ability to visually reinforce concepts in fluid flow and heat transfer during the post-processor stage.

PHOENICS-VR Environment is easy-to-use and allows a student to simulate a flow from beginning to end without resorting to specialised codes, The code is also used widely in the professional engineering, so giving students useful skills which contribute to their preparation for the workplace, [7].

PHOENICS IN ENVIRONMENT

Using a program to simulate the dispersion of pollution has found very widely used in modeling the dispersion of pollutants, which are extremely dangerous and toxic. Very interested is modeling dispersion of pollutants in ondoor places or on the working places where is using this type of materilas in production process. With creating space and circumambient wherein the simulation performs it can be predicted where is the pollutant in bigger concetracion which can be useful when designing the installations in order to reduce negative impact of pollutants on healt of people in closed spaces.

One of the examples simulation technics we can cite a creating of simulation dispersion of pollutants in production Polyvinyl Chloride (PVC) which has wide use in industry. Vinyl Chloride Monomer (VCM) is using in production of PVC materials which is very toxic. This chemical compound can negative affect on brain, liver, cause lang cancer and different malignant diseases, such as leukemia which show numerous medical studies. When designing industrial plants which uses this type of material it is very important to have a good designing of a ventilation system in order to reduce the impact of these pollutants on employee.

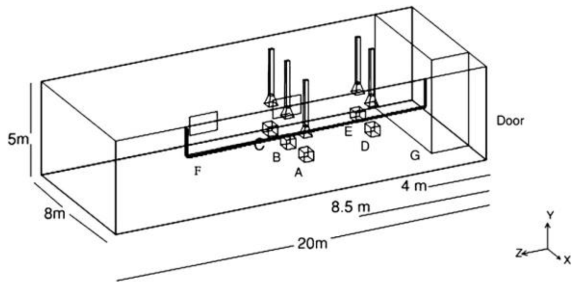


Figure 1. Geometrical representation of industrial building with ventilation system, [9].

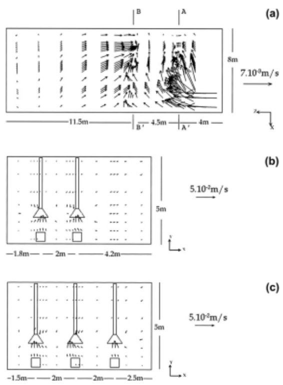


Figure 2. Predicted flow field for Case.
(a) Plane view (1.5m from the floor)
b) Section AA0 and
(c) Section BB0, [9].

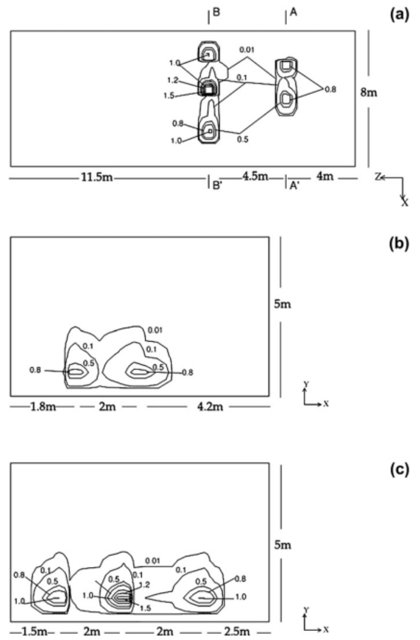


Figure 3. Predicted VCM concentration contours for Case, [9].

On the beginning in creating a simulation it is important to define a domain size. On the figure 1. It is shown a view of hall with realistic parameters for dimension of space and pozitions of ventilations ducts (figure 2.). Below ventilation ducts are installed sources of pollutants. After this steps we can start with creating simulation. Based on the input parameters development of 3D Navier-Stokes equations is obtained results of the dispersion of pollution and values of polluting components in space.
The Navier-Stokes equation can be written in the most useful form for the use in CFD, and development of the finite volume method:

$$\rho \frac{Du}{Dt} = -\frac{\partial p}{\partial x} + div(\mu\ grad\ u) + S_{MX}$$
$$\rho \frac{Du}{Dt} = -\frac{\partial p}{\partial y} + div(\mu\ grad\ v) + S_{MY}$$
$$\rho \frac{Du}{Dt} = -\frac{\partial p}{\partial z} + div(\mu\ grad\ w) + S_{MZ}$$

, [10].

Simulation technics allows changing a positions of ventilation ducts in space and therefore designing special individual case model efficiency of ventilation system. With changing the position of ventilation inlet in the space conditions are changing in the Hall regarding the change of pressure, air velocity, and thus the change dispersion of pollution. Figure 3. shows data for values on the working places and in environment and with creating different conditions seeking a optimal solutions for problems for the simulations which are designed.
This types of simulations are useful and data which are obtained from simulations are very useful when designing different technical systems, gagares, underground railways, etc.
Development of simulation dispersion of pollution has a widely use in simulations of dispersion polution in ambience air of urban areas. Dispersion of pollution depends on objects which are placed in environment. In next example will be create conditions of dispersion of pollution in center city of Zrenjanin.
First step in creating simulations is definig a domain size of simulation. In this case it is a main street in city of Zrenjanin. On figure 3. it is shown view of the street in reality and its projection in software package PHOENICS.

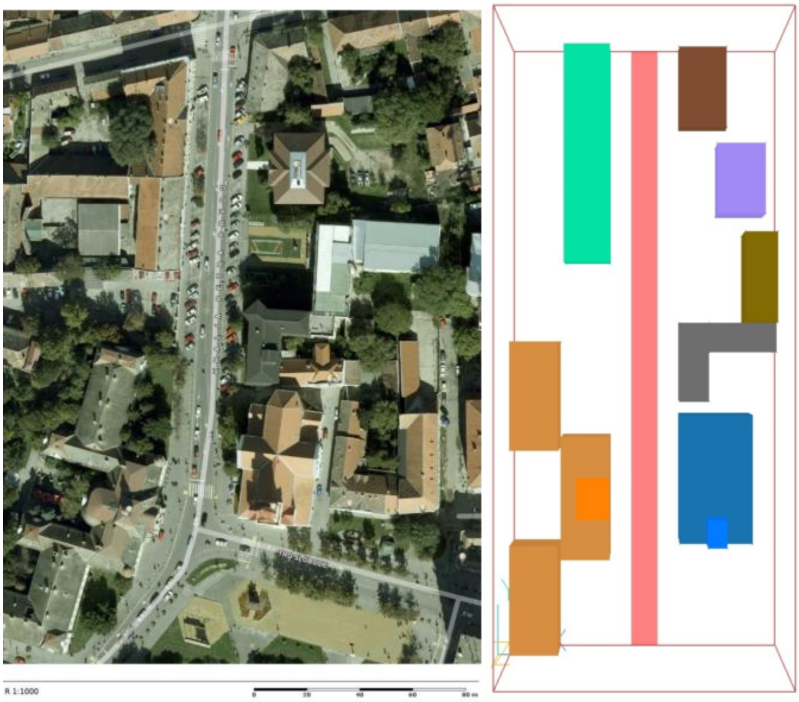


Figure 4. View of analyzed street and graphical description shown in software PHOENICS, [11].

We used a real dimension and data by using databe Geographic Information System (GIS) center [8]. Dimensions are 99x225 m and 40 m high, which is maximum high in the this space, in this case it is high of Catholic church in center of city.
Inlet parameters present data concentrations of pollutants and in analyzed case it is concetracion of pollutants incurred combustion of fuel apropos pollution from traffic. Beside that combustion of fuel produce a mix of many types of pollutants, for analyzed case we will use one pollutant, CO. Of course, in creating simulations it can be used any pollutant depending on place and sourse of pollution. Very important data is air flow in study case. As data for simulation it is used middle parameter of direction and speed of wind for analyzed case.figure 4. shows view of results of simulation.

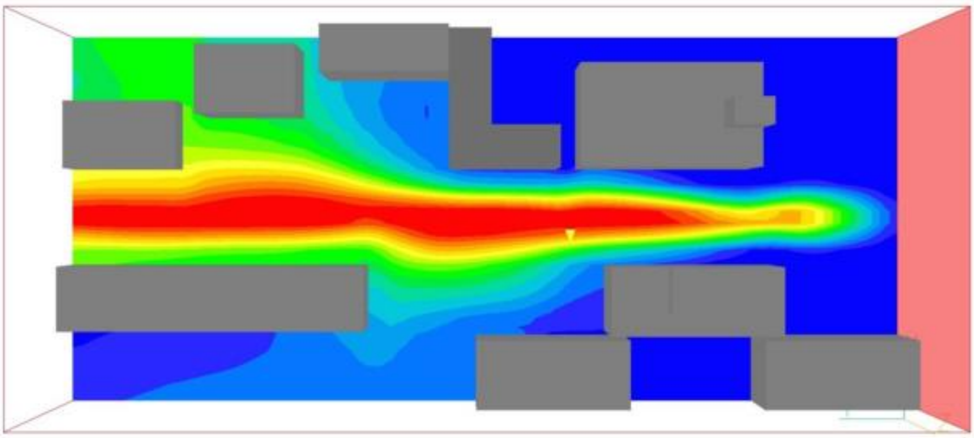


Figure 5. CO concentration at 1.5 meters above ground level, [11].

As stated above, the most important element which effect on dispersion of pollutants is air flow apropos wind in analyzed case. On the figure 5. it is shown view of air flow. On the view it can be seen where is the speed of wind fastets and slowest.

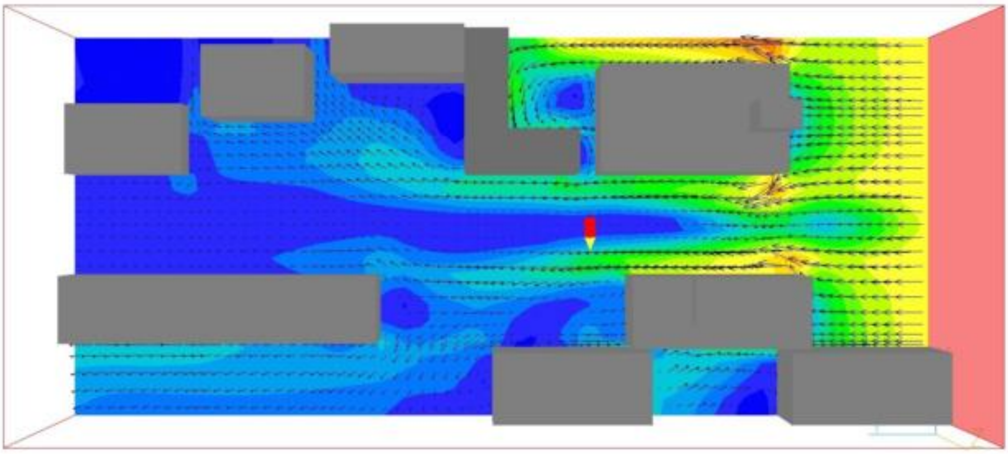


Figure 6. Wind profile at 1.5 meters above ground level, [11].

Configuration of environment has a direct impact od speed and direction of wind, apropos terrain where is it analyze dispersion of pollution. Simulations allows the displey of whirlpool or area where is wind most reserves, apropos his flow in that area is such that leads to pollutin. This is very important data in designing new apartment blocks and buildings in already built areas. Data of simulation it can be useful in the way that desinging could lead to creating optimal conditions for improving quality of ambiente air and reducing the risk of creating so-called black spots which can cause accumulation of pollutants.
With extensions of analyzed case on the widely areas, for example on the whole city or some industrial zone it can be obtained data about whole microclimate and areas which are the most vulnerables. This data are of essential importances in cases when creating spaces for the consstruction of buildings which are of public interest and it where in greater period of the day staying vulnerables groups (kindergartens, schools, hospitals, homes for the aged, etc.), as well as opportunity of positioning objects which could lead to pollution of air.
Software package PHOENICS and similar softwares which works on the same principes solving Navier-Stokes equations, beside creating simulations for all types of fluids and environment. Therefore it has been apllied in simulation of dispersion pollutants in watergangs.
One of that examples are shown in figure 7.

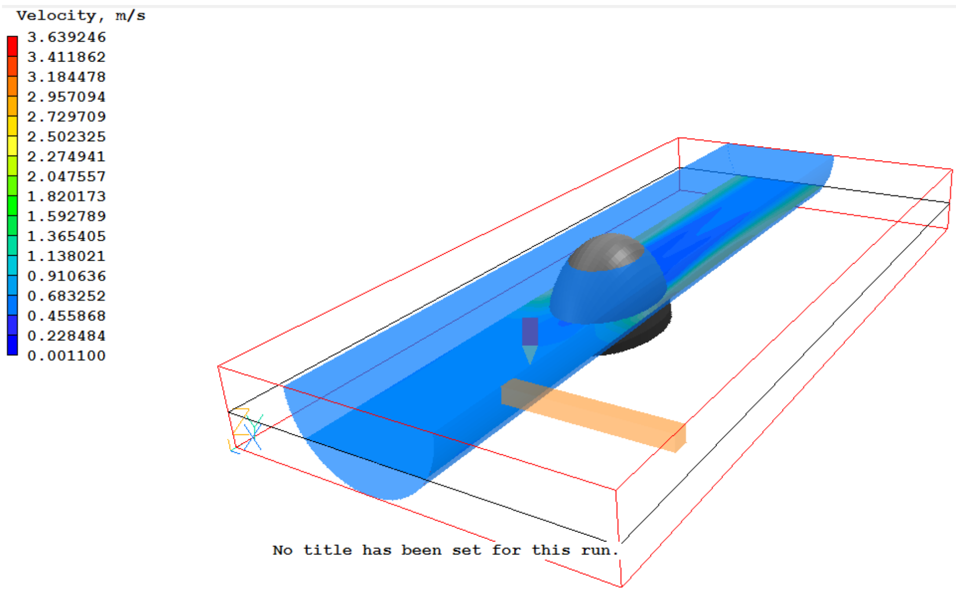


Figure 7. Exampe of dispersion pollutant in the river

CONCLUSION

PHOENICS has found significant applial in the projecting certain technological and technical systems which is important when consider the movement of heat, pressure in the environment, especially in cases where the alteration of these parameters significantly affect on the efficiency and system's stability. Creating a simulation before forming the first product or prototype, have a positive effect in reduction expenses corrections already constructed systems or even compensating produced damage caused by poor design.

REFERENCES

[1] Date, A.V., Introduction to Computational Fluid Dynamics, Cambridge University Press, 2005.
[2] Shaw, T.C., Using Computational Fluid Dynamics, Prentice Hall, 1992.
[3] http://www.cfd-online.com.
[4] Kuzmin, D., Introduction to Computational Fluid Dynamics, Institute of Applied Mathematics.
[5] Olovsson, S., Löfdanhl, L., Olsson, E., Flow calculations in a turbine cascade using PHOENICS-BFC, Numerical Similation of Fluid Flow and Heat/Mass Transfer Processes, Vol.18, pp.291-301, 1986.
[6] http://www.cham.co.uk.
[7] Adair, D., Jaeger, M., Integration of Computational Fluid Dynamics Into a Fluid Mechanics Curriculum, Computer Applications in Engineering Education, Vol.22, pp.131-141, 2014.
[8] Chu, A.K.M., Kwok, R.C.W., Yu, K.N., Study of pollution dispersion in urban areas using Computational Fluid Dynamics (CFD) and Geographic Information System (GIS) Environmental Modelling & Software Vol.20, pp.273-277, 2005.
[9] Kassomenos, P., Karayannis, A., Panagopoulos, I., Karakitsios, S., Petrakis, M., Modelling the dispersion of a toxic substance at a workplace, Environmental Modelling & Software Vol.23, pp.82-89, 2008.
[10] Simić, M., Vujić, B., Đurić, A., Pavlović, A., Brief overview of Navier-Stokes equation
[11] Simić, M., Pavlović, M., Đurić, A., Vujić, B., Popescu, F., Lelea, D., Air pollution from urban traffic in Zrenjanin: Modelling with PHOENICS, Workshop Envirobanat, pp.29-36, 2014.

ABOUT THE SAWDUST BRIQUETTING AS SUSTAINABLE SOLUTION FOR THE ENVIRONMENT PRESERVING ECOSYSTEMS

Imre Kiss[1], Vasile Alexa[1], Sorin Aurel Rațiu[1], Vasile George Cioată[1]
[1]University Politehnica of Timişoara, Faculty of Engineering Hunedoara, Romania
e–mail: imre.kiss@fih.upt.ro

Abstract: The idea of using wood as a renewable source was backed by environment organizations. More recent pellet investment projects as well as facilities currently under construction show that the production of wood pellets is being outsourced by the energy firms to companies specialized in wood pellet production. These firms are 100–percent focused on sourcing the raw material, operating the wood pellet production plant and handling the logistics for transporting the renewable resource. Wood pellets have only become an important part of this boom in the past few years. Owners of large coal–fired power stations in Europe started searching for a way to fulfill the new regulations and to find a solution for the declining economic relevance of traditional coal–fired power stations due to their high carbon dioxide emissions. The answer was to give the old dirty giants a green coat of paint by "co–firing" regular coal power plants with wood pellets.
Key words: biomass, wood pellets, briquetting, sawdust, renewable–energy, environment

INTRODUCTORY NOTES

Biomass energy production is beneficial to the environment preserving ecosystems and assuring sustainable future. We need to make sure biomass energy is produced in sustainable and ecologically safe way, with little or no pollution to air, water or soil. Biomass is a solution to growing pollution problem and can become a significant energy source in the future, being a sustainable and renewable energy source.

Wood pellets belong to the biomass group of renewable–energies and are gaining in importance to fulfill the European's renewable–energy targets [1, 2, 10]. The European Commission decided to reduce Europe's greenhouse–gas emissions by 2020 to 20 percent below their 1990 level and to set a goal of moving Europe to 20 percent renewable energy by 2020 [4, 5, 7, 9]. This decision initiated the boom of renewable–energies in Europe [2, 8, 9].

Increasing dependence on a worldwide level of energy resources is that the interest for other energy sources to increase. At the present time, biomass seems to be the most affordable and cost–effective source of renewable energy. Unlike wind energy and solar, investments necessary for the exploitation biomass are best. Modern biomass fuel technology means process the biomass matter with a series of advanced transformation technology into the alternative fuel (solid form, liquid form, gas form), those bio–fuels are used in power generation, vehicle fuel, heating stoves, etc. The solidification formation bio–fuel refers to the biomass briquettes products, the briquette industry started in the 1980s, during the last few years, the briquette industry has been developing very fast: the technologies are much mature nowadays, the production and application have formed a certain scale [6, 8].

According to [10], but generally valuable in the literature, the main advantages of biomass energy production are:

- Sustainable source – Biomass energy uses organic material and waste for its production. Crops and residues in agriculture and forests are sustainable source of biomass. Managing the resources is important to assure sustainability principles.
- Renewable source – crops, wood, agricultural residue, can be harvested year after year. Unlike fossil fuel reserves biomass reserves will always be available.
- Reducing pollution – biomass combustion process emits far less greenhouse gasses into the air than in fossil fuel combustion process. In the process of "gasification" no pollution gasses are emitted into the air.

Also, according to [10], the main disadvantages of biomass energy production are:

- Resource management – If not managed correctly, forests and land can be used to grow energy crops instead for food production.

» Direct and indirect CO2 emission – combustion of biomass can contribute to higher carbon concentration in the air.

Biomass refers to substances which occur organically and can be used to generate energy. There are a variety of types of biomass, the most popular being wood. A biomass system uses the energy generated when burning wood pellets, wood chips or logs in a biomass boiler to generate heat and/or energy. This can be used to power hot water systems, central heating or to heat spaces [10–12].

Sawdust is by–product from wood sawing process. Actually, sawdust doesn't have much application because of its low burning efficient. However, by pressing the saw dust into pellets, it becomes a kind of high quality biofuel product – sawdust pellets or wood pellets [8, 10, 11].

TYPE BIOMASS FUELS

More and more cities are seeking solutions in order to produce thermal energy from renewable sources. According to a survey conducted by the Ministry of Environment and the Ministry of Economy, biomass (wood waste, pulses and/or livestock) represents the most affordable and durable resource to produce heat and electricity [3, 7, 8]. Biomass comes from many different sources [3, 7, 8]. Most common sources of biomass are:

» Sustainable forest harvesting and residue,
» Agricultural residue like wheat straw and energy crops,
» Animal, municipal and industrial waste.

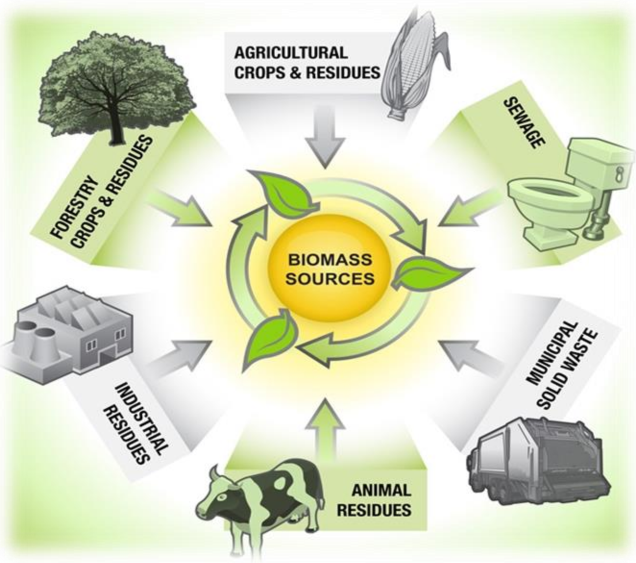


Figure 1. Biomass sources

Therefore, type biomass fuels include agricultural waste (straw, animals human dung, husks of all kinds – of grapes, walnut, etc.), wood and wood waste (hubs, sawdust, paddles, chips), energy crops (poplar, willow, willow trees, seed and rape) and solid waste in the municipality [8, 10]. Organic material, such as crops, agricultural and forest residues and waste are easily obtained and available for biopower production. The briquettable materials include, also, the waste wood, chips and dusts from the wood and paper working.

Wood briquettes

Wood pellets

Figure 2. Solid fuel by woods

In this sense, a lot of companies have as object of activity the recycling and the recovery of wastes or scraps. In these circumstances sawdust will represent raw material for the manufacture solid fuel (briquettes, pellets). It has become more and more important for companies to find low–cost methods of recycling their waste materials. This is especially true if these waste materials have high energy content and we want to take them back into the energy cycle. A number of companies have switched from furnace oil to biomass briquettes to save costs on boiler fuels. The use of biomass briquettes is predominant, where coal and furnace oil are being replaced by biomass briquettes. A number of units are also using biomass briquettes as boiler fuel [10–12].

THE WOOD – ONE OF THE MOST IMPORTANT RENEWABLE ENERGY SOURCES

With the world population grows and the modernization of the city and towns, one of the city's problems has become more significant every year–the garbage processing. The garbage has two resources: the domestic garbage and the industry waste. The wood processing plants create large quantities of wood residue waste in the daily production, now a large part of the sawdust are used to make compressed wood board for furniture producing and wood briquette for the heating stoves and fireplaces [1–4].

Wood is a natural product which – highly compacted as a briquette – almost takes on the burning behavior of coal. Owning to their great density wood briquettes has a higher calorific value than the same quantity of firewood. They can be used instead of coal or wood in domestic solid–fuel stoves as well as in industrial furnaces [10–12].

Wood, one of the most important renewable energy sources in its possession Romania, it is not operated. The potential of wood is not used in systems thermal power plants in Romania, due to a lack of technology and legislation. Romania has made many steps humble about capitalization of wood and other wood products and pulp for the production of thermal power in both centralized thermal systems, as well as personal. This fuel is ignored despite environmental and economic advantages.

Specialists in the field say that should be reconsidered potential wood and wood pulp, which can be used as a source of real power [1–4]. Scientists have pulled signals over two major components, namely reducing energy consumption which polluting the atmosphere, on the one hand, and reducing energy consumption due to quick of the reserves of fossil fuels.

Although Romania has the great advantage to hold an important source of renewable raw material, this is which has not previously been used, and we talking about the bulk of lingo–cellulose's biomass, which enables the development of technologies for recouping and national efficiency, directed at converting thermal energy [1–4].

Figure 3. Lignocellulosic materials

Three main types of wood fuel can be used: logs, wood chips and wood pellets, according to [1–3, 10], but generally valuable in the literature.

» Logs require little processing except for seasoning (drying out). This process can take up to 3 years and brings their moisture content down to about 20% meaning the logs burn hotter and produce less smoke. Logs are usually cheaper than other types of wood fuel but need more space for storage and can only be used in manual–feed boilers or stoves.

» Wood chips are sourced from forestry „thinnings” or made from untreated waste wood. Wood chips are typically used in larger heating systems such as those found in schools or blocks of flats. When they are used in smaller (e.g. domestic) systems the chips must be produced to a standard size and with low moisture content.
» Wood pellets are made from by–products such as saw dust and have a low moisture content of between 8–10%. As a consequence they are more energy–dense than logs or chips and require about a third of the storage space. The uniform shape makes pellets ideal for automated systems.

Figure 4. Main types of wood fuel

Wood fuel is a fuel such as firewood, charcoal, chips, sheets, pellets, and sawdust. The particular form used depends upon factors such as source, quantity, quality and application. In many areas, wood is the most easily available form of fuel, requiring no tools in the case of picking up dead wood, or few tools, although as in any industry, specialized tools, such as skidders and hydraulic wood splitters, have been developed to mechanize production. Sawmill waste and construction industry by–products also include various forms of lumber tailings.

Biomass, the product of recycling, is a man–made renewable resource that contributes to a large portion of recyclable materials. These can include plastics and papers, lumbers, textiles, farming material and fertilizer, to name a few. Because biomass is made from organic products such as animal waste or subsidiaries from agriculture, lumber industries and food industries, biomass has unlimited resources. Recycling and biomass help sustainability throughout the world's industries.

Pellet fuels are heating fuels made from compressed biomass. Wood pellets are the most common type. A form of wood fuel, wood pellets are generally made from compacted sawdust or other wastes from sawmilling and other wood products manufacture. Pellets are manufactured in several types and grades as fuels for electric power plants, homes, and other applications in between. Pellets are extremely dense and can be produced with a low moisture content (below 10%) that allows them to be burned with a very high combustion efficiency.

Recovery of ligno–cellulose's materials by turning them into microbriquettes is not stimulated at national level. A solution would be constitution of a „green” government for the financing of production and exploitation activities or green fuels.

BIOMASS BRIQUETTE EMERGING

A popular biomass briquette emerging in developed countries takes a waste produce such as sawdust, compresses it and then extrudes it to make a reconstituted log that can replace firewood. It is a similar process to forming a wood pellet but on a larger scale. There are no binders involved in this process. The natural lignin in the wood binds the particles of wood together to form a solid. Burning a wood briquette is far more efficient than burning firewood. Moisture content of a briquette can be as low as 4%, whereas green firewood may be as high as 65%.

The extrusion production technology of briquettes is the process of extrusion screw wastes (straw, sunflower husks, buckwheat, etc.) or finely shredded wood waste (sawdust) under high pressure when heated from 160 to 350°C. The quality of such briquettes, especially heat content, is much higher comparing with other methods like using piston presses.

Sawdust briquettes have developed over time with two distinct types: those with holes through the center, and those that are solid. Both types are classified as briquettes but are formed using different techniques. A solid briquette is manufactured using a piston press that compresses sandwiched layers of sawdust together. Briquettes with a hole are produced with a screw press. The hole is from the screw thread passing through the center, but it also increases the surface area of the log and aids efficient combustion.

Biomass briquettes, mostly made of green waste and other organic materials, are commonly used for electricity generation, heat and cooking fuel. The companies promote the use of sawdust briquettes for heating. It is a totally organic. Solid fuel with low moisture from waste wood left after processing (sawdust, wood chips or bark), wastes are crushed, dried up at a rate of 10% and then plants with special presses. Resins and binders existing naturally in the sawdust briquettes are designed to keep them compact and therefore do not contain additives. Using waste wood as sawdust resulted from processing wood in sawmills and furniture, we obtain a valuable product, respecting nature.

Being an alternative energy, wood pellets play more and more crucial role in human life. And the influence of them now is beyond the field of green energy. The development of wood pellets will bring us great benefits such as social, environmental and economic benefits. The use of renewable energy has several environmental, economic and societal benefits. Renewable energy sources do not require the use of fossil fuels and, as a result, they do not emit carbon dioxide. By reducing the amount of carbon dioxide that goes into the atmosphere, we are eliminating pollution and increasing our air quality.

» SOCIAL BENEFITS: Slathering wood pellets produces of great assistance to society. Promoting by government authorities all across the globe, wood pellets industry likes great recognition. Not just so, being an emerging industry, wood pellets creating will give you large amounts of jobs, which in certain degree will alleviate the issue of high unemployment, particularly in rural places.
» ENVIRONMENTAL BENEFITS: In recent centuries, the dominance of non–renewable fuels like coal and oil brought serious atmosphere pollution and greenhouse effect. Wood pellets like an eco–friendly resource can improve this case effectively. In other words, wood pellets could possibly be the definite alternative of fossil fuel and do best to atmosphere.
» ECONOMIC BENEFITS: Once we have known clearly, wood is really an alternative energy source. Simultaneously, the distribution of wood is wide around the globe: not just wood, but additionally organic materials like leaves, branches, grass, and lots of many other materials can be found. Only whenever you process these to pellets, moisture contained could be reduced to ensure that to vow our prime efficiency of wood.

The wood pellets are clean–burning, carbon–neutral, and locally produced–a renewable resource grown in sustainable forests. That’s as green as a fuel can get. Heating the home with pellets offers three ecological advantages: pellets are sourced locally, they’re a renewable resource, and they’re carbon–neutral.

New wood–pellet home heating technologies allow customers to easily upgrade their existing oil–fired furnaces and boilers to wood pellets simply by swapping out the burner. Now you can choose a central heating system that’s completely automated and environmentally friendly while you save on home heating bills year after year.

CONCLUDING REMARKS

Briquetting is a process that biomass is compressed under high pressure and high temperature. The self–bonding of biomass to form a briquette involves the thermo–plastic flow of the biomass. The lignin content that occurs naturally in biomass is liberated under high pressure and temperature. Lignin serves as the glue in the briquetting process, thus binding, compressing the biomass to form into high density briquettes. During this process, no binder needs to be used. So the output briquette is a type of clean and green fuel that is ideal for use in furnaces, boilers and open fires.

Generally the better quality wood is used in the furniture and construction industries leaving very little good quality timber for firewood production. A lot of the time the cost of producing the firewood on a commercial scale is just too high for most to bother with. We found that later in the season that seasoned wood is unavailable due to high demand resulting in the market being flooded with green timber.

Biomass is a renewable energy source because we can always grow more trees and crops, and waste will always exist. When burned, the chemical energy in biomass is released as heat. If we have a fireplace, the wood burn in it is a biomass fuel. Wood waste can be burned to produce steam for making electricity, or to provide heat to industries and homes.

Biomass, unlike any other resource, is available to us in excess. Its abundance is what makes it a useful asset to mankind, and we can never fear its running out. Everywhere has land available for growing biomass. The process of converting biomass into useful energy is a plain process. If biomass is grown on a large scale, it can save tremendous amount of money in importing oil and rural areas become economically more vital and stable. In addition, biomass can be mixed with coal in coal power plants without making any alterations to the plant. Biomass, if used effectively and efficiently, could be a catalyst in the future of earths' renewable energy system. Moreover, it is cheap compared to its rival resources.

Therefore, biomass is seen as an economically viable and environmentally friendly solution to energy generation. Biomass is a financially viable investment as well as being environmentally friendly. Biofuels provide a unique opportunity to address needs ranging from energy independence to environmental sustainability and economic development, with solutions that include the creation of new opportunities and jobs. These demands have led to government initiatives and accelerated research and development at universities and among leaders in the energy industry. The different countries clearly have chosen very different approaches in developing and deploying various bio–energy options. Partly this is caused by the natural conditions (type of resources and crops, climate) and the structure of the energy system, and also by the specific political priorities linked to the agricultural and forestry sectors in those countries. In our current economic climate we are all looking to make positive changes to the way we live financially. At the same time the pressing topic of climate change means that we also need to make environmental changes, and heating is one of the priorities.

REFERENCES

[1] Green Energy in Romania – Current situation and development perspectives (http://oldrbd.doingbusiness.ro)
[2] A potential renewable energy resource development and utilization of biomass energy, FAO Document Repository (http://www.fao.org/documents/en/)
[3] Romania Biomass and Biogas Energy Market 2013 – 2018 (http://renewablemarketwatch.com)
[4] Overview and Status of Renewable Energy Technologies (RET) in Romania, TU Bergakademie Freiberg, 2013
[5] Evaluating Renewable Energy Policy: A Review of Criteria and Indicators for Assessment, Report of International Renewable Energy Agency (IRENA), 2014
[6] Mario Ragwitz & co.: Shaping an effective and efficient European renewable energy market, European Research Project, Fraunhofer Institute for Systems and Innovation Research, Karlsruhe, 2012
[7] Monitoring and Evaluation of the RES directives implementation in EU27 and policy recommendations for 2020, Reference Document on Renewable Energy Sources Policy and Potential, 2009 (http://www.cres.gr/res2020/)
[8] New Energy Externalities Development for Sustainability (http://www.needs–project.org/)
[9] Monitoring and Evaluation of the RES directives implementation in the EU27 and policy recommendations for 2020 (http://www.res2020.eu/)
[10] My wood pellet solution: Wood Pellet Central–Heating Solution for Homeowners and Small Industry (http://www.mywoodpelletsolution.com/overview/)
[11] What is the Best Home Heating Energy Investment? (http://www.mywoodpelletsolution.com/category/news/)
[12] Components of Wood Pellet Heating Systems (http://www.mywoodpelletsolution.com/category/system_components/)

ANALYSIS OF RECYCLING MOTOR VEHICLES IN TERMS OF RATIONAL ENERGY CONSUMPTION

Dragiša Tolmač[1], Jasna Tolmač[1], Slavica Prvulović[1], Milan Pavlović[1], Sanja Stankov[1]
[1]University of Novi Sad, Technical Faculty "Mihajlo Pupin", Zrenjanin, Serbia
e-mail: dragisatolmac@gmail.com

Abstract: Recycling of cars includes a variety of procedures, which allow obtaining products floricane materials (metals, plastics, rubber, glass), suitable for the production of new material goods. In the paper the analysis of the recycling of motor vehicles. Motor vehicle recycling industry contributes to sustainability, environmental protection and energy saving. Using recycled materials saves energy and natural resources. Recycling creates less air and water pollution than primary production of raw materials. Recycling saves storage space, create new jobs in companies engaged in the collection, production and distribution of raw materials.
Key words: recycling, motor vehicles, energy saving

INTRODUCTION

To ensure the successful recycling of motor vehicles is necessary to create an appropriate legal framework and basic infrastructural requirements, which undoubtedly contributed to its development through attracting investments and building technology resources in accordance with the regulations. Also, the introduction of system solutions in the field of automobile recycling contributes to the renewal of the fleet and the consequent reduction of pollutant emissions, traffic safety and saving energentskih and raw material resources (Bian et al., 2010; Aleksic et al., 2011). With the start of mass production of cars and waste from the car, which ended his life, the idea emerged that certain parts of such cars can be re-used (as spares). However, the number of these parts are so small that they appeared large dump cars. These landfills affect the environment, and on the other hand represent a large amount of raw materials that could certain technological processing be re-used for different purposes. Thus, in recent years in developed countries (the U.S., Japan, etc.)., There are large corporations that take on the responsibility that this job entails. One of the major contributions of this new industry is to reduce environmental pollution. On the other hand, recycling of cars has been hiring large numbers of workers. These preblemi occur in all parts of the world so that in all countries a need for companies to deal with the recycling of old cars (Trumic et al., 2008; Puric et al., 2011; Milic and Jovanovic, 2011).

AN OVERVIEW OF EXISTING LITERATURE

Recycling of used motor vehicles (ELV) in high-income countries is very successful, especially after the introduction of the shredder in the recycling process of used cars. The rate of recycling in developed countries more than 90% of the used motor vehicles. ELV Recycling helps protect the environment (Hempfl, 2010; Jovanovic et al., 2008). ELV recycling reduces the minerals from natural sources and generates a source of raw materials for the production of new products derived from recycled materials (prawns, et al., 2005; Tadic et al., 2010). Removing environmentally harmful components and materials, specialty oils, brake fluid, antifreeze, air bags, mercury, freon and similar substances require special treatment and expertise in areas such waste dismantling. In Germany, Centers for dismantling vehicles covering a circle with a radius of 50 kilometers. In Serbia there are about 1.4 million passenger cars and light commercial vehicles. The estimated number of annual waste produced by 120.000 cars a year, which means that a larger number of equipped recycling operators. (Junbeum et al., 2007; Medic, 2011). Recycling of used motor vehicles in the world, is an efficient process which recycles more than 75% of the cars, along with the rate of used cars collected by 95%. In the United States, is recycled about 11 million units, representing a $ 5 billion of revenue. Automobile Recycling Industry in the United States employs more than 40.000 employees in more than 7.000 companies. In the EU, the number of recycled car reaches 9 million per year, equivalent to 2.2 million tons of waste. As in the U.S., profit mainly by selling used parts and metal. Based on the

data (Tolmac et al., 2011a), the number of used cars in the Republic of Serbia, is approximately 100.000 per year. Taking this estimate of the number of used cars, as well as the percentage utilization of certain materials per vehicle, obtained 68.000 tons of ferrous metals, nonferrous metals 6.000 tons, 8.000 tons of plastics and composites, 1.400 tons of fluids, 5.000 tons of rubber, 3.500 tons of glass, 1.000 tonnes of textiles, 1000 battery tons and 6.100 tons of other waste from the used car. In the Republic of Serbia, during the process - recycles 14% of used motor vehicles, because the capacity for industry remains underdeveloped. In the domestic market ELV recycling, demand for secondary raw materials is high, and the level of recycling of 14%, should increase to European levels by 75%. On the basis of the ELV recycling system, we need new investment of over 20 million, in several plants shredder and mobile Balir presses, and increase the efficiency of the (Subaru and Pavlovic 2006; Djordjevic 2004).
In Serbia, there are over a million vehicles whose average age is over 10 years. The collection and disposal of waste vehicles mostly depends on supply and demand. Parts with use value is extracted in smaller amount, depending on their age and condition of end. The automobile recycling facilities in the world it is possible to recycle about 80% by weight of the car. The process of recycling cars is complex because of the variety of materials that are part of the car. Middle-class car, on average, consists of 76% metal, plastic 8%, 4% rubber, fluid 6%, 3% glass and other materials 3% (Trumic et al., 2004). Apply two car recycling technologies, which differ in the way of sorting the material that make up the car. The first technology is based on optical (manuelnoj) separation, and other technology uses multiple methods (grinding, gravity separation methods and special). A third possibility is that the whole car pressed in one piece, using mobile Balir presses (Trumic et al., 2008).
Further classification of non-metals and non-ferrous metals in fruiting material, achieved through a combination of gravity and special separation methods (electrostatic, optical, etc.)., (Trumic, et al., 2009).

RESULTS AND DISCUSSION

Motor vehicle recycling of end of life, according to (Tolmac et al., 2011), is still at an early stage and does not engage a significant number of workers. The research within the project of technological development is defined by a model of integrated and sustainable recycling of motor vehicles at the end of the life cycle (Pavlovic et al., 2011). Thus the set basis for the development of new industries and thus create real conditions for intensive employment in jobs recycling. These tasks include collection and transportation of waste motor vehicles, their removal, selection of components and materials, recovery of components for reuse, crushing shells and chassis, separation of materials, recycling materials, the final disposal of waste. All this requires a different structure of professional personnel, various recycling technologies and the different composition of objects and corresponding requirements for their location (Bian et al., 2010; Afgan et al., 2009).
In Serbia, so far no systematic not address this problem in solving environmental and social, and economic problems when it comes to preserving the natural resources of our country. The project aims to (Pavlovic et al., 2011) to localize potential waste motor vehicles, which can be recycled or used for energy. The most important thing is to determine the scope and structure of the permanent disposal of motor vehicles, especially hazardous waste and suggest measures for their removal or safe storage (Pavlovic, 2009; Pavlovic and Subaru, 2006).
The project (Pavlovic et al., 2011), is predicted to form an appropriate centers for the breakdown of used motor vehicles by the respective regions. The significance of the project is big, because it provides savings in the form of recycled materials. If we know now about 120 thousand cars a year off, and thus are ready for the recycling process, the weight of every vehicle around 1 ton, of which about 70% feromagnetični materials, there are also non-ferrous metals, plastics, rubber; We can not imagine how it is stored resources.
Obtaining metals from recycling leads to saving power generation, such as: steel 74%, aluminum 95%, copper 85%, lead 65%. Getting metal recycling reduces water consumption by 40%, reduces water pollution by 76% and air pollution by 86%. In developed countries (35 to 45)% of the new steel is obtained by recycling (Stojanovic et al., 2004). Recycling is the future to solve the problem of waste motor vehicles, in terms of sustainable development. A clear example that proves the previous statement is given in Table 1 (Tolmac et al., 2011b; Trumic et al., 2008):

Table 1. Saving energy by using recycled materials

Materials	**(%)**
Copper	85
Lead	65
Zinc	60
Aluminum	95
Iron and steel	74
Magnesium	98
Titanium	58
Paper	64
Plastic	80

As can be seen from Table 1, the energy savings by using recycled materials is very important. The investment costs for the construction of waste treatment plants and metal production only (16 to 20)% of the cost to build a plant for processing the raw materials - minerals. In addition, manufacturing technologies based on the processing of secondary metals are much easier and more acceptable for the environment as the example of iron and steel clearly seen in Table 2

Table 2. The benefits of using iron and steel from waste materials

Benefits	**(%)**
Energy savings	74
Saving material from ore	90
Reducing air pollution	86
Reduction of water consumption	40
The reduction of water pollution	76
Reduction of mining waste (tailings)	97

CONCLUSION

Motor vehicle recycling of end of life, according to the proposed model is based on the principles of sustainable development (Pavlovic et al., 2011). The establishment of this model in Serbia, in addition to environmental and economic effects of providing a high level of employment, which is very important for social policy. Thus, the number of employees in the entire cycle of recycling of motor vehicles at the end of the life cycle ranges from 6.000 to 20.000 employees. Number of employees varies as a function of:

- ELV available number in the current year,
- the degree of recyclability,
- the level of motor vehicle dismantling,
- available recycling technologies,
- new products from materials provided by ELV.

Since the operators are to be deployed on the territory of Serbia, so that citizens in their old cars can be submitted at the nearest recycling center which will be issued and a receipt which can be realized certain benefits when purchasing a new car. In this way, the action will involve all those involved in the recycling of batteries, waste oil, antifreeze, glass, plastic and everything that makes a car, and it is necessary to invest a total of over 20 million Euros (Medic 2011; Kozic and Sudarević 2005; Gareth and Shahin, 2006).

Metals and energy consumption in the world has a great trend. The reserves are rapidly being depleted. Scrap metal is a very important secondary resource, whose collection and return of the reprocessing process significantly reduces the consumption of primary raw materials, extends the life of the reserves and reduce environmental pollution. Re-use of metals from waste and general reuse of other materials has great economic justification.

ACKNOWLEDGEMENTS

The results presented in this paper derive from the work on the project "Sustainable Development of technologies and equipment for the recycling of motor vehicles" under document number TR 35033. This project is funded by the Ministry of Education, Science and Technological Development of Republic of Serbia.

REFERENCES

[1] Arsovski, S., Milivojevic, J., Grubor, S., Kokic Arsic, A., Tonic, N., The influence of models of integrated and sustainable recycling of motor vehicles at the end of the life cycle of the level of employment in Serbia, Quality, No. 11-12 , 2010.

[2] Afgan, N.H., Hovanov, N., Andre, P.M., Sustainable Management Organization With Example of Passenger Car Sustainability Assessment, International Journal for Quality Research, Vol. 3, 2009, No. 2.

[3] Aleksić, A., Arsovski, S., Tonić, N., Grubor, S., Resilience of elv dismantling centres, Nacionalna konferencija o kvalitetu – FQ 2011, str.105-111.

[4] Hempfl, K., The commercialization of recyclable materials and recycling waste in Serbia, USAID, 2010.

[5] Ilić, I., Recycling and recycling of secondary raw materials of non-ferrous metals, Bor, 2002.

[6] Kozić, A., Sudarević, D., Access to recycling of motor vehicles, the Association for Quality and Standardization of Serbia, The quality of Festival 2005, 32. National Conference on Quality, Kragujevac, 19-21. May 2005th

[7] Milivojević, J., Grubor, S., Simon, A., Sustainable integrated system of recycling of motor vehicles during the life cycle, the First National Conference on recycling vehicles 2009th, Eck, 06 November, 2009.

[8] Junbeum, K., Junghan, B., Braden A., Recycling Systems and Management of Endof-Life Vehicles (ELVs), A Center for Sustainable Engineering Education Module, October 23, 2007.

[9] Pavlović, M., Tolmač, D., et al., Sustainable development of technologies and equipment for the recycling of motor vehicles, the Ministry of Science and Technology RS. SRO: Technical Faculty "Mihajlo Pupin", Zrenjanin, (2011-2014.), No. Project: 035033rd.

[10] Pavlović, M., Directions for the Development of Recycling of used cars in Serbia, the Association for the recycling of motor vehicles of Serbia, Belgrade, 2009.

[11] Pavlović, M., Subaru, N., Ecological logistics, Tehničkifakultet "Mihajlo Pupin", Zrenjanin, 2006.

[12] Djordjević, M., Kokic, M., Managing the preparation of a feasibility study of recycling of used materials cars, Project Management and Entrepreneurship, Proceedings, p. 72-76, Zlatibor, 9.-12. May 2004.

[13] Medić, D., Analysis of the economic potential of the used car market in Serbia, Technical Faculty "Mihajlo Pupin", Zrenjanin 2011th

[14] Krinke, S., Bosdorf Zimmer, B., Goldmann, D., Life Cycle Assessment of End-of-Life Vehicle Treatment, VOLKSWAGEN AG, June 2005.

[15] Kozić, A., Sudarević, D., Access to the recycling of motor vehicles, FESTIVAL OF QUALITY, May 2005.

[16] Gareth, C., Shahin, R., Cost models for increased value recovery from End-of-Life Vehicles, The centre for Sustainable Manufacturing And Reuse/recycling Technologies, Loughborough University, Wolfson School of Engineering, United Kingdom, PROCEEDINGS OF LCE 2006.

[17] Tadić, D., Arsovski, S., Stefanovic, M., Aleksic, A., A Fuzzy AHP and topsis for ELV dismantling selection, International Journal for Quality Research, Vol. 4, 2010, No.2.

[18] Tolmač, D., Prvulović, S., Dimitrijević, D., Some aspects of recycling cars, I International Conference „ECOLOGY OF URBAN AREAS“ 2011, Proceedings, pp.127-131, ISBN 978-86-7672-145-0, Technical faculty “Mihajlo Pupin“, Zrenjanin, 30. 09. 2011 a.

[19] Tolmač, D., Prvulović, S., Pavlović, M., Dimitrijević D., Basic elements of recycling tires, I International Conference - Process Technology And Environmental Protection (PTEP 2011), Proceedings, pp.90-95, Technical faculty “Mihajlo Pupin”, Zrenjanin, 7th December 2011 b.

[20] Trumić, M., Ćalić, N., Andrić,Lj., Ignjatović, M., Recycling Technologies and Sustainable Development, XIX Symposium on Mineral Processing, Oplenac, Serbia, 2004, pp. 257-265.

[21] Trumić, M. Ž., Trumić, M. S., Marković, Z., Separation of ink particles from waste newspaper by deinking flotation, Journal of Mining and Metallurgy, 43A(2007) pp. 33-41.

[22] Trumić, S. M., Trumić, Ž. M., Bogdanović, G., Marković, Z., Trumić, G., Deinking of recycled pulps using flotation and magnetic process, 12th Conference on Environment and Mineral Processing, VŠB-TU Ostrava, 5-7, June, Czech Republic, (2008), pp. 169-172.

[23] Stojanović Dejan, Stojanović Dragan, Trumić Milan., Technologies of recycling cars, XII Scientific Symposium on natural resources and environmental protection, EKOIST 2004, Bor Lake, 30 May - 02 June, Serbia (2004), pp. 638 – 641.

[24] Purić, R., Lazarević, M., Ostojić, G., Marović, B., Stankovski, S., Rfid-based lifecycle product monitoring for insurance purposes, Facta Universitatis (Mechanical Engineering), Vol.9, No 1, 2011, pp. 119 – 126.

[25] Milić, P., Jovanović, M., The Advanced system for dynamic vehicle routing in the process of waste collection, Facta Universitatis (Mechanical Engineering), Vol.9, No 1, 2011, pp. 127 – 136.

CHARACTERICTICS OF THE SYSTEM TO REDUCE EMISSIONS OF MOTOR VEHICLES

Snežana Vrekić[1], Milosav Djordjević[1]
[1]High Technical School of Professional Studies, Kragujevac, Serbia
e-mail: vreki@yahoo.com

Abstract: With the increase in the number of motor vehicles and intensifying traffic increases, the impact of exhaust gases on the environment. In order to reduce environmental pollution in the world are expressed tendencies of the development of clean vehicles, which do not emit harmful substances. This article discusses the measures for reducing greenhouse gas emissions from transport, using after-treatment of exhaust gases of the engine. Using the catalyst and lambda probe aims to reduce the amount of harmful substances in exhaust gases of the engine. Many countries are investing very substantial efforts in creating and implementing development strategies of transport, as the main lever of economic development.
Key words: exhaust gas, emissions of harmful gases, catalyst, environment

INTRODUCTION

In developing countries, increase standards accompanied by an increase in energy consumption, and they face difficulties both in the process of achieving the objectives of protection of the global climate as a natural resource and in terms of adapting to the expected effects of climate change. Combustion of coal and oil generated a number of harmful products such as carbon monoxide, sulfur dioxide and nitrogen oxides. These compounds cause acid rain and destroy plant life. The adoption of the UN Framework Convention on Climate Change (UNFCCC) in 1992 and its Kyoto Protocol, adopted in 1997, the international community has established a legal framework for resolving the issue of global climate.
Because of the negative effects on the environment and health of people in many countries are investing very substantial efforts in the creation and implementation of transport development which will also allow greater mobility of people and ensure improvement of ecological conditions. With the development of economy, the construction of modern roads that are now moving up to 200,000 vehicles a day, starting appreciably distort the natural environment to the extent that it has to be protected. Soil contamination of times and especially from road traffic can be considerably. Petrol engines emit fine particles of inorganic origin composition of lead, which can be adsorbed directly introduced in the vegetation along the road. The lead content in gasoline has been reduced in recent years, along with popularization of unleaded fuel, significantly reduces the concentration of lead in the vicinity of the road. Petrol engines emit particles and also other trace elements that have been added, motor oils as additives. Soil pollution from traffic occurs in every way and can be on all roads with a traffic flow of more than 20,000 vehicles / day. Trace elements such as chromium, lead, and zinc can remain in the soil for hundreds of years. The risk of soil contamination occurs during the transport of toxic products during road construction and later during its exploitation.
The steep increase in car traffic led to an increase in air pollution, but also the increased risk to human health which is why there was a need for monitoring of air quality in urban areas. Since the last 10 years the number of cars has nearly doubled it is normal to air pollution and doubled except that nothing was done in terms of prevention, mitigation and eventual control air pollution. Also, it is estimated that the number of cars from today's 700 million to the 2050 rise to incredible three billion. All this could have disastrous consequences for the environment and human health if not timely steps toward reducing emissions of greenhouse gases, especially CO_2. Monitoring of air quality should provide essential data necessary for the establishment of a registry of pollutants and to allow the creation of an acceptable program for the protection of air quality. Cadastre should include monitoring the concentration of major pollutants in the air: SO_2, NO2, CO, soot and suspended particles (LC10). The ultimate goal is to monitor long - term trends of air pollution to determine the degree of improvement or deterioration in air quality in urban areas.

The concentration of CO_2 by 2050 will reach a value of 590-710 ppm (according to the IPCC - Intergovernmental Panel on Climate Change), which is three times more than the value of the pre-industrial period. Taking into account these facts, it is possible to state the reasons for the increase in air pollution:
- A further increase in the consumption of fossil fuels (oil),
- Constant growth of the automotive industry and car traffic causing an increase in the concentration of harmful gases and particles such as SO_2, CO, NO_2, LC10, soot, Pb, Cd, Hg, dust deposits (50% of total air pollution),
- Constant development and growth of air traffic. Unlike other atmospheric pollutants, jets emit CO_2 at a height of 30.0000 - 40.000 meters where the gases emitted able to hold hundreds of years. Because of this it is estimated that the total impact of air traffic on the atmosphere perhaps even four times greater than the official figures show,
- Expansion of cities, which is usually inadequate monitoring insfrastrukturnim development,
- Urban heating plants using fossil fuels,
- Dirty industry.

THE EXHAUST GASES OF MOTOR VEHICLES

One of the most important features of the 20th century is the problem of air pollution due to combustion in the internal combustion engine. Observed through the history of development of motor sport, it can be said that along with the development of construction vehicles worked on engine development. The common characteristic of all car manufacturers and all produced model is to cause air pollution. The amount of air pollution depends on engine technology. Engines, LPG least pollute the air, or at least emit pollutants into the air, then come and diesel engines at the end as the biggest polluters come petrol engines. Currently all manufacturers of cars and road transport means working on improvements in engine technology. For them to undertake EURO standards and similar regulations worldwide. The internal combustion engine (IC engine) means the device in which the reactants of combustion (oxidising agent, usually air, and fuel) and the products of combustion are used for the active energy. More specifically, the energy is obtained from the heat released by combustion of the mixture of oxidant and fuel. Useful work is obtained as a result of the action of hot, gaseous products of combustion to moving parts such as pistons, turbine blades and nozzle.
In the modern wave of electrification of the automobile, many internal combustion engines already pushed into oblivion although this drive that the specific combination of power and economy, and today hardly attainable. Great opportunities to improve the cost-effectiveness of the applied combustion engines in vehicles lies in new power transmission solutions, and solutions for brake energy regeneration. Hybrid drive systems in which they can achieve all these ideas represent a certain future and offer space for efficiency improvement of at least 20% and even up to 50-60%, but with the reduction of emission of harmful gases and particles. At the end of all internal combustion engines have one major drawback - polluting. Motor vehicles are a major source of pollutants such as NOx, Pb, CO and other harmful compounds, which in favorable conditions created by the so-called. photochemical smog. The gasoline engine exhaust gas is whole series of gases that result from burning, and can be roughly divided into hazardous and non-hazardous gases. The concentration of exhaust gases other than air factors λ depends on a whole range of structural details. When construction of the engine should definitely meet strict approval requirements for such cleaner air throw gases, but also to produce engines with the lowest possible fuel consumption, making more power and torque, corresponding durability, and so on., which are mutually opposed requirements [1].
Strict restrictions on the content of exhaust gases from spark-ignition engine can not meet even the most modern construction with a very precise regulation of the mixture of education, and for this reason in these engines must apply aftertreatment of exhaust gases. The most commonly applicable devices for exhaust gas after treatment OTO engines are catalysts (catalytic converters), whose main role is environmental protection of the environment. All modern petrol and diesel engines are fitted with a catalytic converter. The catalyst is usually placed in the first muffler to the engine to heat up as soon as possible, and thanks to the materials from which it is made in a chemical reaction takes place in which the harmful components in the exhaust emission (CO, HC, and NOx) are converted into harmless gases (CO_2, H2O, N_2) - Figure 1.

Of course, such a reaction is not purified gases completely, but contributes to the reduction of harmful ingredients. The main role of the catalyst is to burn combustion products reduce the content of toxic components in the exhaust gas, but also contributes to reducing the level of noise and increase resistance to the flow of combustion products. The greatest effect of the catalyst takes place in achieving power with a mixture of air and gasoline in a stoichiometric ratio of 14.7:1. So, for the proper and complete combustion of 1g of fuel, it is 14.7 g air. Then factor $\lambda = 1$. This is accomplished by the lambda probe. For now, the best results are achieved by using ternary catalytic converters in which, in a stoichiometric mixture ($\lambda = 1$), and simultaneously perform oxidation and reduction processes.
The vehicle Koral and Florida that produced Zastava factory, built a three-way catalyst with two ceramic monoliths. Volume of this catalyst was V = 1530cm^3. Ceramic monolith is a honeycomb with 400 holes / inch2, walls and windows are covered with precious metals (platinum, palladium, rhodium). On vehicles Florida with a Peugeot engine was done testing the composition of the exhaust gases (Table 1) according to ECE Regulation R 83.05 and the results were satisfactory.

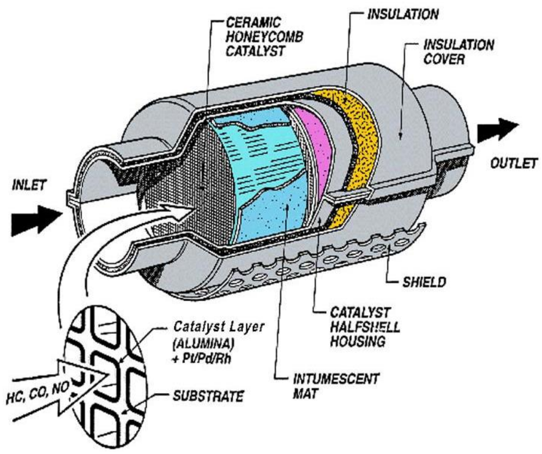


Figure 1. Catalyst

Energy balance of oilseed rape is shown in Table 1, where the total energy entry includes (processing of land, fertilizer, agro-chemical, seed, storage, transportation, processing-production), and the total energy output includes (biofuel, unleavened cake, stalks).

Table 1. Florida vehicle with Peugeot engine

Polluting components	Measured values
CO [g/km]	0,34
NC [g/km]	0,055
NO_x [g/km]	0.032

TECHNOLOGICAL MEASURES

Technological instruments related to the technological improvement of existing fuels, the use of cleaner fuels (liquefied petroleum gas, natural natural gas, biogas, electricity, alcohol, hydrogen, fuel cells), the technological upgrading of the vehicles themselves, which leads to increase their energy efficiency, the use of different communication and information technologies in traffic and transportation, and the like.
The application of the digital engine management - MOTRONIK (electronic circuit with a set of chips and processor that controls all devices essential for the operation of the engine) ensures low fuel consumption and CO_2 emissions by up to 15 %.

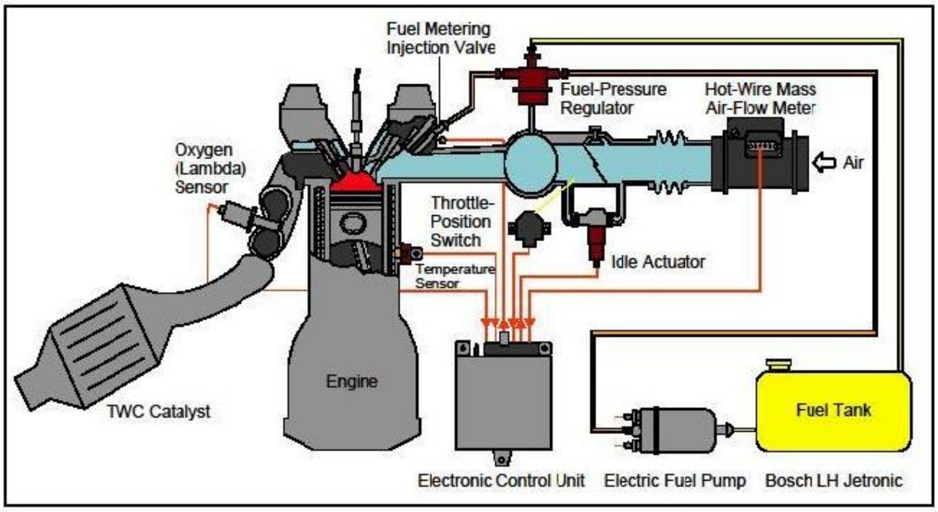


Figure 2. Motronik - unified composition of electronic injection and ignition

Bosch is a world first began selling its injection system - common rail 1997. In comparison to other injection systems, pressure generation and injection are separate common rail technology. Common rail system has a lasting supply of fuel under real pressure even at slow speeds.

Reducing emissions of harmful gases in the internal combustion engine on gasoline-powered ensure:

• optimizing the combustion process in the cylinder of the engine improvements on the engine (a form of the combustion, the flow in the cylinder, fuel atomization, ...) , also known as the so-called reduction of raw emissions,

• purification of exhaust gases after they exit the engine constant improvement of fuel quality: reducing the sulfur content in gasoline and applying environmentally more favorable fuel,

• reducing driving resistance vehicles: reducing air resistance and mass of the vehicle. Bearing in mind the two categories of vehicles, ie. and vehicles with petrol and vehicles with diesel engines, it is possible to conclude that the curb weight is mostly influenced by the external costs of CO_2 emissions and pollutants CO, HC, NOx and PM,

• optimized management of the operation of ancillary devices and motor vehicles, etc .

In the combustion in the cylinder of modern petrol engines are set two main goals:

• harmful emissions must be within the permissible limits and

• specific fuel consumption should be as low as possible.

The aspiration is to achieve these goals primarily by optimizing the combustion process in the cylinder. However, at the present stage of development of technology that is not possible. Therefore, implemented and purification of exhaust gases after they went out of the cylinder.

GUIDELINES FOR THE FUTURE

A significant share of environmental pollution has emissions of motor vehicles, and to all these reductions can be influenced in different ways:

• Improve engine and vehicle,

• Development and implementation of alternative vehicle fuels (fuel cells, electric drive, .. .) especially applicable to urban,

• Improving the quality of fuels,

• Control of distribution and use of fuels,

• The elimination or at least reduction of the older vehicles,

• Improving the public transport system,

• Educating the population on the importance and the problem of air pollution.

The problem of air pollution, acid rain and the formation of "greenhouse effect " as a result of carbon dioxide emissions from cars, a problem that has received primary importance [2]. The ultimate goal is that by 2050, cities in the European Union using only vehicles with zero CO_2 emissions.

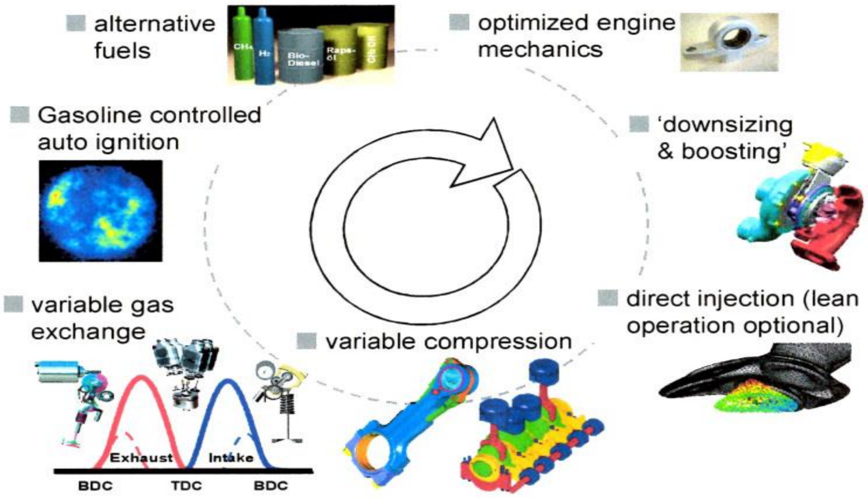


Figure 3. Further optimization of IC engines

Only a drastic reduction in the emission of toxic gases in the near future could stop the emergence of global warming which occurs mainly as a result of human activities. Passenger cars are responsible for about 12% of total CO_2 emission, the main driver of the effects of greenhouse gases in the European Union. It is anticipated that in 2015 all new cars emit an average of 130 grams of CO_2 per kilometer. Legislation have also defines long - term goal that by 2020 the average CO_2 emissions of new cars limited to only 95g per kilometer. The pollution in urban areas is a serious factor that countries and agencies for the protection of the environment must be considered in the decision-making processes. So, should encourage the consumption of alternative fuels for which countries have the greatest interest, whose reserves are huge, and that does not pollute the environment.

CONCLUSION

The progress of humanity is leading to a greater need for the application of motor vehicles, which resulted in the increasing pollution of the environment. A significant share of environmental pollution has emissions of motor vehicles. Because of large - scale pollution there is a need for the reduction of emissions. Contents of harmful components in exhaust emission can be controlled by a combination of burning process improvement and exhaust gas after treatment, as well as optimal control of motor vehicles in general. The catalyst plays an important role in the vehicle and is an important factor in protecting the environment, considering that traffic has a big stake in environmental pollution due to the large number of vehicles in the world.

REFERENCES

[1] Mihalec, I., Lulić Z., Kozarac D., Motori sa unutarnjim izgaranjem, FSB Zagreb, 2010.
[2] Gruden, D., Power units for future-quo vadis?, časopis MVM, Volume 38, Number 3, pp. 9-26, Kragujevac, 2012.

EXPERIMENTAL TESTING OF THE SUPER ABSORBING AIR FILTER YXV „AIR BY CORNELIU"

Sorin Raţiu[1], Corneliu Birtok-Băneasă[2], Vasile Alexa[3], Imre Kiss[4], Vasile Cioată[5]
[1,3,4,5] Politehnica University of Timişoara, Faculty of Engineering Hunedoara
[2] CorneliuGroup Association, www.corneliugroup.ro
e-mail: sorin.ratiu@fih.upt.ro

Abstract: This paper presents the experimental methodology to carry out functional performance tests for an air filter with a particular design of its housing, generically named *Super absorbing YXV „Air by Corneliu"*. The tests were carried out in the Internal Combustion Engines Laboratory, within the specialization "Road vehicles" belonging to the Faculty of Engineering Hunedoara, component of "Politehnica" University of Timişoara. We present some comparative values of various operating parameters of the engine fitted, in the first measuring session, with the original filter, and then with the studied filter.
Key words: air filter, internal combustion engine.

INTRODUCTION

The proper filtration of the air entering the cylinders of an internal combustion engine is essential for extending its service life. Preventing various impurities from entering the engine along with the atmospheric air reduces significantly the wear over time of the engine moving parts.
Unfortunately, in addition to the purpose of filtering the air drawn from the atmosphere, the air filter – as a distinct part of the engine – represents a significant gas-dynamic resistance, interposed on the suction route. If it is not regularly cleaned, and the vehicle travels frequently within a dusty environment, the suction pressure p_a is consistently decreasing and the air-filling coefficient η_V suffers penalties.
The design proposed by the authors aims at reducing the shortcomings described above by designing filter housing with particular geometry, enabling the improvement of the gas-dynamic performance at the engine air inlet. We note that this study does not deal with the nature of the filtering element of the filter, which is a standard one.
Therefore, we can say that the innovative design of the air filtration system is essential for a high performance filtration and air flow improvement, with effects on increasing of the engine performance and service life [1].

PRESENTATION OF THE EXPERIMENTAL EQUIPMENT

For performing the experimental measurements, we had an engine test stand, produced by *Christiani*, consisting of a multi-point fuel injection engine, brand VW, 1.4 MPI, used by the *Golf VI 5K1* models, cylinder capacity: 1390 cm^3, power: 59 KW/80 CP, 4 cylinders in line, manufacturing years: 2009-2012 (figure 1).

Figure 1. Overview of the test stand

The stand offers the possibility to monitor the engine during its operation. It enables the connection to the OBD port of all the testers usually found in garages, and the measurement of signals and electrical quantities, with the possibility of assessing the obtained parameters.

Figure 2. Monitoring the engine parameters

The related software contains a professional interface that allows the PC to be transformed, via an USB port, into a device to be used for diagnostics and visualization of the functional parameters (figure 2). Also, it enables the visualization and simultaneous storing of three measuring blocks, and can graphically display the essential features of the engine.

The tested super absorbing YXV filter has the additional function of accelerating the air speed at the output of the filter. Due to the constructive geometry, it provides a significant increase in the air-filling coefficient of the engine cylinders.

The filter (Figure 3) is provided with a frontal diffuser, lateral surface with the guiding cells and external diffuser – internal diffuser unit.

a. b. c.

Figure 3. Super absorbing filter YXV „Air by Corneliu" [1]
a – exploded virtual model, realised in AutoDesk Inventor; b, c – physical models

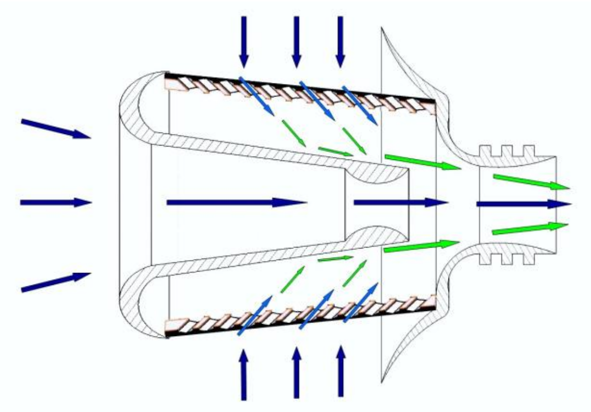


Figure 4. Illustration of the operating principle

TESTING SESSION

The tests consisted in determining the key operational parameters of the engine, at various speeds at idle, the engine being equipped, at a time, with the original filter or with YXV. The measuring sessions were repeated to confirm the results, and the test conditions for the two variants (engine equipped with original filter and with YXV) were maintained strictly constant. The filtering element is the same for both filters.

The experimental methodology:

For the first measuring session, the experimental engine was equipped with the original filter (Figure 5.a). The data acquisition was made at various engine speeds at idle, beginning with the idling speed and continuing with 1500, 2000, 2500, 3000, 3500 and 4000 rpm. We measured:

- engine speed;
- throttle position;
- manifold air pressure;
- coolant temperature;
- manifold air temperature;
- hourly fuel consumption;
- ambient temperature;
- atmospheric pressure.

a. b.

Figure 5. a – Engine equipped with original filter, b - Engine equipped with YXV filter

The next session of measurements was carried out with the engine equipped with YXV filter (Figure 5.b). The same above-specified parameters have been determined, under the same conditions.

We mention that the measuring sessions were conducted inside the laboratory, where the temperature and pressure remained strictly constant.

RESULTS AND CONCLUSIONS

We present below the comparative values of the above-specified parameters on the performance of the engine equipped with original filter and YXV filter, respectively.

The chart presented in Figure 5 shows that, at engine speeds below 2250 rpm, when using the YXV filter, the throttle valve opens less, which means less gas-dynamic resistance due to this filter installation, situation beneficial for the process of filling the engine cylinder with fresh load. At higher speed values, it can be seen that the throttle valve position is approximately identical in both cases.

From Figure 6, we can deduct that, throughout the range of speeds at which the tests have been performed, the pressure in the intake manifold is higher when using YXV than when using the original filter, situation beneficial for the process of filling the engine cylinder with fresh load.

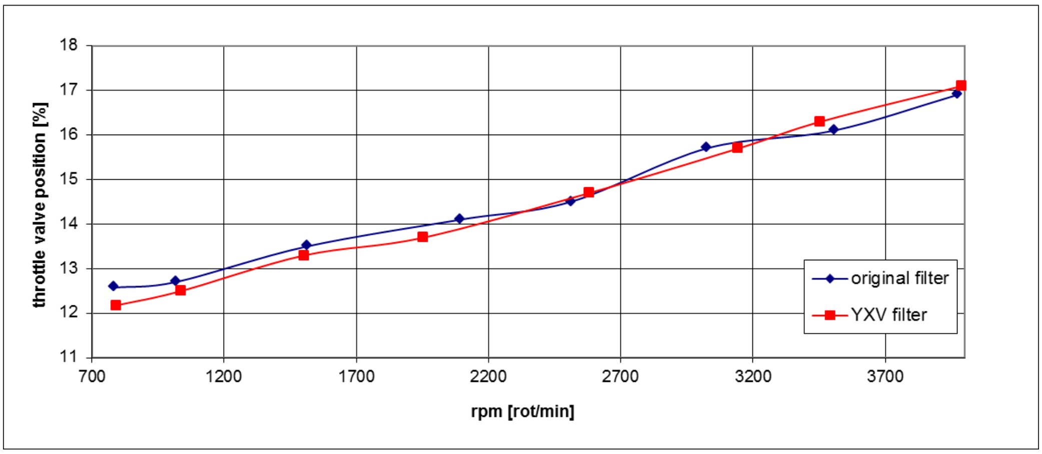


Figure 5. Position of the throttle valve versus engine speed at idle

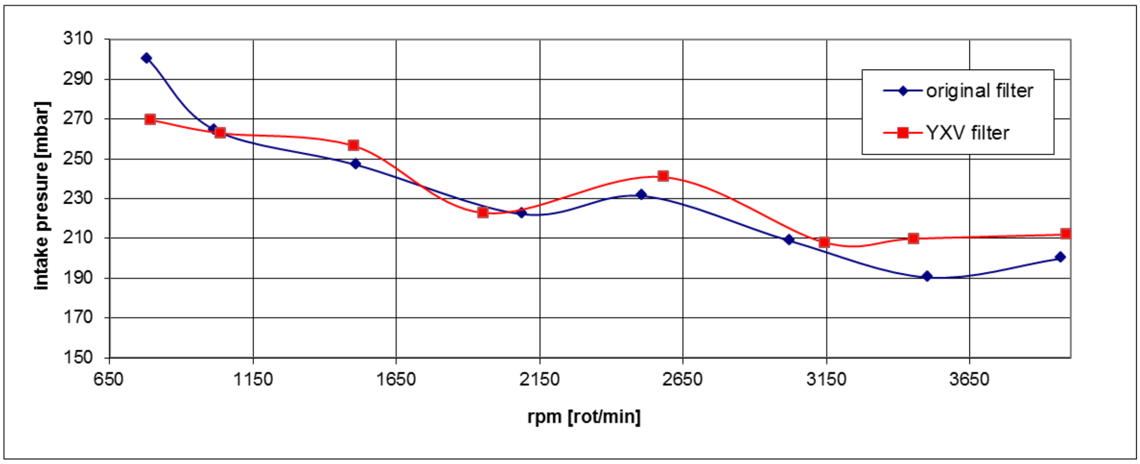


Figure 6. Pressure in the intake manifold versus engine idle speed

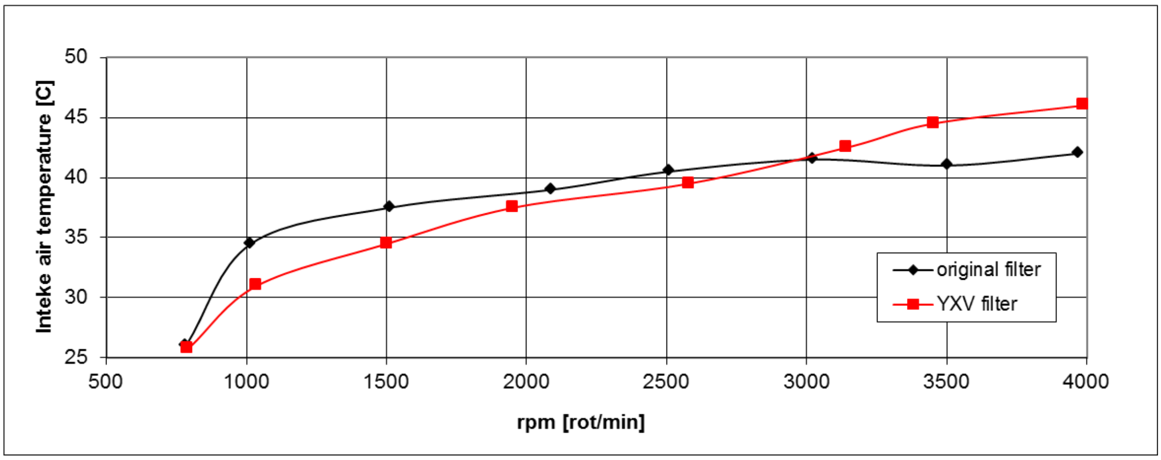


Figure 7. Air temperature in the intake manifold versus engine idle speed

From Figure 7, it can be concluded that, up to a speed of 3100 rpm, the air temperature in the intake manifold, when using the YXV, is lower than that obtained when using the original filter, situation beneficial for the cylinder filling process, because a lower air temperature when entering the engine means a higher density, and therefore a larger amount introduced into the cylinders, with beneficial consequences for the engine power.

The most important parameter monitored during the tests was the hourly fuel consumption, in litres/hour. In figure 8, we can see the variation of the hourly fuel consumption with the engine speed, for the cases when the engine is running equipped with the original filter and with YXV filter, respectively. It appears that, from speed values around 1600 rpm, the fuel consumption begins to decrease considerably when using the YXV filter.
The percentage difference between the hourly consumption with original filter and the hourly consumption with YXV is calculated using the relation:

$$d = 100 - \frac{Ch_{YXV\ filter}}{Ch_{original.\ filter}} \cdot 100\ [\%] \tag{1}$$

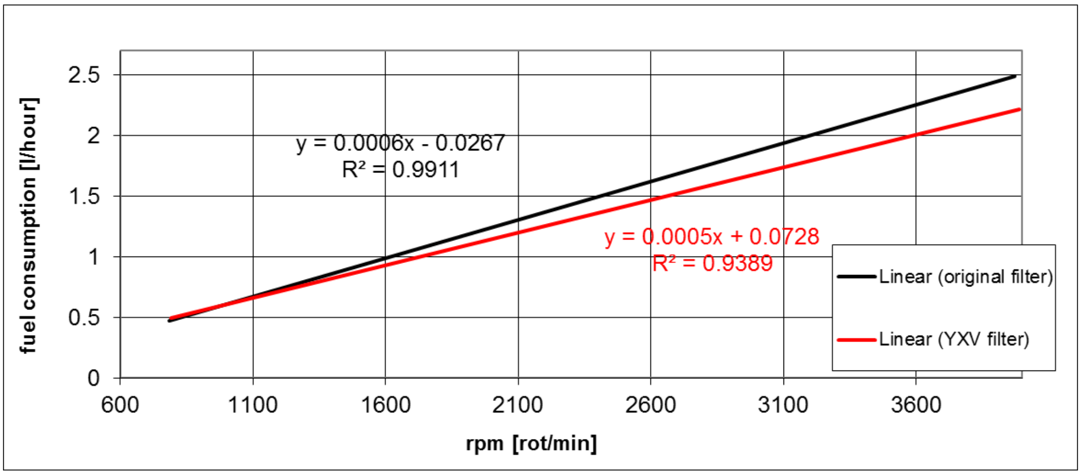


Figure 8. Hourly fuel consumption versus engine idle speed

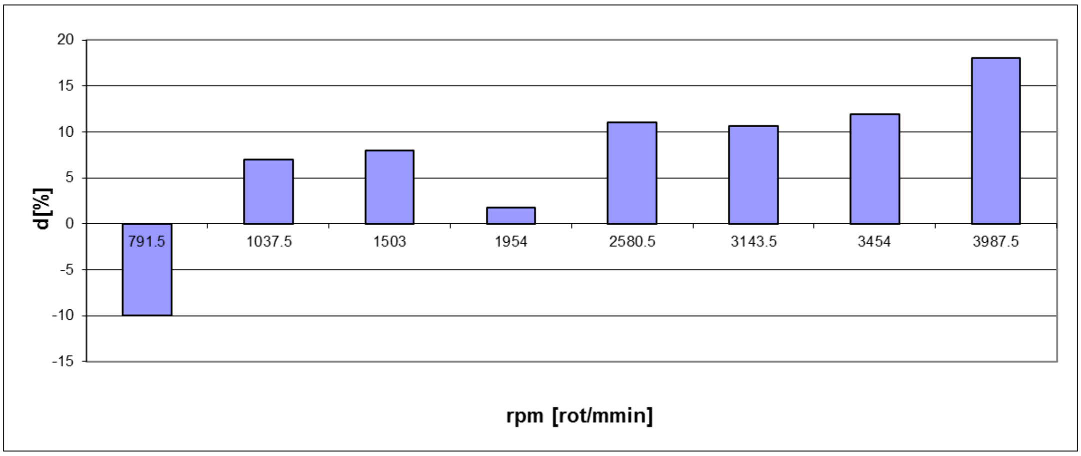


Figure 9. The percentage consumption difference

In figure 9, we can see that the percentage difference is positive at all the engine speeds, with the exception of idle (more precisely: 791.5 rpm). The positive values show lower fuel consumption than in case of the original filter.
Throughout the speed range used for conducting the tests, the reduction of fuel consumption by using the super absorbing YXV filter is 7.2%.
Following the conducted researches and monitoring of the behaviour when installing the filter on various types of engines, we concluded that this one has a number of advantages, such as:

» being in contact with the air, the filter element ensures a minimum gas-dynamic resistance to the absorbed air, increasing thereby the absorption and capture rates;
» the self-cleaning possibility of the filter element;

» visualisation of the filter element, without the prior removal of the filter, for checking its pollutant loading level;
» the capacity of air filter housing to significantly increase the speed of absorbed air, both at the input and output of the filter;
» the ability to create a slightly boost, which increases proportionally to the vehicle movement speed.

REFERENCES

[1.] Birtok-Băneasă, C., Raţiu, S., Admisia aerului în motoare cu ardere internă – Filtre supraaspirante – Sisteme dinamice de transfer [Air intake in internal combustion engines – Super absorbing filters – Dynamical Air Transfer Systems], Publisher: Politehnica, Timişoara, 2011;
[2.] Raţiu, S., Mihon, L. – Motoare cu ardere internă pentru autovehicule rutiere – Procese şi caracteristici [Internal combustion engines for road vehicles – Processes and Features], Publisher: Mirton, Timişoara, 2008;
[3.] Raţiu, S. – Motoare cu ardere internă pentru autovehicule rutiere – Procese şi caracteristici, Experimente de laborator [Internal combustion engines for road vehicles – Processes and Features – Laboratory experiments], Publisher: Mirton, Timişoara, 2009;
[4.] *** International Standard ISO 5011, Inlet air cleaning equipment for internal combustion engines and compressors – Performance testing, Second edition 2000-12-01, corrected and reprinted on 2001-07-15;
[5.] *** Bosch Automotive Hand-book, 8th Edition, May 2011;
[6.] Stahl U., Heinz Reinhardt, New Nonwoven Media for Engine In–take Air Filtration with Improved Performances, SAE technical paper series 2006–01–0272, 2006 Word Congress, Detroit, Michigan, April 3–6, 2006, SP–2014;
[7.] Bugli, N.J., Automotive Engine Air Cleaners – Performance Trends, SAE technical paper series 2001–01–1356, SAE 2001 World Congress, Detroit, Michigan, March 5–8, 2001, ISSN 0148–7191;
[8.] Raţiu, S., et. al., New concepts in modelling air filters for internal combustion engines, The 20th International DAAAM SYMPOSIUM "Intelligent Manufacturing & Automation: Theory, Practice & Education", 25–28th November 2009, Vienna, Austria ISSN 1726–9679.

ENERGY AND ENVIRONMENTAL MANAGEMENT ACCORDING TO STANDARDS ISO 14001 AND ISO 50001

Ana Vukadinović[1], Jasmina Radosavljević[1]
[1] University of Niš, Faculty of Occupational Safety in Niš, Serbia
e-mail: ana.vukadinovic@znrfak.ni.ac.rs

Abstract: The greatest impact on planet natural resources has been made during the Industrial Revolution, around 200 years ago. In the 21st century, many of the problems of pollution caused by industrial revolution have been solved but other impacts such as global warming or ozone depletion took their place. To enable organizations control and mitigation of impacts related to environmental protection and energy consumption the International Organization for Standardization has developed a series of standards including ISO 14001 and ISO 50001. Due to evident climate changes, there is increased public pressure on companies to apply some management system and thus provide a competitive advantage and potentially decrease energy consumption which will lead to reduction of production costs. By accessing the Energy Community Serbia obliged to increase energy efficiency by 9% until 2018. and considering that the industrial sector has a share of about 30% in final energy consumption, it is important to examine the benefits provided by the application of energy management system.
Key words: energy, management, environmental protection, ISO 14001, ISO 50001

INTRODUCTION

Population dependence on fossil fuels began during the Industrial Revolution. Despite the benefits that industrialization brought to humanity the combustion of fossil fuels, at the same time, caused rapid CO_2 release into the atmosphere. The increase in CO_2 emission from 2000 to 2008 was 3.8% per year. According to the IEA (International Energy Agency) energy sector and energy production and use are to blame for 70% of the total amount of "greenhouse gases". During the exploitation of significant amounts of non-renewable resources too little thought of the long-term effects on human health and environmental quality. The financial crisis in 2008 contributed the decrease in CO2 emissions of 2% per annum. During the 2010 and the recovery of the world economy the increase of CO_2 emissions continued. The increase in gross domestic product (GDP) and economic development links with the increasing levels of CO_2, but it is unrealistic to expect to stop with economic development and the development of energy infrastructure [1] in the past 40 years there has been a growing awareness of the negative impact of energy on the environment. Although the Kyoto Protocol is not universally supported in the world, the limited reserves of fossil fuels and impact of their use on the environment should be taken seriously. The public expectation that company business should be carried out in an environmentally responsible manner and that resources are used more efficiently is increasing.

ISO 14001 MANAGEMENT SYSTEM

International Organization for Standardization (ISO) has adopted a family of 21 standards of series 14000 in order to support economic and social subjects in the management of environmental requirements. The most important among them is the standard 14001 and refers to environmental management. [2] After the first publication of series of standards 14000 in 1996 and several years of work of the Technical Committee TC207, in November 2004 the organization ISO has published a second editorial of ISO 14001 standard. [3] Management System according to ISO 14001 allows organizations to develop environmental protection policies, to establish objectives and obligations in accordance with the requirements of this policy and take measures to improve their performance. The standard ISO 14001 is applicable to any organization that wants to create, implement, maintain in working order and improve the environmental management system. The scope of this standard depends on the environmental policy of the organization, the type of its activities, products and services as well as working place and conditions. [4]
Considering the ISO 14001 standard and its application two questions arise. What are the motives of the organization to adopt standard 14001 and what are the impacts of standard application on company performance improvement? The motives of the organization for the implementation of this standard can

be found in the competitive advantages in the way that organizations offer products that do not harm the environment and thus achieve marketing advantage and more attention in the media. Very often standard 14001 is the requirement of public procurements. The benefits of this standard are more efficient manufacturing, reduction of operational costs as well as costs of waste. [5] The rapid development of industry and economy of China and pollution caused by that development have led to a growing number of Chinese companies that applied some kind of environmental management standard and the most popular among them is the ISO 14001. Number of Chinese companies that have implemented this standard in 2011 was 72,124 and China overtook Japan and US and become a leader in the implementation of ISO 14001. Wenlong in his study [5] showed that immediately after the application of ISO 14001 simultaneously increases both sales and expenses such as cost of pollution control, prevention costs, costs of acquisition and maintenance, costs of staff training etc. but social benefits for the whole society overcome these expenses. [5]

The concept of the ISO 14001 standard consists of requirements to control activities so that environmental impact is minimal and three main requirements stand out:

- identification of the main environmental aspects of the organization
- ranking of impacts on the environment by relevance using logical and objective methodology
- management system focuses on improving and minimizing significant environmental impacts

In one sentence we can say that the requirements of standard ISO14001 are:

"The control and the reduction of environmental impacts" [6]

Organization use energy and raw materials and manufacture products and waste. This is referred as the impact on the environment. ISO 14001 defines environmental impact as "any change to the environment, whether adverse or beneficial, which, in whole or in part, is a result of the organization's activities, products, or services." Standard requires an organization to better plan activities, use recycled materials or perhaps change the production process. In reality, when you make the first step by reducing the most significant environmental impact then the less significant impact highlights and the new cycle of improvement begins. The cycle is endless and it is actually improvement of the environmental performance of the organization. [6]

The requirements of ISO14001 include

- The development of environmental policy,
- Identification of environmental aspects and assessment of related environmental impacts
- Establishment of relevant legal and regulatory requirements
- The development and preservation of environmental goals
- The implementation of a documented system that includes elements of training and production control
- Monitoring and measures of operational activities
- Environmental Audit
- Management Audit to ensure the continuous effectiveness

ENERGY AND ENVIRONMENTAL POLLUTION

With an intense growth of the world population there has been noticed significant energy consumption and energy demands in the past 100 years increase every day. According to the estimation of the International Energy Agency (IEA) in the period from 2005 to 2025 a great increase of 40% in primary energy consumption is expected. Demand for energy is growing more than 2% annually. Unsustainable use of natural resources has led to a deterioration of the situation in urban and rural environments. The increase in oil prices on the world market during 2007 has reminded us that apart from renewable energy sources all the other energy sources are "expendable" and the price of oil will continue to grow as the energy reserves reduce. [7]

There is an opinion among scientists that the emission of fossil fuels and the increased concentration of CO_2 caused by this emission lead to climate change with devastating consequences. Temperature, as most common climate indicator, increased by 0.8 ° C since 1880 and decade between 2000 and 2009 was recorded as the warmest ever. According to forecasts by 2100 we can expect 3-5 ° C higher temperatures compared to the preindustrial era. [1] Long-term forecasts for the period from 2010 to 2060 show that 496 Gt CO_2 will be emitted into the atmosphere by fossil fuels combustion. Such a scenario

would cause warming of a 1.3 ° C compared to pre-industrial era and 0.3-0.7 ° C compared to the present. [1] According to the preliminary data of the IEA (International Energy Agency) for the first time after 40 years the emissions of CO_2 for 2014 are at the same level as the previous year when the recorded emission was 32.3 billion tones. A significant role in stopping the increase of CO_2 emission was played by China with changes made in energy consumption and the production of larger amounts of electricity from renewable sources such as hydro, solar and wind power and less from coal combustion.
Governments around the world respond to climate change by implementing energy strategies, technical standards and regulations in the field of environmental protection with the aim of increasing the efficiency of energy production and consumption. These national strategies and instruments create a framework in which the organization adopt its energy strategies and adopt energy management and environmental protection system. These strategies are on a voluntary basis. [7]

ENERGY POLICY AND GLOBAL ENERGY TRENDS

Considering the problems of energy consumption, energy instability and environmental pollution Governments around the world bring energy policies and strategies for energy management. Faced with global pollution, global energy crisis and rising energy prices, many countries have responded by publicizing the energy saving measures. The United States announced new standards for fuel economy, European Union (EU) has set a target of reducing energy consumption by 20% until 2020, China has set the goal of reducing energy intensity by 16% by 2015, Japan agreed to reduce power consumption by 10% by 2030 and Hong Kong with 20 Asian countries agreed to reduce its energy intensity by 25% from 2005 to 2030. [8] China now emits more CO_2 than any other country in the world. [8] Around 50% of the energy used in the EU is provided from imports. It is estimated that by 2030 this figure will rise to 70%. Dependence on imports causes economic and political instability and various economic, social and environmental risks. Considering the fact that 45% of oil is imported from Middle East and 40% of natural gas from Russia [8] then EU targets for reduced use of energy and environmental protection become clearer. To achieve these objectives, the EU countries have recognized energy efficiency as a key instrument. The European Commission in 2007 published a package of 12 reports relating to the issues of energy and climate change and the use of renewable energy sources and during that year a long-term goal was adopted that by 2020 the share of renewable energy in total energy consumption should be 20%. EU made a commitment to reduce CO_2 emissions by 60-80% by 2050 which implies the use of new technologies and the most important among them is Carbon Capture and Storage CCS [9] Green Group of Ministers for Development in 2014 signed the request for the increase of the share of renewable energy to 27% [10] EU energy policy now covers issues related to energy resources, technology and innovation, energy efficiency, single market for gas, electricity and energy infrastructure and the impact that the production, consumption and transmission of energy on the environment. [9] By accessing the Energy Community Serbia took an obligation to increase energy efficiency by 9% by 2018. [11] The National Assembly of the Republic of Serbia in 2013 adopted a law on the efficient use of energy with the basic principles of security, competitiveness, sustainability, organized management, economic viability and energy efficiency. According to this law management system obligators are companies that use more energy than the amount prescribed by the Government as well as organs of state administration or local governments with more than 20,000 inhabitants. These organizations and institutions are obliged to nominate the required number of energy managers, make a plan and program for energy efficiency, implement the measures of efficient energy use, make annual reports on achieving the goals and provide energy audit at least once every five years. [12] The Law defined the basic legislation which establishes a policy of efficient use of energy and these are: Energy Development Strategy of the Republic of Serbia and the Action Plan for Energy Efficiency. In accordance with the Directive 2009/28 / EC on renewable energy sources and binding targets that by 2020 the share of renewable sources in gross final consumption should be 27% the Republic of Serbia adopted a national action plan for renewable energy (NAPOIE). In accordance with the Energy Balance from 2009 the share of renewable energy sources was 21.2% [13]

ISO 50001 ENERGY MANAGEMENT SYSTEM (EnMS)

The experience of numerous companies in the world tells us that the investment in improving the energy performance is the most profitable for company. [7] Energy management is a set of measures that ensure the efficient use of energy resources. Energy management is a complex managerial approach concerning the monitoring of energy consumption and the implementation of measures of rationalization in energy consumption. [14] Research of Gordić et.al. has shown that the application of energy management system in the automobile factory "Zastava" can achieve savings in energy consumption of 25%. [15]
Historically, prior to ISO 50001 standard there was Management System for Energy (MSE 2005), adopted by the American National Standards Institute (ANSI). At a meeting in Arlington was concluded that ISO 50001 should result from standards ISO 9001 and 14001 as the starting basis and as a basis was used also standards ANSI MSE 2000:2008 and EN 16001:2009. [16] The International Organization for Standardization on 15 June 2011, published standard ISO 50001 related to the management of energy systems. Organizations and companies have met the challenge of improving energy performance indicators and energy efficiency in energy consumption. A relatively small number of companies have implemented energy management system (EnMS). Even the Scandinavian countries that are committed to energy preservation and efficiency have implemented the EnMS only in 3-14% of the companies. [15] By March 2014, the ISO 50001 standard was adopted by the 6912 companies worldwide. Figure 1. shows that the leader in the application of this standard in Europe is Germany with 3652 companies that have implemented ISO 50001 EnMS until 2014.

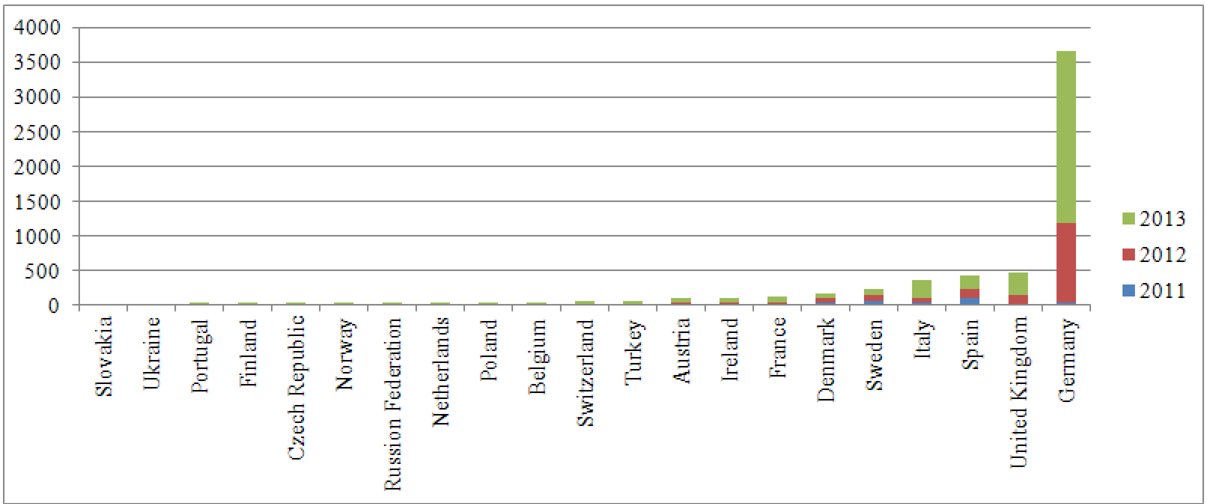


Figure 1. Number of cites that implemented 50001 by country in Europe[17]

Although there are many benefits of using standards ISO50001 most important is to allocate the following:

- To provide financial savings by increasing energy efficiency and the efficient management of energy use
- To reduce the creation of greenhouse gases that most of the scientific community considered as a cause of climate change
- To promote the improvement of public relations by showing that the organization makes genuine efforts in energy management

"Standard ISO 50001 requires that energy policy expresses the organization's commitment to achieving energy performance improvement" Successful energy policy enables the organization to manage the development of EnMS. A well-written energy policy provides the energy manager power in relation to production planning, site planning for new plants, the selection of production facilities, purchase of measuring equipment, etc.

ANALYSIS OF ISO 50001 IMPLEMENTATION IN SOUTH-EAST EUROPE

By analyzing the data for the region of South-east Europe from the International Organization for Standardization [17] came to the record that the standard ISO 50001 was implemented by 181 companies from Romania, 27 from Greece, 14 from Slovenia, 13 Hungary, Croatian 9 7 Bulgaria, Serbia 5 until 2014. Figure 2 shows that the leader in the implementation of the standards in the region is Romania which recorded decrease in final energy consumption and energy consumption in the industrial sector while there has been an increase in gross domestic product (GDP). (Figure 3, Table 1) Objective indicators of this standard application can be expected next year compared to the year of implementation.

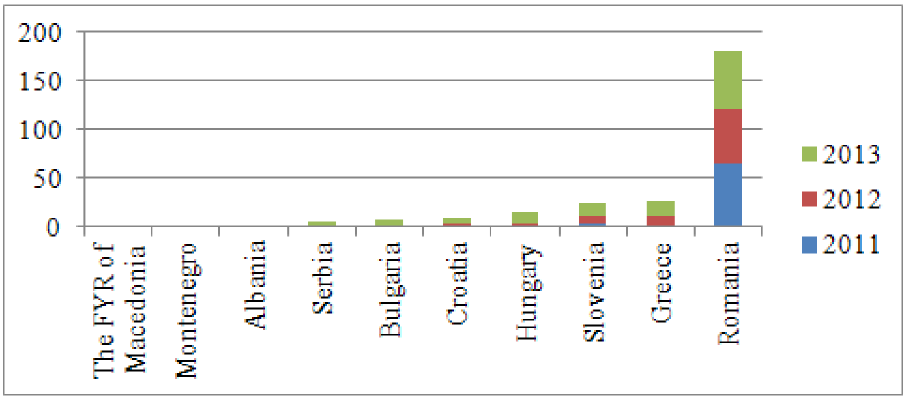


Figure 2. Number of cites that implemented 50001 for Serbia and surrounding countries[17]

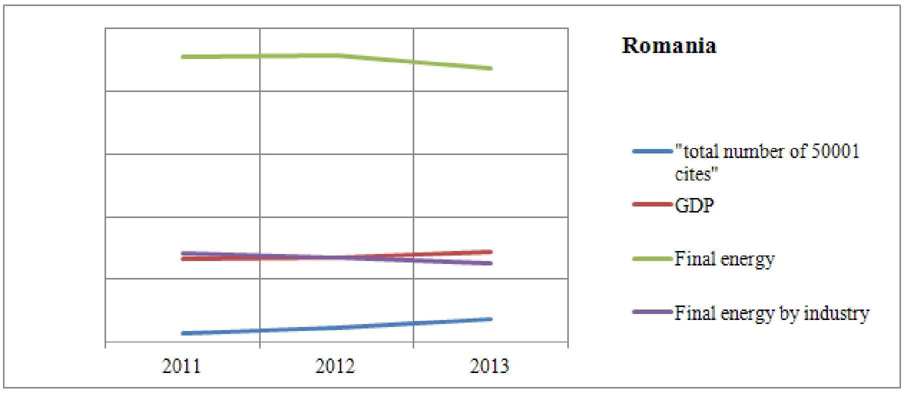


Figure 3. Number of cites in Romania that implemented 50001 and relevant indicators (GDP, Final energy consumption and final energy consumption by industry) [17,18]

Table 1. Number of cites in Romania and Serbia that implemented 50001 and relevant indicators (GDP, Final energy consumption and final energy consumption by industry) [17,18]

	Romania			Serbia		
Year	**2011**	**2012**	**2013**	**2011**	**2012**	**2013**
Total number of cites implemented 50001	66	121	181	0	2	5
GDP (Current prices, euro per capita)	6600	6700	7200	4600	4400	4800
Final Energy Consumption 2011 (1 000 tones of oil equivalent)	22770.7	22801	21757.8	9247.4	8487.3	8314.5
Final energy consumption by industry 2011(1 000 tones of oil equivalent)	7104.8	6786.9	6309.8	2835	2486.6	2477.4

According to data from August 2014, Serbia issued only 6 certificates ISO 50001 but there are companies that are in the process of implementation. [19]

CONCLUSION

The concept of energy conservation refers to reducing energy consumption while energy efficiency generally involves using less energy for the same level and quality of services. In developed countries, there is a growth in the number of companies that implement ISO 50001 and ISO 14001. Unfortunately, awareness of energy management in Serbia is at a very low level and it is an area that should be explored. Taking into account the increasing importance of energy efficiency, this paper aims to improve the situation of certification in accordance with ISO 50001. It is necessary to encourage not only the industrial sector to implement this standard but also educational institutions as well as representatives of local government. One of the goals of this work is to encourage responsible behavior towards energy based on the policy of efficient energy use and energy efficiency measures

Acknowledgement: Research reported in this paper was supported by the Ministry of Science, Republic of Serbia within the project No. III - 43014 and project No. TR-33035.

REFERENCES

[1] Freedman B. Global Environmental Change. London: Springer; 2014. p.940
[2] Jovetić S, Đurić Z, Janković O. Integrisani sistem menadžmenta kvalitetom u lokalnoj upravi grada Kragujevca. pp 349-364
[3] Haider S. I. Environmental Management System ISO 14001:2004. Boca Raton: Taylor and Francis Group; 2011.p.564
[4] Papić Lj. Međunarodni standard ISO 14001 u praksi: zahtevi i komentari. Čačak: Istraživački centar DQM; 2011. 152 str.
[5] Wenlong H, Chong L, Jiangyong C. Impacts of ISO 14001 adoption on firm performance: Evidence from China. China Economic Review. 2015; 32: p.43-56
[6] Whitelaw K. ISO 14001 Environmental Systems Handbook. Burlington: Elsavier; 2004. p.258
[7] Morvay Z, Gvozdenac D. Applied Industrial Energy and Environmental Management.United Kingdom: John Wiley and Sons Ltd; 2008. p.458
[8] Filho W, Voudouris V. Global Energy Policy and Security. London: Springer; 2013. p.332
[9] Tosun J, Biesenbender S, Schulze K. Energy Policy Making in the EU. London: Springer; 2015: p.262.
[10] Green Growth Group Ministers statement [Internet]
[11] Palgo centar. Uvođenje energetskog menadžmenta u gradove i opštine u Srbiji. Beograd; 2011.
[12] Zakon o efikasnom korišćenju energije, Službeni glasnik RS br.25/2013.
[13] Analiza lokalne Strategije i Politike i Akcioni plan za povećanje energetske efikasnosti korišćenjem solarne energije i inteligentnih sistema u opštinama i gradovima prekograničnih regiona. 2014. Project ref. 2007CB16IPO006-2011-2-22
[14] Živković D, Milosavljević P, Milčić D. Aspects of Energy management within Car Industry.
[15] Gordić D et al. Development of energy management system-Case study of Serbian car manufacterer. Energy Conversion and Management: 2010; 51: p.2783-2790
[16] Eccleston C, March F, Cohen T. Inside Energy.Developing and managing an ISO 50001 Energy management System. Boca Raton: Taylor and Francis Group; 2012. p.313
[17] ISO (International Organization for Standardization), Geneva Switzerland [Internet] http://www.iso.org/iso/iso-survey
[18] European Commission, EUROSTAT, Luxembourg [Internet] http://ec.europa.eu/eurostat
[19] Jovanović B. Sertifikacija sistema menadžmenta u industriji. Tehnika. 2014; 6: 1080-1085

A BRIEF OVERVIEW OF IPPC/IED IMPLEMENTATION

Dejan Vasović[1], Jelena Malenović Nikolić[1], Jasmina Radosavljević[1], Ana Vukadinović[1]
[1]University of Niš, Faculty of Occupational Safety in Niš, Niš, Serbia
e-mail: djnvasovic@gmail.com

Abstract: 52,000 large industrial installations (sometimes called operators) are in some way obligated by IPPC/IED policy across the European Union, in sectors such as power generation, metal production, chemicals manufacture, minerals production and intensive poultry and pig farming. The Integrated Pollution Prevention and Control Directive (IPPC Directive) was recognized as the European Union's main regulatory instruments in field of environmental quality management to tackle harmful emissions into the environment until 2010. A little later, on 24th November of 2010, the IPPC Directive was replaced by the new Industrial Emission Directive (IED), potentiating the legislation that implements IPPC Directive and six other directives regarding industrial emissions. The IED's main objectives are to minimize pollution from various industrial sources throughout the European Union. For countries in transition, such as Serbia, the harmonization of the provisions of national legislation with all the elements of IPPC/IED Directive is a very complex process in organizational/administrative terms, which in addition requires significant investments. This work represents a brief review of IPPC/IED main implementation stages with particular regard to Serbian environmental policy and specific short and long term aims and goals.

Key words: environmental management, pollution prevention, pollution control, IPPC/IED

INTRODUCTION

IPPC/IED Directive – EU's background

At the European Union level, first directive concerning integrated pollution prevention and control was Council Directive 96/61/EC of 24th of September 1996, published in Official Journal L 257.[1] This Directive came into force on 30th October 1996. The aim of this Directive edition was the integrated prevention and control of pollution arising from the activities listed out in Annex I of the Directive.[2] Activities listed out in Annex I of the Directive included industries operating in energy sector, basic organic chemicals production, industries operating in waste management sector, and production of pulp from timber, as the slaughtering and production of food products from animal or vegetable raw materials. This Directive provided a basis for preventing environmental pollution from activities listed out in Annex I.[2]

Over time, ever present need for amendments in the field of environmental law lead to issuance of Council Directive 2008/1/EC of the European Parliament and of the Council of 15th January 2008, which replaces the Council Directive 96/61/EC of 24th September 1996 on IPPC matter. Council Directive 2008/1/EC of the European Parliament was published in Official Journal L 24 of 29th January 2008. This Directive came into force on 18th February 2008. As in the case of the previous one, an activity to which the Directive applies was listed out in Annex I of this Directive. Its provisions was remain applicable until 6th January 2014.[3]

On 6th January 2011 the Industrial Emissions Directive (IED) entered into force. The Industrial Emissions Directive (Directive 2010/75/EU of the European Parliament and of the Council of 24th November 2010 on industrial emissions (new term instead of integrated pollution prevention and control)). Directive 2010/75/EU was published in Official Journal L 334 of 12th December 2010.[4] With effect from 7th January 2014, Directive 2010/75/EU definitively replaces following Directives:

1. Directive 78/176/EEC of 20th February 1978 on waste from the titanium dioxide industry (Titanium Dioxide Directive)
2. Directive 82/883/EEC on the surveillance and monitoring of titanium dioxide waste
3. Directive 92/112/EEC on the reduction of titanium dioxide industrial waste
4. Directive 1999/13/EC on reducing emissions of volatile organic compounds (VOCs)
5. Directive 2000/76/EC on waste incineration (Waste Incineration Directive (WID))
6. Directive 2008/1/EC concerning integrated pollution prevention and control (IPPC Directive)

With effect from 1st January 2016, Directive 2010/75/EU definitively replaces Directive 2001/80/EC on the limitation of emissions of certain pollutants from large combustion plants (LCP Directive).[4] The IED aims to reduce or eliminate emissions of pollution from industrial activities, to increase the effectiveness of the best available techniques legislation, to strengthen existing minimum of environmental quality requirements and to reduce all unnecessary administrative burdens regarding implementation of Directive.[4] The main features of IPPC/IED directive linked to the other most prominent environmental legislation are shown on Figure 1.

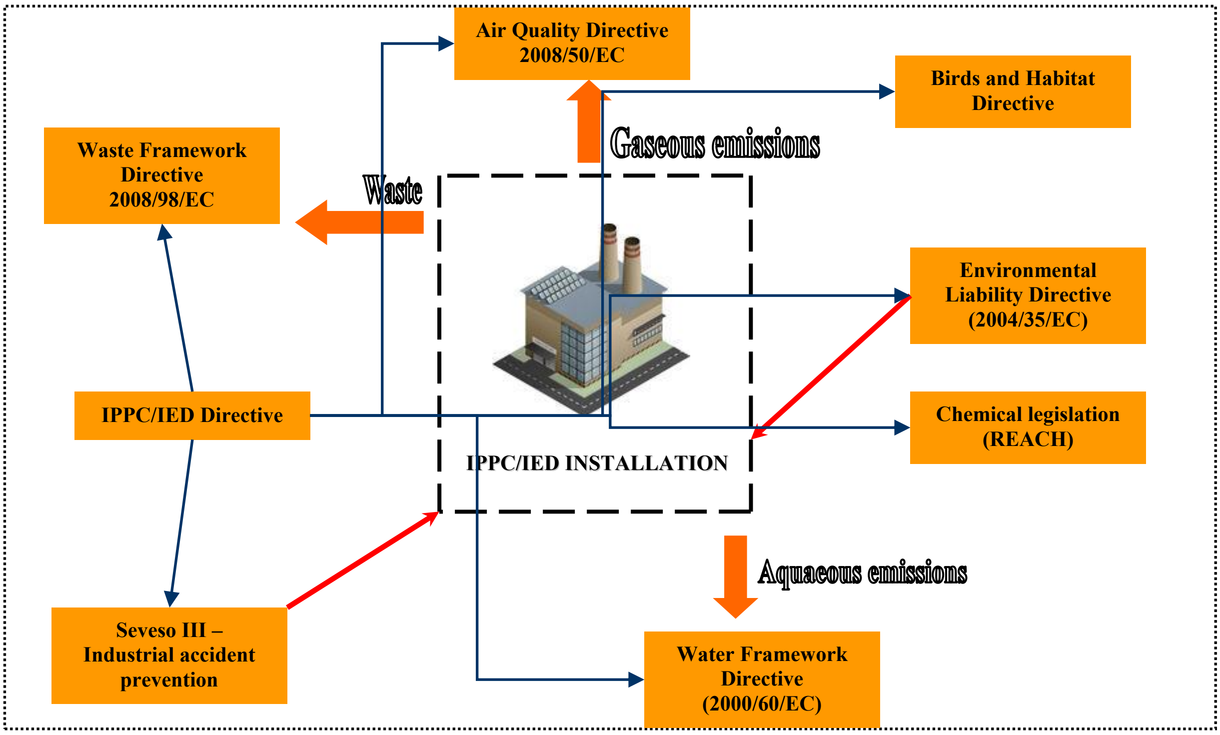


Figure 1. IPPC/IED Directive – linkages with other environmental legislation

Birds and Habitats Directive, Air Quality Framework Directive and the respective daughter directives, Water Framework Directive and daughter directives, Waste Framework Directive, chemicals legislation such as REACH etc. are of particular importance for successful IPPC/IED implementation since IPPC/IED respects environmental quality standards defined in these Directives.

IPPC/IED Directive implementation in Serbia

Directive on Integrated Pollution Prevention and Control (Integrated Pollution Prevention and Control Directive- IPPC Directive) and Directive on industrial emissions (Industrial Emissions Directive - IED) is one of the basic elements of European Union legislation in the field of environmental protection. For countries in transition, such as Serbia, the harmonization of the provisions of national legislation with all the elements of this Directive is a very complex process in organizational/ administrative terms, which in addition requires significant investments. The implementation of EU legislation relating to the integrated management of both prevention and control of pollution (which is actually the purpose of the Directive) requires significant administrative capacity and therefore poses a particular challenge in the process of accession to the European Union. With no less importance is the fact that the provisions of the IPPC / IED directive addressing a large part of the core economic organizations in Serbia (industry) but also a significant part of the agricultural and food production. Consequently, at the level of organizations, there are administrative, organizational and financial challenges associated with the implementation of the provisions of the IPPC / IED directive i.e. provisions of the Law on Integrated Pollution Prevention and Control (Off. Gazette no. 135/2004 and 24/15).[5]

Current list of operators in Serbia, which is necessary to obtain an integrated permit is provided by Serbian Ministry of Agriculture and Environmental Protection (last revision performed in October, 2014).[6] In Serbia, according to this list, provisions of the Law on Integrated Pollution Prevention and Control apply to about 196 organizations. Figure 2 shows the list of operators on which integrated permits applies, distributed according the Rule on types of activities and facilities on which integrated permits applies. [7]

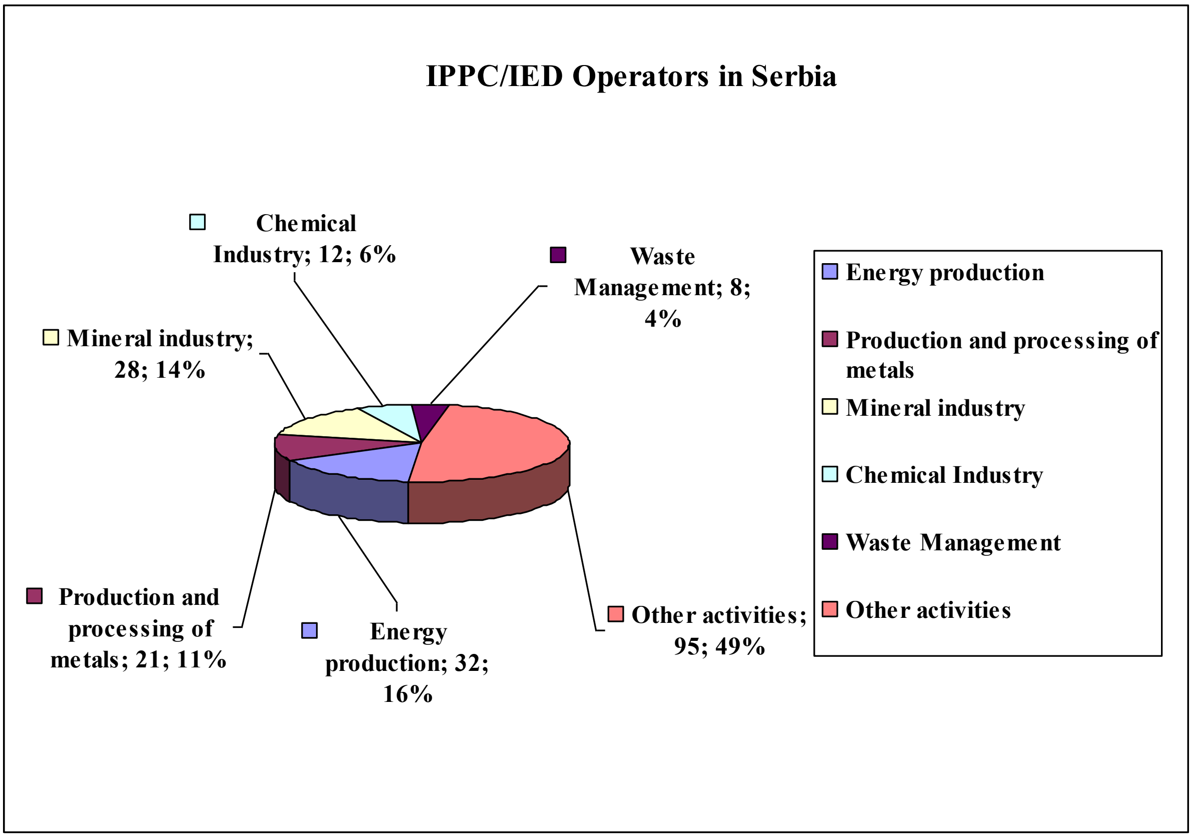


Figure 2. Operators in Serbia, on which integrated permit applies

IPPC/IED Implementation stages

As mentioned before, the harmonization of the provisions of national legislation with all the elements of the IPPC/IED Directive is a very complex process in organizational/administrative terms for countries in transition, such as Serbia. For such reason, it is preferably to make a brief overview regarding IPPC/IED implementation stages as additional toolkit. Such toolkit would have to recognize both IPPC/IED goals and principles, which are shown in Table 1.

Table 1: IPPC/IED goals and principles

IPPC/IED goals	IPPC/IED principles
Emission reduction	Integrated approach
High level of environmental protection	BAT promotion
Material flow (raw material flow) reduction	Flexibility
Energy flow reduction	Careful surveys
Potentiating the role of control institutions	Public participation

A brief overview regarding IPPC/IED implementation stages is shown on Figure 3. [8; restated]

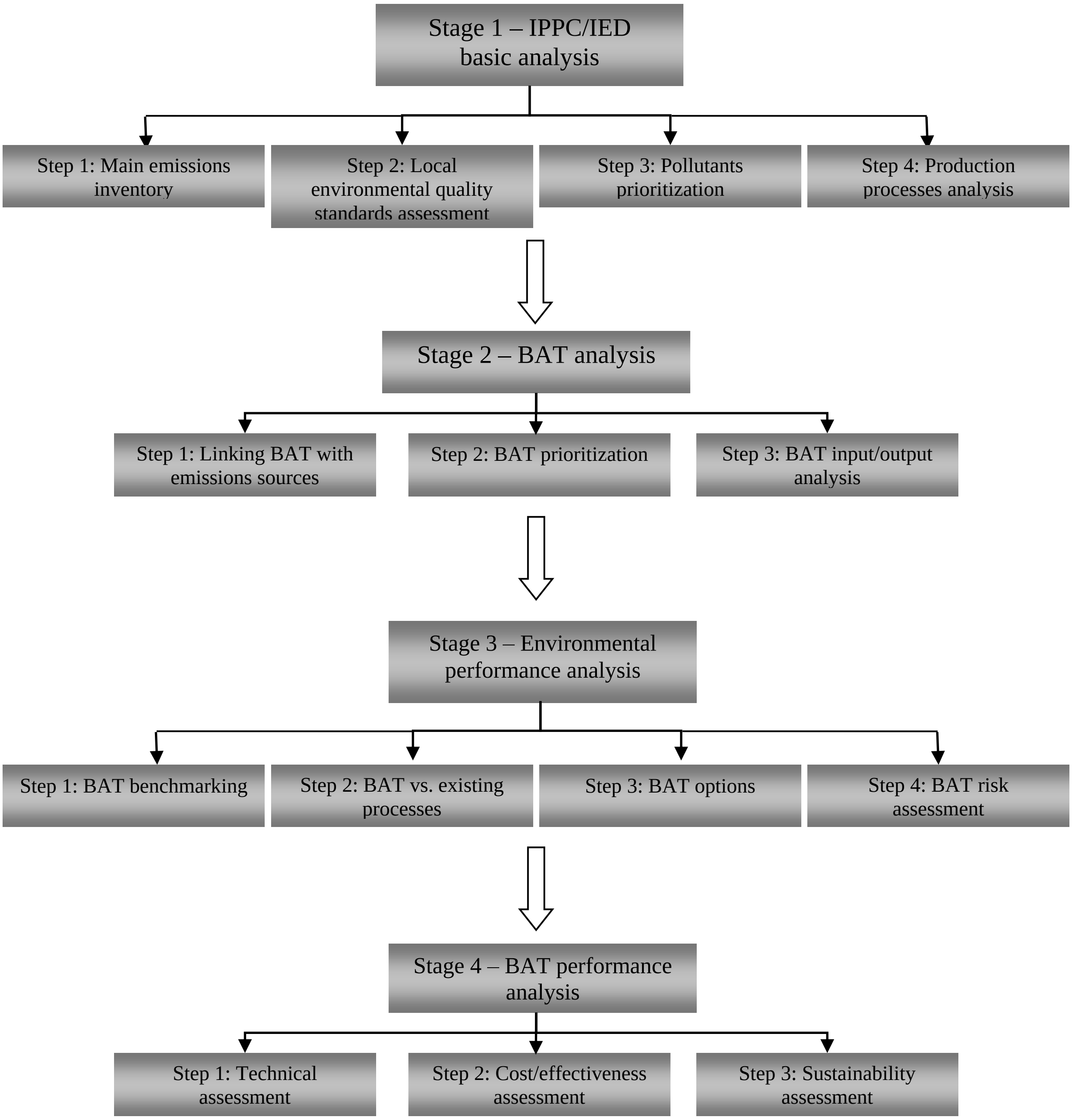


Figure 3. Brief overview regarding IPPC/IED implementation stages

CONCLUSION

Policy in the field of environmental management issues have received considerable attention of researchers from a wide variety of disciplines ranging from ecology and environmental protection, to finances and economy.[9] The reason may lie in the fact that contemporary framework of EU's environmental law mainly represents "*investment heavy*" directives. At the other hand, regarding historical background, environmental regulation has been the main motivation driver for many improvements in the field of environmental performance/environmental protection wide within the industry sector. It is clear that reduction of industrial emissions must be a central target within the broader national environmental protection program. With respect to emissions from industrial installations, the IPPC/IED Directive is one of the key environmental policy instruments of the environmental legislation of the European Union. The paperwork provides brief overview of IPPC/IED implementation and potential implications for operators working in the field of environmental management at the industrial installation level.

Acknowledgments. The presented research is a part of the projects "Development of new information and communication technologies, based on advances mathematical methods, with applications in medicine, telecommunications, power systems, protection of natural heritage and education" (III 44006) and "Research and development of energy efficient and environment friendly polygeneration systems based on renewable energy sources utilization" (III 42006), under the auspices of the Ministry of Education, Science and Technological Development, Republic of Serbia.

REFERENCES

[1] Council Directive 96/61/EC of 24th of September 1996, Official Journal L 257
[2] Council Directive 96/61/EC of 24th of September 1996, Official Journal L 257, Annex I
[3] Council Directive 2008/1/EC 15th January 2008, Official Journal L 24
[4] Council Directive 2010/75/EU of 24th November 2010, Official Journal L 334
[5] Law on Integrated Pollution Prevention and Control (Off. Gazette no. 135/2004 and 24/15)
[6] List of operators in Serbia on which integrated permits applies (last revision October, 2014)
[7] Rule on types of activities and facilities on which integrated permits applies (Off. Gazette no. 84/05)
[8] EuropeAid/131555/C/SER/RS, BAT assessment guidance document, final report
[9] S.C. Vac, G.E. Popita, N. Frunzeti, A. Popovici, E. Merce, T. Gabor., Biogas Plants – a Sustainable Choice. Journal of Environmental Protection and Ecology, Vol. 14, No 4, pp. 1769-1776, 2013.

COMPARISON AND ANALYSIS OF THE WASTE RECYCLING MANAGEMENT IN MACEDONIA AND GERMANY

Ana Karamandi[1], Stojance Nusev[1], Ilios Vilos[1], Cvetanka Mitrevska[2]
[1] University "St. Kliment Ohridski", Faculty of Technical Sciences, Bitola, Republic of Macedonia
[2] Internacional Slavic University Gavrilo Romanovic Derzavin, Faculty for Safety Engineering, Sveti Nikole, Republic of Macedonia
e-mail: ana.karamandi.@gmail.com

Abstract. Waste is an integral part of everyday life and the habit of dealing with waste is taught from childhood and becomes routine and unconscious behavior. Treating waste covers all social categories. Success in dealing with waste and its reduction within one state seeks to engage more entities - the legislature, legal entities for waste management and the educational system. Also, success in dealing with waste and its reduction depends on technological development and availability of modern technologies, chemical and thermal processes for treatment of the waste. The efforts made for treatment of the waste are because we gain great benefits such as reduction of waste, savings on raw materials, minimizing the pollution, protection of the environment and our own health.
Keywords: comparison waste management recycling.

INTRODUCTION

Meaning, short history and importance of the recycling

The word Recycling (*lat. Recycle: re-again, cycle-round*) means repeating the cycle.
To design an object, certain materials and techniques are used by which that object gets its final form. The objects or items can be made from multiple parts of different materials. When the object has no longer value it becomes waste, but the elements and materials of which it is made can be reused or recycled. The re-use or recycling can be done by:

1. Diversion of the object or the parts of which it is composed
2. Processing of materials for obtaining materials in pure raw form from which can later be developed new items.

Recycling is not a new activity for the humanity, people make conversion and reuse of the materials already a long time ago. For example, as it is known, first recycled paper is produced in Japan 1031, the "new paper" produced from old and already used paper; 1776 during the Fight for independence, America has gathered various metals and melt them to obtain raw materials for making weapons; 1904 in Chicago, Cleveland, the first plant for recycling aluminum was opened. With the beginning of the industrialization and mass production, recycling gets more organized form - waste is selected and the materials are recycled for reuse. Here are several reasons for recycling:

- Reducing waste
- Savings on raw materials
- Biodegradability
- Environmental protection

With recycling of the used materials (waste) raw materials are obtained much more easily than they can be obtained from ores that are in the earth. Also the process of recycling uses less power and raw materials (coal, oil, gas, water, electricity) for its issuance than if the materials are derived from ore or other resources. It should be mentioned that the Earth is not an infinite source of materials, so it is good if the materials are re-used.

Nowadays we have a production of materials that are not biodegradable or cannot be decomposed in a natural way with the sun, water and bacteria. Their simple disposal, as is the case with the waste of organic origin, would cause encumbering the parts of land that could be used more appropriate.
Also, some of the materials that are produced, can have a harmful impact on wildlife with their decomposition and cause pollution and destruction of the living organisms (animals and plants) in nature, and they can cause damage to human health. Given that, for protection of the environment, such materials is better to be recycled. In terms of environmental protection, it should be mentioned that the pollution of water, air and soil in the process of recycling is much smaller than in the process of the initially obtaining of materials.

MATERIAL AND METHODS

Comparison of the recycling rates in Macedonia and Germany

From the analysis of waste recycling in European countries in 2004 and 2012, according to European Environment Agency and Eurostat, Macedonia has the lowest rate of recycling in 2004 (2008) and 2012 (2011), compared with Germany which has the highest recycling rate in approximately the same periods.

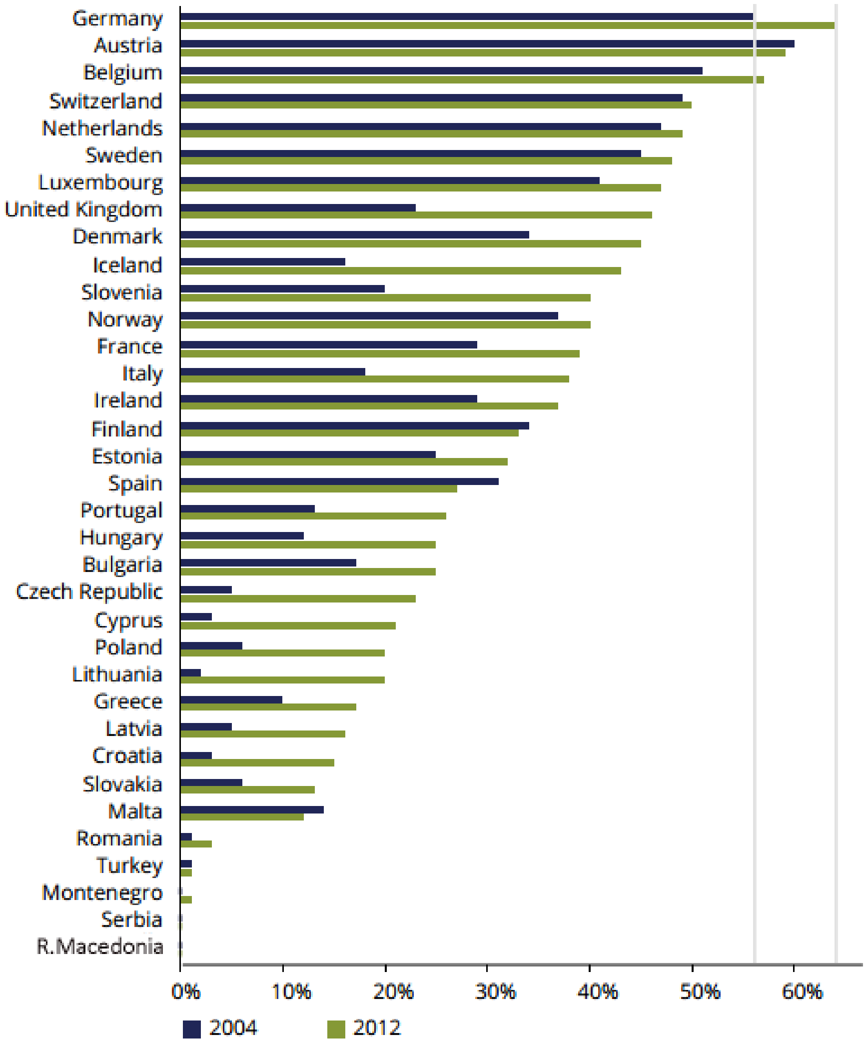


Figure 1. Municipal waste recycling rates in European countries, 2004 and 2012
Source: Eurostat Data Centre on Waste

Note for Figure 1.: The recycling rate is calculated as the percentage of municipal waste generated that is recycled and composted. Changes in reporting methodology means that 2012 data are not fully comparable with 2004 data for Austria, Cyprus, Malta, Slovakia and Spain. 2005 data used instead of 2004 for Poland due to changes in methodology. Due to data availability instead of 2004 data, 2003 data were used for Iceland; 2007 data used for Croatia; 2006 data used for Serbia. For the Republic of Macedonia, 2008 data were used for 2004, and 2011 used for 2012.
Macedonia has recycled a very small part of its waste, only 11.75% in 2011 (Table.1) and 18.86% in 2012 (Table.2) while Germany has level of recycling 63.0% in 2011 and 65.2% in 2012 (Eurostat).
The percentage of recycled waste in Macedonia for a period of one year has increased by 7.11% while the percentage of recycled waste in Germany for one year has increased by 2.2%.

Table 1. Waste by material, placed on the market (tons) and recycled (tons) in 2011

Type of material	Placed on the market	Recycled (or exported for recycling)	Recycling rate (%)
Glass	9 241.36	29.00	0.31
Plastic	13 963.12	2 657.06	19.03
Paper and cardboard	16 660.45	2 927.32	17.57
Metal	1 691.37	66.96	3.96
Wood	2 973.93		
Composite materials	2 808.09		
Other/ packaging not selected by type	1 002.51		
TOTAL	48 340.83	5 680.34	11.75

Source: Ministry of Environment and Physical Planning in R.M.

Table 2. Waste by material, placed on the market (tons) and recycled (tons) in 2012

Type of material	Placed on the market	Recycled (or exported for recycling)	Recycling rate (%)
Glass	42 515.62	-	-
Plastic	8 712.39	4 147.31	31.00
Paper and cardboard	13 379.35	3 853.31	28.65
Metal	13 448.45	2.63	0.17
Wood	1 528.69	15.00	0.54
Composite materials	2 759.27	-	-
Other/ packaging not selected by type	2 687.48	-	-
TOTAL	42 515.62	8 018.24	18.86

Source: Ministry of Environment and Physical Planning in R.M.

RESULTS AND DISCUSSION

Analysis of the waste management in Macedonia and Germany

Macedonia has shorter history of recycling compared with Germany. The "Law on Waste Management" was adopted in 2004 and the "Law on management of packaging and waste from packaging" in Macedonia was adopted in 2009.
The non-profit organization for waste management "Pakomak" was founded on 3 December 2010 by the 11 leading manufacturing companies in Macedonia. "Pakomak" is working to ensure responsible, efficient and most economically affordable management of the customers packaging waste in accordance with the legal obligations.
Since 20 May 2011 "Pakomak" joins the international network of packaging waste management Pro Europe and receives the license to use the symbol "Green Dot" which is a financial symbol. This symbol signifies that for the packaging that has this symbol a fee has been paid for handling the waste

after its use. The fee is calculated by weight of the waste material, and not all macedonian companies are aware for reducing the weight of their packaging.
Another facing problem is absence of companies for recycling glass, wood and composite materials so the waste should be exported or treated in different ways.
Macedonia has many “wild” landfills and is working to close them, so in 2011 “Closure Plan for non-compliant landfill in Macedonia” is prepared.
Also, psychological and sociological behavior of the people on managing their waste and make separation of the waste for recycling should be changed. Therefore, a lot of educational campaigns are made.
Unlike Macedonia, Germany has established the non-profit organization “Duales System Deutschland” GmbH (DSD) on 28 September 1990 by 95 companies, 20 years earlier than Macedonia. In 1991, Germany adopted the “Packaging Ordinance”, which requires all manufacturers to collect and then recycle or reuse the packaging after its disposal by the consumers. DSD is a founding member of the “European Grüner Punkt” (“Green Dot”) and umbrella organization “Pro Europe”.
Making corporations responsible for their packaging to the end of its life cycle, by paying a fee for handling the waste, encourages them to package goods with fewer and lighter materials in order to minimize recycling and disposal costs.
For minimizing the landfills in 1996 Germany adopted “Closed Substance Cycle and Waste Management Act”, which requires businesses to eliminate waste production by implementing one or more of the three management strategies: waste avoidance, waste recovery and environmentally compatible disposal.
Germany today is not facing problems with technologies and capacities for recycling any kind of waste materials, which is not case with Macedonia.
People in Germany are introduced with separation of the waste much earlier, so separation of the waste for recycling today is a part of the everyday life.

CONCLUSION

This comparison and analysis are made to see why Macedonia has so low rate in recycling of its own waste and why Germany is so efficient in handling with waste. A comparison of these two systems for dealing with waste in both countries showed no big difference in the elements that are parts of the system for implementing and managing the waste. The differences consist in the time difference to implement the system and the time required to make a detailed and comprehensive implementation of the system.
It takes time for more detailed organization and management and it takes time to develop the concept and awareness of the people on this topic as well as acquiring new habits for dealing with the waste and recycling.

REFERENCES

[1] European Environment Agency, „The European environment — state and outlook 2015: synthesis report“, Copenhagen, 2015
[2] CVETKOVSKA M., RUSHITI A., „Municipal waste management in the R. Macedonia“, Ministry of Environment and Physical Planning of R. Macedonia, Skopje, Macedonia, 2013
[3] FISCHER C. „Municipal waste management in Germany“, Copenhagen Resource Institute, Copenhagen, Germany, 2013
[4] Pro-europe „Uniformity in Diversity“, Brussels, Belgium, 2010
[7] "Report on the state of the environment in the Republic of Macedonia 2013", Macedonian Information Centre of Environment - Ministry of Environment and Physical Planning Republic of R. Macedonia, Skopje, R. Macedonia, 2014
[5] http://www.pakomak.com.mk/PakomakSite/en-index.html accessed 15 September 2015
[6] http://www.motorcityfreegeek.net accessed 15 September 2015
[7] http://www.gruener-punkt.de/en/group/der-gruene-punkt.html accessed 15 September 2015
[8] http://ec.europa.eu/eurostat accessed 15 September 2015

SOME EXPERIENCES OF SAFETY AND HEALTH OF WORK DURING THE MODERNIZATION OF TPP REK BITOLA

Cvetanka Mitrevska[1], Borce Vasilevski[2], Vangelce Mitrevski[3], Tale Geramitcioski[3], Vladimir Mijakovski[3],
[1]International Slavic University Gavrilo Romanovic Derzavin, St.Nikole
[2]Monting Energetika, Skopje
[3]University St.Kliment Ohridski, Faculty of Technical Sciences, Bitola
Faculty for Safety Engineering, Sveti Nikole
e-mail: cvetanka.mitrevska@t-home.mk

Abstract: In this paper the critical activities for health and safety at work during working operations for assembly/disassembly of parts under pressure were detected. Afther that protective measures during loading, unloading and transportation of elements at height and protective measures during working at height were discussed.
Key words: safety and health of work, protective measures.

INTRODUCTION

Thermal power plant (TPP) 'Bitola' is the largest electricity producer in the Republic of Macedonia with installed capacity of 3x225 MW. TPP 'Bitola' provides 80 % of the total energy production in the Republic of Macedonia, with average annual production 4.200 GWh [1]. It is a lignite fired power plant, in operation since 1982, 1984 and 1988 respectively. With the project Revitalization and Modernization of TPP Bitola which is developed in accordance to the results of the analysis performed in the study ,,Rehabilitation and performance improvement for TPP Bitola'', prepared by MWH-Italy and financed by EBRD [2], is provided to:

- modernization and revitalization of turbines, generators and automation. After that operational life time of TPP Bitola shall be extended for 120.000 hours, increased of coefficient of utilization, increased of power capacity for additional 8.32 MW per unit or 24.96 MW for TPP,
- revitalization and modernization of the boilers with NOx emissions reduction and revitalization of cooling towers and
- revitalization of TPP Bitola for SOx, dust and particle emission reduction.

The activities of modernization of the boiler and reducing of NOx of unit 3 have been finished in 2013. From the revitalization of boilers is expected to:

- increase the coefficient of utilization of boilers, i.e. providing production of 700 t/h super heated steam (545^{o}C, 140 bar), with decreased and variable coal quality
- examination, determining of existing condition of heating areas, replacing the same in accordance with examination results, and at the same time, extending their life time for 120.000 hours
- examination and modification of the system for preparation of coal dust, aero mixture, as well as combustion system in order to provide reduction of NOx during work with coal with variable and lower quality. After this has been accomplished NOx emissions should not be higher than 200mg/Nm^3 (in accordance with Directive 2001/80/EC).

The main causes for accidents of work in thermal power plant are analyzed Kumar et al., [3]. The highest number of injuries are caused by: chain pulling (8.474%), weight lifting (8.474%), slip and trip on the operational area (8.474%), struck by object (6.779%), fall from height (6.779%), conveyor (6.779%)plate cutting (5.085%), crusher house (5.085%), coal mill (5.085%), bucket (5.085%), burn

(5.085%), electrical burn (5.085%), stroked by object (5.085%). Something minor injuries caused by welding (3.390%), accidents by transport vehicle (3.390%), electrical shock (3.390%), and others.
Taking this into account in this paper some safety measures at work during the execution of assembly and disassembly works of parts under pressure, boiler casing and assembly of pipeline components with air under pressure were discussed.

DETECTING THE CRITICAL ACTIVITIES FOR HEALTH & SAFETY AT WORK

The work operations for assembly/disassembly of parts under pressure include the following activities:

- replacement of 175 pipe bends of the economizer-1, WE 1;
- replacement of 175 pipe bends of the economizer-2, WE 2;
- replacement of 38 pipe bends of the shielded super heater, SSm/SSf;
- replacement of 2 super heater packs 1, SCP
- replacement of 2 super heater collectors 1, SCP
- replacement of 35 pipe bends 1, SCP.

The works for disassembling parts under pressure include the following activities:

- installation of electrical screws for vertical transportation and their attestation (validation);
- cutting elements using grinder and torch (autogenously cutting);
- horizontal transportation using carts or manual transportation to the location for lowering loads, vertical transportation of disassembled elements using crane or lift (pieces of lower weight).

The installation of new elements shall be performed as follows:

- vertical transportation using electric winch or lift;
- horizontal transportation using carts or manually to the location of installation;
- alignment and welding of new elements for the existing pipeline or piece.

Hand cranes will be used as temporary support for securing old and new elements from falling and for better alignment.

PROTECTIVE MEASURES DURING THE EXECUTION OF ASSEMBLY AND DISASSEMBLY WORKS

Protective measures during loading, unloading and transportation of elements

At construction sites like this one, where the same workspace has to be shared and there are more contractors, different activities and where the works are being executed at several levels, indoors and outdoors, at height, on stairs etc. special attention should be paid to protective measures during mechanized transportation, manual transfer, proper disposal, lifting and lowering load, carried out at stairs, ladders, platforms and ancillary and temporary supports, props, access points and passages. When performing all activities before commencing the work, the workers are obliged to check if they have endangered the work of other workers and if it is necessary to warn them or to install a warning board, fence the area etc. For manual lifting of materials and equipment you should first check the shape and the surface of the objects to ensure that there are no sharp edges, nails etc.
When transporting load of higher length and weight and working in a group or when using auxiliary means (pads, levers etc.), only one of the experienced workers shall manage the works and give orders for simultaneous and balanced lifting. If there are loads of different lengths, you should first load larger and heavier objects, and than the rest of the objects in order to provide for stability. When removing the load form an underlay, it is important to take into consideration the stability of the under layer and the loads should be uplifted in such a way to ensure safety and to prevent collapse of the load.

During the mechanized loading and uploading, other works shall not be near the machine except of the workers necessary for that purpose.

If the head of works didn't appoint any workers for giving signals, the load driver shall be responsible for giving signals. The signals for lifting and lowering the load of larger size and weight may be given only by the direct head of works who must be familiar with the data on the weight in order to select a proper cable and supporting elements and properly to deploy the workers.

The locations of assembly and disassembly connections, if possible, shall be secured with receding platforms or safety nets for preventing the workers from falling.

During the lifting-lowering, transferring and removing/placing elements, it is forbidden for the workers to stand on the element, on the lifting device, the hanging tools or to stand in the dangerous zone, under the load. It is forbidden for the workers to move over the removed/placed element and in its vicinity until it has been secured against collapsing and displacement, except for the workers who perform the removal/-placement.

Directing and stabilizing the hanging object shall be performed from a safety distance, using ropes or in another indirect way. Moving the newly placed element on the support shall be performed indirectly, by using auxiliary devices, provided that the element is tied to the crane with tight accessories. The element shall be released and untied from the crane when safely placed on the support and ensured against collapsing.

The lowering and lifting procedure may not begin until:

- a safe access has been provided to the location of removing/placing the element,
- supports have been installed and until the tools and accessories for removing and fixing have been prepared,
- it has been checked wither all accesses to the assembly-disassembly zone have been closed for the workers and other persons who don't participate in those works and whether in the endangered zone there are any persons present who must leave the endangered zone,
- the workers who participate in the works have left the area and are standing at a safe distance,
- it has been verified whether the static and mechanical characteristics of the lifting equipment and the distance between the element and the crane is in accordance with the design.

The responsible worker (signaling worker) shall give a signal for starting the lifting/lowering and transferring procedure of the element after making sure that all of the above stated requirements have been met.

Workers at height, who are installing the working platforms or workers who accept the prefabricated elements at locations where there is no possibility for installation of scaffolding for protection against falling, must have safety belts with the shortest possible connection, depending on the necessary radius of movement, to solid parts of the facility or installed constructions and their safe places.

The person fastening the load, the person giving the signals and the crane operator shall be responsible for the proper and safe transportation of the load, because if the load hasn't been properly fastened and connected, the person giving the signals must not give any signal for moving and transporting the load. The crane operator is also not allowed to start the procedure of transporting the improperly fastened load.

When fastening the load on sharp edges, the person fastening the load shall protect the load by putting items under the load din order to prevent its deformation. It is forbidden to use damaged and unmarked ropes and tapes whose load capacity is unknown. The person fastening the load shall be responsible for selecting the recourses, tapes, ropes and cables. The person fasting the load must follow the load and warn the other workers on time that the load is approaching, and after finishing the transport, the piece shall be released, i.e. uncoupled.

When using overhead cranes or any other cranes, regardless of that that was supposed to work or provide crane operator according to the contract, it is necessary to comply with the legal regulations on safety at work. The basic requirement is not to exceed the permitted load capacity, especially for cranes with variable capacity, as well as to fasten the load properly.

For fastening the load, only the specified and appropriate equipment (ropes, chains, tapes) shall be used, on which the capacity data are permanently affixed. All our tools and equipment have been delivered to the construction site, together with the expert findings (the documents are at the disposal of the head of works and the project director). An expert finding (attest or certificate) must be available for any lifting equipment (crane, electric winch puller, cable winch, crane with galvanized chains electric cable puller and other equipment with load capacity over 1 t).

The access to the crane and its operation is allowed only for the authorized person, i.e. crane operator, who is medically fit and qualified for safe work and proper crane operations.

The crane operator may not:

- lift load of unknown weight,
- stress the crane with heavier load than the permitted load capacity,
- lift load with inclined ropes, lower load by swinging on location that is outside the manipulation area of the crane,
- leaves the load hanging without having any reason for that,
- lift load that is not free, i.e. that is placed under another load or pull out load which has been covered up or frozen in the ground,
- transfer load over the workers and over transportation vehicles that are moving,
- operate the crane near unprotected live overhead lines. The operation near overhead lines can be permitted if the value of the horizontal and vertical distance meets the specified values,
- operate the crane when receiving signals from two workers at the same time, as there is only one worker authorized for giving signals,
- before leaving the workplace, the crane operator must release the crane completely, to lift up the hook and to leave the crane at the specified location and in the specified position,
- continue with the operation if it has noticed that some part of the crane is not working properly.

The hand cable winch shall be installed only by hanging a hook in a vertical or horizontal position. The crane shall be attached on a stable construction, and it may not be hung on the structure via steel cable or reclined on the hand winch housing. These requirements must be met due to the housing deformation, as the housing is not provided to carry load, but it serves only as protection of the hand cable winch mechanism.

The position of the bar in the housing, as well as the joints of the clamps must be always inspected. The clamps used for a longer period must be replaced, as the rope can slip under load. It is not allowed to extend the arm in order to achieve greater pulling power. The crane with galvanized chain must be properly used. When using cranes for tensioning and yielding parts of the construction, it is not allowed that the hook is attached to holes or other openings or the edge of the profile and different protrusions. For that purpose rings and ropes must be used so that the hook can properly lift the load and in order to prevent deformations.

The chains composed of steel elements must always be greased in order to prevent corrosion. It is not allowed to increase the tensile force by extending the pipe sin order to prevent overload. The electric winch must be anchored before use, namely it must be properly fixed on the surface in order to avoid shifting and tipping. The direction of the dragging rope must be taken into account and it shall be determined by using a pulley.

At the lowest position of the hook, the rope must be wrapped at least twice around the drum. When wrapping the rope, it must be checked whether the wrapping is performed uniformly in order to avoid skipping and sudden movements when lifting and lowering the load.

The electric winch must have safe breaks that have been checked before putting the device into operation, so that the load can be stopped at any height. The electrical cable for the engine of the electric winch must be inserted using clamping collars. Against electric shock a neutralization systems is applied since the electric installation at the construction site has been neutralized as well.

When installing the pulley, the installation, i.e. its fastening at the construction, as well as the bearing capacity of the construction must be taken into consideration. The electric winch operator must be an experienced and qualified worker, appointed by the head of works.

Loading, transportation and unloading of prefabricated elements using transportation means (trucks, forklifts etc.) shall be performed by applying safety measures and regulations during the loading and unloading procedure.

When transporting the elements, the following requirements must be met:

- during loading or unloading of the elements each vehicle must be secured against movement,
- the group of workers who perform the loading or unloading of prefabricated elements must be managed by the responsible worker, appointed for that purpose,
- no workers may be transported in the storage unit of the vehicle,
- the vehicle drivers are obliged to respect all traffic signs at the construction site,
- the transportation of large and bulk elements must be performed by securing them from falling out of the means of transportation.

The forklift operator must be a qualified person, having a certificate from an authorized institution, appointed by the authorized person at the construction site to perform the duties of a forklift operator.
The responsibilities of the forklift operator are the following:

- before each operation, it must inspect the control mechanism, lifting mechanism, the level of oil in the engine, the water level in the radiator, filter, the bars for attaching the lifting device, greasing etc.,
- it must not start with the operation if the rest of the workers are not standing at a proper safe distance,
- movement on flat and solid ground,
- moving on slopes of less than 16%, i.e. 26% (depending on the type of the forklift),
- when the engine is on, it may not leave the forklift unattended,
- after finishing the works, it shall leave the fork in a low position, lift the hand brake, turn off the engine, take the contact key and keep it.

The following is forbidden: transportation of workers with the forklift, workers supporting the load with their hands during the transportation, standing over the load or having the role of counterweight, standing on the forks and performs work at height. The forklift operator shall be responsible for the safe operation with and around the forklift.

Protective measures during working at height

Work at height means performing work standing on supports at the height of 3.0 m and solid surfaces whereby the workspace hasn't been secured from falling from height.
While working at height, the worker must comply with the following:

- using protective equipment while performing the work,
- always fastened with protective belt, attached, if possible, above his head, and the safety of that location shall be checked before moving to the next support,
- moving and standing on the next support occurs after checking its safety conditions,
- the next temporary support shall not be stressed with additional load (materials, tools etc.), if the worker is not sure that the support can take the additional load,
- it shall not use the temporary support with another worker at the same time,
- hand tools and other accessories that are necessary for performing the work shall be placed within reach, at places they will not fall from or tied if necessary,
- no leaning to a position of unstable balance, holding the object or carrying it,
- the relocation of the protective belt rope from one place to another shall be performed in a position in which the worker is standing on a reliable and safe support, or if there is another rope, when fastened to a safe support,
- it shall not step over an empty space and shall have no sudden movements,
- it follows the approaching prefabricated elements and steps out of its possible path of movement,

- if it is not possible to perform the work in a manner and in the order specified by the project or in agreement with the head of works, the workers shall not continue working, but standing in a safe position, it shall wait and receive new instructions by the responsible worker. After receiving the instructions, it shall continue working.

Work at height can be performed only by workers who are trained for safe work and are medically fit for performance of such works. The worker may not start working, or work at height if tired, sleepy, mentally deranged, under influence of drugs, sedatives, and alcohol and other narcotics. The work at height may be performed only under direct and constant supervision of a professional worker.
The following measures shall be taken when working at height and for prevention of objects falling from great height:

- the passages for workers and the paths for mobile equipment shall be placed at a safe distance,
- the temporary works of the workers that are not directly related to the execution of works at a high building is allowed only in the period of termination of the work at high buildings,
- the accesses and the workplaces that cannot be relocated from the endangered zone shall be secured from falling of materials and tools, using protective galleries and canopies,
- when working at a high building, under the working platform, receiving scaffolds or nets shall be constructed, which are normally an integral part of the scaffold or the device and they shall be relocated together with them,
- the access to workplaces at height shall be executed and organized in such manner that there is no possibility of falling objects on the workers who go up or down, or accidental falls caused by their movement outside the secured zone (zone in which safety measures for falling objects have been carried out),
- the transportation of materials and equipment to the facility, from the facility and through the facility must be performed in such a manner, that does not endanger the parts of the construction site outside the secured zone,
- the zone around the high facility, within which there is a possibility of accidental fall of an object, shall be fenced, and at the entrances warning signs and stuff-only-signs shall be installed.

CONCLUSION

The main aim of this paper is to find out the occupational hazards and accidents in thermal power plant, during modernization and revitalization activities especially during the execution of assembly and disassembly works of parts under pressure. We are hope that our experiences about detecting the critical point (working places) and activities during the work in the power plant REK Bitola of whole period of maintenance the equipment, recognize the most dangerous activities of the workers, shall improve and increase the workers safety. Finally, we made some very important recommendations and order to workers for Health and Safety at Work with the practical and proven solutions and procedures crucial for the workers safety.
During the period of the intensive modernization and revitalization activities of the power plant equipment, statistical parameters shows that the totally safety of the workers who respect the established HSS (Health&Safety Security) procedure. The only incident happened on worker who didn’t respect the HSS procedure and falling down on high during the work, with seriously injures. So, we strongly recommended established HSS procedures for the workers in power plants described in this paper.

REFERENCES

[1] http://www.elem.com.mk. Last update of: 26.09.2015.
[2] JSC Macedonian Power Plants, 2012, Revitalization and modernization of TPP Bitola.
[3] Kumar1, A., Mohan Shrivastava, S., Jain, N.K. Patel, P., 2015, Identification of occupational diseases, health risk, hazard and injuries among the workers engaged in thermal, power plant, International Journal of Research in Engineering and Technology, Vol. 4(1), pp. 149-156.

BIG DATA IN HEALTHCARE SYSTEM

Saeed Rouhani[1], Dusanka Lecic[2], Aleksandar Kupusinac[3]
[1]Faculty of Management, University of Tehran, Tehran, Iran
[2]Faculty of Information Technologies, University of Educons, Sremska Kamenica, Serbia
[3]Faculty of Technical Sciences, University of Novi Sad, Novi Sad, Serbia
e-mail: lecicduska79@gmail.com

Abstract: This work represents a review of using big data in healthcare. Big data is a broad term for data sets large or complex. This expression is used often for predictive analytics. Standard healthcare practice was until now relatively ad-hoc and subjective decision making. With big data standard healthcare practice moves to evidence-based healthcare. The goal of this paper is to show a view of big data in healthcare. Also, the paper shows the impact big data on healthcare systems.
Key words: big data, healthcare,

INTRODUCTION

The last few years has seen huge advances in using technology to analyze and understand the data. In the middle of these trends are big data. Big data is helping businesses to become more efficient and productive in every industry. Healthcare is one of the industries.
Big data in healthcare industries is being used to predict epidemics, cure disease, improve quality of life and avoid preventable deaths. In present the world's population increase and people live longer. Models of treatment delivery are changing fast. Many decisions are being driven by collecting and analyzing data. The drive now is to understand as much about a patient as possible, as early in their life as possible – hopefully picking up warning signs of serious illness at an early enough stage that treatment is far more simple (and less expensive) than if it had not been spotted until later [10].
Modern technologies are used today more and more. It enables us to use as everything from pedometers to measure how far you walk in a day, to calorie counters to help you plan your diet. Millions of us are now using mobile technology to help us try and live healthier lifestyles. More recently, it enables us to track our progress and upload our data to be compiled alongside everyone else's. In the future, it should be possible that we could share the data with our doctor who will use it as part of diagnostic toolbox when you visit them with an ailment. Accessing to huge databases of information about the state of the health of the general public will allow problems to be spotted before they occur.

HISTORY OF BIG DATA IN HEALTHCARE

The healthcare industry historically has generated large amounts of data, driven by record keeping, compliance & regulatory requirements, and patient care [8]. Driven by mandatory requirements and the potential to improve the quality of healthcare delivery meanwhile reducing the costs, big data hold the promise of supporting a wide range of medical and healthcare functions, including among others clinical decision support, disease surveillance, and population health management [2,4,5].
Big data in healthcare refers to electronic health data sets so large and complex that they are difficult to manage with traditional software [1]. Big data in healthcare is overwhelming not only because of its volume but also because of the diversity of data types and the speed at which it must be managed [1].
Big data was demonstrated in March 2014 at the American Society of Engineering Education. Gautam Siwach engaged at Tackling the challenges of Big Data by MIT Computer Science and Artificial Intelligence Laboratory and Dr. Amir Esmailpour at UNH Research Group investigated the key features of big data as formation of clusters and their interconnections. They focused on the security of big data and the actual orientation of the term towards the presence of different type of data in an encrypted form at cloud interface by providing the raw definitions and real time examples within the technology [10].
In May 2013, IMS Center held an industry advisory board meeting focusing on big data where presenters from various industrial companies discussed their concerns, issues and future goals in Big Data environment. Tobias Preis et al. researche about big data based on Google Trends data and they

introduced a method to identify online precursors for stock market moves, using trading strategies based on search volume data provided by Google trends [1].

BIG DATA IN HEALTHCARE

The healthcare industry is behind other industries in the using of big data. One of the problems is resistance to changing. The healthcare workers are accustomed to making decisions independently. They use their own clinical judgment. They don't feel comfortable that they can rely on protocols based on big data. But many of them wanted to invest in information technology because their old systems have a limited ability to standardize and consolidate data.

This industry has a lot of challenges. There is no way to easily share data among different healthcare workers because of privacy concerns. Important information often remains in one group or department because organizations lack procedures for integrating data and communicating findings. But nowadays trends bring us to a point when big data can play a major role.

Question which shows to us is about the fact what is appropriate or right for a patient and right for the healthcare system. Grove et al. have created a holistic, patient centered framework that considers five key pathways to value. These five pathways are based on the concept that value is derived from the balance of healthcare cost and patient impact.

Right living - Patients take an active role in their own treatment, including disease prevention. This pathway encourages patients to make lifestyle choices that help them remain healthy. They choose proper diet and exercise, and they take an active role in their own care if they become sick. ƒ

Right care - This pathway involves ensuring that patients get the timeliest appropriate treatment available. In addition to relying on protocols, right care requires a coordinated approach. All caregivers should have the same information and work toward the same goal to avoid duplication of effort and suboptimal strategies. ƒ

Right provider - Patients should always be treated by high-performing professionals that are best matched to the task and will achieve the best outcome. Therefore, right provider has two meanings. The right match of provider skill set to the complexity of the assignment— for instance, nurses or physicians' assistants performing tasks that do not require a doctor—but also the specific selection of the provider with the best proven outcomes.

Right value - Providers will continuously enhance healthcare value while preserving or improving its quality. This pathway could involve multiple measures for ensuring cost-effectiveness of care, such as tying provider reimbursement to patient outcomes, or eliminating fraud, waste, or abuse in the system. ƒ

Right innovation - This pathway involves the identification of new approaches to delivering care and improving the innovation engines themselves. To capture value in this pathway, stakeholders must make better use of prior trial data. They could also use the data to find opportunities to improve traditional treatment protocols, including those for births and inpatient surgeries [3].

By using big data, healthcare organizations begin to realize significant benefits, which include detecting diseases at early stages; managing specific individual and population health and detecting health care fraud more efficiently. Numerous questions can be addressed with big data analytics.

The release of big data could inspire many companies to develop healthcare applications or similar innovations. It discovered in many healthcare companies strong evidence that the big data revolution has created new species of healthcare innovators. Although we are optimistic about the potential of big data, which could transform healthcare, some structural issues may pose obstacles. Traditional medical-management techniques must change. All stakeholders must recognize the value of big data and be willing to act on its insights, a fundamental mind-set shift for many and one that may prove difficult to achieve. Patients will not benefit from research on exercise. And physicians may not improve patient outcomes if they refuse to follow treatment protocols based on big data.

Platform for big data analytics in healthcare must support the key functions which are necessary for processing the data. The criteria for the evaluation of platform may include: availability, continuity, scalability, ability to manipulate at different levels of granularity, ease of use, and quality assurance [9].

Most platforms that are used today and that are currently available are open source. They are having typical advantages and limitations of open source platforms. To succeed, big data analytic in healthcare needs to be user-friendly and transparent. Real-time big data analytic is a key requirement in healthcare.

For large-scale adoption must exist the dynamic availability of numerous analytic algorithms, models and methods. Also, managerial issues of ownership, governance and standards have to be considered. Healthcare data is often fragmented, rarely standardized. This great challenge needs to be addressed as well.

Privacy issues will continue to be a major concern. New computer programs can remove names and other personal information from records being transported into large databases. Stakeholders across the industry must be vigilant. They must watch for potential problems, that it couldn't be possible that information become public.

CONCLUSION

Finally, health care will need to learn from other data revolutions. Players have taken advantage of data transparency that create value only for themselves. This could also occur in the healthcare sector. For instance, healthcare companies are looking to amortize fixed costs across more patients, and might choose to use big data only to identify patients and disease areas. If they market their services, patients may be in situation that would increase costs without necessarily improving outcomes.

Big data analytics is a promising right direction in healthcare domain. Big-data initiatives have the potential to transform healthcare. Healthcare is a data-rich domain. When more data is being collected, there will be increasing demand for big data analytic. Companies in healthcare that are committed to innovation, are ready to build their capabilities.

REFERENCES

[1] Bian J, Topaloglu U, Yu F, Yu F: Towards Large-scale Twitter Mining for Drugrelated Adverse Events. Maui, Hawaii: SHB; 2012.

[2] Burghard C: Big Data and Analytics Key to Accountable Care Success. IDC Health Insights; 2012.

[3] De Mauro, Andrea; Greco, Marco; Grimaldi, Michele (2015). "What is big data? A consensual definition and a review of key research topics". AIP Conference Proceedings 1644: 97–104.

[4] Dembosky A: “Data Prescription for Better Healthcare.” Financial Times, December 12, 2012, p. 19; 2012.

[5] Feldman B, Martin EM, Skotnes T: “Big Data in Healthcare Hype and Hope.” October 2012. Dr. Bonnie 360; 2012..

[6] Fernandes L, O’Connor M, Weaver V: Big data, bigger outcomes. J AHIMA 2012:38–42. 6. IHTT: Transforming Health Care through Big Data Strategies for leveraging big data in the health care industry; 2013.

[7] Frost & Sullivan: Drowning in Big Data? Reducing Information Technology Complexities and Costs for Healthcare Organizations.

[8] Raghupathi W: Data Mining in Health Care. In Healthcare Informatics: Improving Efficiency and Productivity. Edited by Kudyba S. Taylor & Francis; 2010:211–223.

[9] Rohlhorst F: Big Data Analytics: Turning Big Data into Big Money. USA: John Wiley & Sons; 2012.

[10] http://www.forbes.com/sites/bernardmarr/2015/04/21/

Session 3.

Manufacturing technologies and materials

ABOUT THE MECHANICAL CHARACTERISTICS OF PARTS OBTAINED FROM SEMISOLID STATE ALLOYS

Vasile George Cioată[1], Imre Kiss[1], Vasile Alexa[1], Sorin Aurel Rațiu[1]
[1]"Politehnica" University of Timișoara, Faculty of Engineering, Hunedoara, Romania
e-mail: vasile.cioata@fih.upt.ro

Abstract: The methods of processing metals and alloys in a semisolid state offer numerous advantages, as compared to the conventional processing methods (liquid casting followed by forging, die forging, stamping in a solid state), which result from the behavior and characteristics of the materials in a semi-solid state. Thus, due to their temperature, which is lower than that of the liquid metal, semi-liquid metals can be processed at a higher rate, and the wear of the deforming tools is reduced. The presence of the solid in the process of mould – filling makes viscosity controllable and higher than in the case of liquid metals, which results in pieces having smaller shrinkage holes, with a reduced macro and micro segregation and a fine micro-granular structure.
The paper shows some particularities of the semisolid state processing methods of the metallic materials and points out the advantages of using these methods for producing parts. In the paper is accomplished a study regarding the mechanical characteristics (tensile strength, elongation and Brinell hardness) of pieces obtained through these methods, comparing with conventional methods of processing.
Key words: semisolid state alloys, parts, mechanical characteristics

METHODS OF PROCESSING IN A SEMI-SOLID STATE

The basic principle of processing in a semi-solid state consists in obtaining the pieces during the solidification stage of the alloy. Along this time interval, part of the material is still liquid, while other parts are entirely solid. In order to have a thixotropic behavior, the solid phase has to consist in spheroidal (globular) particles, coated in liquid material. This special microstructure can be obtained by rigorous (mechanical, electromagnetic, etc.) mixing, during solidification.
The methods of processing metals and alloys in a semi-solid state offer numerous advantages, as compared to the conventional processing methods (liquid casting followed by forging, die forging, stamping in a solid state), which result from the behavior and characteristics of the materials in a semi-solid state. Thus, due to their temperature, which is lower than that of the liquid metal, semi-liquid metals can be processed at a higher rate, and the wear of the deforming tools is reduced. The presence of the solid in the process of mould – filling makes viscosity controllable and higher than in the case of liquid metals, which results in pieces having smaller shrinkage holes, with a reduced macro and micro segregation and a fine micro-granular structure. Also, gas capitation is reduced and the surfaces of the pieces are of a higher quality. Materials in a semi-solid state show a lower flow resistance than the solid state materials and therefore one can obtain pieces with an intricate configuration and thin walls. The energy consumption is lower by up to 35% as compared to the conventional processing methods [1].
Processing in a semi-solid state is generally being done in two ways: *Thixoforming* and *Rheocasting*.
Thixoforming is the term generally used to describe the process of obtaining pieces in a finished state from semi-solid state materials, by means of a metallic mould/die and punches. If the piece was cast in a closed metallic mould, the procedure is called Thixocasting, and if the finished piece has been cast in an open mould, it is called *Thixoforging*.
Figure 1 shows a diagram of the thixoforming process, pointing out to the processing stages: ingot elaboration and casting (a), their cropping into semi-finished parts (b), re-heating up of the semi-finished parts (c) and the formatting proper: by thixoforging (d_1) or by thixocasting (d_2).

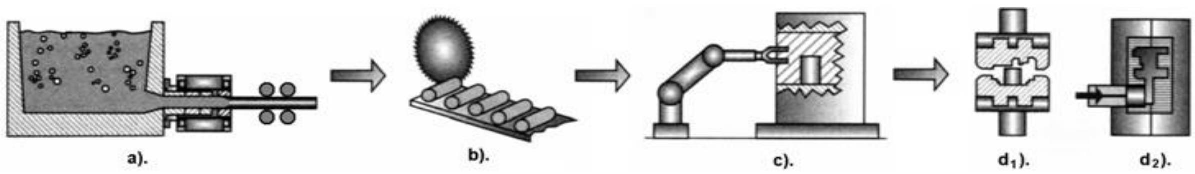


Figure 1. Thixoforming process [2]

The second direction of development, *Rheocasting*, has been used, from the very beginning of researches on processing, in a semi-solid state, as technology of obtaining a material with non-dendritic structure, needed for further processing by thixoforming. In the case of the *NRC* process, shown in figure 2, the liquid alloy elaborated in a furnace (a) is transferred into a specially designed steel crucibles (b) located on a conveyor, next to the pressure-casting machine. The cooling of the alloy is controlled so as to keep it in a semi-solid state. The alloy, in the form of a cylindrical ingot, is heated up in order to homogenize the temperature (c), then it is upturned (d) and finally it is transferred into the chamber of the pressure casting machine (e).

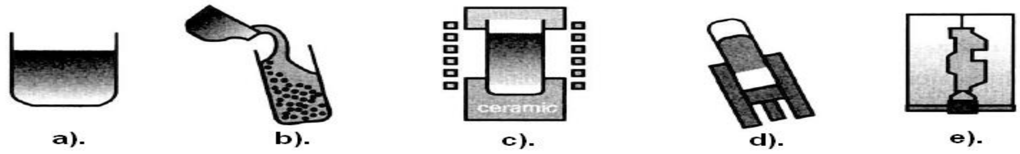


Figure 2. New Rheocasting Process (NRC) [2]

A variant of the Rheocasting method is given in the paper [1]. This variant involves the following processing stages: alloy elaboration, feeding the mould with it and mechanically agitating the material by vibration, in order to obtain a structure with a thixotropic behavior (the solid phase has to consist of spheroidal particles coated by the liquid phase) and the formation proper as a result of vibrations.

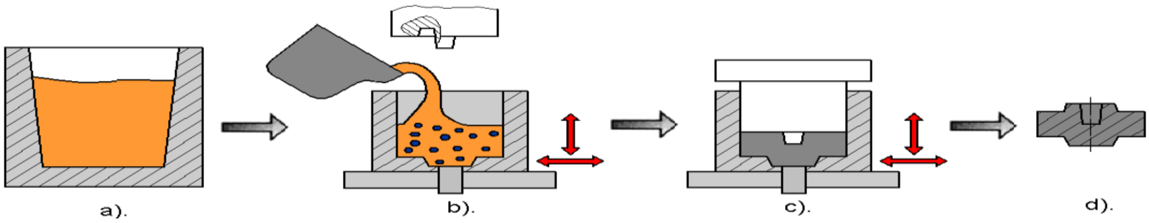


Figure 3. New NRC variant [1]. a). alloy elaboration; b). alloy casting into the mould and the obtaining of a structure with thixotropic behavior; c). the formation proper, under vibrations; d). the finished piece

Figure 3 shows a diagram of this variant and points out to the main stages of processing. The red arrows symbolize the mechanical agitation of the metal and mold, by vibration.
The new NRC variant eliminates the pot-casting operations and the re-heating up in view of homogenizing the ingot temperature, operations which are highly time and energy consuming. Also, the advantages of plastic deformation have been turned into account under vibrations, which are known to positively influence both the casting geometry and the friction between the material and the work tools, as well as the physical and mechanical characteristics of the pieces, whose structures are extremely fine, due to the breaking of the crystallization dendrites and the mechanical prevention of their growth. The formation proper consists in the application, by means of a punch, of a mechanical pressure, meant to fill the mould and lead to a plastic deformation of the material. After solidification, the piece is extracted from the mould by means of a counter-punch.

ALLOYS IN SEMISOLID STATE PROCESSING METHODS

Both the quality of the pieces obtained by processing according to the new NRC variant and the production costs involved are influenced by several factors present in the processing, called the technological parameters of the process.
A theoretical analysis and assessment of the main technological parameters (the temperature of the material fed to the mould, the processing temperature, the mould pre-heating temperature, the deformation force, the molding time, the frequency of the mechanical vibrations and the compressing rate) are given in [1]. For example, in figure 4 is presented the mechanical characteristics of pieces obtained to different preheating temperature of the die, in the next conditions of processing: the deformation force 4000 daN, the processing temperature 565^{0}C and the frequency of the mechanical vibrations 500 s^{-1}. The influence of the mould pre-heating temperature upon the mechanical characteristics is insignificant.

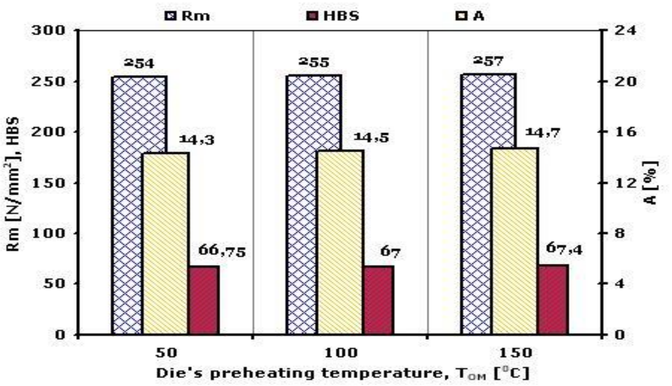


Figure 4. The influence of the die's preheating temperature upon the mechanical characteristics

Thus, in condition of the duplicated values of the deformation's forces, depending on the processing temperature and the vibration's frequency, the tensile strength scale up by 3.5…5.0 %, the hardness HBS scale up by 4…10%, and elongation with 15…20%.

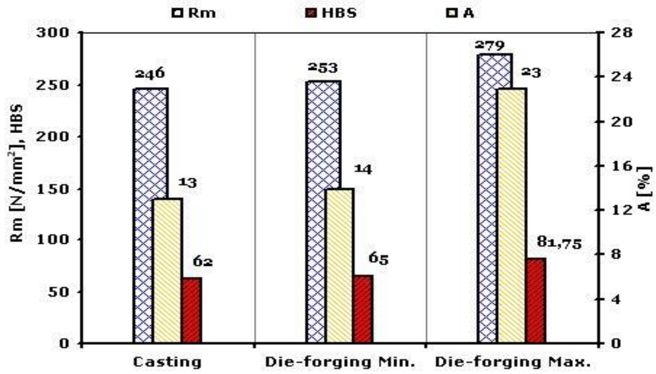
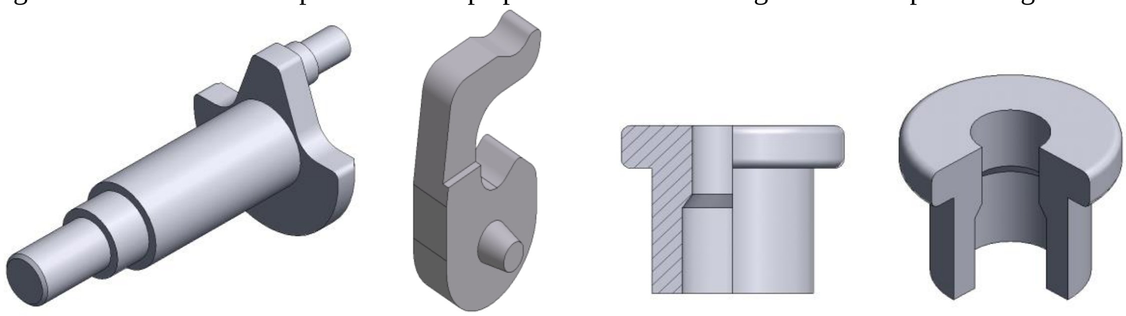


Figure 5. The improvement of the mechanical characteristics of pieces obtained through die-forging in semisolid state, comparison with the pieces obtained through casting in the metallic die

Also, at the duplicated values of the vibration's frequency, the tensile strength scale up by 1…2%, the hardness HBS scale up by 2.1…3.0% and elongation with 8…10%.
In the comparing with casting in the metallic die, the pieces have, in the all situations, better mechanical characteristics (figure 5).
Figure 6 show a few examples of net shape pieces obtained through semisolid processing.



a. b. c.

Figure 6. Example of net shape pieces obtained through semisolid processing

CONCLUSIONS

Semi-solid casting methods are an interesting alternative to conventional die casting, since they produce heat treatable components.
In figure 5, the pieces are processing in next conditions:

» Die-forging Min.: the processing temperature 560^0C, the deformation force 4000daN and vibration's frequency $500s^{-1}$;
» Die-forging Max.: the processing temperature 565^0C, the deformation force 11780daN and vibration's frequency $2500s^{-1}$.

Because the deformation resistance is lower and microstructure and flow properties is controllable, enable the semisolid state processing methods to be used for producing pieces in net shape so that material wastage is minimized. Semisolid processing has the same potential for producing net shape pieces with metallic alloys as plastics, through injection molding, extrusions and forging.

The methods of processing metals and alloys in a semi-solid state offer numerous advantages, as compared to the conventional processing methods (liquid casting followed by forging, die forging, stamping in a solid state), which result from the behavior and characteristics of the materials in a semi-solid state. Thus, due to their temperature, which is lower than that of the liquid metal, semi-liquid metals can be processed at a higher rate, and the wear of the deforming tools is reduced. The presence of the solid in the process of mould – filling makes viscosity controllable and higher than in the case of liquid metals, which results in pieces having smaller shrinkage holes, with a reduced macro and micro segregation and a fine micro-granular structure.

The new NRC variant eliminates the pot-casting operations and the re-heating up in view of homogenizing the ingot temperature, operations which are highly time and energy consuming. Also, the advantages of plastic deformation have been turned into account under vibrations, which are known to positively influence both the casting geometry and the friction between the material and the work tools, as well as the physical and mechanical characteristics of the pieces, whose structures are extremely fine, due to the breaking of the crystallization dendrites and the mechanical prevention of their growth.

The paper shows some particularities of the semisolid state processing methods of the metallic materials and points out the advantages of using these methods for producing parts. In the paper is accomplished a study regarding the mechanical characteristics (tensile strength, elongation and Brinell hardness) of pieces obtained through these methods, comparing with conventional methods of processing.

The new rheocasting process will provide excellent mechanical properties with a positive solution for the cost of material that has been the weakness of the semi-solid casting process.

The products made by this process have shown good mechanical properties. The solidification rate of a rheocasting sample is so high that the microstructures of the products are uniform and fine.

REFERENCES

[1] Cioata, V. G., Studii si cercetari privind matritarea metalelor si aliajelor in stare semilichida (Studies and research on die forging of the metals and alloys in the semisolid state), Doctoral Thesis, University Politehnica Timişoara, pp.6-7, 83-84, 123-132, 2004.
[2] Gullo, G. C., Thixotrope Formgebung von Leichtmetallen - Neue Legierungen und Konzepte, Diss. ETH-Zürich, 2001.
[3] Chira, I., Procedee speciale de turnare, Ed. Didactică şi Pedagogică, Bucureşti, pp. 218-234, 1980.
[4] Ilca, I., Cioată, V. G., Instalaţie şi procedeu de cercetare experimentală a matriţării pieselor din materiale metalice în stare semilichidă, Simpozion Materiale avansate, Tratamente Termice şi Calitatea Managementului, Ed. Politehnica, pp. 150-155, 2005.
[5] Sato, S., Adachi, M., Advanced rheocasting process improves quality and competitiveness, SAE 2000 World Congress, Detroit, USA, Session: Engineered Casting Solutions (Part A), 2000.
[6] Rosso, M., Grande, M.A., Optimization of heat treatment cycles for automotive parts produced by rheocasting process, vol. 116-117, Solid state Phenomena, pp. 505...508, 2006.
[7] Cioata V. G., Kiss I., Possibilities of controlling the qualitative characteristics of the die-forging parts of semisolid materials, Machinebuilding and Electrotechnics, No. 12, Sofia, Bulgaria, pp 27...30, 2005.
[8] Cioata V. G., Kiss I., Experimental research regarding the technological parameters of a new method of processing in the semisolid state, Metalurgia International, No. 6, Bucuresti, pp 35...40, 2008.

STUDY OF THE POSSIBILITY OF APPLYING ALLOYED FLUX-CORED WIRE FOR PRODUCTION OF CORES FOR COATED ELECTRODES

Mihailo Mrdak[1], Nikola Bajić[2], Darko Veljić[2], Marko Rakin[3], Slobodan Stojadinović[4], Zoran Karastojković[5]
[1]Research and Development Center, IMTEL komunikacije a.d. Belgrade, Serbia
[2]IHIS Techno experts d.o.o. – Research and Development Center, Belgrade, Serbia
[3] Faculty of Technology and Metallurgy, University of Belgrade, Karnegijeva 4, Belgrade, Serbia
[4]University of Novi Sad, Technical Faculty „Mihajlo Pupin“, Zrenjanin, Serbia
[5]Advanced Technical School for Vocational Studies, Belgrade
e-mail: drmrdakmihailo@gmail.com

Abstract: The main objective of the paper is to explore the technological possibilities of making improved quality coated electrodes with alloyed flux-cored wire cores. Using experimental equipment at the Research Center IHIS alloyed flux-cored wire was produced with optimal thickness of the metal sheath, internal label IHIS E 35 R-3 Ø 3.25mm in diameter from which the core of the new rutile coated electrode was made. The paper presents the test results of the chemical composition and microstructure of the weld metal made with the new electrode. The test results of the chemical composition and structure of weld metal made with the produced electrode indicate the justifiability of further research towards the development of new coated electrodes with a core of alloyed flux-cored wire.
Key words: coated electrode, alloyed flux-cored wire, weld metal structure

INTRODUCTION

Development and mastering of rutile electrodes with a core of alloyed flux-cored wire for manual metal arc welding and surfacing is a complex research process, which involves defining the chemical composition of the coating and the flux-cored wires [1-3]. The rutile electrode coating (internal marking IHIS E 35 R-3) is mainly composed of rutile TiO_2 containing more than 50% and the rest of the components are: marble, granite, kaolin, FeMn, mica, feldspar, talc, CaF_2, magnesite and Lucel. Introduced into the composition of the coating are ingredients which protect the weld pool and weld metal from the influence of atmospheric gases, create slag, eliminate or restrict the content of oxygen and nitrogen, increase meltability and stabilize the arc [4-7]. When making a coated electrode the coating is applied continuously to the cores using a suitable technological process. The cores are made of alloyed flux-cored wire, 350 mm in length and Ø3.25mm in diameter with a medium thick coating.
Produced rutile electrodes are intended for manual metal arc welding (MMAW) and surfacing with a coated electrode for low alloyed steels, alloyed structural steels, heat resistant steels and high alloyed steels with special properties. At the stage of development and mastering technology for production of coated rutile electrodes of improved quality with cores of alloyed flux-cored wire, and to economize, for experimental welding and testing of weld metal microstructure, steel plates of low carbon alloyed steel thickness of 10 mm were selected. The microstructure of weld metal made with a rutile electrode depends on many factors such as: composition of the coating and core of the electrode, cooling rate, heat input during welding, etc. [8,9].
This paper presents the results of examination of chemical composition and microstructure of weld metal, which should contribute to defining a new quality of special rutile electrodes with a core of flux-cored wire in terms of operational and welding properties. The results showed that a rutile electrode with a core of alloyed flux- cored wire, produced with domestic raw materials, improves the formation of a homogeneous structure of weld metal in welded joints.

MATERIALS AND EXPERIMENTAL DETAILS

Production of rutile electrodes with a core of alloyed flux-cored wire with local raw materials was carried out on experimental equipment in the Research Center IHIS. For the core of the rutile

electrodes selected and produced were alloyed flux-cored wires of designed quality for welding and surfacing low alloyed steel, alloyed structural steel and high alloyed steels with special properties.
The experimental part includes welding a sample of low-carbon non-alloyed steel, 10 mm thick using a produced medium coated rutile electrode (in-house marking IHIS E 35 R-3). Determining the quality of the rutile electrode was done based on the results of testing the chemical composition of pure weld metal using spectrochemical analysis and the OES method on the ARL 2460 and the results of microstructure tests. Examination of the microstructure of the base metal and analysis of micro-constituents present in the weld metal was done on a scanning electron microscope (SEM).

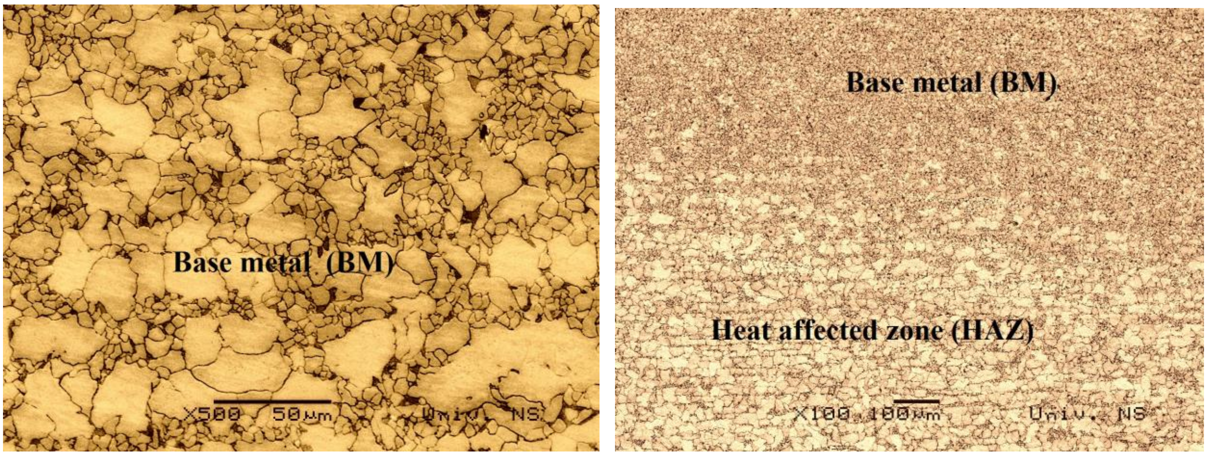
RESULTS AND DISCUSSION

Table 1 shows the chemical composition of pure weld metal of a sample welded using a rutile electrode with a core of alloyed flux-cored wire. Examination of the composition of the weld metal was conducted to link the influence of Ni and Mo, from the core of the flux-cored wire with rutile coating, on the microstructure of the weld metal of the welded joint. Metallographic tests of the weld metal of welded joints showed that the chemical analysis of the weld metal (WM) is directly related to the microstructure.

Table 1. Chemical composition of the pure weld metal

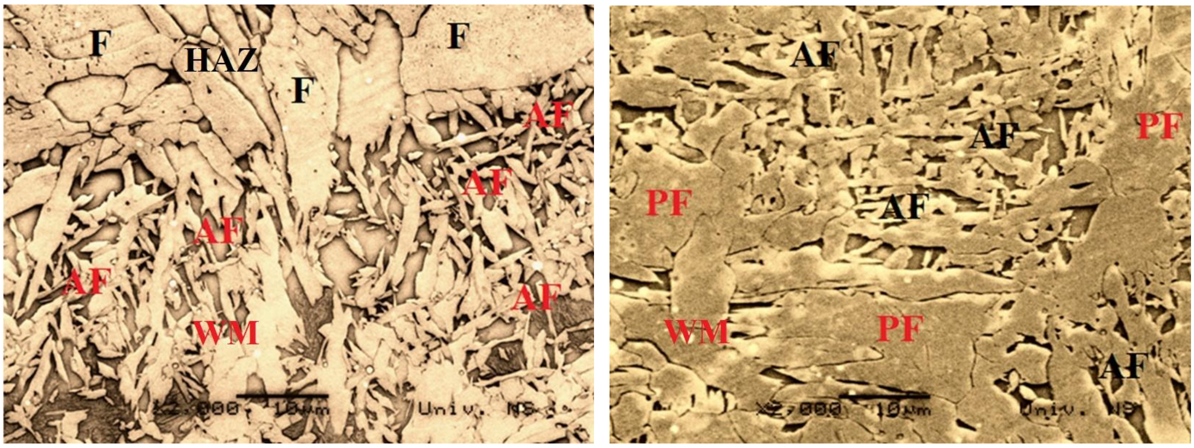
Chemical composition, wt.%									
C	Si	Mn	Cu	Al	Cr	Mo	Ni	Ti	Nb
0.023	0.539	0.97	0.092	< 0.003	0.025	0.32	3.284	0.012	<0.003

Nickel and molybdenum from the core of the electrode made of alloyed flux-cored wire favored forming of a large share of acicular ferrite (AF) in the weld metal, they lowered the share of proeutectoid ferrite (PF) and completely removed upper bainite [10] and this was confirmed by metallographic analysis of the weld metal.
Figure 1a shows the microstructure of the base metal (BM) of 10 mm thick low carbon non-alloyed steel tested on the SEM. The microstructure of the non-alloyed steel is homogeneous and ferritic with a small portion of pearlite. Figure 1b shows the microstructure of the transition zone between the base metal (BM) and the heat affected zone (HAZ). On the SEM micrographs in the heat affected zone (HAZ) an increase in ferrite grains is visible.



a) b)
Figure 1. SEM microstructure: a) base metal (BM), 500x; b) transition zone (BM) and (HAZ), 100x.

Figure 2a shows scanning electron micrographs (SEM) of the fusion line between the heat affected zone (HAZ) and weld metal (WM). The fusion line separates the coarse grain ferrite structure of the heat affected zone (HAZ) and the fine-grained structure of the weld metal (WM). The structure of the weld metal consists of austenite grains with formed acicular ferrite (AF) within the austenite grains.



a) b)

Figure 2. SEM microstructure: a) transition zone between (HAZ) and weld metal (WM), 2000x; b) weld metal (WM), 2000x

Acicular ferrite is a type of ferrite characterized by a three-dimensional lenticular shape. At certain points along the bounderies of the acicular ferrite (AF) non-metallic spherical inclusions, from the rutile coating, can be seen. These inclusions serve as nucleation centers for acicular ferrite (AF) crystallization [11]. This microstructure has an advantage over other microstructures, because it increases the toughness of the weld metal of welded joints. Figure 2b shows scanning electron micrographs (SEM) of the microstructure of pure weld metal. Austenite grains are present in the weld metal; along their boundaries proeutectoid and polygonal ferrite (PF) are present. These types of ferrite are formed as primary phases along grain boundaries during cooling of austenite. Ni and Mo from the core of the alloyed flux-cored wire during cooling of the weld metal reduced the share proeutectoid and polygonal ferrite (PF) and thus increased the share of acicular ferrite (AF). In the austenitic crystal grains there were no observed secondary phases such as routed secondary phase ferrite (FS) and Widmanstatten ferrite which reduce the toughness of the weld metal (WM) of the welded joint. The microstructure of the weld metal of the welded joint is in full compliance with the chemical analysis of the weld metal.

CONCLUSION

Based on the chemical and microstructural analysis of the weld metal of welded joints made with a medium coated rutile electrode with a core of alloyed flux-cored wire marked IHIS E 35 R-3 Ø 3.25mm in diameter, the following conclusions can be made:

• Welding properties of mastered rutile electrodes relating to arc stability, uniformity of slag coverage of metal, splatter of molten material and porosity of the surface of the weld metal showed satisfactory quality.

• Micro-alloying elements Ni and Mo from the core of the alloyed flux-cored wire and non-metallic inclusions from the rutile coating influenced forming of a large share of acicular ferrite (AF) in the weld metal (WM) of welded joints, which indicates high weld metal toughness and uniform distribution of Ni and Mo in the rutile electrode.

• The rutile type electrodes, produced using domestic raw materials with a core of flux-cored wire, created a homogeneous structure of the weld metal and the planned chemical composition.

The results of examination of the weld metal justified further development and application of alloyed flux-cored wire for production of the core of coated rutile electrodes based on local raw materials.

ACKNOWLEDGEMENTS

This work is supported by the Serbian Ministry of Science and Technological Development (project number TR34016) "Development of covering and core production technology based on local raw materials for manufacturing of special coated electrodes designed for steel arc welding".

REFERENCES

[1] Mrdak, M., Bajić, N., Rakin, M., Stojadinović, S., Veljić, D., *Comparison of the microstructure of weld metals in welded joints made with rutile electrodes based on domestic raw materials and electrodes of a well-known manufacturer*, ANNALS of Faculty Engineering Hunedoara – International Journal of Engineering, Tome XIII [2015], Fascicule 2, ISSN: 1584-2665 [print]; ISSN: 1584-2673, pp.75-78, 2015.

[2] Mrdak, M., Bajić, N., Rakin, M., Stojadinović, S., asmina Pekez, J., *Comparison of the microstructure of weld metals in welded joints made with rutile electrodes based on domestic raw materials and electrodes of awell-known manufacturer*, IV International Conference Industrial Engineering and Environmental Protection (IIZS 2014), University of Novi Sad Technical faculty “Mihajlo Pupin” Zrenjanin, Republic of Serbia, 15.10.2014, ISBN 978-86-7672-234-1, pp.119-122, 2014.

[3] Mrdak, M., Bajić, N., Rakin, M., Veljić, D., Grabulov, V., *Analysis of the structure of the weld metal made with a basic type coated electrode*, The 3rd IIW South-East European Welding Congress June 03-05, Timisoara, Romania “Welding and joining technologies for a sustainable developme nt and environment“ ISBN978-606-554-955-5, pp.1-4, 2015.

[4] Rakin, M., Bajić, N., Mrdak, M., Veljić, D., Arsić, M., *Analysis of mechanical and structural properties of micro alloyed steel welded joints depending on quality of cored wire*, Tehnički vjesnik 20, 4, pp.635-640, 2013.

[5] Bajić, N., Mrdak, M., Stojadinovic, S., Pekez, J., Karastojkovic, Z., Rakin M., Veljić, D., 45 th International October Conference on Mining and Metallurgy, Bor, pp.377-380, 2013.

[6] Bajić, N.S., Monografija: ISBN 978-86-89775-00-6, COBISS.SR-ID 204235020, 2013.

[7] Bajić, N., Veljić, D., Rakin, M., Stojadinović, S., Pekez, J., Mrdak, M., Welding&Welded Structures, LVIII, UDK/UDC:621.791.04, ISN 0354-7965, COBISS.SR-ID 105396743, No 4/2013, I-deo, pp.157-161, 2013.

[8] Prokić-Cvetković, R., Doktorska disertacija, Beograd, 2000.

[9] Prokić-Cvetković, R., Milosavljević, A., Sedmak, A., Burzić, Z., Zavarivanje i Zavarene Konstrukcije, p.107, 2000.

[10] Evans, G.M., *The Efect of Molybdenum on the Microstructure and Properties of all Weld metal Deposits,* IW Doc II-A-666-86.

[11] dos Santos. JF., dos Santos, VR., Jorge, JC., Properties of a ferritic metal cored wire weld metal deposited in the pressure range from 51 bar to 110 bar. Proceedings of the 1996 6th International Offshore and Polar Engineering Conference 1996;141–6 (Part 4 (of 4), vol. 4, Los Angeles, CA, USA, May 26– 31).

APPLICATION POTENTIAL OF SOME CRITERIA OF DUCTILE CRACK IN BULK FORMING PROCESSES

Milija Kraišnik[1], Dragiša Vilotić[2], Leposava Šiđanin[2], Milentije Stefanović[3], Jelica Anić[1]
[1]University of East Sarajevo, Faculty of Mechanical Engineering, East Sarajevo
[2]University of Novi Sad, Faculty of Technical Sciences, Novi Sad, Serbia
[3]University of Kragujevac, Faculty of Engineering, Kragujevac, Serbia
e-mail: milijakraisnik@yahoo.com

Abstract: Ductile crack criteria are unavoidable tool for material formability analysis. Their basic task is foreseeing the location of crack occurrence and critical value of deformation level in the course of forming process. However, in order to provide successful application of certain criterion it is necessary to be familiar with material characteristics, specificities of forming processes and forming conditions. For all the above mentioned reasons this paper deals with the analysis of application potential of some widely used criteria of ductile crack in cold bulk forming processes according to representative literature resources. Results can contribute better understanding of phenomenon of material microstructure damage and adequate choice of ductile crack criterion in the analysis of formability in various processes and forming conditions.
Key words: ductile crack, cold bulk forming, microstructure damage

INTRODUCTION

In the course of forming process continuous damage to material microstructure inevitably occurs. Accumulation of critical level happens in the moment of full use of material formability potential which manifests in occurrence of cracks or ductile crack on specimens. In their paper [1], Arentoft et al. provided classification of damage to products obtained in cold bulk forming processes. Experimental research results relating to classification of critical level of accumulated damage in the process of free upsetting of steel cylinder with flat plates with normalized ferrite-pearlite microstructure are presented in [2].
In order to achieve successful design of forming technology it is necessary to use adequate approaches which would enable full use of material formability potential. In that sense, the greatest significance is in ductile crack criteria. Their general purpose is to describe the effects of material damage mechanisms which occur in microscopic level on macroscopic level using experimental data or through mathematical and physical models. Their greatest significance is the ability to forecast the place the crack or fracture would occur in workpiece and estimation of strain limit value.
However, having in mind that bulk forming is performed using various technological methods and under various forming conditions the choice of adequate criterion is very complex. In the literature there are no suggestions about damage critical values for certain materials or the conditions to be fulfilled for using certain criteria. Difficulties arise also in the attempts to establish general strain limit values for the tested material because nucleation of micro voids (the starting point for formation of cracks) and their growth dominantly depend on generated stress state and history of stress state indicators.
In the attempts to overcome the above mentioned difficulties a large number of ductile crack criteria, which with different success rate predicts the occurrence of macroscopic damage on metal components has been developed. Special effort was made in the attempts to analyze and determine possibilities for reliable estimation of initiation and development of material microstructure damage in some forming processes. In majority of papers the above mentioned issue is observed in cold forming processes [3-13], but some data relating to occurrence of ductile crack in forming processes of steel [14] and aluminum alloys [15] in hot state can also be found. Systematic overview of widely used criteria of ductile crack is provided in [16].
In this paper is provided comparative analysis of successful prediction of ductile crack occurrence in the cold bulk forming processes for certain criteria. For the purpose of identification of macroscopic damage in those processes various approaches were used.

EXPERIMENTAL – NUMERIC APPROACH

According to the available literature resources, quantitative description of ductile crack formation in cold bulk forming processes research results based on experimental-numeric approach predominantly refer to upsetting and tension processes. Axial-symmetric specimens were mostly used. However, their shape in the starting point had significant influence on initiation of ductile crack [17]. For that reason it is necessary to perform a larger number of tests on specimens with various geometrical configurations prior to including certain parameter of microstructure damage to ductile crack criteria. Nonetheless, that is not an easy task because the difficulties may upraise in the course of theoretical description of three-dimensional material flow from the viewpoint of distribution of stress-strain components.

However, in case of using modified Cockroft-Lathman criterion [16], the impact of stress state on the development of ductile crack may be excluded from the consideration because the critical value of material damage parameter C (1) can be determined only according to identification of strain state on free surface of specimen [18]:

$$2\varepsilon_1 + \varepsilon_2 = \frac{2}{3}C \qquad (1)$$

where: ε_1 and ε_2 are components of main strains on the place the crack occurred
C – material constant

On the basis of this result Lyamina et al. presented in paper [19] theoretic-experimental method for verification of the above mentioned criterion of ductile crack. If modified Cockroft-Lathman criterion of ductile crack is valid for the tested material (steel C45E) than the value of parameter C should be equal in all upsetting processe4s, regardless of the initial shape of the specimens (Fig. 1.).

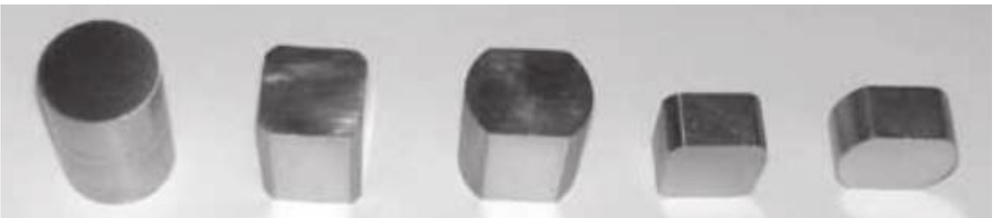
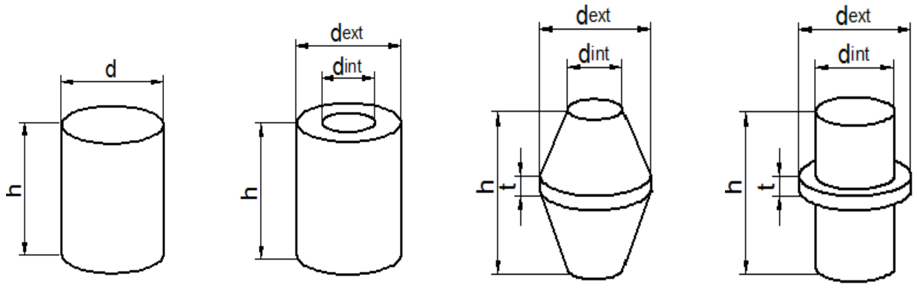


Figure 1. Initial shapes of specimens for upsetting [19]

However, results obtained have shown that the value of parameter C is significantly different for cylindrical (C≈0,7) compared to other types of initial specimen shapes (C≈0,36). For that reason it is stated that modified Cockroft-Lathman criterion is not suitable for tests on steel C45E.

Gouveia et al. [20] have researched the possibility of successful determination of crack initiation by application of certain criteria under the conditions of plane state of stress. This research was limited to upsetting processes of specimens with various initial shape and dimensions: cylindrical specimens with different h/D ratio, hollow cylinders, tapered specimens and cylindrical specimens with flanged (Fig. 2.).



a) b) c) d)

Figure 2. Tested models for upsetting: a) cylinder, b) hollow cylinder, c) tapered specimen, d) cylinder with flanged [20-21]

Geometric shapes and starting dimensions of models for upsetting shown in Figure 2 enabled generating of different stress-strain state in the destruction zone of the specimen which was a necessary assumption for verification of the potential of tested criteria regarding prediction of location of crack initiation and quantification of material damage parameters. Using Freudenthal, Cockroft-Lathman, Brozzo and Oyane criteria of ductile crack provided prognosis of different locations of cracks and critical values of microstructure damage. In comparison with experimental results it can be noted that Freudenthal criterion is not suitable for the above mentioned forming processes, and possible explanation can be found in the fact that this criterion does not take the level of hydrostatic stress into consideration but only the impact of effective stress to the development of damage of microstructure. Results of numeric analysis according to Cockroft-Lathman criterion of ductile crack are in good accordance with the experimental data but in its application one must take certain observations into consideration. First of all, if the main normal stress σ_1 negative, criterion predicts “negative” accumulation of damage. Secondly, this criterion is not sensitive to changes of main normal stresses which may occur during forming process. On the other hand, using Oyane criterion the above mentioned difficulties are eliminated and due to high level of coherence with experimental results the advantage of its application is additionally stressed for the modeling of surface cracks in cold bulk forming processes.
In the continuation of research the same authors have presented the results of numerical simulations relating to possibility of determination of crack occurrence as well as the deformation level when they occur in the processes of sideways extrusion, forging in open tools and shearing forming in the paper [21]. For those purposes they used Oyane and Cockroft-Lathman criteria of ductile crack. Conclusions affirm the possibility of the tested criteria to successfully determine occurrence of inner cracks and the cracks that form on free surfaces of the specimen. However, the criteria are not able to consider the level of accumulated damage which is a consequence of so called “dead” zones of metal, especially in the process of sideways extrusion. For that reason it is necessary to put extra effort in overcoming the difficulties in modeling shear cracks in processes of shearing forming under the influence of great hydrostatic pressure.
Petruška and Janiček [7,11] have also used a large number of criteria of ductile crack in simulations of damage to microstructure under the conditions of increased concentration of stress in upsetting cylindrical specimen with longitudinal notch (Fig. 3.).

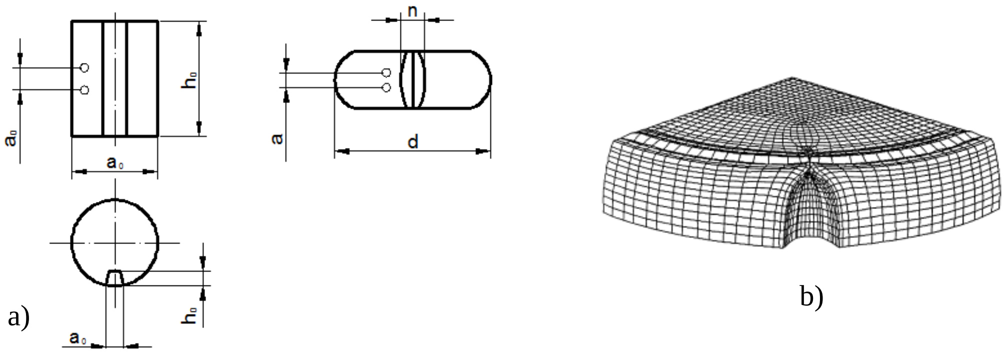


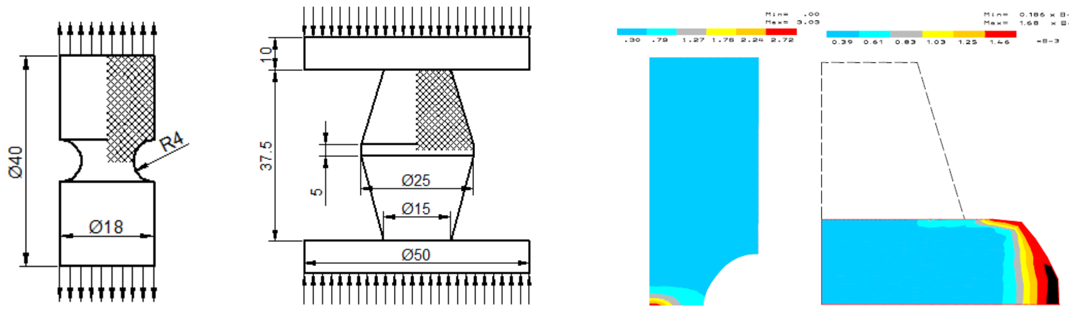
Figure 3. Cylindrical specimens with longitudinal notch: a) initial geometry, b) FEM–final phase [7,11]

Research was conducted under conditions of changeable friction and with specimens with different h/D ratio. It was experimentally determined that in all the tested specimens the first crack occurred at the top of notch. Results of FEM analysis confirmed that all of the used ductile crack criteria: a) Freundenthal, b) Cockroft and Latham, c) Brozzo, d) Oh, e) Oyane, specifically determine the place of initiation and development of cracks which could be expected regarding the used forming model, but the significant differences occur in the values of load under which the critical microstructure damage occurs. Criteria a) to d) show great variations in estimation of critical load (specimen damage) depending on conditions under which the upsetting test is realized. Results’ dissipation is most probably the consequence of different stress state histories at the top of the notch. Only Oyane criterion provides high level of accordance with the experimental data where the results obtained are

independent from the conditions of friction and specimen geometry with the exception of the notch depth.
Results of Narayana Murty et al. [10] represent great contribution in the matter of successful prediction of initiation of ductile crack in cold forming processes. Through the experimental research of upsetting the cylindrical specimen under different contact conditions the authors have tested six most frequently used criteria of ductile crack. According to the obtained results new criterion was defined which in this case provides high level of accordance between the experimental data and numeric calculations:

$$D_{th} = \int_{0}^{\varphi_e^l} \gamma \frac{\sigma_\theta}{\sigma_e} + \delta \frac{\sigma_H}{\sigma_e} d\varphi_e = 1 \tag{2}$$

Material constants γ and δ can be determined according to values of forming limits φ_θ^l and φ_z^l. ductile crack criterion, defined by equation (2), basically represents a combination of Oyane and Oh-Kobayashi criteria which achieved the best results in individual tests. Higher possibilities of the new criteria regarding more precise determination of ductile crack initiation are a consequence of more complex approach to the analysis of impact of stress state character to the development of microstructure damage.
In the research presented in paper [22], using certain number of ductile crack criteria, comparison analysis of possibility of adequate prediction of location of crack initiation in two forming models was performed (Fig. 4.).



a) b) c)

Figure 4. Tested forming models and MKE analysis: a) tension of grooved specimen, b) upsetting of tapered specimen, c) visualization of MKE results – crack criterion based on the theory of continuum damage mechanics [22]

The first model relates to the process of tension of grooved specimen where the maximum value of effective plastic strain is achieved at the place where the cross section narrows but the crack itself is initiated in the center of specimen where the ratio of hydrostatic and effective stress reaches maximum value. The second model is based on the test of upsetting the tapered specimen with flat plates. In this case the initiation of the crack occurs on the outer surface of the specimen close to the equatorial section due to generating of tension components of stress. The choice of models is conditioned with the aspiration to test the crack criteria under the conditions where stress state has different character of action to the development of microstructure damage and occurrence of crack.
Results of experimental-numeric research point to the different abilities of tested criteria in terms of predicting the location of initiation of ductile crack. Criteria based on total work of plastic forming (Freudenthal) and effective plastic strin (Datsko) provide very poor prognosis of place of ductile crack initiation in both forming models. Criteria based on the enlargement of damage to microstructure due to action of main stresses (Cockroft and Lathman, Brozzo et al.), provide correct prediction for initiation zone of ductile crack for upsetting test, but in very wide area. However, that is not the case in tension test where the adverse ratio of hydrostatic and effective stress makes the main reason for microstructure damage.
Ability to predict the location of crack using the criteria based on dominant impact of hydrostatic stress to increase in level of microstructure damage (Norris, Atkins) in researched forming models is

disappointing. This fact states that hydrostatic stress being very influential factor for initiation and development of damage, in the process of prediction of crack initiation it can not be used on its own while defining the criteria of material ductile crack [22]. Oyane criterion provides precise prediction of crack initiation in both tested forming models but in very wide area. Criterion Lemaitre, which was developed according to the mechanics of continuum damage, provides successful prediction of location of crack occurrence in tension test but not in upsetting test. Also, the criterion suggested by Vaz has almost identical result as prediction criterion of Lemaitre. Very precise prediction of crack location in both processes of forming was achieved only by using the criteria suggested by Pires et al. (Fig. 2c). This criterion is actually a modification of Lemaitre's criterion taking in consideration the effect of closing the micro voids which enables different treatment of microstructure damage development in the processes with dominant tension or pressure stress state.

HOLISTIC APPROACH

In the past a number of elite criteria for estimation of damage to material microstructure in the processes of cold bulk forming was developed and majority of them is incorporated in commercial FEM applications. The most widely exploited criteria are ones of ductile crack defined according to the theory of continuum damage mechanics. Their basis is represented by integral formulations determined between individual stress-strain components which enable the calculation of theoretical level of microstructure damage. However, none of the criteria presented in paper [16] provides absolutely defined possibility to predict the exact initiation of crack occurrence with high reliability, the level of microstructure damage as well as the type of crack in different forming processes. Incorrect prognosis are a logical consequence of not taking into consideration time differences in initiation and growth of micro-fractures as well as phenomenological differences in crack types [23].
In order to overcome the above mentioned shortcomings, Kloske [23] and Timmer [24] suggested the criterion for the processes of cold bulk forming which is based on holistic approach of initiation and development of ductile crack. The criterion enables predictions regarding spatial position of the point of crack initiation, moment of accumulation of critical microstructure damage depending on level of strain and crack type. Modeling of damage depends on the length of initiation and development (growth) of micro-voids including the identification of mechanism of damage and corresponding stress-strain state for longitudinal or shear surface cracks. For the development of this model were used various tests of upsetting the specimens with different initial geometry. Upsetting was realized until any type of crack occurred on the outer surface of the specimen (Figure 5). The results obtained were presented with characteristic differences between time-dependent micro-models for each type of the crack.

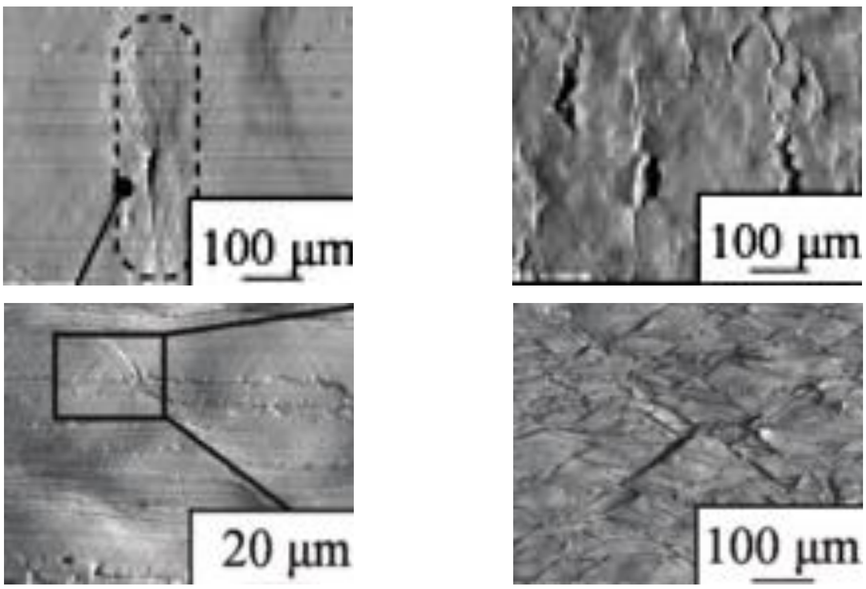
a)
b)


Figure 5. Types of crack on outer surface: a) initiation and growth of longitudinal cracks, b) initiation and growth of shear cracks [24]

Analyzing the stress state on the outer surface of the specimen it was determined that the component of normal stress in tangential direction σ_Θ has the most dominant influence on initiation and development of longitudinal crack. So, longitudinal cracks are initiated when the amount of energy, which is induced in the material due to the action of σ_Θ stress component, reaches critical value which is considered constant for certain material.
In Figure 6 is presented the concept of micro-model of initiation and growth of longitudinal cracks. Positive values of σ_Θ and negative values of axial component of stress σ_z make the cracks open. Opposite from that, negative values of σ_Θ and positive values of σ_z influence the closure of cracks and mitigate the level of microstructure damage.

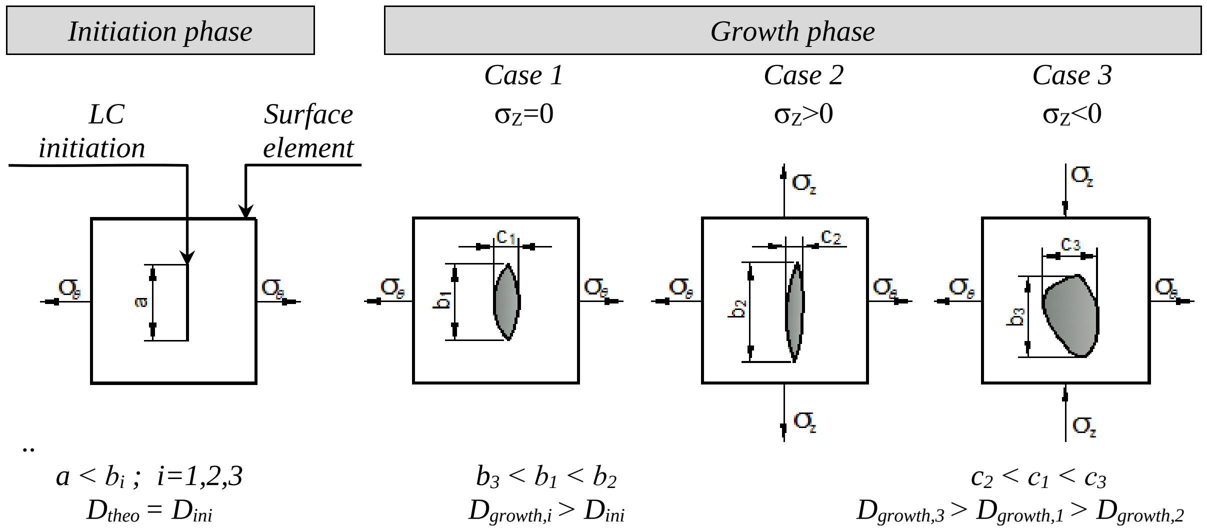


Figure 6. Concept of micro-model for longitudinal cracks [23]

According to micro-concept a sub-criterion for longitudinal ductile crack was formulated (3), whose basic characteristic is time differentiation of phases of initiation and growth of cracks.

$$D_{thco,LC} = \underbrace{\int_{0}^{\varphi_{eff,Inic.}} \max\left(0,\frac{\sigma_\theta}{\sigma_v}\right) d\varphi_{eff}}_{Initation} + \underbrace{\int_{\varphi_{eff,Inic}}^{\varphi_{eff,end}} \left(\frac{\sigma_\theta}{\sigma_v}\cdot\left[\begin{array}{l}\sigma_z \succ 0: \left|\dfrac{\sigma_{z,Inic}}{\sigma_z}\right| \\ \sigma_z \prec 0: \left|\dfrac{\sigma_z}{\sigma_{z,Inic}}\right|\end{array}\right]\right) d\varphi_{eff}}_{Growth} \tag{3}$$

It was determined through identifying the stress state on surface sections of the specimens for initiation phases and development of shear cracks that this type of cracks occurs due to the action of maximal tangential stress $\tau_{\Theta z,max}$. On the critical location of specimen free surface other identified stress components had negative or negligible small positive values. Maximum tangential stress $\tau_{\Theta z,max}$ has the highest value, except in the end of crack growth phase, which promotes it as the most dominant factor in initiation and growth of shear cracks. Concept of micro-model of initiation and growth of horizontal cracks is presented in Figure 7.
Mathematical formulation of the previous model provides the concept of time differentiation of initiation phase and growth of shear cracks in defining the sub-criterion of ductile crack:

$$D_{theo,SC} = \underbrace{\int_{0}^{\varphi_{eff,Inic.}} \frac{\left|\tau_{\theta z,\max}\right|}{\sigma_v} d\varphi_{eff}}_{Initiation,D_{Inic.}=0,1791} + \underbrace{\int_{\varphi_{eff,Inic}}^{\varphi_{eff,end}} \left(\left\{\begin{array}{l}\sigma_m \geq 0: \dfrac{\sigma_m + \left|\tau_{\theta z,\max}\right|}{\sigma_v} \\ \sigma_m \prec 0: \dfrac{\left|\tau_{\theta z,\max}\right|}{\sigma_v}\end{array}\right.\right) d\varphi_{eff}}_{Growth,D_{Gro}} \tag{4}$$

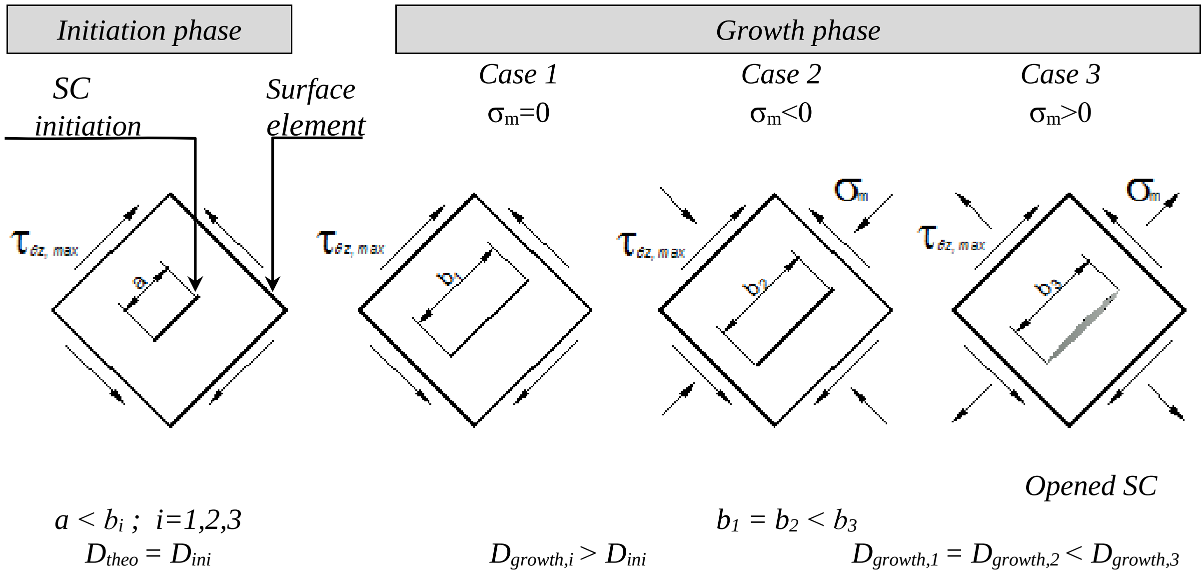


Figure 7. Concept of micro-model for shear cracks [23]

Generally speaking, research results show that the suggested sub-criteria provide greater reliability of prediction of exact moment the ductile crack occurs in comparison to previously used approaches and mathematical formulation. Synthesis of both sub-criteria with the aim of defining the comprehensive criterion of ductile crack as well as the final verification is the following research challenge.

CONCLUSION

It is obvious that the criteria of ductile crack together with the formability tests present extremely useful tool regarding the optimization of the technological forming process. Considering the fact that there is no unified criterion of ductile crack which can be applied to all materials, it is necessary to verify its application to the specific material experimentally and under specific processes and forming conditions. That means that it is necessary to identify one or more criteria which are in accordance with the experimental data. Such task is impossible to accomplish without the use of powerful numeric methods (generally represented by FEM), on the basis of which special program packs for material formability analysis are developed. Therefore, only the integrated approach is the promising technique for the success in the area of prediction of occurrence of ductile crack in the forming processes.

REFERENCES

[1] Arentoft M., Wanhe T.: The basis for a design support system to prevent defects in forging, Journal of materials processing technology, Volume 69, Issues 1–3, pp. 227-232, 1997.
[2] Kraišnik, M.: Impact of stress-strain state to development of microstructure damage and material formability in the process of cold bulk forming, Doctoral dissertation, Faculty of Mechanical Engineering, East Sarajevo, 2014. (In Serbian)
[3] Ahmadi S., Eivani A.R., Akbarzadeh A.: Experimental and analytical studies on the prediction of forming limit diagrams, Computational materials science, Volume 44, pp. 1252-1257, 2009.
[4] Choi S., Lee Y.S., Oh H. K.: Ductile fracture in axisymmetric extrusion, Journal of materials processing technology 74, pp. 263–267, 1998.
[5] Gupta S., Reddy N. V., Dixit P.M.: Ductile fracture prediction in axisymmetric upsetting using continuum damage mechanics, Journal of materials processing technology 141, pp. 256–265, 2003.
[6] Hoa V.C., Seo D.W., Lim J.K.: Site of ductile fracture initiation in cold forging: A finite element model, Theoretical and applied fracture mechanics 44, pp. 58–69, 2005.

[7] Janiček L., Petruška J.: Ductile fracture in compression and cracking of notched cylindrical specimens, Proceedings of the 6th International conference on technology of plasticity – ICTP, Erlangen/Nuremberg, Germany, pp. 2287-2292, 1999.

[8] Li H., Fu M.W , Lu J., Yang H.: Ductile fracture: experiments and computations, International journal of plasticity 27, pp. 147–180, 2011.

[9] Lapovok R , Hodgson D.: A damage accumulation model for complex strain paths: prediction of ductile failure in metals, Journal of the mechanics and physics of solids 57, pp. 1851–1864, 2009.

[10] Narayana Murty S.V.S., Nageswara Rao B., Kashyap B.P.: Improved ductile fracture criterion for cold forming of spheroidised steel, Journal of materials processing technology 147, pp. 94–101, 2004.

[11] Petruška J., Janiček L.: Computationally-experimental workability determination of compressed cylindrical specimen with surface defect, Journal of materials processing technology 80–81, pp. 572–578, 1998.

[12] Venugopal Rao A., Ramakrishnan N., Krishna kumar R. : A comparative evaluation of the theoretical failure criteria for workability in cold forging, Journal of materials processing technology 142, pp. 29–42, 2003.

[13] Xue L.: Damage accumulation and fracture initiation in uncracked ductile solids subject to triaxial loading, International journal of solids and structures 44, pp. 5163–5181, 2007.

[14] Zhang J., Kwon H.C., Kim H.Y., Byon S.M., Park H.D., Im Y.T.: Micro-cracking of low carbon steel in hot-forming processes, Journal of materials processing technology 162–163, pp. 447–453, 2005.

[15] Alexandrov S., Wang P.T., Roadman R.E.: A fracture criterion of aluminum alloys in hot metal forming, Journal of materials processing technology 160, pp. 257–265, 2005.

[16] Kraišnik M., Vilotić D., Šiđanin L., Stefanović M.: Various approaches to defining the criteria of ductile crack in cold bulk forming processes, IV International Conference Industrial Engineering and Environmental Protection, Zrenjanin, Serbia (pp. 111-118), 2014.; Annals of Faculty Engineering Hunedoara – International Journal of Engineering, Tome XIII – Fascicule 2, Hunedoara, University Politehnica Timisoara, Romania, pp. 213-218, 2015.

[17] Sljapic V., Hartley P., I. Pillinger: Observations on fracture in axi-symmetric and three-dimensional cold upsetting of brass, Journal of materials processing technology 125–126, pp. 267–274, 2002.

[18] Alexandrov, S., Vilotic, D.: A theoretical - experimental method for the identification of the modified Cockroft - Latham ductile fracture criterion, Proceedings of the institution of mechanical engineers - part C: Journal of mechanical engineering science, 222-9, pp. 1869-1872, 2008.

[19] Lyamina E., Alexandrov S., Vilotic D., Movrin D.: Effect of shape of samples on ductile fracture initiation in upsetting, Steel research international 81, No. 9, pp. 306-309, 2010.

[20] Gouveia B.P.P.A., Rodrigues J.M.C., Martins P.A.F.: Fracture predicting in bulk. metal forming, International journal of mechanical sciences, Vol. 38, No. 4, pp. 361-372., 1996.

[21] Gouveia B.P.P.A., Rodrigues J.M.C., Martins P.A.F: Ductile fracture in metalworking: experimental and theoretical research, Journal of materials processing technology 101, pp. 52-63, 2000.

[22] Zheng C., Cesar de Sa J.M.A., Pires F.M. A.: A comparison of models for ductile fracture prediction in forging processes, Informatyka w technologii materialów, Volume 7, No. 4, pp. 389-396, 2007.

[23] Klocke F., Timmer A., Bäcker V.: Crack prediction in cold forging operations through a phenomenological differentiation of crack types, 12th International cold forging congress proceedings – ICFC, Stuttgart, Germany, pp. 65-72, 2011.

[24] Timer A., Klocke F., Bäcker M., Zimmermann M., Feldhaus B.: Holistic crack prediction in cold forging operations through a temporal and phenomenological distinguishing crack criterion, Steel research international, special edition, pp. 929-934, 2011.

IMPACT OF THE THICKNESS OF THE END PLATE OF THE END PLATE CONECTIONS WITH HIGH STRENGHT BOLTS SCREWS ON THE CAPACITY OF ROTATION OF THE JOINTS

Ilios Vilos[1], Cvetanka Mitrevska[2]
[1] University "St. Kliment Ohridski", Faculty of Technical Sciences, Bitola, Republic of Macedonia
[2] International Slavic University Gavrilo Romanovic Derzavin, Faculty for Safety Engineering, Sveti Nikole, Republic of Macedonia
e-mail: vilos.ilios@uklo.edu.mk

Abstract: In this paper FE method for obtaining a M-F moment –rotation diagram for the end plate connection with high strength bolt is given. The contact between the coulomb and the end plate is modeling with specific spring elements and the behavior of the high strength bolts is modeling with specific experimental research.
Keywords: end plate connection, high strength bolts, contact problem.

INTRODUCTION

As a basic constructive element in the steel buildings, the frames are made of columns and beams connected to each other with joints. Joints, as a part of the construction, in large part define the behavior of the construction. Generally, the distribution of the forces, shifts and deformations in the joints is more complex than their distribution in the elements which they connect.

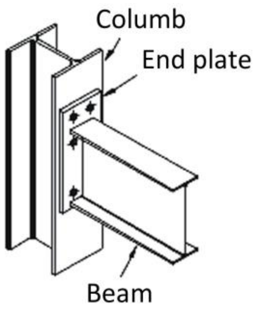


Figure 1. Typical end plate connection

Joints in the frame systems are most commonly with end plate which is welded to the beam and the connection to the column is made with bolts that are either ordinary or high strength (Fig.1). Despite the load-bearing characteristics, the deformation characteristics are also the basic characteristics of the steel frames.
Basic deformation characteristic of the joints on the frames is their capacity for rotation. The capacity of rotation of the joints can be described by the curve which gives the proportion of the rotation of the connection with the moment that is acted to the connection. This curve is called M-F moment-rotation curve of the connection.
For calculation of the deformation characteristics of the frame, previously should be obtained M-F curves of the joints of which they are made.
Below is a method how to get real M-F diagrams for connections of the end plate and the high strength bolts, that takes into consideration all the characteristics of the connection. In this paper attention is paid to the impact of the thickness of the end plate on M-F diagram.
Deformation characteristics of the frames depend on the size of the columns, the dimensions of the beams, dimensions and characteristics of the floor deck, dimensions of the beams and dimensions and characteristics of the joints.

Deformation characteristics of the joints with end connection and high strength bolts depend on the material from which is made the structure, the dimensions of the column, the dimensions of the elements of the column, the method of stiffing the column, the dimensions of the beam and the dimensions of the components of the beam, the dimensions of the face plate, the thickness of the face plate and the size and type of bolts.

The dimensions of the column and the elements of the column (height of the column, width of the rib and the thickness of the rib and the belt), also the size of the beam and the beam elements (height of the beam, width of the rib and the thickness of the rib and the belt) is obtained by the static calculation. The static influences in the joint are the basic elements from which the parameters of the relationship with end panel are selected. But, often, the structural characteristics of the connection and the technical regulations in each country, affects the choice of the dimensions of the elements of the connection. Elements of the connection with the faceplate are its type, its dimensions: height, width, selection of the type and size of the screw and selection of the thickness of the faceplate.

NUMEROLOGICAL MODEL

Numerological model of the construction

The numerical model is based on the real model which is given on Fig.2 and which is consisted of column and console loaded with force on the top. Column has dimensions: height 300 mm of which 250 mm height of the rib with thickness of 12mm and two belts with a thickness of 25 mm. Width of the rib is 200 mm. The console has a height of 230 mm, belt which is high 206 mm and metal sheet with thickness 8mm. Belts thickness is 120 mm and thickness of metal sheet is 12 mm. The dimensions of the end plate 120 x 300 mm with schedule of screw holes M16 10.9 as the shown on Fig.2 the end plate thickness is 12, 14 and 16 mm respectively.

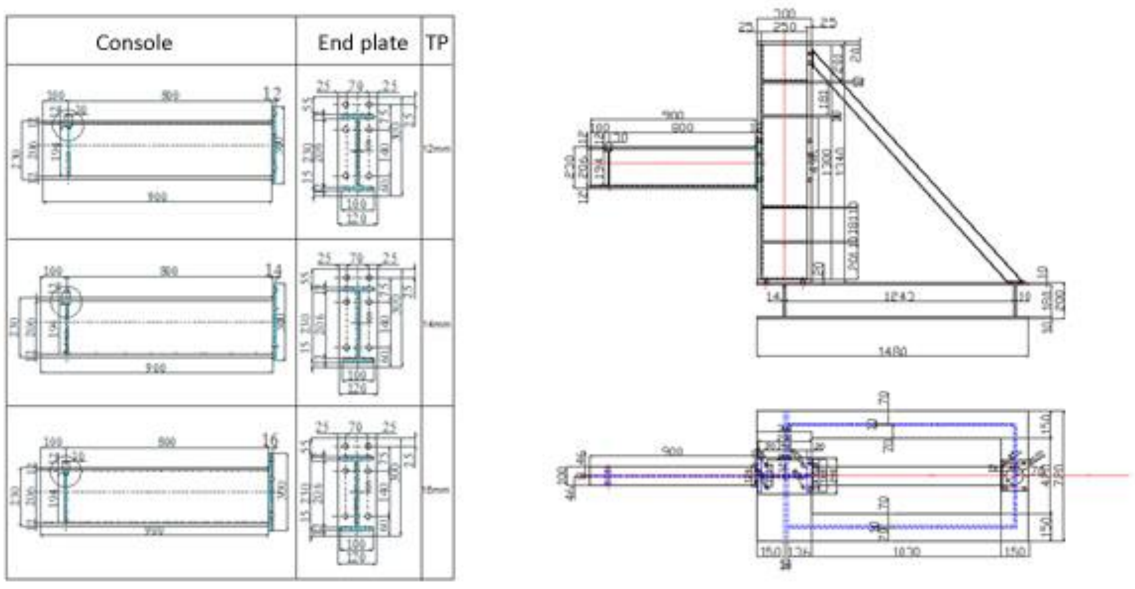


Figure 2. Real model of consisted of column and console loaded with force on the top

Below is mathematical model modeled by FEM Fig.3. The numerical analysis is made with SOFISTIK software package, where the construction is modeled within 3937 QUAD scaly stratified elements with five degrees of freedom in each joint. The model of the construction has a total of 3707 joints. The used element is degenerated scaly element that represents a quadratic finite element with five degrees of freedom per joint with parabolic interpolation of the displacements. Formulation of this element is based on the following assumptions: a) normal of the middle surface remain straight, but not always normal. Norman does not shorten. b) Deformation energy that corresponds to stresses which are perpendicular to the central area is overlooked. Each joint is defined by three shifts and two rotations perpendicular to the middle surface. Displacements and rotations are interpolated independently of each other which allow the shear deformations to be taken into account. Theory of Reissner-Mindlin applied to plates. In the element is implemented layered model that realistically present the state of stresses and deformations along the height of the element. This is of particular importance in non-linear analysis where the state of stresses and deformations along the height of the intersection of the element is different. Stresses are calculated in the middle layer of the element, and in this case each element is divided into 10 layers.

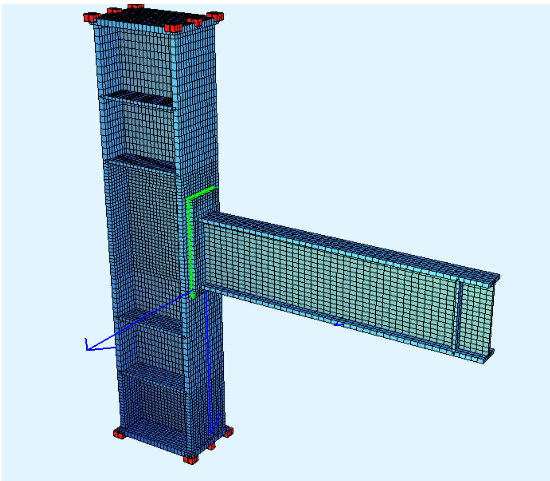


Figure 3. FEM model of the real model

Modeling of the material

The material from which it is made whole structure is steel with yield limit Sn = 240 Mpa. The material in the aforementioned software package is encapsulated by the (σ−ε) diagram in six points with dilation entered in promiles and the stress is in MPa. The picture on the left side of Fig.4 present (σ−ε) diagram obtained by examination of the material obtained from the manufacturer, and on the right side of Fig.4 is shown the diagram approximated 6 points.

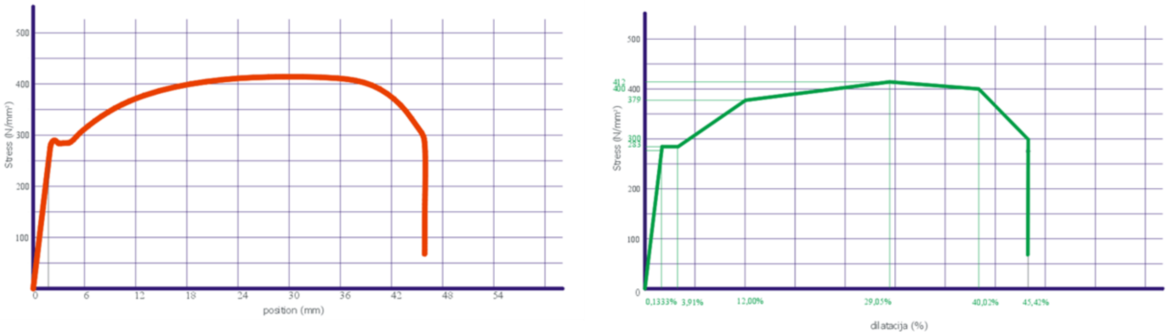


Figure 4. σ−ε diagram of the material of the structure

Modeling of the contact between the end plate and the column

Special specifics which modeling the connection represent the modeling of contact between the end plate of the connection of the console and belt of the column. The problem is consisted of allowing free deformation of parts of the end plate where shifts of the joints that are normal to the plane of the plate are in a direction which is away from the column, and the remaining joints which shifts are toward the column - the shifts should resist column with its rigid. For modeling of these effects are used special elements types "spring" that which give upon case of tightening. Fig.5. Generation of the network of finite elements of the contact column and end plate made 338 joints and used a total of 338 spring elements in each joint by one. Rigidity of these elements is 10x109 kN/m. Since the plate has dimensions of 12 x 30 cm and has a total of 338 finite element, stiffness of the finite element is 145.883,00 kN and stiffness of secondary elements is 1.633.334 kN.

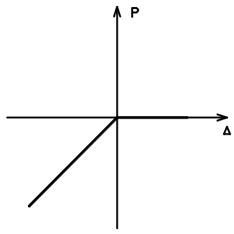


Figure 5. σ−ε diagram of contact spring

Modeling of the bolts

Numerical modeling of the bolts in this kind of connections presents specific and requires special attention because the behavior of the bolts the behavior of the end plate define the behavior of the link. Despite this, in the bolts are inserted the power of previous tightening which should somehow be introduced. When modeling the bolts there is no general approach and the various authors in accordance with the possibilities of different software packages make various models. From the literature review may be separated following numerical solutions. In the numerical model used in this research bolts are modeled as springs that are placed in the center of the hole of the screw. Springs which are modeling the bolts, rigidity is not explicitly set as a constant, but rigidity is set implicitly through the force-deformation diagram (F-D). This diagram, obtained by experimental research, fully defines the behavior of "spring" items during the analysis. So the local influence of the screw, ie its impact around the hole should be somehow taken into account. The software package allows in advance to prescribe shifts for certain points of the system or in advance to prescribe the same shifts to group of points (Fig.6). This characteristic of the software package is used to realistically model the physical behavior of the screw in the area of the hole.

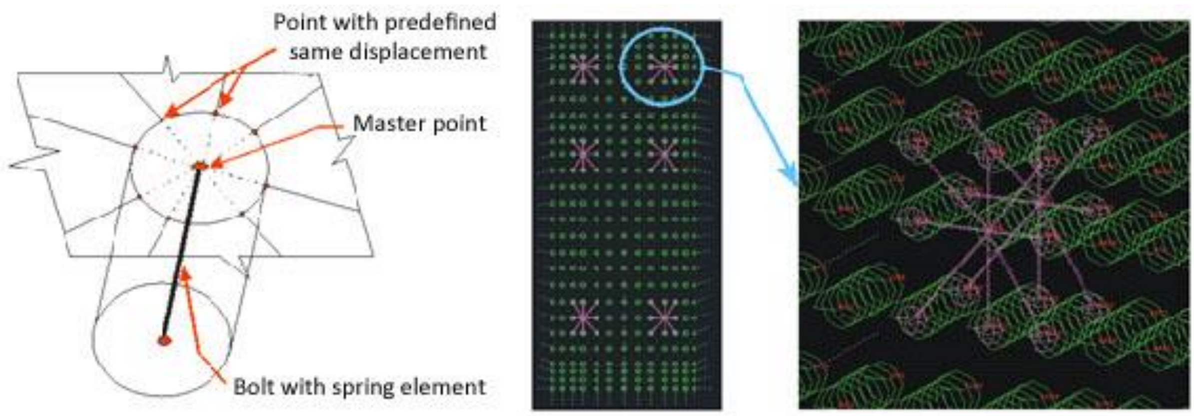


Figure 6. Modeling of the bolt

To all points that are situated in the perimeter of the hole, in advance is prescribed displacement which is same with the displacement of the end of the spring which is used for modeling the screw. This way, all the points from the area of the hole have same deformation like the center of the hole.

LOADING OF THE CONSTRUCTION

The construction is load with a concentrated force that is in the direction of the global Z axis of the system (Fig. 7). The loading is done this way. The construction is loaded incremental with base load that is taken for size of the increment of 1 kN. The first load of 1x1 = 1kN. For this load are calculated all values: full stress and strength condition in all 3937 elements which discretized the system, forces that modeling springs of the contact and forces in the bolts. If the condition is linear at every point of construction increment of 1 rises to 2. Again, the procedure repeated by increasing the increment for the full amount until then, when any element does not appear in plastic condition. Then the system starts to take the previous permitted situation as a starting and increment begins to increase for the previous plus 0.5. Than the whole procedure is repeated again and on each next step factor before the increment is with lower step of growth until for the previous one and the next step, the situation of stresses and deformations in all the structure is the same, which is the boundary of the system. Force that achieves this condition is the limits force ie the limit loads of the construction. The analysis obtain the following border forces: for the console of 12 mm border force is 83.07kN. For the console of 14mm border force is 91.76kN and for console with 16mm border force is 98.93 KH.

GETTING THE M-F DIAGRAMS

Obtaining of these curves is indirect from displacements of top and lower point of contact of belts with end plate. (Fig .7) These displacements are obtained from the FEM calculation, separate for each thickness of top plate.

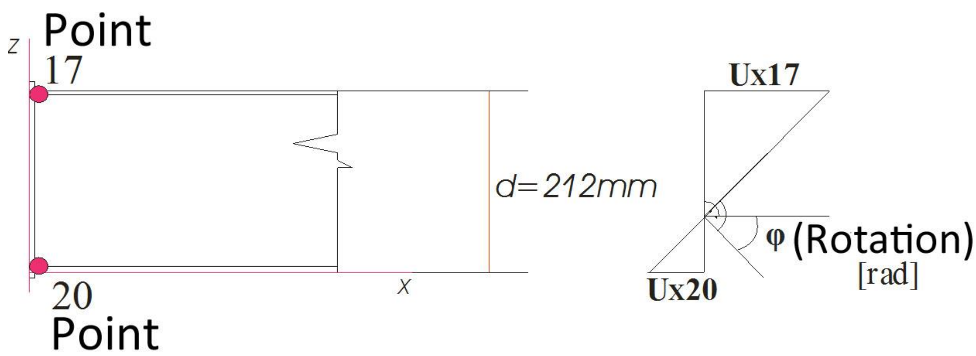


Figure 7. Defining M-F diagram trough the displacement of the upper and lower point of the contact of belts with end plate

Rotation of the cross section its obtained from relation if in this relation values of horizontal displacement for corresponding points are replaced, the value of rotation cross section its obtained. The results (the M-F diagram) are show in diagram for each thickness off the end plates separately.
So, ultimate moment Mu = 66.465 KNm is for a connection with end plate thickness of 12 mm. The connection with end plate with thickness of14mm has Mu = 73.908 KNm and the connection with the end plate with thickness of 16 mm has Mu = 78.712 KNm.

CONCLUSION

On the diagram in Fig. 8, M-F curve for the end plate with thickness of 12 mm is shown in blue, and the end plate with thickness of 14mm in red, and M-F diagram of the console with end plate with thickness of 16mm is shown in green. The curves show that the console with thickest end panel has the highest ultimate moment, and in terms of rotation of the cross section t has the smallest rotation. And opposite consol with the thin end plate has bigger rotation for same initiated moment. The diagram also shows that the thickness of the end plate affect the initial stiffness (rigidness). Connections with thicker end plate have greater initial stiffness. From this it follows that in the projection of the structures connections with thicker end panel will have a greater initial stiffness and smaller turning of the joints for the same external influences.

REFERENCES

[1] CITIPIOGLU, A.M., HAJ-ALI, RM, WHILE, D.W. Refined 3D finite element modeling of partially restrained connections including slip, Journal of consructional Steel research, 58,995-1013, 2002
[2] BUTTER, J., Finite Element Analysis of Structural Steelwork Beam To Column Bolted Connections, Joints in Steel Constructions-Moment Connections. BCSA/SCI Pub.Ni.207/95, 1995
[3] GERAMITCIOSKI T., VILOS I., Experimental Determination of F-D diagram for High Strent Bolts with 10.9 Clas of Strenght, International Scientific Journal „Problems of Mehanics“ No.2 (23). 2006
[4] BATHE, K.J., DVORKIN, E.N., „A Four-Node Plate Bending element Based on Mindlin/Reissner Plate Theory and a Mixed Interpolation“ Int.Journal four numerical Method in Engineering Vol.21, pp367-383, 1985
[5] ZIENKIEWICH,O.C., TAILOR,R.L., ZHIU,J.Z. „The Finite Element Method its Basis & Fundaments „Elsivier Butterworth-Heinemann“6thedition, 2005
[6] KOKALANOV G. MIHAJLOV V. „Computer Design of Flat Plates“ 1st Symposium Computing in Engineering, University of Zagreb, Zagreb 2003
[7] VILOS.I., GERAMITCIOVSKI.T, LAZAROV.Lj., KOKALANOV. G., Modeling of Beam-to-coloumn Joints According Eurocode3,12 International Symposium, 27-29 September 2007
[8] VILOS. I., Contribution Towards Research of the Limit State of the End Plate Connections With High StrenghtBolts of Steel Structures, Phd Thesis, 2006

COMPARISON OF DIFFERENT ADDITIVE MANUFACTURING METHODS

Aleksandar Rajić[1], Eleonora Desnica[2], Slobodan Stojadinović[2],
[1]Technical College of Applied Sciences, Zrenjanin, Serbia
[2]University of Novi Sad, Technical Faculty ″Mihajlo Pupin″, Zrenjanin, Serbia
e-mail: aleksandar.rajic@vts-zr.edu.rs

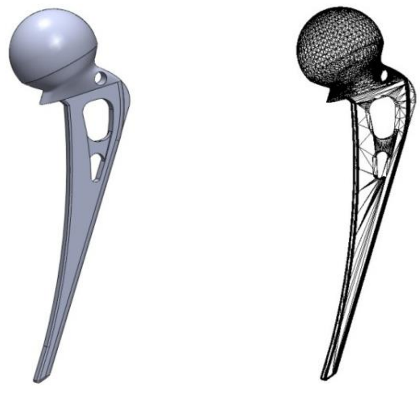
Abstract: The paper presents the possibilities to apply Additive Manufacturing (AM) technology in designing the prototypes of master patterns of hip implant for investment casting. The master pattern manufacturing by wax injection is the starting operation in the investment casting procedure. Research presents the comparison of different AM processes (PolyJet 3D Printing, Selective Laser Sintering, 3D Printing and Fused Deposition Modelling) considering the characteristics of the material and the dimensional accuracy of hip implant patterns.
Key words: Additive Manufacturing, PJP, SLS, 3DP, FDM, investment casting pattern, hip implant

INTRODUCTION

One of the primary uses of Additive Manufacturing technology is to quickly produce prototypes for model validation and testing purposes. Presently, almost all commercialized AM techniques have been employed to produce casting patterns with varying success and many AM solutions in investment casting are being used by various industries and researchers. The study presented in this paper represents a part of the developed research in design and development of hip implant master pattern. In the study the preparation of the model and the parameters of the printing process were analyzed as well as the dimensional accuracy of the master pattern of hip implant manufactured by using four different AM processes: PolyJet 3D Printing (PJP), Selective Laser Sintering (SLS), 3D Printing (3DP) and Fused Deposition Modelling (FDM).

MODELLING OF THE HIP IMPLANT PATTERN

A total hip replacement (THR) is a surgical procedure whereby the diseased connective tissue and bone of the hip joint are surgically replaced with artificial materials. The hip joint is a ball and socket joint. The ball is the head of the femur. The socket (acetabulum) is a cup-shaped indentation in the pelvis. During hip replacement surgery, the head of the femur is removed and replaced with a metal ball set on a stem. The stem is inserted into the canal of the femur, [1].
Until a few years ago, cemented Austin Moore type hip implant had been manufactured in the Foundry of investment castings Ada for orthopaedic purposes. The 3D CAD model of the hip implant stem was created using the SolidWorks software. The geometry of the hip implant is presented in Fig. 1(a). The CAD geometry of the hip implant was exported on an STL file, resulting in 9580 triangles, as shown in Fig. 1(b).



(a) (b)

Figure 1. Visual display of the hip implant model: (a) SolidWorks solid model and (b) STL model (9580 triangles)

ADDITIVE MANUFACTURING OF HIP IMPLANT PATTERNS

In this part of the research different AM models were produced which may be used as a starting point to obtain master patterns for the investment casting procedure. Different AM processes were analyzed and compared regarding characteristics of the applied materials and printing process. The processes, systems and materials used for manufacturing of the AM model in the research were the following:
1. PolyJet 3D Printing, Objet 30, VeroGrey FC850
2. Selective Laser Sintering, EOS Formiga P100, PA2200
3. 3D Printing, Spectrum Z510, ZP151
4. Fused Deposition Modelling, Stratasys Prodigy Plus, ABS.

PolyJet 3D Printing (PJP) technology

The hip implant models were manufactured on the Objet30 Stratasys machine in the "Centre for Numerical Simulation and Digital/Rapid Prototyping" at the Faculty of Engineering and Management, Resita, Romania. The principle is very similar to 2D printing process of inkjet pointer and it is shown on Fig. 2. The injected material is a polymer which after cooling forms the required layer or binder which bonds powder particles. The process consists only of UV bulbs and photopolymer materials. Objet 30 printer (Fig. 3) fully cure each layer of super fine UV photopolymer and support materials as eight jetting heads precisely deposit the product. Support material is easily separated from the part by either a water jet or hand and brush. No special baths or extra finishing treatments are needed.

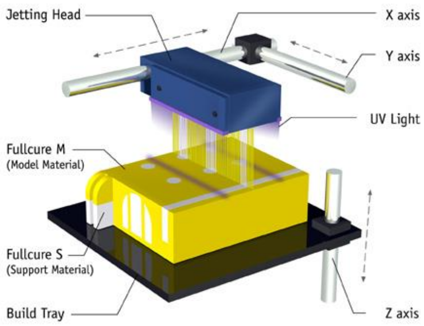


Figure 2. Basic principle of PolyJet printing process [2]

Figure 3. Objet 30 3D Printer

Models that are saved in a CAD program as STL files may be inserted into the Objet Studio tray. Fig. 4 shows the STL files loaded in Objet Studio software. To minimize the print time: the longest dimension of a model must be placed along the X-axis, the smallest dimension of a model must be placed along the Z-axis and the tallest model must be placed on the left of the tray. When a tray is ready to be printed, it is sent to Job Manager, where it is placed in the print queue. When the job reaches the head of the queue, Job Manager pre-processes the tray file to create slices, and feeds them to the 3D printer, [3]. Fig. 5 shows the printing process of the two hip implants.

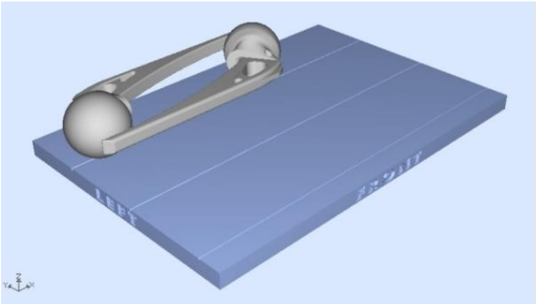


Figure 4. The STL file of the two hip implants loaded in Objet Studio software and placed on printer tray

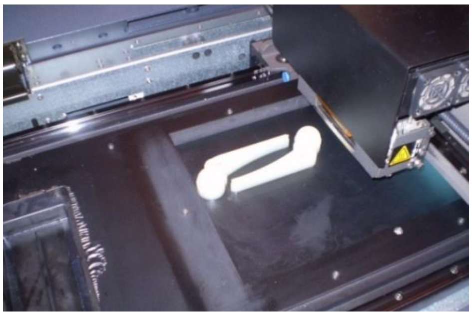


Figure 5. Printing process of the two hip implants by PJP technology

Selective laser sintering (SLS) technology

The hip implant models were manufactured on the Formiga P100 machine in the laboratory "3D Impuls" at the Faculty of Mechanical Engineering and Construction in Kraljevo, Serbia. The development of the model on this machine was based on the technology of Selective Laser Sintering (SLS). Unlike the PolyJet process where the layers are formed by extruding the photopolymers and the support materials from the nozzles, in the SLS process a laser is used to sinter the particles of a material. Instead of the liquid photopolymer, in the SLS process various powdered materials are used. The schematic representation of the SLS process is given in Fig. 6. Formiga P100 (Fig. 7) machine is designed for working with plastic materials in direct manufacturing of small series and prototyping of functional spare parts, [3].

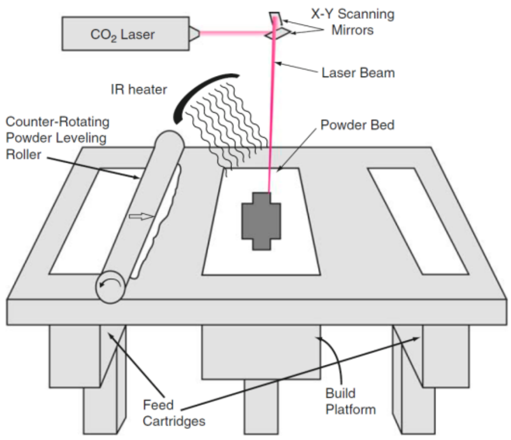


Figure 6. Schematic representation of the SLS process [2]

Figure 7. Formiga P100 EOS SLS machine

The rational positioning of the parts within the building area is based on uniform distribution of the melting areas during the manufacturing (Fig. 8). A part agglomeration in a certain area having the same Z positions could lead to a local temperature enhancement, influencing the stability of the job. The preparation of the printing model was done in Magics, EOS RP-Tools and PSW. The Magics software was used to position the parts on the working platform with 5 mm distance between them to avoid the heat effect between the neighbouring parts. EOS RP-Tools was used to define the layer thickness of 1 mm, to slice the file at the layer thickness and to verify and correct the layers. In the PSW software, the material and the parameters of the process were assigned and the executable file was verified only to be exported into the machine. The process of printing the model was started automatically upon reaching the operating temperature of the chamber of 172 °C. The laser power was 25 W, the scanning velocity was 2.54 m/s and the hatch spacing was 0.26 x 10^{-3} m. After the machine and the parts had been cooled down, the parts were removed, cleaned and washed. Fig. 9 shows the printing process of the SLS hip implants made by polyamide PA 2200.

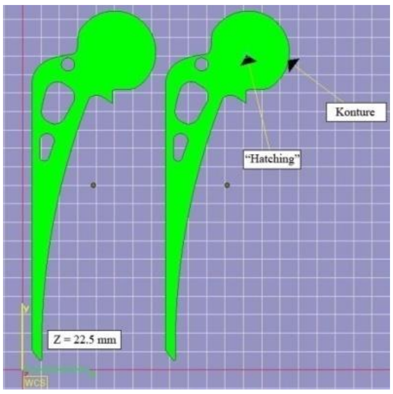


Figure 8. SLS parts positioning on the building platform

Figure 9. Printing process of the SLS implants

3D Printing (3DP) technology

The hip implant models were manufactured on the Spectrum Z510 machine owned by the company “3D Svet” from Belgrade. The developing of the models on this machine is based on 3D Printing (3DP) technology. Unlike the printing processes described earlier, 3DP prints a binder into a powder bed to manufacture a part. Hence, in 3DP, only a small portion of the part material is delivered through the print-head; most of the part material is composed of powder in the powder bed. Typically, binder droplets (80 mm in diameter) form spherical agglomerates of binder liquid and powder particles and provide bonding to the previously printed layer. Once a layer is printed, the powder bed is lowered and a new layer of powder is spread onto it, very similar to the recoating methods used in SLS processes, as presented earlier. This process is repeated until the part or the array of parts, is completed. A schematic of the 3DP process is shown in Fig. 10. After printing, the part is removed from the powder bed, depowdered and dried. The part can then be infiltrated with wax, epoxy, or other materials to increase strength and durability. Because the powder layers support the structures being printed, the printer creates parts without support structures and will print parts with complex geometries. Spectrum Z510 system (Fig. 11) used in this study excel as low cost fast prototyping machines, [3].

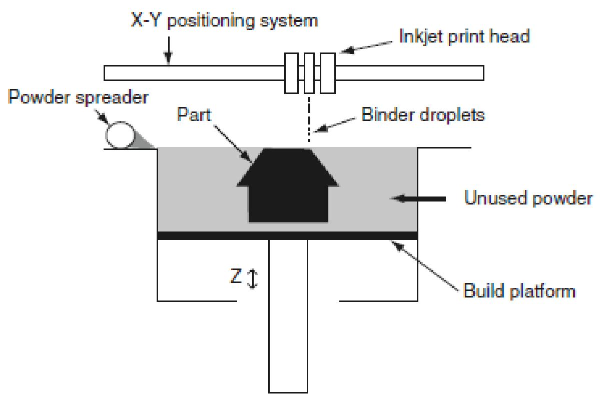


Figure 10. Schematic of the 3D Printing process [2]

Figure 11. Spectrum Z510 system

Z Print (Fig. 12) is software for preparing and optimizing the build area. The software will place the parts within the build box to maximize build speed. The smallest dimension of parts must be placed along the Z-axis (vertical). The parts will be strongest along Y-axis and X-axis and less strong along Z-axis. This is because the cross section are printed in continuous strips along the Y or the “fast” axis, bands across the X or the “slow” axis and laminated layers along the Z-axis. Fig. 13. shows the printing process of the hip implants made of composite powder by 3DP technology.

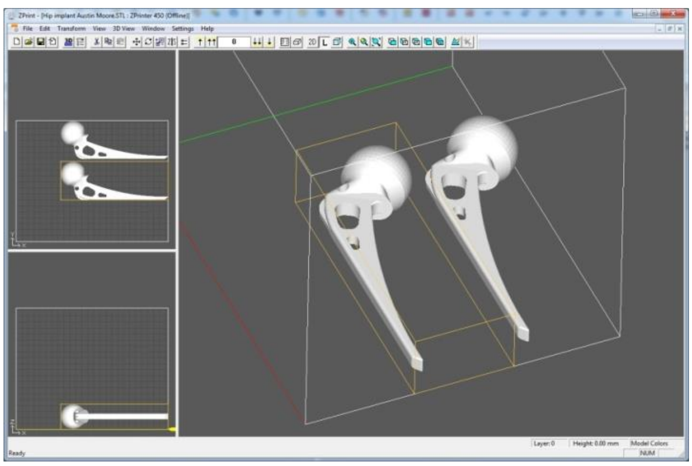


Figure 12. The STL file of the hip implants loaded in Z Print software and placed on printer tray

Figure 13. Printing process of the hip implants by 3DP technology

FDM technology

FDM begins with a software process, developed by Stratasys, which processes an STL file in minutes, mathematically slicing and orienting the model for the build process, as shown in Fig. 14. If required, support structures are automatically generated. The machine dispenses two materials – one for the model and one for a disposable support structure. FDM works on an "additive" principle by laying down material in layers. A plastic filament or metal wire is unwound from a coil and supplies material to an extrusion nozzle which can turn the flow on and off. The nozzle is heated to melt the material and can be moved in both horizontal and vertical directions by a numerically controlled mechanism The materials are deposited in layers as fine as 0,1778 mm thick and the part is built from the bottom up – one layer at a time. As building materials are used different types of polymers (ABS, PC, etc.). The hip implant models were manufactured on the Stratasys Prodigy Plus system (Fig. 15) owned by Rapid Prototyping Laboratory of Czech Technical University in Prague, Faculty of Mechanical Engineering.

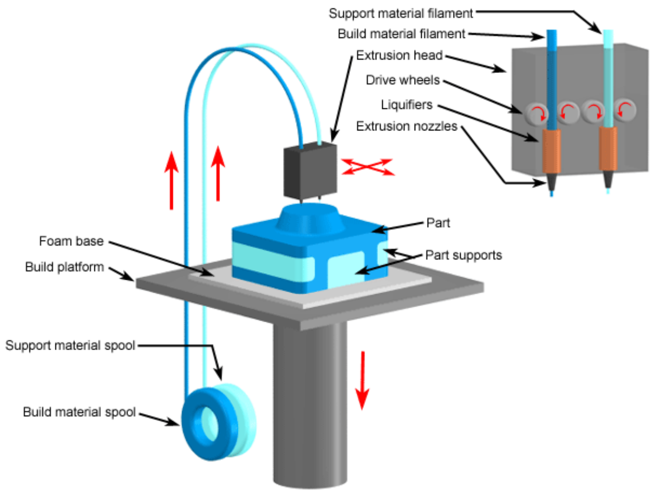


Figure 14. Schematic of the FDM process [2]

Figure 15. Stratasys Prodigy Plus system

Stratasys Insight software (Fig. 16) was used for production process preparation and control code generation. Fig. 17. shows the result of printing process of the hip implant by FDM technology.

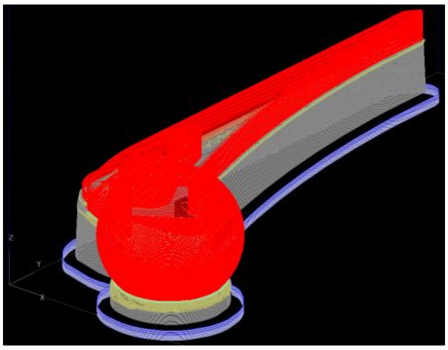


Figure 16. The STL file of hip implant in Stratasys Insight software

Figure 17. Hip implant ABS model with support structure

RESULTS AND DISCUSSION

The final hip implant prototypes are shown in Fig. 18, with a four different AM models: PJP, SLS, 3DP and FDM. Taking into account that the prototypes have an educational purpose, the obtained hip implant models will be used as teaching aids for students in the classroom as well as for future researches. For the same reason, the model validation was performed by simple dimensional verifications. The accuracy of hip implant models was determined by measuring certain dimensions and comparing the results with the corresponding nominal values. The measurements were performed with a digital calliper (resolution 0.01 mm). Each dimension was measured 3 times. The dimensions taken into consideration are shown in Fig. 19.

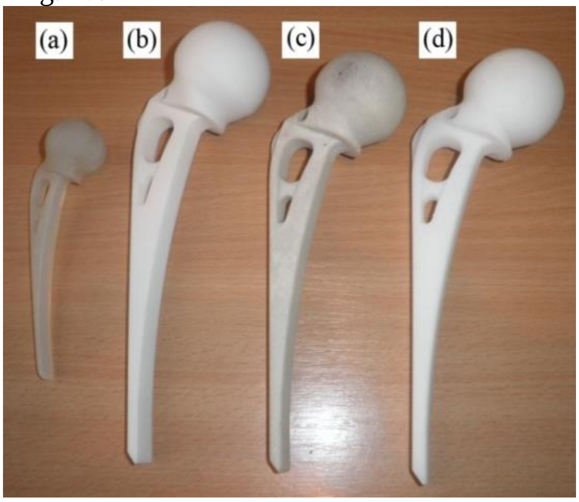


Figure 18. Finished hip implant models: (a) PJP, (b) SLS model, (c) 3DP and (d) FDM model

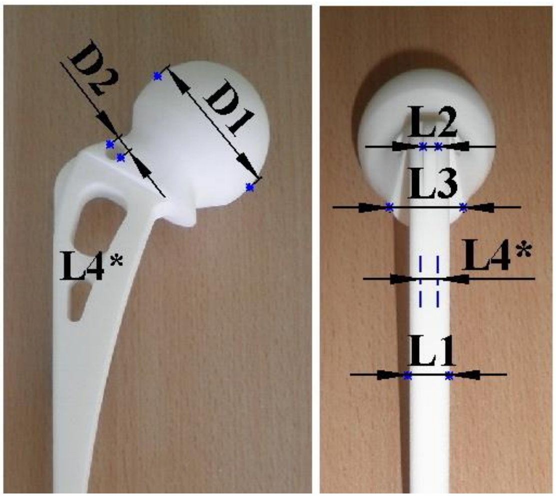


Figure 19. Critical dimensions of hip implant

Fig. 20. shows dimensional accuracy for different hip implant AM prototypes.

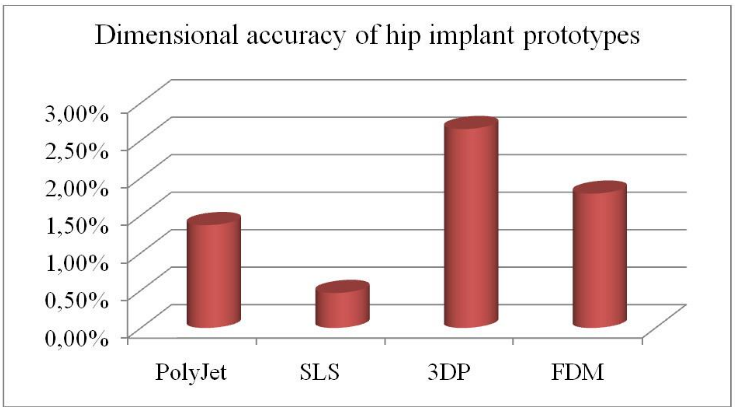


Figure 20. Dimensional accuracy of different AM prototypes

Comparison of AM pattern material properties may be seen in Table 1.

Table 1. Properties of AM pattern materials [6-9]

Technology	**PJ**	**SLS**	**3DP**	**FDM**
Material	VeroGrey FC850	PA 2200	ZP 151	ABS plus
Tensile Strength [MPa]	60	45	26	22
Modulus of Elasticity [MPa]	3000	1700	9450	2200
Elongation at yield [%]	15	15	0,2	6
Impact Strenght (notched Izod test) [J/m]	25	32,8	n/a	106
Hardness Shore	86	75	87	109 (Rockwell)
Layer thickness [mm]	0,028	0,1	0,0889	0,1778
Surface roughness	very high quality	rough and porous	rough and textured	rough and porous

CONCLUSIONS

The synergy produced by uniting CAD, Additive Manufacturing technology and investment casting process, is an outstanding contribution of engineering in medical sciences. Instead of making tools, AM patterns could be directly fabricated from a design engineer's CAD solid model within a matter of hours and provide a casting in a matter of days. Each of the type of AM processes described in this research had its own advantages and limitations, and so it depends upon the end-user to select the appropriate AM technique in conjunction with the IC process to manufacture a part in an efficient manner.
The PJP, SLS, 3DP and FDM technologies can be used to create complex objects, like hip implants and to use these objects for investment casting process as non wax pattern or for AM-fabricated moulds for wax injection (indirect tooling). Also, by using the PJP, SLS, 3DP and PJP patterns it is possible to make a silicon mould and with it cast the wax patterns in the vacuum chamber. Investment casting technology is applied hereafter.

REFERENCES

[1] Rajic, A. Stojadinovic, S., Nedelcu, D., Desnica, E., Vulicevic, Lj.V.: Applications of the Additive Manufacturing technology to manufacture the hip implants, Annals of Faculty Engineering Hunedoara – International Journal of Engineering, Tome XII, Fascicule 2, pp. 101-106, 2014.
[2] Gibson, I.: Advanced Manufacturing Technology for Medical Applications, Reverse Engineering, Software Conversion and Rapid Prototyping, John Wiley & Sons Ltd., 2005.
[3] Rajic, A., Desnica, E., Stojadinovic, S., Nedelcu, D.: Numerical Simulation and Additive Manufacturing technology in design of knee implant patterns, Journal of Optoelectronics and Advanced Materials, Vol. 16, No. 9-10, pp. 1180-1190, 2014.
[4] Gibson, I., Rosen, D.W., Stucker, B.: Additive Manufacturing Technologies: Rapid Prototyping to Direct Digital Manufacturing, Springer, 2010.
[5] Cheah, C.M., Chua, C.K., Lee, C.W., Feng, C., Totong, K.: Rapid prototyping and tooling techniques: a review of applications for rapid investment casting, International Journal of Advanced Manufacturing Technology, Vol. 25, pp. 308-320, 2005.
[6] http://eos.materialdatacenter.com/eo/standard/main/ds
[7] http://usglobalimages.stratasys.com/Main/Secure/Material%20Specs%20MS/PolyJet-Material-Specs/PolyJet_Materials_Data_Sheet.pdf?v=635376606224140355
[8] https://3dscentral.3dsystems.com/attachments/2238_95034%20zp151%20User%20Guide.pdf
[9] http://usglobalimages.stratasys.com/Main/Files/Material_Spec_Sheets/MSS_FDM_ABSplusP430.pdf?v=635784487047289661

INFLUENCE OF MIXING CONDITIONS ON BIOSORPTION OF NICKEL IONS

Milan Milivojević[1], Steva Levic[2], Verica Đorđević[1], Nevenka Rajić[1], Viktor Nedović[2], Branko Bugarski[1]
[1]University of Belgrade, Faculty of Technology and Metalurgy, Belgrade, Serbia
[2]University of Belgrade, Faculty of Agriculture, Belgrade, Serbia
e-mail: mmilan@tmf.bg.ac.rs

Abstract: In this study, calcium alginate and calcium alginate in the form of spherical beads were investigated for aqueous Ni^{2+} adsorption. The adsorption was carried out using 5 and 10% of adsorbents in different systems: 1) under static conditions and 2) in a reactor with a mechanical mixing. The efficiency of Ni^{2+} adsorptions and the influences of different hydrodynamic conditions on nickel ions removal from the aqueous solution by alginate beads were investigated. Result showed that static conditions provided better conditions for Ni^{2+} adsorption than systems based on mechanical mixing.
Key words: calcium alginate, Ni^{2+} adsorption

INTRODUCTION

Biosorption of heavy metals can be defined as removal of metals (and others compounds) from solutions by biological materials. Growing problems connected with heavy metals pollution, created needs for development a suitable removing system. There are numerous procedures for heavy metals removal. Many of these are based on traditional physical or chemical methods. However, many of these processes produce large quantity of wastes required for treat. Because of these, biosorption becomes the most suitable alternative for conventional procedures. One of the most intensively investigated groups of absorbents is microorganisms. A huge numbers of microorganisms have been investigated as biosorbents for the removal of metals or organic materials. On the other hand, there are numerous materials suitable for metals sorption: waste biomass; agricultural wastes; polysaccharide material, etc. [1].
Alginate is water-soluble linear polysaccharide extracted from brown algal. In those algal species, alginate in dry weight can be represented in significant percent 10-40%. The chemical structure of alginate is composed of alternating blocks of 1-4 linked.-L-guluronic and ß-D-mannuronic acid fragments. Chemical composition of alginate is strong connected with algal species used for alginate extraction, especially mannuronic/ guluronic ratio [2, 3].
In wastewater treatment, alginate could play an important role in removal heavy metal ions due its advantages, such as facile obtaining procedure and biodegradability. Also, alginate can be applied with other polymer materials, for example with polyvinyl alcohol [1, 4]. It was reported that alginate beads metal adsorption capacity is significantly higher than capacity of commercially available sorbents, such as activated carbons, bentonite, etc [2].Very popular approach in biosorption studies with is combination of alginate (a wall material) and different microorganisms [1], like an alga [5] or yeast [6].

MATERIAL AND METHODS

Materials. Sodium alginate (medium viscosity) was supplied from Sigma; calcium- chloride dihydrate was supplied from Himedia, and nickel chloride hexahydrate from Merck. The stock solutions of reactants were used and the diluted solutions were prepared and stored in fridge at 4ºC.

Encapsulation procedures
Preparation of Ca-alginate beads was realized by dripping technique [3]. Spherical beads were prepared by extrusion alginate solution (1,5 %) dispersion through a stainless steel needle (16 gauge) using a syringe pump (Razel, Scientific Instruments, Stamford, CT). The distance between needle and collecting solution (0,015 g/ml calcium chloride) was 2,5 cm, while the flow rate of polymer solution

was 70 ml/h. The beads were kept in $CaCl_2$ solution for 45 min. to strengthen the gel, washed and stored in deionized water at 4ºC.

Batch sorption experiments
Nickel-chloride hexahydrate was dissolved in distilled water. The final nickel concentration was 400mg/L. Two amounts of alginate beads were used in biosorption studies: 5 and 10% beads per total solution volume. Also, batch biosorptions were realized in 100mL glass with 50mL solution (400mg/L nickel concentration) and with mixing on magnetic mixer (250 rpm) with different beads amounts. All experiments were realized at room temperature in period of 24 hours.

Determination of nickel concentration
Nickel (II) concentrations in solution were doubly checked by ICP-MS (Agilent 7500CE) and by simple complexation titrations using EDTA and the solochrome black indicator
At least five measurements have been done for each determination [7].

RESULTS AND DISCUSSION

Alginate beads characterization
The beads prepared by the dripping technique method were examined in terms of size and shape. Dimension and shape of beads were evaluated by light microscope DMLS (Leica), camera DC 300(Leica), with software IM 1000 (Leica) for measuring. Beads properties are shown in Figure 1. Diameters of beads were found to be 2,65mm for alginate beads.

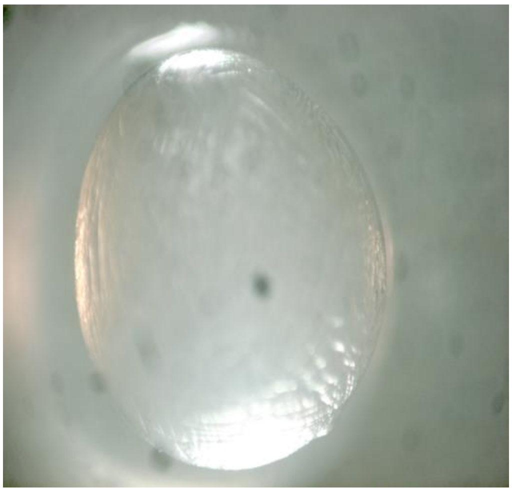


Figure 1. Photographs of Alginate beads.

Biosortion studies
Alginate beads have been investigated for its potential use for the removal of nickel under different hydrodynamics conditions. There were differences between alginate beads nickel adsorption capacity in different hydrodynamic conditions. Several authors [2, 8, 9] reported a competition between metal ions and protons for organic binding sites, or for alginate binding site. Based on these data, it can be defined affinity of alginic acid to metal ions follows the order: $Pb^{2+} > Cu^{2+} > Cd^{2+} > Ba^{2+} > Sr^{2+} > Ca^{2+} > Co^{2+} > Ni^{2+} > Mn^{2+} > Mg^{2+}$. Based on those data, alginate has a relatively low affinity to nickel. This can explain a low amount of adsorbed nickel.
As depicted in Figure 2, the alginate beads metal adsorption capacity is significantly higher in case of static conditions than in magnetic mixer. This can be proving that rate limiting step in nickel ions adsorption on alginate beads is not diffusion rate but chemisorption.

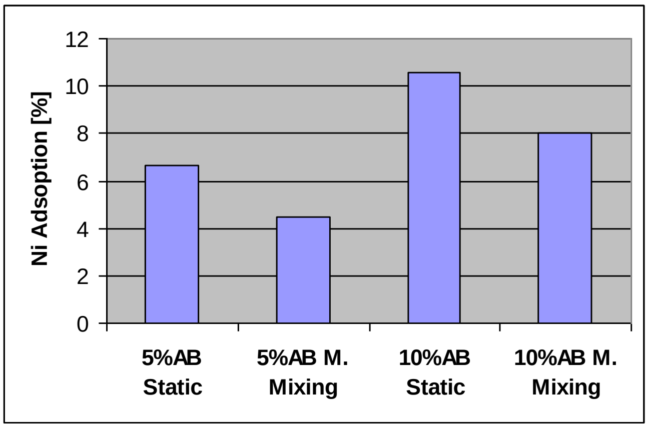


Figure 2. Biosorption of nickel under different adsorbent quantities and hydrodynamic conditions.

The pH of the initial solution was not changed during experiments although based on literature [2], the pH was found to have a significant effect on the sorption capacity of the alginate beads.

CONCLUSION

The aim of this study was to investigate hydrodynamics characteristics and biosorption properties of alginate beads. A simple preparation procedure for alginate beads is proposed, resulting in correct shape and size beads. Results showed significantly better adsorption of nickel ions in the static conditions compared to system with mechanical mixing thus indicating a hemisorption as a rate limiting step.

ACKNOWLEDGEMENTS

The authors gratefully acknowledge funding support of the Ministry of Education, Science and Technological Development of the Republic Serbia grant III 46001 and III 46010.

REFERENCES

[1] Wang., J. and Chen, C., Biosorption for heavy metals removal and their future, Biotechnology Advances, Vol. 27, pp. 195-226, 2009.
[2] Papageorgiou, K. S., Katsaros, K. F., Kouvelos, P. E., John W. Nolan, W. J., Deit, H., and Kanellopoulos, K. N., Heavy metal sorption by calcium alginate beads from *Laminaria digitata,* Journal of Hazardous Materials Vol. 137, pp. 1765–1772, 2006.
[3] Nitã, I., Iorgulescu, M., Florea Spiroiu, M., Ghiurea, M., Petcu, C., and Cinteza, O., The adsorption of heavy metal ions on porous calcium alginate microparticles, Analele UniversităŃii din Bucuresti – Chimie, Anul XVI (serie nouă), vol. I, pp. 59 – 67, 2007.
[4] Kuczajowska-Zadrożna, M., E. Klimiuk, E., and Wojnowska-Bary, I., Cyclical Cadmium Adsorption and Desorption by Activated Sludge Immobilized on Alginate Carriers Polish Journal of Environmental Studies Vol. 13, No. 2, pp. 161-169, 2004.
[5] Abdel Hameed, M. S., Continuous removal and recovery of lead by alginate beads, free and alginate-immobilized *Chlorella vulgaris,* African Journal of Biotechnology Vol. 5 (19), pp. 1819-1823, 2006.
[6] Wang, J., Chen, C., Biosorption of heavy metals by Saccharomyces cerevisiae: A review, Biotechnology Advances Vol. 24, pp. 427–451, 2006.
[7] Vogel¢s Textbook of Qualitative Inorganic Analysis, Fourth Ed., London, p. 321, Longman 1978.
[8] A. Haug, The affinity of some divalent metals to different types of alginates, Acta Chem. Scand. Vol. 15 pp. 1794–1795, 1961.
[9] Karagunduz, A., and Unal, D., New method for evaluation of heavy metal binding to alginate beads using pH and conductivity data, Adsorption, Vol. 12, No. 3, pp. 175-184, 2006.

THE GEOMETRIC ANALYZES OF SIZED BEARING IN EXPLOITATION

Danilo Mikić[2], Eleonora Desnica[1], Aleksandar Ašonja[2]
[1]University of Novi Sad, Technical Faculty "Mihajlo Pupin", Zrenjanin, Serbia,
[2]The Association of Intellectuals for the Development of Science in Serbia, "The Serbian Academic Center", Novi Sad, Serbia,
e-mail: mikictdanilo@gmail.com

Abstract: The main goal of the research presented in this paper is an analysis of the ball bearings 6206 piston compressors. Ball bearings, that transmit the load are very critical for the safe and efficient operation of rotating machines.
In this paper presents analysis of through testing of wear of ball bearing of elements, wear the inner track, the outer tracks and balls, and the final goal was to present the resulting tribological processes. Purpose of monitoring the the state of wear balls was used the micrometer. Other place of testing performed of implemented measures were visual control.
Key words: reliability, ball bearing clearance, wear, temperature

INTRODUCTION

During exploitation technical systems leads to irreversible changes in the system caused by various processes: friction, wear, corrosion, deformation, effects of the environment and the like. [1]. Deviation of system characteristics of the projected value is considered a cancellation of the system, the most common case of such cancellation elements are balls on of rolling bearings, the inner tracks and outer tracks. Cancellation system is manifested by the appearance of temperature, noise and vibration systems.Gliding of the balls is a function of lubrication, tolerance of balls in the cage, the angular rotation and lateral forces, surface quality, as well as speed and load. Lubrication has a dominant influence on the gliding of the ball. Glide occurs due to the resistance forces on the ball, which was created by the viscous resistance force of lubricant, and is greater than the slip moment to point contacts. This attempt was aimed at easier access to obtain the theoretical model to study the effect of defect size, load and speed of the bearing vibration and predict spectral components. To preserve the production process and avoid minimum failures in the process, it is necessary to maintain the equipment and critical machine parts. The development of rotating machines with ball bearings goes very quickly and improvements are focused on increasing the reliability of machines and their versatility. Improved reliability of ball bearings is to operate in special environments such as corrosive environments, high temperatures, high speed, and high vacuum environments, have become very important [2].
It can be said that the performance bearings affect key functions, such as durability, noise and vibration behavior of the compressor. In a study conducted by Kim and Han [3] an analytical model the behavior of dynamic coupling of the piston and crankshaft was developed and compared to the model of terminal bearing. Same study presents a numerical procedure which combines the Newton-Raphson method and pattern of repeated excessive burden.
Having in mind the above mentioned, this study aims to investigate the tribological behavior of ball bearing 6206 with emphasis on the occurrence of temperature, wear, deformation in terms of lubrication and provide new information and knowledge. The influence of load, movement speed and the friction and gliding, on the tribological behavior of bearing wear intensity was analyzed with the exploitation of research.

MATERIAL AND METHODS

Changes of geometric sizes of the bearing in exploitation

The paper presents justification of monitoring characteristics of piston compressors, which are used to suck gas from a tank, pipe or the environment and suppress them (with the more significant increase of of pressure) to the second tank, piping, or generally to some of consumers [4]. Piston compressors applies clips that run directly via the piston mechanism pretending rotary motion of the rotor in the oscillatory linear motion [5]. The exploitation of the system was limited to a visual assessment of behavior of the system as well dynamic measurements of geometrical the process parameters [6].
In order to study bearings in a piston compressor included the effects of a particular damage to ball bearings SKF 6206, are shown in individual damage on the inner ring, outer ring, and balls that occurred during exploitation, established after the dismantling of bearings on the desk (Figure 1). Important geometric characteristics of ball (roll) bearing are diameters of rolling slopes, and the mid diameter of the bearing. They can be expressed by the geometric characteristics of the rolling tracks. On the geometry of the bearing, influencing factors are, material quality of the balls and tracks, surface quality balls and tracks, the way of maintenance, lubricant type, the conditions under which bearing exploits, etc..

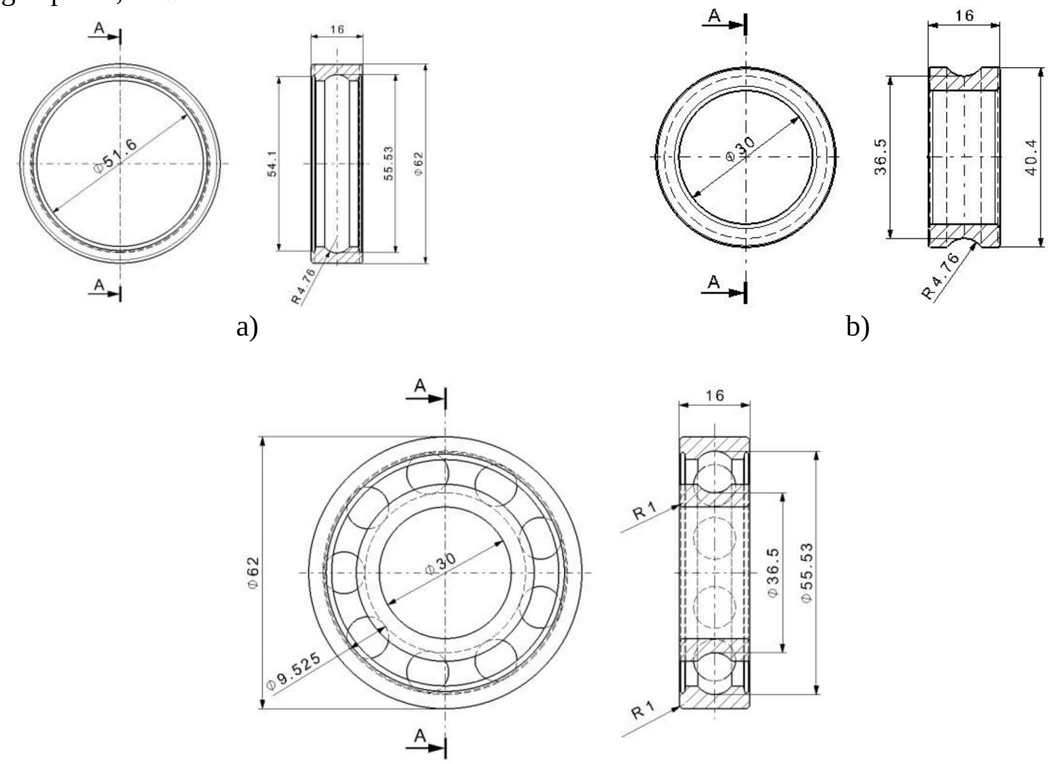


Figure 1. Geometrical size rolling ball bearing SKF 6206
a) The outer bearing ring, b) The inner bearing ring
c) Damage to the outer and inner ring

The outer ring of the physical new beds 55.53 is measured at the beginning with a tolerance of ± 0.010μm, while the ring physical defective bearing extended to 55.56 mm. The inner ring of the new bearing is 36.5 ± 0.010μm, measured at the beginning, before exploitation 36.49 mm after exploitation-defective to 36.46 mm. From the above analysis it can be seen that the inner ring is worn out (Table 1).
Also track ball represents a measure of geometrical conformity of runs and balls in a plane passing through the (time) axis bearing (also called the center line or rotational axis), which line passes through the center bearing normal to the plane and transverse to the track.

In Figure 2 are presented the dimensions of single row of ball bearing, diametrical diameter balls, and tolerance obtained after of measurements [7].
Radial ball bearings have some effect from axial effect because they are designed to have a diameter tolerance. Also figure 2 shows that the radial bearing with the touch due to axial movement of the inner and outer rings is applied when it is not measurable force. Measurement of the balls was performed after dismantling bearings on test bench of examination of bearings, using a micrometer with an accuracy of 0.025 mm. By measuring the balls we determined deviation dimensions of balls compared to the standard value of 9.525 mm, which can be seen in Figure 2 ,,Diagram of ball dimensions".

Table 1. Shows the values of the new geometry of the bearing, as the deformed bearing

Geometry the bearing According to SKF	Values after defect	
Bearing outside diameter -D	62 mm	61.995
Bearing bore diameter -d	30 mm	29.998
Bearing width- B	16 mm	16.01
Ball diameter - d_k	9, 525 mm	9.441
Contact angle - β	0 º	0.8′
Number of balls - n	9	9
Weight balls - G	3.55 gr	3.48 gr
The inner diameter of the outer ring track - $D_{a\ max}$	55.53 mm	55.56
The diameter of the bearing outer track opening - $d_{a\ min}$	36.5 mm	36.46
Mass-bearing weight - G_1	200 gr	195gr
Basic static load rating, radial - C_0	11.2kN=11200 N	
Basic dynamic load rating, radial - C	20.3 kN=20300 N	
Limiting speed - n_G	15000 r/min	
Reference speed - n_B	24000 r/min	
The radius of curvature $r_{min} = r_{a\ max}$	1 mm	
Fatigue limit load, radial - C_{ur}	0.475kN=475 N	
Modulus of elasticity bearing of materials	$E=2,06.10^{11}$ Pa	
Poisson coefficient	μ=0,3	

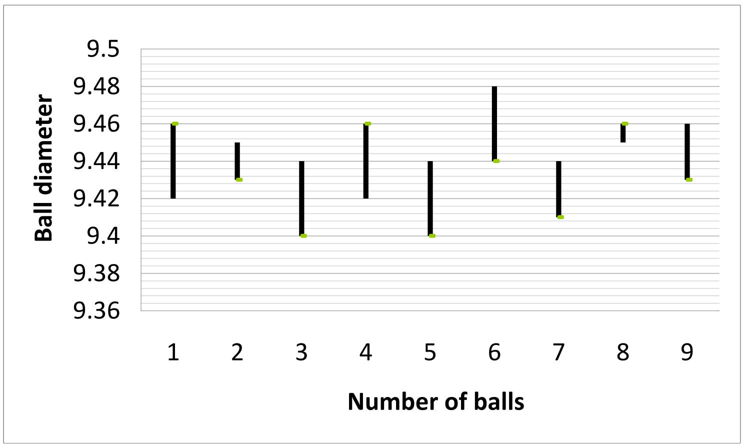


Figure 2. Changes in size balls after dismantling the bearing

RESULTS AND DISCUSSION

Types of damage in ball bearing is certainly the contact between the rolling elements and the ring or rings in the unloaded condition in point or line [8, 9]. Under load leads to elastic deformation at the contact point, so that the load transfer is realized by the small contact surfaces. Therefore, in spite of very high strength and hardness of the material parts of the bearing, as well as careful preparation, installation and maintenance, after a period of time leads to fatigue and damage to the contact surfaces [10]. The damage is the result of local contact overload and manifested first appearance of micro cracks just beneath the surface. In the future work of micro-cracks extending to the surface, which creates small holes and fissures. This damage is called pitting. Damage during work flow rapidly, and then leads to the separation of large metal parts, which is particularly acute in the inner ring of the bearing. The damage caused by unstable operation of bearing is followed with impacts and increased noise, which eventually leads to the violent rupture of the ring.
Due to variations in shape and dimensions of the bearing parts, in addition to rolling in bearing there and to a lesser extent gliding. It has the effect of abrasive wear of the bearing, in combination with further pitting damages desktop beds. Given that this damage ultimately lead to failure of the bearing, to perform tests in order to determine the operating time to the appearance of fatigue. The test consists in setting up a large number of bearing on the same test tables, and their work under the same conditions relating to the load, frequency of rotation and lubrication.
As the analysis of the results can be seen, the elements tribomechanical system of roller bearings can be caused by different types of wear and damage. On one bearing can occur at the same time several kinds of wear and tear, but, as a rule, one of the resulting species is dominant and it will fundamentally determine the future direction of development of tribological processes and finally the life of the bearing.
Which forms of wear occur, and which will be the dominant form, depends on many factors. Fatigue wear (pitting) is one of the most common and also the most typical kind of bearing wear. It is characterized by the appearance of wells in the initial stage and the destruction of the contact surfaces in the final stage of the process. Fatigue wear are exposed to all the elements of bearing: rolling elements, racks, the backrests of the inner ring.
Depending on a number of influencing factors, pitting may howl in different places on elements of tribomechanical bearing systems. Figure 3 shows the appearance of pitting on the inside of the track rolling bearings. It is obvious that pitting was not affecting the whole rolling surface but only a part, however, wear analysis shows that it is a devastating pitting.

Figure 3. Fatigue wear (pitting) on the outer surface of the bearing inner track

Fatigue abrasion damage from fatigue cracks that occur below the surface are very rare. Damage caused by fatigue, occur more often on the surface of the components inside the rolling contact, as a result of inadequate lubrication or contamination. The causes of damage can not be recognized for a long time, until the damage advances. Fatigue can be recognized as spot damage in the material inside the rolling track ball bearing. Fatigue wear occurs on the outer rolling track and on the ball (Figure 4).

Figure 4. Pitting on the outside rolling track ball bearing and the ball

Fretting corrosion is the type of wear that occurs at low oscillatory displacements of one surface over another in terms of action corrosive environments. The conditions in which they arise are: small amplitudes of composite elements (within a few tens of micrometers) and in connection with the aggravated taking of wear debris from the zone of contact; low speed, relative displacement of coupled elements (a few millimeters per second); the presence of oxidation external environment (eg, oxygen, air) chemical reactions that causes oxidization of the contact surface with the consequences of their destruction.
Wear at fretting-corrosion differs from fretting wear - wear that occurs most often in small oscillatory relative movements. The main difference is that fretting occurs in the absence of oxidizing environments in the development of chemical reactions without material contact surfaces and wear debris with oxygen. In addition to the fatigue wear on certain parts beds it is evident fretting corrosion. In Figure 5, the case of fretting corrosion.

Figure 5. Fretting corrosion on the outside rolling track of ball bearing [11]

Tracking of features mentioned mechanical systems amounted to a visual assessment of the behavior of the system as well as the measurement of vibration and temperature of the system in operation with the use of the projected dynamic process parameters [12, 13].
The outer ring of the physical new bearing 55.53 is measured at the beginning with a tolerance of ± 0.010μm, while the ring physical defective bearing extended to 55.56 mm. The inner ring of the new bearing is 36.5 ± 0.010μm, measured at the beginning, before mining 36.49 mm after exploitation-defective to 36.46 mm. So the inner ring is worn out.
Results of diagnostic research during the test of bearings on a laboratory table have pointed to the very complex conditions that have resulted in a variety of mid-functioning mechanical systems. The reasons why the bearing life of bearings in exploiting condition results differs from test results obtained in laboratory conditions and why the level of exploitation bearings assemblies of mechanical systems is more complex, should be sought in the following assertions:
- insufficient level of technical maintenance (primarily in the lubrication performance which has to be carried out in accordance with the manufacturer's bearings, which are all the same and performed periodically).

CONCLUSION

Diagnostics of the ball bearings of piston compressors for the given conditions of use and indicated primarily on all the shortcomings of the said assembly of mechanical systems in the process of exploitation, on basis of which the proposed measures are the possibilities for further exploitation (through a lifetime of ball bearings) in order to increase the reliability of piston compressors .The damage can occur in rolling elements of bearings due to defects in material, crack on the contact surfaces due to material fatigue, or defects or cracks on the rolling elements. The changes in the geometry of the bearing cause impulses when there is contact between the damaged area.

REFERENCES

[1] Stojanovic, B., Babic, M., Marjanovic. N., Ivanovic, L., Ilic, A., Tribomechanical Systems in Mechanical Power Transmitters, Journal of the Balkan Tribological Association, 18 (4), pp. 497-506, 2012.
[2] H. Ahmadi and K. Mollazade, Bearing Fault Diagnosis of a Mine Stone Crasher by Vibration Condition Monitoring Technique, Research Journal of Applied Sciences, Engineering and Technology 1(3): 112-115, 2009.
[3] Kim, T. J., Han, J. S., Comparison of the dynamic behavior and lubrication characteristics of a reciprocating compressor crankshaft in both finite and short bearing models. Tribology Transactions 47 (1), pp.61–69, 2004.
[4] Fabris, O., Grljusic, M. Compressors, University of Split, Faculty of Electrical Engineering, Mechanical Engineering and naval architecture, Split, Croatia, 2010.
[5] Desnica, E., Mikić, D., Various approaches to kinematic analysis in the process of design of piston mechanisms, Annals of Faculty Engineering Hunedoara – International Journal of Engineering, Romania,Tome VII, fascicule 2, pp.63-68, 2014.
[6] Desnica E., Asonja, A., Mikic, D., Stojanovic, B., (2014). Reliability of model of bearing assembly on an agricultural Cardan shaft, Journal of the Balkan Tribological Association, Vol.21, No 1, pp.38–48, 2015.
[7] Mário Ricci, Dincon ’09, Ball bearings subjected to a variable eccentric thrust load, pp.1-7. 8 TH Brazilian Conference on Dynamics, Control and Applications, maj 18-22, 2009.
[8] Nataraj C., Harsha S.P.: The effect of bearing cage run-out on the nonlinear dynamics of a rotating shaft, Communications in Nonlinear Science and Numerical Simulation,Vol. 13, ISSN: 1007-5704 Issue 4, pp. 822-838, 2008.
[9] Harnoy A.: Bearing design in machinery: Engineering tribology and lubrication, Marcel Dekker, Inc., Marcel Dekker, Inc., ISBN: 0-8247-0703-6, 2003.
[10] Harris, T.A.: Rolling bearing analysis, Foutrh edition, John Wiley & Sons, Inc , ISBN: 0-471-35457-0, 2001.
[11] SKF – Product Information 401: Bearing failures and their causes – Sweden, 1994.
[12] R .Tomovic,.: Calculation of the boundary values of rolling bearing deflection in relation to the number of active rolling elements, Mechanism and Machine Theory 47, pp.74–88, 2012.
[13] Mikic, D., Asonja, A., Gligoric, R., Savin, L., Tomic, M., Dynamic Solving of Rotational Transformation Matrix Using the D’ALAMBER Principle, TTEM - Technics Technologies Education Management, Journal of Scciety for Development of Teaching and Business Processes in vew net Environment in Sarajevo, B&H, Vol.7, No.3, pp.1187-1195. (ISSN: 1840-1503), 2012.

RADIOGRAPHIC TESTING OF CIRCULAR WELDED JOINTS AND STRUCTURES

Slobodan Anđelić[1], Živoslav Adamović[1], Ištvan Kucora[2]
[1]University of Novi Sad, Technical Faculty "Mihajlo Pupin", Zrenjanin, Serbia
[2]„HIP-Petrohemija" Pancevo, Serbia
e-mail: zivoslav.adamovic@gmail.com

Abstract: Detection of cracks is usually considered the most important aspect of NDE (Nondestructive Evaluation - NDE). There are many approaches to understand the choice of NDE methods. One of them is to take into account the existence of only six primary factors associated with the choice of NDE methods: The reason for the execution of NDE; The types of cracks are significant to the facility; The size and orientation of the crack, which is unacceptable; Proposed location for significant cracks facility; The size and shape of the object; Material characteristics to evaluate. The choice of method for inspection of welded parts, hard and soft solder joints for errors (which are in welding terminology referred to as discontinuities) depends on many variables, including the nature of the discontinuity, the accessibility of the compound, the type of composite materials, the number of compounds to be tested, the possibility of discovering Inspection methods, the required level of quality and economic importance.
Key words: Radiography, Nondestructive Testing, Defects in Material, Quality.

INTRODUCTION

Due to the large number, today known methods of testing materials, there are different classifications for which more clearly the similarities and differences between the individual test method. One of the first classifications of the test material is one in which it is divided into:

- Destructive testing sample (comes to destruction, permanent damage to the sample),
- Nondestructive testing sample (not permanently damaged samples) [2].

According to the mode of action of force there are different static and dynamic tests. Under static tests imply that it is carried out in a peaceful action of forces so that the voltage gradually rises, usually no faster than 10 MPa in seconds. In dynamic testing the impact force acts are frequently updated or changed by a specific law. Number of changes in load usually is in the range 3-20000 ppm. With respect to the type strains different tensile test, pressing, bending, torsion, shear, etc. with the possibility of combining them. All of these tests can be carried out under static or dynamic effect of the force so that it is possible to make quite a number of different combinations. Mechanical testing is usually carried out at room temperature, but also on the low, that is, elevated temperatures [5].

BASIS OF DESTRUCTIVE TESTING

In the production of welded structures NDE often makes the final operation. Inspection of the building is aiming to detect and reviews errors that may affect the function and structural integrity. Allowable defects must be remedied and fix those positions. Errors may occur in the weld, heat affected zone (HAZ) and base material, located on the surface or in the interior. For their detection is of particular importance selection of optimal methods and techniques of NDE.

Operating parameters of welded structures during operation affecting the eligibility criteria and scope of errors NDE. Generally, welded construction is not completed until the required quality cannot confirm the appropriate non-destructive inspection [6].

RADIOGRAPHIC TESTING OF MATERIALS

Radiographic testing method is one of the earliest methods of nondestructive testing of materials, and today is its use mandatory in the industry. Using different sources of ionizing radiation (gamma, X, neutron, proton) and opportunities for detecting discontinuities in different ways, to the widest application of radiographic tests in various industrial sectors. However, the use of radiographic testing method requires specially trained personnel for both the method and testing techniques, and for the safe use of sources of ionizing radiation in accordance with the Law on Protection against Ionizing Radiation and accompanying regulations.

For the application of radiographic testing methods are used to various standards and can be grouped as standards which:

- define the requirements for training and certification of personnel who perform testing (SRPS EN 473, ISO 9712),
- define the general principles of the method (EN 444, JUS ISO 5579),
- applied in certain industrial sectors (SRPS 1435, SRPS 13480-5, EN 10246-10, EN 12681),
- relating to equipment and supplies (EN 462-1, 2, 3, 4, 5, EN 584-1, 2),
- define the types of irregularities (JUS CT 20, ASTM ...),
- define the eligibility criteria (JUS ISO 5817).

For radiographic testing method is required personnel who have been trained and certified according to the standard SRPS EN 473.

Radiographic examination of the material is based on the ventilation of the material and the registration of changes in the intensity of radiation passing through the material and the analysis of changes that give information about the homogeneity ventilated materials. During the passage of radiation through the material a certain thickness, there is a change in the intensity of radiation due to the interaction of radiation and material that are registered detection system. Radiographic method using X-ray film as a detection system which moves the surface distribution of the intensity of radiation that passes through the test material and the fall of the movie. After chemical treatment of exposed film, the difference in the values of the intensity of radiation is manifested as a difference in the density of opacity on chest x, defining the shape of discontinuity. The density of opacity radiographs depends on a number of factors, such as:

- energy spectrum and intensity of the radiation falling on the film,
- exposure time,
- the type and thickness of material to be tested,
- characteristic X-ray film,
- characteristics of doping foil chemical processing etc.

Schematic representation of the control radiographic control methods is shown on the next figure.

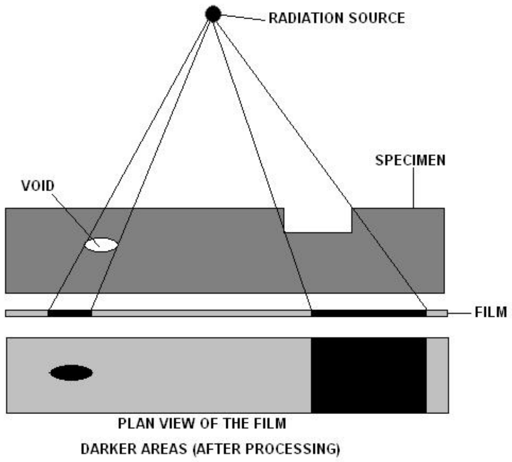


Figure 1. Schematic Representation of Radiographic Quality Control

Classification of radiographic techniques

Radiographic techniques are:

- Class A: basic techniques;
- Class B: improved techniques.

Techniques Class B should be used when a class does not provide sufficient sensitivity. Techniques better than class B are possible and may be approved by the Contracting partners specifications of all relevant test parameters. The choice of radiographic techniques should be agreed between the interested parties.

If, for technical reasons, it is not possible to satisfy one of the conditions specified for Class B, as well as the type of radiation source or distance, f, from the source to the property, the parties may agree that this condition be taken for Class A. Loss of sensitivity being compensated for by increasing the minimum density to 3.0 or choice of contrast film systems. Due to the higher sensitivity compared to class A, the test sections can be considered as if they were tested in Class B. Circular welded steel pipes, most of the application is covered using a technique class A. Class B Techniques are provided for the more important and difficult application where class A is not sensitive enough to detect all the expected errors. Class B includes techniques that use only fine-grained films and lead protective film; therefore generally require a longer exposure. Depending on the quality level may compound, using radiographic techniques to A or B, in accordance with EN 1435, as shown in table 1.

Table 1. Radiographic testing

Quality levels according to SRPS EN 25817 or EN 30042	Testing and levels according to SRPS 1435	Acceptance levels according to SRPS EN 12517
B	B	1
C	B 1)	2
D	A	3
1) the largest area of exposure should be one that meets the requirements of class A in EN 1435		

ACCESSORIES AND EQUIPMENT FOR RADIOGRAPHIC TESTING

Aeration of the material to be tested using the Ionizing radiations. Depending on the type of ionizing radiation, there is the use of different devices for broadcasting ionizing radiation. The industries most used X and γ ionize radiation and therefore must be familiar with the types and characteristics of devices that emit this radiation.

The Sources of γ Radiation

As γ radiation sources of radiographic examination are used isotopic sources. Isotope of γ radiation sources used for radiography is generally made of β unstable artificial radionuclides, hermetically packed in carriers of pure aluminum or stainless steel.

Figure 2. Portable Protective Carriers With a Radioisotope for Field Testing

The sources of γ radiation, which are commonly used for radiographic examination of metallic materials, are iridium-192 (Ir-192), cobalt-60 (Co-60), thulium-170 (T-170), 169-ytterbium (Yb-169) and more recently time selenium-75 (Se-75).

The Sources of X Radiation

For Aeration materials used thermal bremsstrahlung X rays produced in the X-ray devices voltage 100-500 kV and devices such as Van de Graf generator, linear accelerator and betatron, which is obtained by X radiation energy 1 MeV to 30 MeV. Each X-ray device consists mainly of three components:

1) X-ray tubes,
2) sources of high voltage and
3) command and control units.

Figure 3. Standard Industrial Equipment Appliances for X-rays Testing

Roentgen Films

Roentgen films consist of a flexible film of cellulose acetate (substrate) on which a thin layer over the thin bonding layer inflicted by a piece on both sides of the photographic emulsion of silver halide. When ventilation of the material passes through the test material, interacts with the emulsion of the film and a latent image which is chemically treated and received a radiogram.

Figure 4. Packaging of Radiographic Films

Roentgen film is sensitive to other electromagnetic radiation, as well as the many other factors that can act in the process of preparation, exposure and chemical treatment and cause false discontinuity.

The Strengthening Foil

The strengthening foil enhancing effect of radiation exposure is in the movie. They are placed in front of and behind the film and their task is to X or γ radiation is converted into electronic or by light, which is much more sensitive photographic emulsions. According to the material of which they are made, there are different:

- foils of heavy metals (mainly lead) and
- fluorescent foil.

Cartridge - Cassettes For The Films

Cassettes for the films can be flexible and rigid. They are made of opaque plastic, rubber and thin aluminum sheet standard different sizes, depending on the dimensions of the film. Cassettes protect the film from light, dirt and harmful gases.

Figure 5. PVC Cassettes for X-ray Films [7]

Identification Tags

Usually, these are the letters and numbers of standard sizes and are made of lead or depleted uranium injected in plastic film. Tags are placed on cassettes with the film, in order to bring radiograph obtained in connection with the testing place.

Figure 6. Lead Letters And numbers

Indicators of Images Quality

The main objective radiographic examination is to detect internal discontinuities, which is achieved primarily by creating high-quality radiographs. Achievement of this goal depends on a number of parameters associated with the characteristics of sources of ionizing radiation, the subject matter, radiographic film and chemical processing of exposed film, which directly determines the sensitivity of radiographic techniques. To determine the quality of the radiographs are used to special standards that Ventilates together with the subject matter. On radiographically these standards registered on the basis of determining the minimum size standards, which is registered on the radiograph, it is possible on the basis of the requirements of standards, norms, specifications, agreements, etc., to determine the quality of radiographs. These standards are referred to as indicators of the quality of the image, or penetrometers.
Indicators of quality are made of a material identical with the material to be tested. All indicators are standardized and standard designation must be visible on the display. The standard defines the appearance, description, dimensions, materials and method of marking. The choice of indicators is done on the basis of the type and thickness of material in order to achieve high-quality radiographs. For radiography using the indicators of different structures, such as:

- wired indicators,
- stepped with holes
- plate, etc.

Figure 7. Wire and flat indicators

Equipment for Viewing Radiographs (Illuminations)

Illuminators are used for polymerization of radiographs to detect in homogeneities in the cases examined. Illuminator is a source of diffuse light or certain continuous variable intensity that is transmitted through the surface of a standard size and shape. In recent illuminator intense brightness of the screen establishes the foot control. To analyze the details of radiographs are used and reflectors with aperture, magnifying glasses for aggrandizement (10 times), and other supplies.

Figure 8. The Illuminator

RADIOGRAPHIC TESTING OF STEEL TUBES

There are different settings mutual position of the film and the source of radiation, depending on the size and accessibility of the compound in the steel tube:

- Film inside - source of radiation outside;
- Film outside - source of radiation inside;
- The film and the source of radiation outside - double wall, double vision;
- The film and the source of radiation outside - double wall, single image.

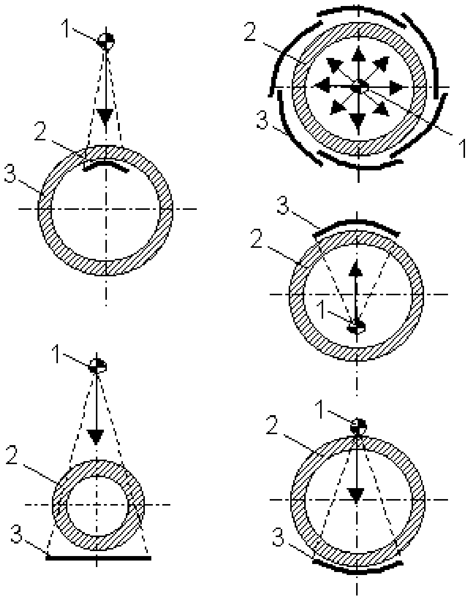


Figure 9. Schematic Representation of Radiographic Inspection of Welded Joints in Cylindrical Elements [8]
1 - source of radiation, 2 - welded element, 3 – radiogram

If it is possible, especially when the greater part of the radiation utilized to cover the area you need to irradiate, it is recommended that the operator set the device so that the axis of the device for emitting parallel tubes that are radiographically examined. This picture best defined even at the edges of the film, and achieved an even distribution of radiation intensity. ISO 1106-3 is not determined by radiographic criteria for eligibility of compounds, but it is taken into consideration with used radiographic technique. In addition to the usual meaning of "pipe" refers to the second cylindrical body, such as pipelines, jackets and boilers pressure vessels. If the techniques described in SRPS ISO 1106-3 correctly used, it should be possible to without difficulty, given IQI values listed in the SRPS ISO 2504 as minimum requirements. However, the technique of double wall thickness of the steel in the determinations in SRPS ISO 2504 refers to the double wall thickness.

Selection of Welded Joints for Radiographic Testing

In the selection of the initial samples are chosen welds loaded in the critical locations. The smallest percentage of compounds that must be radiographically examined, when it comes to pipelines, respectively, pipelines and oil pipelines, above and below ground, is defined project - technical documentation on which to run machine - installation works. The supervisory authority has the right to require large amounts of weld pipelines in case the need arises. For Radiography of welds should be engaged in legally authorized, specialized and equipped with a specialist company to record welds, developing films and their interpretation. Each individual tube, pipe element or device shall be visually examined just before installation to determine whether there is any defect that could adversely affect the usability of the (Art. 34). All welds on the pipeline, and product pipelines must be visually inspected after welding and before applying other methods of nondestructive testing (Art. 38) [3]. Testing of welds nondestructive must be made by the whole extent of the welded joint. Non-destructive testing can be handled by a legal entity that meets the requirements of SRPS ISO / IEC 17025 for the appropriate type and method of testing.
Depending on the grade belt smallest percentage of welds that must be examined radiographic method is:

1. belt of I grade 10%
2. belt of II grade 50%
3. belts of III and IV grade 100%.

Radiography should be at a rate that follows the welding operation.
Of the total of completed welds in one day, determined by the number of welds for radiographic imaging have the same day to record and film immediately to develop the next morning and could not control the welds perform any repairs or deletion. Each radiograph should be wearing that bears the number of welders and weld recorded. All welded connections established with an error needs to be repaired or cut out of the pipeline and re-welded and re-record them [4].
All these tests welds should be sure to attend the supervisory authority of investors, where test data are entered in the log book or welding, and provide guidance for all necessary repairs, or cutting out defective welds. For radiographic testing and inspection of X or γ rays, the visibility of errors depends on the details of radiographic techniques. Since the quality of the radiographs cannot be fully verified using the image quality indicators (IQI), the standard SRPS ISO 5579 explains the basic rules and technical procedures for obtaining good quality radiographs.

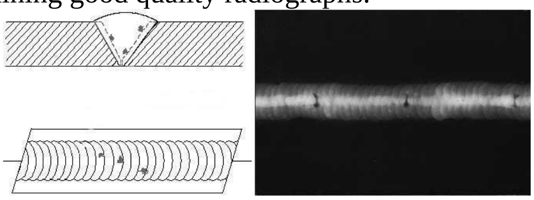


Figure 10. Radiogram of Slag Inclusions

The contractor is bound to the person who performs the radiographic inspection of welded joints to submit a request for examination which should include the number of welds with defined diameter and wall thickness of the pipeline being tested.

TESTING REPORT

For each radiograph, or a series of radiographs should make a report on the examination of the data on the usable radiographic technique and any special circumstances that allow better interpretation of the results. Details about the format and content should be regulated in a separate standard application or agreed between the parties. If the test is carried out only by that standard, the report should contain at least the following information: company name Examiners, the number of reports, object, material, workmanship state, nominal thickness, radiographic technique and class, used labeling system, setting and testing plan for installation of the film, radiation source, type and size of the focal point and used equipment, system chosen film, foil and filters, tube voltage and current sources, exposure time and distance from the source to the film.

CONCLUSION

In the process industry, where it monitors the condition of the equipment during the production, control cannot be typed, but must be in developing and preparing to have in mind the technological conditions of work, as well as information about the places where the first can expect stronger damage and fluid leaks. On the basis of these data can be accessed by choosing the most appropriate imaging techniques, determining the necessary parameters, as well as determining the dynamics of the recording. Until the advent of damage to tubing installations usually comes to tubing knees, reduce, near the welded joints (especially when the root layer of poorly executed), in front and behind the valves and latches and push the suction part of the pump. Practically radiographic testing in process conditions takes place by first based on literature, experience of production and statistical monitoring determine critical locations in plants (for equipment and piping systems). For each potentially critical spots analyzed working conditions during operation. When selecting radiographic methods for control equipment in exploitation conditions should be kept in mind, that the best results are achieved by profiled and normal radiograph technique.

REFERENCES

[1] API 1104: Standard for Welding Pipelines and Related Facilities, dostupno na: https://law.resource.org/pub/us/cfr/ibr/002/api.1104.1999.pdf
[2] Molnar, R.: Mašinski materijali – praktikum sa radnom sveskom, Visoka tehnička škola strukovnih studija u Zrenjaninu, Zrenjanin, 2000.
[3] Pravilnik o tehničkim uslovima za nesmetan i bezbedan transport naftovodima i produktovodima, Ministarstvo energetike, razvoja i zaštite životne sredine, Beograd, 2012.
[4] Tehnički uslovi za projektovanje i izvođenje postrojenja za prenos i isporuku toplotne energije, JP Toplifikacija, Požarevac, 1999.
[5] Terzić, P.: Ispitivanje materijala – mehanička ispitivanja, Univerzitet u Beogradu, TMF, Beograd, 1988.
[6] www.scribd.com/doc/140581970/Kurs-IWE-i-IWT-2012
[7] www.trimid.rs/proizvodi/radiografska_ispitivanja.8.html
[8] www.sfsb.hr/kth/zavar/tii/kbr_met.html

APPLICATION OF INDUSTRIAL ROBOTS IN WELDING

Slobodan Anđelić[1], Živoslav Adamović[1]
[1]University of Novi Sad, Technical Faculty "Mihajlo Pupin", Zrenjanin, Serbia
e-mail: zivoslav.adamovic@gmail.com

Abstract: The most important advantages of automated welding are precision and productivity. Robotic welding improves the reproducibility of the weld. Once the robot is programmed correctly, it will produce precise, identical welds every time on the parts of the same size and specification. Automated movements of gun reduce the potential error, which means waste reduction and conversion. With robotic welding can be achieved by increased productivity. The robot can not only works faster than humans, but it can operate 24 hours a day, 365 days a year without stopping, which is much more efficient than manual welding, provided that it is fully equipped and optimized. Another benefit of automated welding is lower labor costs. Robotic welding also eliminates the risk of injury by shifting operators away from harmful vapors and molten metal near the weld arc.
Key words: Robots, Spot Welding, Arc Welding

INTRODUCTION

Welding processes that consist of a lot of repeatable tasks on similar parts would be useful for automation. Number of parts of any kind that needs to be welded determines whether the process will be automated or not. If a parts needs to be adjusted in order to fit, or if they distances that need to be welded too wide, or if they are every time in different positions of the automatic process, that would be difficult or impossible. Robots are useful for repeatable tasks or similar parts that require more than one axis to be welded or where access is difficult parts. Industrial robot is multipurpose, reprogrammable, manipulating and automatically controlled machines, with more degrees of freedom, which can be in a fixed position or mobile, used for automated application in industry.

STRUCTURE AND TYPES OF INDUSTRIAL ROBOTS

The Anthropomorphic Robot Configurations

In most robotic configurations, even in this, the first degree of freedom (calculated from base) and the rotational axis of the first joint is vertical. This joint provides a complete rotation around the vertical axis robot. Axes of second and third joints are parallel, horizontal and perpendicular to the axis of the first joint. The second and third movements of the wrist to ensure that the top of the minimum configuration is positioned in an arbitrary point in the vertical plane containing the axis of the first joint. Sketch kinematic structure and the anthropomorphic robot image configurations they shown in Fig 1. The mechanical structure of the anthropomorphic robot configuration looks like a structure of the hands of man and therefore to the second segment of the minimum configurations often used the name of her arms, and the third forearm. The main characteristic of the anthropomorphic robot configurations that may go beyond the obstacles that got in his way.

Figure 1. The Anthropomorphic Robot Configurations

By looking at the kinematic scheme of this configuration, we see that the starting example of the third joint influences the intensity of the moment around the axis of the second joint, even in the event that the joint does not move. This influence is called entanglement. Therefore it is said that if the movement of one joint affects significantly the drive torque (or driving force if they translational joints) other joints, observed configuration has a significant coupling between the joints. The anthropomorphic robot configurations are typical in that they have a large entanglement between the joints.

The Polar (Spherical) Configured Robot

The axis of the first joint of spherical configuration is directed vertically upward, until the second axis horizontal and perpendicular to the axis of the first joint. The third joint is translational. Thus, in a spherical configuration type and schedule the first two joints are the same as in anthropomorphic. The kinematic diagram of spherical configuration is shown in Fig 2. As previously, the second and third joint allows positioning of the top of the minimum configuration at any point in the vertical plane, while the vertical plane of rotation around the axis of the first joint to top of the robot power is positioned anywhere within the workspace.

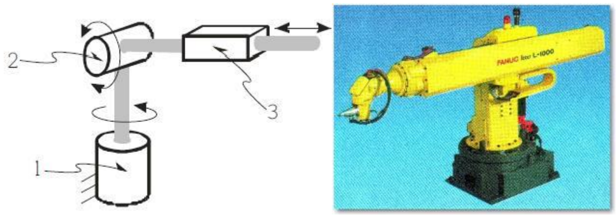


Figure 2. The polar (spherical) configured robot

This configuration got its name based on the shape of the workspace that is part of the sphere, and considering that the polar angle of rotation of the second joint and the continuation of the third joint corresponding polar coordinates. Access to the workplace should be free of obstacles, considering them a robot of this configuration cannot be bypassed.

The Cylindrical Coordinated Robots

The minimum configuration of the cylindrical coordinated robot has one rotational and two translational joint. In this configuration, the first segment is a rotating pole on the vertical axis, so the first rotary joint and placed in the same manner as in the previous configuration. The second and third joints are translational (linear). A wasp second joint is vertical. This means that its movement raises or lowers the complete structure that is located away from the wrist to the top of the robot. A wasp of the third joint is horizontal, so it’s starting attaching nearing and departing or gripper relative to the vertical pole of the robot.

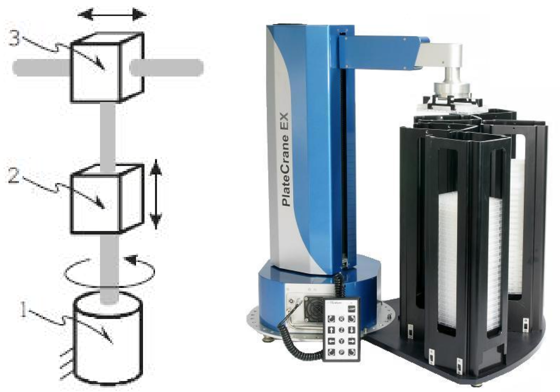


Figure 3. The Cylindrical Coordinated Robots

This configuration is called a cylindrical configuration because of the shape of workspace that is part of the cylinder. Robots of these configurations have very little entanglement between the joints.

The SCARA Configured Robot

The SCARA configured robot (Selective Compliance Assembly The robot Arm), have two rotational and one translational joint. Two mutually parallel rotational joint with vertical axes of rotation have been placed based on the pole, so that both segments are moving in the horizontal plane. End of the second segment of a translational joint, whose axis is also vertical, seen in Fig 4. A wrist grip has often only one degree of freedom and the reversal of the vertical axis.

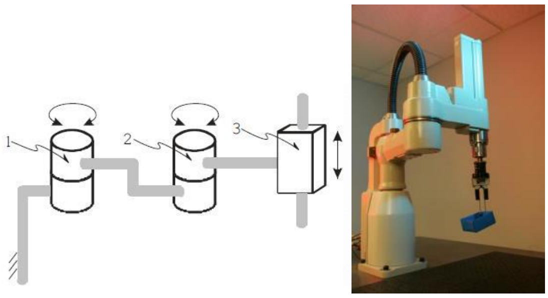


Figure 4. The SCARA Configured Robot

Accordingly, SCARA configured Robots typically have only four degrees of freedom. Motions of rotating joints are positioned translational joint in desired point horizontal plane, then lowered thinner translational joint leads handle to the desired position within the workspace. SCARA configuration has very little entanglement between the joints since the gravitational load completely alone receives mechanical structure of rotating joints.
The SCARA configured robot was first implemented in Japan in 1972, and are generally intended for assembly tasks. They are characterized by large precise of positioning and speed, as well as the relatively large bearing capacity. The biggest drawback SCARA robot comes from its construction-set is high and occupies a large part of the space above the area in which you perform work tasks, so that the area must be free.

The Descartes Configured Robot

The minimum configuration for these robots consists of three translational joints whose axes parallel to axes Descartes coordinate system. And hence the name of this configuration can be rectangular, Cartesian or gantry, if the robot is placed on the base, which is applied over the workspace where top-down approach. Considering the type and arrangement of joints in of this robot configuration, contributions to each of the joint movement of the gripper is obvious, which is a program, or even manually guiding considerably facilitated.

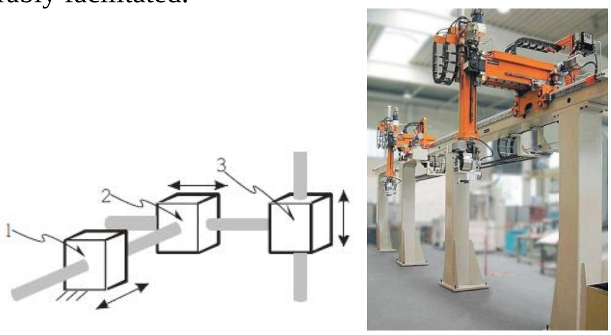


Figure 5. The Descartes Configured Robot

Workspace is a parallelepiped whose dimensions depend on the extent of movement of each joint. Robots of these configurations have very little entanglement between the joints. In order to reduce occupied space in the drive robots such a configuration is often put on the stand that raise over working machine rails (gantry robot). Naturally, in these cases, access to the workspace working machines must be free from above. The plinth may be such that the robot can go to regular observance and a few machines.

A Parallel Robots

All previously described configuration had the basic form of the kinematic chain, and only was displaying differences in types and dispositions joints. The parallel robots in this regard by the structures are different, but we believe that it takes them mention the here. They represent the two platforms (the nominal position) and these platforms are parallel, that are associated with variable length segments? One platform is considered the base (upper platform), and the other is working whose position and orientation is controlled and it is to handle.

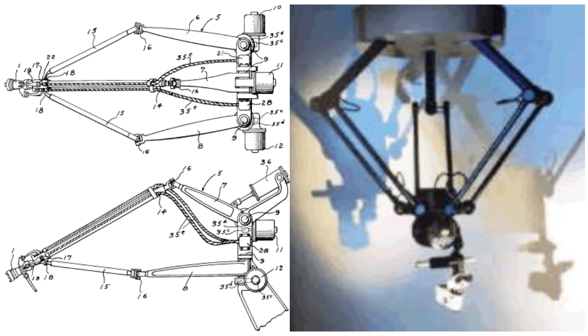


Figure 6. A Parallel Robots

By changing the distance between the corresponding joints on the base and work platform is changing the position and orientation of the working platform on which to set or grab a tool that the robot is carrying. Changing the distance between the joints on the base and the working platform can be implemented or segments of variable length (telescoping segments with translational joints) or as elements of a rotary joint as show Fig 6. Robots of this configuration are characterized by extreme agility (speed of movement when crossing from one position in the second) and relatively low weight in relation to capacity since each segment (arm) carries only one-third of the load as opposed to the type of robot kinematics chain where each segment is suffering the entire load.

USE OF INDUSTRIAL ROBOTS IN WELDING

For the introduction of robotization, mechanization and automation in welding there are a number of reasons, two of which are the most important:

1. increase productivity and quality,
2. humanization of work.

A rough estimation of some of the welds on the following points:

- 75% of the parts for welding products in the annual series 100-5000
- 85% of the parts for welding weighs less than 40 kg
- 80 % of welded joints are corner joints
- 70 % of parts for welding has a thickness of 3, 4 or 5 mm
- 40% of the welds are circular
- 85% of the welds are less than 2 m.

This information should be taken in mind when thinking about introducing robotization. The main arguments for the introduction of robotization are: lack of experienced welders and a long period of training. Robots are most frequently used for resistance spot welding, and increasingly for arc welding, in particular procedures for gas shielded and submerged. The task of the robot for arc welding in the general case to make it more longer or shorter compounds in different positions, with different thicknesses of sheet metal and the various forms grooves. Most production welding process can be used in automated applications. The most popular is the GMAW process with full wire (80% of applications). This process is best for most situations with a large production because it does not require cleaning after welding.

MIG welding process (Metal Inert Gas) or arc welding arc wire to protect neutral (inert) gas (Gas Metal Arc Welding - GMAW), is a type of arc welding. It is a semi-automatic or automatic welding process, which uses constantly bringing bare wires as electrodes for welding, and is protected with an inert (neutral) or semi-inert mixture of protective gases (usually argon), to protect the welded joint from contamination. The process is faster than manual arc welding. The electrode is also the additional material, which is usually homogeneous with basic material that is welded.

The robot is programmed to keep the welding process, depending on the location, at the right speed fissure. While the welder based on experiences and perceptions of visual and acoustic discovered and eliminated interference in the welding process (e.g. change of speed as delivery wire), the robot is deaf and blind. Therefore, a robot with fixed programmed welding parameters gives good results only with accurate and expensive preparation and constant monitoring. To reach the robots the ability of welders to react to changes in the geometry of groove, ports and baths, they would have to have the management systems that simulate hands, senses and brain of welders.

The relation to the robot of welders need special attention because of it definitely depends on the success of robotization. For now relatively modest world experience shows that robots give the best results in conjunction with the educated welders who possess a high level of knowledge of welding and a sufficient level of knowledge in programming.

Therefore, special attention must be paid to education, to welders and technicians (engineers) for welding, which is the essence of the message from the firm of Gary Howard Hobart (world leading company in the production of the robot), who said that the timely education key to success in robotization. It is the welding engineer responsible for the initial preparation, construction parts for welding and choice of high production welding technology.

Benefits Of The Robot Welding

The most important advantages of automated welding are precision and productivity. Robotic welding improves the reproducibility of the weld. Once the robot is programmed correctly, the robot will produce precise, identical welds every time on the parts of the same size and specification. Automated movements gun reduce the potential error, which means waste reduction and conversion. With robotic welding can be achieved and increased productivity. The robot not only runs faster than humans, but it can operate 24 hours a day, 365 days a year without stopping, which is much more efficient than manual welding, provided that it is fully equipped and optimized. Another benefit of automated welding lower labor costs.

Robotic welding also eliminates the risk of injury by shifting operators away from harmful vapors and molten metal near the weld arc.

THE ARC WELDING ROBOTS

During the short time that the industrial robots used for welding, robot's arm is most popular. Welding's robot's arm is replaced almost all other types except gantry robot, which is used for very large and very small robots.

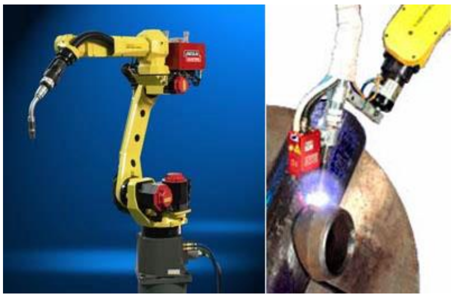


Figure 7. The Arc Welding Robots

The main reason for the popularity of the robot's hand is because it allows handling the gun for welding in the same way as you would a man did. The angle of the welding and angle times may change to provide a quality weld in all positions. The robotic arm allows arc welding in places that are inaccessible or difficult to reach. Although the robot cannot perform identical movements as an operating man, the robot arm is very close. In addition, the robot arm is most compact and has the largest working environment relative to its size. Typically, robots have five or six axes for free programming.

SPOT WELDING ROBOTS

The robots can repeatedly to moves the gun at each location and position versus the welding weld. They also can be to repeat the programmed schedules welding. The operator who wielded by hand is not able to weld well as the robot due to weight of the gun and the monotony of work. Robots for spot welding should be to have six or more axes and should be able to approach the counts in the random field from every angle. This allows the flexibility to carry a gun position welding. Some of the positions that are strange to the operator, such as welding upside down (bottom), are easy tasks for the robot.

Figure 8. The Spot Welding Robots

THE COMPONENTS INTEGRATED INTO ROBOTIC WELDING

Robotic equipment performs and controls the robotic welding process. Equipment for automatic arc welding is different from equipment designed for manual welding. Automatic arc welding consists of heavy highly repeatable cycle and welding equipment must be able to work in these conditions. In addition, the equipment must have features and controls to interface with the main control system. To be exercised arc welding, required a special kind of electricity. To make the robot welder could properly perform his task he needs a number of auxiliary systems:

- power sources for arc welding,
- gun for welding,
- wire feeder,
- fixing and positioning of parts,
- gun cleaner and
- TCP-unit calibration.

Power Sources For Arc Welding

The power source must deliver a controlled electric powered towards the demands of the welding process. Normally, the current is between 10 and 35 Volts and between 5 and 500 amps. Various welding procedures have specific characteristics that require arch-specific output welding machines. Automatic machines for arc welding may require complex power source than the one used for semi-automatic welding. Automatic welding machines usually communicates electronically with the power to control welding program and achieve the best results. The power source for arc welding is designed to provide electricity appropriate values and characteristics to would provide a stable arc welding.

Figure 9. Power Sources For Arc Welding

There are three different types of power sources for arc welding, which are different and static characteristics of the output curve. "Constant power" is conventional type of power source used for many years for manual welding with electrodes. It can be used for welding under a protective layer and the tungsten arc welding. Power of source "constant voltage" is commonly used for welding wire throttle and small diameter cored arc. Power of source "constant electricity" is commonly used for gas tungsten arc welding or plasma welding. The choice depends on the power supply:

- the processes
- the amount of power
- the power requirement
- the economic factors and convenience.

The Welding Gun

The system of automatic welding gun is used to forward the electrodes in the arc, to conduct current to the electrodes and to be a shield for arc area. There are many types of welding guns and gun selection depends on the welding process, changes in the course of welding, welding current, size of electrode and resources protection. Guns can be classified into categories according to the method of cooling. Guns can be cooled with water or air that circulates from environment. The gun can be used for welding electrode such as welding gas or flux cored bar, or gas for the protection and may not be used. Guns differ in dependence whether they are real or at an angle. Pistols angle is commonly used for robotic welding, to be able to accede to the weld. The main function of the gun is to carry welding current to the electrode. This means that the process of melting electrode welding gun conduct current to the electrode while the electrode moves through the gun. Another major function of the gun is to protect the gas, if it is used.

Figure 10. The Welding Gun

Welding gas is used for shield gas that can be active (usually carbon dioxide or inert gas, argon, CO_2 or oxygen). Welding guns are usually placed at the end of a robot with the appropriate base. It is preferable to use collision protection to prevent damage to expensive equipment in case of gluing electrodes, crash during installation or start-up.

The Wire Feeder

The wire feeder is used to add fill metal during welding robot. This allows flexibility in the determination of different amounts of wire that needs to be added to meet the requirements for assembly. Wire feeder is usually placed on a robotic arm, separate from the power source. For robotic welding, it is necessary to have a control interface between the robot controllers, power source and wire feeder.

Figure 11. The Wire Feeder

The system of wire feeder has to fit with the welding process and the type of power source used. There are two basic types of wire feeders. The first type is used for melting electrode welding processes and it's called the electrode wire feeder. This part of the welding electrode processes and melted metal is transferred from the electrode arc welding and becomes sludge. There are two types of electrode wire feeder. Power Source "constant power" requires a system in which the feeder is sensitive to changes in voltage where the amount added is changing constantly. System "constant-voltage" requires constantly adding wire during the welding process. Another type of feeder is known as a cold wire feeder and is used for arc welding with argon. The electrodes are not used in this cycle and filling wire which melts in the heat of the arc and the arc becomes welded metal.

Fixing And Positioning Of Parts

In order to successfully put together the parts in robotic applications, components must be arranged precisely and firmly keep in one place during welding. This means that you should pay particular attention to the design discipline and tools that will adhere to the parts straight. Tools must provide quick and easy setup, and have firmly to hold the parts in place while the parts not welded. Also, tools for compliance must provide welding gun approach each point welding. Although special positioners provides more options and improve the capabilities of robotic systems, the starting point for positioning parts in robotic welding can be a discipline that is used for manual welding. Useful working environment the robot is limited because the way in which the welding gun set does not allow the gun to approach the spot welds to be. Special positioners eliminate some of these limitations so that make jobs more accessible to the welding gun. Positioners used with the robots have to be more accurate than those which are used for manual or semi-automatic welding. In addition, the robot controller must be able to control of the positioner and must be compatible with those of the robot. This allows the simultaneous, coordinated movement several axes at the same time during welding. Attaching and removing the fixed clamps or positioners may require a lot of time and is not practical. Often it is much more efficient to use two or more fixed on the rotary positioner discipline, even though the initial price more expensive. The operator can set the parts on a rotating table, while the robot welds the same time. It is obvious that this speeds up the process and forces the robot to weld as possible.

The Gun Cleaner

Periodic cleaning guns for arc welding are required for reliable and properly functioning equipment for robotic welding. Highly repeatable cycles of automated self-cleaning cycles require gun.

Figure 12. The Gun Cleaner

There are systems that inject anti depositional Substance in the gun. Also, there are tools that are used to remove sediment that clung and cutting wires. The control system activates the weld cleaning system automatically in the required intervals.

TCP – Unit For Calibration

The sensor at the end of the robot arm calibration and the center of the coordinate system tools are vital to the successful implementation of the system. Analysis of profile data produced relative position of the seam in relation to system tools. If the known position of the sensor coordinate system relative to the final position of the robot, and if the known position of the coordinate system of the tool relative to the last position, then you can use the data to accurately position the TCP relative to the subject of welding.

Figure 13. TCP - Unit For Calibration

Although the sensor at the end of the hand is used to solve the problems of accuracy and error positioning of parts, this can only happen if the frame sensor, the last position, and frame accurate tools known in relation to each other. If the sensor by any chance moves, the robotic units become identical systems for the production of garbage. Precisely for this reason, companies that are supposed to benefit from the sensor welding, oppose the use of these systems. What is needed is a technique that allows it to automatically calibrate frames, but also a system that allows you to quickly determine if calibration is required. The latter possibility is perhaps more important in practice, because it can be used to indicate that calibration errors arise as a result of an unexpected event during welding.

CONCLUSION

Robotic welding is one of the most frequent applications of industrial robots and this is an area where all together the speed, precision and uninterrupted operation of the robot, whether it is in question arc, or some other spot welding. Basic features of the robot autonomy in work, flexibility and programmability: easy they are changing the parameters of work and very quickly can be given a completely new work assignment. In almost all the jobs that they entrust, robots appear to be significantly more accurate and faster than humans. Also, the robot has no eight-hour working time, does not tire at screwing, do not waste time in small-talk phone or with colleagues ... Perhaps most importantly, the robots can work in conditions that are not good for human health or may even threaten his life .Robots work faster than humans, and work is always the same - precisely and accurately - so the end result is higher quality product or at least consistent quality. In addition to savings in time and manpower, the savings could be in the fact that robots could replace better -paid skilled workers (welders) less qualified worker who serves robot (digester). It is not difficult to assume that robots are not cheap. Price, of course, depends on the application. For the simplest robotic system should be set aside 50,000 Euros, while, for example, the entire line of dozens of robots for assembling bodywork in the automotive industry can cost up to 50 million Euros. Purely economic point of view, the robot can be worth it, but for six months, which shows just examples of robot - welders, provided that wisely and extensively employ.

REFERENCES

[1] http://automatika.rs/baza-znanja/mehatronika/industrijski-roboti.html
[2] http://automatizacija1.etf.rs/poglavlja/Robotika%201.htm
[3] http://cent.mas.bg.ac.rs/nastava/teh_mas_obrade/prezentacije/tmoa18_2.pdf
[4] http://ftn.mrdnise.com/fajlovi/35-industtrijska781.pdf
[5] http://mehatronika.gomodesign.rs/primena-robota-u-industriji/
[6] http://www.icm.rs/robotika/pdf/RobotskoZavarivanje.pdf

Session 4.

Maintenance

GEAR FAILURES EMBEDDED IN MANUAL GEARBOXES

Miroslav Milutinović[1], Spasoje Trifković[1], Aleksije Đurić[1], Nikola Vučetić[1]
[1]University of East Sarajevo, Faculty of Mechanical Engineering, East Sarajevo
e-mail: m.milutinovic82@gmail.com

Abstract: During exploitation motor vehicle gearboxes are exposed to varying conditions. The changes are stochastic and dependent on many factors. These changes directly affect also to the gearboxes damage, and therefore the gears damage. Different types of damage can occur on gears, so that this paper will give focus on the damage on gears. According to DIN 3979 over 20 types of damage appearing on gear are given, while in this paper only damages on gears that are in gearboxes embedded will be presented. The paper contains the results of the damage percentage of manual gearboxes and the results of cumulative damage of manual six-speed gearboxes.
Key words: gear, gearbox, micro pitting, pitting, scoring, scuffing

INTRODUCTION

During operation of the gearbox, gears occupy a very important place. Defects and damages during the work of gearbox occur on the gears, so diagnosing of failures shows that the received signal is efficient and suitable for early detection of local failures of gearboxes [1]. In [1] monitoring and diagnostics of industrial gearbox was carried out. According to the lowest spectrum that is based on the current frequency spectrum, new parameter was developed. The parameter for estimation of the gearbox damage, on the basis of real measured signals, has been proved as insensitive to variations due to changes caused by various speeds and loads.
During operation of gearboxes, gear tooth flanks are exposed to the contact pressures, and therefore the combination of rolling and sliding [2]. This kind of load can cause a specific type of fatigue that is called rolling-sliding contact fatigue [2]. In order to successfully construction and dimensioning of gear pairs, in [2, 3], the posible damaged of gear pairs due to fatigue are given, as well as the mechanisms that lead to their occurrence.
During the work of gearbox comes to damage of gears, bearings, couplings, seals, etc... The damage speed of these components are influenced by the working conditions of gear. Based on years of research the authors of [4] presents the results which indicate that all gear failures occur due to the frequency of the system startup. Summarizing the results, it was concluded that the bearings are subject of damage more than 49%, while the gear failure occurs 41%. The remaining 10% damages are related to the other components [4].
Based on the Neale Consulting Engineers Ltd (NCEL) report, mistake making gear, outdoor dirt, the input torque of the gearbox, oil and metal particles in it, bearings damages and unexpected loads of bearings have been established as primary effects which may cause the damage on the gear teeth and bearings [4]. In that report the defects when making gears were represented by 6%, which are the result of different influences which depend on machines, measuring equipment, process control and various other influences. If we specify stricter criteria in control of gear making, and thereby strictly control of subsequent processing, these errors could be minimized. However, without stringent control the percentage of errors could increase. Since the destruction of gears depend on several factors and how there are stochastic, in [5] author gives a destruction probability diagram of gears for annealed gears, where we can see that with the increasing number of changes the stress that gears can withstand is decreased. With stress decreases, which gears can withstand during operation, possibility of damage is increased. Author of [6] gives the results of gear damage due to pitting, poor lubrication and explains destruction of surface-annealed gears, while the authors of the paper [7] carry out an analysis of the impact of gear pairs with different damages and their effect on the generation of noise and vibration. In the paper [7] tests were performed on eight different gear pairs, of which on one pair was no damage, three pairs of gear were damaged by pitting, three pairs were damaged by spalling, while one pair was with a broken tooth. During the tests it was concluded that there is no a direct proportion

between the vibration generated by gears and their wear, as well as other damages caused during their operation (rotation). Contrary, wear may affect the reduction of vibration level since the gears mutually adjusted.
Investigation in [8] and [9] were performed on test benches with closed power flow and with application of standardized respectively FZG methodologies (TU Munich).

POTENTIAL DAMAGES THAT MAY APPEAR IN GEARBOXES

During operation of gearbox, i.e. during power transmission through the gear different types of damage may incur. During the years of testing gear power transmitters, damages at 931 gears were appeared, of which the most prominent is fracture of gears [10]. On the other side, on high-power gear drives most common damage are incurred due to overload (21.7% [11]). These are some of the indicators that the gears are exposed to stochastic changes and that should be paid great attention to the potential damage that can occur on them. Depending on the load, as well as working conditions which they are exposed, it is possible occurrence of over 20 types of defects of gears, which are given in DIN 3979th. Basically, fracture of gears in gearboxes happens very rarely, or if arise they are consequence of accidents, while damage or complete destruction of the working surfaces of gear teeth more frequently appear. Any of these defects can be formed by combining various influences, such as defects in material, residual stresses, poor production quality of the gears, poor lubrication, etc. The process of gear destruction is permanent and initially poorly expressed and it is very slow, while at the end of life circle becomes progressive. Operating conditions of gearboxes are variable, so that this process consists of different entities such as: micro pitting, pitting, spalling, abrasion, scratch and plastic injection of particles, scuffing, etc. An overview of some possible damages in gearboxes will be given below.
Micro pitting is a type of damage to the tooth flanks, which occurs due to high pressure and increased speed of skating. As such kind of damage occurs in the beginning of life circle of gear due to even out irregularities on the gear flanks. Micro pitting is similar to abrasive wear in the initial stages of formation and development, which creates confusion among many young engineers. Besides that, micro pitting can occur after a relatively small number of coupling (if the gears are made of a material of poor quality) or after a larger number of coupling (surface reinforced gears). Usage of inadequate sophisticated additive to enable the operation of gear in extreme conditions may indirectly contribute to the emergence of micro pitting. The process can be identified with the naked eye as a gray color or spots on the flanks, which represents the formation of micro cracks or dimple depth up to several microns. Figure 1 shows a schematic representation of damage due to micro-pitting and Figure 2 presents the resulting micro pitting on the side of the gear. Identical damage is possible on the gear that is built into the gearbox.

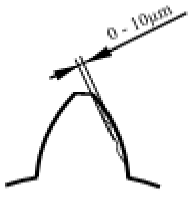


FIgure 1. Micropitting

Figure 2. Micropitting [2]

Pitting is the type of gear failure that occurs between the sliding surfaces under high pressure. In the case of pairing gears made of various materials pitting occurs on the gear made of poorer material, whereas in the case when the gears are made of the same material pitting occurs on the gear with a smaller number of teeth. In the case of gears built into the gearbox, pitting occurs on gears with the smaller number of teeth, which are usually driven gears, that is not the case at the higher speeds where the driver gears have a higher number of teeth of the driven gears. The cracks are small at the beginning, while during the lifetime lubricant enters the cracks, causing further damage. Depending on the lubricant, according to Hertz's pressure, the maximum stress can occur below the surface layer (by poorer lubrication) or between the bumps on contact surfaces (by better lubrication) [6]. Unlike micro pitting, pitting occurs after larger number of changes (10^5), and its appearance is not possible at the number of changes of less than 10^4. A better machined surface reduces the possibility of pitting, which causes an increasing of machined surfaces quality. Increasing of the quality of lubrication and oil film thickness decreases the frictional force and the possibility of pitting. According to ISO 10825 there are two types of pitting: initial and destructive pitting. The cause of the initial pitting can be attributed to the accuracy of making gear pair or poorer quality of the machined surfaces of gear. The destructive pitting can occur due to the development of micro cracks under certain overloads, while it can also appear as a growth of damages of initial pitting. Figure 3 shows a schematic representation of damage due to pitting.

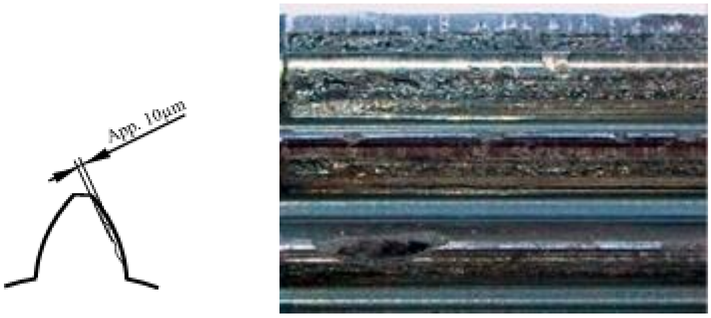


Figure 3. Gear pitting failures [12]

Spalling is another form of failure of hardened gear tooth flanks. It is characterized by appearing as a brittle fracture. Spalling is characterized by the appearance of cavities of several tens of microns to 0.2 mm (Figure 4) i.e. from 0.25-0.35 to the half of length of the contact line on gears flank [13]. Basically, spalling is similar to destructive pitting, with the difference that the damages are higher. In this type of gear failure cracks are initially wider under the surface of the gear (parallel to the surface), so that at one time, due to the increased surface pressure, changes their direction to the surface layer, bursting material particles in the form of flakes leaving the form of brittle fracture. Usually from the gear surface strengthening depend the size of torn particles. In the case of surface hardened gear flanks, separation of larger pieces of the gear surface layer is occurred, whereby the bottom of the fracture is usually between hardened and unhardened layer. On gear damages caused by spalling, the characteristic sharp edges along the surface can be noticed. Initial cracks are small, and when the number of such particles accumulating in one place creates larger cracks. Figure 5 presents the damage due spalling on the gear flank.

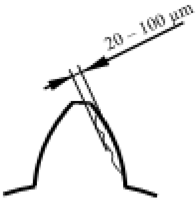


Figure 4. Splalling

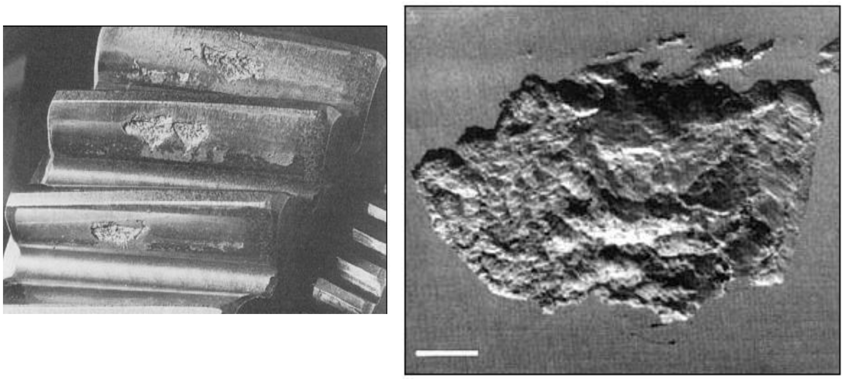


Figure 5. Spalling [14]

Scuffing is a type of gear failure, which is manifesting by large number of longitudinal damages in the form of furrows in the direction of sliding (figure 6). The position of furrows depends on the contact surfaces (Figure 7). The cause of this type of damage is interruption of oil film between the contact surfaces of the gear flanks caused by overload or high sliding speeds. Due to the interruption of the oil film, comes to direct contact between gear flanks, whereby the contact surfaces are heated because of the increasing of friction. This heating causes connection (welding) contact surfaces of gear flanks. Further operating of gear causes the violent separation and tearing of the surface layers. Surfaces remain welded to the gear flanks and damage each subsequent surface of gear flanks that it is paired.

Figure 6. Gear scuffing failures [12]

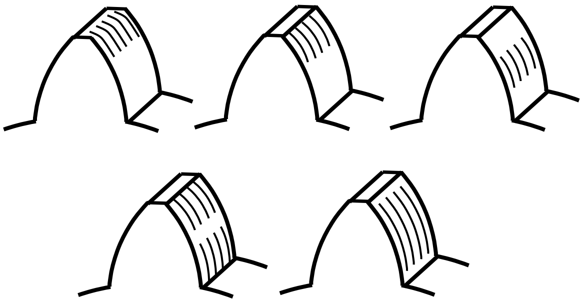


Figure 7. The position of furrows due to scuffing damage

There are basically two types of scuffing: cold and hot scuffing. Cold scuffing occurs at low speed of sliding between the materials of lower quality, while hot scuffing occurs at a much higher speeds of sliding and surface pressures by heat-treated surfaces.

Breakage of gear. During operation of the gear, occurrence of fatal damage is possible, such as breakage of gears. This damage occurs very rarely in gearboxes. The cause of such damage is the occurrence of initial cracks that occurs in the weakest areas, where there is a high concentration of stress and bending stress. The damage extends over the entire surface of the tooth root, causing breakage that can be violent or fatigue. Fatigue fractures are due to impact loads, causing a stress at the base of the gear teeth, which is larger than the static strength and are characterized by the fact that the refractive surfaces are coarse-grained structure. A fatigue fractures occurs as a result of action of dynamic loads in the tooth root and they are higher than permanent dynamic strength. Such damages are characterized by two zones of fractures, zone of fine-grained structure that arises due to the fatigue and the zone of coarse grain structure due to complete destruction. By the shape and structure of the breakage, it can be concluded which case of breakage was come. Gear teeth breakage is rare in gearboxes, but when it occur its cause of fatigue loads. This kind of breakage occurs mostly on gears which are build gearboxes of vehicles that drive over rough terrain, as a result of stochastic changes. According to available literature, there is no evidence that was coming to the violent breakages at the gearboxes.

One example of a crack in the root of the tooth is shown in figure 8, while figure 9. shown breakage of more gear teeth caused by a high-cyclic fatigue.

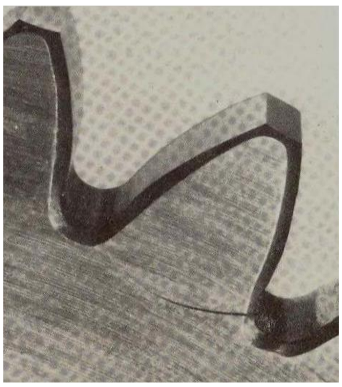


Figure 8 Crack of tooth root [14]

Figure 9. Breakage of more gearteeth [15]

During the work of gearbox comes to rapid changes of loads that directly act on the gears. Load changes influence directly the expansion of initial cracks, and thereby to gear breakage.

ANALYSIS OF GEARBOX DAMAGES

During operation of the gearboxes in the exploitation in different conditions, most of the components are exposed to changeable loads. Changes in working conditions, and thus changes of stress and the parameters of operating conditions can be constant or stochastic. Besides, conditions of use of same type gearboxes can be different. All of that directly affects to the damage of components, which may be different. According to statistics, 80% of cases of mechanical damage occurring due to fatigue.
Based on years of monitoring of the occurrence of damage at the gearboxes, obtained results are: 60% of damage occurs on the gears, while 20% damage occurs in bearings and 20% to other components .
Interview method with long-term users and maintainers of gearboxes was used For the data acquisition. The average age of the maintainers of freight motor vehicles was 32 years and 4 months. Most of the respondents had a full years of service in the maintenance freight vehicles. On the basis of this experience, it can be considered that their answers are very reliable.
According to the results, it did not coming to significant damages at the gearboxes before freight motor vehicle has done 300.000 km, and failures that have occurred was mainly on the synchro coupling. Some of the failures that have emerged are falling out one ball from synchro coupling, which causing the jamming of the system of speed change.
Only after 500.000 km significant failures on the gearboxes were emerged and become more and more common, as confirmed by 28% of respondents. The damages has been appeared in the inner bearing and synchro coupling, but also occasionally traces damage by wear have emerged at gear pair. Significant damages of the gears which are embedded in manual gearboxes emerged after 900.000 km.
Respondents maintained manual and automatic gearboxes. In this paper only the analysis of manual gearboxes are included. Figure 10. shows the percentage of failures for different types of manual gearbox. The largest number of defects was emerging at the five-speed gearboxes. In addition to damage to the gears, failures on the sealing seams and synchro coupling were occurring.
Damage to gear pairs is generally created after driving 300.000 km and more. These damages are more balanced by freight motor vehicles which are driven across different terrains, while by freight motor vehicles, which are driven across mountainous terrains, damages appeared to lower gearbox speeds. In the case of vehicle driving only across lowland terrains, damages were created to higher gearbox speeds. Figure 11. shows the diagram of gear pairs damages for each respective speed of six-speed gearbox, for freight motor vehicles which were driven across different terrains.

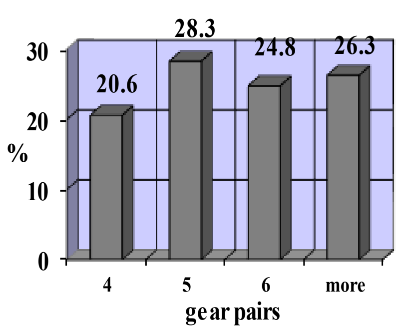


Figure 10. The percentage of failures for different types of manual gearbox

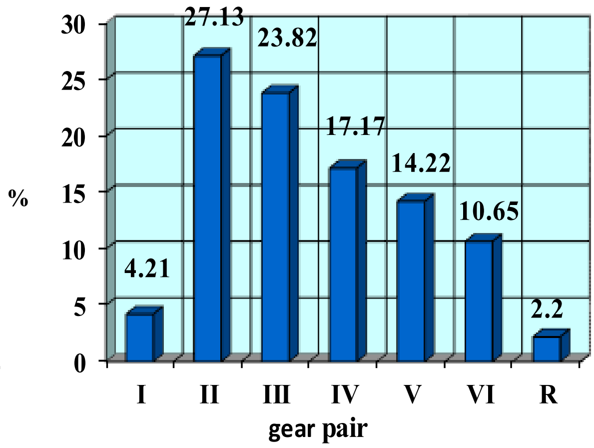


Figure 11. Diagram of gear pairs damages for each respective speed of six-speed gearbox

During the disassembly of each gearbox, verification of all elements was carried out and the possible damages were determined.Types of damages have depended on many factors on which generally affect the operating conditions.

CONCLUSION

During operation of the motor vehicle gearbox transmissions are subjected to stochastic changes that depend on a number of factors, which directly affect the damages of gearbox, and thereby the gears. There are several types of gear failure, and in this paper are described only damages caused at gearboxes. This paper reviews the results of the percentage damages of gears built in six-speed gearbox. The results are based on empirical data, as well as on information obtained by the maintainers of motor vehicle in which these types of gearboxes were incorporated.

REFERENCES

[1] Wang Y, He Z, Xiang J, Zi Y: Application of local mean decomposition to the surveillance and diagnostics of low-speed helical gearbox, Mechanism and Machine Theory 47: 2012, pp.62–73

[2] Robert B., Marina F., Markus L., Božidar K.: ROLLING-SLIDING-CONTACT FATIGUE DAMAGE OF THE GEARTOOTH FLANKS, Eng. Rev. 30-2 , 2010, pp. 37-46

[3] Fernandes P.J.L., McDuling C.: Surface contact fatique failures in gears, Engineering Failure Analisis, Vol. 4, No. 2, 1997, pp. 99-107

[4] Collins J.A.: Failure of Materials in Mechanical Design Analysis, Prediction, Prevention, John Wiley&Sons, New York, 1981

[5] Ognjanovic M.: Failure Probability of Gear Teeth Wear, Fracture of Nano and Engineering Materials and Structures, C., 19., 2006, pp 1059-1060

[6] Ognjanovic M.: Progressive Gear Teeth Wear and Failure Probability Modeling, RESEARCH, Tribology in industry, Volume 26, No. 3&4, 2004 pp.44-49

[7] Yibo C., Xiaopeng X., Yan L.,Tianhuai D.: A Study of the Correlation between Gear Wear and Vibration, ADVANCED TRIBOLOGY 2010, Part 3, II., 2pp.73-277,

[8] Hoenn B.R., Michaelis K., Hochmann M..: Grease lubrication – Pitting load-carrying capacity of gears, Power Transmissions '09, 1-2 October, Chalkidiki, Greece, Vol.2009, pp 475-479

[9] Joachim F., Kurz N., Glatthaar B.: Influence of Coating and Surface Improvements on the Lifetime of Gears, International Conference on Gears, Volume 2, March 13-15, VDI-BERICHTE NR.1665, 2002, pp.565-582

[10] Uche R.: Reliability model in gear life prediction, International Journal of Academic Research, Vol. 3. No. 3. May 2011, II Part, pp 468-492

[11] Woljhafen G.P.: Schadenskunde-ein Kriterium der Vorbeugenden Instandhaltung im Rahmen der Tribotechnik, Klüber Lubrication, München, 1982, pp. 17-23

[12] Piermaria D., Klaus M.: Recognizing gear failures, MACHINE DESIGN, JUNE 21, 2007, pp 64-67

[13] Živković P.: Istraživanje gubitaka energije i razaranja delova planetarnih prenosnika snage, Doktorska disertacija, Beograd 2006

[14] Gopinath K., Mayuram M.M.: Machine Design II, Indian Institute of Technology Madras

[15] Ozturka H., Yesilyurt I., Sabuncu M.: Investigation of effectiveness of some vibration based techniques in early detection of real-time fatigue failure in gears, Shock and Vibration 17, 2010, pp.741–757, ISSN 10709622/10

MAINTENANCE AND EFFECTIVENESS OF MACHINERY

Dušan Đurović[1], Miodrag Bulatović[2]
[1] Ad „ Mehanizcaija i programat" Nikšić, Montenegro
[2] Mechanical Engineering in Podgorica, Montenegro
e-mail: bulatovm@ac.me

Abstract: System maintenance is multidisciplinary process with a large number of variable input parameter, among which the important place occupied by behavior of the system during its operation or its exploitation and structures underlying the effectiveness of system.
Behavior of the system is manifested in a simple but fundamental indicators and that the time at work and the time of failure in the function which the system readiness and reliability.
In this article, along with rezulteta research on a particular object, is shown in the correlation system - effectiveness of the system - maintenance, or the impact of maintenance as the primary logistics system effectiveness.
Key words: system, the effectiveness of the system maintenance.

PRODUCTION - TECHNICAL SYSTEMS AND FAILURES

Technical production system is a set susystems that act directly or indirectly, work on the subject from entering the system, in the form of raw materials or semi-finished products, to release in the form of the finished product (fig.1).

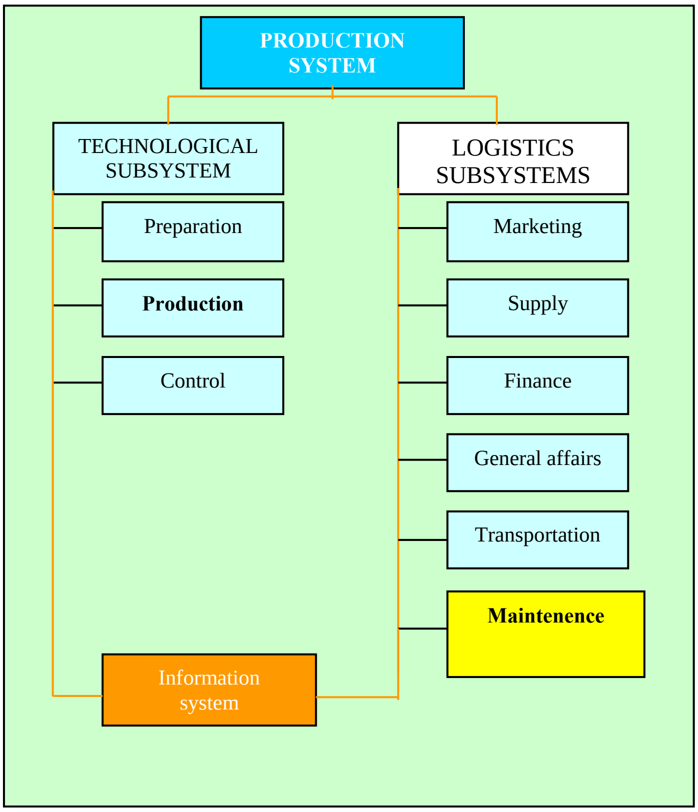


Figure 1. The basic scheme of the production system

Malfunctuoning of the system and the possibility of failure occurring due to changens of initial material properties of parts of the system which is built.

Under machine failures implies an event that occurs when the value of the functional parameters of the system or system elements exceed the allowable, predefinited limits.
Causes weakening and diminishing performance of the system are in the physical and chemical changes that take place under certain laws of probability.
The process of failure occurrence is a kinetic process over time, with the internal mechanism and rate dependent material properties, loads, modes, temperatures, and many other factors.
At the same time, the weakening process operates several factors, individually and in interaction: the type of material, the site of, a form of energy, the internal mechanisms of physical-chemical processes (aging, wear, corrosion, fatigue, creep), the terms and manner of operation and maintenance

MAINTENANCE - A MULTIFACTORIAL LOGISTICS

Reflection as a function of the process of acne is more roles where changing and logistic importance of this function, has the character of multi factorial logistics:

Maintenance as the main activity of production
Then the process of maintaining a primary production business of the company in terms of providing services to third parties and has a fundamental responsibility in the field of safety and health for all workers in their own organization and to users of the product.

Maintaining production activities as logistics companies.
Then the process of maintaining a basic logistics and manufacturing activities has resulted in the provision of the production process and is responsible directly to the safety and health of their employees and beneficiaries who are subject to its activities.

Maintenance - basic services.
Then the function maintenance utility has its own elementary task (education and training, public relations, consulting services, craft characters, etc.), maintenance is emerging as a service and assumes responsibility of the manufacturer of the product in the process of exploitation and that means responsibility for the safety and health of users of these products.

The user strives to maintain appropriate activities working capacity of the system as long as possible
Of the interventions that have been boiled down to "quit waiting for" maintenance has developed into a multidisciplinary activity with a number of applied scientific content in the fulfillment of its objective function.
Maintenance can be defined as "the function of which is regulated constant monitoring of facilities and carry out certain repairs and revisions, allowing permanent preservation of functional capacity and production and ancillary facilities and equipment."

The main goals are the maintenance functions:

a)Technical and technological objectives, which include:

- Maintain and increase working capacity to the level of effectiveness of the system,
- Achieving long-life machine to the limits of economic costs,
- Improving the production process and product satisfaction of quality system standards, increase the productive capacity of the system as a whole development of machinery and equipment innovation

b) Economic goals:

- Rational use of machinery, equipment and resources (spare parts, materials, tools and equipment, raw materials, human resources, etc..)
- In order to preserve the function of profitability, productivity and efficiency

c) The sociological objectives:

- To preserve and increase the psychological stability of employees increasing security of the system,
- Motivation to work in trusted systems,
- Rational use of human resources, environmental factor in order to protect the environment and so on.

EFFECTIVENESS - MEASURE THE SUCCESS OF THE SYSTEM AND MAINTENANCE

Criteria for the exercise of the functions at certain times and certain environmental conditions the system must be able to:

- to come into effect and realize the expected size of the output in minimum time period and the circumstances surrounding - ***system availability A (t)***,

$$OG(t) = \frac{\sum_{i=1}^{n} t_{ri}}{\sum_{i=1}^{n} t_{ri} + \sum_{j=1}^{m} t_{oj}} = \frac{Tr}{Tr + To}$$

- to do the work within the permissible deviations in the expected duration of the circumstances and the environment - ***the system reliability R (t),***

$$R(t) = \frac{n - N}{n}$$

- To adapt to disturbances in the
- labor process - ***functional suitability FS***.

The effectiveness of the system is a synthesis of availability, reliability and suitability, as the probability that the system after the entry into effect successfully serves as criteria and adapts to the conditions (use and maintenance) for the estimated time of:

$$Es(t)=A(t) \,.\, R(t) \,.\, FS, \qquad 0<E<1$$

For systems with no time and resources to give up their elimination, all the factors in the effectiveness of the functional dependence of the high complexity of the scheme.
By increasing the number of subsystems and parts the system, increasing the complexity of the system increases the possibility of failure.
If only the technology is embedded a minimum, it also increases the possibility of failure.

EXAMPLE OF RESEARCH AVAILABILITY

Research Facility

The object of research is the company AD "Mehanizacija i programat" – Nikšić, Montenegro.

The company belongs to the class of medium-sized construction companies able to execute complex construction engineering - roads and outbuildings and construction materials and concrete.

This means that it has a very diverse and numerous equipment (construction and transportation machinery, vehicles, facilities maintenance, logistics, equipment, and inventory) with significant performance.

Problem and Purpose

By observing and analyzing the impact of maintenance on the production process is concluded that the existing concepts and methods of organization and implementation of maintenance are not enough to provide the necessary availability of construction equipment in the work, which is reflected in reduced effectiveness of the system.

The main causes of the identified problems are manifold, with special highlights:

- Lack of knowledge to optimally place the concept, methods and technology maintenance.
- Problem of determining the break-even point and operating and maintenance cost,
- Lack of modern technological methods and equipment (technical diagnostics)
- Lack of systematic monitoring systems in the process of maintenance and operation,

- Lack of application of IT tools (hardware and software) in the complex process of maintaining

Research

Jaw crusher mobile

Map failure to budget availability and availability coefficient

	MAP OF FAILURE **Organizational unit: Mehanizacija i programat** **Machine-device: Mobile jaw crusher C12** **Follow-up period:18.09.2008 – 16.02.2010**								Page: Num.of pages:
Nb	**Condition of failure**				**The cause of delay and type - failure**	**Time to eliminate failure T_{ef}(h)**	**Availability**		**REMARK**
	Date	**From (h)**	**To (h)**	**Of all** Tdt(h			**$A_i(t)$**	**$A_o(t)$**	
1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
					2008.				
1.	18.09.08.	9	12.3	3.5	Regular service at 250 hours	2			
2.	26.09.08.	7	8	1	Filling for centralized lubrication - 12 cartridges	0.5			
3.	18.11.08.	7	7.3	0.5	Refilling the tank for central lubrication -4 cartridge	0,25			
4.	24.11.08.	8	15	7	Cleaning the hydraulic systems and machine control	6			
5.	01.12.08.	7	10	3	Regular service at 250 hours	2			
6.	08.12.08.	7	7.3	0.5	Refilling the tank for central lubrication -5 cartridges	0,25			
7.	27.12.08. .	7	7.3	0.5	Refilling the tank for central lubrication - 4 cartridges	1/4			
8.	29.12.08.	14	15	1	Refilling the tank for central lubrication - 5 cartridges	0,5			
.									
.									
.									
I.	Total down time			**Tdt = 18**		**Tef = 11,5**			
	Number of working hours			**Twh = 1007**	Availability function deadlock **Adt1 = Twh/ (Twh+Tdt)**		**Adt1 = 0,982**		
					Availability function removes downtime **Aoo1 = Twh/ (Twh+Tef)**			**Aef1 = 0,91**	
					I – VI. 2009				
					VII-XII 2009				

III	Total down time			**Tdt = 97,5**		**Tef = 62,75**			
	Number of working hours			**Twh = 2460**	Availability function deadlock **Adt3 = Twh/ (Twh+Tdt)**		**Adt3= 0,969**		
					Availability function removes downtime **Aef3 = Twh/ (Twh+Tef)**			**Aef3 = 0,975**	
I – VI 2010									
IV	Total down time			**Tdt = 104,5**		**Tef = 75**			
	Number of working hours			**Twh = 2750**	Availability finkciji deadlock **Adt4 = Twh/ (Twh+Tz)**		**Adt4 = 9,666**		
					Availability function removes downtime **Aef4 = Twh/ (Twh+Tef)**			**Aef4 = 0,973**	
TOTAL AVAILABILITY – COEFFICIENT OF AVAILABILITY									
	Total down time			**Tdt = 104,5**		**Tef = 75**			
	Number of working hours			**Twh = 2750**	Availability fuction deadlock **Adt = Kdt = Twh/ (Twh+Tdt)**		**Atz = K = 0,962**		
					Availability function deadlock **Atz = Kef = Twh/ (Twf+Tef)**			**Aoo = KG = 0,975**	

Analyzes the results of availability (Fig.2)

Availability in function of working hours Twh and down time Tdt:

$$Adt= Twh/ (Twh+Tdt)$$

Availability in function of working hours Twh and eliminate failure Tef:

$$Aef= Twh/ (Twh+Tef)$$

The coefficient of availability in function of working hours Twh and down time Tdt:

$$Kdt= Twh/ (Twh+Tdt)$$

The coefficient of availability in function of working hours Twh and eliminate failure Tef:

$$Kef= Twh/ (Twh+Tef)$$

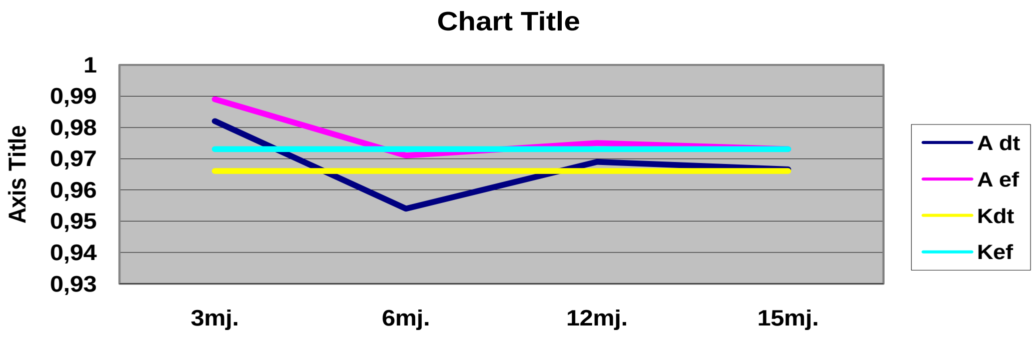


Figure 2. Availability of the system

Movements of the availability of the system shows the expected decline after the commissioning of the system after the initial failure, and exponential behavior in the area of random failure, which means that the maintenance of a satisfactory response (fig.2).
The difference between the Kdt and Kef of 0.013 or 1.3% shows that organizational downtime in relation to the time of repair is minimal, or repairs to the organization to be effective.

CONCLUSIONS

- System maintenance is multidisciplinary process with a large number of variables that characterize the behavior of the system during its operation and exploitation.
- The behavior of the system is manifested in a simple but fundamental indicators such as the time at work and time of failure as a function of which the readiness and reliability of the system.
- Failure of the system is a consequence of weakening and diminishing admirable job systems that occur under certain laws of probability and a kinetic process over time, whose internal mechanism and rate dependent material properties, loads, modes, temperatures, and many other factors.
- Research conducted at the facility surveys show a high degree of readiness of equipment (machinery and transport equipment), which means maintaining good performance in terms of time at work and denunciation.

REFERENCES

[1] Bulatović, M., Effectiveness and maintenance of production systems, Monograph, Faculty of Mechanical Engineering, Podgorica, Montenegro, 2008.
[2] Djurovic, D, maintenance of the weather condition and image of the scheme, Term paper on PhD studies, Faculty of Mechanical Engineering, Podgorica, Montenegro, 2010
[3] Guberinić, S., Management systems, System of discipline, Techniques and methods, Belgrade, 1970.
[4] Technical documentation of company AD „Mehanizacija i programat" – Nikšić, Montenegro, 2012.

REMOTE MONITORING AND CONTROL OF MIXER FOR LIQUID DETERGENT PRODUCTION

Slavica Prvulović[1], Dragisa Tolmač[1], Vladimir Ilin[1]
[1]University of Novi Sad, Technical Faculty "Mihajlo Pupin", Zrenjanin, Serbia
e-mail: prvulovicslavica@yahoo.com

Abstract: This work is about remote monitoring and control of mixer for liquid detergent production and significance of SCADA systems in managing process. Using this way of work with mixer, human is less important and that decreases the risk of human-made errors during routine work.
Key words: SCADA, system, elements of control system

INTRODUCTION

In engineering process equipment mixing operation is used everywhere where there is a need for making unequable disorders in fluid and significant turbulences respectively. This goal is achieved using mechanical rotating elements. Mixers are used in all cases when there is need for equalization of concentration of certain quality and for speeding up of process of some operations (extraction, adsorption, head transfer etc.)[2], [7], [8], [9].
Task of the mixing device in this case is dual. First, mixer must provide equal distribution of discontinuous phase in container, and second, mixer must produce high degree of turbulence near suspended particles, bubbles or drops, speeding up mass transfer between phases, fluid speeds that will not allow phases stratification. Beside that, developed turbulence must be equal in the whole space. For this type of operations using medium size rotor with directed revolutions number is recommended [4], [5], [3].

MATERIAL AND METHOD

In this work is described using of mixer:
Container for liquid detergents (home chemicals, shampoos...) with mixer is vertical, stable container with outer heating cover and insulation. Envelope DN 2300mm, 2750 mm long, is made of austenite material Č.4573 5 mm thick. On the bottom side, container is closed with anchored, shallow bottom DN 2300 mm from austenite material Č.4573 5 mm thick. Outer heating spiral, cross section 20x90 and outer diameter Ø2346, is made of steel sheet Č.4580, 3 mm thick.
The container is equipped with claw-type mixer with three blades and one anchor blade for cleaning the bottom of the container. Drive for the mixer is motor – reducer mounted type with power P=25 kW and number of revolutions n = 62 min^{-1} . Embedded is motor – reducer, with power P=25 kW and number of revolutions 1400 min^{-1} .
Reducer is type A703/URFA-23,5 with output number of revolutions n_2 = 62 min^{-1}.
Container is equipped with connectors for all installations and armature that is needed for normal functioning. There is also thermal insulation of the container with mineral wool coated with insulating sheet metal with quality Č.4580.
Container is placed on three supports which are welded to the heating coat. The container is categorized as container under pressure IV class according to "PTN 16/83", SRPS M.E2.150, SRPS M.E2.152. On input steam pipeline is safety valve with spring.
The mixer itself has pipe chamber for heating and cooling that are separated. Lower half is heated with steam that is pressurized to 3 bar, and there starts heat transfer from heating surface to liquid that should be heated. After technological process of heating is done, pneumatic valves are activated using SCADA system. They are opening and, through pipe cooling chamber, cooling liquid GLIKOL flows through it, around the upper surface of the mixer. Cooling liquid is being cooled by CHILLER Eurochiller NAX700 and keeping the temperature about 8^{0}C. After the cooling phase is finished, content from mixer is transported, using pump below the mixer, to receiving reservoir, and from there it is transported to the final product filling machine.

Process of formulation begins as operator in command room chooses the product that he want to make, select it, and set wanted parameter for quantity that he want to produce.
SCADA system in which operator is monitoring and controlling the process is done in SCADA ASPIC 3.30. Main raw materials are stored from cistern to receiving reservoirs (10 pieces for 30 m3) from where they are moved to production mixer using dosage pumps, according to determined order and quantities, depending on which product is produced.

Figure 1. – Part of the mixer in the production

System is controlled using programmed PLC which is via OPC server program for adequate PLC in this case FATEK, connected with SCADOM ASPIC 3.30.
Each mixer has it's own PLC which Leder diagram is made according to logic:
After the working product (program) is chosen, valves open above the mixer in exactly determined order, and using pumps, dosage of raw materials in mixer is done.
Valves are PRISMA type RABV 1533-40 with inductive position sensors, and their signal is inserted into PLC.
Valves are from stainless steel and they have pneumatic one-way actuators (springs back movement). Valves are being controlled using pneumatic block which contains eight electromagnetic distributors 3/2, type 5470 and power 24V DC. Above each distributor there is an electrical module with LED diode indicator. Signals are also inserted to PLC.
When certain quantity of raw material is dosed into the mixer, measuring cells, on which mixer is set, are giving a signal to PLC that the quantity of raw material is dosed, PLC closes the valve that was opened at that moment, and opens the next valve from other raw material, the pump starts and dosing for the next component starts.
Process of dosing stops when all seven raw materials are dosed into the mixer.

Figure 2. Foot of mixer with measuring cell

After dosing of components, PLC gives signal and opens an electro valve for steam, and heating of the mixer starts. When mass inside the mixer gets to specified temperature that is being measured using

PT 100 probe inside the mass, the probe sends a signal to PLC which closes the steam valve and starts mixer's motor, paddles are starting, and mixing begins.
Mixing is time limited, and after time limit, PLC sends signal to the motor to stop working, pneumatic valve for cooling opens.
Through the cooling spiral flows cool water from chiller. When the mass is cooled to certain temperature, PT probe sends signal to PLC which closes the cooling valve and then starts the pump which transports the mass from mixer to a receiving reservoir[1], [6].
All pumps are regulated with frequency regulator type OMRON V1000.

Figure 3. Electrical regulating steam valve

Figure 4. Frequency regulator OMRON V1000

As being said, system itself is being controlled using programmed PLC that is, through OPC server program for adequate PLC (in this case FATEK), connected with SCADA ASPIC 3.30.

Figure 5. PLC Fatek

Like presented in the image, all ports for measuring cells and pumps signals are used. There is also a converter of analog signal.

RESULTS AND DISCUSSION

OPC Server

OPC server (Open Process Control) is software program and it provides compatibility with many hardware devices. It is based on Microsoft Windows Technology and it urges for open process control. It presents an industrial standard created in cooperation with some of leading companies for hardware and software equipment, working in cooperation with Microsoft.
The standard defines methods of data exchange in real time.
Traditionally, programmer for each software or application writes adjusted server or driver. OPC eliminates this request and provides connecting with HMI and SCAD, i.e. application control.

SCADA ASPIC 3.03

Aspic 3.03 is opened, compact and reliable tool for process visualization and control for WINDOWS 95/98/2000/XP. With ASPIC 3.03 you can visually present and control all data what come from OPC server. ASPIC 3.03 offers sophisticated alarm system and status messages. It enables text and graphic reports. It also enables that only personnel with permission can work and control certain device or process.
Access privileges – there are 16 levels of privileges available, each level is granted with a number of actions that user is allowed to do, and there is an option of encoding.
It has it's own symbol base but it also allows drawings input.
ASPIC is designed using experience from realization of many one-purpose systems for various industries. The main goal of this project is to provide system that saves time and money to users during building new surveillance systems or upgrading existing ones.
ASPIC is easy to use and enables efficient surveillance, control, and reporting about possibilities necessary for safe work of some technological processes or whole production facilities.
ASPIC is richer and comparable with other products with the same function. It's design follows the philosophy that recognize intuitive processes in application development.
Production process in liquid products production is controlled with ASPIC SCADA.
SCADA itself is designed in that way that operator in command room is allowed to monitor the process visually with minimal impact to process itself. It is designed that way to contain a lot of reports with parameters that are monitored and important for production process.

Figure 6. Command room from where the process is monitored

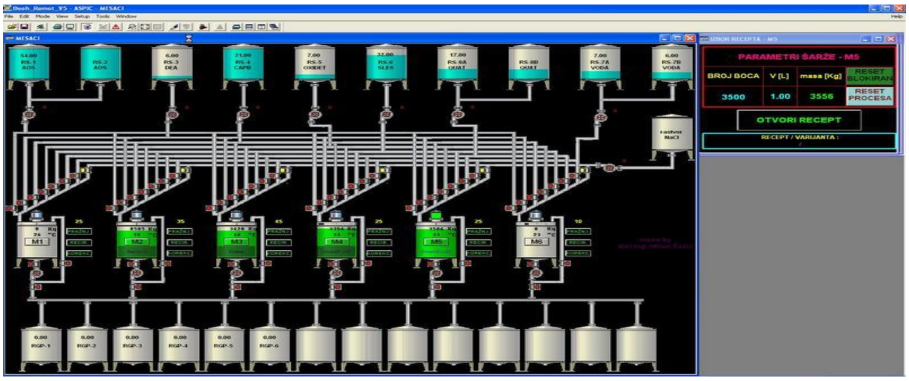


Figure 7. Elements that are monitored

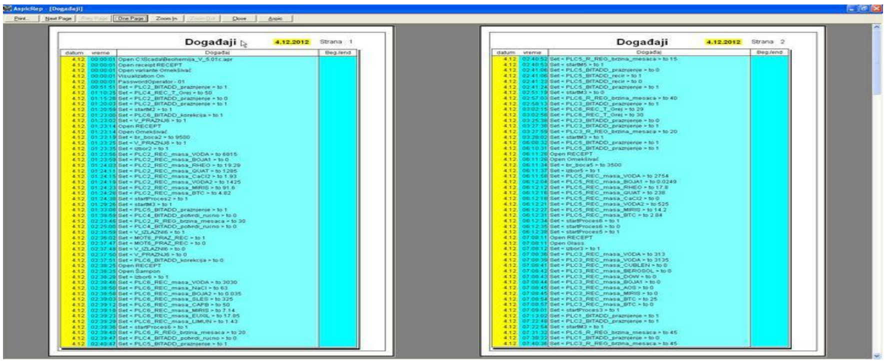


Figure 8. Document about events during the process

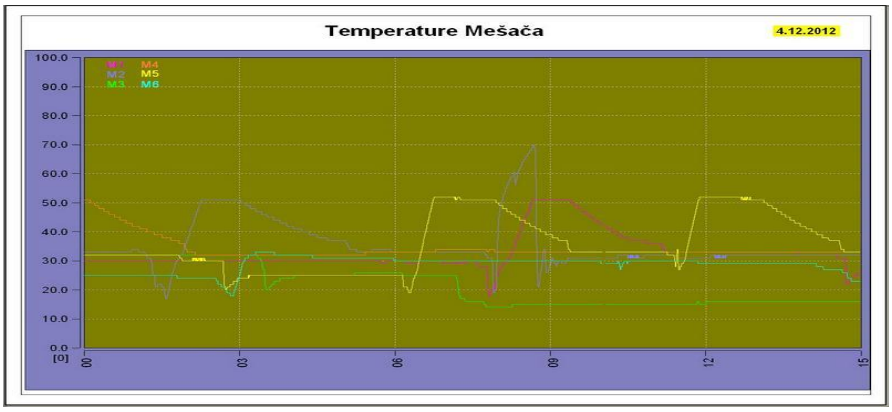


Figure 9. Analysis of all mixer's temperatures during the process

According to events analysis and temperatures, it is exactly known in each moment what have been happening in process if there were some mistakes during work, e.g. who made that mistake.

CONCLUSION

This mixer, as in this work said, has separate coat for heating and cooling. Upper zone of the mixer is being cooled while the bottom zone is heating. Today, for production increase e.g. speeding of the process of mixing, to get into the process of technical solution that means next:

- Install heat exchanger so the hot water directly gets into the mixer. That reduces the time because during regular procedure of dosing water in mixer, already hot water is dosed, and there is no time spent for heating in mixer.
- When heat exchanger is installed, spirals on mixer will be re-connected (spirals for heating and cooling of the mixer). Now the whole spiral will be used only for cooling the mixer and, because of increasing the cooling surface, the time of cooling the mass in mixer will be reduced.

All of this will have an impact on reduction of total time spent on formulating and will also increase the capacity of liquid detergents production [5], [9].
This method of work made the total control of the process without possibility of human mistake. That reduced the number of operators which have and impact on final product price. This system requests, beside quality checked equipment that is installed in system, quality staff in maintenance service so the process can be maintained.

REFERENCES

[1] Aleksandrov, S., Jovanović, Z., Nikolić. S., Čajetinacm, S.:, Formiranje SCADA sistema zasnovanog na OPC server i LabView za upravljanje mehatronskim sistemima, Facta universitatis - series: Automatic Control and Robotics, vol. 10, br. 2, str. 189-198, 2011.
[2] Đuragić, O., Lević, J., Sredanović, S., Lević Lj.: Mešalice u proizvodnji hrane za životinje, Časopis za procesnu tehniku i energetiku u poljoprivredi / PTEP, vol. 12, br. 3, str. 154-157, 2008.
[3] Galaction, A. I..Lupăşteanu, A.M.., Turnea, M., Caşcaval, D. : Komparativna analiza efikasnosti mešanja u bioreaktorima sa radijalnim mešalicama i suspendovanim, Chemical Industry and Chemical Engineering Quarterly / CICEQ, vol. 16, br. 1, str. 47-64, 2010.
[4] Potkonjak, V., Ponjičan, O.: Tehničko-tehnološke odlike mešalica i mešaona koncentrovane stočne hrane, Časopis za procesnu tehniku i energetiku u poljoprivredi / PTEP, vol. 4, br. 3-4, str. 75-78, 2000.
[5] Prvulović, S., Tolmač., D., Tolmač, J. : Procesni sistemi i postrojenja, Tehnički fakultet "Mihajlo Pupin", Zrenjanin, 2014.
[6] Tamphasana, D. T, Bimlesh, K.: CFD simulacija strujanja u sudovima bez odbojnika sa turbinskom mešalicom sa 6 konkavnih lopatica. Chemical Industry and Chemical Engineering Quarterly / CICEQ, vol. 18, br. 4-1, str. 535-546, 2012.
[7] Tolmač, D.: Mašine i Aparati, Tehnički fakultet "M. Pupin", Zrenjanin, 2009.
[8] Tolmač, D.: Mašine i Uređaji – Rešeni zadaci, Tehnički fakultet "M. Pupin", Zrenjanin.2006.
[9] Tolmač, D., Prvulović, S., Radovanović, Lj, Blagojevoć, Z.: Teorija Projektovanja Sistema – projektovanje, investicije, reinženjering , Tehnički fakultet "M. Pupin", Zrenjanin.2007.

TECHNICAL SOLUTION FOR THE RECONSTRUCTION OF CORROSION PROTECTION SYSTEM ON ATMOSPHERIC DISTILLATION UNIT

Aleksandra Aleksić[1], Radoslav Mićić[2], Jasna Tolmač[2], Dragiša Tolmač[2], Slavica Prvulović[2]
[1]Department for development and investition, NIS Gazprom Neft, Novi Sad, Serbia
[2]University of Novi Sad, Technical Faculty "Mihajlo Pupin", Zrenjanin, Serbia
e-mail: aleksandra.v.aleksic@nis.eu

Abstract: Launch of new products with European quality standards, on the existing industrial complex, requires modernization of part of the existing and construction of new plants. Such a project is modular and requires highly complex works to the vital equipment as well the auxiliary systems. The condition of the project is to maintain and utilize as much as possible the existing process equipment, which is suitable for the new process conditions after the reconstruction, in order to reduce investment costs, but also replacement of old equipment and installation of new processing plants. The purpose of reconstruction of the atmospheric distillation plant is to prepare raw materials for further processing at the new plant for the production of base oils. The main objective of this project is the modernization of the plant, to be processed the required quantity of crude oil and to prepare raw materials for further processing. In the present study is presented the reconstruction of the system for corrosion protection as a key part of the introductory process of which depend on all subsequent treatment processes.
Key words: project, reconstruction, corrosion protection, refining, technical task

INTRODUCTION

Refining of crude oil is divided into primary and secondary processes. With the primary oil processing (fractionation) are generate the basic petroleum products without changing the size and structure of hydrocarbons (Cerić, 2012), while the secondary processes are conversion processes in which are obtained quality cost-effective products, usually by changing the chemical composition. The basic principle of primary oil processing has not significantly changed since the beginning of oil refining process as opposed to secondary processing to be significantly developed and continues to develop (Micic, 2013). This paper should give a solution for the reconstruction of the corrosion protection that belongs to the plant atmospheric distillation crude oil, which was built in the '70s of the XX century. At the plant, except the reconstruction of the battery of heat exchangers, there were no other works until now. Distillation obtained light fractions such as gasoline, kerosene and gas oil and atmospheric residue (about 70%). The energy efficiency of the plant is increased so that the raw materials of the heat obtained from the distillation of the product in the first battery of heat exchangers, while the second part of the heat is obtained in the heater (Speight, 2002; Grewal, 2011; Thomas, 2011). Numerous mechanisms of corrosion are related to variations of the operating conditions of the plant in relation to the designed parameters. Deviations may be different, and among them quite often incorrectly applied corrosion protection program. During the processing of cheaper low quality crude oil, atmospheric column distillation of crude oil is exposed to high concentrations of chloride and sulfur compounds which have a high level of corrosion activity and affect the proper and safe operation of the column. Prevention of corrosion problems of a top column system for atmospheric distillation of crude oil due to the effects large amounts of inorganic chloride salt, is as good as possible desalination of crude oil because it reduces the content inorganic chlorides (Sertić-Bionda, 2006).

Desalting affects the amount of suspended metal compounds in the "down stream" equipment via fluid (atmospheric and vacuum residue). In most cases, the underlying cause of the problems associated with a high chloride content is due to insufficient or inadequate control of desalting to ensure conditions for fractionation of crude oil above the dew point. The desalter malfunctioning in a number of refineries are the primary cause of corrosion problems especially in top part of the column. Operation of the desalter enters in the problematic work due to various reasons and it remains year

after year in many refineries. This threatened not only quality but also safe operation of the plant for atmospheric distillation. The most frequent problem with most refineries are small dimensions of the desalter and outdated electrical system, inadequate instrumentation with which to track critical operating parameters, bad or omitted maintenance and irregular cleaning. Stainless steels are exposed to serious corrosion problems in refineries such as the effect of hydrochloric acid and naphthenic process flows (Aleksić, 2013).
As mentioned, crude oil containing water and hydrochloric salts whose presence is undesirable with regard to the fact that chloride salts cause corrosion on process equipment, and the presence of water requires a higher consumption of heat and cooling water in the distillation process. Since these industrial plants are seen to produce high-quality products it is very important to predict proper desalination of the crude oil. Project need to include new desalter and system for chemical dosing.

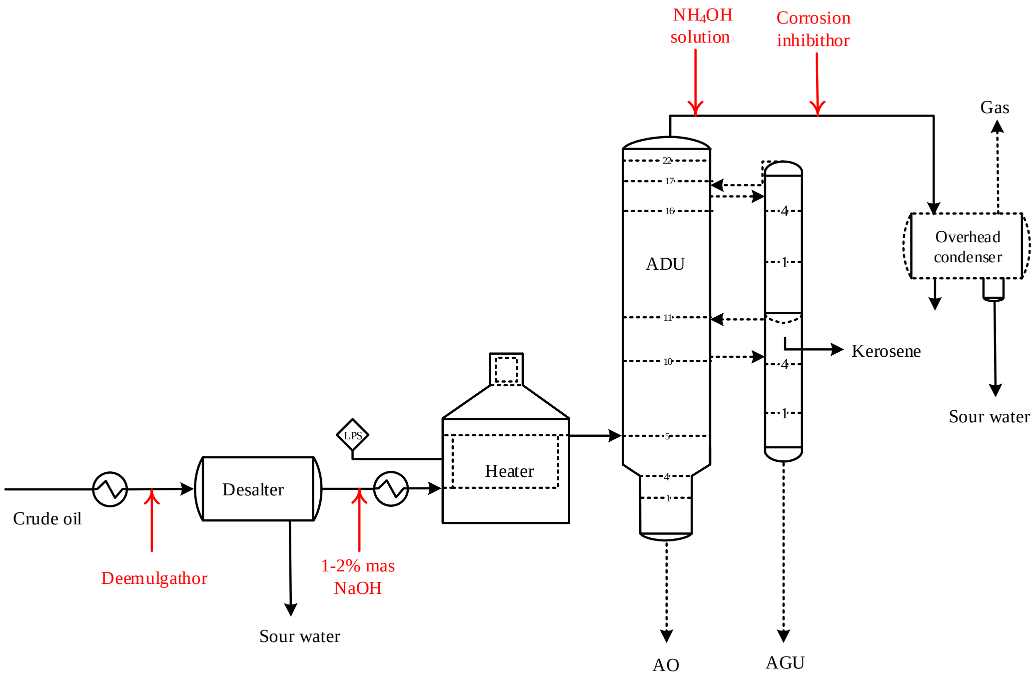


Figure 1. ADU unit with main corrosion protection points

Parts of the process of refining crude oil, which are susceptible to corrosion are exchangers for preheating raw materials (HCl and H_2S), pipe furnace (compounds sulfur and H_2S), a column for atmospheric distillation (sulfur compounds, organic acids and H_2S), the top of the column (HCI and H_2S and water). Typical corrosion protection scheme is figured above (Fig.1).

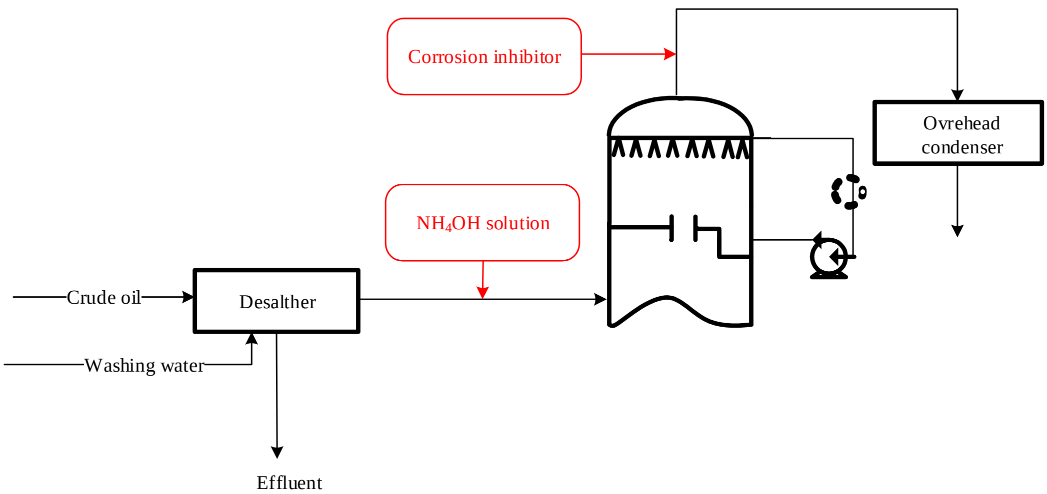


Figure 2. Typical corrosion protection system

For corrosion protection in the process is needed introducing of chemical compounds like (Fig.1,2):
- deemulgator;
- sodium hydroxide (1-3% by weight);
- ammonia (3-7% by weight);
- corrosion inhibitor.

These compounds shell be introduced into the ADU unit columns by using dosing system.

RESULTS AND DISCUSSION

After detail inspection of the existing state of field, in order to provide safe and efficient processing, within the project it is proposed desalter reconstruction and procurement of the new dosing system as well.

Desalter

Since the existing desalter has not been used for a long time it is proposed to replace certain parts in the interior desalter to ensure the removal of excess salt and water and to improve the security system. A new desalting package is required to remove water-soluble salts from the crude oil. Based on the crude inlet salts content, a desalting efficiency of at least 97% (< 1.5 ptb in desalted crude) is required. Such salts removal efficiency would require a one-stage desalting system.

Table 1. Desalter operation characteristics

Characteristic	unit
Conditions of inputs	
Crude Oil .23 ° API (kg/hr)	62550
Water content (% v/v)	0.3
The salt content (mg/l)	45
Rinse water (kg/hr)	5000
temperature (° C)	136
(bar g)	13
Conditions of outputs	
Crude Oil 23 ° API (kg/hr)	62500
Water content (% v/v)	0,2 max
The salt content (mg/l)	5 max
Rinse water (kg/hr)	5050
Pressure drop in the mixer valve (bar)	1,5

Based on expected configuration, the desalting package consists of the following items to be supplied (Global, 2013):
- Mixing Valve to be located upstream Desalter vessel.
- Electric Equipment.
- Crude Oil Distributors.
- Hydrocarbon/Water Interface
- Proper safety and interlock devices.

Regarding Desalter nozzles, the following connections are foreseen:
- Crude oil/desalting water inlet nozzle/s and desalted crude and effluent water outlet nozzle/s.
- Steam-out connection/s, chemical cleaning connection/s, drain connection/s, vent nozzle/s,manhole/s, etc., as per final Desalter dimension.
- PSV nozzle/s. Nozzle/s size to be confirmed later based on Desalter dimension.

- Proper instrument connections. As a minimum, one nozzle for a pressure gauge shall be provided.
- Sampling connection/s and devices.
- Any other connection required for proper package operation and maintenance.

Table 2. Operating conditions

Process characteristic
Operating Temperature
Inlet (ºC): 120÷155 (147.3 ºC normal before water mixing).
Outlet (ºC): 135.6 (desalted crude downstream desalter).
Operating Pressure
Inlet (bar g): 14÷18 (upstream mixing valve).
Outlet (bar g): 13 (downstream desalter)
Maximum Allowable Pressure Drop [bar]: 4 (total including Mixing Valve and crude distributors, etc. maximum flow rate).

On the atmospheric distillation plant is not used catalysts. It is contemplated injection of certain chemicals in the process to protect the equipment and prevent corrosion and to improve the separation of oil and water in desalter. Preliminary determined using the following chemicals:

- demulsifiers, which is injected into the flow of crude oil a desalter.
- neutralizer, which is injected into the flow of crude oil after desalter,
- corrosion inhibitor, which is injected in the top vapor stream at the top of the column,
- solution of ammonia which is injected into a stream of vapor at the top of the column.

To introduce these chemicals besides reconstruction of the existing desalter with new nozzles and interiors it will be necessary to to procure new vessels (Tab. 3).

Table 3. Main equipment list and propositions

Equipment	**Dimensions/characteristics**	**Proposition**
Desalter	5820 mm T-T p = 20,0 bar g T= 160ºC 5820 mm T-T p =20,0 bar g 2960 mm ID x 5820 mm T-T p =20,0 bar g T = 160ºC	reconstructed *interior of desalter ** new nozzles DN 2" (output waste water)
The vessel for washing water	by vendor	New, with dosing pumps, interconnecting piping and instrumentation
The vessel for base	by vendor	New, with dosing pumps, interconnecting piping and instrumentation
The vessel for deemulgator	by vendor	New, with dosing pumps, interconnecting piping and instrumentation
The vessel for ammonia	by vendor	New, with dosing pumps, interconnecting piping and instrumentation
The vessel for inhibitor	by vendor	New, with dosing pumps, interconnecting piping and instrumentation

CONCLUSION

The desalting requirements specified for the launch of new products with European quality standards, on the existing industrial complex, requires modernization of part of the existing and construction of new plants. In the context of the ADU revamp, it was checked and confirmed that the existing single stage desalter is suitable for the specified conditions, and it can be reused for the future operation instead of new one. Keep the existing vessel and replace all existing internals (crude oil distributors, electric equipment, etc), mixing valve, instrumentation and other components.

In contrary, the dosing package needed to protect the unit from the typical corrosion shall able to operate at 110% of the normal capacity so it need to be procured. Under the package there has to be provided several vessels for storing and introducing needed chemicals. So for this reason, procurement of those with necessary additional equipment (pumps, interconnecting pipes, instrumentation, valves etc.) as second part of the technical solution is also seen. Dosing package includes corrosion inhibitor, ammonia solution, demulsifier and neutralizer injection.

REFERENCES

[1] Aleksić, A. (2013). Analiza promotora niskotemperaturne korozije na tehničko-tehnološku opremu. Fakultet tehničkih nauka u Novom Sadu.
[2] Cerić, E., 2012. *Nafta procesi i proizvodi.* Sarajevo: IBC doo Sarajevo.
[3] Global, C. L. (2013). Engineering Design Package, ADU, VDU Revamp. Bloomfield, New Jersey.
[4] Grewal, S., 2011. *Manufacturing Process Design and Costing.*:Springer.
[5] Mićić, R., 2011. *Hidrodesulfurizacija.* Noi Sad: Tehnološki fakultet Novi Sad.
[6] Sertić-Bionda, K., 2006. *Pricesi prerade nafte.* Zagreb: Fakultet hemijskog inženjerstva i tehnologije.
[7] Speight, J. G., 2002. *Chemical and process design handbook.*:The McGraw-Hill Companies, Inc.
[8] Thomas, C. E., 2011. *Process Technology Equipment and Systems*:Delmar, Cengage Learning.

Session 5.

Design and maintenance of process plants

PILOT PLANT FOR TREATMENT OF RAW DRINKING WATER WITH HIGH CONTENT OF ARSENIC USING FERRATE(VI)

Ljiljana Nikolić Bujanović[1], Milan Čekerevac[1], Milena Tomić[1], Mladen Zdravković[1], Marijana Stamenković Đoković [2]
[1] IHIS Techno-Experts d.o.o., Research and Development Center, Batajnički put 23 Belgrade, Serbia
[2] IHIS Science & Technology Park, Batajnički put 23, Belgrade, Serbia
e-mail: ljiljanan.bujanovic@ihis.co.rs

Abstract: The paper presents the results of treatment of raw drinking water, loaded with organic substances (COD = 94.68 mg / l) and high concentration of As (up to 38.66 mg / l). The treatment of raw water was carried out by *in situ* electrochemically synthesized ferrate(VI) in a pilot plant with a flow-through electrochemical cell. For the treatment of water the pilot plant batch type with three reaction columns was formed. The developed method was applied to the treatment of raw water from four different sources. The results showed the removal of up to 97% As, and permanganate index close to the statutory limit value (12 mg / l of $KMnO_4$).
Key words: Arsenic, ferrate(VI), electrochemical synthesis, oxidation, coagulation, pilot plant

INTRODUCTION

Preparation of drinking water is a very complex area in which is engaged a significant part of scientific and technical potentials in the world. Increasing demands in terms of quality and quantity of drinking water and, on the other side, increasingly polluted water resources result in intensive researches in this area.
Very serious difficulties in the process of preparing high-quality drinking water is the increased amount of natural organic matter in water resources, or the formation of a large number of by-products of disinfection and coagulation. In addition to organic matter in water resources a large number of inorganic pollutants, including arsenic, as one of the most widespread, can be found. Based on the UN Synthesis Report arsenic poisoning is the second major health risk related to drinking water [1]. The World Health Organization in 2001 estimated that about 130 million people are exposed to a concentration of 50 µg / l of arsenic in drinking water. The European Directive has defined maximum allowable concentration of arsenic in drinking water of 10 µg / l [2]. Arsenic in drinking water has never been a subject of interest in most European countries because the maximum allowable concentration of 10 µg / l of arsenic in drinking water have been rarely exceeded. However, in countries such as Hungary, Serbia, Croatia, Greece, Italy and Spain elevated arsenic content in drinking water was confirmed and additional efforts are needed in the treatment of raw water with the aim of achieving the maximum allowable As concentration of 10 µg / l [3,4].
Groundwater in the territory of the Republic of Serbia is the basic resource of water supply system and in the territory of AP Vojvodina water supply is exclusively oriented to groundwater. Much of the groundwater contains unacceptably high levels of arsenic. According to the Regulation on hygienic quality of drinking water [5] maximum allowable concentration of arsenic in drinking water is 10 µg / l. More than 40% of the population of AP Vojvodina is supplied with water containing a higher concentration of arsenic than allowed [1]. In most cases, the concentration of arsenic in drinking water ranges from 50 to 100 µg / l, but there are also municipalities, such as Zrenjanin, where the concentration of arsenic in drinking water ranges from 150 to 250 µg / l [6]. Content of the natural organic matters in these waters expressed through the consumption of potassium permanganate is from 20 to 150 mg / l, and in extreme cases up to 200 mg / l [1]. There are many harmful effects of arsenic on human health - cardiovascular diseases, diseases of the respiratory system, nervous system, various skin lesions, and cancer [7]. Most of the water supply systems in Vojvodina, except the system in Subotica do not own the technology for arsenic removal from groundwater. Efficient removal of organic matter and arsenic from drinking water resources is still one of the greatest challenges in modern production of safe drinking water. A number of different techniques for reducing the content of organic substances in water are being applied, of which the most applied are conventional physic-

chemical methods, such as coagulation-flocculation processes or improved treatment of coagulation. This is a multiphase technique that requires a considerable area of land, continuous supply of chemicals, and generates a significant amount of sludge. Literature indicates that cost-friendly treatment of wastewater and drinking water resources with minimal use of chemicals, which allows the sustainable management of water resources, is necessary. One alternative could be a potential treatment of raw water by ferrate(VI), which at the same time oxidizes the organic material and converts arsenic(III) is to As(V), which is far more mobile and removes from the solution as a slurry in the process of coagulation by generated $Fe(OH)_3$.

MATERIAL AND METHODS

The Na_2FeO_4 solution, concentration of 3,5 g/l used for the treatment was synthesized electrochemically. The process of electrochemical synthesis of the alkaline solution of ferrate(VI) was carried out in a laboratory facility, Figure 1, for electrochemical synthesis of ferrate(VI) composed of a two-part flow-through electrochemical cell and based on the transpassive anodic dissolution of iron alloys in a 10 M NaOH solution, in accordance with previous studies [8,9]. The concentration of synthesized ferrate(VI) was controlled by the titrimetric chromite method at a temperature of 25 °C. Freshly synthesized ferrate(VI) was used for the treatment of the solution.
Within these activities the laboratory pilot device for the removal of As(III) from raw drinking water loaded with organic substances is formed.

Figure 1. Pilot plant for the electrochemical synthesis of ferrate(VI)

Figure 2. Pilot plant for the treatment of raw drinking water by ferrate(VI)

Pilot plant for the treatment of raw drinking water by ferrate(VI) is composed of three reaction columns:
- Reaction column for the treatment of water by ferrate(VI),
- Reaction column for coagulation,
- Filtration column.

Between the reaction column are: transport pump for fluids, compressor for aeration, receiving tank, sedimentation tank, dosers for ferrate(VI) and $AlCl_3$, tanks for acid and hydroxide and tank for treated water.
Formed pilot plant is a batch-type with capacity of 10 liters and batch exchanges on every 30 minutes.
In the formed pilot plant for the treatment of raw drinking water with high content of As, Figure 2, raw water from four different sources is treated. The procedure consist of: the treatment of raw water in the first reaction column by ferrate(VI) added from the doser, with aeration by air compressor, Figure 3, wherein the oxidation of As(III) to As(V) and the partial coagulation occur.

Figure 3. Reaction column for the treatment of raw water by ferrate(VI) with aeration

Figure 4. The reaction column for coagulation

After pH adjustment to the value pH = 6 by H_2SO_4, the treated water is transported by pumps and system of pipes and control valves, to the reaction column for coagulation, Figure 4. In second reaction column is carried out the process of coagulation by some of the common coagulants ($AlCl_3$, $FeCl_3$, $Al(OH)_3$) at pH = 8, with pH adjustment by NaOH. From the second reaction column the treated water is discharged into the sedimentation tank, Figure 5. From the sedimentation tank clear solution is transported by pump into the filtration column, Figure 6, with pH adjustment to neutral value of pH = 6 - 7 by H_2SO_4.
Filtration column contains sand filters with various granulation after which the purified water in the receiving tank has satisfactory characteristics, necessary for drinking water.

Figure 5. Sedimentation tank

Figure 6. Filtration column with filtration sand of different granulite

RESULTS AND DISCUSSION

Pilot plant is applied for the treatment of raw drinking water from 4 different locations from the theritory of Banat (locations known to the authors) with initial characteristics given in Table 1.

Table 1. Initial content of As and permanganate index of raw drinking water from various locations

Location 1		**Location 2**		**Location 3**		**Location 4**	
As, mg/l	$KMnO_4$, mg/l	As, mg/l	$KMnO_4$, mg/l	As, mg/l	$KMnO_4$, mg/l	As, mg/l	$KMnO_4$, mg/l
38,66	94,82	1,62	13,91	1,1	38,56	3,57	16,44

The samples of raw water from all locations were treated with two different concentration of ferrate(VI) of 71 µM and 142 µM in the ratio (As : Fe(VI)) = 1 : 5 and 1 : 10. After ferrate(VI) treatment, in each sample was added a coagulant, $AlCl_3$ in a molar ratio ($AlCl_3$: Fe(VI)) = 1 : 1. After filtration and pH adjustment to 6-7 As concentration and the presence of organic matter (permanganate consumption) are analyzed.

Table 2. As content in untreated drinking water from the territory of Banat after treatment by ferrate(VI)

Location 1		**Location 2**		**Location 3**		**Location 4**	
Reduction of As,%		Reduction of As,%		Reduction of As,%		Reduction of As,%	
71 µM, Fe(VI)	142 µM Fe(VI)	71 µM Fe(VI)	142 µM Fe(VI)	71 µM Fe(VI)	142 µM Fe(VI)	71 µM Fe(VI)	142 µM Fe(VI)
		93	97	84,5	96,4	90	95

Results of the treatment and analysis of As and permanganate index are shown in Tables 2 and 3, in percentage of reduction compared to initial values.

Table 3. Percentage of reduction of permanganate index in raw drinking water from the territory of Banat after treatment by ferrate(VI)

Location 1		**Location 2**		**Location 3**		**Location 4**	
Reduction of permanganate index		Reduction of permanganate index		Reduction of permanganate index		Reduction of permanganate index	
71 µM, Fe(VI)	142 µM Fe(VI)	71 µM Fe(VI)	142 µM Fe(VI)	71 µM Fe(VI)	142 µM Fe(VI)	71 µM Fe(VI)	142 µM Fe(VI)
		30,4	47	41	50,5	39	51

CONCLUSION

Aim of the work to define the procedure for As removal from the raw drinking water by ferrate(VI) is reached. As removal is up to 97%, while permanganate index is close to the statutory limit values (12 mg / l $KMnO_4$) [5]. Further optimization of the process would reach the concentration of total As below 10 µg / l which is, according to the Regulations on Hygienic Quality of Drinking Water of the Republic of Serbia, the limit value of arsenic concentration in drinking water.

The application of ferrate(VI) in the treatment of raw drinking water is possible and desirable, due to the high environmental performances of ferrate(VI) in comparison to the oxidants based on oxygen, ozone or hydrogen peroxide and aluminum-based and chlorine-based coagulants. Alternative or pre-treatment to conventional methods, can potentially be the treatment of raw water by ferrate(VI), which at the same time oxidizes the organic material, and As(III) to As(V), which is far more mobile than As(III) and can be removed from the solution by coagulation and flocculation with the resultant $Fe(OH)_3$ as a slurry.

The created pilot plant for the purification of raw drinking water has proved very effective application of ferrate(VI) in both, primary and secondary treatment process for raw drinking water. However, the treatment of fresh drinking water need to be specifically optimized depending on the initial values of As and permanganate index. In the presented pilot plant the treatment of raw drinking water by some other oxidizing and coagulation agents is also possible.

REFERENCES

[1] Mohora E., Mogućnost primene i efikasnost elektrokoagulacione tehnike u preradi podzemne vode sa visokim sadržajem prirodnih organskih materija - doktorska disertacija, 2012.
[2] WHO, Guidelines for Drinking-Water Quality, Vol.4. World Health Organisation, Geneva, pp. 315–318, 2011.
[3] Milenković Lj., Koščal M., Mijatović M., Geomorphological Map of Serbia 1:500,000, Geozavod-Gemini and Magic Map, Belgrade, 2003.
[4] IPA, Arsenic Platform, HUSRB/1002/121/075, 2012.
[5] Pravilnik o higijenskoj ispravnosti vode za piće ("Sl. list SRJ", br. 42/98 i 44/99)
[6] Ćuk M., Todorović M., Stojković J., Arsenic in groundwater for water supply in Vojvodina, XIV Srpski Simpozijum o Hidrogeologiji, Zlatibor, pp. 611-615, 2012.
[7] Kongkea P., Sthiannopkao S., Kim K.W., Wong M.H., Sao V., Hashim J.H., Yasin M., Salleh M., Syed Mohamed A., Health risk assessment of inorganic arsenic intake of Cambodia residents through groundwater drinking pathway, Water Research, Vol.44, pp. 5777–5788, 2010.
[8] Wood R.H., The heat, free energy, and entropy of the ferrate(VI) ion, Journal of American Chemical Society Vol.80, pp. 2038-2041, 1958.
[9] Čekerevac M.I., Nikolić-Bujanović Lj.N., Jokić A., Simičić M.V., Investigation of electrochemical synthesis of ferrate Part II: Optimization of the process parameters, Hemijska industrija, Vol.64(2), pp. 111-119, 2010.

GAS DETECTION THERMOGRAPHY

Hrvoje Glavaš[1], Anita Kvaček[1], Daniel Muštran[2]
[1]Josip Juraj Strossmayer University of Osijek, Faculty of Electrical Engineering, Osijek
[2]HEP - Distribution System Operator, Elektroslavonija Osijek
e-mail: hrvoje.glavas@etfos.hr

Abstract: Infrared thermography is present in civil use since the end of fifties of the last century. Despite technical advances and development of thermography, until today statutory regulation and technical standardization in the field of thermography has fallen behind compare to the fast technical progress of equipment. First thermographic cameras hardly detected gases. Development of camera equipment, primarily sensors, filters, speed and signal processing, made detecting of gases with infrared camera (in the past decade) the simplest non-destructive testing method. There are two technical solutions for gas leaks. First, solution is a camera that analyses very narrow spectral band. Those cameras detects leaking of known gases. Second solution is a camera with changeable filters that analyze radiation (in real time) in a very narrow band and detect different (particular) type of gases. This paper gives basic review of gas detection thermography.
Key words: thermography, gas detection

INTRODUCTION

Infrared thermography is a method for determining the temperature distribution on the surface of the object by measuring the intensity of radiation of the electromagnetic spectrum in the infrared region. Thermography is classified as one of non-destructive testing methods (NDT). There are no unique standards in the field of thermal imaging. Education in the field of non-destructive testing is defined by the ISO 9712:2012 Non-destructive testing - Qualification and certification of NDT personnel. ISO 9712:2012 defines three levels of education in the field of NDT, [1]. The necessary knowledge in the field of thermal imaging is described in BS ISO 18436-7:2014 "'Condition monitoring and diagnostics of machines - Requirements for qualification and assessment of personnel Part 7: Thermography", [2]. Infrared cameras for gas detection can help in decrease of environmental damage. For example gas detection cameras can detect many gases as: Methane, CO, CO_2, Benzene, Sulphur Hexafluoride, and so on. Gas used widely in electric distribution, SF6, thanks to its properties provides technical solutions for small size high voltage equipment which saves space in urban areas it is often used and few thousand times more problematic than CO_2. Methane is the second most prevalent greenhouse gas emitted by human activities.

THE INFRARED BANDS IN THE ELECTROMAGNETIC SPECTRUM

The infrared bands in the electromagnetic spectrum can be divided: Near-infrared (NIR): 0.75-1 µm, Short-wave infrared (SWIR): 1-2.7 µm, Mid-wave infrared (MWIR): 3-5 µm, Long-wave infrared (LWIR): 8-14 µm, Ultralong-wave infrared (ULWIR): 14-30 µm, as shown in Fig. 1.

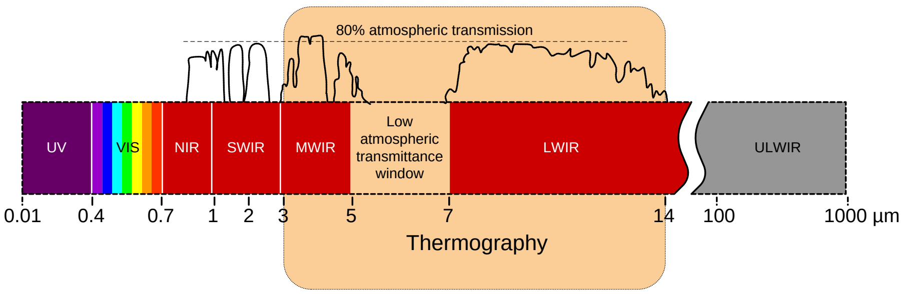


Figure 1. The infrared bands in the electromagnetic spectrum

Majority of thermal cameras register the radiation in two parts of the spectrum, MWIR and LWIR, [3]. The mid wave gas detection cameras have a detector response of 3-5 µm which is further spectrally adapted to approximately 3.3 μm by use of a cooled filter. This makes this particular model of camera most responsive to the gases commonly found in the petrochemical industries. Flir gas camera can detect many gases [4] but it has been laboratory tested against 19 which are: Benzene, Butane, Ethane, Ethylbenzene, Ethylene, Heptane, Hexane, Isoprene, MEK, Methane, Methanol, MIBK, Octane, Pentane, 1-Pentane, Propane, Propylene, Toluene and Xylene. The long wave gas detection camera has a detector response of 10-11 μm which is further spectrally adapted to approximately 10.5 μm by use of a cooled filter. This makes camera most responsive to Sulphur Hexafluoride (SF6) as well as Anhydrous Ammonia, Ethyl Cyanoacrylate ('Superglue'), Chlorine Dioxide, Acetic Acid, FREON-12, Ethylene and Methyl Ethyl Ketone (MEK), Acetyl Chloride , Allyl Bromide, Allyl Chloride, Allyl Fluoride, Bromomethane, FREON-11, Furan, Hydrazine, Methylsilane, Methyl Vinyl Ketone, Propenal, Propene, Tetrahydrofuran, Trichloroethylene, Uranyl Fluoride, Vinyl Chloride, Vinyl Cyanide, Vinyl Ether. Thermal resolution of infrared camera defines its quality in detection. Thermal resolution consist of four areas: Spectral resolution, Spatial resolution, Radiometric resolution and Temporal Resolution, [5]. For example spectral resolution of cameras used for building thermography most often detect long wavelength infrared radiation (8–14 μm). This is so because this band is less subject to solar reflectance problems. Radiant flux emitted by a surface at ambient temperatures is greater in the 8–14 μm band than it is in the 3–5 μm band, but the change in radiant flux for a small change in the temperature of a surface is greater in the 3–5 μm band [6], as can be seen in table 1.

Table 1. Radiance and contrast for different thermal wavelength bands, for a surface at ambient temperature

Wavelengt Band (μm)	**Radiance (watts/m2/steradian)**	**Contrast (% Change in Radiance for 1 °C delta T)**
3-5 μm	4.06	37.7
8-12 μm	93.4	16.9
8-14 μm	133.2	15.7

Spatial resolution refers to the smallest detectable target that can be measured. Radiometric resolution 'thermal sensitivity' refers to the smallest temperature differential, which can be perceived by the cameras pixels. Temporal resolution relates to the image refresh frequency of the camera.

GAS DETECTION THERMAL CAMERA

Thermographic camera has similar construction as digital video camera, except lens is opaque to visible light, detector and software are more complex. Detectors used in Gas Detection cameras are known as quantum detectors that require cooling to temperatures around -203°C. The MW camera uses an InSb detector and the LW camera uses a QWIP detector. Gas detection camera mainly differs from measurement cameras. The main difference is that sensor is cooled and there is a filter mounted on the front of the detector. The detector cools the filter to prevent any radiation exchange between the filter and the detector. The filter restricts the wavelengths of radiation allowed to pass through to the detector to a very narrow band called the band pass. This technique is called spectral adaptation. The filter band passes through wavelengths for different gas detection cameras. One of the largest infrared camera producers for civilian use is FLIR. At the moment FLIR produces these gas detection infrared cameras:

3.2 – 3.4 μm **GF300/320**, minimum detected leak rate (MDLR): 1-Pentene - 5.6g/hr, Benzene - 3.5g/hr, Butane -0.4g/hr, Ethane - 0.6g/hr, Ethanol - 0.7g/hr, Ethylbenzene - 1.5g/hr, Ethylene - 4.4g/hr, Heptane - 1.8g/hr, Hexane - 1.7g/hr, Isoprene - 8.1g/hr, MEK - 3.5g/hr, Methane - 0.8g/hr, Methanol - 3.8g/hr, MIBK - 2.1g/hr, Octane - 1.2g/hr, Pentane - 3.0g/hr, Propane - 0.4g/hr, Propylene - 2.9g/hr, Toluene - 3.8g/hr, Xylene - 1.9g/hr

3.8 – 4.05 μm **GF309** Furnace and Electrical Inspections

4.2 – 4.4 μm **GF343 CO_2 Leak Detection**,

4.52 – 4.67 μm **GF346 CO** Detection and Electrical Inspections Carbon Monoxide (CO), Nitrous Oxide (N_2O), Ketene, Ethenone (C_2H_2O), Butyl Isocyanide, Hexyl Isocyanide,

	Cyanogen Bromide (CNBr), Acetonitrile (C_2H_3N), Acetyl Cyanide, Chlorine Isocyanate (CClNO), Bromine Isocyanate (CBrNO), Methyl Thiocyanate (C_2H_3NS), Ethyl Thiocyanate, Chlorodimethylsilane ($(Ch_3)_2SiHCl$), Dichloromethylsilane, Silane (H_4Si), Germane (GeH_4), Arsine (AsH_3)
8.0 – 8.6 µm	**GF304 Refrigerant Leak Detection**, R404A, R407C, R410A, R134A, R417A, R422A, R507A, R143A, R125, R245fa
10.3 – 10.7 µm	**GF306 SF6**, SF6 (Sulfur Hexafluoride) - 0.026g/hr, Acetic Acid ($C_2H_4O_2$), Anhydrous Ammonia (NH_3), Chlorine Dioxide (ClO_2), Dichlorodifluoromethane "FREON-12" (CCl_2F_2), Ethyl Cyanoacrylate "Superglue" ($C_6H_7NO_2$), Ethylene (C_2H_4)

Gas detection technique with infrared camera is shown in figure 2. Infrared camera registers background radiation which passes through gas. Some IR wavelengths are transparent some opaque due to absorption so the gas can be seen on camera as darken region on bright background. The emission of gas and the emission of atmosphere are very small comparison to emission of background, so total infrared radiance at given wavelength can be expressed as:

$$E_{SUM}(\lambda) = \tau_{SUM}\left\lfloor \tau_a \tau_g E_b(\lambda, T_b) \right\rfloor \tag{1}$$

where:
- $E_{SUM}(\lambda)$ is the total infrared radiance at given wavelength,
- τ_{SUM} is spectral transmission of objective and spectral filters,
- τ_g is spectral transmission of gas,
- τ_a is spectral transmission of atmosphere,
- $E_b(\lambda, T_b)$ is infrared radiance of background at given wavelength and temperature.

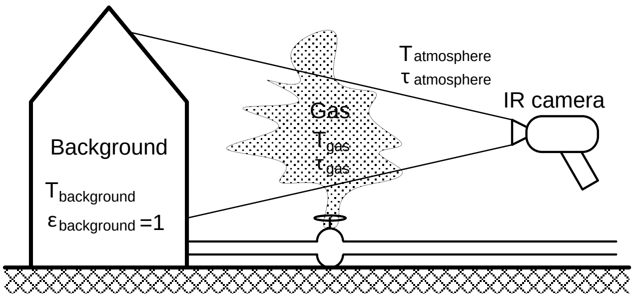


Figure 2. Measuring process for gas analysis in atmosphere

Transmission of the gas according to [7] can be defined as:

$$\tau_g(\lambda) = e^{-\sum k_i(\lambda) C_i d} \tag{2}$$

where k_i is absorption coefficient, C_i is average concentration of the chemical compound.

Depending of camera filter and gas characteristics identification of gases can be done. Infrared absorption spectra for water and carbon dioxide is shone on figure 3.

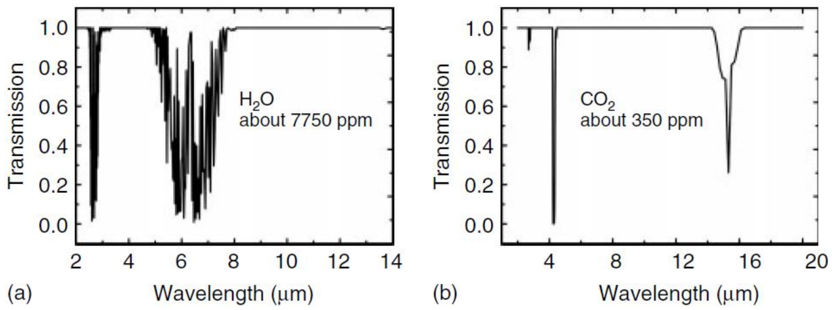


Figure 3. Transmission of H_2O and CO_2 as a function of wavelength, source [8]

Degree of transparency of gases varies with wavelength or ability to absorb infrared radiation. There are some IR wavelengths where gases are opaque due to absorption.

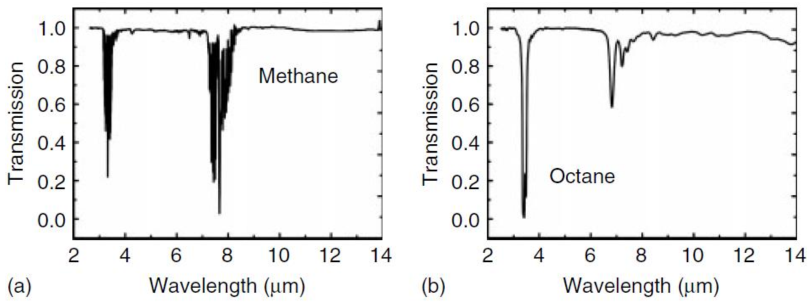


Figure 4. Transmission of CH_4 and C_8H_{18} as a function of wavelength, source [8]

On figure 4 a) it can be seen that methane can be easily detected in region from 7 - 8 µm but if we take into account that region 7 µm has low atmospheric transmittance and greater contrast in lover wavelength 3.2 – 3.4 µm region is used even methane transmission in that region is smaller. Figure 4 b) presents Octane transmission for different wavelengths. At a first look, it is obvious, that 3.2 – 3.4 µm camera will be used for detection of Octane.

Thermal image of gas can be seen on figure 5. which presents leakage of natural gas from reservoir in two pallets. On average natural gas processing plants lose between 0.05 to 0.5% of their total production to fugitive emissions. Up to 95% of these emissions can be prevented by identification and repair. Most equipment doesn't leak, almost 84% of all emission comes from 0.13% equipment, [9].

Figure 5. Detection of leakage of natural gas from reservoir, source [10]

Telops Inc. from Quebec City is a leading supplier of hyperspectral imaging systems [11] and high performance infrared cameras for the defense, industrial, environmental and research industries. They adopted little different approach to gas detection. Telops infrared camera shown on figure 6 is high performance cooled multispectral infrared camera which cover the complete mid-infrared spectral range or as shown in picture 7 very longwave.

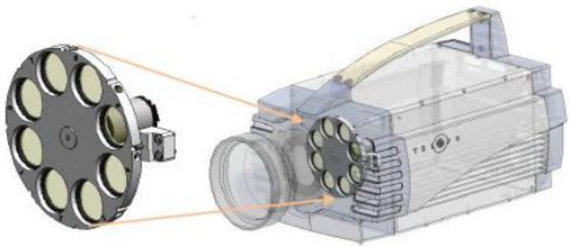


Figure 6. Telops MS-IR infrared camera

Telops Inc. integrated motorized filter wheel in camera which during of time of about 130 ms completes 4 full revolutions. Example of usage on methanol detection can be seen in Figure 7, absorption/emission of LWIR radiation mostly occurs in the 9.1-10.2 µm spectral range due to a spectral feature associated with the C-OH stretch vibration mode of methanol. Consequently, the greatest thermal contrast is obtained through filters #5 and #6.

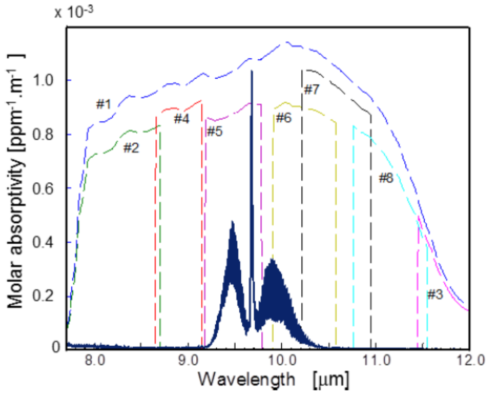


Figure 7. Telops MS-IR infrared camera filters detection area and absorption spectrum of methanol presented by dark blue curve

CONCLUSION

The ability of gases to absorb infrared radiation is base for gas detection with infrared camera. Degree of transparency of gases varies with concentration and wavelength, due to specified characteristic with usage of filters they can be identified. There are many technical solutions for infrared cameras that use the principle of absorption in a narrow spectral band. The main arguments for using infrared cameras in detecting gases is identifying gas leaking at an early stage and to avoid negative influence to environment. Considered that around 80% of all emission comes from 0.13% of equipment infrared thermography represents one of the most important methods in detecting gas leaking and conservation of technology systems.

REFERENCES

[1] ISO 9712:2012 Non-destructive testing - Qualification and certification of NDT personnel
[2] BS ISO 18436-7:2014 Condition monitoring and diagnostics of machines - Requirements for qualification and assessment of personnel Part 7: Thermography
[3] Clemente Ibarra-Castanedo, Abdelhakim Bendada, Xavier P.V. Maldague, "Infrared vision applications for the nondestructive testing of materials" 5th Pan American Conference for NDT 2-6 October 2011, Cancun, Mexico
[4] Flir, "GAS DETECTION The Professional Guide" 2009
[5] Matthew Fox, David Coley, Steve Goodhewa, Pieterde Wilde: "Thermography methodologies for detecting energy related building defects" enewable and Sustainable Energy Reviews 40, 296–310, 2014.
[6] Williams, T. L. "Thermal imaging cameras : characteristics and performance" CRC Press 2009.
[7] M. Kastek, T. Sosnowski, T. Piątkowski, H. Polakowski, "Methane detection in far infrared using multispectral IR camera" , 9th International Conference on Quantitative InfraRed Thermography, Krakow - Poland 2008.
[8] Michael Vollmer, Klaus-Peter Mollmann: "Infrared Thermal Imaging", WILEY 2010
[9] CONCAWE: "Optical methods for remote measurement of diffuse VOCs: their role in the quantification of annual refinery emissions" Brussels 2008
[10] http://www.huict.hr/ (15.08.2014.)
[11] TELOPS Inc."Time-resolved Infrared Multispectral Imaging of Gases" Canada 2014

MATHEMATICAL MODEL AND COMPUTER PROGRAM FOR CALCULATING ENERGY LOSSES OF FRICTION AT RING-TYPE WATER NETWORKS

Kire Popovski[1], Cvetanka Mitrevska[2], Vangelce Mitrevski[1], Igor Popovski[1], Blagoj Ristovski[3]

[1] University "St. Kliment Ohridski", Faculty of Technical Sciences, Bitola, Republic of Macedonia

[2] Internacional Slavic University Gavrilo Romanovic Derzavin, Faculty for Safety Engineering, Sveti Nikole, Republic of Macedonia

[3] University "St. Kliment Ohridski", Faculty of Information and Communications Technology, Bitola, Republic of Macedonia

e-mail: kire.popovski@tfb.uklo.edu.mk

Abstract. A computer program has been made to reduce the calculation time and to increase the accuracy of the calculation with no additional cost. The program does not require previous experience and advanced computer knowledge to operate it. There are two types of water supply networks, branched and ring-type. Ring type consists of a series of closed rings surrounding the consumers and supply them with water through sections. This type of water supply networks has an advantage over branched type because they do not require stopping of water in the entire network in a case of exclusion of certain parts of the network. When all input parameters are known, it is necessary to calculate the diameters of all sections and meet the required pressure drop in each of them.

Keywords: ring water supply networks.

MATHEMATICAL MODEL FOR COMPUTER PROGRAM

According to hydraulic connections, there are two types of water supply networks, branched and looped (ring-type). Looped water supply network, Pic. 1, consists of a number of closed loops (rings) surrounding the consumers while supplying them with water through sections. This ring of network has advantage over branched type because there is no need to interrupt the supply to all network if and intervention is required only on one part of it. When calculation for looped type of water supply network is performed, two laws of hydraulics have to be satisfied.

a) The sum of volume flows in every node must to be zero, that is the amount of water entering and leaving the node must be equal and

b) At constant flow, the pressure difference between two cross-sections in the network is used to overcome the resistance and geodetic height between the cross-sections.

In order to explain the mathematical model, which used as a base for development of computer programme, an example shown in Pic. 1 is used. Every branch is labeled with number and the corresponding volume flow (ex. 1-14 means branch 1, 14 l/s). Network is comprised of 4 loops also labeled with numbers in the middle. To run the computer programme properly, it has to be previously "filled" with input data (with known network data).

Volume flow (inlet and outlet) and length of section represent input data for every node.

Total allowed pressure drop in the system is $\Sigma\Delta p$=5000 Pa, [1]. This value of pressure drop is enough to allow the complete calculation of the network to be with satisfying accuracy, but the computer programme itself allows the total pressure drop in some cases to reach values smaller than 100 Pa.

Number of loops: j = 4

Number of sections: i = 12

Friction coefficient of the pipe: λ=0,018

Density of water: ρ=1000 kg/m^3

For calculation of the network parameters, relative direction of water movement in the loops have to be adopted. In this case, we adopt clockwise direction to be 'positive'.

With above shown input data it is neccessary to calculate cross-sections of all section and to match the allowed pressure drop in each of them.

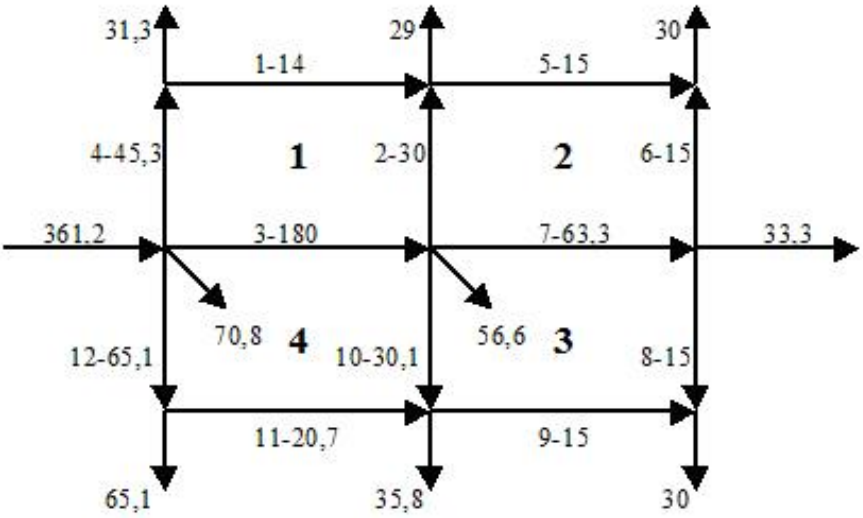


Figure 1. Ring - type water network

The calculation goes under the following order:
Pipe diameter,

$$D_i = 0{,}025 \cdot (\rho \cdot q_i)^{0,48} \quad \text{m} \quad . \tag{1}$$

Calculated diameter is standardized onto the first greater standard size.
Recommended values for velocity of water in pipes are, w=0,75 - 2 m/s.
Hydraulic resistances,

$$S_i = \rho \cdot 0{,}01454 \cdot L_i \cdot D_i^{-5,33} \qquad \text{Pa·s}^2/\text{m}^6 \quad . \tag{2}$$

Energy losses due to friction (pressure drop),

$$\Delta p_i = S_i \cdot q_i^2 \qquad \text{Pa} \quad . \tag{3}$$

Correction of the flow in the loop,

$$\Delta q_j = -\frac{\sum \Delta p_i}{2 \cdot \sum S_i \cdot q_i} \qquad \text{m}^3/\text{s} \quad . \tag{4}$$

NUMERICAL EXAMPLE AND COMPARISON OF RESULTS

Calculation is performed through iterations while the number of iterations is determined by the value of pressure drop, i.e. number of iterations must be sufficient to result in pressure drop equal or smaller than recommended value.
Number of iteration depends on the accuracy determined in the computer programme. In this case, the accuracy is set to 0,11 l/s which means that the difference between calculated flow in the section from the previous iteration and currently calculated flow in the same section should not be greater than 0,1 l/s.
Accuracy of mathematical model and computer programme is proved by comparing with the same network calculated according to [1]. Comparison is presented on Table 2.

Table 1. Review of calculate water flow in each iteration

Section	*l* m	*Q* l/s	*q* – 1 l/s	*q* - 2 l/s	*q* - 3 l/s	*d* mm	Δ*p* Pa
1	880.000	14.000	9.410	9.241	9.233	100.0	234975
2	735.000	30.000	32.242	32.362	32.362	151.0	267734
3	880.000	180.000	185.000	185.469	185.445	313.9	212451
4	735.000	45.300	36.760	36.593	36.602	160.3	249003
5	880.000	15.000	14.280	14.281	14.241	100.0	559026
6	735.000	15.000	16.305	16.304	16.365	100.0	616599
7	880.000	63.300	64.744	63.719	63.708	211.1	208051
8	735.000	15.000	15.908	16.739	16.739	100.0	645149
9	880.000	15.000	14.485	15.035	15.035	100.0	623128
10	735.000	30.100	30.722	29.906	29.909	151.0	228694
11	880.000	20.700	18.623	18.291	18.275	125.0	280049
12	735.000	65.100	62.434	62.163	62.147	211.1	165357

Table 2. Comparison of results

Section	Starting flow l/s	Calculated flow l/s	Calculated flow l/s according to [1]	*l* m	*d* mm	*d* mm according to [1]
1	14.000	9.233	9.470	880	100.0	150
2	30.000	32.362	32.500	735	151.0	200
3	180.000	185.445	190.480	880	313.9	400
4	45.300	36.602	40.770	735	160.3	200
5	15.000	14.241	12.970	880	100.0	150
6	15.000	16.365	17.030	735	100.0	150
7	63.300	63.708	67.580	880	211.1	300
8	15.000	16.739	17.250	735	100.0	150
9	15.000	15.035	12.750	880	100.0	150
10	30.100	29.909	33.800	735	151.0	200
11	20.700	18.275	14.750	880	125.0	150
12	65.100	62.147	59.150	735	211.1	250

NOMENKLATURE

d diameter of the section,
H geodetic height of node in the network,
l length of section,
p pressure in network,
q volume flow of water in section,
w velocity of water in section,
Δ*p* energy loss due to friction.

REFERENCES

[1] ŠAŠIĆ, M., Transport fluida u cevima, Mašinski fakultet, Beograd, Serbija, 1982.
[2] STOJANOVSKI, V., POPOVSKI, K., Transportni sistemi i transport vo cevki, Zbirka na rešeni i ispitni zadači, I del, Tehnički fakultet, Bitola, Makedonija, 2004.
[3] DYMOND, J.H., NIETO DE CASTRO, C.A., Transport properties of fluids: their correlation, prediction and estimation, Cambridge University Press, UK, 1996.
[4] SWAMEE, P.K., SHARMA, K.A., Design of water supply pipe networks, Wiley-interscience, 2008.
[5] PRESSMAN, R. S. Software Engineering: A Practitioner's Approach. Programming Visual Basic, 3rd Edition, New York, USA, 2005.

MATHEMATICAL MODEL AND COMPUTER PROGRAM FOR CALCULATING ENERGY LOSSES OF FRICTION AT BRANCH TYPE WATER SUPPLY NETWORK

Kire Popovski[1], Cvetanka Mitrevska[2], Vangelce Mitrevski[1], Igor Popovski[1], Blagoj Ristovski [3]
[1] University "St. Kliment Ohridski", Faculty of Technical Sciences, Bitola, Republic of Macedonia
[2] Internacional Slavic University Gavrilo Romanovic Derzavin, Faculty for Safety Engineering, Sveti Nikole, Republic of Macedonia
[3] University "St. Kliment Ohridski", Faculty of Information and Communications Technology, Bitola, Republic of Macedonia
e-mail: kire.popovski@tfb.uklo.edu.mk

Abstract: For a classic calculation of water supply networks, it takes time and precision, and computer programs are very expensive. To reduce the budget time and increase precision, and without spending material resources, a computer program is developed that is fully automatic, and the usage of it does not require any previous experience or extensive knowledge of computer technology.
Key words: branch type water supply networks.

MATHEMATICAL MODEL FOR COMPUTER PROGRAM

There are two types of water supply networks, branched and cyclic. Branched supply network consists of a main line, branch and sub branch. This network is used to supply water to a small number of consumers at a distance permitting short interruptions in the supply itself, and which may result from any cause.
Input data into a computer program are flows on the edges of the network, the length of the shares, geodetic height of nodes and pressures on consumer sites. These data are entered in the file, a computer program calculates and standardizes the diameter of all of the shares and their energy loss from friction. The results are recorded in a separate output file that can be used if necessary.
For a better explanation the scheme of water supply network that is used also as a numerical example, Figure 1, [1].
On the basis of the following mathematical model, a computer program is developed, and therefore the explanation of the mathematical model will be an explanation of the computer programs.
The input data for the program are known (default) data on the network:
- Volumetric flow rates and pressures at the ends of the network (point 7, 6, 4, 10, 9),
- The length of all of the shares,
- Geodetic head nodes, i height differences of the input and output of each share, (eg. for section 1-2:) H_2-H_1,

The next step is the calculation of volumetric flow rate of each node. Algebraic sum of the flow of each node should be zero, namely the input flow in the node should be equal to the flow that comes out, [1],

$$q_{2,5} = q_{5,7} + q_{5,6} \quad , \tag{1}$$

$$q_{3,8} = q_{8,10} + q_{8,9} \quad , \tag{2}$$

$$q_{2,3} = q_{3,4} + q_{3,8} \quad , \tag{3}$$

$$q_{1,2} = q_{2,3} + q_{2,5} \quad . \tag{4}$$

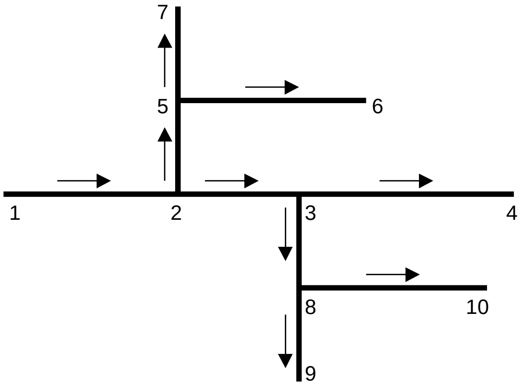


Figure 1. Branch type water supply network, [1]

Then the velocity of the water in each section is concluded. The value of speed is: $w_{i,j}$=0,75-2 m/s, [1], due to the reduction in energy loss and preventing the occurrence of the water hammer.
With this adopted speeds are calculated diameters of shares,

$$d_{i,j} = \sqrt{\frac{4 \cdot q_{i,j}}{\pi \cdot w_{i,j}}} \quad . \tag{5}$$

Manning's formula for calculating the energy losses of friction in the sections is,

$$\Delta p_{i,j} = 0{,}0144 \cdot \rho \cdot l_{i,j} \cdot q_{i,j}^{2} \cdot d_{i,j}^{-5,33} \quad . \tag{6}$$

The flow of water in sections is turbulent.
At the end, calculates the pressure at the beginning of the network by walking on the current flow to each consumer, [1],

$$\begin{aligned} p_{1,2,3,4} = {} & \Delta p_{1,2} + \rho \cdot g \cdot (H_2 - H_1) + \Delta p_{2,3} + \rho \cdot g \cdot (H_3 - H_2) + \\ & + \Delta p_{3,4} + \rho \cdot g \cdot (H_4 - H_3) + p_4 \end{aligned} \quad , \tag{7}$$

$$\begin{aligned} p_{1,2,5,6} = {} & \Delta p_{1,2} + \rho \cdot g \cdot (H_2 - H_1) + \Delta p_{2,5} + \rho \cdot g \cdot (H_5 - H_2) + \\ & + \Delta p_{5,6} + \rho \cdot g \cdot (H_6 - H_5) + p_6 \end{aligned} \quad , \tag{8}$$

,,

$$\begin{aligned} p_{1,2,5,7} = {} & \Delta p_{1,2} + \rho \cdot g \cdot (H_2 - H_1) + \Delta p_{2,5} + \rho \cdot g \cdot (H_5 - H_2) + \\ & + \Delta p_{5,7} + \rho \cdot g \cdot (H_7 - H_5) + p_7 \end{aligned} \quad , \tag{9}$$

$$\begin{aligned} p_{1,2,3,8,9} = {} & \Delta p_{1,2} + \rho \cdot g \cdot (H_2 - H_1) + \Delta p_{2,3} + \rho \cdot g \cdot (H_3 - H_2) + \\ & + \Delta p_{3,8} + \rho \cdot g \cdot (H_8 - H_3) + \Delta p_{8,9} + \rho \cdot g \cdot (H_9 - H_8) + p_9 \end{aligned} \quad , \tag{10}$$

$$\begin{aligned} p_{1,2,3,8,10} = {} & \Delta p_{1,2} + \rho \cdot g \cdot (H_2 - H_1) + \Delta p_{2,3} + \rho \cdot g \cdot (H_3 - H_2) + \\ & + \Delta p_{3,8} + \rho \cdot g \cdot (H_8 - H_3) + \Delta p_{8,10} + \rho \cdot g \cdot (H_{10} - H_8) + p_{10} \end{aligned} \quad . \tag{11}$$

For an accurate calculation of the network it is necessary to meet the requirement,

$$p_{1,2,3,4} = p_{1,2,5,6} = p_{1,2,5,7} = p_{1,2,3,8,9} = p_{1,2,3,8,10} \quad . \tag{12}$$

In this case, each consumer would obtain the required amount of water, but with the first iteration it is impossible to get it. So taken, so-called, authoritative power line, namely a power line that has the highest value. In this case it is a straight $p_{1,2,5,6}$=12,4 bar, because,

$$p_{1,2,3,4} = 11{,}3 \quad \text{bar,} \tag{13}$$

$$p_{1,2,5,6} = 12{,}4 \quad \text{bar,} \tag{14}$$

$$p_{1,2,5,7} = 11{,}7 \quad \text{bar,} \tag{15}$$

$$p_{1,2,3,8,9} = 10{,}8 \quad \text{bar,} \tag{16}$$

$$p_{1,2,3,8,10} = 12{,}3 \quad \text{bar,} \tag{17}$$

The diameters and energy losses per shares in the given current direction don't change in the course of further calculating and diameters and energy losses of the second quarter are corrected in the following iterations.

NUMERICAL EXAMPLE AND COMPARISON OF RESULTS

The calculated value of the computer-program were compared to the calculations made without standardized diameter. The input and calculated values according to [1] are shown in Table 1, and according to the computer program in Table. 2.
The pressure at the beginning of the network by walking on the current flow to each consumer is,

$$p_{1,2,3,4} = 9{,}4 \quad \text{bar,} \tag{18}$$

$$p_{1,2,5,6} = 9{,}733 \quad \text{bar,} \tag{19}$$

$$p_{1,2,5,7} = 9{,}53 \quad \text{bar,} \tag{20}$$

$$p_{1,2,3,8,9} = 8{,}825 \quad \text{bar,} \tag{21}$$

$$p_{1,2,3,8,10} = 9{,}145 \quad \text{bar,} \tag{22}$$

Table 1. Entry and calculated values, [1]

Sections	q_{ij} m^3/s	l_{ij} m	$H_j - H_i$ m	p_j Pa	d_{ij} m	Δp_{ij} Pa	d_{ij} m	Δp_{ij} Pa
5,6	0,040	2800	0	4,00	200	3,43	200	3,43
5,7	0,060	2000	+6	4,50	250	1,68	235	2,34
2,5	0,100	1500	-2	7,43	300	1,32	300	1,32
3,4	0,025	1000	0	4,50	150	2,22	140	3,19
8,9	0,100	1200	+7	4,00	300	1,06	256	2,46
8,10	0,075	1800	-2	5,00	250	2,36	250	2,36
3,8	0,175	900	0	7,16	400	0,53	400	0,53
2,3	0,200	500	+4	7,69	400	0,38	385	0,47
1,2	0,300	5800	+8	8,55	500	3,02	500	3,02

Table 2. Entry and calculated value according computer program

Sections	q_{ij} m^3/s	l_{ij} m	$H_j - H_i$ M	p_j Pa	d_{ij} m	Δp_{ij} Pa	w_{ij} m/s
5,6	0,040	2800	0	4,00	211,1	2,571	1,143
5,7	0,060	2000	+6	4,50	263,0	1,280	1,104
2,5	0,100	1500	-2	7,43	345,6	0,622	1,066
3,4	0,025	1000	0	4,50	160,3	1,556	1,239
8,9	0,100	1200	+7	4,00	345,6	0,498	1,066
8,10	0,075	1800	-2	5,00	313,9	0,701	0,969
3,8	0,175	900	0	7,16	445,2	0,296	1,124
2,3	0,200	500	+4	7,69	445,2	0,215	1,285
1,2	0,300	5800	+8	8,55	542,8	1,952	1,296

CONCLUSION

The necessary condition for the ideal calculation of the network,

$$p_{1,2,3,4} = p_{1,2,5,6} = p_{1,2,5,7} = p_{1,2,3,8,9} = p_{1,2,3,8,10} \quad , \tag{23}$$

can not be achieved due to the standardization of pipe diameters. In the computer calculation maximum deviation is 0.9 bar.

NOMENCLATURE

d diameter sections,
H geodetic height of nodes in the network,
l length of shares,
p the pressure in the network,
q water flow rate into shares,
w water velocity in the shares,
Δp energy loss from friction.

REFERENCES

[1] ŠAŠIĆ, M., Transport fluida u cevima, Mašinski fakultet, Beograd, Serbija, 1982.
[2] STOJANOVSKI, V., POPOVSKI, K., Transportni sistemi i transport vo cevki, Zbirka na rešeni i ispitni zadači, I del, Tehnički fakultet, Bitola, Makedonija, 2004.
[3] DYMOND, J.H., NIETO DE CASTRO, C.A., Transport properties of fluids: their correlation, prediction and estimation, Cambridge University Press, UK, 1996.
[4] SWAMEE, P.K., SHARMA, K.A., Design of water supply pipe networks, Wiley-interscience, 2008.
[5] PRESSMAN, R. S. Software Engineering: A Practitioner's Approach. Programming Visual Basic, 3rd Edition, New York, USA, 2005.

IMPROVING THE COOLING WATER IN COOLING TOWERS WITH FILM TYPE FILLINGS BY CHANGE THE PARAMETERS OF WATER AND AIR

Davor Milić[1], Dušan Golubović[1], Đorđe Drakulić[1], Krsto Batinić[1]
[1] University of East Sarajevo, Faculty of Mechanical Engineering,
e-mail: mdavor82@gmail.com

Abstract:This paper shows dependences cold water temperature of coefficient A, height of the filling h_p, and air number λ for different values of temperature of wet thermometer (t_{wB}) and different width of cooling area (Δt_w) in cooling towers with film type filling. Besides, the basic features of this type of filling are shown, as well as basic of technological calculation of cooling towers. For the purpose of analysis one – dimensional model of water cooling in counter flow cooling tower by Merkel basic equation was applied.
Key words*:* cooling tower, filling, film flow,cooling efficiency

INTRODUCTION

For the functioning of various industrial and thermal power plants is essential to conduct heat from the plant into the environment and thus indirectly improve the energy efficiency of the plant. The paper presents the possibility of improving the cooling water in the counter flow cooling tower power plant. Cooling towers are basic element of recirculation cooling systems for process water. Applied in industrial plants, refineries, power plants and other installations in which it is necessary to conduct heat. In most large cooling towers, cooling water and air are in direct contact. Cooling water is pumped into the sprinkler system and the nozzles inside the cooling tower where it is sprayed, and then under the force of gravity falls across the fill into the pool below the tower. Air from the atmosphere enters the basis of the cooling tower and moving in the opposite direction to the movement of falling water. To improve the level of heat transfer in the tower is necessary to ensure greater contact surface between water and air. Part of the tower where there is direct contact between water and air is called fill and it is placed over the cross section of the tower. Cooling water is mostly performed in cooling tower fillings. Therefore, analysis of the application of different types of fillings is an extremely important task, but also opens up the possibility of improving cooling efficiency. Runoff water can be in the form of drops, films or combined over the surface of fill while the air flows between the sheets. During the contact of water and air temperature of the water decreases while the air temperature rises.
In practice, the following types of fillingsare used, depending on the flow of water:

- droplet flow
- Film flow
- combined (film-droplet flow).

FILLINGS FOR THE FILM FLOW WATER

Improving evaporative cooling water is achieved using the plastic fill for the film flow of water (Fig. 1) [2]. Flat panels of fills are normally designed for an counter and cross flow of water and air. The panels are mounted in vertical or inclined at an angle of 5 ° to reduce the speed drops through the gaps between the plates. There are flat and corrugated board for this filling. The waves are parallel with respect to the flow of air so that there is no additional aerodynamic resistance. The thermal characteristics of this type of filling is defined by the equation:

$$Me = K_{Me}\lambda^n \tag{1}$$

Which is derived on the basis of the experiment the values for λ=0,7 to 2; R_{ew}>17 and d=25 to 65 mm. The coefficient for film K_{Me} in equation (1) is defined in the form of [2],

$$K_{Me} = \frac{47,2}{d} \tag{2}$$

For this type of filling with flat plates is defined hydraulic diameter [2]:

$$\mathrm{d} = \frac{4\varepsilon}{\mathrm{A_p}} \tag{3}$$

Where ε represents the ratio of empty space of filling and the total volume of filling, and $\mathrm{A_p}\left\lfloor\frac{1}{\mathrm{m}}\right\rfloor$ the surface filling per unit volume of the cooling tower.

For variable mass flow rates of water and air, gives the following dependence,

$$\frac{Me}{h_p} = f\left(\Pi_v, \Pi_w\right) \tag{4}$$

where:

$$\Pi_v = \frac{q_{mv}}{q_{mvref}} \tag{5}$$

$$\Pi_w = \frac{q_{mw}}{q_{mwref}} \tag{6}$$

Equation (4) is given for filling with film flow of water composed of flat panel characteristics of ε =0,817, interfacial area per unit volume of filling $\mathrm{A_p}$=95 $\left\lfloor\frac{1}{\mathrm{m}}\right\rfloor$ and assuming that the air and water have the same mean temperature of 25ºC. Graphical representation of equation (4) for given parameters and the dependence of the speed of the water film from the flow factor Π_w is shown in Fig. 2.

For the design, construction and operation of wet cooling towers in the technical literature was introduced simplification with the introduction of volumetric coefficient of mass transfer and heat humid air and

water. $\beta_v = \beta\frac{S}{V} = K_\beta \Pi_g^n \Pi_w^s$ (7)

For flat film fill defined Merkel's number in the form of:

$$Me = K_{Me}\lambda^n \cdot \Pi_w^s \cdot h_p \tag{8}$$

The coefficient of heat transfer and mass is larger for filling with sparging than with a film of water. However, in the same volume can be placed much higher surface area of film fill. Therefore, at the same volume of air resistance coefficient of heat transfer and mass is 1.6 ÷ 2.5 times higher for film fill. That is why modern wet cooling towers generally are constructed with the film filled.

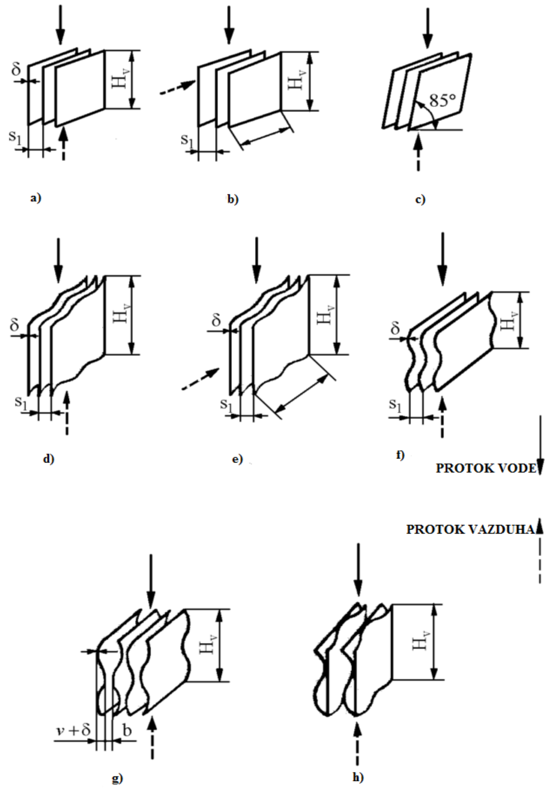


Figure 1. Plated fill for the film water flow: a,b,c) fill with smooth surface and d,e,f,g,h) fill with corrugated plates [2].

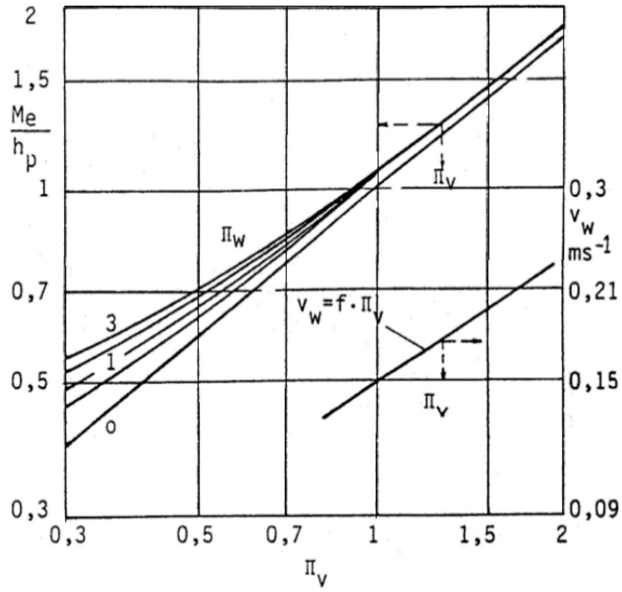


Figure2. Graphical representation of equation (4) for film filling and dependence rate of water film from flow factor Π_w [2].

TEHNOLOGICAL CALCULATION FOR COOLING TOWER

Technological calculation requires full coordination of thermal and aerodynamic calculations, because the air flow through the tower is not known in advance, because it is a function of the structural parameters of the cooling tower and the individual parameters. Technology calculation consists of two parts:

a) Determination of the tower dimensions for the external conditions, water temperature, thermal and hydraulic load.
b) Determination of the cooling tower efficiency (temperature of cold water) with defined geometry for different parameters of outside air.

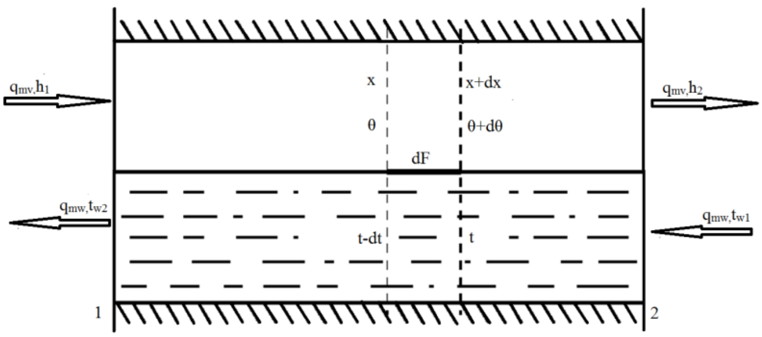


Figure 3. Water surface in contact with air

Consider the free water surface between the section 1 and 2, in direct contact with air (Figure 3) as is the case in the filling of water cooling tower. Air flow is q_{mv} kg/s , water flow is q_{mw} kg/s, water

temperature entering in the tower t_{w1}, and the exit water temperature t_{w2}. Enthalpy of the air at the entrance is h_1, and exit enthalpy is h_2.
The basic equation of heat balance for the entire tower is:

$$\int_{t_{w2}}^{t_{w1}} \frac{c_{pw} dt_w}{h_{vs} - h_v} = \frac{\beta_x}{q_{mw}} \int_0^F dF = \frac{\beta_x F}{q_{mw}} \tag{9}$$

If the coeficient β_x given in relation to the volume (as β_{xv}), assuming that β_{xv} does not depend on the thermodinamic parameters of the air and water wich is very close to reality, entirely analogues for the last equation is get:

$$\int_{t_{w2}}^{t_{w1}} \frac{c_{pw} dt_w}{h_{vs} - h_v} = \frac{\beta_{xv} V}{q_{mw}} \tag{10}$$

In the literature integral on the left side of equation 10 is called Merkel's number , *Me*.

$$Me = \int_{t_{w2}}^{t_{w1}} \frac{c_{pw} dt_w}{h_{vs} - h_v} \tag{11}$$

The right side of integral 10 is filling caracteristic and it is usually expresed as:

$$\frac{\beta_{xv} V}{q_{mw}} = A \cdot \lambda^n \cdot h_p \tag{12}$$

Where are: A and n – coefficients obtained experimentally, h_p[m] – filling height

$\lambda = \frac{q_{mv}}{q_{mw}}$ - air number

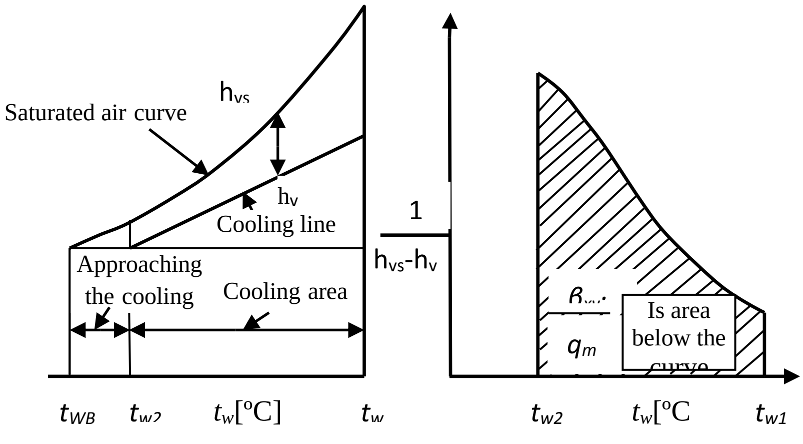


Figure 4. Graphical interpretation of the integral 11

COOLING DIAGRAMS FOR DIFFERENT WATER AND AIR PARAMETERS

This chapter provides an analysis of the filling characteristics for the film stream of water depending on the coefficient A, filling height h_p and air number λ for various wet thermometer temperature (t_{wb}) and various cooling zone widths (Δt_w). The first is analyzed drop type filling with the following characteristics: A = 2.0; n = 0,5; h_p = 1,2 m; λ = 0.5 for Me = 1,7; λ = 1.0 for Me = 2,4; λ = 1.5 for Me = 2,9 and the following results were obtained.

Figure 5 shows the dependence of water temperature entering in the cooling tower (t_{w1}) and water temperature at the output of the cooling tower (t_{w2}) from λ = 0.5 to 1.5, Δt_w = 5 ° C and t_{wb} = 16,7ºC (Figure 5 a.), t_{wb} = 20 ° C (Figure 5 b.) and t_{wb} = 23,3ºC (Figure 5 c.). Figure 5 d. shows the t_{w2} dependence on λ and t_{wb}.

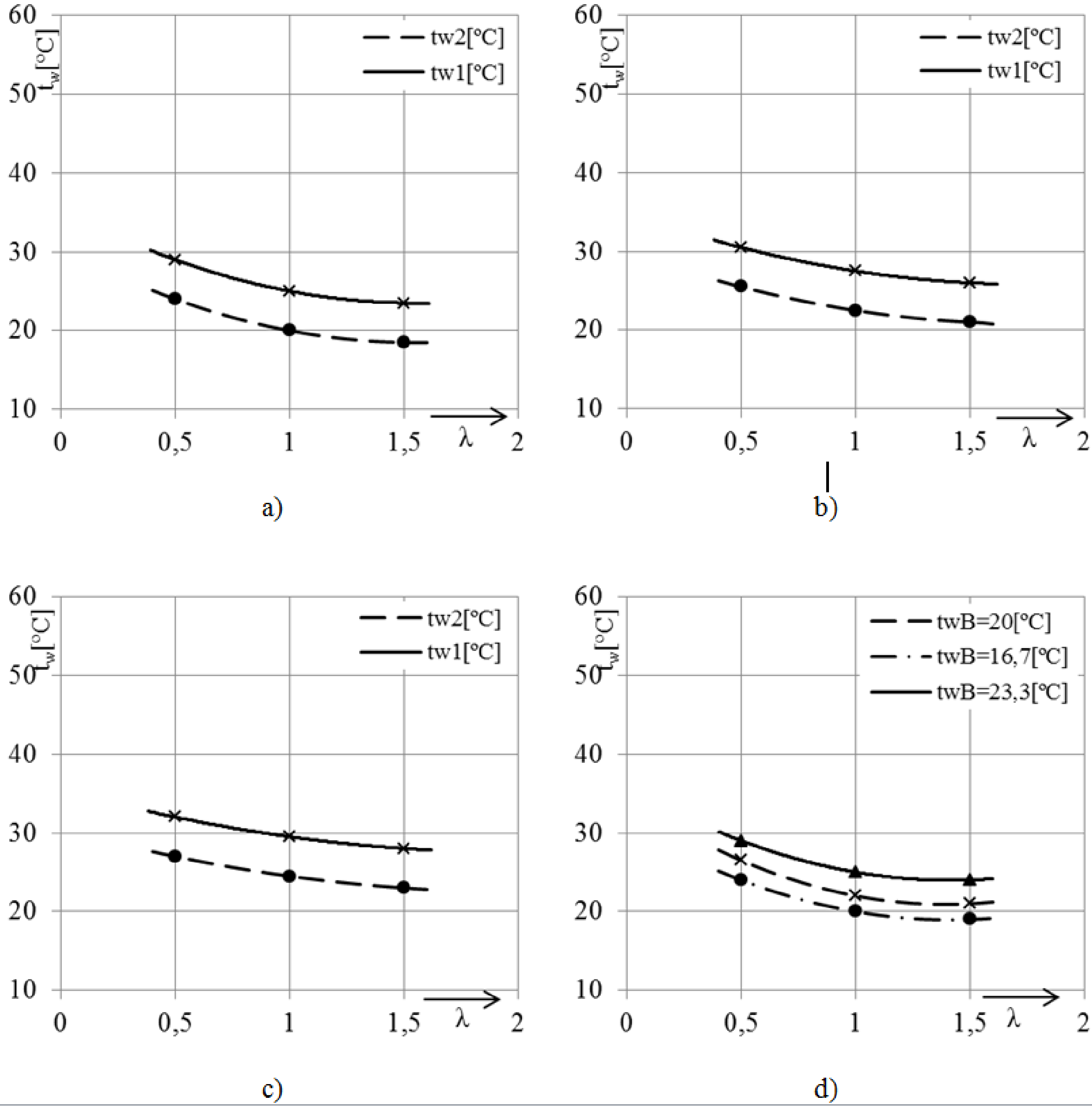


Figure 5. Water temperature dependency at the cooling tower input (t_{w1}) and the water temperature at the cooling tower output (t_{w2}) on λ= 0,5 to 1,5, Δt_w=5 ºC and t_{wB}=16,7ºC (Fig.5a.), t_{wB}=20ºC (Fig.5b.) and t_{wB}=23,3ºC (Fig. 5 c.)

The Figure 6 shows dependency water temperature at the cooling tower input (t_{w1}) and water temperature at the cooling tower output (t_{w2}) on λ= 0,5 to 1,5, Δt_w=10 ºC and t_{wB}=16,7ºC (Fig. 6 a.), t_{wB}= 20 ºC (Fig.6b.) and t_{wB}=23,3ºC (Fig.6 c.). On the Figure 6 d., is presented dependency of t_{w2} on λ and t_{wB}.

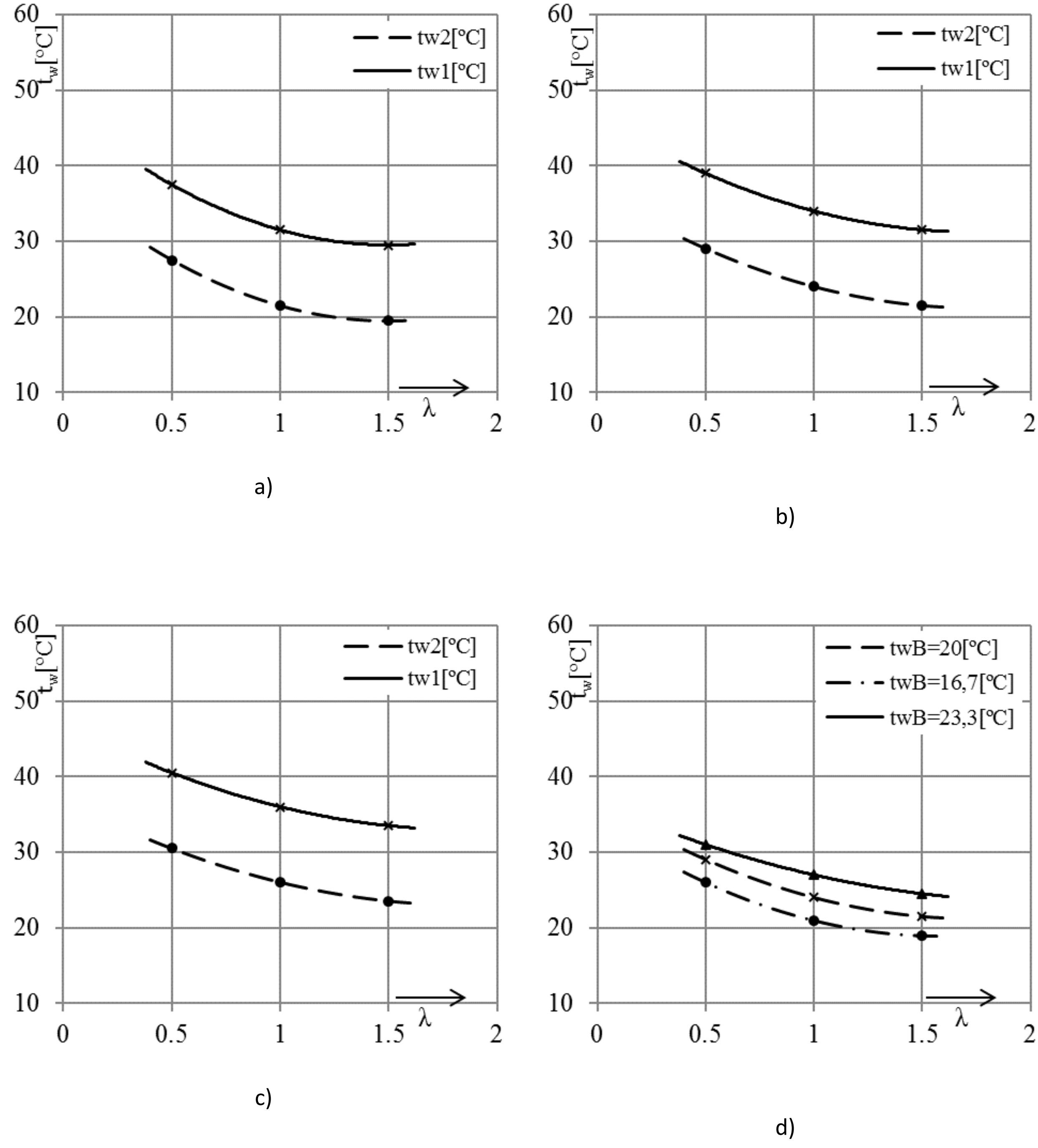


Figure 6. Water temperature dependency at cooling tower input (t_{w1}) and water temperature at cooling tower output (t_{w2}) on λ= 0,5 to 1,5, Δt_w=10 ºC and t_{wB}=16,7ºC (Fig.6a.), t_{wB}=20ºC (Fig.6b.) and t_{wB}=23,3ºC (Fig.6c.)

The Figure 7 shows dependency water temperature at colling tower input (t_{w1}) and water temperature at cooling tower output (t_{w2}) on λ= 0,5 to 1,5, Δt_w=15 ºC and t_{wB}=16,7ºC (Fig. 7 a.), t_{wB}= 20 ºC (Fig. 7b.) and t_{wB}=23,3ºC (Fig. 7c.). On the Figure 7 d. Is prezented dependency of t_{w2} on λ and t_{wB}.

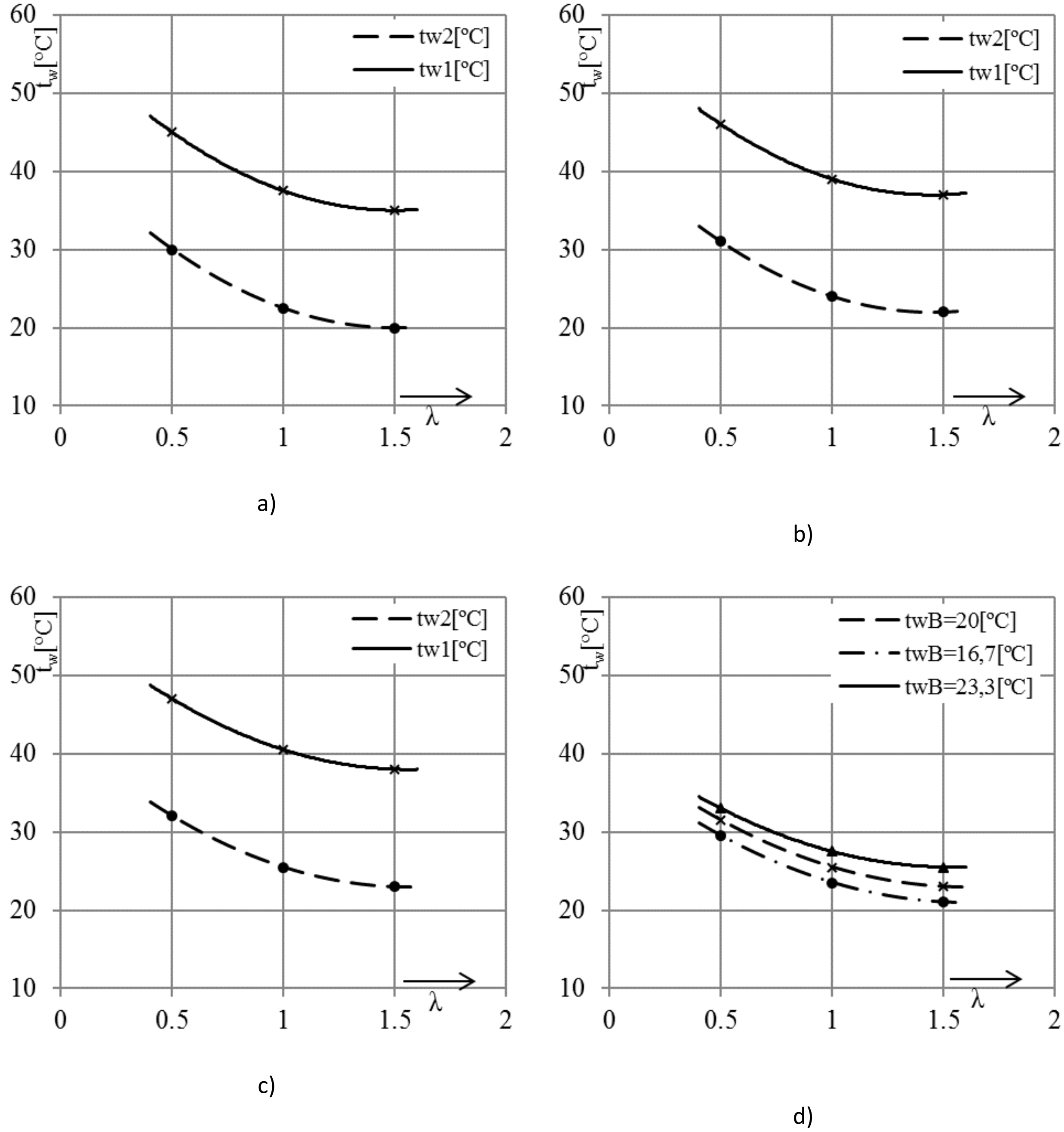


Figure 7. Water temperature dependency at cooling tower input (t_{w1}) and water temperature at cooling tower output (t_{w2}) on λ= 0,5 to 1,5, Δt_w=15 ºC and t_{wB}=16,7ºC (Fig. 7a.), t_{wB}=20ºC (Fig. 7b.) and t_{wB}=23,3ºC(Fig. 7c.)

CONCLUSION

In this paper are presented possibilitis of water colling improvement. The analysis of simultaneous heat and mass transfer in counter, wet cooling towers with film type water stream is done. For the analysis was applied the one-dimensional water cooling model in counter cooling tower by using Merkel basic equation. Also, in the paper are presented the coefficients of heat and mass transfer of the film type fillings. Tehnology calculation of the cooling tower is given. It was analyzed contribution to water cooling by changing the water and air parameters in cooling tower. The filling height improves cooling, not linearly, but with decreasing gradient. Hight height of fillings are not efficient. The usual height of filling is (0,9 ÷ 1,8) m. For higher value of air number (λ) cooling tower output temperature decreases (t_{w2}), but fall gradient is reduced. This means that high values of λ are unnecessary. Typical values of λ are λ= 0,6÷1,3. Cooling water is in the range (5 ÷ 15)ºC. For smaller values of the output temperature (t_{w2}), lesser Δt_w, higher value of λ and higher filling height are favorable. By the proper selection water and air parameters we can significantly affect on water cooling in cooling towers.

REFERENCES

[1] Milić, D., Analysis of cooling water improvement by changing fill characteristics in the hyperbolic cooling tower, University of East Sarajevo, Faculty of Mechanical Engineering, Master thesis, 2014.

[2] Zemanek, I.: Heat and Mass Transfer in Cooling Tower Packings, National Research Institute for Machine Desing, Praha, 1989.

[3] Golubović, D.: Film-drop filling type of the wet cooling towers, The Federal Institute of Intellectual Property, Belgrade, 2000.

[4] Golubović, D., Milić, D., Stanić, S., Drakulić, Đ.: Analysis of energy efficiency by change of characteristics of fillings in cooling towers, Društvo termičara Srbije, Divčibare, 2013.

Session 6.

Basic operations, machinery and processes

NUMERICAL STUDY OF TRAFFIC FLOW MODELS

Sean Breckling[1], Pushkin Kachroo[2], Puneet Lakhanpal[2], Monika Neda[3]
[1]Department of Mathematical Sciences, University of Nevada – Las Vegas, Las Vegas, NV, 89154-4020, USA.
[2]Electrical and Computer Engineering, University of Nevada – Las Vegas, Las Vegas, NV, 89154-4020, USA.
[3]Department of Mathematical Sciences, University of Nevada – Las Vegas, Las Vegas, NV, 89154-4020, USA.
e-mail: monika.neda@unlv.edu

Abstract: We numerically investigate traffic models driven by the worldwide safety issues of the traffic flow. Traffic flow has been considered to be a continuum flow of a compressible liquid having a certain density profile and an associated velocity, depending upon density, position and time. Herein, the Lighthill Witham and Richards (LWR) model combined with the Greenshield's model, is studied. Numerical solutions are computed using the finite element method. Furthermore, the finite element time relaxation method is introduced for the treatment of the shocks.
Key words: Traffic, Finite Element Method, Simulation

INTRODUCTION

With global urbanization on the rise, more people are utilizing urban transportation infrastructure. Where many see traffic congestion as a daily nuisance, public officials see it as an important safety concern. In an effort to best optimize municipal traffic patterns, accurate, predictive, real-time models of vehicular traffic flow are of particular interest. To this end, accurate numerical approximation of macroscopic / hydrodynamic traffic models continues to be an active area of research. Herein we introduce a new regularization technique for the Lighthill-Whitham-Richards Model (LWR), as well as present the results from numerical experiments.
Traffic flow can be defined as the study of how the vehicles move between origin and destination, and how the individual drivers interact with others. Since the driver behavior cannot be predicted with absolute certainty, mathematical models have been built which study the consistent behavior between the traffic streams via relationships such as flow q, density ρ and the mean velocity v. These mathematical models try to describe how these relationships evolve in space and time, and how they can be used to solve the real traffic flow conditions to be further used in traffic flow control and optimization [3, 7].
The LWR model was introduced back in mid-1950s as a one-dimensional macroscopic model to study the traffic flow. Considering the LWR with the Greenshield's model, we have

$$\frac{\partial \rho}{\partial t} + \left(v_f - \frac{2v_f}{\rho_m}\rho \right) \frac{\partial \rho}{\partial x} = 0. \tag{1}$$

It is known that when we solve the hyperbolic traffic flow given by Equation (1) oscillations exist around the shock solutions. In this work we study some potential high resolution methods, i.e. methods that are at least second order accurate on smooth solutions and yet give well resolved, non-oscillatory discontinuities.

Finite Element Method with Time Relaxation

Let Ω denote the domain, while the $L^2(\Omega)$ norm and the inner product are denoted by $\|.\|$ and $(. , .)$ respectively. The function spaces used are $\mathbf{X} := H^1_0(\Omega)$ and the dual space of $\mathbf{X}$ is denoted as

X′, with norm ‖.‖$_{-1}$. For the finite element method, we derive a weak/variational formulation discretized in space by polynomial approximations and in time by a corresponding numerical method, [8, 5, 4].

A simple regularization technique was proposed by Adams, Stoltz and Kleiser in [1] and [2]. In this technique, if ρ represents the variable of interest, h represents the characteristic mesh width, and $\delta = O(h)$ a chosen length scale, ρ^* is created to be another variable representing the part of ρ varying over length scales < $O(\delta)$ i.e. the fluctuating part of ρ, [9, 10, 11]. The term $\chi\rho^*$ is then added to the differential equation such that our model in Equation (2) is transformed to be,

$$\rho_t + v_f \rho' - \frac{2v_f}{\rho_m}\rho \cdot \rho' + \chi \rho^* = 0 \tag{2}$$

The term $\chi\rho*$ drives the unresolved density scales exponentially to zero. The coefficient χ is called as the relaxation coefficient and has the units $(Time)^{-1}$. Now, the variational formulation of Equation (2) is stated as: Find $\rho \in L^2(0, T; \mathbf{X}) \cap L^\infty(0, T; L^2(\Omega))$ with $\rho_t \in L^2(0, T; \mathbf{X}')$ satisfying

$$\begin{array}{lcll} (\rho_t, v) + v_f(\rho', v) - \frac{2v_f}{\rho_m}(\rho \cdot \rho', v) + \chi(\rho - G_N\overline{\rho}, v) & = & 0 & , \forall v \in X \\ \rho(x, 0) & = & \rho_0(x) & , \forall x \in \Omega \end{array} \tag{3}$$

In Equation (3) $\overline{\rho}$ denotes a spatially averaged function of ρ defined as: $\overline{\rho} := G(\rho)$ satisfying

$$\begin{array}{lcll} -\delta^2\overline{\rho}'' + \overline{\rho} & = & \rho & , \text{in } \Omega \\ \overline{\rho} & = & 0 & , \text{on } \partial\Omega \end{array} \tag{4}$$

where δ represents the filter radius. According to Ervin et al. [11], the operator G_N in Equation (3) represents the N^{th} van Cittert approximate de-convolution operator defined by

$$G_N\phi := \sum_{n=0}^{N}(I - G)^n\phi, \quad N = 0, 1, 2, \ldots , \tag{5}$$

where N represents the order of de-convolution. For example, the approximate de-convolution operator corresponding to order of de-convolution N = 0, 1, 2 are $G_0\overline{\rho} = \overline{\rho}$, $G_1\overline{\rho} = 2\overline{\rho} - \overline{\overline{\rho}}$ and $G_2\overline{\rho} = 3\overline{\rho} - 3\overline{\overline{\rho}} + \overline{\overline{\overline{\rho}}}$, respectively.

For numerical simulations based on finite element method and Backward-Euler temporal discretization we used linear extrapolation $\rho^n = 2\rho^{n-1} - \rho^{n-2}$ for the nonlinear term. The discretized finite element formulation for time interval (0, T] could be written as: For n = 1, 2, . . . ,N_T , find $\rho^n_h \in$ $\mathbf{X}_h$ (finite element subspace of **X**) such that,

$$\begin{aligned} (\rho_h^n, v) + \Delta t v_f(\rho_h^{n\prime}, v) - \frac{2v_f}{\rho_m}\Delta t((2\rho_h^{n-1} - \rho_h^{n-2}).\rho_h^{n\prime}, v) + \chi\Delta t(\rho_h^n - G_N\overline{\rho}_h^n, v) \\ = (\rho_h^{n-1}, v)\forall v \in X_h \end{aligned} \tag{6}$$

NUMERICAL RESULTS

Accuracy Measures

For computation of numerical accuracy, the following measures were used:

1. *l^2 norm of the error:*

$$\|e\| = \sqrt{\sum_{k=1}^{n}|e_k|^2}$$

where e_k is one term from the error vector with k = 1,2, … n.

2. *Bounded Variation (BV) norm of the error:*

$$V_b^a(e) = \sup_{p \in P} \sum_{i=0}^{n_p - 1} |e(x_{i+1}) - e(x_i)|$$

$$\{P = \{x_0, \ldots, x_{nP}\} | P \ is \ a \ partition \ of \ [a, b]\}$$

Next, we list important parameters that are common to all numerical simulations.

Table 1. Common parameters used in numerical simulations

Parameter Name	Description	Value
a	Beginning point of the road segment	-200
b	Ending point of the road segment	200
l	Length of the road segment	a-b = 400 units
T	Final time	5 seconds
M	Number of nodes	1001
h	FEM mesh width	0.3996004
k	Time step	0.008064516
N	Number of iterations	620
ρ_m	Jam density	0.04
ρ_o	Initial Density	0.02
v_f	Free-flow Speed	25
ρ_l	Left density towards $x = 0^-$ at $t = 0$	0.01
ρ_r	Right density towards $x = 0^+$ at $t = 0$	0.025

Apart from the above parameters, the finite element method simulations used continuous piecewise-quadratic basis functions, and were computed using the FreeFem++ package [6].

Shocks Moving Toward the Right

A shock moves toward the right if ρ_l and ρ_r (Table 1) are selected such that the shock velocity becomes positive. In this particular case, the shock speed is computed as

$$\lambda = \frac{f(\rho_r) - f(\rho_l)}{\rho_r - \rho_l} = \frac{\rho_l * v_f * (1 - \frac{\rho_l}{\rho_m}) - \rho_r * v_f * (1 - \frac{\rho_r}{\rho_m})}{\rho_l - \rho_r}$$

$$\lambda = \frac{0.01 * 25 * (1 - \frac{0.01}{0.04}) - 0.025 * 25 * (1 - \frac{0.025}{0.04})}{0.01 - 0.025} = 3.125$$

Therefore, for the chosen ρ_l and ρ_r we have that $\lambda > 0$, which causes the shock to move to the right.
In Equation (3), the relaxation parameter χ can be set to 0 yielding a finite element variational problem without any relaxation. Figures 1 and 2 provide the FEM solution at the final time T=5s, as well as the l^2 and BV norm of the error at each time $t \in [0, T]$, respectively.
As can be observed in Figures 1. and 2., the finite element method is not able to numerically simulate the moving shock and results in a tremendous amount of oscillations.

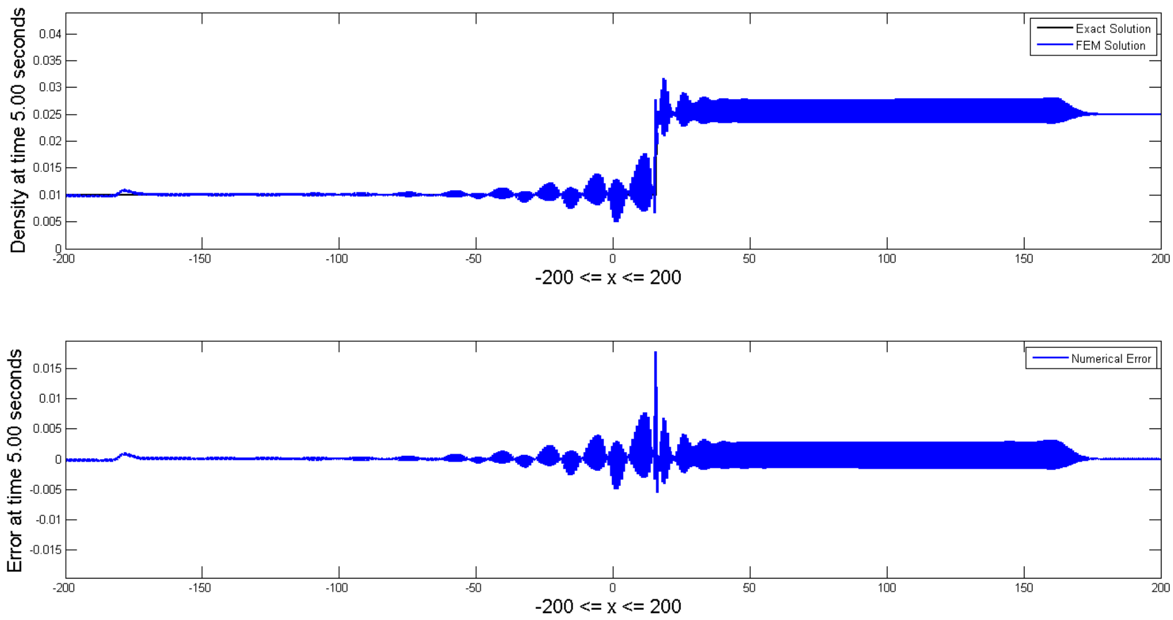


Figure 1. The FEM solution without time relaxation (TOP: Density, BOTTOM: Numerical Error).

6

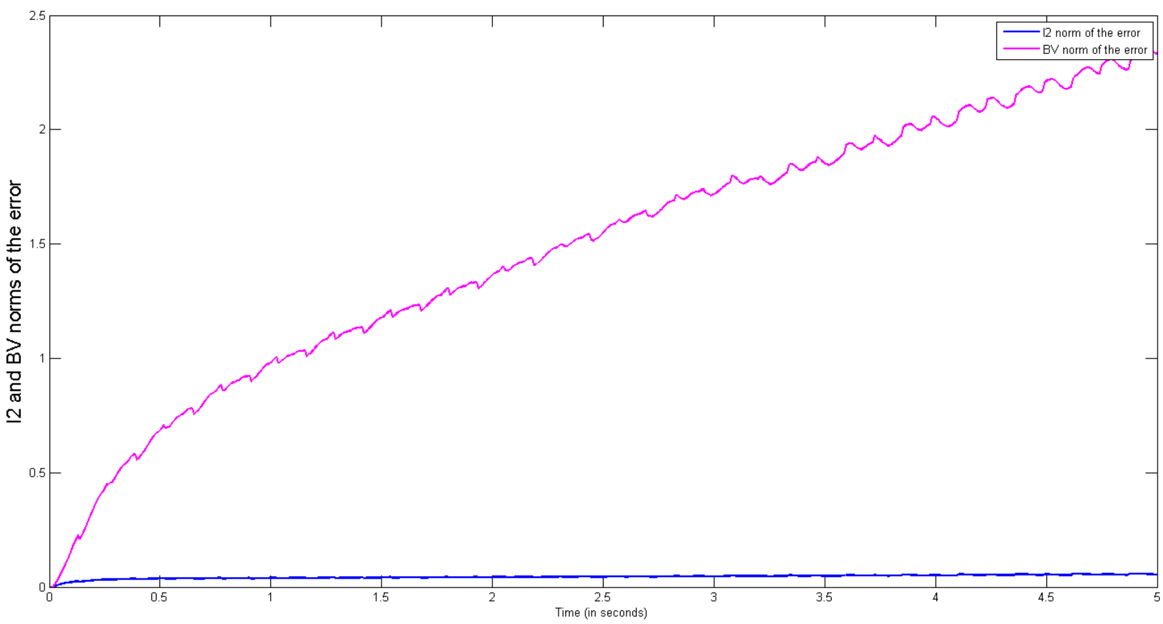


Figure 2. The l^2 (Blue) and BV (Pink) norms of the numerical error resulting from the FEM without time-relaxation.

FEM Solution with Time Relaxation

The chosen parameters χ=9 and δ=5h were found to best-minimize numerical error when paired with a time-relaxation order N=1. The successful results obtained by this simulation are shown in Figures 3 and 4. The added stabilization suppressed the development of the oscillations.

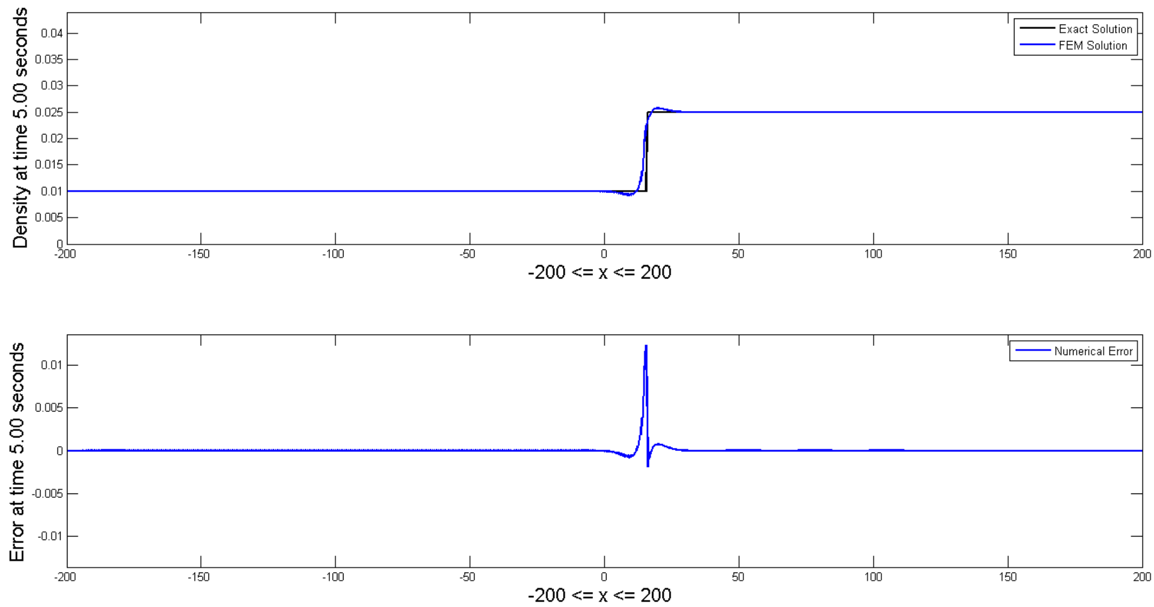


Figure 3. TOP: The time-relaxed FEM solution plotted with the exact solution. BOTTOM: the numerical error.

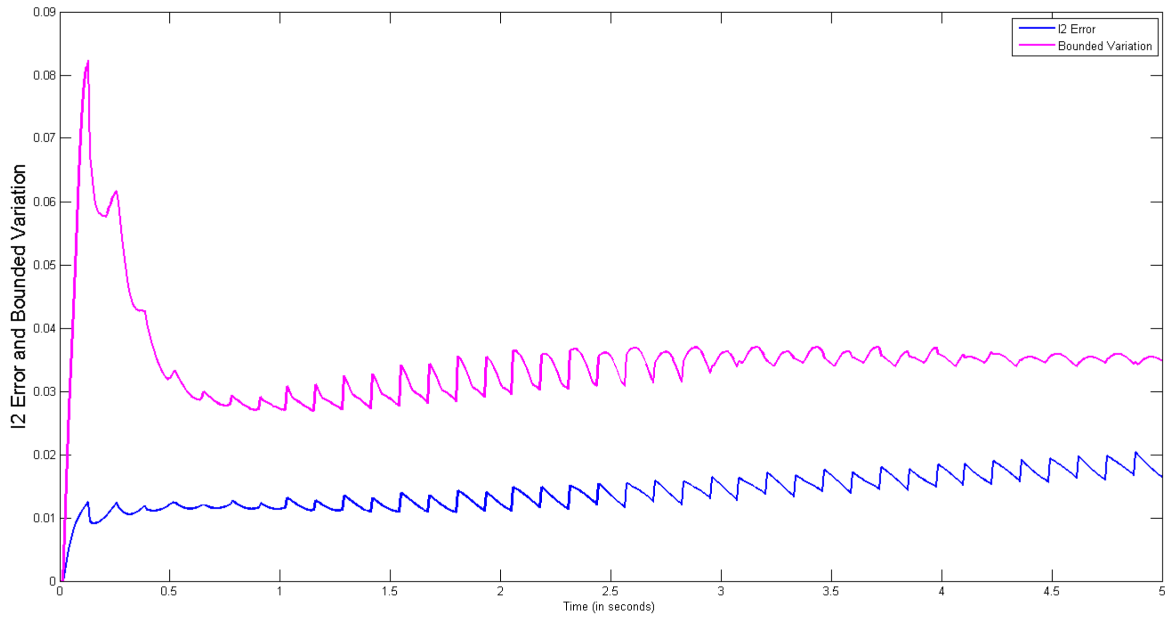


Figure 4. The l^2 (Blue) and BV (Pink) norms of the numerical error resulting from the time-relaxed FEM simulation.

If we keep the parameter choices of χ=9 and δ=5h we can compare numerical results by varying the time-relaxation order (N), see Figure 5. The performance of FEM time relaxation N = 1 and N = 2 are comparable for the chosen time relaxation parameters. Hence, to avoid the oscillations seen in Figure 2, it suffices to incorporate the time-relaxation scheme at order N=1.

CONCLUSION

Numerical simulations for the LWR and Greenshield's model were presented demonstrating the effects of time-relaxation on the finite element method. In the presence of shocks, the finite element method performs poorly, resulting in significant erroneous oscillations. When the time relaxation terms are introduced, we see the successful simulation of the shock. However, increasing the order of the time relaxation does not necessarily result in a more-smooth, more-regular solution. In fact, time relaxation of order N=1 gave comparable results to N=2 case.

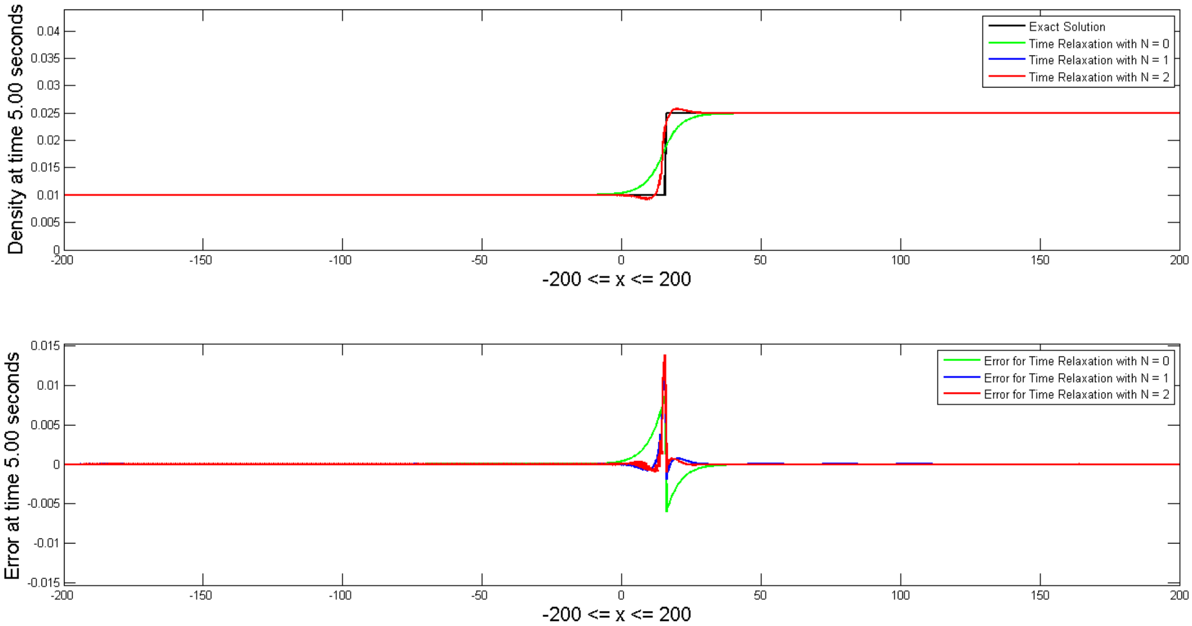


Figure 5. A direct comparison of FEM time-relaxation solutions with relaxation orders N=0, 1, and 2. In each experiment, χ=9 and δ=5h. (TOP: Density at t=5s, BOTTOM: Error at t=5s.)

REFERENCES

[1] N. Adams and S. Stolz. Deconvolution methods for subgrid-scale approximation in large eddy simulation. Modern Simulation Strategies for Turbulent Flow, pages 21–41, 2001.

[2] N. Adams and S. Stolz. A subgrid-scale deconvolution approach for shock capturing. Journal of Computational Physics, 178(2):391–426, 2002.

[3] N. Bellomo and M. Delitala. On the mathematical theory of vehicular traffic. Fluid Dynamic and Kinetic Modeling, I, 2002.

[4] S.C. Brenner and L.R. Scott. The Mathematical Theory of Finite Element Methods. Springer-Verlag, 1994.

[5] M.D. Gunzburger. Finite Element Methods for Viscous Incompressible Flows. Academic Press, Boston, 1989.

[6] Hecht, F. New development in FreeFem++. J. Numer. Math. 20 (2012), no. 3-4, 251–265.

[7] P. Kachroo. Pedestrian Dynamics: mathematical theory and evaculation control. CRC Press, 2009.

[8] W. Layton. Introduction to Finite Element Methods for Incompressible, Viscous Flows. SIAM publications, 2008.

[9] W. Layton and M. Neda. Truncation of scales by time relaxation. Journal of Mathematical Analysis and Applications, 325:788–807, 2007.

[10] W. Layton and L. Rebholz. Approximate Deconvolution Models of Turbulence. Springer, 2012.

[11] W. J. Layton V. J. Ervin and M. Neda. Numerical analysis of a higher order time relaxation

A COMPARATIVE ANALYSIS OF DIRECT AND INVERTED DECOUPLING FOR TITO PROCESS

Saša Prodanović[1], Aleksandar Košarac[1]
[1]University of East Sarajevo, Faculty of Mechanical Engineering, East Sarajevo
e-mail: sasa.prodanovic77@gmail.com

Abstract: Decoupling control is very frequent problem in industry, where cancellation of mutual coupling (interaction) is aimed. Depending on process nature, various decouplers enable different quality of its responses, i.e. process behavior. In this paper, associated with decentralized PI controller, direct and inverted decoupler were analyzed and compared in controlling of two inputs two outputs (TITO) process. According that, better solution for decoupling of this kind of processes has been suggested. Two variations of flow tank were taken into consideration. Investigation was supported by simulations.
Key words: PI control, direct decoupling, inverted decoupling, TITO process, flow tank

INTRODUCTION

Consideration of process multi variability, leads to more accurate, but more complicated approach in the choosing of control strategy. Applying of decoupling control is quite often way for overcoming interaction between process inputs and outputs. There are numerous methods for decoupler design given in literature [1-6]. There belong direct and inverted decouplers. Both of them have advantages and lacks for certain kinds of processes. Their possibilities to give good process responses are researched for flow tank that is taken as a two inputs two outputs (TITO) process, and modeled in [7-9]. This type of flow tank is researched because it is very often part of equipment in various fields of industry like mechanical, food, chemical, pharmaceutical, etc.

CONTROL STRATEGY FOR FLOW TANK

In this tank level h and temperature t are controlled variables (process outputs). Flow rates (Q_1 and Q_2) through the valves are manipulated variables (process inputs). Temperatures of water sources that should be mixed on constant number of revolutions are t_1=15 °C and t_2=70 °C. Reference values (set points) are: for level 1 m, and for temperature 30 °C. The resulting water is coming out through the outlet valve with flow rate Q_3. It is on/off valve [8]. Investigated process has been controlled using centralized strategy that contains decentralized controller (monovariable controllers) and decoupler, as shown in Fig.1.

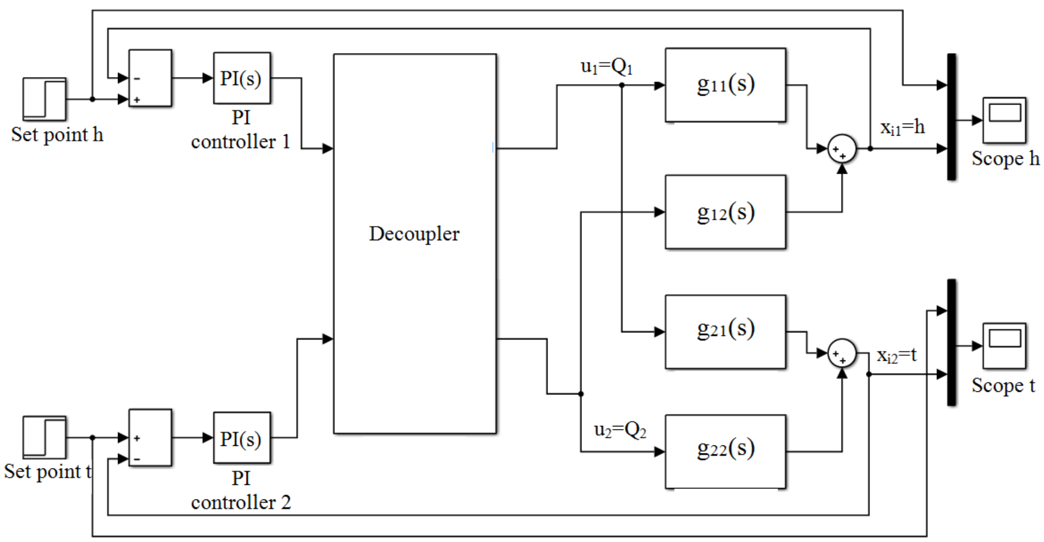


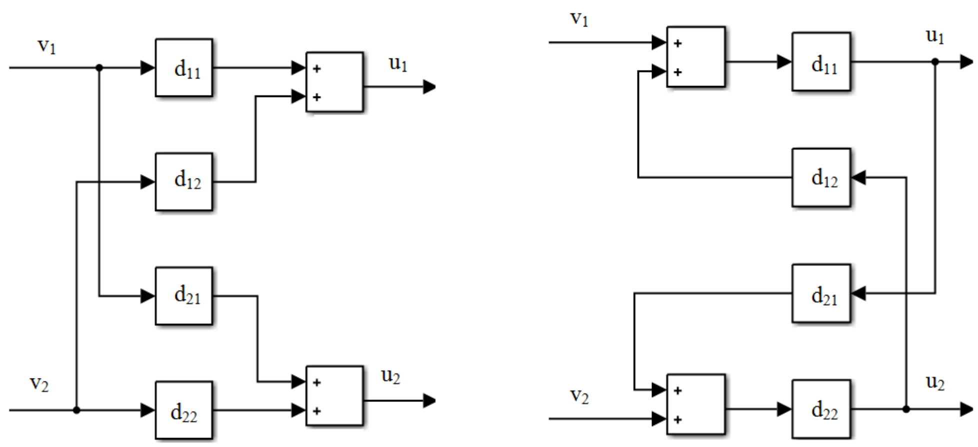
Figure 1. Decentralized controller and decoupler for flow tank as TITO process [5]

Chosen flow tank represents one group of similar processes and its characteristics mustn't be equal to above listed characteristics. That is obvious from two different transfer function matrixes that were subject of consideration in the present paper. General form of transfer function matrix is given by (1).

$$G(s)=\begin{bmatrix} g_{11}(s) & g_{12}(s) \\ g_{21}(s) & g_{22}(s) \end{bmatrix}=\begin{bmatrix} \dfrac{K}{Ts+1} & \dfrac{K}{Ts+1} \\ \dfrac{K_1}{T_1 s+1}e^{-L_1 s} & \dfrac{K_2}{T_2 s+1}e^{-L_2 s} \end{bmatrix} \tag{1}$$

Where: $g_{ij}(s)$ – elements of transfer function matrix, K, K_1 and K_2 – gains, T, T_1 and T_2 – time constants, L_1 and L_2 – delay times.
According [2], there are two kinds of decoupler (direct and inverted) that have same transfer function matrix given by (2). However, they are different by their structure, which is shown in Fig. 2.

$$D(s)=\begin{bmatrix} 1 & d_{12}(s) \\ d_{21}(s) & 1 \end{bmatrix}=\begin{bmatrix} 1 & \dfrac{-g_{12}(s)}{g_{11}(s)} \\ \dfrac{-g_{21}(s)}{g_{22}(s)} & 1 \end{bmatrix} \tag{2}$$



a) b)

Figure 2. Direct (a) and inverted (b) decoupler for 2x2 process

EXAMPLES

Taking into account above mentioned, two characteristic examples have been researched in order to show different possibilities of decouplers for this kind of flow tanks.
Example 1: Certain process taken in this example is expressed by (3). PI controllers are tuned according [10] and they follow: PI controller 1 (K_c=2,875 and K_I=0,05096) , PI controller 2 (K_c=0,125 and K_I=0,01096).

$$G(s)=\begin{bmatrix} \dfrac{0{,}01}{63s+1} & \dfrac{0{,}01}{63s+1} \\ \dfrac{-0{,}15}{10s+1}e^{-3s} & \dfrac{0{,}4}{10s+1}e^{-2s} \end{bmatrix} \tag{3}$$

Based on (2), elements of decoupler matrix are calculated in [7] and hence: d_{12}=-1 and $d_{21}=0{,}375\cdot e^{-s}$.
Simulations have been carried out using strategy in Fig. 1. for both cases of decoupler shown in Fig. 2. Their results are given in Fig. 3. where is decreasing of overshoot was goal. Here can be seen that both direct and inverted decoupler eliminate overshoot, but direct one enables shorter rise and settling time in both outputs. Moreover, in temperature output, decouplers satisfy specified request without slowing

the response in comparing to case without decoupler. In accordance with above mentioned, direct type of decoupler is better solution for certain flow tank (3).

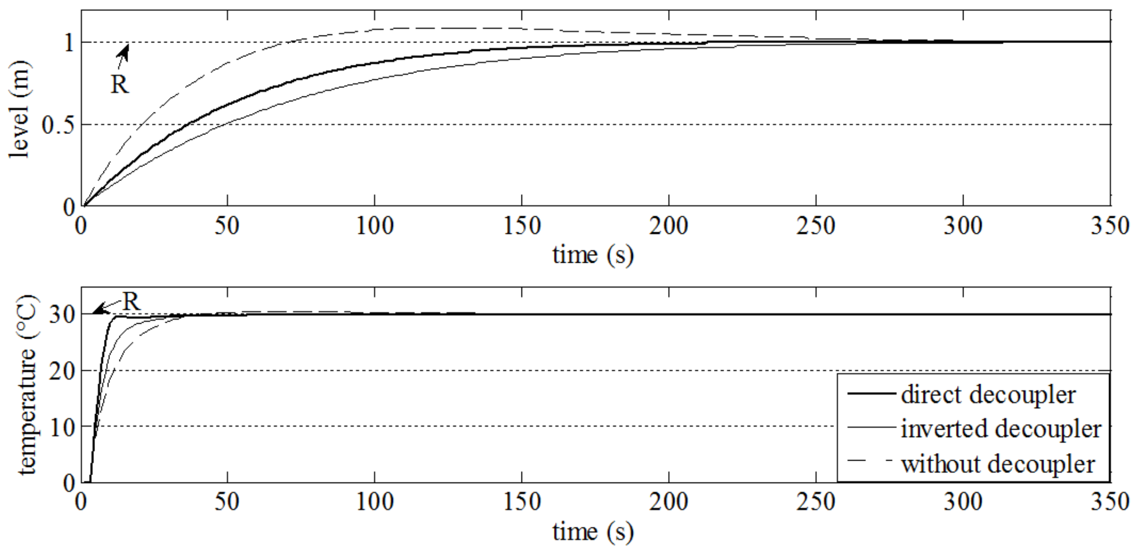


Figure 3. Process responses of flow tank expressed by (3)

Example 2: In order to extend research, this example is introduced into consideration. Process structure wasn't changed. Parameters were only changed. Its mathematical model is shown by (4). PI controllers are tuned using automatized method in Matlab software as follows: PI controller 1 (K_c=0,808 and K_I=0,0098) , PI controller 2 (K_c=0,0199 and K_I=0,0005). Significant decreasing of overshoot, without significant slowing down of response, was required also in this example.

$$G(s)=\begin{bmatrix} \dfrac{0{,}01}{63s+1} & \dfrac{0{,}05}{63s+1} \\ \dfrac{-0{,}6}{10s+1}e^{-5s} & \dfrac{0{,}4}{10s+1}e^{-2s} \end{bmatrix} \tag{4}$$

Using (2), elements of decoupler matrix are: d_{12}=-5 and $d_{21}=1{,}5\cdot[(10s+1)/(20s+1)]\cdot e^{-3s}$.
Based on control strategy in Fig. 1., simulations give process responses in Fig. 4. and 5.

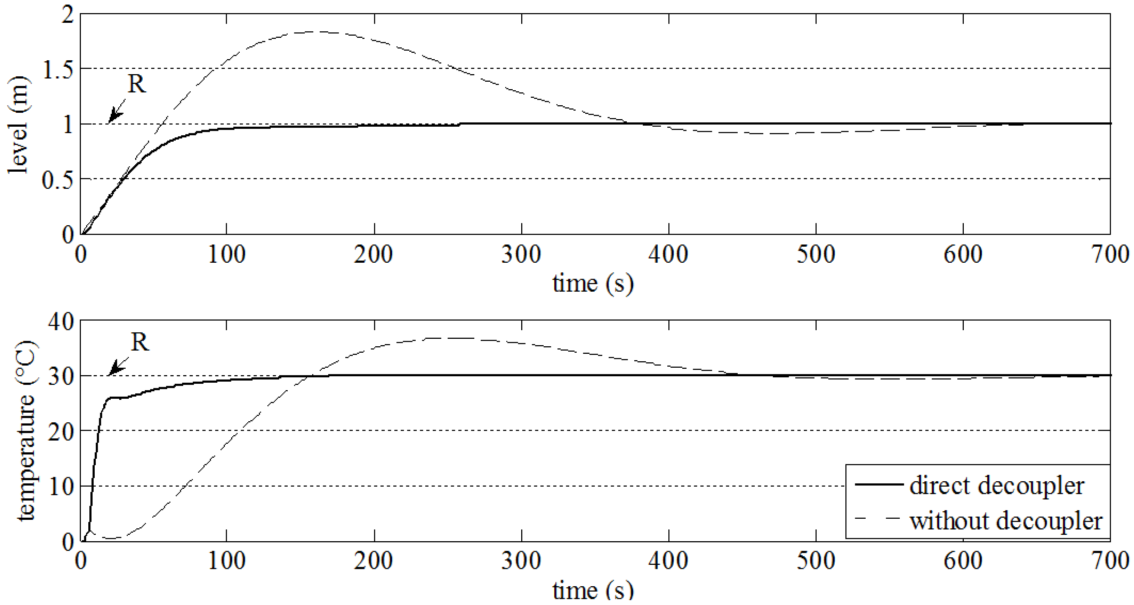


Figure 4. Process responses of flow tank expressed by (4) with direct decoupler and without decoupler

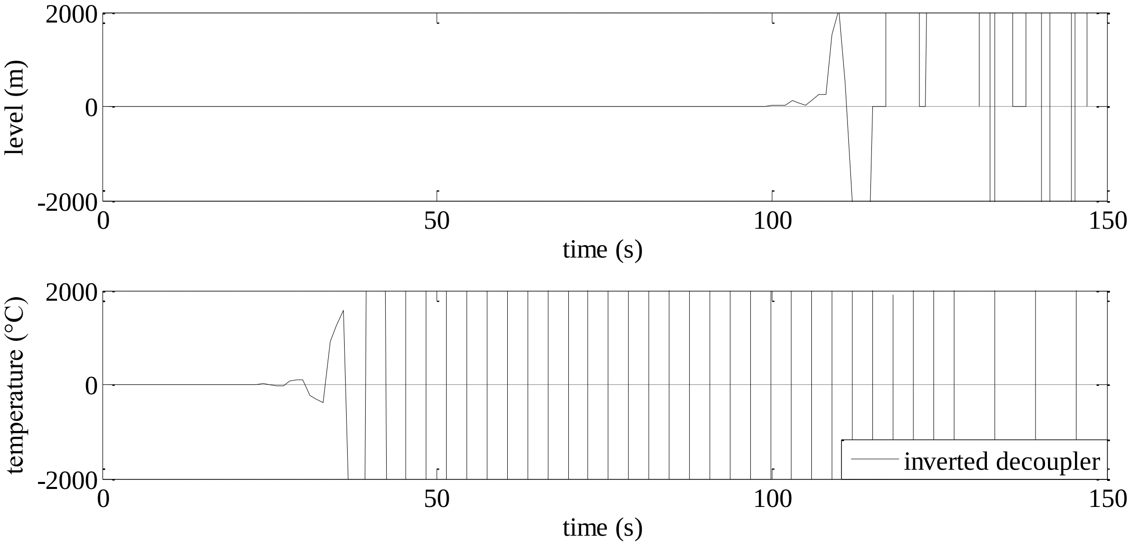


Figure 5. Process responses of flow tank expressed by (4) with inverted decoupler

Responses of process (4) shown in Fig. 5. confirm that inverted decoupler, applied to some processes, can cause instability. Naturally, that is unacceptable, as also in this case. Due to that, there is no doubt, that direct decoupler is better solution for this processes, noticing responses in Fig. 4. which were obtained by its use. Comparing with response obtained without decoupler, satisfying of specified characteristics is obvious. In the striving to clearness, and noticing quite different values on ordinate axes, responses in case with inverted decoupler are shown in the separated figure 5.

CONCLUSION

Always actual and endless issue of decoupling of multivariable process has obtained a small addition in this paper. Focus was put on the decouplers and because of that, parameters of PI controllers retained the same values within particular presented examples.

Direct decoupler proved to be more suitable for two processes that were researched, because it better fulfills specified requirements regarding quality indicators of response. These processes (flow tanks) also confirm that each object should be considered as particular issue during decoupler design. Improvement of any response parameter does not necessarily mean deterioration of another one. Also, very important fact is that some decouplers can cause instability of entire control system, and because of that they have serious limitations for these processes.

REFERENCES

[1] Åström K. J., Johansson, K. H., Wang, Q. G., Design of decoupled PI controller for two-by-two systems, IEE Proceedings on Control Theory and Applications, 149, pp. 74–81, 2002.

[2] Morilla, F., Garrido, J., Vázquez, F.: Multivariable decoupling control, Revista Iberoamericana de Automática e Informática industrial, vol. 10, pp. 3-17, 2013. (In Spanish)

[3] Garrido, J., Vázquez, F., Morilla, F. Centralized Inverted Decoupling for TITO Processes, Proceedings of the 15th IEEE International Conference on Emerging Technologies and Factory Automation. Bilbao, Spain, 2010.

[4] Garrido, J., Vázquez, F., Morilla, F., Hägglund, T., Practical advantages of inverted decoupling, Proceedings of the Institution of Mechanical Engineers, Part I: Journal of Systems and Control Engineering, 225, pp. 977-992, 2011.

[5] Morilla, F., Vázquez, F., Garrido, J., Centralized PID control by decoupling for TITO processes, Proceedings of the 13th IEEE International Conference on Emerging Technologies and Factory Automation. Hamburg, Germany, 2008.

[6] Cai, W. J., Ni, W., He, M. J., Ni, C. Y., Normalized decoupling - a new approach for MIMO process control system design, Industrial and Engineering Chemistry Research, 47, pp. 7347-7356, 2008.

[7] Prodanović, S., Nedić, N., Non-conventional Control of Level and Temperature in the Flow Tank, 2nd International Conference on Mechanical Engineering Technologies and Application - COMETa2014, Jahorina, B&H, 2014., pp. 421-428: ANNALS of Faculty Engineering Hunedoara – International Journal of Engineering, Tome XIII (2015) – Fascicule 3 [August], pp. 105-108.

[8] Prodanović, S., Nedić, N. and Brašić, V., Some Considerations of Mutual Coupling in Multivariable Processes, XII International SAUM Conference on Systems, Automatic Control and Measurements, Niš, Serbia, pp. 257-260, 2014.

[9] Prodanović, S., Nedić, N., Lukić, Lj., Possibilities for Disturbance Rejection in the Decoupled TITO Process, 12th International Scientific Conference MMA 2015 Flexible Technology, Novi Sad, Serbia, pp. 71-74, 2015.

[10] Dubonjić, LJ., Nedić, N., Filipović, V. and Pršić N., Design of PI Controllers for Hydraulic Control Systems, Mathematical Problems in Engineering, Volume 2013, pp. 1-10, 2013.

EXPERIMENTAL KINETICS IN PILOT SCALE HEAT PUMP DRYING OF GREEN PEAS

Stefan D. Jovanović[1], Jelena N. Janevski[1], Mladen M. Stojiljković[1], Branislav V. Stojanović[1]
[1]University of Niš, Faculty of Mechanical Engineering, Niš, Serbia
e-mail: djoje@masfak.ni.ac.rs

Abstract: Drying is one of the most necessary process and technology in today's world and it is used, among other things, for food processing. The basic goal is to process the food for consumption by increasing its shelf life, and in order to achieve this moisture must be removed from raw material as moisture, which is the main promoter of biological activity and spoilage of the fresh products. Conventional drying is known for its high energy consumption and therefore it is costly. The conventional drying has also a negative impact on the environment and climate, providing the basis for heat pump drying development to ensure sustainable practice within the food industry. Heat pump drying is a relatively new technology developed at NTNU. It unifies the drying and heat pump cycles in which the heat pump is used to recycle energy, for reheat the air during drying the raw material. By recycling the heat from the dryer exhaust, energy is saved and the total energy input to the system is drastically reduced. In this master thesis a laboratory heat pump dryer is applied for drying green peas. The drying air was set on temperature regimes of 45°C, 35°C and 15°C with three levels of relative humidity: 60%, 40% and 20%, from which temperature regime of 45°C was set on 40% and 20%. Therefore, eight drying tests were performed and each test was done in period of three hours. The drying of green peas was conducted in fluidized bed mode. The results have shown that higher temperatures increase the rate of moisture removal from the green peas. Difference in relative humidity of the drying air also plays an important role in the process although the effect is much less compared to the temperature.
Key words: energy consumption, recycling heat, drying green peas

INTRODUCTION

Today's world is facing an increase in human population and consequently need to produce more fresh and dried products for this expanding population. The consequence is a worldwide market rapid expansion, demanding more products and goods to be placed on trade as well as for the larger diverse range of products. Major factors in fulfilling these requirements are process development, economical profitability and sustainability of the environment and society. At the same time these new technologies should fulfill the objective of economical profitability, which is mostly dependable on energy efficiency due to the trend of increasing energy cost and cost of resources used to produce that energy, mostly carbon based fuels. Currently, as a process drying consumes up to 50% of the total amount of energy used in industrial purposes. One of the relatively new technologies that fulfill all these requirements is heat pump drying (HPD). The conventional dryers consume large amounts of energy and have an equivalent contribution to the emission of greenhouse gas (*GHG*) to the atmosphere. Another significant contributor to *GHG* emission is the artificially produced chemical refrigerants and foam-blowing agents.

This paper covers the experiments and modeling green peas drying on a pilot scale heat pump dryer. Focus will be given on the effect of heat pump operating conditions, drying temperature and relative humidity on kinetics and on the dried product's characteristics. Heat pump dryers have been known to be energy efficient when used in conjunction with drying operations. The principal advantage of heat pump dryers emerge from the ability of the heat pumps to recover energy from the exhaust gas as well as their ability to control the drying gas temperature and humidity. Many researchers have demonstrated the importance of producing a range of precise drying conditions to dry a wide range of products and improve their quality. The main components of the single stage heat pump system are the expansion valve, evaporator, internal and external condenser and compressor as illustrated in figure 1. After flowing through the evaporator and condenser of the heat pump the dry and warm air is ready to flow into the drying chamber in which the material, which is to be processed, is being placed. The simplified heat pump dryer has two separated loops with common heat exchangers. The drying air loop (*abcd*) contains the air cooler (*EVA*), heater (*CON*), blower and drying chamber. The refrigerant loop (*12341*) main components are the expansion valve (*THR*), evaporator (*EVA*), condenser (*CON*) and a compressor (*COM*). The fluid of the heat pump and drying air loops are coupled through the common evaporator and condenser to recover the exhaust energy.

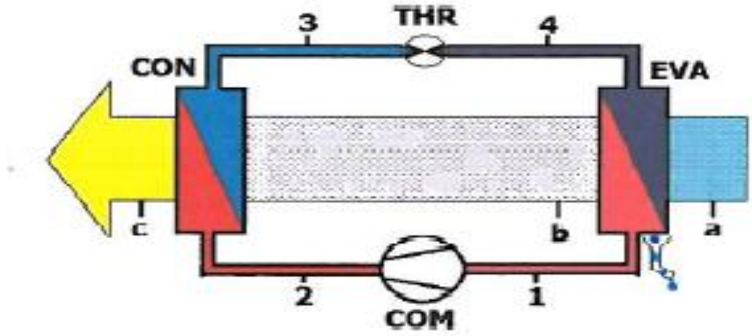


Figure 1. Principle of operation in a simplified heat pump dryer

PRINCIPLE OF HEAT PUMP DRYING

Figure 2 illustrates the isentropic and non-isentropic saturated vapor compression heat pumps with dry expansion evaporator and drying channels. Figure 4a shows the main components: *A* – compressor, *B* – three way valve, *C* – external condenser, *D* – drying channel with air heater, *E* – liquid receiver, *F* – expansion valve, *G* – drying channel with air cooler. Also, Figures 4a and 4b show the layout and the state points in the cycles in a log pressure versus enthalpy diagram, respectively. From state point 1 the saturated vapor is isentropic and non-isentropic compressed to super-heated vapor to points 2_i and 2, respectively. Then, the vapor flows through the condensers changes phase to saturated liquid and is collected in the receiver. The saturated liquid leaves the receiver at point 3 and it is throttled to a liquid and vapor mixture at point 4. Then, the mixture flows through the evaporator and becomes saturated vapor at point 1 to be compressed again.

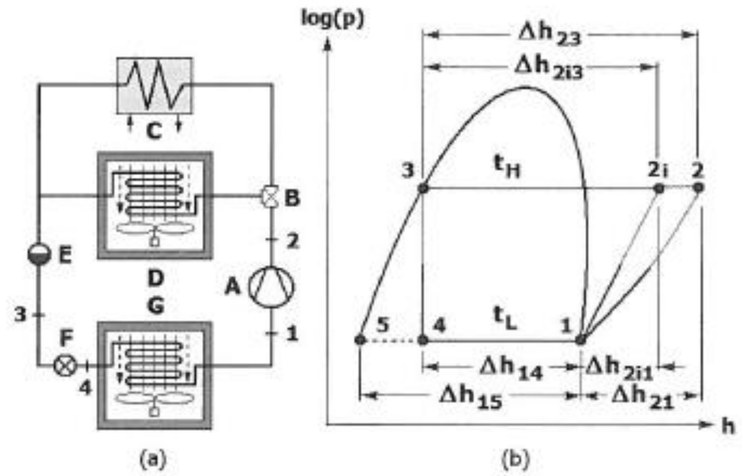


Figure 2. The isentropic and non-isentropic saturated vapour compression heat pumps indicating the corresponding specific enthalpy differences in each process

Advantages:

- Heat pump drying (HPD) offers one of the highest specific moisture extraction ratio (SMER), often in range of 1.0 to 4.0, since heat can be recovered from moisture-laden air.
- Heat pump dryers can significantly improve product quality by drying on low temperatures. At low temperatures, the drying potential of the air can be maintained by further reduction of the air humidity.

- A wide range of drying conditions typically -20°C to 100°C (with auxiliary heating) and relative humidity 15 to 80% (with humidification system) can be generated.
- Excellent control of the environment for high value products and reduced electrical energy consumption for low-value products.

However, heat pump dryers must be correctly designed to operate in the desired set points.

FLUIDIZED BED AND PRODUCT QUALITY

Fluidized bed dryers (FBD) are used extensively for the drying of wet particulate and granular materials that can be fluidized, and even slurries, pastes, and suspensions that can be fluidized in beds of inert solids. They are commonly used in processing many products such as chemicals, carbohydrates, foodstuff, biomaterials, beverage products, ceramics, pharmaceuticals in powder or agglomerated form, healthcare products, pesticides and agrochemicals, dyestuffs and pigments, detergents and surface-active agents, fertilizers, polymer and resins, tannins, products for calcination, combustion, incineration, waste management processes, and environmental protection processes. Fluidized bed operation gives important advantages such as good solid mixing, high rates of heat and mass transfer, and easy material transport.

Some advantages of fluidized bed drying are the high rate of moisture removal, high thermal efficiency, ease of control and low maintenance cost. The high rate of moisture removal is due to the large interfacial surface area which is in order of 3000 to 45000 m^2/m^3 in the fluidized bed. This is also the reason for very high rates of heat transfer achieved in fluidized beds.

Some of the limitations in drying application of the fluidization are high pressure drop and high electrical power consumption for the blower. Also the drying product may be damaged in intensive fluidization or particle to particle and particle to wall collisions.

Water activity

Water activity is defined as the ratio of the vapor pressure of water in a food to the saturated vapor pressure of water at the same temperature, as it is shown in the next equation:

$$a_w = \frac{P}{P_0} \tag{1}$$

where P is the vapor pressure at the green peas surface and P_0 is the vapor pressure of pure water at the same temperature.

Color

Many naturally occurring pigments are destroyed by heat processing, chemically altered by change in pH or oxidized during storage. As a result the processed food may lose its characteristic color and hence its value.

Density

For particulate solids and powders there are two forms of density: the density of individual pieces and the density of the bulk of material, which also includes the air spaces between the pieces. The latter measure is termed the *bulk density* and is the mass of solids divided by the bulk volume. The bulk density of a material depends on the solids density and the geometry, size and surface properties of the individual particles.

EXPERIMENTAL DESIGN

The experiments were conducted in a heat pump drying system with a fluidized bed. Each batch of raw material placed inside the drying chamber had a mass of 1000 grams. The green peas samples were dried at three values of drying air temperature and three values for the relative humidity. The temperatures were 45°C, 35°C and 15°Cand each temperature was fixed tested at relative humidity of 60%, 40% and 20% with exception of 45°C as previously mentioned. This resulted in a design of eight drying tests. The details of experimental conditions and setup for all eight tests are presented in Table 1.

The frozen green peas were mixed and homogenized to form a large batch that was partitioned into eight uniform batches of green peas to be dried according to the mentioned design. One drying test took 3 hours to complete. During the drying of all tests the drying chamber was taken out every 20 minutes period to measure the change in mass. Relatively small masses of dried product samples were also extracted at every 60 minute interval, which makes 3 extractions every test. The extracted material was put in small vessels whose mass was determined previously, and then the total mass of vessel with extracted sample was measured, after which they were put into preheated oven for 24 hour drying period. The drying oven was set at a temperature of 105°C and for 24 hours. The already known mass of the empty vessel and total mass of vessel with the product allows us to calculate the mass of extracted product. The product was dried in the fluidized bed with the air velocity kept at approximately 1 m/s.

Table 1. Experimental conditions and setup for all six heat pump drying tests

Test Number	Temperature [°C]	Relative humidity [%]
1.	45	40
2.	45	20
3.	35	60
4.	35	40
5.	35	20
6.	15	60
7.	15	40
8.	15	20

The drying chamber and supporting cabinet

The drying chamber is placed inside the isolated wooden cabinet made of plywood with styrofoam insulation. The cabinet's dimensions are 0.8x0.8m in cross section with height of 1.5m. The drying chamber is made of plexiglas and it is easily locked and unlocked in central base positioned within the cabinet using a three pin lock-rotation mechanisms. The chamber is inserted in the drying loop but separated from outdoors by a sampling access door located in the front of the cabinet. The door is opened and closed using two external locks. There are two inlet and outlet tubes connecting the cabinet and chamber to the drying loop. The inlet tube is connected to the central base of the cabinet and to the cylindrical chamber containing the green peas. The chamber exhaust flows through the outlet tube that is positioned at the upper part of the cabinet. During the process of moisture removal the green peas contained in the cylindrical chamber is in a fluidized by controlled air flow. A Mettler Toledo scale (XP 600 2M DeltaRange with an accuracy of 0.1 g) was used for measuring the mass of each batch of green peas the whole drying chamber containing the raw material. The density was measured based on standard determination of both mass and volume. Moisture content was measured with the use of a Mettler Toledo HB43-S moisture analyzer and the water activity was determined using the Aqua Lab CX-2 device.

A color meter, model X-RITE 948 Spectrodensitometer was used for measuring the color components such as brightness, red-green and yellow-blue.

ANALYSIS OF DATA AND MEASUREMENTS

Water content

The water content of the green peas sample is defined either on a wet or on dry basis.

The moisture content in wet basis is calculated using the equation:

$$w_{wb} = \frac{m_w}{m_t} = \frac{m_t - m_d}{m_t} \tag{2}$$

The moisture content on dry basis $w_{db}$is calculated by dividing the mass of water m_w in green peas sample with mass of dry-matter *md* as shown in equation:

$$w_{db} = \frac{m_w}{m_d} \tag{3}$$

Water activity

The water activity measurements of the green peas were made using an “Aqua Lab CX-2” meter made by Decagon Devices, Inc., Washington.

Color measurement

The color measurements of green peas were madethe “X-Rite 948 Spectrocolorimeter”. The measurements were made during every stage of testing and it was conducted on whole green peas.

The bulk density

We have used both the density of individual particles and the density of the bulk material, which also includes the air spaces between the particles. The latter measure is termed the *bulk density* and it is the mass of solids divided by the bulk volume as expressed through the equation:

$$\rho_b = \frac{m}{V} \tag{4}$$

The particle density

To obtain the particle density from each test samples of ten individual green peas were taken and the diameters were measured using a caliper with accuracy to 1/20mm.
Similarly the particle density is obtained using ratio of the average mass of ten particles and average volume of same particles and it is expressed by equation:

$$\rho_p = \frac{\overline{m}}{\overline{V}} \tag{5}$$

RESULTS AND DISCUSSION

Drying Kinetics

Table 2 shows the values of moisture content on dry basis calculated for tests 1 and 2 done with temperature of 45°C and relative humidity of 40% and 20%. The development of moisture content on dry basis follows the kinetic measurements at time intervals of 20 minutes over a period of three hours. It is obvious that test 2 with the lowest relative humidity is the one with the lowest moisture content after this drying time. The experimental data for these tests are plotted in Figure 3.

Table 2. Development of the moisture content on dry basis for tests 1and 2

Moisture content on dry basis [%]		
Elapsed time [min]	Test 1	Test 2
0	323.19	323.19
20	180.58	170.84
40	119.64	114.6
60	84.34	81.76
80	63.06	61.57
100	49.77	48.88
120	40.88	40.12
140	34.66	33.6
160	30.17	29.5
180	26.66	24.8

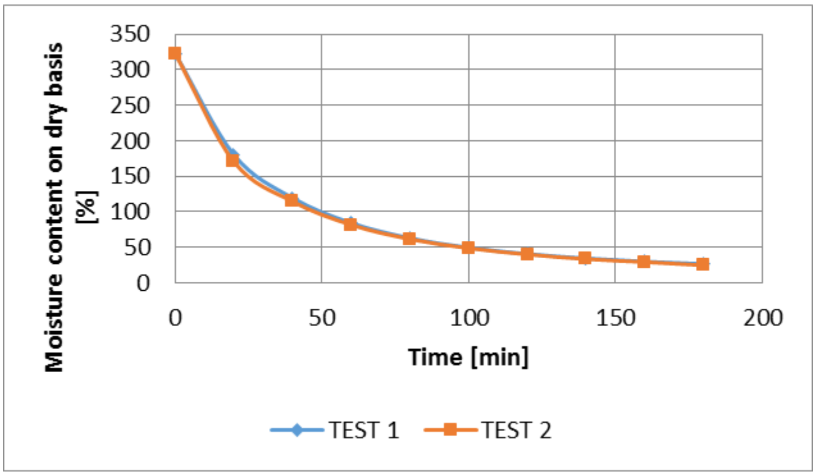


Figure 3. Development of water content on a dry basis for test 1 and 2

Table 3 shows the development of moisture content on dry basis for tests 6, 7 and 8 done with temperature of 15°C and relative humidity of 60%, 40% and 20%. Test number 8 is the one with lowest moisture content and it is the same test in which the drying air had the lowest relative humidity. The experimental data for these tests are plotted and presented in Figure 4.

Table 3. Development of moisture content on dry basis for tests 6, 7 and 8

Moisture content on dry basis [%]			
Elapsed time [min]	Test 6	Test 7	Test 8
0	323.19	323.19	323.19
20	295.13	252.98	229.07
40	252.43	195.68	183.16
60	210.71	160.85	153.15
80	180.45	131.19	126.62
100	154.08	111.38	106.01
120	132.84	95.68	92.64
140	110.92	79.73	78.42
160	97.93	70.46	69.83
180	86.67	62.21	61.96

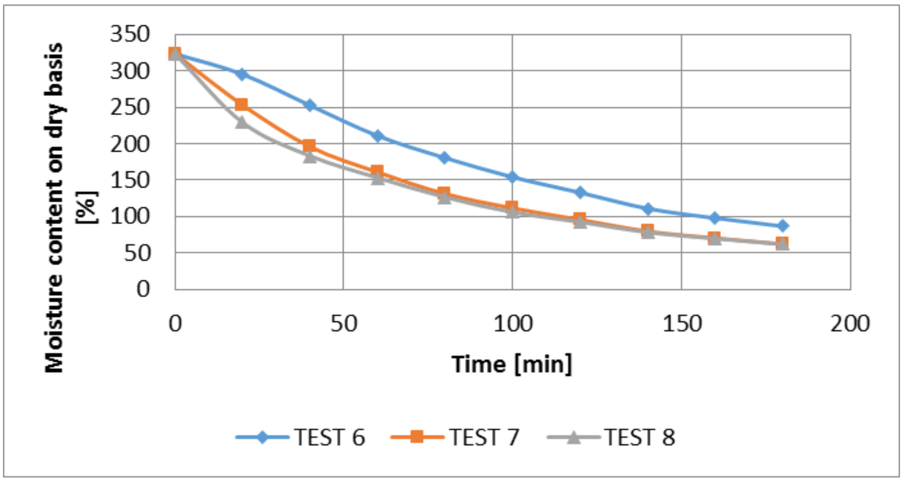


Figure 4. Development of moisture content on dry basis for tests 6, 7 and 8

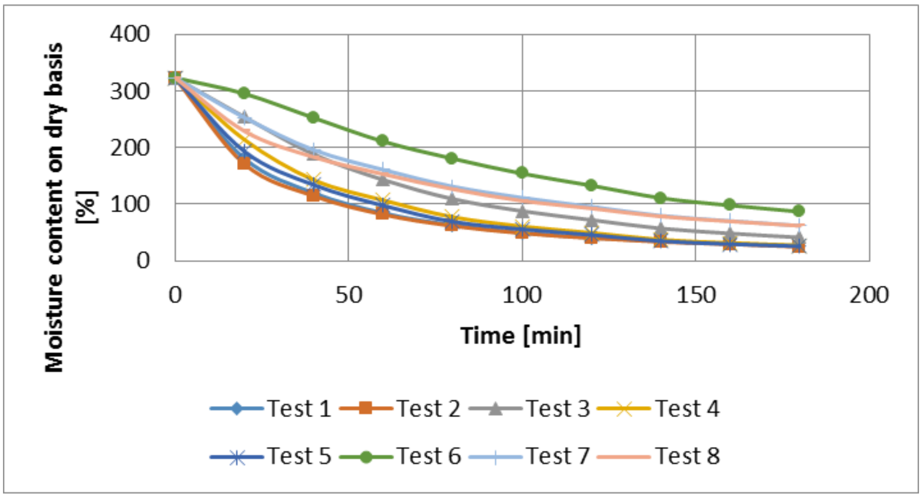


Figure 5. Development of moisture content on dry basis for all tests

CONCLUSIONS

This project work focus on heat pump drying of green peas at varying conditions. The tests and measurements were done using three sets of temperatures combined with two and three relative humidity modes, respectively. The results have shown that the temperature of the drying air has the highest influence on products moisture content.

There is also a significant influence of the relative humidity of the drying air on the final product's moisture content. We can see that the tests with 45°C inlet air have faster moisture removal but also that Test 4 and Test 5 with 35°C inlet air 40% and 20% of relative humidity is approaching the value of the test 1. On the other hand the set of tests with 15°C have high values of moisture content and it is obvious that for that low temperature not even changes in relative humidity can increase moisture removal rate.

Overall, test 2 produced the dried green peas with lowest moisture content. In terms of color a higher temperature regime influenced the most drastic change in the color properties of the final product but still the values remained relatively close between tests. The biggest difference that can be noticed is the similarity of values for Test 1 to Test 4, and also the similarity in results of color for Test 5 to Test 8.

REFERENCES

[1] Kenneth J. Valentas, Enrique Rotstein and R. Paul Singh. Handbook of Food Engineering Practice. CRC Press, 1997.
[2] Arun S. Mujumdar. Handbook of Industrial Drying. Third Edition, Taylor & Francis, 2007.
[3] [3] P. J. Fellows. Food Processing Technology – Principles and Practice. Second Edition, Woodhead Publishing Limited, Cambridge, 2000.
[4] Jangam S. V. and Thorat B. N. 16th International Drying Symposium (IDS2008) – Mathematical Analysis of Heat Pump Drying System. Hyderabad, India, 9 – 12 November, 2008.
[5] Shi Y., Li S., Chai B., Wang H., Zhang Z. and Yang X. 16th International Drying Symposium (IDS2008) – Current Status and Development Strategy of China Drying Technology Research and Industry. Hyderabad, India, 9 – 12 November, 2008.
[6] Odilio Alves-Filho. Heat Pump Drying: Theory, Design and Industrial Application. Department of Energy and Process Engineering, NTNU. Trondheim, Norway, 2013.
[7] Alves – Filho O. and Eikevik T. M. 16th International Drying Symposium (IDS2008) –Hybrid Heat Pump Drying Technologies for Porous Materials. Hyderabad, India, 9 – 12 November, 2008.
[8] Yuvanaree Namsanguan, Warunee Tia, Sakamon Devahast in and Somchart Soponronnarit. 5th Asia – Pacific Drying Conference – Experimental Investigation of Two – Stage Superheated Steam and Heat Pump Drying of Shrimp. Hong Kong, 13 – 15 August 2007.

ANALYSIS OF POSSIBILITIES OF APPLYING BERNOULLI′S EQUATION IN TECHNIQUE

Jasna Tolmac[1], Aleksandra Aleksic[2]
[1]University of Novi Sad, Technical Faculty "Mihajlo Pupin", Zrenjanin, Serbia
[2]NIS a.d. Gazprom Neft, Novi Sad, Serbia
e-mail: jasnatolmac@yahoo.com

Abstract: Bernoulli's equation is one of the most important equations of fluid dynamics (called so by the Swiss scientist who set it in the 18th century). Bernoulli's equation is widely used in praxis, i.e. in applied fluid mechanics, respectively hydraulics. It is obtained by applying the law of conservation of energy. The paper describes the analysis of the possibilities of applying Bernoulli′s equation through several examples, as its importance in the technique, respectively praxis.
Key words: Bernoulli's equation, pressure, pump, pipeline.

INTRODUCTION

One of the most important equations of fluid dynamics is the Bernoulli′s equation. The equation is named after Swiss scientist Daniel Bernoulli who set it in the 18th century. Bernoulli's equation describes the flow of ideal fluid through the pipe. It is obtained by applying the law of conservation of energy on *stationary flow of ideal incompressible fluid.* In performing this equation takes in consideration that on the fluid affects only the force of gravity. However, on the real fluids affect an intermolecular forces too, which manifest themselves as viscosity (creates resistance to flow of fluid). Because of that, the action of these forces must be shown in the equation that describes the flow of real fluid through a pipe. We can conclude that the work required for the flow of real fluid through a pipe to be higher than that of ideal fluid.
Bernoulli's equation is widely used in praxis. In the paper will be describe the analysis of the possibilities of applying Bernoulli′s equation through several examples, as its importance in the technique, respectively praxis.

Example 1

The centrifugal pump represses water from the reservoir A to the reservoir B.

The following data are known:

Q = 0,01 m^3/s – water flow
C_1 = 1,5 m/s – first velocity of water flow
C_2 = 2,5 m/s – second velocity of water flow
Z_1 = 2,0 m – intake height
Z_2 = 3,0 m – repress height to measuring point for manometer
p_v = 0,4 bar – vacuum−meter pressure (vacuum) on intake pipeline – under pressure
p_m = 2 bar – manometer−pressure on repress pipeline – over pressure
H_g = 20 m − geodesic height of water level in reservoirs
η_p = 0,65 – efficiency of pump

It is necessary to determine the pump effort, pressure losses and pump power.

Solution

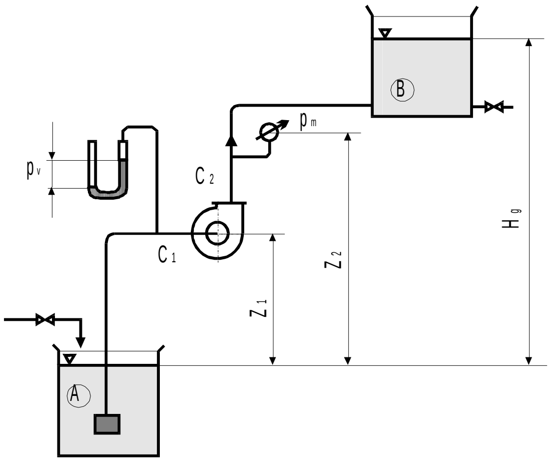


Figure 1. Scheme of pump installation

The absolute pressure on intake in pipeline:

$$p_1 = p_a - p_v$$

The absolute pressure on repress in pipeline:

$$p_2 = p_a + p_m$$

The difference between the absolute pressures on repress and intake in pipeline:

$$p_2 - p_1 = p_m + p_v$$

Bernoulli's equation:

$$p_1 + \frac{1}{2} \cdot \rho \cdot C_1^2 + \rho \cdot g \cdot Z_1 = p_2 + \frac{1}{2} \cdot \rho \cdot C_2^2 + \rho \cdot g \cdot Z_2$$

Pump effort is according to Bernoulli's equation:

$$H = p_2 - p_1 + \frac{1}{2} \cdot \rho \cdot \left(C_2^2 - C_1^2\right) + \rho \cdot g \cdot \left(Z_2 - Z_1\right)$$

$$H = p_m + p_v + \frac{1}{2} \cdot \rho \cdot \left(C_2^2 - C_1^2\right) + \rho \cdot g \cdot \left(Z_2 - Z_1\right)$$

$$H = 2 \cdot 10^5 + 0{,}4 \cdot 10^5 + \frac{1}{2} \cdot 10^3 \cdot \left(2{,}5^2 - 1{,}5^2\right) + 10^3 \cdot 9{,}81 \cdot \left(3 - 2\right)$$

$$H = 251810 \ \frac{N}{m^2}$$

$$H = 2{,}518 \ bar$$

Given that 1 *bar* = 10,3 *mWP* (meters of water pillar), it follows that the pump effort:

$$H = 2{,}518 \cdot 10{,}3$$

$$H = 26 \ m$$

Pressure losses:

$$\sum h_g = H - \rho \cdot g \cdot H_g = 251810 - 10^3 \cdot 9{,}81 \cdot 20 = 55610 \ \frac{N}{m^2}$$

$$\sum h_g = 0{,}556 \ bar$$

Pump power:

$$N = \frac{Q \cdot H}{1000 \cdot \eta_p} = \frac{0{,}01 \cdot 251810}{1000 \cdot 0{,}65} = 3{,}87 \ kW$$

Selecting the multistage centrifugal pump TYPE VPN − 100 with the following characteristics:
Q = 11,5 *l/s*, H = 27 *m*, N = 7,5 *kW*.

Example 2

When testing centrifugal pump, following values were measured:
p_v = 0,3 *bar* – pressure on enter in pump (section 1−1)
p_m = 1,3 *bar* – pressure on exit from pump (section 2−2)

Remaining data are:
Q = 36 m^3/h = 0,01 m^3/s – water flow
d_1 = 80 *mm* – diameter of intake pipeline
d_2 = 60 *mm* – diameter of repress pipeline
η_p = 0,75 − efficiency of pump

It is necessary to determine the pump effort and pump power.

Solution

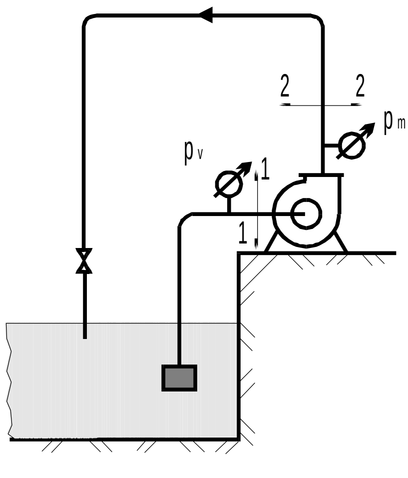


Figure 2. Scheme of test installation

Velocities of water flow are calculated from the equation of continuity:

$$C_1 = \frac{4 \cdot Q}{d_1^2 \cdot \pi} = \frac{4 \cdot 0{,}01}{0{,}08^2 \cdot 3{,}14} = 2 \ \frac{m}{s}$$

$$C_2 = \frac{4 \cdot Q}{d_2^2 \cdot \pi} = \frac{4 \cdot 0{,}01}{0{,}06^2 \cdot 3{,}14} = 3{,}5 \ \frac{m}{s}$$

Pump effort is according to Bernoulli's equation:

$$H = p_m + p_v + \frac{1}{2} \cdot \rho \cdot \left(C_2^2 - C_1^2\right) + \rho \cdot g \cdot \left(Z_2 - Z_1\right)$$

It can be taken approximately $Z_1 \approx Z_2$ which satisfy practical application.

$$H = \left(1{,}3 + 0{,}3\right) \cdot 10^5 + \frac{1}{2} \cdot 10^3 \cdot \left(3{,}5^2 - 2^2\right) = 164125 \ \frac{N}{m^2}$$

$$H = 1{,}641 \ bar$$

Given that 1 *bar* = 10,3 *mWP* (meters of water pillar), it follows that the pump effort:

$$H = 1{,}641 \cdot 10{,}3$$

$$H = 17 \ m$$

Pump power:

$$N = \frac{Q \cdot H}{1000 \cdot \eta_p} = \frac{0{,}01 \cdot 164125}{1000 \cdot 0{,}75} = 2{,}2 \ kW$$

Selecting the multistage centrifugal pump TYPE VPN − 100 with the following characteristics:
Q = 11,5 *l/s*, *H* = 18 *m*, *N* = 4 *kW*.

Example 3

For the purposes of the production process is carry out transport of technological water from the reservoir R_1 to the reservoir R_2, by using of pump and pipeline.
The following data are known:
Q = 20 m^3/h water – capacity of transport
V = 2 m/s − velocity of water flow in pipeline
ρ = 1000 kg/m^3 – water density
p_m = 3 *bar* – over pressure in reservoir R_2
L = 75 *m* – length of pipeline
H = 10 *m* – difference of water level in reservoirs
λ = 0,03 − coefficient of fluid (water) friction on the pipe walls
η_p = 0,5 − efficiency of pump
ξ_k = 0,5 − coefficient of resistance of a knee
ξ_v = 2,5 − coefficient of resistance of a valve
Pipeline has n_1 = 5 knees of 90° and n_2 = 3 valves. For reservoir R_2: $p \cdot V$ > 0,3 $bar \cdot m^3$.
It is necessary to determine the pipeline diameter, pressure fall − pump effort and pump power.

Solution

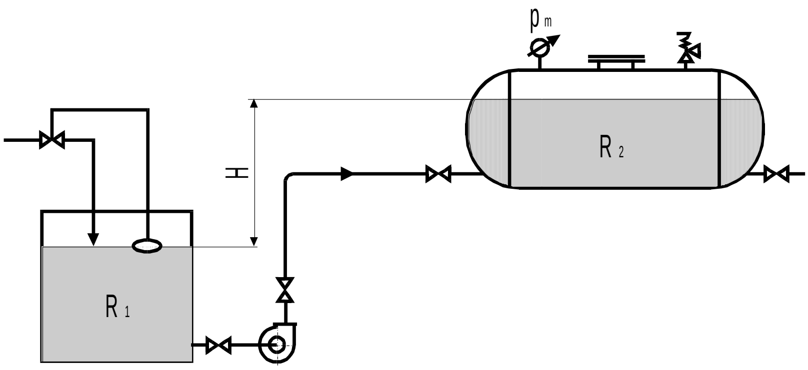


Figure 3. Scheme of reservoirs, pump and pipeline with measuring − control equipment

Pipeline diameter is calculated from the equation of continuity:

$$d = \sqrt{\frac{4 \cdot Q}{\pi \cdot V}} = \sqrt{\frac{4 \cdot 20}{\pi \cdot 2 \cdot 3600}} = 0{,}059\ m \Rightarrow d = 60\ mm$$

The sum of the coefficients of local resistances:

$$\sum \xi = n_1 \cdot \xi_k + n_2 \cdot \xi_v = 5 \cdot 0{,}5 + 3 \cdot 2{,}5 = 10$$

Bernoulli's equation:

$$p_a + \rho \cdot g \cdot H_1 = p_a + p_m + \left(\lambda \cdot \frac{L}{d} + \sum \xi \right) \cdot \frac{1}{2} \cdot \rho \cdot V^2 + \rho \cdot g \cdot H_2$$

Calculating of the pressure fall in the pipeline and pump effort:

$$\Delta p = \left(\lambda \cdot \frac{L}{d} + \sum \xi \right) \cdot \frac{1}{2} \cdot \rho \cdot V^2 + \rho \cdot g \cdot (H_2 - H_1) + p_m$$

$$\Delta p = \left(\lambda \cdot \frac{L}{d} + \sum \xi \right) \cdot \frac{1}{2} \cdot \rho \cdot V^2 + \rho \cdot g \cdot H + p_m$$

$$\Delta p = \left(0{,}03 \cdot \frac{75}{0{,}06} + 10 \right) \cdot \frac{1}{2} \cdot 1000 \cdot 2^2 + 1000 \cdot 9{,}81 \cdot 10 + 3 \cdot 10^5 = 493100\ Pa$$

$$\Delta p = 4{,}931\ bar$$

Given that 1 *bar* = 10,3 *mWP* (meters of water pillar), it follows that the pump effort:

$$H_{\mathrm{p}} = 4{,}931 \cdot 10{,}3$$

$$H_{\mathrm{p}} = 50{,}8\ m$$

Pump power:

$$N_1 = \frac{Q \cdot \Delta p}{1000 \cdot \eta_p} = \frac{20 \cdot 493100}{1000 \cdot 0{,}5 \cdot 3600} = 5{,}5\ kW$$

Selecting the multistage centrifugal pump TYPE VPN − 80 with the following characteristics:
Q = 6,35 *l/s*, *H* = 56 *m*, *N* = 7,5 *kW*.

CONCLUSION

By analyzing the Bernoulli′s equation, it can be reached to the characteristic facts in fluid dynamics. At the end we can see that just from all this analyzed examples, via Bernoulli′s equation it can be reached to the calculating of the pressure fall, and thus the pump effort with its power which are significant for application in industrial plants. Thus that it can be reached, points to the outstanding importance of Bernoulli′s equation and its great use in praxis, i.e. in applied fluid mechanics, respectively hydraulics.

REFERENCES

[1] Prof. Ph.D. Dragisa Tolmac, M.Sc. Jasna Tolmac: Designing of Technological Systems – Collection of Solved Problems, Technical Faculty "Mihajlo Pupin", Zrenjanin, 2015.
[2] Prof. Ph.D. Dragisa Tolmac: Machines and Devices – Solved Problems, Technical Faculty "Mihajlo Pupin", Zrenjanin, 2006.
[3] Prof. Ph.D. Dragisa Tolmac: Designing of Technological Systems - Production Systems, Technical Faculty "Mihajlo Pupin", Zrenjanin, 2008.

[4] Prof. Ph.D. Dragisa Tolmac: Machines and Apparatus, Technical Faculty "Mihajlo Pupin", Zrenjanin, 2009.
[5] PhD Jevrem Janjic, PhD Istvan Bikit, PhD N. Cindro: General Course of Physics – First Part, Belgrade, 1994.
[6] PhD Engeener Dragisa M. Ivanovic, Engeener Vlastimir M. Vucic: Physics I, Belgrade, 1960.

EXPERIMENTAL METHODS FOR PROVING LENZ′S LAW

Jasna Tolmac[1], Vjekoslav Sajfert[1]
[1]University of Novi Sad, Technical Faculty "Mihajlo Pupin", Zrenjanin, Serbia
e-mail: jasnatolmac@yahoo.com

Abstract: This paper describes two experimental methods that are based on the basic concept of Lenz's and Faraday's law of electromagnetic induction, which is the electromotive force (EMF) in order to facilitate understanding of the effect that when changing the surface of closed current contour in a constant magnetic field, leads to the induction of EMF and the current in that contour. These experimental methods may also encourage a better understanding of Lenz's law, as well as understanding the connection between physical terms - electromagnetic induction, Newtonian mechanics and energy.
Key words: electromagnetic induction, electromotive force (EMF), electric current, magnetic field.

INTRODUCTION

In 1820, Hans Christian Oersted discovered that the flow of electric current enables the creating of the magnetic field. The reverse effect, creating an electric current due to the existence of magnetic field discovered Michael Faraday in 1831. Electromagnetic induction is the phenomenon of electric current or electromotive force due to motion of the conductor in a magnetic field or due to change of the magnetic field. Today, on the principle of induction, almost exclusively, mechanical energy is directly converted into electrical energy.
Electro-dynamical forces which are affecting on the electrons can lead to the appearance of electric current. Such currents that are caused by electromagnetic forces are called induced currents. Today in electrical engineering, electric currents obtain, almost exclusively, to such electromagnetic effect or electromagnetic induction.

ELECTROMAGNETIC INDUCTION

Any movement of electric charges (and electric current) in the surrounding area, forms a magnetic field, i.e. there is a conversion of energy of the electric field into the energy of the magnetic field. It is natural to ask the question: Is it possible to reverse the process, i.e. is it possible that the energy of the magnetic field is converted into energy of electric current? The connection between electricity and magnetism established the Michael Faraday. Electromotive force is induces or when the conductor moves in a magnetic field, or when it is closed conductor finds himself in a changeable magnetic field.

LENZ'S RULE

Lenz's rule can be written in more ways:

The induced current has always such a direction that its field tends to prevent the cause of induction. Induced EMF in the circuit induces (creates) electric current in that circuit, which induces a magnetic field that opposes the change of magnetic flux.

The induced current in the closed current contour always flows in such a direction that its magnetic field is opposes to a magnetic field which induces that current.

The direction of the induced current (EMF) is such that it opposes the cause that leads to its induction.

EXPERIMENTAL METHODS

Electromagnetic induction is an abstract concept, so it is understandable why many students have difficulties with understanding of its concept. For this reason it is advisable to perform experimental methods to make students able to visualize, understand and learn the concept of electromagnetic induction. To facilitate understanding of Faraday's and Lenz's law, proposed experimental methods based on the basic concept of Faraday's and Lenz's law, which is called the electromotive force (EMF) which is induced in a conductor moving through a constant magnetic field.

In 1831, Michael Faraday, British physicist and chemist, conducted an experiment that showed that changeable magnetic field can induce an electric current in the circuit. This led to the formulation of a fundamental and very important law known under the name of *Faraday's law of electromagnetic induction*, which says that whenever there is a change in the flux of the magnetic field through a closed conductive loop, EMF (and therefore an electric current as well) is induced in the loop. Faraday also discovered that the intensity of induced EMF proportional to the time change of the magnetic flux and it is given by the formula:

$$\varepsilon = -N\frac{d\Phi}{dt} \tag{1}$$

N is the number of windings in the coil, and $d\Phi/dt$ is the change of magnetic flux with time. The minus sign indicates that the induced EMF opposes the change of magnetic flux.

Three years later, in 1834, German physicist Heinrich Lenz established rule for determining the direction of induced current. This was later called Lenz's law, which states that the direction of the induced current in the conductive loop coincides with the direction of the magnetic field which opposes the change of magnetic flux through the surface covered by the conductive loop. Therefore, the induced current tends to keep the original magnetic flux through the circuit from changing.

The methods described below aim to define the EMF and its correlate with the concepts of electromagnetic induction, Newtonian mechanics and energy.

If, for example, induced EMF caused by the motion of conductor, in that conductor EMF provides current of such a direction that the force of the external field affects on the conductor in a direction opposite of the movement. If the conductor is at rest, and induced EMF arises due to change of the flux of the magnetic field, it tends to prevent the change. So induced EMF, respectively current has always such a direction that opposes the cause that produces it, i.e. the cause of which it caused.

On this basis, in the first experiment we suppose that the aluminum rod will slow down after entering in the magnetic field. In the second experiment, we suppose that the number of oscillations to a halt of aluminum ring without magnet be higher, and with magnet smaller.

Lenz's rule is a consequence of the law of conservation of energy. Induced EMF ensues by transformation of various forms of energy into the energy of the electric field. So, electric field must be supply with energy. This is achieved through the action of mechanical forces (movement of conductor) or a change of magnetic flux. Induced current carries the energy, i.e. it is capable of performing the work. The mentioned energy takes from its "cause" why it has the direction which "against" to that cause, i.e. affects in contravention of its activities.

This rule is conditioned by the law of conservation of energy. Induced currents always perform work, respectively heating conductor. This work must be in the same amount invested in the induction. The appearance of force which is opposite of the movement agrees with investment of work in the process of induction.

FIRST EXPERIMENT

A simple experiment to demonstrate electromotive force and Lenz's law

Setting experiment

1.Strong horseshoe magnet, aluminium rod, U-shaped copper rod, perspex.

The surface should be inclined at an angle of 15 degrees, so the aluminum rod could glide down freely and without stoppage.

2. Set up the apparatus as in Figure 1. Set an aluminium rod over the copper rod (both on the ground).

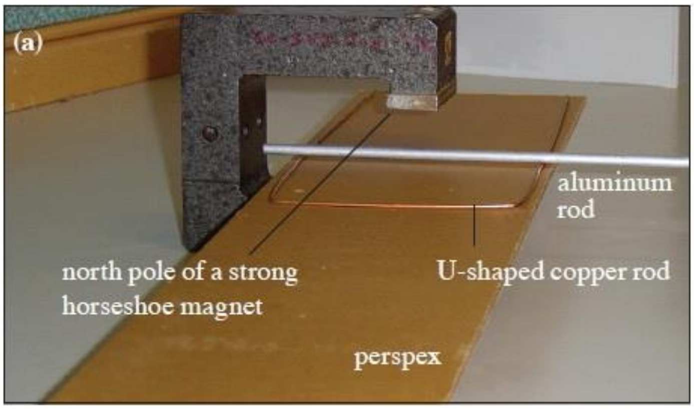


Figure 1.

3. Let aluminium rod to roll along the copper rod.
4. Observe the movement of aluminum rod before entering the magnetic field, within the magnetic field and after leaving the magnetic field.

Description of the experiment and explanation

When aluminium rod let go, sliding down along the U-shaped copper rod, lying on inclined acrylic surface. Prior to entering aluminium rod in the magnetic field, there is no induction of current in it, and its accelerated downward movement caused by gravity. Aluminium rod accelerates and its gravitational potential energy is converted into kinetic energy. Aluminium rod continues to slide downward until it enters into magnetic field, which produces a strong horseshoe magnet. In order to quantitatively describe the change in the magnetic field, considers the magnetic flux.
The intensity of the magnetic flux (Φ) depends on the intensity of the magnetic field (B), its orientation, the surface (A) and angle (θ). Changing any of these parameters causes a change of magnetic flux. Therefore, in this system, the aluminium rod slides downward into the uniform magnetic field (B), a magnetic flux (Φ) through the closed contour is decrease, because the enclosed by the contour area (A) is decrease. The change of magnetic flux induces EMF and induces a current through the closed contour which formed by the aluminium rod and copper rod.
As an effect of Lenz's law, induced EMF opposes to change. Since a change in this case the decrease of the magnetic flux, induced EMF must be oriented in the same direction as the original external magnetic field (Figure 2).

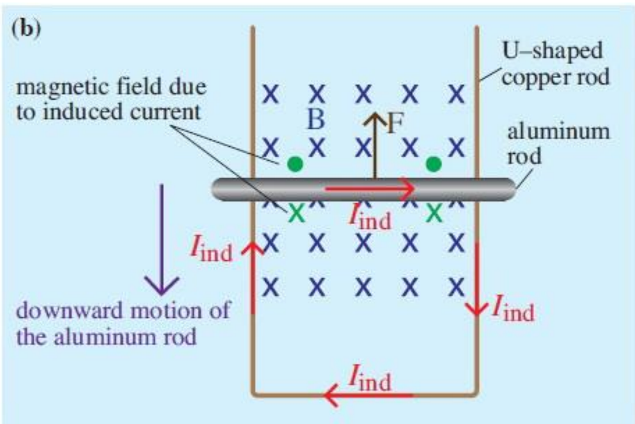


Figure 2.

With this orientation, induced EMF will increase the magnetic field in contour and thereby increase the magnetic flux. In accordance with right-hand rule, induced current (I_{ind}) must circulate in a clockwise direction, to increase the magnetic field inside the contour. The induced current (I_{ind}) in aluminum rod flows from left to right, in order to, according to Lenz's rule, opposes to change which

causes it. Flow of induced current from left to right in the aluminum rod, interacts with the original magnetic field, giving directed upward magnetic force on the aluminum rod, opposite direction of movement of aluminum rod, which therefore tends to slow it. Finally, at one moment the gravitational force cancels the effect of magnetic force. From this moment and on, the aluminum rod slides down at constant speed and therefore constant kinetic energy, to the exit of the magnetic field.
Like when the rod is let go, at exiting from the magnetic field, there is no induced current and acceleration of rod downward is gravitational acceleration.

SECOND EXPERIMENT

A simple experiment to demonstrate electromotive force and Lenz's law (Magnetic brake)

The oscillation of the pendulum in the form of a ring made of an aluminum foil can be stopped by using a magnet.

Setting experiment

Required material:

- Aluminium foil
- Thread
- Stand
- 2 Magnetic rods

Preparation of the experiment:

Make a ring of aluminum foil (diameter 5 - 8 cm), and using a woolen thread to hang it on the stand like on Figure 3. Thus obtained pendulum moved from its equilibrium position by 90 degrees and count periods of oscillation to a halt (because of air resistance and friction of the thread on the horizontal rod).

Repeat the experiment while it should keep the magnet so that the ring passes through the hoop during oscillation.

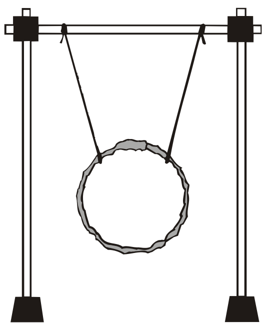


Figure 3.

Description of the experiment and explanation

Every time when ring enters or leaves from the field of magnet, it changes the magnetic flux through which the ring passes. Due to change of magnetic flux, induces a voltage which causes a current in the ring of aluminum. That current produces a magnetic field, which according to Lenz's rule, so focused, that prevents the movement of which it caused. If the aluminum ring "pushes" to magnet, then the

induced magnetic field such that rejects aluminum ring from the magnet. If the ring "slides" from the magnet, then induced magnetic field pulls up it to the magnet. In both cases, the ring has a negative acceleration, respectively ring brakes. Number of oscillations to a halt without the magnet (when we hold a magnet) is $20 - 25$, and with magnet is $10 - 15$.
This experimental methods are based on the basic concept of Lenz's and Faraday's law of electromagnetic induction, which is the electromotive force (EMF) in order to facilitate understanding of the effect that when changing the surface of closed current contour in a constant magnetic field, leads to the induction of EMF and the current in that contour. These experimental methods may also encourage a better understanding of Lenz's law, as well as understanding the connection between physical terms - electromagnetic induction, Newtonian mechanics and energy.

CONCLUSION

Michael Faraday discovered electromagnetic induction in 1831, which enabled him to transfer energy (power) from one circuit to another, changing the current in the first circuit. This discovery of Faraday enabled the production and transmission of electrical energy to large distance from the source and its distribution to the towns and factories. Although it has been 184 years since the discovery of Faraday, still discovering new applications of electromagnetic induction.
Many electrical devices use batteries as a power source (for example: mobile phone, lamp), but it is a far greater number of devices and systems that use electrical energy produced in power plants on the principle of electromagnetic induction. Today power plants have huge capacity and can produce more megawatts of power. Also, on the principle of electromagnetic induction works the speedometer in the car. Electromagnetic induction is used in industry in induction furnaces (it can be achieved very high temperatures - enough to melt metals). Electromagnetic induction is widely used in magnetic recording and storage of information (hard disk on a computer).

REFERENCES

[1] Prof. Ph.D. Vjekoslav Sajfert: Electrical Engineering, University of Novi Sad, Technical Faculty "Mihajlo Pupin", Zrenjanin, Zrenjanin 2007.
[2] PhD Jevrem Janjic, PhD Istvan Bikit, PhD N. Cindro: General Course of Physics - Second Part, Belgrade, 2002.
[3] PhD Engineer Dragisa M. Ivanovic, Engineer Vlastimir M. Vucic: Physics II – Electromagnetics and Optics, Belgrade, 1960.
[4] sr.wikipedia.org/wiki/Lencov_zakon
[5] Kwan Lyna and Boey Kok Leong, March 2012. A Simple Demonstartion of Motional Electromotive Force, *Physics Education* 47:2, 147–149.
[6] Natasa Kadelburg, Kosta Panic: Physics for Third Grade of Gymnasium, ″Circle″ Belgrade, 2011.

SOME SPECIFIC OF VIBRATORY CONVEYOR DRIVES

Željko Despotović[1], Vladimir Šinik[2], Slobodan Janković[2], Dalibor Dobrilović[2], Momčilo Bjelica[2]
[1]Institute "Mihajlo Pupin", Belgrade, Serbia
[2]University of Novi Sad, Technical Faculty "Mihajlo Pupin", Zrenjanin, Serbia
e-mail: sinik.vladimir@gmail.com

Abstract: The paper describes some of the basics of kinematics and dynamics of vibratory conveyor drive. Featured are dynamic modes of material that is being transported. Presented is the optimum material handling, and most rational mode. Introducing the empirical dependence transport speed as a function of angle bending conveyor, amplitude of oscillation of the transport container, the oscillation frequency excitation angle at which operates the actuating force and the coefficient mode of operation of the conveyor. Featured are some of the drive vibratory conveyors, and especially the operation of electromagnetic vibratory conveyor.
Key words: Vibratory conveyor drive, Kinematic and dynamic modes, Electromagnetic vibratory conveyor

INTRODUCTION

Vibratory movement is one of the most efficient methods of conveyance of granular and particulate materials. Vibratory conveyers (VC) are widely applied in many technological processes involving gravimetric transport, processing, and dosing of granular materials. From the macroscopic point of view, the process of vibratory conveyance is based on recurrent micro-displacements of particles of the material being conveyed [1-11].

Basic Types of Operations in VC

- conveying along to the horizontal surface
- conveying along to the lightly inclined surface
- conveying along to the spiral elevator
- vibratory dosing; loading and (or) discharging
- vibratory finishing; pulverization and separation
- vibratory compaction
- vibratory rapping (electrostatic precipitators)

VIBRATORY CONVEYANCE KINEMATICS

Simplification of the kinematics of a typical vibratory conveyor is shown in Figure 1. Basic kinematic size vibratory conveyors are presented in Figure 1(a) are: displacement, -X_l, velocity-v_L and acceleration transport containers-a_L; trajectories of particles of bulk material is shown curve - X_p. The fact of the support element on one imaginary particle bulk medium to be transported, is shown in Figure 1 (b). It is assumed that during the cycle of the vibrating conveyor oscillates between the position of the court with the labeled (M) and (P), so that the value of the vibration width $2 \cdot X_m$. The increase in the speed of oscillation is between the (M) and (N), so that the vibrating receptacle is speeding up, while decreasing the speed of oscillation between the (N) and (P), when the vibratory bowl slows down. For travel transmission containers to above, between the position (M) and (N), the particle is in contact with the surface transportation containers.
In the position (N) particle velocity becomes greater than the speed of transportation containers and leaving its surface and keeps moving free-fall trajectory by (P) - (Q). During this time vibrating the container was moved to the lowermost very position, so that the particles fall on its surface, and the next cycle begins again the particles move from point (Q).

- Conveying process is based on a sequential throw movement of particles

- Vibrations of tank, i.e. "load-carrying element" (LCE), in which the material is placed, induce the movement of material particles, so that they resemble a highly viscous liquid and the material becomes easier to transport and to dose
- The conveying material flow directly depends on the average value of particles throw movements, being on a certain LCE working vibration frequency.
- This average value, on the other hand, depends on vibratory width (VW) i.e. doubled amplitude oscillation of the LCE

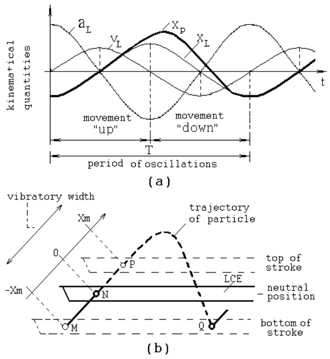


Figure 1. Kinematics vibratory conveyor;
(a) waveforms characteristic values, (b) the trajectory of virtual particles

VIBRATORY CONVEYANCE DYNAMICS

This chapter describes the behavior of an imaginary particle mass m_p horizontally arranged support element vibratory conveyor which is supported on a substrate inclined elastic rods.

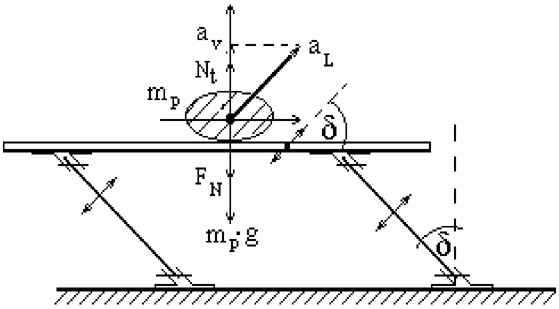


Figure 2. Diagram of forces acting on the particle material to be transported

The dynamic equations of motion of the observed particles is described by the equation

$$m_p \cdot a_v = \sum_{i=1}^{n} F_i = -m_p \cdot g + N_t$$

The vertical component of the acceleration of underlying surface is variable time t and is given by the relation:

$$a_v = a_L \cdot \sin\beta = -X_m \cdot \Omega^2 \cdot \sin\delta \cdot \sin\Omega \cdot t$$

while the force of pressing the particles of material to the surface of the support element:

$$F_N = m_p \cdot (g - X_m \cdot \Omega^2 \sin\delta \cdot \sin\Omega \cdot t)$$

X_m -amplitude oscillation of LCE surface

Ω -excitation frequency

The ratio of the maximum vertical component of the acceleration of the support element and the acceleration due to gravity is called the coefficient mode vibratory conveyor and is marked with. This coefficient is characterized by a dynamic mode of vibratory conveyors and character movement of particles on the carrier surface of the conveyor. It is given by the relation:

$$K = \frac{X_m \cdot \Omega^2 \cdot \sin\delta}{g}$$

VIBRATORY CONVEYANCE OPTIMISATION

The most rational regime is provided by a continuous micro-throw of the particle, so that time of its pass is equal or multiple to the total oscillation period of the vibratory conveyor

$$t_p = n \cdot T$$

where n is any integer.

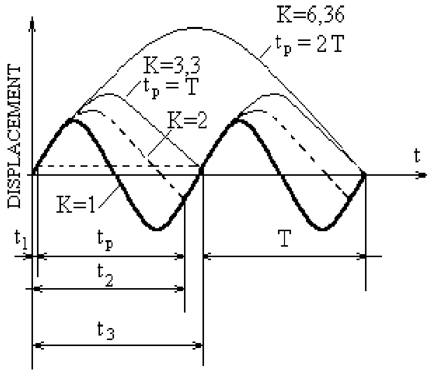


Figure 3. Diagram of movement of particulate materials vibratory conveyor for different values of the mode

Theoretically and experimentally established that the pace of sustained, continuous movement in rebounding particulate material obtained at a [40], [57]:

$$K = \sqrt{\left(\frac{\cos 2\pi \cdot n - 2\pi^2 \cdot n^2 - 1}{2\pi \cdot n - \sin 2\pi \cdot n}\right)^2 + 1}$$

From the point of vibratory transport, the most interesting practical case when the coefficient value mode ranges $3.297 > K > 1$.

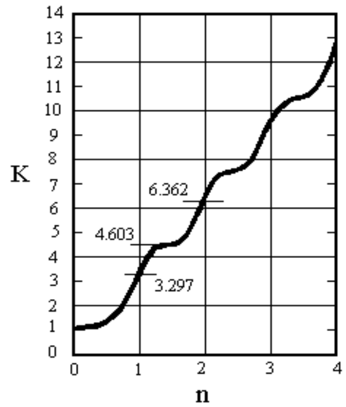


Figure 4. The dependency ratio mode of the number of overflight during one period of oscillation conveyor.

THE VIBRATORY CONVEYANCE SPEED

Speed transporting material as a basic measure of the mass flow is dependent on many factors. We will mention only those who are influential and can be operated in practical applications of vibratory transport. This is primarily on the properties of the transported material particles, the inclination angle conveyor, the angle at which the transmission court acts excitation force amplitude and frequency of the excitation force and coefficient mode. Empirical dependence of the speed of transport material (m / s) as a function of these factors is given by the relation [40] :

$$v_t = (K_1 \pm K_2 \cdot \sin\gamma_t) \cdot X_m \cdot \Omega \cdot \sqrt{1 - \frac{1}{K^2}} \cdot \cos\delta$$

where are they:

K_1 *and* K_2 -- empirical coefficients

γ_t *-inclination angle of VC (= 0 for horizontal VC)*

X_m -amplitude oscillations of vibratory tank i.e. LCE

Ω -excitation frequency

δ -vibration angle

K *-operation regime factor of VC*

The Empirical Coefficients K1 and K2 are depending upon physically properties of the conveying material.

Table 1.

*** at researches and experiments of В.КДлъчков and Внииптмаш*

CONVEYING MATERIAL	DIMENSION CHARACTER. PARTICLES of MATERIAL (mm)	HUMIDUTY (%)	K_1	K_2
lumped	5....200	/	0,9...1,1	1,5...2,0
granular	0,1...5,0	0,5... 10,0	0,8...1,0	1,6...2,5
powder	0,1....0,5	0,5....5,0	0,4...0,5	1,6...3,0
dusted	< 0,1	0,5....5,0	0,2...0,5	2,0...5,0

VIBRATORY CONVEYING DRIVES

MECHANICAL
- eccentrics
- centrifugal
- inertial

ELECTRICAL
- rotary→ electric motion
- linear→electromagnetic

Generally, the term vibratory drive means the overall device for generating mechanical oscillations, their conversion and transfer to support member conveyor system. Historical development of vibratory drives flowed gradually. Thus, the first resulting centrifugal and eccentric drives, while later started to apply electromagnetic.

When centrifugal and the cam drive excite vibratory conveyor constitutes a vibration excitation circuit and the support member with a coupling appropriate elements.

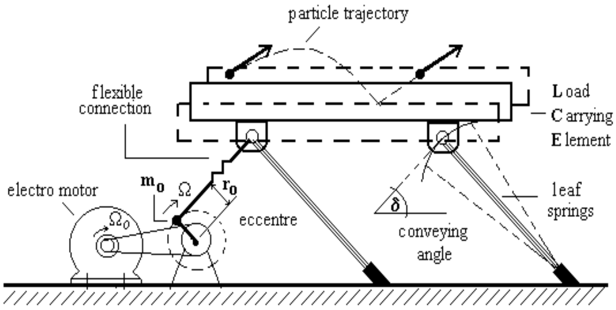


Figure 5. Eccentric drive vibratory conveyors

When centrifugal drive (Sl.1.3) applicable eccentric weight in combination with a rotary motion. In these types of conveyors is applied or single-cycle-cycle mode excitation.

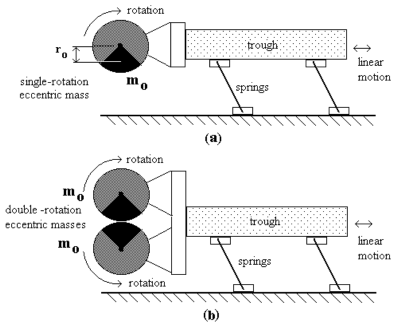


Figure. 6. Centrifugally Vibratory Conveying Drive;

a)- eccentric drive with one mass , (b)- eccentric drive with two masses.

- When a reciprocating motion has to be electrically produced, the use of a rotary electric motor with a suitable transmission is really a rather roundabout way of solving the problem
- It is generally a better solution to look for an incremental-motion system with magnetic coupling, so-called electromagnetic vibratory actuator (EVA) , which produces a direct *"to-and-from"* movement
- Electromagnetic drives offer easy and simple control for the mass flow conveying materials
- In comparison to all previously mentioned drives, these have a more simple construction and they are compact, robust and reliable in operation
- The absence of wearing mechanical part, such as gears, cams belts, bearings, eccentrics or motors, makes electromagnetic vibratory conveyors and feeders most economical equipment

THE VIBRATORY CONVEYER HAVING ELECTROMAGNETIC DRIVE

Electromagnetic VCS [12-25]. are divided into two types: single-drive and multi-drive. The single-drive systems can be one-, two- and three-mass; the multiple-drive systems can be one-or multiple-mass as shown in Fig. 7. Description of one-mass system is shown in Fig 7 (a). It comprises following elements: *LCE*, with which the *active section* of the EVA is connected, *elastic element*, connecting the active section with the *reactive section,* having been fastened on the frame.

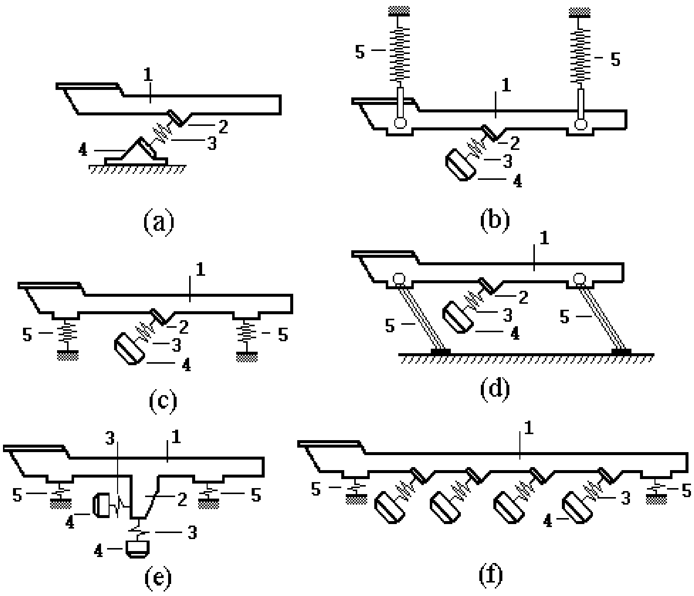


Figure 7. VCS with electromagnetic drives

The main components of the two-mass systems are shown in Fig. 7(b): *LCE*, to which the active section of EVA is attached, comprising *active section* and *reactive section*, with built-in *elastic connection*. The vibratory machine base is separated from the load-carrying structure by means of *plate springs*. A special drive, comprising two identical actuators, which oscillate in mutually perpendicular directions like in Fig. 7(c), is used for elliptical oscillation. The multipledrive multiple-mass system as shown in Fig.7 (d), has a *LCE* on which a number of identical actuators with *elastic connections* are tied.

A typical vibratory conveyer in a system of dosing granular material is shown in Fig. 8. It consists of a *carrying element* -1, electromagnetic vibratory actuator – EVA as the source of the excitation force, and *elastic elements* – 2. Standard structure of these elements is lamellar, made of steel sheets. Recent practice is to use elastic elements made of composite materials (*fiberglass*). These elements are fastened stiff to the *base* – 3, which rests on *rubber supports* – 4 elastically with respect to the surface supporting the mechanism.

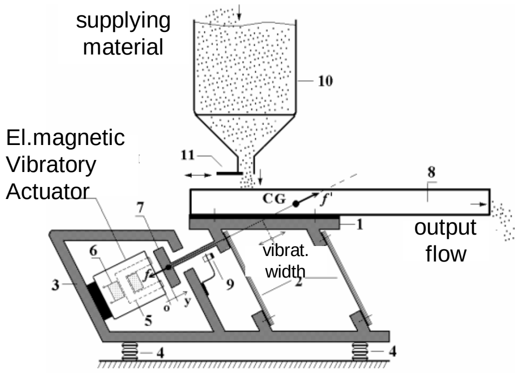


Figure 8. Vibratory resonant conveyer having electromagnetic drive

EVA consists of: a *magnetic core* – 5, closed in an *electrical coil* – 6, and an *armature* – 7, which is fixed to a movable carrying element, i.e. vibrating vessel – 8 along which the material is being conveyed. Electromagnetic driving force *f* generated by EVA acts upon the armature, i.e. upon the vibrating vessel. The vibratory displacement is detected by a contactless inductive sensor – 9. The material which is dosed is brought to the carrying element from a *bunker* – 10. Adjustment of the material inflow is accomplished by a *slide valve* – 11 which is placed at the bottom of the bunker. For defining control strategy of the vibratory conveyer, it is required to analyze the electromagnetic and mechanical parts of the system.

CONCLUSION

For a complete review of the problem of vibratory transport is necessary to analyze the kinematics and dynamic modes of material that is being transported. From the above it can be seen that it is necessary to take into account the optimal transfer of materials and the most rational regime. When required intermittent movement with a small move produced electrically, using a rotary electric motor with the corresponding cam or inertial masses and the corresponding transmission (reducer, pulley, elastic couplings, etc.) Is in practice often detour to the solution of the problem. Generally, the better solution is one electromechanical system that directly produces a linear or rotary motion. One of the possible solutions are systems with electromagnetic incremental converters or electromagnetic vibratory actuators, which are based on different principles. One such application, involves the use of force acting on the armature of soft iron or a permanent magnet in a magnetic field produced by alternating or even pulsating current.

REFERENCES

[1] I.F. Goncharevich, K.V. Frolov, and E.I. Rivin, Theory of vibratory technology, Hemisphere Publishing Corporation, New York, 1990.

[2] T. Dyr, P. Wodzinski, ,“Model Particle Velocity on a Vibrating Surface” Physicochemical Problems of Mineral Processing, vol.36, pp. 147-157, May 2002.

[3] E.M. Sloot and N.P. Kruyt , ”Theoretical and experimental study of the conveyance of granular materials by inclined vibratory conveyors”, Powder Technology, vol.87, no 3, pp.203-210, 1996.
[4] Soto-Yarritu,G.R and Martinez,A.A, “Computer Simulation of Granular Material: Vibrating Feeders”, Powder Handling and Processing, vol.13, no.2, 2001.
[5] Barjamović,N.,“Tiristori u sistemima za doziranje rasutih materijala”, II simpozijum Energetska elektronika – Ee ’75, Beograd (YU), pp.334-348, Oktobar 1975.
[6] Cock, H.G., “Vibratory Feeders“ PHILIPS Technical Review, Vol.24, pp.84-95, May 1975.
[7] Despotovic,Z., Stojiljkovic,Z., “A Realization AC/DC Transistor Power Converter for Driving Electromagnetic Vibratory Conveyors”, PROCEEDINGS of the V Symposium of Industrial Electronics-INDEL, Banja Luka, 11-13.IX.2004, Vol. T2A, pp.34-40.
[8] Despotović,Z. and Stojiljkovic,Z., ”Current Controlled Transistor Power Converter for Driving Electromagnetic Vibratory Conveyor” PROCEEDINGS of the XIII International Symposium of the Power Electronics, N.Sad 2.XI-4.XI.2005, Vol.T1-2.1, pp 1-5 .
[9] Dyr,T. Wodzinski,P.,“Model Particle Velocity on a Vibrating Surface” Physicochemical Problems of Mineral Processing, Vol.36, pp. 147-157, May 2002.
[10] El-Hor, H., Linz, S.J, Grochowsky.R, Walcel.P, Kruelle, C.A, Rouija.M, Gotzendorfer,T., Rehberg,I. “Model for Transport of Granular Matter on Vibratory Conveyors”, www.uni-bayreuth.de/departments/ ep5/preprints/elhor-p&g-1191.pdf
[11] Sloot E.M. and Kruyt .N.P , ”Theoretical and experimental study of the transport of granular materials by inclined vibratory conveyors”, Powder Technology, Vol.87, No3, pp.203-210, 1996.
[12] E.H.Werninck, “Electric Motor Handbook”, McGraw-HILL Book Company (UK) Limited, 1978.
[13] M.A. Parameswaran and S.Ganapahy, ”Vibratory Conveying-Analysis and Design: A Review”, Mechanism and Machine Theory, Vol.14, No. 2, pp. 89-97, April 1979.
[14] T. Doi, K. Yoshida, Y. Tamai, K. Kono, K. Naito, and T. Ono, “Modeling and Feedback Control for Vibratory Feeder of Electromagnetic Type”, Journal of Robotics and Mechatronics, vol. 11, no. 5, pp. 563-572, June 1999.
[15] T.Doi, K.Yoshida, Y.Tamai, K.Kono, K.Naito,T. Ono, “Feedback Control for Vibratory Feeder of Electromagnetic Type”, Proc. ICAM’98, 1998, pp. 849-854.
[16] Z.Despotovic and Z.Stojiljkovic, ” Power Converter Control Circuits for Two-Mass Vibratory Conveying System with Electromagnetic Drive: Simulations and Experimental Results”, IEEE Transation on Industrial Electronics, Vol.54, Issue I, Feb. 2007,pp.453-466
[17] I.J.Sokolov, V.I.Babitsky and N.A.Halliwell, “Autoresonant vibro-impact system with electromagnetic excitation”, Journal of Sound and Vibration, no. 308, pp. 375-391, 2007.
[18] S.Seely, Electromechanical energy conversion”, McGraw-HILL Book Company INC., New York, 1962.
[19] Z. Despotovic, and Z. Stojiljkovic,”PSPICE Simulation of Two Mass Vibratory Conveying System with Electromagnetic Drive”, PROCEEDINGS of International conference “Computer as a tool”, Belgrade 21.XI.-24. XI 2005, vol. II, pp.1509-1512.
[20] G. Winkler , “Analysing the Vibrating Conveyor”, International Journal of Mechanics, vol.20, pp.561-570, 1978.
[21] P.Wolfsteiner, F.Pfeiffer, “Dynamics of a vibratory feeder”, PROCEEDINGS of DETC '97, ASME Design Engineering Technical Conferences, Sacramento, California, DETC97/VIB-3905,Sept.14-17,1997,pp.1-9
[22] A.I.Ribic and Z.Despotovic, ” High-Performance Feedback Control of Electromagnetic Vibratory Feeder”, IEEE Transation on Industrial Electronics, Vol.57, Issue :9, Aug. 2010,pp.3087-3094.
[23] Mohan,N., Undeland,T.M., Robbins,W.P., “Power Electronics-Converters, Applications and Design” , John Wiley&Sons, INC. , New York, 1995.
[24] Rashid, M.H., “Power Electronics” , Prentice–Hall Englewood Cliffs, New York, 1988.
[25] Thorborg,K. “Power Electronics”, Prentice Hall International (UK) Ltd. 1988.

SIMULATION OF PNEUMATIC CYLINDER SYSTEMS WITH LONG PNEUMATIC PIPES

Đorđe Dihovični[1], Živoslav Adamović[2]
[1]Visoka tehnička škola, Bulevar Zorana Đinđića 152-a, Novi Beograd, Serbia
[2]University of Novi Sad, Technical Faculty "Mihajlo Pupin", Zrenjanin, Serbia
e-mail: zivoslav.adamovic@gmail.com

Abstract: The paper describes simulation of pneumatic cylinder systems with long pneumatic pipes. Problem is considered from parameter distribution and time delay perspective. It is applied the control for special group of distributed parameter systems, with distributed control, where control depends of one space and one time coordinate, and finite spectrum assignment method is implemented for time delay system. The stability on finite space interval is analyzed and efficient program support is developed in symbolic Maple program language.
Key words: distributed control systems, distributed control, program support

INTRODUCTION

A main scope of this paper, is a simulation, an analyse and program support of pneumatic cylinder systems. For complete description of pneumatic system cylinder system it is very important to analyze the characteristics of the pipes connected to a cylinder, which behavior can't be found without taking into account an influence from transient in long pneumatic lines. Methods of analyse of control systems and simulation methods, which are used for observing dynamic behavior of linear dynamic systems with time delay, and distributed parameter systems, based on linear algebra, operation calculus, functional analyse, integral differential equations and linear matrix non-equations are applied. Signal transient in long pneumatic lines is analysed from time delay and parameter distribution view of point. The pressure or flow changing phenomena in pneumatic control systems is very complex, and has a significant effect on the stability, response and construction issues of the system and its components. Up to now, the published papers have not been shown complete analyze of this phenomena and as well have not presented the adequate control system.
It is obvious that phenomena of transient of the pressure and the flow in pneumatic control systems, especially with long pneumatic lines have character of time delay and parameter distribution, and that further perspective. Mathematical models of these systems are described by partial different equations, but apart from distributed phenomena we can't neglect system time delay.
It is obvious that phenomena of transient of the pressure and the flow in pneumatic control systems, especially with long pneumatic lines have character of time delay and parameter distribution, and that further analyze should be implemented. This paper describes the simulation of pneumatic cylinder system, observing the problem from time delay and parameter distribution perspective. Mathematical models of these systems are described by partial different equations, but apart from distributed phenomena we can't neglect system time delay.

MATHEMATICAL MODEL

The Figure 1 shows a schematic diagram of pneumatic cylinder system. The system consists of cylinder, inlet and outlet pipes and two speed control valves at the charge and discharge sides. Detailed procedure of creating this mathematical model is described in [1].

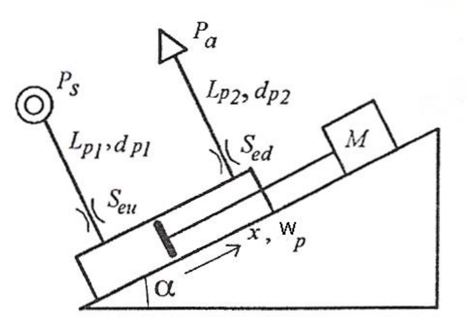


Figure 1. Schematic diagram of pneumatic cylinder system

Cylinder model

For describing behavior of pneumatic cylinder, the basic equations that are used are: state equation of gases, energy equation and motion equation.

$$\frac{dP}{dt} = \frac{1}{V} \cdot \left(\frac{P \cdot V}{\theta} \frac{d\theta}{dt} + R \cdot \theta \cdot G - P \cdot \frac{dV_d}{dt} \right) \quad (1)$$

where P is pressure (kPa), V- is volume (m^3), θ - temperature (K), R- universal gas constant (J/kgK), and V_d- is dead volume (m^3).

The temperature change of the air in each cylinder chamber, from the first law of thermodynamics, can be written as:

$$\frac{d\theta_d}{dt} = \frac{1}{C_v \cdot m_d} \cdot \left\{ S_{hd} \cdot h_d (\theta_a - \theta_d) + R \cdot \dot{m}_d \cdot \theta_d - P_d \cdot \frac{dV_d}{dt} \right\} \quad (2)$$

$$\frac{d\theta_u}{dt} = \frac{1}{C_v \cdot m_u} \cdot \left\{ S_{hu} \cdot h_u (\theta_a - \theta_u) + C_p \cdot \dot{m}_u \cdot T_1 - C_v \cdot \dot{m}_u \cdot \theta_u - P_u \cdot \frac{dV_u}{dt} \right\} \quad (3)$$

where C_v- is specific heat at constant volume (J/kgK), m- mass of the air (kg), S_h –heat transfer area (m^2), $\dot{m}$ - mass flow rate (kg/s), and subscript d denotes downstream side, and subscript u denotes upstream side.

Taking into account that thermal conductivity and the heat capacity of the cylinder are sufficiently large compared with them of the air, the wall temperature is considered to be constant.

In equation of motion, the friction force is considered as sum of the Coulomb and viscous friction, and force of viscous friction is considered as linear function of piston velocity, and other parameters have constant effect to friction force of cylinder. Then, equation of motion may be presented in following form:

$$M \cdot \frac{dw_p}{dt} = P_u \cdot S_u - P_d \cdot S_d + P_a \cdot (S_d - S_u) - M \cdot g \cdot \sin\alpha - c \cdot w_p - F_q \quad (4)$$

where S- cylinder piston area (m^2), w_p- piston velocity (m/s), M- load mass (kg), c-cylinder viscous friction (Ns/m), P_a- atmospheric pressure (kPa), F_q- Coulomb friction (N), g- acceleration of gravity (m/s^2).

Pipe model

By using the finite difference method, it can be possible to calculate the airflow through the pneumatic pipe. The pipe is divided into n partitions.

Applying the continuity equation, and using relation for mass of the air $m = \rho \cdot A \cdot \partial z$ and mass flow $\dot{m} = \rho \cdot A \cdot w$, it can be obtained:

$$\frac{\partial m_i}{\partial t} = \dot{m}_{i-1} - \dot{m}_i \tag{5}$$

Starting from the gas equation, and assuming that the volume of each part is constant, deriving the state equation it follows:

$$\frac{dP_i}{dt} = \frac{R \cdot \theta_i}{V}\left(\dot{m}_{i-1} - \dot{m}_i\right) + \frac{R \cdot m_i}{V}\frac{d\theta_i}{dt} \tag{6}$$

The motion equation of the air is derived from Newton's second law of motion and is described as:

$$\frac{\partial w}{\partial t} = \frac{P_i - P_{i+q}}{\rho_i \cdot \delta\, z} - \frac{\lambda}{2d} \cdot w_i \cdot \left|w_i\right| - \left|w_i\right| \cdot \frac{\partial w_i}{\partial z} \tag{7}$$

where λ is pipe viscous friction coefficient and is calculated as a function of the Reynolds number:

$$\lambda = \frac{64}{\mathrm{Re}}, \qquad \mathrm{Re} < 2.5x10^3 \tag{8}$$

$$\lambda = 0.3164 \cdot \mathrm{Re}^{-0.25}, \quad \mathrm{Re} < 2.5x10^3 \tag{9}$$

The respective energy can be written as:

$$\Delta E_{st} = E_{1i} - E_{2i} + L_{1i} - L_{2i} + Q_i \tag{10}$$

where E_{1i} is input energy, E_{2i} is output energy, L_{1i} is cylinder stroke in downstream side, and L_{2i} is cylinder stroke in upstream side of pipe model, and the total energy is calculated as sum of kinematic and potential energy.
Deriving the total energy ΔE_{st} , it is obtained the energy change ΔE_{st}:

$$\Delta E_{st} = \frac{d}{dt}\left\{C_v \cdot m_i \cdot \theta_i + \frac{1}{2} \cdot m_i \cdot \left(\frac{w_{i-1} + w_i}{2}\right)^2\right\} \tag{11}$$

In equation (10), the inflow and outflow energy as well as the work made by the inflow and outflow air can be presented with following:

$$\begin{aligned}
&w_{i-1} \geq 0 \quad E_1 = C_v \cdot \dot{m}_{i-1}\, \theta_{i-1} + \frac{1}{2} \cdot \dot{m}_{i-1} \cdot w_{i-1}^2, \qquad L_1 = R \cdot \theta_{i-1} \cdot \dot{m}_{i-1} \\
&w_{i-1} < 0 \quad E_1 = C_v \cdot \dot{m}_{i-1}\, \theta_i + \frac{1}{2} \cdot \dot{m}_{i-1} \cdot w_{i-1}^2, \qquad L_1 = R \cdot \theta_i \cdot \dot{m}_{i-1} \\
&w_i \geq 0 \quad E_2 = C_v \cdot \dot{m}_i\, \theta_{i-} + \frac{1}{2} \cdot \dot{m}_i \cdot w_i^2, \qquad L_1 = R \cdot \theta_i \cdot \dot{m}_i \\
&w_i < 0 \quad E_2 = C_v \cdot \dot{m}_i\, \theta_{i+1} + \frac{1}{2} \cdot \dot{m}_i \cdot w_i^2, \qquad L_1 = R \cdot \theta_{i+1} \cdot \dot{m}_i
\end{aligned} \tag{12}$$

From the following equation the heat energy Q can be calculated:

$$Q = h_i \cdot S_h \cdot \left(\theta_a - \theta_i\right) \tag{13}$$

where h is heat transfer coefficient which can be easily calculated from the Nusselt number Nu, and thermal conductivity k:

$$h_i = \frac{2Nu_i \cdot k_i}{d_p} \tag{14}$$

where d_p is pipe diameter.
Nusselt number can be calculated from Ditus and Boelter formula for smooth tubes, and for fully developed turbulent flow:

$$Nu_i = 0.023 \cdot \mathrm{Re}_i^{\,0.8} \cdot \mathrm{Pr}^{0.4} \tag{15}$$

and thermal conductivity k can be calculated as a linear function of temperature:

$$k_i = 7.95 \cdot 10^{-5} \cdot \theta_i + 2.0465 \cdot 10^{-3} \tag{16}$$

APPLICATION OF DISTRIBUTED CONTROL

Control of distributed parameter systems, which depends of time and space coordinate is called distributed control. If we choose control U, for pressure difference in two close parts of pneumatic pipe, and for state X, if we choose air velocity through the pneumatic pipe, with assumptions that are shown during derivation of mathematical model of pneumatic pipe, finally it is obtained:

$$\frac{\partial X}{\partial t} + |X| \cdot \frac{\partial X}{\partial z} + a \cdot X \cdot |X| = b \cdot U,\ z \in [0, L] \tag{17}$$

where $a = \dfrac{\lambda}{2d}$, $\quad b = \dfrac{1}{\rho \cdot \delta\, z}$.

Nominal distributed control can be solved by using procedure which is described in [5], and result of that control is nominal state $w_N(t,z)$ of chosen system. In that case it yields:

$$\begin{aligned} L(X_N(t,z)) = {} & \frac{1}{b} \cdot \frac{\partial X_N}{\partial t} + \frac{1}{b} \cdot |X| \cdot \frac{\partial X}{\partial z} \\ & + \frac{1}{b} \cdot a \cdot X \cdot |X| = U(t,z) \end{aligned} \tag{18}$$

where L is appropriate operator.

System (18) is exposed to many disturbances, so the real dynamic must be different from nominal. It is applied deviation from nominal system state, and then the nominal system state can be realized as:

$$x(t,z) = X(t,z) - X_N(t,z),\ 0 < z \le L \tag{19}$$

Time derivation of deviation from nominal system state, can be presented by following equation:

$$\frac{\partial x(t,z)}{\partial t} = \frac{\partial X(t,z)}{\partial t} - \frac{\partial X_N(t,z)}{\partial t} \tag{20}$$

and from equations (17), it yields:

$$\frac{\partial x(t,z)}{\partial t} = r(t,z) + |X| \cdot \frac{\partial X}{\partial z} + a \cdot X \cdot |X| - b \cdot U \tag{21}$$

where $r = \dfrac{\partial X_N}{\partial t}$

PRACTICAL STABILITY

Using the concept of extern linearization, which is described in, [5], we can include distributed control in the following form:

$$\begin{aligned} U(t,z) = {} & \left[(a-k) \cdot X \cdot |X| + k \cdot X_N \cdot |X| + |X| \cdot \frac{\partial X}{\partial z} + r \right] / b, \\ & 0 \le z \le L \end{aligned} \tag{22}$$

Including the equation (44) in the equation (43), it yields:

$$\frac{\partial x(t,z)}{\partial t} = -k \cdot x(t,z),\ 0 \le z \le L \tag{23}$$

Functional V is chosen in the form:

$$V(x) = \frac{1}{2} \cdot \int_0^L [x(t,z)]^2 \cdot dz = \frac{1}{2} \cdot \|x(t,z)\|^2 \tag{24}$$

Derivation of functional *V* is given as:

$$\frac{dV(x)}{dt} = \int_0^L x \cdot \frac{\partial x}{\partial t} \cdot dz$$
$$= -k \cdot \int_0^L [x(t,z)]^2 \cdot dz = -2 \cdot k \cdot V(x) \tag{25}$$

Taking into account that *V(x)* is positive defined functional, time derivation of functional given by equation (47) will be negative defined function for $k>0$, and in that way all necessary conditions from Ljapunov theorem applied to functional V, are fulfilled.

TIME DELAY APPROACH

Pneumatic cylinder systems significantly depend on behavior of pneumatic pipes, and thus it is necessary to further investigate influence of long pipes. It is obvious that phenomena of transient of the pressure and the flow in pneumatic control systems, especially with long pneumatic lines have character of time delay and parameter distribution, and that further analyze should be implemented.
Let consider the case of transient of the pressure signal through connected pneumatic lines, by using modal approximation of each pneumatic line, as in [12]. Taking into account that delays are neglected, it is obtained system transfer matrix:

$$W(s) = \sum_{k=0}^{N} \frac{n_k}{s - p_k} \tag{26}$$

where p are poles and n system nulls, and k is index.
When we consider the system with time delay caused by transitient of pneumatic signal through the long pipes, then the transfer matrix by using finite spectrum assignment method, are presented as:

$$W(s) = \sum_{k=0}^{N} \frac{1}{s - p_k} \cdot \beta_k \tag{27}$$

$$\beta_k = n_k \cdot \exp(-\tau_k \cdot p_k) \tag{28}$$

where τ is time delay.
It is possible for given positive defined matrix P and Q, determine matrix P_c, which consists set of pre-dominant poles, that can be assigned by using appropriate control law, as well as matrix F, as it is descibed in [3]:

$$F = P - P_C \tag{29}$$

and transfer matrix with time delay can be factorized, by using appropriate transformation:

$$W(s) = R(s) \cdot P^{-1}(s) \tag{30}$$

The Figure 2 describes connected pneumatic lines:

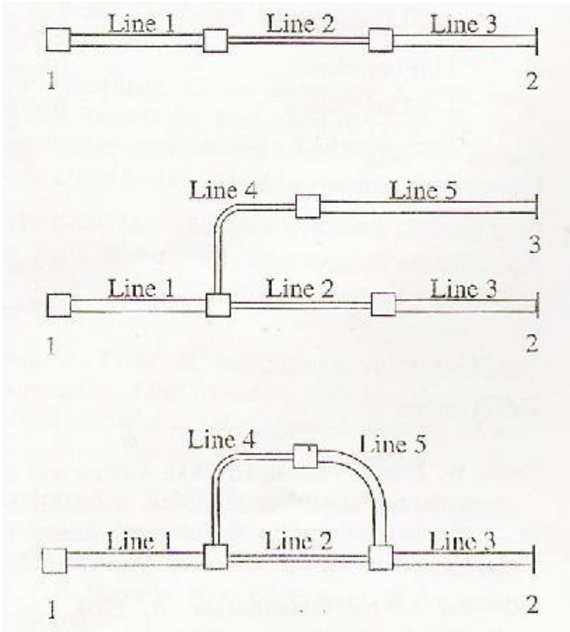


Figure 2. Connected pneumatic lines

Linear time delay systems have infinite number of poles and nules of cvazi-characteristic equation, and it has been shown that it is impossible by using state feedback, assign them to appropriate places in left plane *s*.
By using finite spectrum assignment method in frequent domain, which is given in [3], poles from the system described by equation (26), can be transfered to determined places.

PROGRAM SUPPORT

Here is presented the program support for finite spectrum assignment method in frequent domain, applied to pneumatic transition signal in long pipes.
Program support is developed in symbolic program language Maple.

```
fcsa = prog(G, Pc, Q)
local u, j, k, rd, cd;
#Function fsam returns transfer matrix and
Desired poles given by matrix Pc and  Q
#
wuth(lunalg):
uu : = array(udentuty, 1..2, 1..2);
l  := scalarmul(uu, -1);
cd :=coldum(W);
rd :=rowdum(W);
for u from 1 to cd d0
        c[u,j] :=solve(denom(W[u,j]);
uf u=j then
        p[u,j] :=p[u,j]*1/numer(W[u,j]);
else
        p[u,j] :=0
fu:
r[u,j] := lcoeff(numer(W([u,j]);
l*c[u,j];
        od;
od;
```

```
W0 :=multuply(r,p);
for u from 1 to cd do
        for j from 1 to rd do
        If u=j then
          gu[u,j] :=scalarmul(G,1);
        else
          gu[u,j] :=0;
        fu;
        od;
od;
ee :=multiply(l, Pc);
f :=add(p,ee);
pj := scalarmul(uu,s);
mo :=multiply(u,pj);
p0 :=add(p,m0);
q0 :=add(Q,m0);
for u from 1 to cd do
        for j from 1 to rd do
        uf u=j then
          r0[u,j] :=scalarmul(r, -1);
        else
          r0[u,j] :=0;
        fu;
        od;
od;
k0 :=add(f, r0);
gf:=multiply(q0,f);
kp:=scalarmul(k0, p0);
ru :=unverse(r);
h0 := multiply(ru0,hr0);
h :=add(pj, h0);
gy := scalarmul(g,p);
y :=unverse(Pc);
Wyv :=scalarmul(gy, y);
```

CONCLUSION

Further investigation would lead into scientific integration approach of model design, mathematical-software interpretation, developing of control algorithm in the function of the model, choosing construction solutions depending on required performances, developing of integral control and production, optimal control algorithm developing, and exchanging the information and knowledge with the other experts through the Internet.

REFERENCES

[1] L.R Tokashiki, T. Fujita. T Kagawa and W.Pan, Dynamic Characteristics of Pneumatic Cylinders Including pipes, 9th Bath International Fluid Power Workshop, September 1996, pp 1-14,

[2] Dj. Dihovicni, N. Nedic, Stability of Distributed Parameter Systems on Finite Space Interval, 32-end Yupiter Conference, Zlatibor 2006, pp 306-312

[3] Dj. Dihovicni, D.Lj. Debeljkovic, S.A.Milinkovic, V.P.Ilic, Program support for finite spectrum assignment method in multivariable time delay systems, Proceedings of the International Conference and Intelligent Technologies in Human Related Sciences, Leon, Spain, July 5-7, 1996, pp 399-401

[4] Edmond Richer, Yildirim Hurmuzlu, A High Performance Pneumatic Force Actuator System, ASME Journal of Dynamic Systems Measurement and Control, September 2000, pp 416-425.

[5] B. Novakovic, “Metode vodjenja tehnickih sistema (Book style),” Skolska knjiga, Zagreb 1989.

[6] Ernat- Dieter Gilles, “A Systeme mit verteilten Parametern, (Book style),” Wien 1973

[7] Manual of Hydraulics and Pneumatics, The Japan Hydraulics and Pneumatics Society, 1989

[8] Ikegami T. Fujita T. Kagawa T. Pneumatic cylinder with meter-out velocity control, 9th Symposium on Fluid Control Matsuayama, Japan 1994

[9] Brown FT. The Transient Response of Fluid Lines. J. of Basic Engineering, Trans of ASME, Series D, 84-4, 547/553, 1962

[10] Kagawa T Fujita T, Takeuchi M. Dynamic Response and Simulation Model of Pneumatic Pipe Systems, Proc 7th Bath International Fluid Power Workshop 1994

[11] N.N. ISO 6358, Pneumatic Fluid Power Components using compressible fluids Determination of flow rate characteristics, October 1989

[12] Sorli M., Almondo A., Time Domain Fluid Transmission Line Modelling Using a Passivity Preserving Rational Approximation of the Frequencz Dependent rational Matrix“, International Journal of Fluid Control, Volume 7, Number 1, 2006, pp 41-51

Session 7.

Oil and gas industry

THE TECHNO-ECONOMICAL AND ENVIROMENTAL RESULTS OF GASIFICATION IN THE SLAVONIA REGION (Croatia)

Milan Ivanović[1], Hrvoje Glavaš[2]
[1] PANON- think tank for strategic studies, Osijek, Croatia
[2] Josip Juraj Strossmayer University of Osijek, Faculty of Electrical Engineering, Osijek
e-mail: panon.institut@gmail.com

Abstract: The paper provides a brief historical overview of the beginning of the use of natural gas in Slavonia, construction of main and distribution pipelines, the number of consumers and consumption in this Croatian region. It implies a change of consumption structure of substitutional energy and increased share of natural gas in total energy consumption in the region. Especially indicated techno-economical and the environmental importance of the completion of the gasification of the region started 40 years ago and emphasized new opportunities for better energy supply with renewable energy sources.
Key words: gas distribution, gas pipelines, gas consumption, natural gas, Slavonia

INTRODUCTION

Usage of Natural gas in Slavonia started after the discovery of oil fields Beničanci (1968) and gas field Boksic-Lug. (1973), [1], [2]. Production (and usage) of natural gas in Croatia at the time was not developed, system of main gas pipelines were missing. Production of natural gas in that period is presented on Figure 1. which emphasizes the importance of the contribution of gas from the Slavonian field since 1972, and especially since 1975.

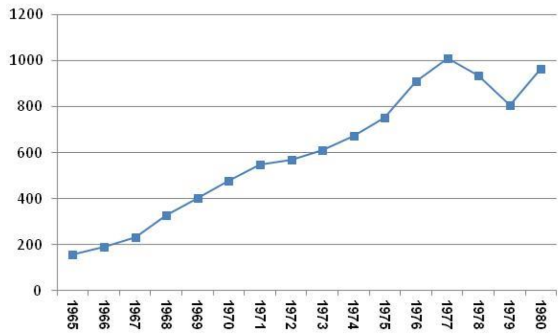


Figure 1. Natural gas production in Croatia from 1965 up to 1980 ($10^6 m^3$), [3]

Balance between production and consumption of natural gas in the first years of usage (1972-1985) in Slavonia is presented with data in Table 1.

Table 1. Production and consumption of natural gas in Slavonia from 1972 up to 1985 (106 m3); [2]

Year	Production	Consumption	Difference (delivered to in system)
1972	60.0	0.5	burned
1973	57.7	3.4	burned
1974	56.5	3.4	burned
1975	175.9	14.0	161.9
1976	312.4	74.4	236.0
1977	387.2	82.4	304.8
1978	358.1	106.4	251.7
1979	318.5	149.5	169.0
1980	507.2	152.4	354.8
1981	589.8	176.7	413.1
1982	485.7	213.6	272.1
1983	433.1	232.0	201.1
1984	442.7	239.4	203.3
1985	440.0	240.0	200.0

GASIFICATION PROCESS IN SLAVONIA

The first natural gas consumer in Slavonia the Brickyard "Slavonia" in Našice was connected to fields Beničanci in 1972. On this source from end of 1975 Kombinat "Belišće" is also connected. At that time the production and consumption of gas from fields Beničanci was balanced. At the end of 1975 on natural gas from the gas field Boksic Lug connected the brickyard " Graditelj" Sladojevci (P. Slatina), which is located next to the main gas pipeline Boksic - Zagreb.

The company "Elektroslavonia" Osijek join to the process of gasification in the region a few months after discovery of the gas field Boksic Lug thru: a) the construction of gas turbine power plant in Osijek, and b) the appointment (by local authorities) for holders of gasification activities at the regional level. By appointment for holders of gasification activities in the area of Slavonia and Baranja - in the summer of 1975 „Elektroslavonia“ established the Department for the development of gasification in 1979, "Gas distribution" grown-up and in 1981 became legal business entity. Gas turbine power plant in Osijek consumes natural gas from February 1976. In 1977 to the gas network of Osijek are connected: a brickyard "Opeka" and the Agricultural Institute for seed drier and for heating of residential buildings in the Settlement of solidarity. In Miholjac street gas network (10 km) was built and put into operation in 1977. At mid-year of same year pipeline for wood combine "Đurđenovac" was commissioned and the first section of (3 km) street pipeline in Nasice,[2] [5].

Experts of "Elektroslavonia" created in 1978. "The program of gasification areas Slavonia in the period 1979.- 1985" which was adopted during the 1979 Assembly of all 14 municipalities in the region and the Assembly of the Slavonia region. This program analyzed introduction of natural gas problems in 25 cities and municipal centers and have established priorities and stages of gasification of the region, [6]. Since that time, continuously expansion of regional gas pipelines gradually leads to the creation of Croatian gas-supply system.

The construction of main gas pipelines and distribution networks

The main gas pipeline was financed and constructed by "INA-Naftaplin", Zagreb (Fig.2) and distribution network was built by local investors (Fig.2). The development of gasification Slavonia describe data on: construction of gas networks, the number of consumers and consumption of natural gas in the region.

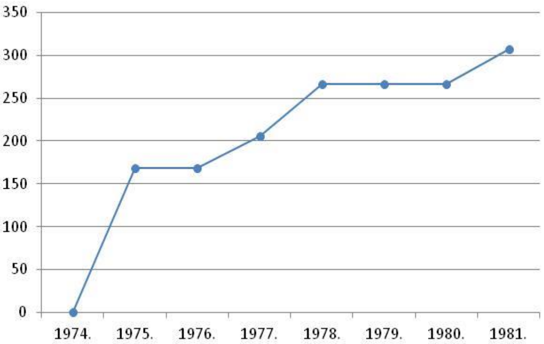


Figure 2. The length of main gas pipelines built in Slavonia from 1975 to 1981 (km) [7]

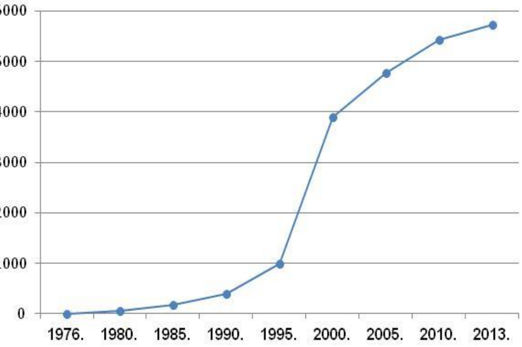


Figure 3. The length of distribution gas networks in Slavonia from 1976 to 2013 (km) [8]

The development of natural gas consumption

Number of natural gas consumers in the Slavonia region in the period from 1976 to 1991 is shown in Table 2. from which exponential growth of number of consumers in the industrial and utility organizations (service and public sector) and households can be seen. Connection of new consumers depended primarily on the amount of available natural gas, connection between local consumption with the main network, size of consumption and state of construction of locally funded distribution network.

Table 2. Number of consumers of natural gas in Slavonia from 1976 to 1991 [1] [4] [9]

Nº		1976	1977	1978	1979	1980	1981	1983	1985	1987	1989	1991
	Total	**2**	**386**	**812**	**1,380**	**2,186**	**3,218**	**5,383**	**6,672**	**8,372**	**15,473**	**20,093**
a	Ind. & comunall.	2	16	38	63	99	207	356	497	578	694	894
b	Households	0	370	774	1,317	2,087	3,011	5,017	6,175	7,794	14,749	19,219

Available quantities of natural gas were not sufficient at that time, and the "Program of gasification of Slavonia" did not achieve planned dynamics and capacities due to lack of gas consumption and distribution pipelines gas was directed to the existing large customers in other parts of the Croatia (Zagreb and surroundings). From a total of 14 Slavonian municipalities in 1991 gas used 9. Without access to gas were: Beli Manastir, Đakovo, Nova Gradiska, Vukovar and Županja. However, during period of time intensive work was done on the preparatory work for the installation of gas on their territories; for the municipality Nova Gradiska recorded potential gas consumption, and for municipality Beli. Manastir, Đakovo and Županja made the conceptual designs of connection to the gas system and the outcome of gas pipeline network in municipal centers with associated cost estimates, while in Vukovar was already made and detailed design of the main distribution pipeline. [1] [4] [9] [10]

In addition to natural gas consumption in Slavonia through distributors "Elektroslavonija" natural (free and water intake) gas used and the so-called direct consumers: it is a large industrial facilities to which the gas was delivered "INA - Naftaplin".[1]

Bringing the exploitation of oil and gas fields Ilača, Đeletovci and Privlaka enabled during 1984 continued construction of the gas network. About ten million m^3 of gas captured from these fields is spent (since 1986) in Vinkovci building materials industry "Dilj" and PIK Vinkovci (1987). However, this amount of gas is not just paying the annual needs "Dilj" and the gas network until 1991 did not spread to other consumers in Vinkovci.

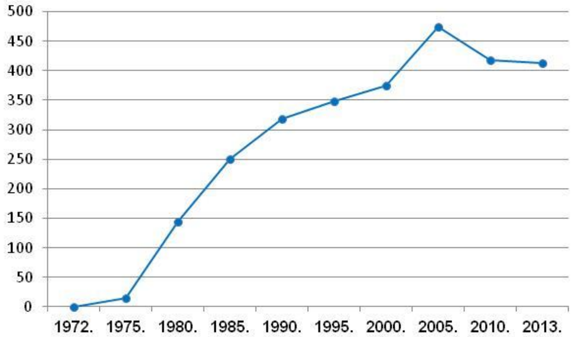


Figure 4. Total consumption of natural gas in Slavonia and Baranja 1996 - 2014th (10^6 m^3); [4] [8] [11] [12] [13]

From 1991 up to 1995 damage from military destruction to the gas system were repaired and process of gasification of the region of Slavonia was continued - so in the period from 1996 to 2014 was built about 4,000 km of new distribution pipelines. Natural gas consumption in Slavonia and Baranja has been increasing from 1996 until 2009 when - because of the economic downturn - industrial

[1] Direct consumers of natural gas were then: Kombinat Belišće, Cementara Našice, „Dilj“ Vinkovci, IGM „Slavonija“ - Našice, „Graditelj“ - P. Slatina, „Radnik“ - Donji Miholjac, PIK „Đuro Salaj“ - Valpovo, Holding „Đuro Đaković - Slavonski Brod, „Domin“ - Sl. Brod i PIK Vinkovci;

production was reduced, and in the public sector and household consumption is reduced or rationalized due influenced of the implementation of energy efficiency measures. Figure 5 shows the changes of natural gas consumption in the region of eastern Croatia.

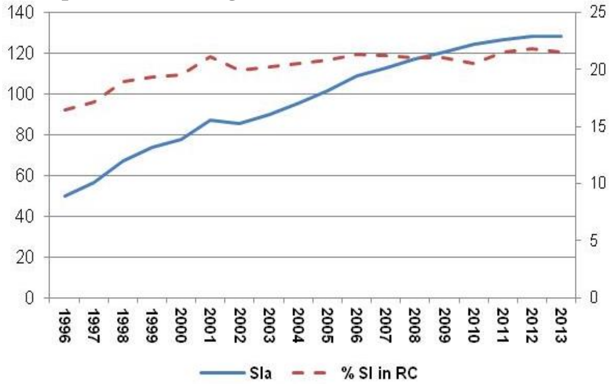


Figure 5. Number of households of natural gas consumers in Slavonia for period 1996-2014 (000); [4] [8] [11] [12] [13]

SIGNIFICANCE OF GASIFICATION IN ENERGY SUPPLY OF SLAVONIA

The advantages of natural gas in energy consumption

Significant advantages of natural gas in energy consumption compared to other energy sources can be classified in three groups:
a) Energy benefits of natural gas
b) Environmental benefits of natural gas
c) Economic advantages of natural gas

Benefits of using natural gas in relation to other energy forms can be seen in: [9], [12] and [13]. General conclusion is that usage of natural gas in the energy sector brings to the significant energy, environmental and economic benefits / advantages compared to the same amount of energy required from other energy forms, and ultimately increase social functionality of energy consumption, ie. lower energy costs per GDP.

Changes in the structure of energy consumption in Slavonia

Energy consumption of industry (households and communal consumption) in the region of Slavonia and Baranja in the early days of gasification essentially was based on coal, table 3 and table 4.

Table 3. Energy consumption of industry in the Slavonia area, [1] [2] [9]

Nº	Energy source	Unit	1972	1977	1978	1979
1.	Electricity	MWh	281,593	432,458	495,539	503532
2.	Anthracite	t	0	605	17	4
3.	Coke	t	16,679	21,168	23,847	22,273
4.	Stone coal	t	4,962	0	400	465
5.	Brown coal	t	247,201	174,445	169,495	145,310
6.	Lignite	t	59,381	44,904	50,614	41,315
7.	Fuel oils	t	19 ,690	22,525	27,034	25,629
8.	Oil fuel	t	75,503	93,212	111,967	112,520
9.	Natural gas	10^3m^3	500	84,830	104,527	129,141
10.	LPG	t	3,094	3,512	2,850	3,751
	Total: (recalculated)	10^3m^3	300,518	382,582	435,211	444,185

The development of the gas network and the use of natural gas almost kicked out coal from Slavonia. So at the beginning of XXI c. hundreds of thousands of tons of coal were replaced by natural gas. Natural gas reduced transportation costs, enable more efficient management of technological processes, raise living standards and community and reduced greenhouse gas emissions.

Table 4. Consumption of substitutable energy in Slavonia in 1982 [14]

Nº	Energy source	Unit	Consumption			
			Economy	Utility	Households	Total
1.	Coke	t	25,217	-	-	25,217
2.	Stone coal	t	159	-	-	159
3.	Brown coal	t	259,037	7,706	42,515	309,318
4.	Lignite	t	72,745	4,475	171,845	249,072
5.	Wood and wood wastes	t	115,491	11,715	405,581	532,785
6.	Fuel oils	t	23,800	36,400	27,800	88,000
7.	Oil fuel	t	82,629	20,040	-	102,669
8.	LPG	t	5,900	3,012	8,000	16,952
9.	Natural gas	10^3m^3	197,512	8,279	7,749	213,540

Biomass for heating

Heating is a sector that can benefit the most biomass. Abandoning the use of fossil fuels and switch to renewable energy is a worldwide trend. Development of technology enabled the cheap fuel from cellulose waste material by mechanical means, without the use of a binder. Briquette burns evenly with a little smoke and no fly ash (a 10 times less ash than coal). Combustion practical environmental friendly compared with other solid fuels, as it contains little sulfur (100 times less than coal). Manufacturing of briquettes is developed so that it can be applied to different materials - from the waste material in the industry to bulky cellulosic combustible residues grains from agricultural fields.
The use of biomass create new and maintain existing employment, increase local and regional economic activity, create additional income in agriculture, forestry and wood industry through the sale of biomass-fuel. In addition - outflow of funds for the purchase of fossil fuels is reduced and cash flows in the local community are established (investments - profit - taxes). The impact on employment and socio-economic aspects represents the biggest advantage of using biomass.
Our research of biomass potential from crop residues, fruit and grape growing Slavonia and Baranja [10] [16] determine the energy potential of this type biomass amounting to over 800,000 tons of oil equivalent per year (Fig. 6). So, this is a very significant potential that can be used for heating in households, but also in other sectors.

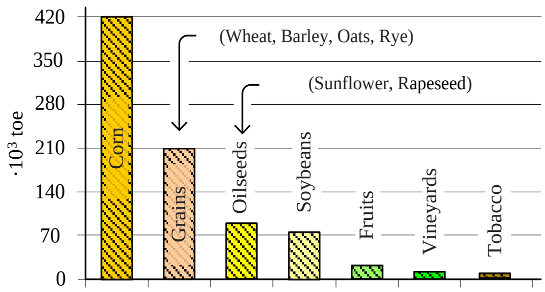


Figure 6. Total energy potential of biomass from crop residues, fruit and grape production in the area of Slavonia [16]

CONCLUSION

a) The process of gasification of Slavonia began with oil discovery in the region Beničanci (1968) and gas discovery in Boksic-Lug (1973). In the past 43 years a respectable system of main and distribution pipelines has built. Gas consumption includes all consumption sectors: industry, agriculture and services, public institutions, households, boiler and heating plants. Process of gasification of the region was stopped in 1991 and started again in 1995 after eliminating significant damage from sever military destruction. In the period from 1996 to 2014 development of gasification was continued with new dynamics, more than 4,000 km of new distribution pipelines was built, which allowed the gasification of a number of settlements in the region in all sectors of consumption from industry to households.

b) Natural gas consumption in Slavonia and Baranja has been increasing from 1996 until 2009 when - because of the economic downturn - industrial production was reduced, and in the public sector and household consumption is reduced or rationalized due influenced of the implementation of energy efficiency measures.

c) Our analysis of gasification of Slavonia and consumption of natural gas emphasize the economic and ecological importance of the introduction of natural gas as energy supply for region. Instead of several hundred thousand tons of coal a year Slavonia and Baranja is now using natural gas. gasification, reduced transportation costs of energy supply, enable more efficient management of technological processes, raise living standards and community and reduced greenhouse gas emissions.

d) Along with the good performance of gasification of the region paper emphasized strategic importance of utilization of large biomass potential for households and public institutions heating. The use of biomass for heating reduce imports of natural gas, reduce CO_2 emissions and contribute to local economic development through local employment and local cash flows.

REFERENCES

[1] Baličević, Ivan; Budimir, Jovo; Ivanović, Milan: Stanje i problemi energetike u Slavoniji i Baranji, Privreda, 8/1981. Osijek

[2] Grupa autora: Monografija „Slavonija '85.“; Privredna komora Slavonije i Baranje, Osijek,1986.

[3] Republički zavod za statistiku: Statistički godišnjak SR Hrvatske; 1972.;1974.;1976;1981.; Zagreb

[4] Baličević, Ivan: Opskrba prirodnim plinom istočne Hrvatske za vrijeme i nakon rata; II. forum „Dan energije u Hrvatskoj“, Zagreb, 12. 12. 1992.

[5] Ivanović, Milan: Strukturne promjene u energetskoj potrošnji u industriji slavonsko-baranjske regije u razdoblju 1978.-1984.; Privreda br.11, Osijek,1986.

[6] Grupa autora: Program plinifikacije područja ZO Osijek u razdoblju 1979.- 1985. godine, „Elektroslavonija“, Osijek, 1979

[7] Grupa autora: INA Naftaplin - 1952.-1982. INA Naftaplin, Zagreb, 1982.

[8] HSUP: Plinsko gospodarstvo Hrvatske '1998. (...) '2014. Hrvatska stručna udruga za plin, Zagreb, (www.hsup.hr/)

[9] Ivanović, Milan: Energetika na području Slavonije i Baranje do 2010. godine, ISSN 0350-9427 „Privreda”, Vol. 34 br. 5, str. 415–432; Osijek, 1990.

[10] Ivanović, Milan: Efikasnost korištenja energije, ISBN 953-6032-02-3, Elektrotehnički fakultet Osijek,1991

[11] Ivanović Milan: Znanost i regionalna energetika - Istraživanja o razvoju energetike i korištenju energije u Slavoniji. ISBN 953-6032-502-3; Elektrotehnički fakultet Osijek, 2006.

[12] Ivanović, Milan; Tonković, Zlatko; Glavaš, Hrvoje; Energetska učinkovitost potrošnje prirodnog plina u kućanstvima Osječko baranjske županije; PLIN 2011. Zbornik radova

[13] Ivanović, Milan; Glavaš, Hrvoje; Tonković, Zlatko; Energetska učinkovitost potrošnje prirodnog plina u industriji Slavonsko baranjske regije; PLIN 2012. Zbornik radova

[14] Ivanović, Milan; Beg, Stjepan: Izrada regionalne energetske bilance kao činilac racionalizacije potrošnje energije; VI. Savjetovanje o energiji, Opatija, 31.5.-2.6.1984. Zbornik, sv.2; str. 12.1.-12.11, Savez energetičara Jugoslavije

[15] Ivanović, M.; Glavaš, H.; Blažević, D.: Program učinkovitog korištenja energije u neposrednoj potrošnji za Osječko-baranjsku županiju 2012.-2014.; Elektrotehnicki fakultet Osijek, rujan 2011.

[16] Ivanović, Milan; Glavaš, Hrvoje; Potencijali i mogućnosti korištenja biomase iz ratarske, voćarske i vinogradarske proizvodnje u energetske svrhe na području regije Slavonija i Baranja; Elektrotehnički fakultet Osijek, 2012.

TREATMENT AND MITIGATION OF FOULING DEPOSIT

James G. Speight[1], Ljiljana Radovanovic[2]
[1]CD&W Inc., Laramie,Wyoming 82070, USA
[2]University of Novi Sad, Technical Faculty “Mihajlo Pupin”, Zrenjanin, Serbia
e-mail: jamessp@msn.com

Abstract: Fouling as it pertains to petroleum is deposit formation, encrustation, deposition, scaling, scale formation, slagging, and sludge formation) which has an adverse effect on operations. It is the accumulation of unwanted material within a processing unit or on the on solid surfaces of the unit to the detriment of function. For example, when it does occur during refinery operations, the major effects include (1) loss of heat transfer as indicated by charge outlet temperature decrease and pressure drop increase, (2) blocked process pipes, (3) under-deposit corrosion and pollution, (4) localized hot spots in reactors, all of which culminate in production losses and increased maintenance costs.
It is the purpose of this paper to present the types of fouling that occur in the petroleum industry and to describe the strategies to mitigate fouling (1) diagnosis, which involved determining the cause of fouling, (2) investigation, which involves determining the source of the fouling, (3) innovation, which involves a knowledge of the chemistry and physics of fouling and to interrupt and/or reduce the foulant precursors at each step, and (4) mitigation, which involves selection of the most appropriate method for the unit environment under which fouling is caused.
Key words: fouling, treatment, mitigation

INTRODUCTION

Fouling, as it pertains to petroleum refineries (Speight, 2000; Speight and Ozum, 2002; Parkash 2003; Hsu and Robinson, 2006; Gary et al., 2007; Speight, 2014a), is deposit formation, encrustation, deposition, scaling, scale formation, slagging, and sludge formation) which has an adverse effect on operations (Speight, 2015a). It is the accumulation of unwanted material within a processing unit or on the on solid surfaces of the unit to the detriment of function. For example, when it does occur during refinery operations, the major effects include (1) loss of heat transfer as indicated by charge outlet temperature decrease and pressure drop increase, (2) blocked process pipes, (3) under-deposit corrosion and pollution, (4) localized hot spots in reactors, all of which culminate in production losses and increased maintenance costs. In addition, the term *macrofouling* is often used to generally describe the blockage of tubes and pipes while, on the other hand microfouling is generally iced to describe scaling on the walls of tubes and pipes. Again, the outcome is a loss of efficiency and output to the refinery.

TREATMENT AND MITIGATION

If fouling cannot be prevented, it is necessary to make some provision for periodic removal of the foulant deposit. Some deposits can be removed by purely chemical means but the application of chemical cleaning techniques is a specialized process and, on the one hand, should be undertaken only when the characteristics of the foulant have been identified. Ob the other hand, since chemical cleaning ordinarily does not require removal of the equipment or disassembly of the piping, it is considered to be the most convenient of the cleaning techniques in those cases where it can be used.
However, it is only after the behavior of the feedstock under process conditions has been identified that a realistic fouling strategy can be developed. This will involve taking into account all of the possible scenarios with the (preferential) focus on one. It must be a multi-disciplinary approach for the recovery or refinery operations: engineers do not know oil of the chemistry involved and chemists do not know all of the engineering aspects involved. It is well worth while delving through related inter-and intra-company historical documents to determine what has been achieved in the past – the old adage or thought: *let us study history so that we will not make mistakes when repeating it* holds a lot of truth.

Treatment

As with other solids-depositing problems, prevention can be more cost effective than removal. Treatment is essentially the means by which foulant deposits can be removed from pipes and/or equipment to ensure the necessary fluid flow through the pipe or into the equipment. It is, therefore, essential the most appropriate method of control be put into place (McClaflin and Whitfill, 1984), remembering that each system may require a different or modified procedure for control.

Production Operations

The accumulation of wax constituents can be removed by methods that can be conveniently categorized as: (1) mechanical removal, (2) use of solvents, and (3) application of heat.
Mechanical methods such as scrapers, knives, and other tools are most commonly used to remove paraffin deposits in the wellbore. They can be very effective and are relatively inexpensive. The most common solvent used to remove paraffin from tubulars and the near-wellbore region is crude oil. Use of hot oil is the least expensive method and is commonly used on stripper wells to remove wax deposits. In the procedure, oil taken from stock-tank bottoms is heated to temperatures on the order of or in excess of 150^{o}C (300^{o}F) and is then injected or gravity fed into the tubing or annulus (more common). The high temperature induces solubilization of the paraffin deposits in the injected crude, which is then produced back to the surface. However, the use of hot oil, although successful for the removal of was deposits, can result in formation damage so the use of hot salt water to melt the wax may be preferred.
Solvents, which include crude oil, kerosene, diesel, and surfactant formulations that can solubilize the paraffin, have also been used. Organic solvents that consist of a blend of aromatics are usually used to remove mixtures of wax and asphaltene deposits. However, the cost of such treatments can be significantly higher than that of hot oil or water treatments. Paraffin inhibitors are compounds that consist of crystal modifiers that prevent the deposition of paraffin onto pipe surfaces. These surface-active materials retard paraffin deposition by inhibiting the adhesion of paraffin to sites on the tubing walls. Surfactants used in these applications include wetting agents, dispersants, and crystal modifiers. However, the inhibitors may be system specific and should be laboratory-tested for a specific crude oil to evaluate the effectiveness of the procedure (De Boer et al., 1995).
Dispersants, which are typically surfactants which may also keep the pipe surface water wet, act to keep the wax nuclei from agglomerating by minimizing the tendency of the wax constituents to adhere. As with scale prevention, a smooth surface tends to decrease wax adherence but the operational challenge problem is to maintain such a surface for an extended period of time. These inhibitors must be delivered into the crude oil at temperatures above the wax appearance temperature which need not cause a problem for surface equipment, but it could cause a problem for wellbore treatment, if the bottomhole temperatures are low. Various forms of erosion (erosion corrosion which can lead to corrosion fouling by the wax) are highly detrimental.
One method to apply to the wax-deposition prevention is the application of heat – electric heaters can be employed to raise the crude oil temperature as it enters the wellbore. The limitations are the maintenance costs of the heating system and the availability of electrical power. Maintaining a sufficiently high production level may also keep the upper-wellbore temperature above the wax appearance temperature. In addition, high flow rates tend to minimize wax adherence to metal surfaces because of the shearing action of the flowing fluid. Insulated pipelines are also an alternative to minimize, if not eliminate, the problem, but the cost can be prohibitive for long pipelines. Steam has also to remove wax that has caused severe plugging in tubulars. The lack of solubility of paraffin in hot water necessitates the use of surfactants with steam or hot water so that the melted wax can be removed. The chemical generation of heat has also been proposed as a method of melting wax deposits. One field-tested scheme uses the thermochemical process of reacting two specific nitrogen salt solutions, acidic ammonium chloride and sodium nitrite (Khalil et al., 1997). An organic solvent is included to keep the wax in solution after the system has cooled.
On the other hand, adjustments can be made in the production string that can minimize the likelihood of wax deposition. Such actions are designed to minimize the cooling of the crude oil as it is produced to the surface, which can be accomplished by designing pumping wells or tubing sizes and gas lift

systems that maximize the flow of oil to the surface and minimize the heat lost to the surrounding formations.

Removal of asphaltene deposits also requires the use of solvents or mechanical devices. However, the solvents used for asphaltene removal are quite different from those used for paraffins because asphaltenes are soluble in aromatic solvents, mixtures of aromatic solvents such as xylene have been used to remove asphaltene deposits. It should be noted here that the use of solvents such as diesel and kerosene are often inadequate and only enhance the deposition of foulant (in this case, asphaltene constituents) because such liquids contain primarily straight-chain alkanes and, as used, are prolonging or even inducing further e asphaltene precipitation.

Refinery Operations

The modern refinery which handles feedstock blends of a variety of crude oils, efficient operation of the desalter is a key element for processing different feedstocks. Continued operation of the desalter requires continuous monitoring of the unit. Conventional analytical methods can be used on a day-to-day basis to properly monitor desalter performance. However, the variability seen in analytical characteristics of the heavy feedstock blends requires increased vigilance in the frequency of desalter performance measurements, in order to respond quickly to unit disturbances.

For example, the level of filterable solids levels is a crucial monitoring parameter with many heavy feedstocks and measuring the filterable solids content must be a frequent (perhaps even a daily) occurrence. Back-up action plans must also be in place to respond to any upsets that might occur when solids levels are particularly high, or when the instability of the asphaltene (and resin) constituents occurs. Such events can be reduced if a laboratory program in in place that affords valuable information about the behavior (and fouling potential) of the blends.

Such a program would determine the compatibility of various feedstocks accepted by the refinery that would enhance prediction of the behavior of specific feedstock blends and prevent blending of incompatible feedstocks and to select the best set of desalting conditions and chemical treatment methods to handle various crude blends. The characteristics of many heavy feedstocks can include high solids levels, unstable asphaltene derivatives, non-extractable chlorides, and considerable variability in one or more of these parameters for a given grade of crude oil. Proper desalter operation, suitable chemical treatment programs and enhanced desalter monitoring are all keys to successful heavy feedstock processing.

It is necessary that the refinery have on-hand a developed mitigation strategy which should focus the best course of action. The will involve the development (and testing) of a procedure that has led to (1) determining the cause of refinery fouling, (2) tracing the precursors of fouling to the source, and (3) devising ways to stop the precursor formation, which lead to selecting viable alternatives for mitigation action. Following the identification and accessing the relative importance of the mechanism of fouling, a chemical treatment program can be designed to obtain maximum inhibition efficiency. Such a program could involve the use of (1) dispersants, corrosion inhibitors, or (3) metal coordinators.

Dispersants are designed to limit the particle size of solids in the system. Various dispersants have different efficacies, depending on the components to be dispersed (Schantz and Stephenson, 1991). Dispersant chemistries are available that address deposition problems such as coke particles, asphaltene precipitation, asphaltene association or aggregation, organic or inorganic deposition by preventing smaller particles from agglomerating to form larger particles which deposit more easily (Hammami et al., 2000; Gawrys, 2003; Gharfeh at al., 2004; Gholoum et al., 2003; Gholoum and Oskui, 2004; Karan et al., 2003; Udourioh et al., 2004). Similarly, dispersants also prevent the small particles from being attracted to already existing deposits in the system. *Corrosion inhibitors* are designed to minimize the contact between the metal surface and the corrosive fluid in order to minimize the formation and deposition of corrosion products in the system. A *metal coordinator* (*metal deactivator*) will modify the metal ions by complexing, thus reducing the catalytic activity of the metal, so that initiation of polymerization reactions is minimized.

Finally, the typical or preferred method of controlling fouling is to prevent the ingress of the fouling species into the system. However, knowing that no system is foolproof, chemical or mechanical cleaning processes for the removal of deposits and scales are recommended when fouling reaches the point of impacting the system performance or an onset of significant fouling-induced degradation (e.g., by corrosion). These processes comprise use of acids, complexing agents, cleaning with high-velocity water jets (*water lancing*), recirculating (*blasting*) with metal, sponge or other balls, or propelling offline mechanical bullet-type tube cleaners in pipes (*pigs*).

The use of pigs (*pigging*) is the primary mechanical method of removing deposits (especially wax deposits) from the internal walls of pipelines. The pig cuts the deposit from the pipe walls; a bypass can be set with a variable-flow pass, allowing the pig to prevent deposit buildup in front. Pig sizing can vary, and multiple pig runs with pigs of increasing size can be used. For subsea pigging, a looped flowline is required or a subsea pig launcher for a single flowline. The major uncertainty in this operation is the wax hardness as it is formed in the pipeline. Coiled tubing with the appropriate cutters at the end also can be used for deposit wax removal but while this method is appropriate for wellbore cleaning the disadvantage of this method for pipeline cleaning is the limited reach of the coiled tubing.

Various aromatic solvents can be used to dissolve the wax. These are generally not heated, relying solely on the solvency properties of the fluid. As with asphaltene dissolution, o-xylene has been one of the more effective solvents for waxes. Kerosene and diesel tend to be poor solvents. However, as with asphaltenes dissolution, one solvent does not necessarily work equally well on all wax deposits; an example of solvent screening procedures is given in (Ferworn, et al., 1997).

However, chemical cleaning raises the potential for environmental problems through the handling, application, storage and disposal of chemicals, mechanical cleaning operations can be an environmental friendly alternate solution. In some heat-transfer applications, mechanical mitigation with dynamic scraped-surface heat exchangers is an option. Also ultrasonic or abrasive cleaning methods are available for many specific applications.

Mitigation

There are several different techniques that can be employed for the removal of fouling. All such techniques require, however, system shutdown after a period of low efficiency operation. The chief techniques normally utilized are either chemical or mechanical cleaning, but other procedures may sometimes be employed for some specific applications such as ultrasonic cleaning, which is a more recent procedure, and abrasive cleaning.

Initially, in order to prevent or mitigate the impact of fouling, consideration should be given to the fouling potential of the feedstocks during plant design as well as during plant operation and maintenance. However, fouling mitigation and control is a very complex process and anticipating the likely extent of fouling problems to be encountered with changing feedstocks is a majordifficulty faced alike by designers and operators of heat exchangers. In most cases, it is often felt that a comprehensive modeling of the process should be in place, as long as the modeling program is supported by on-siteobservations of the equipment performance. Modeling, however, is not an easy process, and the different models that have been developed may be of limited value and application. In fact, in some cases, the results of a modeling program may be difficult to accept if the full characteristics of the feedstock are not taken into account.

Using the asphaltene fraction as the example, the asphaltene fraction is a complex mixture of chemical types than can be separated into sub-fractions by solvents or adsorbents (Bestougeff and Darmois, 1948; Bestougeff and Mouton, 1977; Bestougeff and Byramjee, 1994; Speight, 1994; Andersen et al., 1997; Speight, 2014a).

In order to remove entrained resin material, precipitation of the asphaltene constituents from benzene or toluene is often necessary (Speight et al., 1984; Ali et al., 1985) a practice that is often ignored.

Briefly, the resin constituents are soluble in the liquids that precipitate asphaltene constituents and are usually soluble in most organic liquids, except in the lower alcohols and acetone, but they are precipitated by liquid propane and liquid butanes. The resin constituents often co-precipitate with the asphaltene constituents in controlled propane deasphalting procedures, and the product, called *propane asphalt*, contains appreciable amounts of adsorbed resins and has the properties of a low-melting-point asphalt. The resin fraction is dark, semisolid or solid, and adhesive (Koots and Speight, 1975; Carnahan et al., 1999; Andersen and Speight, 2001). In addition, both the resin and asphaltene fractions are complex (Francisco and Speight. 1984; Speight, 1994, 2014a) and the molecular constituents behave differently under refinery conditions and this behavior cannot be represented by an average behavior patterns.

In addition to the complexity of the, the control and mitigation of fouling requires that it is necessary to consider the equipment operating conditions such as temperature range, fluid flow rate, as well as chemical composition and, where possible, make such changes as are required by the severity and type of the fouling. For example, some types of fouling can be minimized by using high flow velocity or turbulent flow but consideration must be given to the possibility of metal erosion as it may be necessary to restrict the flow velocity to values consistent with satisfactory tube life. This is especially true if the feedstock contains particles that are capable of causing pitting corrosion.

More generally, feedstock pre-cleaning has been successful in reducing fouling in various refinery systems. Prior treatment of feedstock includes caustic scrubbing, desalting, filtration or sedimentation of feed. Caustic scrubbing removes sulfur compounds and desalting reduces trace metal contamination and fouling. Furthermore, depending on system parameters, including fluid temperature, viscosity, pressure, solid concentration, particle size distribution, and fluid compatibility with the filter media, a filter can be designed to remove solid particles from the fluid. Filtration, however, can only remove the larger-sized particles leaving the smaller-sized particles in the feedstock (Mukherjee, 1996).

Finally, another aspect of fouling mitigation is the use of additives. As example, fouling control during visbreaking can be achieved using (one or a combination of) additives which can confer stability on the visbreaker feedstock, thus allowing the unit to be operated at increased severity. Additives also help control fouling phenomena within critical locations of the process (charge/resid preheat exchangers and column) and improve the stability of heavy fuel oil made from the visbreaker bottoms (visbreaker tar) (Agorreta et al., 2011). The additives (the composition of which will be feedstock dependent) can enable the unit to reach higher severities and thus higher conversions, while monitoring helps to determine and control the unit limits. If the limits are exceeded, fouling rates can be very high at typical additive injection rates.

Chemical Cleaning

A major component (often unrecognized by the casual observer is the operation and maintenance of heat exchangers. In some refineries, the large shell-and-tube heat exchangers are disassembled of both ends and internals, the tube bundle removed, and then transported to a cleaning facility for cleaning, reassembly, and tested for operational capability.

Chemical cleaning is one technique to achieve the objectives of cheaper and quicker maintenance on fouled heat exchangers. The process typically uses a chemical to dissolve some or all of the constituents of the solid foulant deposit. This type of cleaning is performed by flowing the solvent chemical through the exchanger (circulating or once-through) without the need for disassembly. Current attempts to chemically clean heat exchange equipment have shown some success but the benefits may not be proponed compared to the alternative method of dismantling and washing with a high pressure water jet. The usual method is to circulate hydrocarbon liquids such as naphtha, kerosene, or gas oil to dissolved or and wash away the deposit.

In other cases, and to protect the heat exchanger from foulant damage, the efforts or pro-active insofar as anti-foulants or chemical fouling inhibitors may be used to reduce fouling in many systems mainly by preventing reactions causing fouling. This procedure also minimizes (mitigates) the different steps of the fouling process such as crystallization, agglomeration of (unreacted or reacted) resin-type or asphaltene-type constituents. These anti-foulants include anti-oxidation additives used to inhibit oxidation reaction which change the polarity of the constituents thereby rendering the oxidation products incompatible with the body of the fluid (oxidative fouling, fouling by phase separation). In addition, metal coordinators which react with the trace metals, prevent these metals (or minerals) from fouling catalysts or accounting as nuclei which can promote fouling (Dubey and Waxman, 1995). Chemical removal of fouling material can also be achieved by use of weak acids and specific solvents or detergents. Chlorination may be used for the removal of carbonate deposits.

In cases where biofouling occurs, the foulant deposit may be removed by either chemical treatment or mechanical brushing processes. In chemical cleaning techniques biocides are employed such as chlorine, chlorine dioxide, bromine, ozone and surfactants. A more usual practice, however, is by

continuous or intermittent chlorination which is detrimental to the responsible organisms. Other cleaning techniques that can be effective in controlling biological fouling include thermal shock treatment by application of heat or de-slugging with steam or hot water.
In some units, chemical cleaning may be the only alternative if uniform or complete cleaning is required and for cleaning inaccessible areas. In particular, chemical cleaning is often the only options the shell side of a heat exchanger due to the inaccessibility of the foulant. On the other hand, the heat exchanger tubes can be mechanically cleaned provided that the tube pattern and pitch provide sufficient space and access to the inside of the bundle, and if mechanical cleaning is required for one of the fluids, the usual practice is to put that fluid in the tube side.
Another option is removal of the foulant and various strategies and devices for the continuous mitigation and reduction of fouling have been proposed. These strategies include periodic reversal of the flow direction for the removal of weakly adherent deposits, intermittent air injection and/or increasing wall shear stress by raising flow velocity or by increasing the tendency for turbulent flow.
In some heat-transfer applications, mechanical mitigation with dynamic scraped surface heat exchangers is an option. In self-cleaning fluidized-bed exchangers, a fluidized bed of particles can be used to control fouling on the outside or inside of tubular exchangers. The self- cleaning exchanger consists of a large number of parallel vertical tubes, in which small solid particles are kept in a fluidized condition by the velocity of the fluid. However, in order to remove the deposition, the particles will have a somewhat abrasive effect on the tube walls and caution is advised not to take this too far and encourage abrasive corrosion (Speight, 2014c).

Mechanical Cleaning

Mechanical cleaning is usually preferred over chemical cleaning because it can be a more environmentally-friendly alternative, whereas chemical cleaning raises various environmentally-related issues because of the need to handle the application, storage and disposal of chemicals (which must be assumed, unless proven otherwise, to be environmentally unfriendly). However, mechanical cleaning may damage the equipment, particularly tubes, and it does not produce a chemically clean surface.
Mechanical techniques for the removal of fouling include scraping and air bumping. Air bumping is a technique that involves the creation of slugs of air, thereby creating localized turbulence as slugs pass through the equipment. For tightly plugged tubes, drilling (often called *bulleting*) may be employed and for weakly adherent deposits application of high velocity water jets or a mixture of sand and water jets is often successful (Mukherjee, 1996).
Insofar as equipment deign may be considered as a mechanical operation, fouling mitigation and control require considerations in design and construction operations. The design options to be included are: (1) the inclusion of area of high turbulence, (2) the absence of stagnant areas, since the uniform fluid flow and smooth surfaces reduce fouling and the need for frequent cleaning. In addition, design of heat exchangers must be in place to diminish the effects of fouling on performance during in-service operation. The factors that need to be considered in the designs include (1) the extra surface required to ensure that the heat exchangers will meet process specifications up to shut-down for cleaning, (2) the additional pressure drop expected due to fouling, and (3) the choice of appropriate construction materials. The mechanical arrangements that may be necessary for fouling inspection or fouling removal and cleaning must also be included.
Appropriate choice of construction materials for heat transfer surfaces may be necessary to alleviate fouling problems. Surface coatings and treatment, ultraviolet, acoustic, electric and radiation treatment, may help to alleviate fouling problems. Similarly, if biofouling is expected or encountered, the use of non-ferrous high copper alloys, which are poisonous to some organisms, can discourage the settling of these organisms on the heat transfer surfaces. Alloys containing high percentages of copper (typically, <70% w/w) are effective in preventing or minimizing biological fouling. Realizing that copper is detrimental to aquatic life, there much be control over the discharge of copper-containing water rivers, lakes, and ocean waters.
Corrosion-type fouling can also be minimized by the choice of a construction material which does not readily corrode or produce voluminous deposits of corrosion products. A wide range of corrosion resistant materials based on stainless steel is now available to the heat exchanger manufacturer. Non-

corrosive materials such as titanium and nickel based alloys may be used sometimes to prevent corrosion. If one of the fluids is more corrosive, it may be convenient to send it through the tube side of a heat exchanger and the shell side can then be built with a lower-quality and cheaper material.

REFERENCES

[1] Agorreta, E., Angulo, C., Soriano, A., and Respini, M. 2011. Simulation Model Increases Visbreaker Conversion. Petroleum Technology Quarterly, Q1: 29-35.

[2] Andersen, S.I., Keul, A., and Stenby, E., 1997, Variation in Composition of the Sub-Fractions of Petroleum Asphaltene constituents. Petroleum Science and Technology, 15: 611-645.

[3] Bestougeff, M.A., and Darmois, R. 1948. Études des Asphaltènes.Comptes Rend. 227: 129.

[4] Bestougeff, M. A., and Mouton, Y. 1977. Bull. Liason Lab. Pont. Chaus.Special Volume.p. 79.

[5] Bestougeff, M.A., and Byramjee, R.J. 1994. Chemical Constitution of Asphaltene constituents. In: In: Asphaltene constituents and Asphalts. Developments in Petroleum Science.40. T.F. Yen and G.V. Chilingarian (Editors).Elsevier, Amsterdam, Netherlands.Chapter 3.

[6] De Boer, R.B., Leerlooyer, K., Eigner, M.R.P., Van Bergen A.R.D. 1995. Screening of Crude Oils for Asphalt Precipitation: Theory, Practice and the Selection of Inhibitors. SPE Production & Facilities, February, page 55-61.

[7] Dubey, S.T., and Waxman, M.H. 1995. Asphaltene Adsorption and Desorption from Mineral Surfaces. SPE Reserve. Eng. J., 389-395.

[8] Ferworn, K., Hammami, A., and Ellis, H. 1997. Control of Wax Deposition: An Experimental Investigation of Crystal Morphology and an Evaluation of Various Chemical Solvents. Proceedings. International Symposium on Oilfield Chemistry, Houston, February 18-21.

[9] Francisco, M.A., and Speight.J.G. 1984.Asphaltene Characterization by a Non-spectroscopic Method.Preprints. Div. Fuel. Chem. Am. Chem. Soc. 29(1): 36. Gawrys, K. Spiecker L., Matthew P., and Kilpatrick P.K. 2003.The Role of Asphaltene Solubility and Chemical Composition on Asphaltene Aggregation. Petroleum Science and Technology, 21(3,4): 461-489.

[10] Gharfeh, S., A. Yen, S. Asomaning, and D. Blumer.2004. Asphaltene Flocculation Onset Determinations for Heavy Crude Oil and Its Implications. Petroleum Science and Technology, 22(7,8): 1055-1075.

[11] Gholoum, E.F., Oskui, G.P., and Salman, M. 2003 Investigation of Asphaltene Onset Conditions for Kuwaiti Reservoirs. SPE Paper No. 81571. Proceedings.SPE 13th Middle East Oil Show Conference. Bahrain. April 5-8. Society of Petroleum Engineers, Richardson, Texas.

[12] Gholoum, E.F., and Oskui, G.P. 2004. Investigation of the Asphaltene Precipitation Process for Kuwaiti Reservoirs. Petroleum Science and Technology, 22(7,8): 1165-1185.

[13] Hammami, A., Phelps, H., and Little, T.M. 2000.Asphaltene Precipitation from Live Oils: An Experimental Investigation of the Onset Conditions and Reversibility. Energy Fuels 14, 14-18.

[14] Karan, K., Hammami, A., Flannery, M., and Stankiewicz, B.A. 2003.Evaluation of Asphaltene Instability and a Chemical Control during Production of Live Oils.Petroleum Science and Technology. 21(3,4): 629-645.

[15] Khalil, C.N., Rocha, N.O., and Silva, E.B. 1997. Detection of Formation Damage Associated to Paraffin in Reservoirs of the RecôncavoBaiano. Paper No. SPE-37238.Proceedings. International Symposium on Oilfield Chemistry, Houston, February 18-21.

[16] McClaflin, G.G. and Whitfill, D.L. 1984. Control of Paraffin Deposition in Production Operations.J Pet. Technol., 36(11): 1965-1970.

[17] Mukherjee, R. 1996. Conquer Heat Exchanger Fouling. Hydrocarbon Processing, January: 121-127.

[18] Schantz, S.S. and Stephenson, W.K. 1991. Asphaltene Deposition: Development and Application of Polymeric Asphaltene Dispersants. Paper No. SPE-22783.Proceedings.SPE Annual Technical Conference and Exhibition, Dallas, Texas. October 6-9.

[19] Speight, J.G. 1994. Chemical and Physical Studies of Petroleum Asphaltenes. In: Asphalts and Asphaltenes, 1. T.F. Yen and G.V. Chilingarian (Editors). Elsevier, Amsterdam, Netherlands.Chapter 2.

[20] Speight.J.G. 2014a.The Chemistry and Technology of Petroleum 5th Edition.CRC Press, Taylor & Francis Group, Boca Raton Florida.

[21] Speight, J.G. 2014c.Oil and Gas Corrosion Prevention.Gulf Professional Publishing, Elsevier, Oxford, United Kingdom.

[22] Udourioh, G.A., Ibezim-Ezeani, M.I, and Ofodile S.E. 2014.Comparative Investigation of Heavy Organics Precipitation from Crude Oil Using Binary Mixtures and Single n-Alkane Organic Solvents.Journal of Petroleum and Gas Exploration Research, 4(4) 53-59.

Session 8.

Computer technologies and engineering education

COMPUTER ANIMATIONS AS A TOOL FOR CREATION OF THE VISUAL IDENTITY OF THE COMPANY

Biljana Gemović[1], Nataša Subić[1]
[1] The Higher Education Technical School of Professional Studies in Novi Sad, Skolska 1, Serbia
e-mail: gemovic@vtsns.edu.rs

Abstract: This paper describes the use of computer animation for the creation of a Web site of the Higher Education Technical School of Professional Studies in Novi Sad.
The basis of Computer animation and examples of the realisation of the animation for the web site of the Higher Education Technical School of Professional Studies in Novi Sad realized through the subject Computer Animation at the degree programs in Web Design and Multimedia are being presented.
Key words: computer animation, visual identity, 2D animation

HISTORICAL DEVELOPMENT

With the advent of computers, the era of computer animations began. First timidly, rather tensely, poorly and shortly, and afterwards: better and better over time, truer, more natural, more convincing and even cheaper. Workstations, which until then were the only ones capable of producing computer animations, but too expensive, costing several thousands of dollars, made way for ordinary PCs and better software, so that every computer is better equipped at present. The hardware structure of today's computers is made of graphic processor, which with a little larger RAM can render fast and high quality computer animation.
The first to appear were small home computers such as "Commodore 64", "Atari", and especially "Amiga" which with programs: "Videoscape", "Deluxe Paint" and "Real 3D" were carriers of the pioneering work in computer animation.
Unlike classical animation, computer animation is more complex and more complicated, and therefore more expensive, but it is more relevantly applicable, more effective and better in all areas. By computer animation we can conjure anything we wish, so this form of animation is represented in construction, school education, art, science, military industry and there is almost no area where it is not needed.
The main difference between the classic animation-animated film and computer one is that with classical animation the images are hand-drawn, arranged and recorded by camera, while with computer animation the characters-objects are modeled and textures are "pasted" to a "wire" model and, by command, the animation objects are moved-animated.

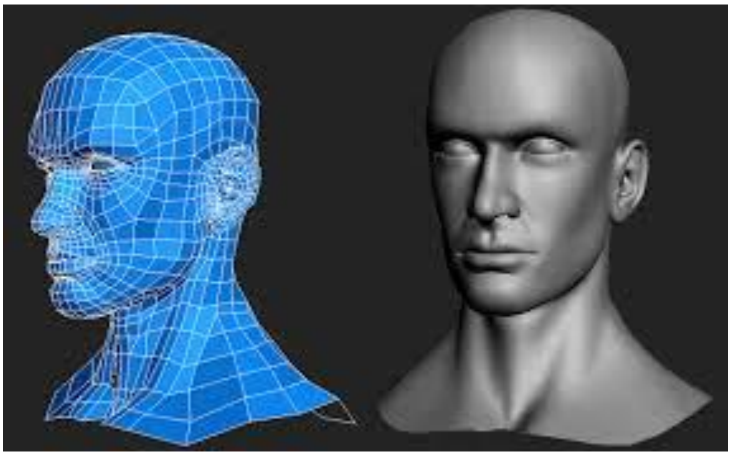


Figure 1. Example of wire model and models with texture

Today there are very powerful programs for this: "Maya" or "3D Max" real professional programs used in the film industry. It is natural that the work on computer animation is not easy at all, it requires knowledge of the program for animation. A good cartoonist does not have to be a good animator as well, while a poor cartoonist can be a great animator. Whether working on classical or computer animation, a good animator must have a keen sense of time - timing, and the "plasticity of movement" should not even be emphasized. Without this, no one can be a good animator.

COMPUTER ANIMATION - CONTEMPORARY TREND

Three-dimensional or 3D image is a 2D projection of a computer model of a real physical object. In fact, it does not even has to be an object of the kind that already exists. Realistic 3D modeling is often used to visualize a non-existent character or environment, or an object that is impossible to be photographed from a certain angle (for example, the dark side of the Moon). It is also used to delineate or change the characteristics of such an object. After this and a number of other processes (rendering, for example) we get a 3D computer graphic which, according to one of the definitions, represents a three-dimensional virtual representation of objects recorded in the computer, for the purpose of performing the calculating and generating of the image. 3D graphics is compared with a photograph or sculpting, while the 2D graphics is similar to drawing.

On the other hand, we have a 3D animation, whose development in recent years has been very rapid, along with the development of computer technology. In fact, 3D animation has become very "trendy" also here, judging by the commercials that we see on television: from a little cow who is riding a bicycle, via tomato rolling over the refrigerator, to workers who handle the coffee in the warehouse.

3D graphics and animation are today mainly represented in the modeling of objects, buildings and landscapes, creating 3D video effects, integration of 3D objects with "live" recording, as well as in the development of the film industry. Among the available programmes and packages that can realize them, only a few is widely accepted. The most popular is the programme of the *Maya* company *Alias Wavefront.* It is used in the largest studios for visual effects, in combination with *Pixar*'s programme of *RenderMan*. The following is the 3*D Studio Max* of the company *Discreet*, created as a successor to the programme 3D Studio, nowadays widespread in the computer games industry and in the "cottage industry". There is also Hashov *Animation: Master*, originally made for the Amigaof the late eighties of the past century, and today it is also compatible with Windows and Mac OS platforms. The next is *SoftImage XSI* of a Canadian company Avid. Once a major competitor to *Maya* programme, it lost the quality and popularity since it was bought by Microsoft in 1994.

VISUAL IDENTITY OF THE COMPANY

Each organization has its own identity. Identity is a set of features by which the organization is identified and presented on the market. In addition to the identity, the organisation also has an image - what kind of impression the brand makes to an individual. In this part of advertising where a product, service or idea is directed to the audience by means of advertising, the most important role has the **visual identity.**

The visual identity is the primary means of identification, collection of visual and physical characteristics of a product, service, idea or company, which distinguish it from other products, services, ideas or companies in the market and thus represent their visual uniqueness. The main function of the visual identity is to enable companies to acquire, improve and maintain competitive advantage.

It is now generally accepted that the identity of a corporation represents its overall communication embodied in the culture, beliefs, attitudes, employees, management, strategy, and presented by its visual identity. In business terms, the visual identity is synonymous with companies' image.

THE USE OF COMPUTERS IN ANIMATION

Computers can very efficiently be used for animation. The programme Premiere contains command Stop Frame in Capture menu, by which we can register only one frame, which is in the format of the image, or a part of AVI or QuickTime sequences. This also applies to the programme Flash by which

we can make the animations frame-by-frame, animations by changing the movement or changing the shape and the like. We can also change the drawings, change the positions of the model and then re-register the change. Frames that do not fit can be deleted. All registered frames can later be exported as a special video recording, or as a group of images which can be processed in the known image processing programme - Photoshop. When creating animations it is very convenient to use computers, because the images can easily be changed, saved, deleted and added in a sequence. With classical animation it is not necessary to use the camera.
Some of the techniques in work are:
Digital foils (layers) - which in the programmes for processing of images and programmes for creation of animations are also called layers, enable that a static image gets represented as a separate part. The process of making animations by technique of working with layers is such that you first create a background layer of the first frame. Then, on separate layers parts to be moved are created. When the first frame is saved, the following is made in a way that the exhisting background is copied and other layers are added to which changes required for the movement ie animation have been made[1].
Sprite animation - is based on moving objects, called *sprite* animations. Complex movement can be obtained by assigning several images to one sprite. This type of animation is suitable for the simulation of walking. The values that change when moving of the objects are calculated by computer. Movement and look of the animated object in this kind of animation can be controlled by the user. Also, sprite animation can be useful for different types of simulation as well as for the presentations on the Internet [1].
Animation using key frames - In classical animation, the key frames are drawn by the main animators. They provide posts and details on the protagonists. Mostly, the key frames are made for characteristic posts, the so-called extremes - the beginning or end of walking, the utmost top or bottom position with the fall and so on. [1]. In creating computer animation, drawing of inter-frames is called interpolation - the calculation of the value of the function which is between the set points. Computer programs are very good at interpolation, enabling numerical calculation of values. Numerical calculation of vector images is much more simple than the calculation of the bitmapped images. A variety of transformations that can be interpolarised - rotation, scaling, reflection, etc. may be applied to vector forms. The movement may be composed of such transformations derived from the processing of numerical inter-frames [1].

ONE OF THE PROGRAMMES FOR THE CREATION OF THE ANIMATION – ADOBE FLASH

Flash dominates as a tool for designing Web presentations. At one point it got all the tools:

- tools for creating graphics, tools for animation of these graphics,
- tools for creating interface elements and interactivity, as well as
- tools for creating HTML required to display graphics, animation and interface elements as a Web page in a reader.

With each new generation of Flash, Adobe has been adding new functions and features. They have expanded the possibilities of the program as machines for animation and interactivity creators, while retaining the ease of use of drawing tools, as well as additional animations and programming options of Adobe Flash CS5 which represents a powerful tool for the creation of creative content for print, Web, interactive applications, video, audio or mobile devices. In the new version of Flash already existing features have been improved and new ones that greatly facilitate the creation of multimedia animations have been added. What distinguishes Flash CS5 from the previous versions are the following innovations:

- The new file format files .sfl (Flash CS5 Uncompressed Document) - enables work on the same file by several persons,
- The ability to create applications for iPhone,
- Using online services,
- Using Flash Catalyst CS5 -for designing interactive contents without writing a code and Flash Builder -for the development of gorgeous applications for the Internet.

CREATION OF 2D ANIMATION IN ADOBE FLASH PROGRAMME

One of the possibilities for creating 2D animation is in the programme Adobe Flash. Such an animation is recorded as a .fla document. It can be exported in various other extensions suitable for a further use. For the animation of any length, that simoultaneously also has a sound; the best quality is achieved by using a video format. QuickTime has become the standard for video format. This video format can be changed, combined with other clips, and it can even have effects added. Operating environment is set up to create graphical elements and their animation in time. The elements of the environment are:

- Stage
- Timeline
- Box of tools
- Library of symbols
- Panels

Through these elements, the environment of Adobe Flash programme allows an easy and practical training of students, as well as the application of their theoretical knowledge in the field of 2D animation.
On the examples in Figure 2, the applications of the above techniques and their consolidation into a final animation which makes the example of the visual identity of the School, may be seen.
By combining the techniques of layers, key frames in which images previously processed in Adobe Photoshop programme were inserted, by connecting frames via the command *Motion tween* in Adobe Flash programme, the final product is created.

Figure 2. Examples of 2D computer animation made in Adobe Flash

All these are simple techniques that the students of the Higher Education Technical School of Professional Studies in Novi Sad had mastered, who being consolidated with the idea of creating a visual identity of the School through the form of displaying in 2D animation, presented their experience and integrated knowledge.
In the further development of the web site of the Higher Education Technical School of Professional Studies, the implementation of some of these works of students in order to make the website more attractive to students and motivate new generations to give their contribution to the creative work in computer animation is planned.

CONCLUSION

Animation represents the illusion of movement created by a sequence of moving still images. Flash uses standard techniques for animation which create the illusion of movement and provide the possibility to synchronize animations with several graphic elements, sounds and video recordings.
The paper presents the application of 2D animations created by using programme Adobe Flash and its use in the review of the visual identity of the Higher Education Technical School of Professional Studies.
It is difficult to talk about the development of any technology. The general opinion of the people in this area is that in the computer animation is the future (as well as in anything that is closely related to the development of computer technology), and that it is up to us to use it as best as possible. We should use technology instead of allowing it to use us, as it may happen in the computer world.

REFERENCES

[1] http://book.tsp.edu.rs, Computer graphics and multimedia IT
[2] B. Vigs Henningsen, Faculty of Education and Social Studies: Animation as a Learning Tool, 2013
[3] D. Vasilic, Possible use of flash animation in teaching Renewable Energy Sources, Graduate Paper, Technical Faculty Cacak, 2012
[4] N. Subić, B. Gemović, T. Krunić, Application of computer animation in order to safely work on your PC, INFOTEH-JAHORINA Vol. 12, March 2013.
[5] V. Pavlović, S. Dragićević, Ž. Papić, Methodology of application applets and animation in teaching technical and IT education, 3. Conference "Science and Informatics in Education", Collection of works, p. 475-482, Technical Faculty Cacak, 7 - 9 May 2010
[6] D. Cvetković, Z. Kostić – Univerzitet Singidunum, Belgrade, 2009
[7] J. Gonzalez – Flash professional, Kompjuter biblioteka 2007.

SOCIAL NETWORKS IN E EDUCATION

Nenad Kojić[1], Natalija Vugdelija[1], Radica Kojić[2]
[1]ICT College of vocational studies, Zdravka Čelara 16, Beograd
[2]Primary school “Oslobodioci Beograda”, Preradovićeva 2, Beograd
e-mail: nenad.kojic@ict.edu.rs

Abstract: One of the most frequent methods of education for professionals in ICT industry is e-learning, but e-learning platforms are not often shared among users and can be inflexible for users. While using educational material, students are often not provided with teachers’ assistance, or other interactions. This leads to creation of an environment, which is not interesting for students. Important characteristics of online social networks, such as content sharing, collaboration and criticism catalyze the formation of active and stimulating environment for students. Through an experiment at ICT College, we show that main social networks can be used as support for e-learning platforms, helping students to achieve better learning results.
Key words: Social networks, e-learning, innovations.

INTRODUCTION

Continual education is very important in modern world, especially for topics like information and communication technologies, which have rapid increase. Learning is an activity with the aim of improving knowledge, skills and abilities. It is a synthesis of formal, non-formal and informal knowledge (unplanned teaching and learning through everyday activities). Formal education implies the existence of an educational system that is organized and managed by the state / government institutions, regardless of whether the state is the founder or founders are private individuals. Under the informal education we mean the kind of learning that is developed and cultivated outside the formal, and obligatory institutional education, and within alternative structures where youth organizations are the main holders.
Taking part in these activities, young people acquire knowledge and develop different kinds of skills such as: communication skills, leadership and management skills, intellectual understanding, as well as successfully addressing various types of problems.
Humans are social beings by nature. So it was before the creation of the Internet, when they hung out in the communes, built contacts and friendships on the streets, public places, markets, showrooms. Today, nothing has changed except that most of us have a virtual place that represents our identity from the analog world, and in the network with others their communication dynamics creates virtual sphere. Some authors present a new method for sentiment analysis in Facebook[1].
The rapid technological development, as well as the expansion of the Internet in the last 20 years has influenced almost every aspect of human society. Easy and quick exchange of information, and the availability of large amount of data on the global network have made the Internet an indispensable factor for development of each segment of society[2]. Under the influence of new technologies and the opportunities offered by the global networks, there has been a change in communication between people. Existing forms of communication have received their electronic equivalents. Social media is a general term that covers a large number of platforms and applications that allow users to communicate, collaborate and share information. Implies the existence of web tools that can be easily accessed, which are simple to use, which can be used or generate specific information like on-line response or reaction to what is happening in the life of an individual[3].
Social networks are important because they build relationships and connections in different contexts. People engage socially, share information, ask for validation and recognition of themselves in the group, the approval of their own status and it happens in a very easy way. The present form of social networks provides numerous options, concerning the choice of communication practices, community involvement in the network space, privacy and information control. Most social networks permit the formation of groups of specific interests. Some can be used for professional development, some for educational purposes, and some for both[4]. In such environment the process of learning and education go through changes and they adapt to emerging trends[5].

Along with the development of new web services and tools are examined opportunities and ways in which to implement social media into a system of knowledge transfer. There are some questions which kind of media would be most effective and gave the best results in the learning process, how to adjust and get closer to end users[6], [7].

POSSIBILITIES OF SOCIAL MEDIA IN TEACHING PROCESS

Technology quality and interaction with instructor would affect learners' perceived satisfaction[8]. New trends in education indicate a significantly changed role of teachers and students in relation to the existing one in our schools. The teachers should play the role of coordinator of activities and not just the speaker, while students should be active participants in the classroom and not just observers. This means that students need to acquire certain skills themselves, under expert supervision and guidance of teachers. Thus developing creativity, ability to solve problems independently and respect the individuality of students. The group as well as individual work should be forced, which is very conducive to the application of information technology[9].

Human - Computer interaction is not just a mechanical relationship. In this relationship hypothetical interface mediates, "interface between computer technology and cognitive psychology," which is a complex interaction between human cognition and computing environment[10]. The student develops skills that can be applied in solving the real problem situations[11].

Pedagogical basis for the application of the tools of information and communication technologies (ICTs) until now were already established pedagogical theories, most of them famous constructivist theory of learning, because many other theories were based on them taking the good examples of learning on the Net, which combines the powers of the Internet to provide a wealth of information from various sources, to be the medium for the publication of opinions and information of every person and the ability to use the Internet as a communication channel to create a collaborative learning groups. Many educators, however, find that these pedagogical theories were emerged before the advent of the "digital age" and that they don't correspond to the changed profile of the student in terms of learning and communication technology[12].

Learning is possible through constant construction of "network " society, capacity to learn is more important than actual knowledge, the starting point of learning is not the content but the contact with people, groups, nodes in learning, knowledge given by a group rather than an individual - this is the basis of which a new educational theory called connectivism is built[13].

The reasons and ways to use social networks in e-learning education are manifold. Social media encompass a variety of tools, applications and platforms that can provide a wealth of resources and materials to support all courses[14].

It is possible to use all the resources offered by social networks: discussion forums, discussion, comparison, collaboration, exchange of views and networking[15].

Facebook as a social network service for a short and efficient exchange of information can have a positive impact of education stakeholders because of some good features. Learning is great fun and the students have a better idea of what is really going on in courses. Some papers aims to determine the attitudes and perceptions of students parcipating in Facebook-enhanced higer education courses[16]. Some authors try to identify student's perception on using Facebook as learning tool. They used activity theory as a conteptual framework and analytical tool to demonstrate studets' perceptions in using Facebook[17].

THE USE OF SOCIAL NETWORK IN ICT COLLEGE IN BELGRADE

In ICT College in Belgrade, during the first trimester of the school year 2014-2015, social networks were used in "New generation networks" course, on Electronic communications programs of study. There were 39 students who attended the course on that year. They could be part of the pre-exam requirements through voluntary reporting of seminar work, if they wanted to (37 students participate in that activity).

Topics seminar papers were prepared in advance and included various aspects of New generation networks. Students on this occasion divided into smaller groups of up to a maximum of 5 students per group, with each group assigned a special topic seminar paper. Students have chosen social network

Facebook as a platform for the exchange of the necessary materials to create essays on a given topic, such as pdf files, videos and pictures and it was an innovation in the development of coursework. On that occasion, professor created a special account that was closed in character, exclusively for students who have chosen this subject.

Students had the opportunity to use all available tools that Facebook offers. First they themselves within each group organize and share tasks with each other, in order to successfully do this essay. Students are themselves inflict the pace of seminar work depending on other commitments that were in this trimester. They periodically as necessary to include the Facebook on a daily basis or less frequently, asking pieces of work that have been done up to that point, leave comments, put like on successfully made parts of the work of other students, ask questions, give suggestions to each other and exhibited the existing problems. The task of the students was to design a presentation with appropriate video presentation of about 10 minutes in which to explain to their colleagues whatever they were doing and what they learned. Their individual exposure consisted of a whole, which means that the students in the group depend on each other. Their presentations were supposed to be connected so that other colleagues can eventually gain a complete overview of the subject with which a particular group dealt with.

The idea was to develop students' ability to manage information through teaching them the seminar paper. In the process of realization of the task, students should find the relevant resources and based on them to process a given topic.

The role of the professor was to the three pre-defined terms throughout the week (Monday, Wednesday and Friday from 21h to 22h) advertised on Facebook and to guide students toward successful completion. Professor could with appropriate comments in a timely revised each group, put additional materials if needed and include on chat or through video streaming to communicate with students in order to resolve any problems.

In order to realize the objectives more successfully, utilizing the benefits of social networks, which are important when working in groups that have the same goal[18]. Some results indicated that reputation would affect knowledge sharing attitude of Groups members and sense of self-worth would directly and indirectly (through subjective norm) affect the attitude[19].

Students during the preparation of seminar papers, found various sources of information and decided whether it was worth and appropriate material. Students in the group familiar with the material, evaluate the accuracy and relevance of Web resources, and trying to adequately describe the categorization and writing additional notes, which is in some way a qualitative analysis of resources, forcing students to analyze, classify and map the facts. Sharing this information with other students in the group is a constructive process[20]. Students use a variety of tools to make the appropriate video material, which should be accompanied by their presentation of seminar paper, which other students can see and comment on.

RESULTS AND DISCUSSION

Upon completion of the course, survey was realized among students that was supposed to show the extent to which the use of the social network Facebook helps mastering the seminar work. 35 (94.59%) of surveyed students are actively using the Internet connection.

Among students surveyed, 37 of them (100%) had previously opened an account on social networking sites, 35 (94.59%) on Facebook, 19 (51.35%) on Twitter, while 17 of them (45.95%) has opened an account on Facebook and on Twitter. It was the first time that all of the students use some social network.

When asked how often students were active on social networking site Facebook in order to prepare their seminar works, 6 of them said 1 hour each day, 2 students said every day for 2 hours, 14 students were active every other day for 1 hour, 4 students participated three times each week for 2 hours in the same terms when it included a presence of professor, 11 students were actively once a week for 1 hour, see figure 1.

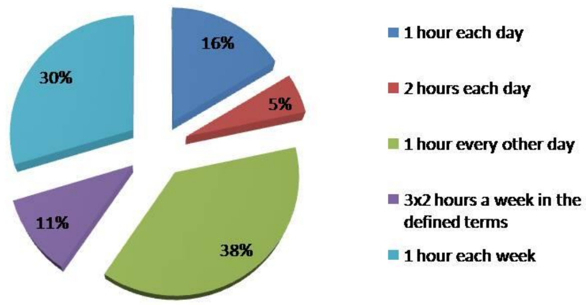


Figure 1. Student activity on the social network Facebook during the preparation of seminar papers

The next question was to what purpose students used social network Twitter in the seminar work. Student answers are shown in Figure 2. 8 student used the social network exclusively for the exchange of material, whether it was pdf files, images or video materials, 14 students in addition to the exchange of materials, leaved comments on the pieces of work that their colleagues within the group had made and raised on the site.

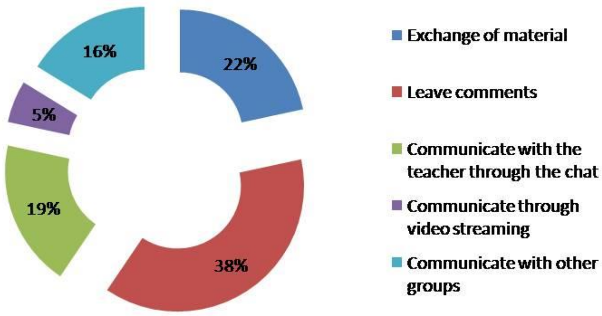


Figure 2. Student activities on Facebook

7 students has regularly communicated with the professor, 2 students used the live video streaming communication. 6 students have commented and actively communicate with students from other groups with whom they shared experiences.
Students have used the basic and additional tools that Facebook social network provides.
When asked how long students need to complete their seminar work, most of them completed their seminar works between 2 and 5 days, ses Figure 3.

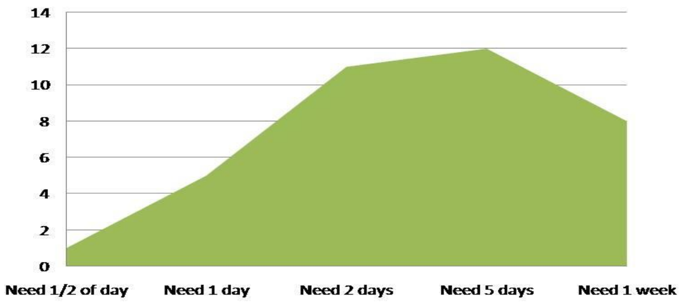


Figure 3. Time required to complete a seminar work

The final question was whether students were satisfied with using social network Facebook in educational environment for acquiring necessary knowledge: 30 students said yes, 1 student was not satisfied, while 6 students were partially satisfied. Results of using Facebook as an online learning

environment for from 2008 to 2011 highlighted many positive outcomes and recommendations for the future use of Facebook as a learning tool[21]. Among students in a Public University in Kuala Lumpur, there was investigate the level of acceptance of using Facebook as a learning tool based on triangulation of quantitative and qualitative methods[22].
It has been shown that social networks can be useful to use in the classroom, although not easy to measure profits arising from the use thereof. Even with the high information exchanging frequency made bu Facebook notification features, it’s still hard to increase students’ interaction without course interaction strategy[23]. They have little experience with collaborative learning, and learning on the Internet before the High School, but they are aware of how important it is continuous learning throughout life, although pay insufficient attention to the importance of the successful functioning of the group.
Let us mention some disadvantages in the use of social networks:
The need for a constant connection to the Internet
In our conditions, a big commitment of professors as mentors groups is required to coordinate their work.
Lack of knowledge of foreign languages makes it difficult for students found understanding of Web content.
There is a number of students who work without getting much of what does the rest of the group.
One of the main advantages of this type of work is visibly greater motivation and active participation of students in the learning process. Almost all the students who participated in this project were positively enthusiastic about the use of social media in the classroom, as Facebook and Twitter, which has already been used and is still used for instructional purposes in ICT College in Belgrade[24].
Based on the survey conducted after this course it is clear that the use of the social network Facebook had a positive impact on the implementation of teaching. It has been noticed and satisfaction of students who used Facebook for the first time in the learning process, and the fact that they have tried almost all the basic and additional tools quickly and efficiently.

CONCLUSIONS

The advantage of using social media in education is that it can provide surprisingly useful educational tool, giving students and teachers a simple way to communicate that goes beyond working hours and classrooms. Educational institutions must be in step with the rapid development of information and communication technologies in order to understand the way in which social networks affect children and young people, recognize their strengths and weaknesses, and thus educate students about safe participation in an online environment.
E-learning is not a replacement for traditional learning, but rather complement, the upgrade of the traditional learning. It should complement and facilitate the learning and information gathering. Promotes the progress of students so that they develop a need to learn something new, to explore the different areas, learn to handle large volumes of information that are available to them later on, at some point in your business or private life usage, to improve and to find their place in the business world that will suit their abilities, interests and needs.
Example of use of the social network Facebook to continue showing good results, both in increasing students' motivation to actively participate in the learning process, as well as the quality of the knowledge acquired. Students positively accept participation on Facebook for educational purposes only and similar innovations and want it to become common practice.

REFERENCES

[1] Ortigosa, A., Martín, J. M., Carro, R. M., Sentiment analysis in Facebook and its application to e-learning, Computers in Human Behavior, Vol.31, pp.527-541, 2014.
[2] Nakamura, L., Chow-White, P. (Eds.), Race after the Internet, Routledge, 2013.
[3] Tarik, M., Karim, A., The use of web 2.0 innovations on education and training, Education, Vol. 2, No. 5, pp. 183-187, 2012.

[4] Garrison, D. R., E-learning in the 21st century: A framework for research and practice, Taylor & Francis, 2011.
[5] Bates, A. T., *Technology, e-learning and distance education*, Routledge, 2005.
[6] Clark, R. C., Mayer, R. E., E-learning and the science of instruction: Proven guidelines for consumers and designers of multimedia learning, John Wiley & Sons, 2011.
[7] Dalsgaard, C., Social software: E-learning beyond learning management systems, European Journal of Open, Distance and E-Learning, 2006.
[8] Chou, C. H., Pi, S. M., The effectiveness of Facebook Groups for E-Learning', International Journal of Information and Education Technology, Vol.5, No.7, pp.477-82, 2015.
[9] Vugdelija, N., Milanović, K., Folksonomija u nastavi, VIII International Scientific – Professional Symposium INFOTEH®-JAHORINA, 2009.
[10] Kumar, D. D., Helgeson, S. L. White, A. L., Computer technology-cognitive psychology interface and science performance assessment. Educational Technology Research and Development, Vol. 42, No. 4, pp. 6-16, 1994.
[11] Helgeson, S. L., Kumar, D. D., A review of educational technology in science assessment. Journal of Computers in Mathematics and Science Teaching, Vol.12, No.3/4, pp. 227-243, 1993.
[12] Prenksy, M., Digital Natives, Digital Immigrants: Do they really think differently? On the Horizon, NCB University Press, Vol. 6, December, 2001.
[13] Siemens, G., Connectivism: A learning theory for the digital age, International Journal of Instructional Technology and Distance Learning, Vol. 2, No.1, 2005.
[14] Janjić, I., Miličić, R., Spariosu, L., Facebook as a medium for exchanging information among students, The 8th International Scientific Conference "eLearning and Software for Education", Bucharest, 2012.
[15] Oki, E., Rojas-Cessa, R., Tatipamula, M.,Vogt, C., Advanced internet protocols, services, and applications, John Wiley & Sons, 2012 .
[16] Duncan, D. G.,Barczyk, C. C., Facebook in the university classroom: Do students perceive that it enhances community of practice and sense of community. International Journal of Business and Social Science, Vol. 4, No.3, pp.1-14, 2013.
[17] Goh, W. W., Hong, J. L., Goh, K. S., Students' behavior and perception of using Facebook as a learning tool. In Computer Science & Education (ICCSE), pp.731-736, 2013.
[18] Vugdelija, N., Savić, A. Knežević, N., Korišćenje socijalnih medija za online aktivaciju budućih studenata, XI International Scientific – Professional Symposium INFOTEH®-JAHORINA, 2012.
[19] Pi, S. M., Chou, C. H., Liao, H. L., A study of Facebook Groups members' knowledge sharing. Computers in Human Behavior, Vol. 29, No.5, pp.1971-1979, 2013.
[20] Grosseck, G., The role of DEL.ICIO.US in education: Crating significant learning experiences, Infomedia: The international journal on informatics and new media in education, Sombor, 2008
[21] McCarthy, J., Learning in Facebook: First year tertiary student reflections from 2008 to 2011, Australasian Journal of Educational Technology, Vol.29, No.3, 2013.
[22] Mali, A. S., Hassan, S. S. S., Students' Acceptance Using Facebook as a Learning Tool: A Case Study, International Journal of Asian Social Science, Vol.3, No.9, pp.2019-2025, 2013.
[23] Lee, W. B., Teng, C. W., Hsueh, N. L., Li, Y. H., Using Facebook to Better Engage College Students in Learning, In Advances in Intelligent Systems and Applications, Vol. 1, pp. 403-408, 2013.
[24] Radosavljevic, V., Vugdelija, N., Društvene mreže kao web 2.0 alat u nastavnom procesu, XII International Scientific – Professional Symposium INFOTEH®-JAHORINA, 2013.
[25] Kent, M., Leaver, T. (Eds.)., An Education in Facebook?: Higher Education and the World's Largest Social Network, Routledge, 2014.

LEARNING MATHEMATICS USING MULTIMEDIA IN ENGINEERING EDUCATION

Marina Milovanović[1], Jasmina Perišić [1], Svetlana Vukotić[1], Marina Bugarčić[1], Ljiljana Radovanović[2], Marko Ristić[3]
[1]Faculty of Entrepreneurial Business of the UNION "Nikola Tesla" University, Belgrade, Serbia,
[2]University of Novi Sad, Technical Faculty "Mihajlo Pupin", Đure Đakovica bb, Zrenjanin, Serbia,
[3]Institute Goša, 35, Milana Rakića str., Belgrade, Serbia,
e-mail: milovanovicmm@gmail.com

Abstract: Multimedia learning of mathematics encompasses learning from instructional material, both traditional (paper, blackboard, etc.) and computer based (graphs, animations, etc.), that combine words and pictures in the domain of mathematics. This paper has both a theoretical and practical orientation. On one hand, our aim was to present how students of two engineering faculties learn with multimedia and how to design multimedia environments that promote learning. In this study we present some of the most important principles of multimedia learning and design. We provide a definition of multimedia learning and multimedia presentation, present distinction between two approaches to multimedia design. On the other hand, the practical aim of this paper, based on the above factors of multimedia learning and design, was to prepare multimedia lessons (selected examples) in mathematics and present them to the students of two engineering faculties: the Faculty of Architecture and the Faculty of Civil Construction Management of the UNION "Nikola Tesla" University, Belgrade, Serbia. The main information source in multimedia lectures was software created in Macromedia Flash, with definitions, theorems, examples, tasks as well as in traditional lectures but with emphasized visualisation possibilities, animations, illustrations etc. Besides that, survey carried out at the end of this research clearly showed that students were highly interested in this way of learning.
Key words: Multimedia learning, Multimedia presentation, Multimedia design, Multimedia example in mathematics, Engineering education

INTRODUCTION

Multimedia learning and multimedia presentation

Multimedia refers to the presentation of instructional material using both words and pictures [5, 6]. According to this, **words** – or the verbal form of the instructional material – can be either *printed* or *spoken*, while **pictures** – or the pictorial form of instructional material – can encompass *static* graphics, such as illustrations, graphs, maps, or *dynamics* graphics, such as animation or video. ***Multimedia instructional message*** or *multimedia instructional presentation* involving words and pictures that is intended to faster learning.
The case of multimedia uses the premise that learners can better understand an explanation when it is presented in words and pictures than when it is presented in words alone.
Cognitive theory, emphasises the importance of visualisation in learning, too. The principle of this theory is that there are two qualitatively different methods of learning: verbal and visual. Words, on the one hand, enable the description of the matter even from the abstract aspect, while pictures, on the other hand, enable the visual experience of the matter. These two methods of learning are complementary and not exclusive, so the overall conclusion is that the students should combine text and picture and, in this way, learn more readily, which is actually the final objective.
During past few years, multimedia learning has become very important and interesting topic in the field of teaching methodology. Mayer's and Atkinson's researches resulted in establishing the basic principles of multimedia learning and design, which were confirmed in our paper, too [1, 5, 6]. Nowadays, usage of different kinds of multimedia is largely included in the education because it allows the wider spectrum of possibilities in teaching and learning. Visualisation is very useful in the process of explaining mathematical ideas, abstract terms, theorems, problems, etc.

Modern methods in multimedia approach to learning include the whole range of different possibilities applicable in mathematics lectures for different levels of education and with different levels of interactivity [4], [7], [8], [9], [10].
This paper has both a theoretical and practical orientation. On one hand, our aim was to present how students of two engineering faculties learn with multimedia and how to design multimedia environments that promote learning.

Two metaphors of multimedia design and learning

According to the information acquisition view, learning involves adding information to one's memory. This view entails assumptions about nature of the learner, the nature of the teacher, and the goals of multimedia presentation. First, learning is based on information, an objective item, that can be moved from place to place (such as from the computer screen to the human mind). Second, the learner's job is to receive information; thus, the learner is a passive being who takes in information from the outside and stores it in memory. Third, the teacher's job, or, in the case, the multimedia designer's job, is to present information. Fourth, the goal of multimedia is to delivery information as efficiently as possible. The underlying metaphor is that multimedia is a delivery system. According to this metaphor multimedia is a vehicle for efficiently delivering information to the learner. Table 1 summarizes the differences between the two views of multimedia learning with explanations of starting points, goals and issues [5], [6].

Table 1. Two views of multimedia design

Design approach	*Starting point*	*Goal*	*Issues*
Technology-centered	Capabilities of multimedia technology	Provide access of information	How can we used cutting-edge technology in design multimedia presentation?
Learner-centered	How the human mind works	Aid human cognition	How can we adapt multimedia technology to aid human cognition?

The goal of multimedia is to help people develop an understanding of important aspects of the presented material. Table 2 summarizes the differences between the two views of multimedia learning [5], [6]. In this paper we favour a knowledge instruction because it offers a more useful conception of learning when the goal is to help people to understand and to be able to use what they learned.

Table 2. Two metaphors of multimedia learning

Metaphor	*Definition*	*Content*	*Learning*	*Teacher*	*Goal of multimedia*
Information acquisition	Adding information to memory	Information	Passive information receiver	Information provider	Deliver information; act as a delivery vehicle
Knowledge construction	Building a coherent mental structure	Knowledge	Active sense maker	Cognitive guide	Provide cognitive guidance; act as a helpful communicator

Design of multimedia lessons

Multimedia learning can be effective only if multimedia lessons are adequately designed.
For many years, the investigations on multimedia learning and their results have been rather unconnected and without a concrete effect on learning. But, today there are numerous studies that define clearly the factors affecting the multimedia learning and the principles of successful multimedia design.

There are twelve factors, each with a theoretical background, which can be defined as variable. The student's style is an independent variable, whilst learning is the dependent variable. Other elements are visual knowledge, audio knowledge, student control, attention, working memory, motivation, cognitive engagement, intelligence, transfer and length of data storage. All the factors are interrelated and have a complex effect on multimedia learning and design [3].

Some of the most significant principles of multimedia learning were established by [5], [6]:

1) *Multimedia Principle*: Students learn better from words and pictures than from words alone.
2) *Spatial Contiguity Principle*: Students learn better when corresponding words and pictures are presented near rather than far from each other on the page screen.
3) *Temporal Contiguity Principle*: Students learn better when corresponding words and pictures are presented simultaneously rather than successively.
4) *Coherence Principle*: Students learn better when extraneous words, pictures, and sounds are excluded rather than included.
5) *Modality Principle*: Students learn better from animation and narration than from animation and on-screen text.
6) *Redundancy Principle*: Students learn better from animation and narration than from animation, narration, and on-screen text.
7) *Individual Differences Principle*: Design effects are stronger for low-knowledge learners than for high- knowledge learners and for high-spatial learners rather than for low-spatial learners.

Table 3 shows in short the factors that make a multimedia presentation effective.

Table 3. Factors affecting the success of a multimedia presentation

CHARACTERISTICS	***Description***
Multimedia	Present the text and picture together
Unity	Present the text and picture close to each other
Conciseness	Exclude the superfluous text and picture
Structure	Include textual and visual explanations of the presented, step by step

MATERIAL AND METHODS

Aim and questions of the research

The practical aim of this paper, was based on the above factors of multimedia learning and design, to prepare *multimedia lessons on definite integral* and to present one *selected example.* Thanks to the experiences of some previous researches and results, some of the questions during this research were:

1. What do students think about multimedia lectures and presentations? Do they prefer this or traditional way and why?
2. Do students think it is easier to understand and learn the matter individually and during the classes by multimedia lectures?

Participants of the Research

The research was conducted on two groups of 50 students of the first year: at the Faculty of the Architecture (25 students) and the Faculty of Civil Construction Management (25 students) of the UNION University, Belgrade, Serbia.

Multimedia learning of mathematics. Example

Lectures in both groups of students included exactly the same information on the finite integrals, i.e. axioms, theorems, examples and tasks like on the traditional class of math, but the main information source was software created in Macromedia Flash 10.0, which is proven to be very successful and illustrative for creating multimedia applications in mathematics lectures [2]. Our multimedia lecturing material was created in accordance with methodical approach, i.e. cognitive theory of multimedia learning [5], [6], as well as with principles of multimedia teaching and design based on researches in the field of teaching mathematics [1]. This material includes large number of dynamic and graphic presentations of definitions, theorems, characteristics, examples and tests from the area of the finite integrals based on step-by-step method with accent on visualisation. Important quality of making one's own multimedia lectures is possibility of creating combination of traditional lecture and multimedia support in those areas we have mentioned as the 'weak links' (finite integral definition, area, volume, etc.).

Example: *Determining the volume of body by revolving.*
Task: Determine the volume of a right circular cone with altitude h and base radius r.
Solution: The cone is generated by revolving the right-angled triangle OAB around the Ox-axis, which can be clearly shown by using animation (Figure 1).
Animation parts which represents the given task and the triangle revolution.

Numerical solution of given problem is also shown step-by-step, by using animation.
Slant height of the cone is defined as line:

$$y = x \cdot tg\alpha = \frac{r}{h} \cdot x$$

Therefore, according to the formula for calculus of volume:

$$V = \pi \int_0^h \left(\frac{r}{h} \cdot x\right)^2 dx = \frac{\pi \cdot r^2}{h^2} \cdot \frac{x^3}{3} \Bigg|_0^h = \frac{\pi \cdot h \cdot r^2}{3}.$$

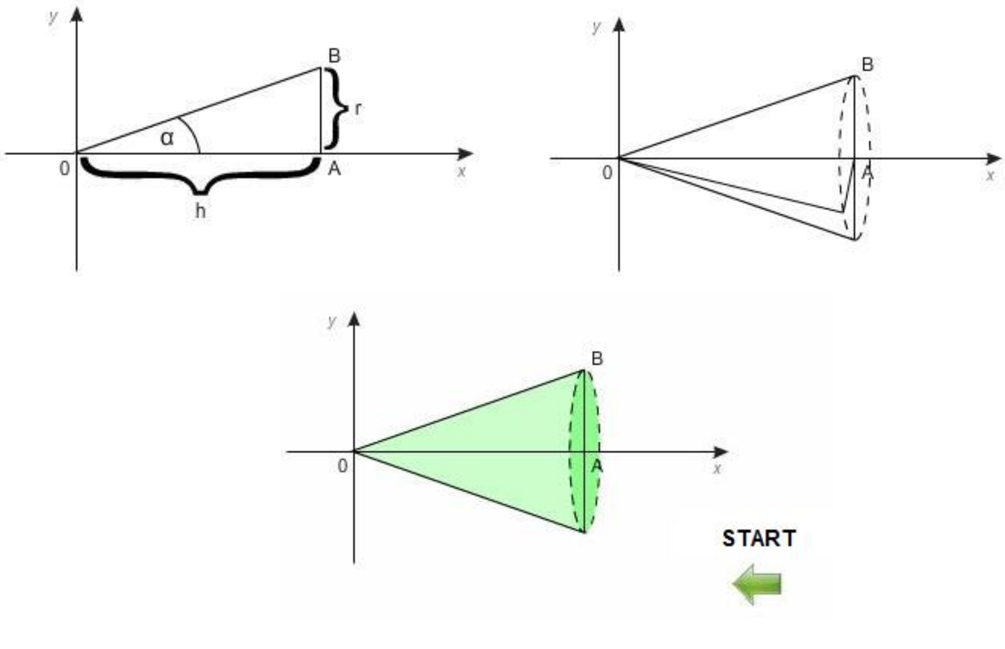


Figure 1. Example: Determining the volume of body by revolving

RESULTS

In summary, multimedia learning helps to promote a better understanding of how to foster meaningful learning through the integration of words and pictures (printed or spoken text and illustrations, graphs, maps, animation or video).

When asked whether they prefer classical or multimedia way of learning, 12% (3 students) answered classical and 82% (22 students) answered multimedia at the Faculty of Architecture, while at the Faculty of Civil Construction Management 20% (5 students) answered classical and 80% (20 students) answered multimedia, explaining it with the following reasons:

- ‘It is much easier to see and understand some things, and much easier to comprehend with the help of step-by-step animation.’
- ‘Much more interesting and easier to follow, in opposite to traditional monotonous lectures with formulas and static graphs.’
- ‘More interesting and easier to see, understand and remember.’
- ‘I understand it much better this way and I would like to have similar lectures in other subjects, too.’
- ‘This enables me to learn faster and easier and to understand mathematical problems which demand visualisation.’
- ‘Quite interesting, although classical lectures can be interesting – depending on teacher.’

When asked whether it was easier for them to learn, understand and solve problems after having lectures and individual work with multimedia approach, students answered the question as shown in Figure 2:

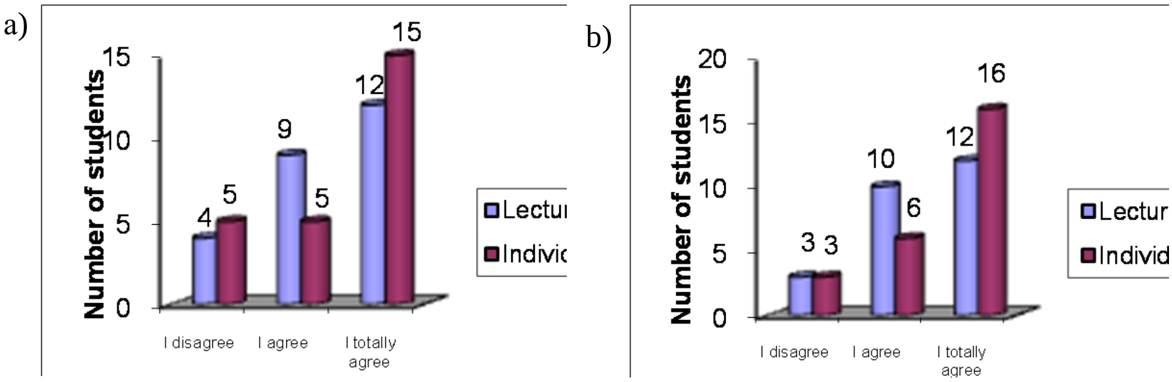


Figure 2. Students’ answers to the question: *Should PC be used in lecturing and learning mathematics? (a – Architecture, b – Civil Construction Management)*

DISCUSSION AND CONCLUSIONS

During past few years, multimedia learning has become very important and interesting topic in the field of teaching methodology. Mayer’s and Atkinson’s researches resulted in establishing the basic principles of multimedia learning and design, which were confirmed in our research, too [1], [5], [6]. Our multimedia lessons about the finite integrals, created in accordance with these principles, proved to be successful. According to the students’ reactions, highly understandable animations from multimedia lessons are the best proof that a picture is worth a thousand words. Their remark, and consequently one of this research’s conclusions, was that there should be much more of this kind of lessons in education, made – of course – in accordance with certain rules and created in the right way.

Many researches in different scientific fields, including mathematics, have proven that multimedia makes learning process much easier.

Researches on learning the finite integrals with software packages Mathematica and GeoGebra have shown that students who had used PC in learning process had higher scores on tests [4]. Although this research was conducted with different multimedia teaching tools for the same subject – the finite

integral as one of the most important areas in mathematical analyses – our results only proved the universality of multimedia in the process of teaching mathematics.
Wishart's research included analyses of comments on how much multimedia approach affects teaching and learning processes [13]. Teachers emphasized that multimedia lectures have made their work easier and have proved to be motivating for students, while students said that multimedia lessons, in comparison with traditional methods, have offered better visual idea about the topic. As shown in Graph 2, great number of them insisted that multimedia tools enabled easier understanding, learning and implementation of knowledge.
Their remark, and consequently one of this research's conclusions, was that there should be more multimedia lessons, i.e. that multimedia is an important aspect of teaching and learning process.
One of this research's conclusions can be put in the way one student did it during the survey (by answering the question: What is multimedia learning): 'Multimedia learning is use of multimedia as an addition to the traditional way of learning. Multimedia enables us to have better understanding of many mathematical problems and to experiment with them.'

ACKNOWLEDGMENTS

This paper is the result of research within the project TR 34028, which is financially supported by Ministry of Education, Science and Technological Development of Serbia, Messer Tehnogas and PD TE – KO Kostolac.

REFERENCES

[1] Atkinson, R., Multimedia Learning of Mathematics in The Cambridge handbook of Multimedia Learning, R. Mayer, Cambridge University Press, pp. 393-408, 2005.
[2] Bakhoum, E., Animating an equation: a guide to using FLASH in mathematics education, International Journal of Mathematical Education in Science and Technology. Taylor & Francis, Vol. 39(5), pp. 637-655, 2008.
[3] Hede, A., Integrated Model of Multimedia Effects on Learning. Journal of Educational Multimedia and Hypermedia Vol. 11(2), pp. 177-191, 2002.
[4] Herceg, D., Herceg, Đ., The definite integral and computer, The teaching of mathematics, Vol. 12(1), pp.33-44, 2009.
[5] Mayer, R., Multimedia learning (2nd ed.), Cambridge University Press, New York, 2009.
[6] Mayer, R., Cognitive theory of multimedia learning, The Cambridge handbook of multimedia learning (2nd ed.), Cambridge University Press, Cambridge, pp. 43–71, 2014.
[7] Миловановић, М., Интерактивна мултимедија, Докторска дисертација, Природно математички факултет, Универзитет у Крагујевцу, 2014.
[8] Milovanović, M., Takaci, Đ., Milajic, A., Multimedia approach in teaching mathematics – examples of interactive lessons from mathematical analysis and geometry in Interactive Multimedia, InTech, Croatia, ISBN: 979-953-307-623-1, 2011.
[9] Takači, Đ., Stojković, R., Radovanovic, J., The influence of computer on examining trigonometric functions, Teaching Mathematics and Computer Science, Debrecen, Hungary, Vol. 6(1), pp. 111-123, 2008.
[10] Takači Đ. and Pešić, D., The Continuity of Functions in Mathematical Education-Visualization method, Nastava matematike (The Teaching of Mathematics), Belgrade, Vol. 49(3-4), 2004.
[11] Tall, D., A graphical to integration and fundamental theorem, Mathematics teaching, Vol. 113, pp. 48-51, 1986.
[12] Tall, D.O., West, B., Graphic insight into calculus and differential equations, In A. G. Howson, and J. Kahane, The Influence of Computers and Informatics on Mathematics and its Teaching, ICMI Study Series. Strasbourg: Cambridge University Press. pp. 107-119, 1986.
[13] Wishart, J., Students' and Teachers' Perceptions of Motivation and Learning Through the Use in Schools of Multimedia Encyclopedias on CD-ROM, Journal of Educational Multimedia and Hypermedia Vol. 9(4), pp. 331-345,), 2000.

STATE SPACE MODELING FROM FEM MODEL USING BALANCED REDUCTION

Aleksandar Košarac[1], Milan Zeljković[2], Cvijetin Mlađenović[2], Aleksandar Živković[2], Saša Prodanović[1]
[1]University of East Sarajevo, Faculty of Mechanical Engineering
[2]University of Novi Sad, Technical Faculty of Technical Sciences
e-mail: akosarac@gmail.com

Abstract: This paper shows discretized model of main spindle working unit module obtained by ANSYS software. Based on the conducted modal analysis for first ten bending modes within frequency range from 0 to 10 kHz, main shapes and natural frequency (eigenfrequency) have been determined, and modal matrix was formed. Obtained results were afterwards used to determine model dynamic behavior in the state space using MATLAB. State space model was further used as reference one for modal reduction whereby balanced reduction method was applied. Frequency response of full model (all oscillatory modes) and reduced model for direct FRF and cross FRF are presented through Bode diagram. Reliability of the model is verified by comparing the impulse response of full model and reduced model in time domain.
Key words: natural frequencies, model order reduction, modal reduction, balanced reduction, state space

INTRODUCTION

Considering that finite element models may have high degree of freedom, MKE analysis may require more time, especially causing problems when analysis are often repeated during the designing process. Therefore, methods simplifying finite elements models are developed in the manner that the most important characteristics of the original dynamic system are included.
Model reduction is a method used to decrease the time required for simulation when finite element model are used and to obtain simplified model preserving at the same time wanted dynamic characteristics of original system. The task of the model reduction is to replace mathematical model of the system or of the process with the one (model) that is far smaller from the original one but still provides input/output relationships of the system or of the process. This paper is the sequel of the research presented in [4] which showed modal analysis by FEM on the working unit module main spindle, where based on the first ten bending vibration modes modal matrix was determined through analyzing displacement in ten measuring points. Afterwards, modal reduction was conducted whereby two methods of ranking of individual mode contribution to the overall frequency response were used, as follows: dc gain and peak gain. Which one, out of two, will be used, depends entirely whether damping ratio ζ has unique value or different value for individual modes. This paper presents SISO model (Single Input Single Output) wherein, for mode ranking, dc gain and peak gain might be used, but also other methods, such as balanced reduction. Hereby concepts of controllability and observability will be used for modes ranking. The method of reducing models "balanced reduction" is applied, using both ranking concepts simultaneously. In this paper FEM modal analysis results and balanced reduction technique were used to obtain a low order state space model of main spindle. Response of the main spindle due to excitation will be obtained using reduced number of vibration modes.
Equivalent dynamic model of main spindle with measurement points analyzed in this paper, is shown in figure 1, while discretized model of main spindle is shown in figure 2.

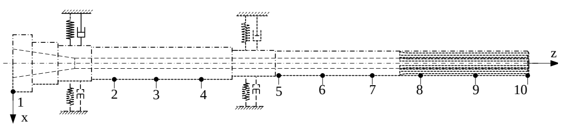


Figure. 1. Equivalent dynamic model of spindle with measurement points [4]

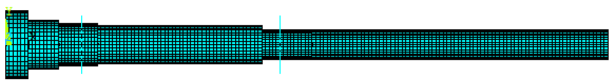


Figure. 2. Discretized model of main spindle [4]

Main spindle is supported by the two sets of angular contact ceramic ball bearings in front, SKF S7011

CD/HCP4A and two sets of angular contact ceramic ball bearings in rear SKF 7008 CD/HCP4A, installed back to back [5], [6]. SOLID186 a higher order 3-D 20-node solid element is used to simulate main spindle, and spring damper element COMBIN 14 is applied to simulate the elastic support of the two set of bearings. Eighteen elements were set along the circumferential direction of the spindle on each set of bearing, simulating rolling elements. Since the inertial force and the thermal expansion of bearing elements affects the balls, an uneven distribution of contact forces appears and an uneven contact angle change occurs. The consequence of the aforementioned is the uneven distribution in bearing stiffness, depending on the position of the ball [6]. Values of bearing stiffness depending on the preload and main spindle dimension in are provided in [4], [5]. The first ten eigenvalues for bending motion of main spindle extracted using Block-Lanczos method are shown in Table 1.

Table 1. Eigenvalues for bending motion of main spindle, Hz

f_1	f_2	f_3	f_4	f_5	f_6	f_7	f_8	f_9	f_{10}
154,37	926,92	1641	2351,8	2538,1	4533,1	5687,4	6972,7	8228,9	9637,4

CONTROLABILITY AND OBSERVABILITY

There are different definitions of controllability and observability for state space system, described by equation (1).

$$\begin{aligned} \dot{x} &= Ax + Bu \\ y &= Cx \end{aligned} \tag{1}$$

According to [3] system is controllable if there is an input „u“ that can move the system from some arbitrary state x_1 to another arbitrary state x_2 in a finite time. Similar, the system is observable if the initial state x_0 of a system can be inferred from knowledge of the input u and the output y over a finite time (0,t).

Controllability as a measure of interaction between the input and the states involves the system matrix A and the input matrix B. Observability, as a measure of interaction between the states and the output involves the system matrix A and the output matrix C.

Controllability and observabillity criteria

There are several criteria that determine whether a system is controllable and observable. A linear time-invariant system (A,B,C), with *s* inputs is completely controllable if and only if the *N*x*sN* matrix

$$\left\lfloor B\ AB\ A^2B\ \cdots A^{n-1}B \right\rfloor \tag{2}$$

has rank N. A linear time-invariant system (A,B,C) with *r* outputs is completely observable if and only if the *rN*x*N* matrix of has rank N.

$$\left\lfloor \begin{matrix} C \\ CA \\ CA^2 \\ \cdots \\ CA^{n-1} \end{matrix} \right\rfloor \tag{3}$$

There are two disadvantages of this criterion. The first one is that the criteria is suitable for operating with a small dimensions system only. In fact, it is to answer the question whether a system of controllable or observable A^{n-1} should be found, which is obviously a problem from the standpoint of numerical data processing with a larger system.

Another disadvantage is that the answer to the question of whether the system is controllable or observable, is only a "yes" or "no", which may not be the case if the application of other criteria.

Another criterion in determining the controllability and observability uses gramians to determine system properties.

Gramians controllability and observability can be determined from differential equations

$$\begin{aligned}\dot{W}_c &= AW_c + W_c A^T + BB^T \\ \dot{W}_o &= A^T W_o + W_o A + C^T C\end{aligned} \tag{4}$$

whose solutions is a time-dependent matrix. For a stable system, stationary solutions are obtained assuming $\dot{W}_c = \dot{W}_o = 0$ whereby differential equations become equations, known as Lyapunov's equations

$$\begin{aligned}AW_c + W_c A^T + BB^T = 0 \\ A^T W_o + W_o A + C^T C = 0\end{aligned} \tag{5}$$

where W_c is controllability Gramian, and W_o observability Gramian.

Another definition of controllability and observability involves gramians W_c and W_o, the solutions to the Lyapunov equation (5) defined as

$$\begin{aligned}W_c &= \int_0^\infty e^{A\tau} BB^T e^{A^T\tau} d\tau \\ W_o &= \int_0^\infty e^{A^T\tau} C^T C e^{A\tau} d\tau\end{aligned} \tag{6}$$

If the solutions $W_c(t)$ and $W_o(t)$ are non – singular, then system is controllable, i.e. observable.

In modal coordinates the diagonal entries of the controllability and observability gramians are as follows [2], [3]:

$$\begin{aligned}w_{ci} &= \frac{\|B_i\|_2^2}{4\varsigma_i\omega_i} = \frac{\left\|\begin{bmatrix}0 \\ F_k z_{nki}\end{bmatrix}\right\|_2^2}{4\varsigma_i\omega_i} = \frac{F_k^2 z_{nki}^2}{4\varsigma_i\omega_i} \\ w_{oi} &= \frac{\|C_i\|_2^2}{4\varsigma_i\omega_i} = \frac{\left\|\begin{bmatrix}z_{nji} & 0\end{bmatrix}\right\|_2^2}{4\varsigma_i\omega_i} = \frac{z_{nji}^2}{4\varsigma_i\omega_i}\end{aligned} \tag{7}$$

while Hankel singular values are obtained from

$$\gamma_i \cong \frac{\|B_i\|_2 \|C_i\|_2}{4\varsigma_i\omega_i} \tag{8}$$

For systems that have relatively small values of the damping ratio ζ, gram matrix is diagonal dominant, which means that the element outside the main diagonal have significantly lower values than elements which belong to the main diagonal.
The syntax for the MATLAB function *balreal* which produces a balanced realization of the linear time-invariant model with equal and diagonal controllability and observability gramians is:

$$[sysb, g, T, Ti] \; = \; balreal(sys) \tag{9}$$

where *sysb* is new balanced system, and *g* is diagonal of the joint gramian. Diagonal entries of the joint gramian g are squares of the Hankel singular values of the system. After the balanced gramian diagonal terms are sorted in descending order, *modred* function, option *mdc* or *del* can be applied to eliminate states with the lowest joint controllability/observability.

RESULTS AND DISCUSSION

Figure 3 and 4 shows direct FRF (X1/F1) and cross FRF (X10/F1), where all ten modes were included. Modes are sorted based on the dc gain whereby damping ratio has a uniform value ζ = 0.001. Individual modes contribution was shown on both figures also.

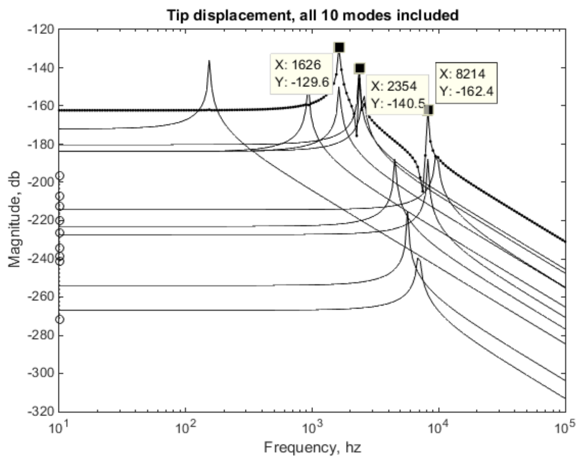


Figure 3. Direct FRF, all 10 modes included

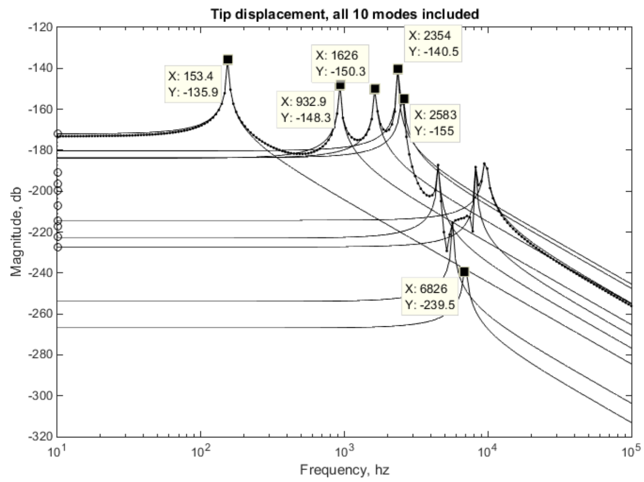


Figure 4. Cross FRF (X10/F1)– all ten modes include

FRF shown in figure 3 does not contain first two natural frequencies (154,37 Hz and 926,92 Hz) i.e. modal contribution of the first two modes is smaller than contribution of modes three, four, five and nine. Explanation how to calculate modal contribution and preform ranking of all modes for this case is provided in [4]. Reasons for this can be found in figure 5 and figure 6, where it can be seen that the main spindle tip displacement on the first two natural frequencies is negligible. On the other hand, figure 4 represents cross FRF, i.e. displacement of measurement point 10 (figure 1), where first two natural frequencies are present. From figures 5 and 6 it can be noticed that point 10 has maximum displacement. Also, figures 7 and 8 show that at third and fourth natural frequencies (1641 Hz and 2351,8 Hz) both measurement points (1 and 10) have significant displacement. As a result both frequencies are present in direct and cross FRF, as can be seen from figures 3 and 4.

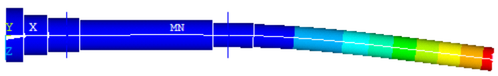


Figure 5. First bending mode 154,37 Hz

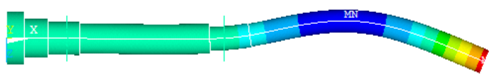


Figure 6. Second bending mode 926,92 Hz

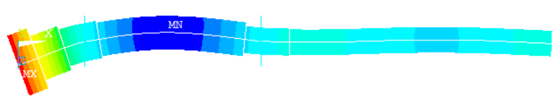


Figure 7. Third bending mode 1641 Hz

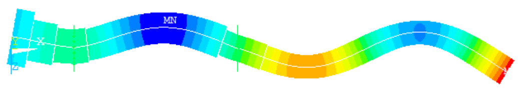


Figure 8. Fourth bending mode 2351,83 Hz

Figures 9 and 10 show direct FRF where full model and first four modes were included, with different reductions technique used. Frequency response plot in figure 9 shows:

- Full model (all oscillatory modes)
- *Sorted truncated* where dc gain was used for mode ranking, after that least significant modes were deleted
- *Sorted mdc* where dc gain was used for mode ranking and MATLAB function *modred* with *mdc* option to reduce
- *Balreal modred mdc* where MATLAB function *modred* was used with *mdc* option to eliminate states with the lowest joint controllability/observability,

while frequency response plots in figure 10 shows

- Full model (all oscillatory modes)
- *Sorted truncated* where dc gain was used for mode ranking, after that least significant modes were deleted
- *Sorted del* where dc gain was used for mode ranking and MATLAB function *modred* with *del* option to reduce
- *Balreal modred del* where MATLAB function *modred* was used with *del* option to eliminate states with the lowest joint controllability/observability.

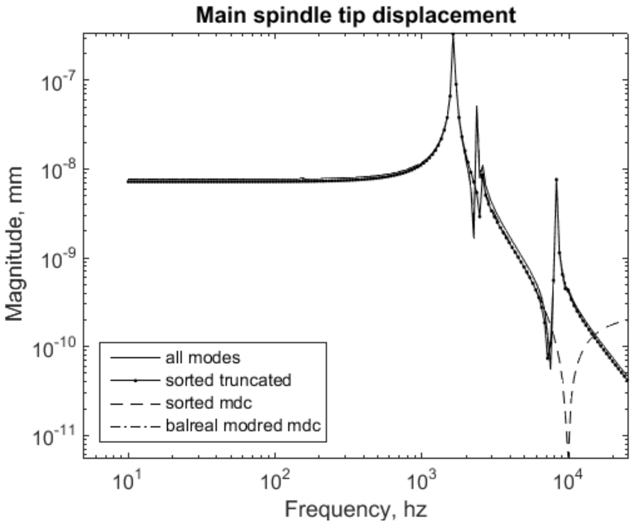


Figure 9. FRF for full model and four modes included, *balreal modred mdc* option used

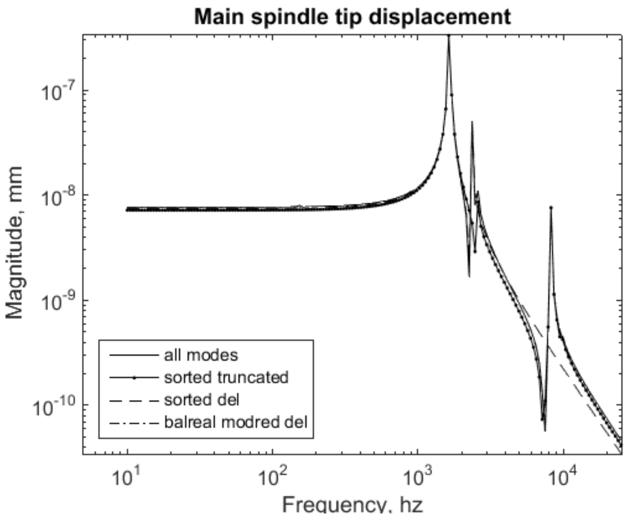


Figure 10. FRF for full model and four modes included, *balreal modred del* option used

It can be noticed that in the high frequency portion, magnitude is rising when *modred* function *mdc* option is used which is not a case with *del* option. But, when modes are sorted using balanced system controllability and observability gramians there is no rising magnitude regardless which option was used. Comparison of the impulse responses in time domain is shown in figure 11. Impulse response contains full model and four modes included with different reduction options used. It can be seen that there are no significant differences in the time domain response.

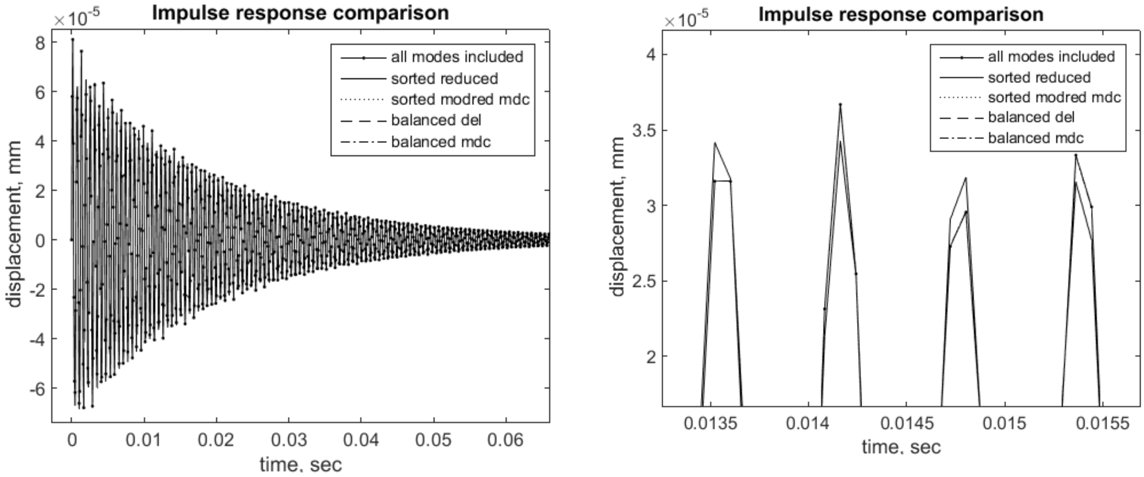


Figure 11. Impulse response comparison, full model and four modes included

CONCLUSION

This paper shows, on the main spindle example, how the model can be transformed from finite elements into state space representation i.e. how to take the results of FEM and reduce the model size extracting lower order state space model in MATLAB (model reduction). Therefore, the goal is not only to obtain reliable dynamic model, since such a model is FEM model.

In the sense of the written, working on the subject above resulted in the following:

- Convert a large finite element model ("large model" assumes model with thousands of hundreds of DOF) to a smaller MATLAB model which still provides correct response for the forcing input, i.e. still maintaining the input / output relationship.
- Modal reduction was made by using balanced reduction technique.
- A reduced solution provides very reliable dynamic of the model with a significant reduction in number of states. Reduced mode can be further inserted into a more complex control system model and used to find system dynamics.

REFERENCES

[1] Garitaonandia, I, Sabalza, X, Fernandes, M.H, Munoa, J, Hernandez, M.J., Albizuri, J.: State space modelling of a centerless grinding machine, EUROCON 2005 - The International Conference on "Computer as a tool", Serbia and Montenegro, Belgrade, November 20-24,2005.

[2] Gawronski, W,K.: Dynamics and Control of Structures, A modal approach, Springer, 1988

[3] Hatch, M. R.: MATLAB and ANSYS, Chapman & Hall/CRC, 2001.

[4] Košarac, A., Zeljković M., Mlađenović, C., Živković, A.: Create SISO state space model of main spindle from ANSYS model, MMA 2015 Flexible Technology, 12th International Scientific Conference Novi Sad, Serbia, September 25-26, 2015, 37-41

[5] Zeljković, M.: Sistem za automatizovano projektovanje i predikciju ponašanja sklopa glavnog vretena mašina alatki, Doktorska disertacija, Fakultet tehničkih nauka, Novi Sad, 1996.

[6] Živković, A., Zeljković, M., Tabaković, S., Milojević, Z.: Mathematical modelling and experimental testing of high – speed spindle behaviour, The International Journal of Advanced Manufacturing Technology, (2015) 77: 1071-1086.

USING OPEN-SOUCE HARDWARE FOR SOLAR POWERED WIRELESS SENSOR STATION RESEARCH

Dalibor Dobrilović[1], Jasmina Pekez[1], Eleonora Desnica[1], Miroslav Lambic[1]
[1]University of Novi Sad, Technical Faculty "Mihajlo Pupin", Zrenjanin, Serbia
e-mail: ddobrilo@tfzr.uns.ac.rs

Abstract: In recent period we are witnesses of the growing importance of Internet of Things, Wireless Sensor Networks and similar technologies. All these technologies have in common deployment of a large number of outdoor stations and nodes in certain scenarios. Because of the outdoor location of the nodes, as well the need for efficient energy consumption, the very important question, which emerged together with the implementation of these scenarios, is the question of sensor station power supply. The solar powered sensor stations show itself as the most efficient, economical, and practical and sometimes only possible solution for outdoor environments. In this paper is presented approach in using open-source hardware for building prototypes of solar powered wireless sensor stations. The sensor station platform is also presented in this paper, as well as the analyses of presented platform usage in academic institutions for research and teaching.
Key words: solar powered sensor station, open-source hardware, wireless sensor station

INTRODUCTION

In variety of emerging technologies in modern days we are witnesses of the growing importance of IoT (Internet of Things) [1,2,3], WSN (Wireless Sensor Networks) [4,5] and similar technologies. Those technologies opened wide range of new possible usage scenarios such as smart cities, smart home, smart agriculture, smart environment, smart water, etc. All these technologies have in common one thing - the deployment of a large number of outdoor stations and nodes in certain scenarios. According to the prognosis in 2020 in world will be around 26 billion of intelligent devices [6]. The growth of IoT devices is presented in the figure (Fig. 1). Considering the large projected number of IoT devices the question of power supply for these nodes becomes more important. Importance of this question increases because it is realistic to expect that the large number of projected 26 billion of devices will be deployed at outdoor locations. So, the efficient energy consumption of sensor stations and need for avoidance of frequent battery changes in order to ensure enough supply power becomes main motivation for this research. The idea is to find the way to provide low-cost, efficient and flexible platform to be used in academic institutions for research and even teaching of these topics. Using this approach, the possibility to make experiments with application of solar powered sensor stations becomes reality in academic and research institutions with no pressure to their budgets.

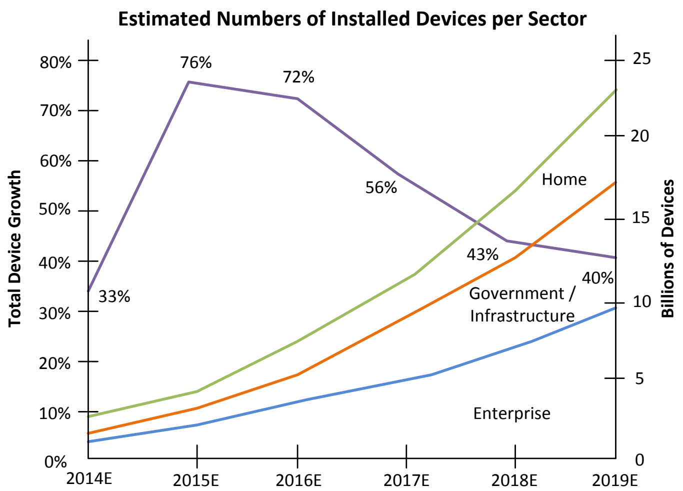


Figure 1. Estimated number of installed IoT devices in the World until 2019 [7]

In this paper is presented an approach of using open-source hardware platforms for solar powered sensor nodes in teaching and research at academic institutions. The paper is structured as follows: after the introduction, in the second chapter is presented the platform with its main components, together with the open-hardware principles. In the third chapter is presented the experience in usage of the proposed platform. The conclusion and the further work are given in the last chapter.

PLATFORM BUILT ON OPEN-SOURCE HARDWARE

Open-source hardware

According to the [8] Open Source Hardware (OSHW) Statement of Principles 1.0 - open source hardware is hardware whose design is made publicly available so that anyone can study, modify, distribute, make, and sell the design or hardware based on that design. The hardware's source, the design from which it is made, is available in the preferred format for making modifications to it. Ideally, open source hardware uses readily-available components and materials, standard processes, open infrastructure, unrestricted content, and open-source design tools to maximize the ability of individuals to make and use hardware. Open source hardware gives people the freedom to control their technology while sharing knowledge and encouraging commerce through the open exchange of designs.
Generally, this approach in defining the open-source hardware principles provided creation of the largely supported market with compatible and low-cost products. These principles also made those components more available and allowed the development of small electronic devices, especially in the field of IoT, accessible to everyone. In a way, open-source hardware principles powered up the development and expansion of IoT.

Solar powered Wireless Sensor Network platform

Platform presented in this research is build upon the Arduino Uno microcontroller board [9,10]. The components of the platform are presented in Table 1 and on Fig. 2. The basic component of the platform is Arduino UNO. Arduino UNO is a microcontroller board based on the ATmega328P. It has 14 digital input/output pins (of which 6 can be used as PWM outputs), 6 analog inputs, etc. It is one of the most popular microcontroller board open-source platforms in the world. Considering it open design, there is variety of clone boards or similar boards of other producers that are available on the market. Due its wide popularity and number of variants it is hard to estimate how much copies are sold in the world up to date. Before, in our institutions, some research related to usage of this platform in academy courses [11,12] were made as well as on other academic institution throughout the world.

Table 1. Platform for solar powered wireless sensor station

No.	Item No.	Description
1	Arduino UNO Rev 3	Microcontroller board based on Atmel AT386
2	Solar Charger Shield v2.2	Expansion module designed to enable power from various batteries that has the voltage of 3.0V-4.2V to shift up for 5V output needed for Arduino, or to be used in combination with Li-ion battery and solar panel to form an autonomous sensor unit.
3	Solar panel	1.5W solar panel with dimensions 81x137mm
4	500mAH LiPo Battery	Polymer Lithium Ion battery 500mAh
5	XBee shield	Expansion module for Arduino designed for mounting communication modules based on Bee socket
6	Mesh Bee	Communication module design for ZigBee protocol
7	Temperature and humidity sensor	DHT22

The solar charger shield is a stackable expansion board that enables battery power to the Arduino UNO. It allows usage of various batteries with voltage of 3.0V to 4.2V to shift it up for 5V output

needed to Arduino. This shield is also designed to be used in combination with Li-ion battery and solar panel to form an autonomous sensor unit. The maximum current provided by the board can get up to 600mA which is more than enough for all Arduino configurations, a three times more than the power consumption of the presented sensor station. A micro USB connector, on the shiedd, is also useful to charge the battery connected directly to the PC via USB cable.
Solar shield in this example is used in combination with the 1.5W solar panel with dimension 81 x 137mm. Solar panel is attached to the shield with 2-pin JST 2.0 PH connector. The solar panel is used to supply Arduino Uno and charge battery attached to the same board. The attached battery has smaller capacity - 500mAh and it is polymer Li-on battery. With the two LEDs on the board it can be seen if the battery is charged (red light) or if the battery is full (green light). With above components the autonomous power supply is provided, but the sensor station still lacks the communication and sensing capabilities.

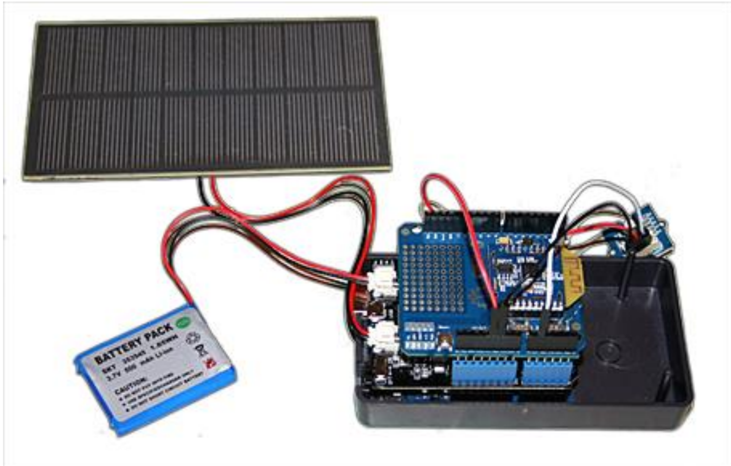


Figure 2. The solar powered platform based on Arduino UNO and solar shield

In order to make this station outdoor sensor node, this station needs communication module and sensor. The communication module which is included in the configuration is Bee socket based module Seeedstudio Mesh® Bee [13,14]. MeshBee® is a 2.4 GHz wireless ZigBee RF module. It uses microchip JN516x from NXP that enables several different standards-based ZigBee mesh networking [15,16]. It supports ZigBee Pro stack. It has indoor/urban range up to 30m and outdoor line-of-sight range up to 100m. Its receive sensitivity is -95dBm, working frequency is 2.4GHz and it operates at following data transmission rate: 4800, 9600, 19200, 38400, 57600 and 115200 bps. It has socket compatibility with well known Digi International XBee communication modules [4,17] (2 x 10-pin sockets). Its connectivity with Arduino solar platform is allowed using Tinysine XBee shield v2.
The Seeedstudio Mesh® Bee communication module on this solar station is configured as Router [4] and it has wireless communication with central network module with a role of Coordinator [4] attached to PC. This configuration with one Coordinator and one Router is needed in order to establish ZigBee network or ZigBee PAN. In this way, solar powered station transmits sensor collected data to the computer.
In order to make this station the sensor station, at least one sensor should be used. In this particular scenario is used digital temperature and humidity sensor – DHT22. This sensor collects the data and station send its every 10 seconds to the ZigBee Coordinator device directly attached to PC (Fig. 3). The time period is determined with the program uploaded to the station. On a PC is installed simple prototype application for collecting the data with logging the received temperature and humidity values together with the code of the sending station, data and time of the data retrieval.

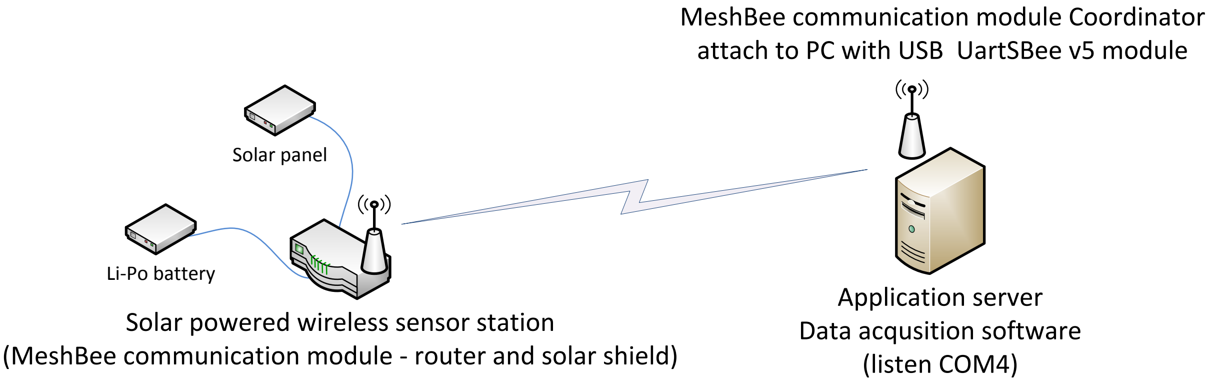


Figure 3. Network made with solar powered wireless sensor station

RESULTS AND DISCUSSION

The goal of this paper was to show the possibilities of using the open-source hardware in academic institution for the research related to solar powered wireless sensor stations. The platform presented in the second section of the paper is tested for a short time and it worked well during the testing period. The station is power supplied combining Li-Po battery and solar panel. The collected and successfully sent temperature data are presented at Fig. 4.
During the operation, station collected temperature and humidity data and sent it via ZigBee network to the remote PC station. In this test conditions, the station is located only 5m from the sensor station. The longer ranges are possible as well up to 30m in indoor/outdoor non-line-of-site environment and up to 100m in line-of-sight conditions in outdoor environment. These ranges are declared by the manufacturer and they are proved by the experiments taken at our institution for indoor usage [18].

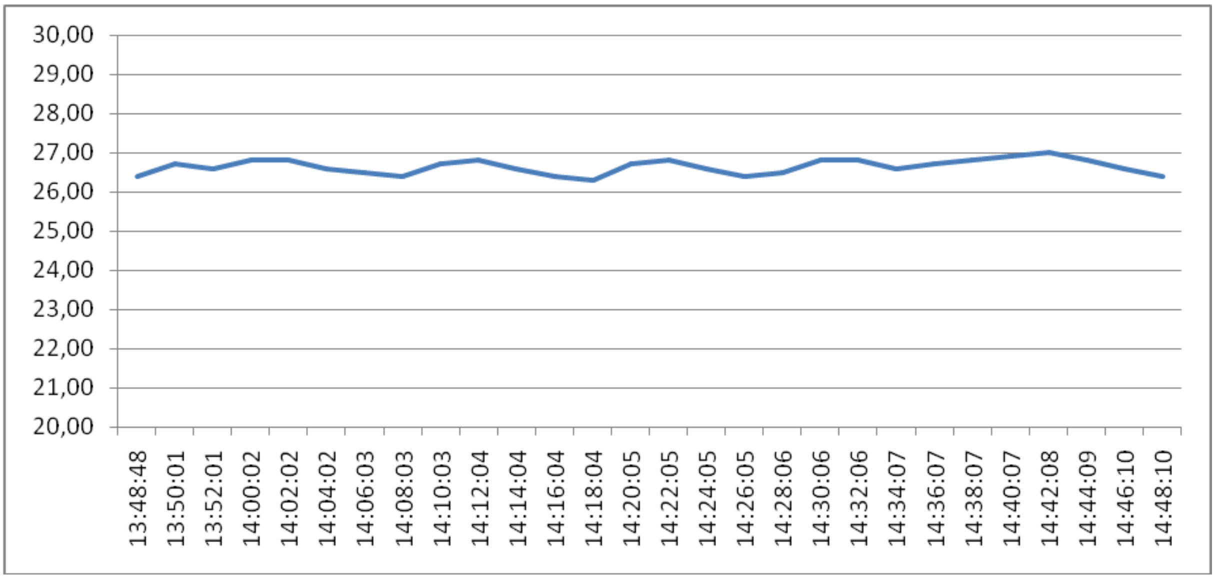


Figure 4. The measured values for temperature during the station test work

In this stage of the research, the process of monitoring and analyzing of solar charging, battery drain and behavior of the station under the different conditions connected to UV radiation intensity are not performed. One of the major obstacles for accurate and useful measurements is caused by two factors. One factor is that in this stage only one small capacity battery is available for the research. The second factor is rather high energy consumption needed to establish and maintain ZigBee connection. In order to continue the research on this topic, the power consumption of the solar sensor station should be

measured and optimized as well. After that, the experiments with the higher capacity battery should be made as well as with the larger size and higher power solar panels.
Nevertheless, considering that Arduino platform is specially designed for DIY (Do It Yourself) projects and prototyping, all components are easy to assemble. This is a solder less platform which makes these stations easy to improve, reprogram and reconfigure. These capabilities make proposed platform very suitable for usage in the research at academic institutions. Also, this platform can be used in teaching process, because it will allow students much space for hand on labs and making experiments with different configurations.

CONCLUSION

In this paper it was presented the possible usage of open-source hardware at academic institutions for researches connected to the solar powered wireless sensor stations. This research is motivated with the growing importance of WSN and IoT platforms, and it has the special focus on outdoor deployed autonomous sensor stations.
Considering the enormous expansion and growth of the number of such stations projected for the next 5 years and beyond, the research connected with the most economic and most manageable power supply for such stations becomes important for the academic institutions and their researchers in multidisciplinary fields. The open-source hardware offers low cost, well designed electronic components. One set of these components is used to assembly ZigBee based solar powered sensor station. Also, open-source hardware platform is used to form complete network for sensor data acquisition consisting in this case only with two nodes (Fig. 3).
The created platform worked well during testing period and proved itself as a platform functional enough to be used in research facilities. Considering that this platform is easy to be reconfigured and that with additional equipment it may be used for monitoring and experimenting with the solar power wireless sensor stations and IoT devices, we can say that the proposed platform is useful and suitable environment for the research and teaching in academic institutions.

REFERENCES

[1] Adrian McEwen, Hakim Cassimally, Designing the Internet of Things, John Wiley and Sons, Ltd., UK, 2014.
[2] C. Pfister, Getting Started with the Internet of Things, O’Reilly Media, Inc., USA, 2011.
[3] M. Schwartz, Internet of Things with the Arduino Yún, Packt Publishing, UK, 2014.
[4] R. Faludi, Building Wireless Sensor Networks, O’Reilly Media, Inc., USA, 2011.
[5] S. C. Mukhopadhyay, Wireless Sensor Networks and Ecological Monitoring, Springer-Verlag Berlin Heidelberg, Germany, 2013.
[6] J. Rivera, R. van der Meulen, Gartner Says the Internet of Things Installed Base Will Grow to 26 Billion Units By 2020, http://www.gartner.com/newsroom/id/2636073, December 12, 2013.
[7] J. Greenough, “The 'Internet of Things' will be the world's most massive device market and save companies billions of dollars”, http://www.businessinsider.com/how-the-internet-of-things-market-will-grow-2014-10, Business Insider Inc, Apr. 14, 2015.
[8] Open-source Hardware Association, Official site, http://www.oshwa.org/definition/, retrieved, September 2015.
[9] M. Banzi, Getting Started with Arduino, O’Reilly Media, Inc., USA, 2009.
[10] J. Oxer, H. Blemings, Practical Arduino Cool Projects for Open Source Hardware, APress Press, USA, 2009.
[11] D. Dobrilovic, Z. Stojanov, B. Odadzic, "Teaching application development for RFID/ZigBee networks using open source hardware", Proceedings of 2014 IEEE X International Symposium on Telecommunications (BIHTEL), 27-29 October 2014, pp 1-6, DOI: 10.1109/BIHTEL.2014.6987641, Sarajevo, Bosnia and Herzegovina, 2014.
[12] D. Dobrilovic, Z. Stojanov, B. Odadzic, V. Sinik, "Platform for teaching communication systems based on open-source hardware", IEEE Global Engineering Education Conference

EDUCON 2015, 18-20 March 2015, pp. 737 - 741, DOI: 10.1109/EDUCON.2015.7096051, Tallin, Estonia, 2015.

[13] O. Wang, MeshBee® Open Source ZigBee RF Module User's Manual, Seeed Technology Inc., 2014.

[14] O. Wang, MeshBee® Open Source ZigBee RF Module CookBook, Seeed Technology Inc., 2014.

[15] S. Farahani, ZigBee Wireless Networks and Transceivers, Elsevier Ltd., UK, 2008.

[16] H. Labiod, H. Afifi, C. De Santis, WI-FI, Bluetooth, ZigBee and Wimax, Springer, Netherlands, 2007.

[17] Digi International Inc. official site, XBee/RF Solutions, http://www.digi.com/products/xbee-rf-solutions, retrieved September, 2015.

[18] D. Dobrilovic, Z. Stojanov, V. Sinik, "Testing Zigbee RF module applicability for usage in temperature monitoring systems, Proceedings of IEEE International 22nd Telecommunications Forum TELFOR 2014, 25-27 November 2014, pp. 415-418, DOI:10.1109/TELFOR.2014.7034436, Belgrade, Serbia, 2014.

APPLICATION OF COMPUTER TECHNOLOGIES (CAD/CAM SYSTEMS) FOR QUALITY IMPROVEMENT OF EDUCATION

Ivan Palinkaš[1], Aleksandar Ašonja[2], Eleonora Desnica[1], Jasmina Pekez[1], Duško Letić[1]
[1]University of Novi Sad, Technical Faculty "Mihajlo Pupin", Zrenjanin, Serbia
[2]Faculty of Economics and Engineering Management, University Business Academy, Novi Sad, Serbia
e-mail: ivanpalinkas@gmail.com

Abstract: This paper presents one of modern CAD tool for modeling (Autodesk Inventor) and one of CAM tool for defining parameters of machining and programming CNC machines (InventorCAM). These tools are used to determine whether usage of these tools improves the quality of education in production preparation for students.
Key words: education, production, modeling, machining

INTRODUCTION

Manufacturing is a primary area of human activities necessary to meet the needs of participants in work processes, work systems and stable development of the society in accordance with established objectives. Without producing society could not survive even the shortest period of time regardless of the natural resources of the country and forms in which it is located. [01]
In production processes designers play an important role. In modern production design can not be imagined without computer supported technologies. Computer design requires a higher level of knowledge in relation to the classic design, because it means, in addition to design methods, knowledge of hardware and software to work. [02] Modern computational programs are solving more complicated and more extensive problems, so the use of such programs is complex and must be approached systematically and methodically. [02] Particularly important area of computing for technical needs is a field of computer graphics. [02]
Using computer technology gives the possibility of testing the created models, ie, replaces the need for creating more prototypes in order to test the practical construction. In production systems, there is a need to connect the computer with the executive elements of production (CNC machines). This provides a more efficient production (reduced production time, reduces the cost of production, increases accuracy and quality of the product).
Bearing all this in mind, it can be said that important part of must have in education of future designers is supported by computer technology (in this case, the CAD/CAM technology). Similarly, the constant upgrading of existing knowledge engineers in the field of application of new technologies is the imperative of quality production and ensure competitiveness in the market.

CAD/CAM TECHNOLOGY DEVELOPMENT

Computer-aided design is one of many disciplines used by engineers and designers in many ways, depending on the specific profession and the type of software. The basic function of CAD activities is certainly a part of integrated management of development activities in the product lifecycle (Product Lifecicle Management - PLM), and as such is used in conjunction with other tools, which are either integrated modules or stand-alone products, such as: Computer Aided Engineering (CAE), computer-aided manufacturing (CAM), engineering finite element analysis (FEA), including Computer Numerical Control (CNC). [10]

Autodesk Inventor and InventorCAM

Autodesk Inventor and InventorCAM represent CAD/CAM software tools used in:
1. parametric modeling, animation assemblies created from individual parts, creating technical documentation (Inventor)

Parametric modeling helps designers to present their idea as a 3D model. The model is created based on the geometrical design features that can change at any time for necessary corrections in the design process.

2. Implementation of 3D models into production (software prepares 3D models for physical processing, generating G code used for programming CNC machines) (InventorCAM).

InventorCAM is a certified integrated CAM engine for Inventor that has full connectivity with the model in Inventor. InventorCAM is used in the mechanical manufacturing, electronic, medical and consumer products, machine design, automotive and aerospace industries, as well as workshops for the manufacture of molds, tools and rapid prototyping.
Today, successful companies are using integrated CAD/CAM systems to quickly place the product in market and reduce costs. With InventorCAM software there is advantage of the integration of Inventor + InventorCAM software that can be used.

INVENTOR AND INVENTORCAM APPLICATION IN QUALITY IMPROVEMENT OF EDUCATION

By using Inventor and Inventor-CAM software attempt was made to explain to the students the possibility of modeling of products and milling operation. In this way, instead of classical lectures (PowerPoint presentation or slideshow) students view video material of modeling and milling operations represented in manufacturing. On the figures 1, 2 and 3 are presented segments of a given presentation.
Here it will shown the usage of Inventor and InventorCAM in modeling and milling. The purpose of these models is their display in the classroom. For this reason, existing examples of machining is used from course of InventorCAM manufacturer's, (Figure 1 and Figure 2 that the students will be shown the proposed methodology of analysis, while the third example is the model of the pump cover (Figure 3). The model used in the third example is modeled in Autodesk Inventor following the model provided for learning the software.

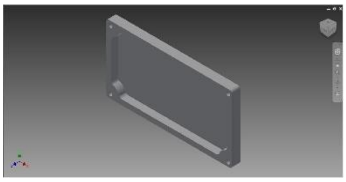


Figure 1. Model view prepared for milling process

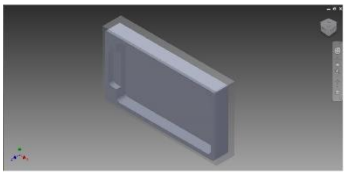


Figure 2. Model view prepared for iMachining milling process

Figure 3. Model view of pump cover

Modeling in Autodesk Inventor
One of the ways of creating 3D models in Inventor relies on the creation of 2D drawings which can get a surface or solid (in this case the solid). Further procedure relies on the use of the same algorithms, but on another level, as well as the processing of the obtained models (drilling holes, chamfering ...) The following illustration (Figure 4 to Figure 7) shows some of the steps of modeling the cover.

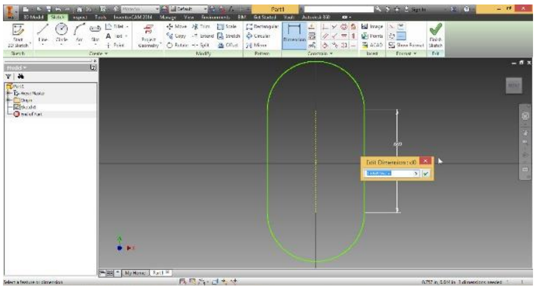


Figure 4. Creation of 2D sketch

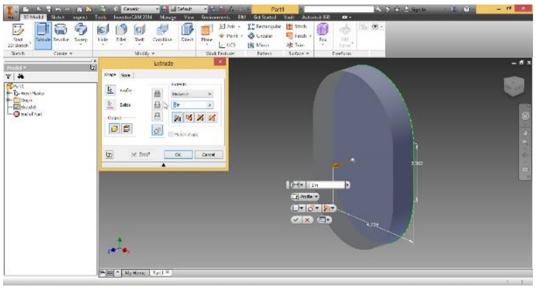


Figure 5. Creation od 3D solid model with command extrude

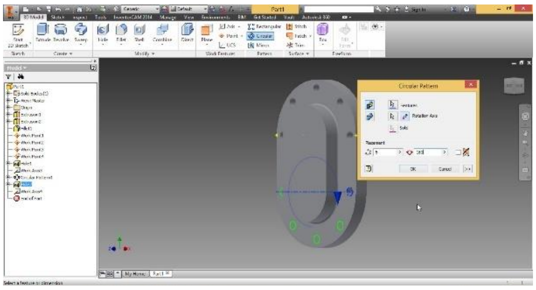


Figure 6. Usage of Create pattern command

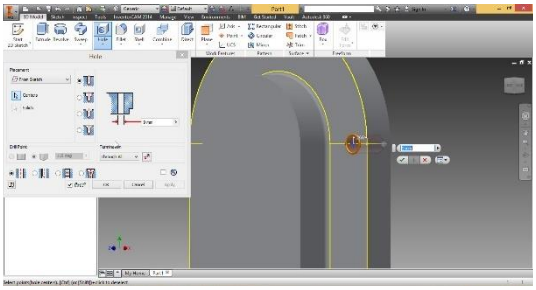


Figure 7. Command Drill

Milling machining

After creating a model in Inventor, machining is defined in InventorCAM-in. After the selection of InventorCAM in Inventor menu bar the type of machining is defined. In this case, the milling (Milling). Then the storage location of the model and procedure is defined, and continue to initial settings.

The initial settings are as follows (Figure 8):

- Definition of CNC machines on which to perform machining
- Defining the coordinate system
- Define the size of the workpiece (in this case the workpiece is rectangular)
- Defining the final layout (select models)

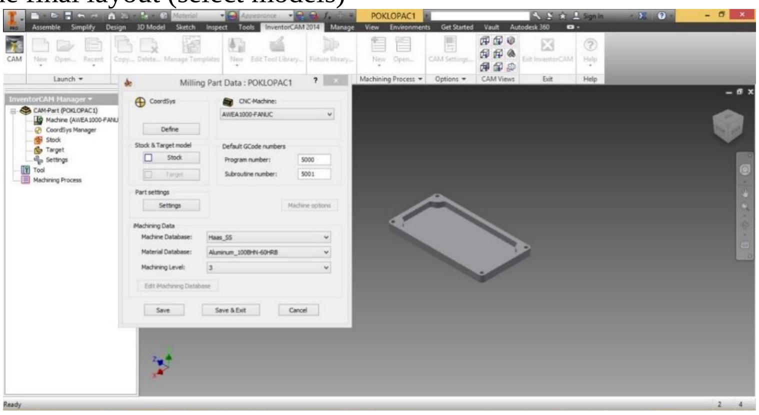


Figure 8. Initial settings dialog

When these settings are made, then it is proceed to the determination of machining operations. Machining of this part includes following operations:

- Machining of the upper surface (Face) (Figure 9);
- Machining of the side of part (Profile) (Figure 10);
- Machining of pocket (Pocket) (Figure 11);
- Drilling holes (Drilling) (Figure 12).

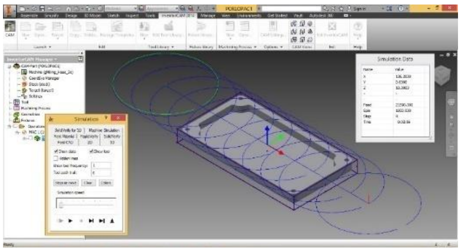


Figure 9. Face milling simulation

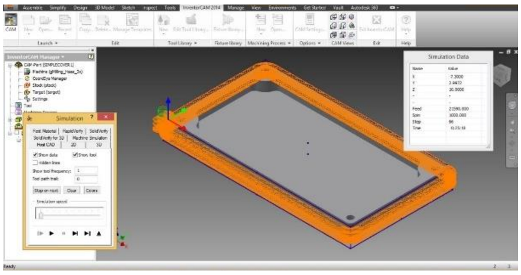


Figure 10. Profile milling simulation

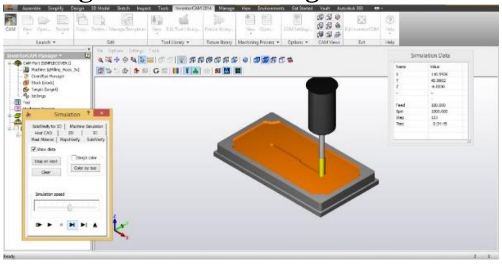


Figure 11. Profile milling simulation

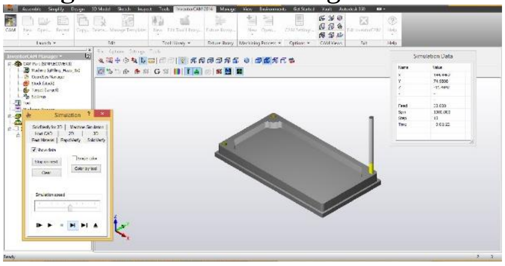


Figure 12. Drilling simulation

Within each operation the following segments are defined:

– Geometry Processing (Geometry) - can be selected in various ways depending on the needs. The most common ways are selecting a machining surface or surface edges, which represents the boder of the machining;
– The tool to be used for machining, the type and characteristics of the cutter (Tool) - perform the settings for dimensions of the blade, the cutting conditions, the material of the blade, determining the type of the holder, blade shape, type of cooling medium, ... In addition there is the view of the blade that is selected in the area with all the segments that have been set;
– The depth of machining (Level) - set the depth and the number of passes of the tool in the operation;
– Strategy process that is applied - the path of the blade (Technology) - can be set the way to enter the blade (spiral, zig - zag ...), the way in which the blade moves (of course depending on the type of milling) (Hatch, Contour, One Pass, Spiral);
– Determination of the inputs and outputs of the tool in machining (Link) - determined by the way the tool will go into operation and how to get out of it.

There more setup options, but for this example are not necessary.

Machining with iMachining technology

Technology iMachining represents revolution in machining. Using its algorithms only saves machining time up to 70%, increasing the life of the tool, provides more efficient machining, and so on. This machining technology is performed in a similar manner as the regular machining technology. Beginning is with the selection of the model and saving the file on computer, and then followed by the selection of equipment, the origin, the size of the workpiece and defining the model.

Then the machining operation is chosen. With this type of machining, closed contour, open contour and half-closed contours are defined. In places where we define an open contour or half-closed contour the tool is allowed to enter in machining.

Defining the operation is performed in the same way as in regular machining. The only difference is that for each contour is defined the iRough and iFinish machining (there is no difference between the outer or inner edge). Details of the machining can be set, or can be set to automatic algorithms.

Machining of pump cover

Making the pump cover has been done on the milling machine, using regular milling machining. The machining is like and processing the first model except that the pump cover machining is performed on the two sides to be fully processed. To achieve this, one must define another coordinate system in the plane of the model to the other. Figures below (Figure 13 and Figure 14), represent part of the procedure of machining the cover.

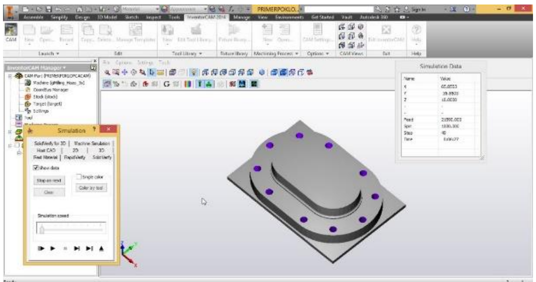


Figure 13. Simulation of drilling through workpiece

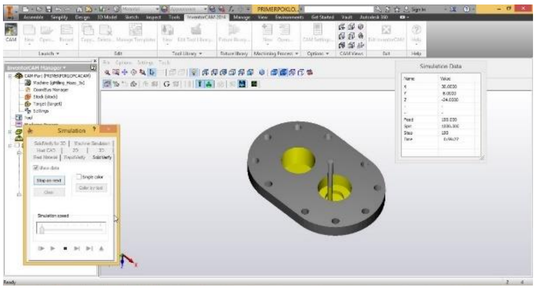


Figure 14. Pocket milling

ANALYSIS OF USAGE OF CAD/CAM TECHNOLOGIES IN ORDER TO IMPROVE THE QUALITY OF EDUCATION

The main goal of research is to determine whether, and to what extent, the quality of lectures is improving in the field of modeling and machining, using CAD/CAM software (learning the software or displaying its use in the visual presentation). The expected result is a presentation of the impact of CAD/CAM technology to the education of students.

The sample of this research were students of the Technical Faculty "Mihajlo Pupin" on study programme Industrial Engineering and Mechanical Engineering. It covers an undergraduate and master studies. The total number of participants is 32. Research is conducted in year 2015.

Students are tested by means of a survey.

The research was conducted in the following manner: a lecture was held for students in area of production preparation and related to the machining technology. Briefly was explained to students what is the preparation of production, what are machining technologies and then presented the possibilities of modeling software (Inventor) as well as the capabilities of the software for machining (InventorCAM). Emphasis is placed on the machining operations and animations using the same InventorCAM to determine if using this method of explanation of machining students better accept and understand.

DISCUSSION AND RESEARCH RESULTS

Using the survey on students (Table 1) it can be determined if application of CAD/CAM technology in classroom increases the quality of lectures. Results are as follows:

Table 1. Students' opinions on the application of CAD / CAM technology in the lectures

Statement	I absolutely disagree	I do not agree	Neither of the two	I agree	I absolutely agree
1. Shown presentation greatly increases understanding of machining process	0 (0%)	0 (0%)	4 (13%)	12 (37%)	16 (50%)
2. It would be very helpful to introduce the usage of these softwares in education	0 (0%)	0 (0%)	2 (6%)	9 (28%)	21 (66%)
3. This kind of presentation can replace the lack of practice	17 (53%)	8 (25%)	1 (3%)	2 (6%)	4 (13%)
4. This type of presentation (visual presentation) can help in quality improvement of education	0 (0%)	0 (0%)	0 (0%)	6 (19%)	26 (81%)
5. I am interested to learn this software	0 (0%)	0 (0%)	9 (28%)	10 (31%)	13 (41%)

After analysis of acquired data conclusions are next:

1. Using CAD/CAM technologies in order to explain machining process leads to greater understanding of the matter in a large number of students (Figure 15). There is not a single student who claims that this method of presentation has not helped.

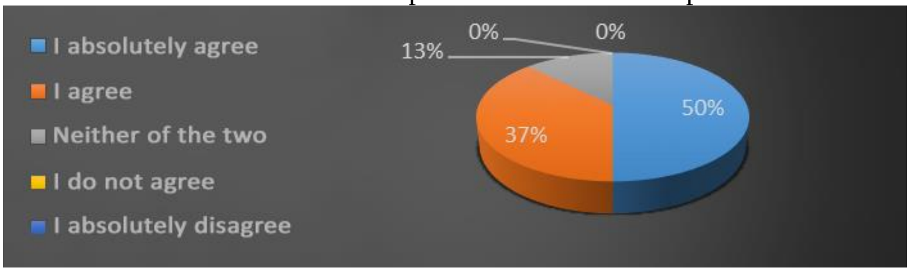


Figure 15. Percentages of acquired results in first statement of survay

2. Application of CAD/CAM technology contributes to quality improvement of education and provide students knowledge of technological development in the world of machining (Figure 16).

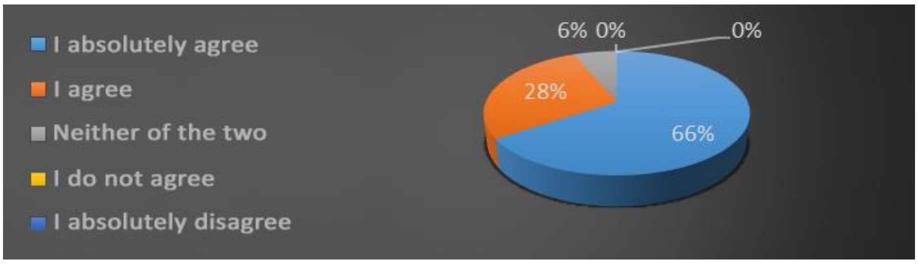


Figure 16. Percentages of acquired results in second statement of survay

3. Practice represent one of important and integral way of transferring knowledge in education system and it is nessesary in learning of Mechanical engineers. It can't be replace, and most of subjects agrees with that (Figure 17).

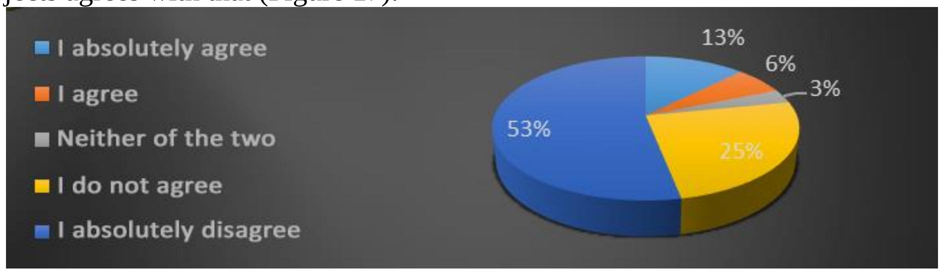


Figure 17. Percentages of acquired results in third statement of survay

4. The development of computer technology led to the possibility of creating diverse visual presentations that contribute to improved teaching. Today, the purpose of teaching, from different software can make a visual presentation (on this example it is done from InventorCAM and visual presentation is the animation of milling). From the results, we can see that all the students believe that the presentation will help to improve the quality of education (Figure 18)

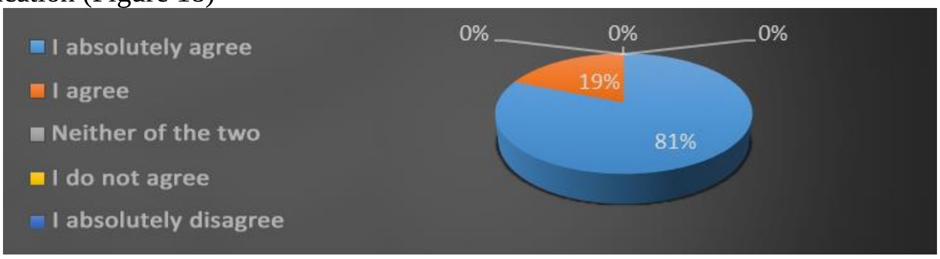


Figure 18. Percentages of acquired results in fourth statement of survay

5. There is interest of students to learn new technology (learning and application of new CAD/CAM technology) (Figure 19). Of all students, no one is opposed to learning software in the field of production).

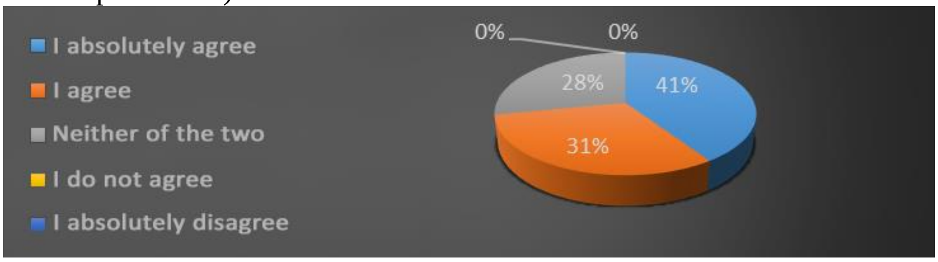


Figure 19. Percentages of acquired results in fifth statement of survay

The conclusion to be drawn from the whole of research, is that the use of CAD/CAM software for display segments of production improves the quality of education.

CONCLUSION

Improvement of production must be reflected in the improvement of production technology solutions, improvement of tools and improvement of the expertise of employees.

One of the starting factor must be the education of young people for work in production. One can no longer imagine a production without the use of information technologies. In production are especially interesting CAD/CAM technology. As should actively train engineers who are already in production, so should give young employees the necessary tools to work.

The benefits we receive by using CAD/CAM technology (in this case, Inventor and InventorCAM) are the following: savings up to 70% of processing time on the CNC machine; increasing the working life; using patented algorithms and receive an automatic setting of optimal speed, optimal trajectory, the optimal size of the workpiece before machining, as well as tools and materials specification of the machine; saving and increased efficiency which can be seen as a profit and success in the market.

This paper presents a modern CAD modeling tools (SolidWorks), and one of the CAM tools used to create parameters for programming CNC machines (InventorCAM). These tools are used to determine whether their use improves the quality of education in the preparation of production. According to the results of tests it is determined that in this way raises the quality of education and the students are introduced in new software necessary for their further teachings. Software themselves can not replace the practical education, but does provide an insight into modern production methods.

It remains only to think about the future implementations of these technologies. One of perspective might be in the field of lifelong learning, and to create courses that will attended engineers who want to improve themselves in their profession.

REFERENCES

[1] Zelenković, D. M., *Projektovanje proizvodnih sistema*, Naučna knjiga, Beograd 1987.
[2] Letić, D., Desnica, E., Inženjerska grafika I, Tehnički fakultet „Mihajlo Pupin“, Zrenjanin, 2011.
[3] http://www.referenceforbusiness.com/management/Comp-De/Continuing-Education-and-Lifelong-Learning-Trends.html
[4] Prvulović, S., Tolmač, D., *Tehnologije obrade proizvoda 1. deo,* Tehnički fakultet „Mihajlo Pupin“, Zrenjanin, 2011.
[5] Prvulović, S., Tolmač, D., *Tehnologije obrade proizvoda 2. deo,* Tehnički fakultet „Mihajlo Pupin“, Zrenjanin, 2011.
[6] Cvetković, D. *Industrijski inženjering i dizajn*, Univerzitet Singidunum, Beograd, 2012.
[7] Mirkov, G., *CNC tehnika 1,* Zavod za udžbenike i nastavna sredstva, Beograd, 2003.
[8] Gerov, Z., Programiranje NUMA - Programiranje NU glodalica pomoću programskog paketa Shop Mill, Master rad, Univerzitet u Nišu, Mašinski fakultet, Niš, 2011.

[9] Cvetković, D. *CAD/CAM Teorija, praksa i upravljanje proizvodnjom*, Univerzitet Singidunum, Beograd, 2010.
[10] Letić, D., Desnica, E., Inženjerska grafika II, Tehnički fakultet „Mihajlo Pupin“, Zrenjanin, 2011.
[11] Autodesk Inventor 2015 help file
[12] Devedžić, G., Ivanović, L., Erić, M.,*Trendovi primene CAD/CAM sistema u inženjerstvu i edukaciji*, 30. jubilarno savetovanje proizvodnog mašinstva, Vrnjačka Banja, 2005.

MODERN TRENDS IN APPLICATION OF 3D PRINTERS

Ivan Palinkaš[1], Dušanka Milanov[1], Edit Terek[1], Eleonora Desnica[1]
[1]University of Novi Sad, Technical Faculty "Mihajlo Pupin", Zrenjanin, Serbia
e-mail: ivan@tfzr.uns.ac.rs

Abstract: This work represents a review of today's usage of 3D printers, and tendencies for future usages in industry and in other branches like medicine, art, etc. The most important usage is prototyping, product development and innovation. The current technologies on which 3D printing is based will be shown as well as objects that can be produced with these technologies of manufacturing. At the end there will be researched estimations of future application in area of 3D printing
Key words: 3D printing, manufacturing, application of 3D printers

INTRODUCTION

3D printing is process of creating 3D solid objects from digital file. This is done by additive processes (laying down successive layers of material until object is finished.)
First the virtual design of the object needs to be created. It can be done in CAD (Computer Aided Design) software or by 3D scanning of object in order to make a digital copy.
To prepare a digital file for printing, the 3D modeling software "slices" the final model into hundreds or thousands of horizontal layers. When the sliced file is uploaded in a 3D printer, the object can be created layer by layer. The 3D printer reads every slice (or 2D image) and creates the object, blending each layer with hardly any visible sign of the layers, with as a result the three dimensional object.[1]

Processes and technologies

Not all 3D printers use the same technology to realize their objects. All of them are additive, differing mainly in the way layers are build to create the final object. Some methods use melting or softening material to produce the layers. Selective laser sintering (SLS) and fused deposition modeling (FDM) are the most common technologies using this way of printing.[2]
To be more accurate ASTM group (American Society for Testing and Materials) classify AM processes in 7 categories:[1]
Vat Photopolymerisation - A 3D printer based on this method has a container filled with photopolymer resin which is then hardened with UV light source.

Stereolithography (SLA) - This technology employs a vat of liquid ultraviolet curable photopolymer resin and an ultraviolet laser to build the object's layers one at a time. For each layer, the laser beam traces a cross-section of the part pattern on the surface of the liquid resin. Exposure to the ultraviolet laser light cures and solidifies the pattern traced on the resin and joins it to the layer below.

After the pattern has been traced, the SLA's elevator platform descends by a distance equal to the thickness of a single layer, typically 0.05 mm to 0.15 mm (0.002″ to 0.006″). Then, a resin-filled blade sweeps across the cross section of the part, re-coating it with fresh material. On this new liquid surface, the subsequent layer pattern is traced, joining the previous layer. The complete three dimensional object is formed by this project. Stereolithography requires the use of supporting structures which serve to attach the part to the elevator platform and to hold the object because it floats in the basin filled with liquid resin. These are removed manually after the object is finished.

Other technologies using Vat Photopolymerisation are the new ultrafast Continuous Liquid Interface Production or CLIP and marginally used older Film Transfer Imaging and Solid Ground Curing.

Material Jetting - In this process, material is applied in droplets through a small diameter nozzle, similar to the way a common inkjet paper printer works, but it is applied layer-by-layer to a build platform making a 3D object and then hardened by UV light.

Binder Jetting - With binder jetting two materials are used: powder base material and a liquid binder. In the build chamber, powder is spread in equal layers and binder is applied through jet nozzles that "glue" the powder particles in the shape of a programmed 3D object. The finished object is "glued together" by binder remains in the container with the powder base material. After the print is finished, the remaining powder is cleaned off and used for 3D printing the next object.

Material Extrusion - The most commonly used technology in this process is Fused deposition modeling (FDM)

The FDM technology works using a plastic filament or metal wire which is unwound from a coil and supplying material to an extrusion nozzle which can turn the flow on and off. The nozzle is heated to melt the material and can be moved in both horizontal and vertical directions by a numerically controlled mechanism, directly controlled by a computer-aided manufacturing (CAM) software package. The object is produced by extruding melted material to form layers as the material hardens immediately after extrusion from the nozzle. This technology is most widely used with two plastic filament material types: ABS (Acrylonitrile Butadiene Styrene) and PLA (Polylactic acid) but many other materials are available ranging in properties from wood filed, conductive, flexible etc.

Powder Bed Fusion - The most commonly used technology in this processes is Selective laser sintering (SLS)

This technology uses a high power laser to fuse small particles of plastic, metal, ceramic or glass powders into a mass that has the desired three dimensional shape. The laser selectively fuses the powdered material by scanning the cross-sections (or layers) generated by the 3D modeling program on the surface of a powder bed. After each cross-section is scanned, the powder bed is lowered by one layer thickness. Then a new layer of material is applied on top and the process is repeated until the object is completed.

All untouched powder remains as it is and becomes a support structure for the object. Therefore there is no need for any support structure which is an advantage over SLS and SLA. All unused powder can be used for the next print.

Sheet Lamination - involves material in sheets which is bound together with external force. Sheets can be metal, paper or a form of polymer. Metal sheets are welded together by ultrasonic welding in layers and then CNC milled into a proper shape. Paper sheets can be used also, but they are glued by adhesive glue and cut in shape by precise blades.

Directed Energy Deposition - This process is mostly used in the high-tech metal industry and in rapid manufacturing applications. The 3D printing apparatus is usually attached to a multi-axis robotic arm and consists of a nozzle that deposits metal powder or wire on a surface and an energy source (laser, electron beam or plasma arc) that melts it, forming a solid object.

APPLICATIONS OF 3D PRINTING

3D printing is versatile technology and has found application in almost every corner of human life (rapid prototyping, architectural scale models, medicine prosthetics and printing using human tissue, entertainment, reconstructing fossils in paleontology, replicating ancient artefacts, reconstructing bones and body parts in forensic pathology and reconstructing heavily damaged evidence acquired from crime scene investigations, etc)[1]

Medical industry - The outlook for medical use of 3D printing is evolving at an extremely rapid pace as specialists are beginning to utilize 3D printing in more advanced ways. Patients around the world are experiencing improved quality of care through 3D printed implants and prosthetics never before seen.

As of the early two-thousands 3D printing technology has been studied by biotech firms and academia for possible use in tissue engineering applications where organs and body parts are built using inkjet techniques. Layers of living cells are deposited onto a gel medium and slowly built up to form three dimensional structures.

One of other example is printing joints with method for converting 3D models into printable, functional, non-assembly models with internal friction. To this end, it has been designed an intuitive work-flow that takes an appropriately rigged 3D model, automatically fits novel 3D-printable and posable joints, and provides an interface for specifying rotational constraints.[5]

Aerospace and aviation industries - The growth in utilisation of 3D printing in the aerospace and aviation industries can, for a large part, be derived from the developments in the metal additive manufacturing sector.
NASA for instance prints combustion chamber liners using selective laser melting and as of march 2015 the FAA cleared GE Aviation's first 3D printed jet engine part to fly: a laser sintered housing for a compressor inlet temperature sensor (Fig. 1).

Figure 1. 3D printed T25 sensor enclosure unit produced by GE Aviation and certified by FAA [3]

Automotive industry - Although the automotive industry was among the earliest adopters of 3D printing it has for decades relegated 3d printing technology to low volume prototyping applications.
Nowadays the use of 3D printing in automotive is evolving from relatively simple concept models for fit and finish checks and design verification, to functional parts that are used in test vehicles, engines, and platforms.
Industrial printing - In the last couple of years the term 3D printing has become more known and the technology has reached a broader public. Still, most people haven't even heard of the term while the technology has been in use for decades. Especially manufacturers have long used these printers in their design process to create prototypes for traditional manufacturing and research purposes. Using 3D printers for these purposes is called rapid prototyping.
Nike uses 3D printers to create multi-colored prototypes of shoes. They used to spend thousands of dollars on a prototype and wait weeks for it. Now, the cost is only in the hundreds of dollars, and changes can be made instantly on the computer and the prototype reprinted on the same day.
Besides rapid prototyping, 3D printing is also used for rapid manufacturing. Rapid manufacturing is a new method of manufacturing where companies are using 3D printers for short run custom manufacturing. In this way of manufacturing the printed objects are not prototypes but the actual end user product.
Personal printing and services - Personal 3D printing or domestic 3D printing is mainly for hobbyists and enthusiasts and really started growing in 2011. This puts 3D printers into more and more hands. For people that cannot afford 3D printer there are printing services that will print and send requested part from 3D model. These kind of services can already be found in a lot of different industries like dental, medical, entertainment and art.

3D PRINTING MARKET FORECASTS AND ESTIMATES IN 2015

Manufacturers across a broad spectrum of industries including automotive, aerospace, dental, discrete, high tech, and medical products are all actively piloting and using 3D printing technologies today. Prototyping continues to dominate the reasons why enterprises pursue 3D printing, with the opportunity of improving new product development and time-to-market being long-term goals.
These and many other take-aways are from the following summarized list of 3D printing market forecasts and estimates below:[4]

General Electric plans to mass-produce 25,000 LEAP engine nozzles with Additive Manufacturing (AM), and already have $22B in commitments. Forecasts for growth of the AM market by equity research analysts range from: $7 billion by 2020, on 18 percent CAGR (Paul Coster of JP Morgan), to bull market scenarios as high as $21.3 billion by 2020, on 34 percent CAGR (Ben Uglow of Morgan Stanley) (Fig. 2).

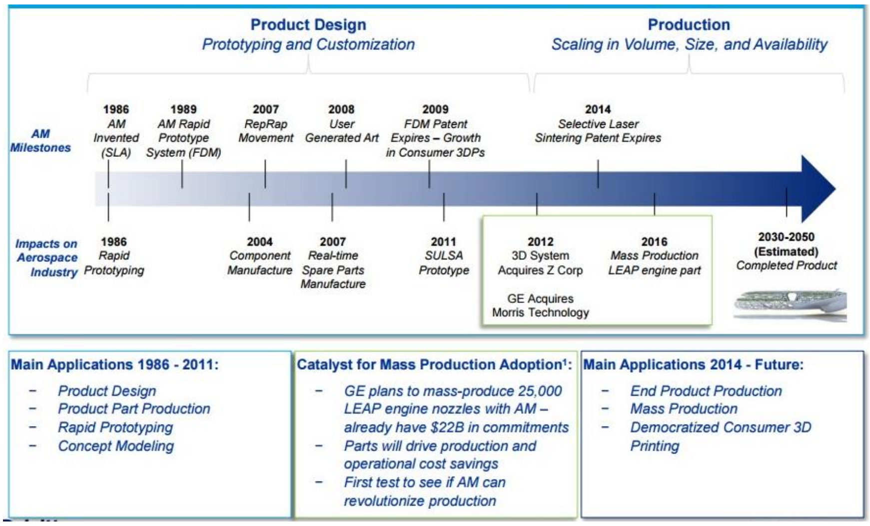


Figure 2. Additive Manufacturing Adoption Timeline

According to Wohlers Report 2014, the worldwide 3D printing industry is now expected to grow from \$3.07B in revenue in 2013 to \$12.8B by 2018, and exceed \$21B in worldwide revenue by 2020. Wohlers Report 2013 had forecast the industry would grow to become a \$10.8B industry by 2021 (Fig. 3)

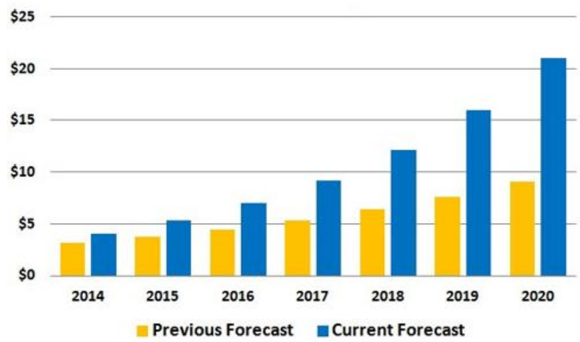


Figure 3. Worldwide 3D printing industry forecast (in billions)

Prototyping (24.5%), product development (16.1%) and innovation (11.1%) are the three most common reasons companies are pursuing 3D printing. Of those surveyed in a recent Gartner study, 37% had just one 3D printer within their organizations, with 18% owning 10 or more. The average number of printers per organization was 5.4 (Fig. 4)

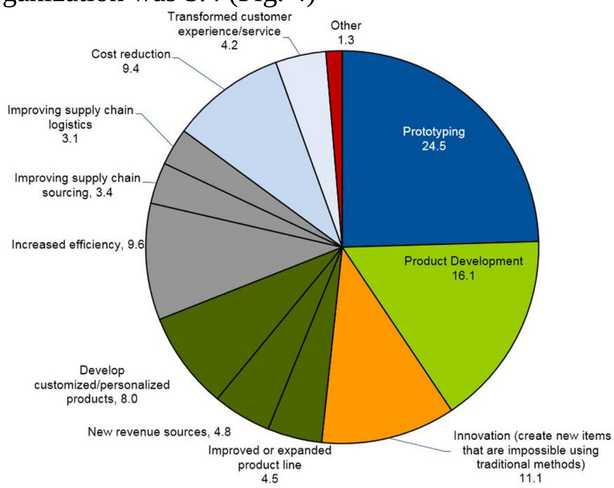


Figure 4. Reasons for using 3D printing

Gartner projects the 3D printing market globally will grow from $1.6B in 2015 to $13.4B in 2018, attaining a 103.1% CAGR. Allied Market Research (AMR) projects the 3D printing market will grow from $2.3B in 2013 to $8.6B in 2020, attaining a CAGR of 20.6% (Fig. 5).

RESEARCH FIRM	YEAR ($ Billions) 2013	2014E	2015E	2017E	2018E	2020E	CAGR	CAGR Period
AMR	$2.3					$8.6	20.6%	2013-2020
Canalys	$2.5	$3.8			$16.7		45.7%	2013-2018
CCS Insight	$1.2				$4.8		33.0%	2013-2018
Freedonia				$5.0				
Gartner			$1.6		$13.4		103.1%	2015-2018
IBISWorld *		$1.4					15.7%	2014-2019
IDC							29.0%	2012-2017
Wohler	$3.1				$12.8	$21.0	33.0%	2013-2018

* U.S. market only

Figure 5. 3D printing market global growth

3D Systems' (NYSE:DDD) sales into design and manufacturing increased 27% from 2013 to 2014, growing to $609.8M in sales. Sales into healthcare increased 80%, from $71.7M in 2013 to $129.3M in 2014. The consumer segment of 3D Systems' business grew 26% in the last year, from $34.8M in 2013 to $43.8M in 2014.

PwC estimates 67% of manufacturers are already using 3D printing. Of these, 28.9% are experimenting to determine how 3D printing can be optimally integrated into their production processes. 24.6% are using 3D printing for prototyping.

Siemens predicts that 3D printing will become 50% cheaper and up to 400% faster in the next five years. Siemens is also predicting 3D Printing will be a €7.7B ($8.3B) global market by 2023.

The global 3D printing market was valued $2.3B in 2013 and is anticipated to reach $8.6B by 2020, attaining a Compound Annual Growth Rate (CAGR) of 20.6%.

CSC has created a roadmap of 3D printing adoption across seven industries including general manufacturing and supply chain management. The figure 6 illustrates how 3D printing will revolutionize industry value chains over time.

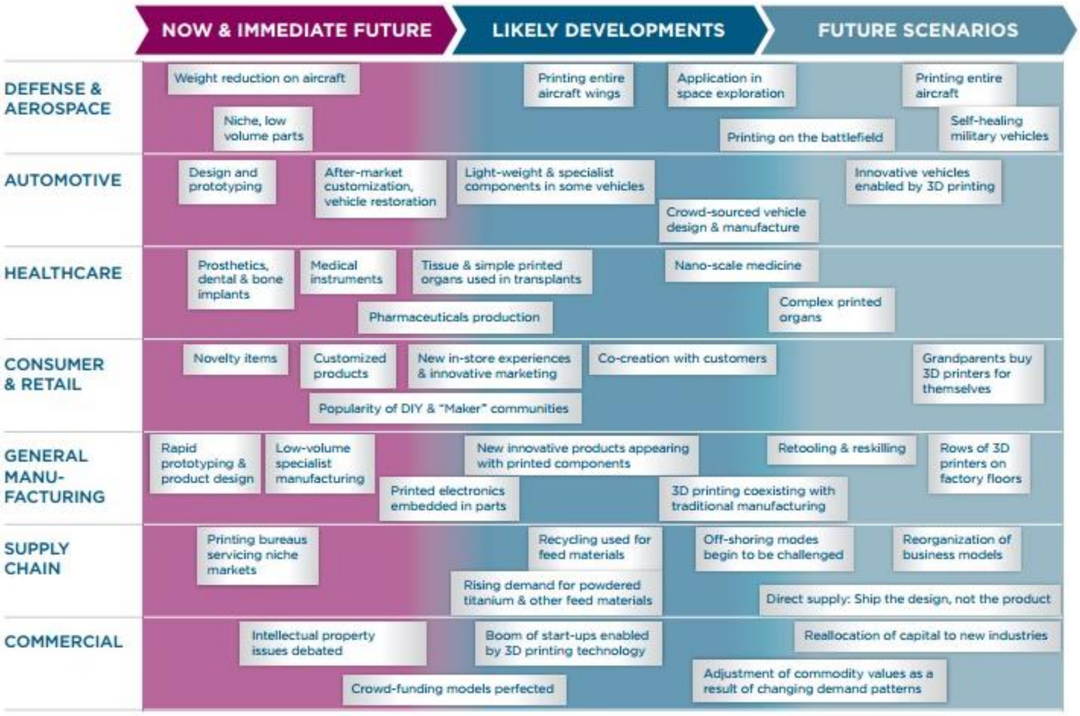


Figure 6. 3D printing impact on industry

The automotive industry's adoption of 3D printing is projected to increase from $365.4M in 2015 to $1.8B in 2023, attaining a 19.51% CAGR. The aerospace industry's adoption of 3D printing solutions is projected to increase from $723M in 2015 to $3.45B in 2023, attaining an 18.97% CAGR.

CONCLUSION

In the history of manufacturing, subtractive methods have often come first. The province of machining (generating exact shapes with high precision) was generally a subtractive affair, from filing and turning through milling and grinding. [1]

Additive manufacturing's earliest applications have been on the toolroom end of the manufacturing spectrum. For example, rapid prototyping was one of the earliest additive variants and its mission was to reduce the lead time and cost of developing prototypes of new parts and devices, which was earlier only done with subtractive toolroom methods (typically slowly and expensively). However, as the years go by and technology continually advances, additive methods are moving ever further into the production end of manufacturing. Parts that formerly were the sole province of subtractive methods can now in some cases be made more profitably via additive ones. [1]

As shown in this paper, 3D printing is technology with many applications and with promising development in field. It is increasingly replacing older technologies of manufacturing, especially in area of rapid prototyping because of the benefits that that technologies have (faster time of creating product, lower costs, etc.)

REFERENCES

[1] Whar is 3D printing?, retrieved from http://3dprinting.com/what-is-3d-printing/

[2] Ramić, E., Milanov, D., Palinkaš, I., Terek, E., Gligorović B., Application of 3D printing in industrial modeling, IV International conference Industrial Engineering And Environmental Protection 2014 (IIZS 2014), Procedings, str.(289-293), (ISBN: 978-86-7672-234-1), October 15th 2014.

[3] GE Aviation gets FAA Certification for First 3D Printed Jet Engine Part, retrieved from http://3dprinting.com/news/ge-aviation-gets-faa-certification-for-first-3d-printed-jet-engine-part/

[4] Forbes/Tech, 2015 Roundup Of 3D Printing Market Forecasts And Estimates, retrieved from http://www.forbes.com/sites/louiscolumbus/2015/03/31/2015-roundup-of-3d-printing-market-forecasts-and-estimates/#279c46fc1dc6, on September 2015.

[5] Jacques Calì, Dan A. Calian, Cristina Amati, Rebecca Kleinberger, Anthony Steed, Jan Kautz, Tim Weyrich, Journal ACM Transactions on Graphics (TOG) - Proceedings of ACM SIGGRAPH Asia 2012, Volume 31 Issue 6, November 2012, Article No. 130

[6] Lipson, H., Kurman, M., Fabricated – The new world of 3D printing, John Wiley & Sons, Inc. 2013.

PREDICTION OF THE HDL CHOLESTEROL LEVEL BY USING ARTIFICIAL NEURAL NETWORKIG

Aleksandar Kupusinac[1], Edita Stokić[2], Andrea Katić[1], Marko Vasiljević[1], Ivan Stojić[1] Dunja Vrbaški[3]
[1]Faculty of Technical Sciences, University of Novi Sad, Novi Sad, Serbia
[2]University of Novi Sad, Medical Faculty, Novi Sad, Serbia
[3]University of Novi Sad, Medical Faculty, 2D Soft, Cara Dušana 7, 21000 Novi Sad, Serbia
e-mail: sasak@uns.ac.rs

Abstract: Artificial neural network (ANN) is a form of artificial intelligence that has been extensively applied in numerous research areas. ANNs take previously solved examples and learn hidden relationships between inputs and outputs. Trained ANNs are able to predict the output from a given input of new data. This paper presents prediction of HDL cholesterol level by using ANN. Input values are gender, age, body mass index and waist circumference. ANN training and testing are done by dataset that includes 1517 persons. Based on repeated random subsampling validation, the optimal ANN architecture has 14 hidden neurons and the average accuracy of our solution is 80.34%. This approach could be a useful tool in both, individual and public health prevention since it can select persons with increased risk of low HDL cholesterol level in an easy, non-invasive and cheap way.
Key words: Artificial neural networks, Cardiometabolic risk, HDL-cholesterol, Obesity.

INTRODUCTION

Between the main risk factors for coronary heart diseases, including diabetes, hypertension, dyslipidemia, the obesity is of particular importance since the increase of fat mass launches a cascade of adipokine-mediated metabolic, inflammatory and haemostasic disturbances accelerating the process of atherosclerosis (Stokić et al, 2009; Stokić et al, 2010; Klein et al 2007). The body mass index (*BMI*) is widely accepted and used to measure and define the obesity, based on numerous studies provided by many international and national institutions. The values $BMI \geq 25\ kg/m^2$ are classified as overweight, and values $BMI \geq 30\ kg/m^2$ are classified as obese and indicate increased risk of obesity-related adverse health outcomes (Klein et al 2007). The most intensive changes take place inside the visceral fat deposit of the abdomen and that is the reason why the central or abdominal obesity is specially associated with an increased cardiometabolic risk (Appel et al, 2004; Berg and Scherer, 2005; Rutter et al, 2005; Kupusinac et al, 2013). The waist circumference (*WC*) is often used as an effective marker of abdominal visceral fat content and comorbidities associated with obesity (Despres et al, 1990; Ashwell et al, 1996; Stevens et al, 2010). The values $WC \geq 80\ cm$ for women and $WC \geq 94\ cm$ for men indicate increased risk and are widely used in clinical practice. Disturbances of lipid and lipoprotein metabolism are present in 30% of obese persons and is manifested as one or more of disruptions stated: hypercholesterolemia, hypertriglyceridemia, drop of the level of protective HDL cholesterol (*HDL*) and increase of the level of LDL cholesterol (*LDL*) with increased fraction of small, dense, aterogenous LDL particles. *BMI* is inversely associated with *HDL*, directly associated with triglycerides and no significantly associated with *LDL* (Shamai et al, 2011).

In this paper, the feed-forward ANN with one hidden layer and back-propagation as the training algorithm has been applied to predicting *HDL* level based on gender (*GEN*), age (*AGE*), *BMI* and *WC*. We will test various ANN architectures in MATLAB (Neural Network Toolbox) and select an optimal. Then, we will consider *HDL* value for the limits $BMI = 30\ kg/m^2$ and $WC = 80\ cm$ for woman and $WC = 94\ cm$ for man.

MEASUREMENTS

The examined group consisted of 1517 respondents (792 women and 725 men) aged 18 to 76 years, with *BMI* values between 16.60 and 48.00 kg/m^2, *WC* values between 59.50 and 146 *cm* and with *HDL* values between 0.46 and 2.43 *mmol/l*. In the Table 1 are shown the minimal, average and maximal values.

Table 1. Dataset characteristics.

	Minimum	**Average**	**Maximum**
Women (*N=792*)			
AGE [*y*]	18	41.71	76
BMI [kg/m^2]	16.60	30.46	48.00
WC [*cm*]	59.50	92.55	145
HDL [*mmol/l*]	0.46	1.20	2.43
Men (*N=725*)			
AGE [*y*]	18	46.16	72
BMI [kg/m^2]	19.41	28.16	45.88
WC [*cm*]	61.20	97.67	146
HDL [*mmol/l*]	0.49	1.13	1.99
All (*N=1517*)			
AGE [*y*]	18	43.86	76
BMI [kg/m^2]	16.60	29.35	48.00
WC [*cm*]	59.50	95.02	146
HDL [*mmol/l*]	0.46	1.17	2.43

This study was completely conducted in accordance with the Declaration of Helsinki. The respondents volunteered and all measurements were taken in the morning hours (after the fasted overnight) at the Department of Endocrinology, Diabetes and Metabolic Disorders of the Clinical Centre of Vojvodina in Novi Sad (Serbia).
BMI is calculated on the following way:

$$\mathrm{BMI}[\mathrm{kg}/m^2] = \frac{\mathrm{BM}[\mathrm{kg}]}{(\mathrm{BH}[m])^2},$$

where *BM* is body mass measured using balanced beam scale with the precision of 0.1 *kg* and *BH* is body height measured using Harpenden anthropometer with the precision of 0.1 *cm*.
WC was measured using flexible tape with precision 0.1 *cm*, at the level of middle distance between the lowest point on the costal arch and the highest point on the iliac crest. The values *HDL* were determined by precipitation procedure with sodium-phospho-wolframate and the following reference values were used: *HDL*<1.03 *mmol/l* for men and *HDL*<1.29 *mmol/l* for women (Grundy et al, 2005).

ANN SYSTEM

This section presents our solution – ANN system for prediction of the *HDL* level. The ANN input values are vectors:

$$\overline{X}(i) = \left(\mathrm{GEN}(i), \mathrm{AGE}(i), \mathrm{BMI}(i), \mathrm{WC}(i)\right),$$

while the output values are:

$$Y(i) = \mathrm{HDL}(i),$$

where $i = 1, 2, \ldots, 1517$.
The optimal number of hidden neurons can be determined using various approaches, but we have used repeated random subsampling validation. The dataset is randomly divided into two parts with the proportion 90:10. The ANN training set is the first part (1365 persons) and the ANN testing set is the

second part (152 persons). In the testing phase, ANN estimates *HDL* based on given *GEN*, *AGE*, *BMI* and *WC* and the prediction accuracy is:

$$\mathrm{AC}[\%] = 100\left(1 - \frac{|\mathrm{HDL}^{*} - \mathrm{HDL}|}{\mathrm{HDL}}\right),$$

where *HDL* is the measured value and HDL^* is the value estimated by ANN. Various architectures with one hidden layer and 1-15 hidden neurons were trained and tested 100 times. The trained ANNs were tested on the unknown data (testing set). The mean square error *MSE* and mean prediction accuracy *MPA* were calculated. The obtained results are given in Table 2. and presented in form *mean±standard_deviation*.

Table 2. Testing phase.

Hidden neurons	*MSE±SD*	*MPA±SD*
1	0.0789±0.0075	79.8057±0.7651
2	0.0807±0.0065	79.8624±0.9251
3	0.0804±0.0193	80.0998±0.7960
4	0.0771±0.0086	80.0130±0.7272
5	0.0773±0.0067	80.0917±0.9454
6	0.0779±0.0083	80.0604±0.8469
7	0.0801±0.0086	80.0585±1.0983
8	0.0794±0.0084	80.0293±0.9824
9	0.0781±0.0080	80.2477±0.9234
10	0.0792±0.0085	80.1119±0.8728
11	0.0804±0.0075	79.9793±0.7973
12	0.0801±0.0068	79.9741±0.7386
13	0.0802±0.0097	79.9843±1.1178
14	**0.0779±0.0075**	**80.3356±0.9359**
15	0.0791±0.0069	80.2374±0.8182

Every trained ANN architecture was asked to estimate *HDL* value for the limits *BMI* = 30 kg/m^2 and *WC* = 80 *cm* for woman and *WC* = 94 *cm* for man. The average estimated *HDL* values are given in the Table 3.

Table 3. Estimated *HDL* values.

Hidden neurons	Women	Men
1	1.1834	1.1380
2	1.1857	1.1370
3	1.1864	1.1366
4	1.1942	1.1311
5	1.1959	1.1231
6	1.2026	1.1147
7	1.2203	1.1254
8	1.2191	1.1198
9	1.1915	1.1058
10	1.2140	1.0947
11	1.2349	1.0972
12	1.2355	1.0835
13	1.2446	1.0984
14	**1.2438**	**1.0861**
15	1.2404	1.0890

Based on results given in the Table 3, we conclude that the single-layered ANN architecture with 14 hidden neurons provides the maximal mean prediction accuracy with standard deviation as small as possible (80.3356±0.9359) and it is accepted as the optimum and depicted on the Figure 1. From Table 4, optimal ANN (with 14 hidden neurons) estimated the following *HDL* values:

- *HDL* = 1.2438 *mmol/l* for the limits *BMI* = 30 kg/m^2 and *WC* = 80 *cm* for woman.
- *HDL* = 1.0861 *mmol/l* for the limits *BMI* = 30 kg/m^2 and *WC* = 94 *cm* for man.

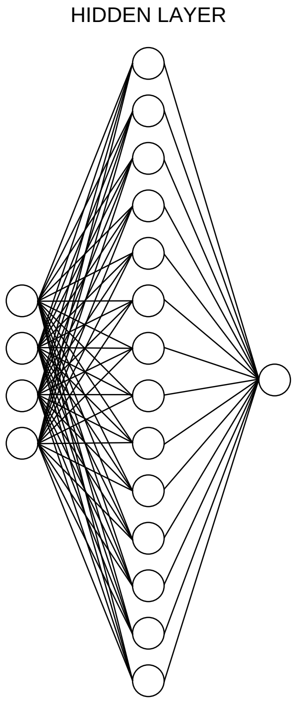


Figure 1.

CONCLUSION

In this paper, we have presented an ANN solution for predicting *HDL* level based on gender (*GEN*), age (*AGE*), *BMI* and *WC*. Based on our results, value *HDL* = 1.2438 *mmol/l* corresponds to a woman with *BMI* = 30 kg/m^2 and *WC* = 80 *cm*. Also, value *HDL* = 1.0861 *mmol/l* corresponds to a man with *BMI* = 30 kg/m^2 and *WC* = 94 *cm*. This approach could be a useful tool in both, individual and public health prevention since it can select persons with increased cardiometabolic risk in an easy, non-invasive and cheap way.

REFERENCES

[1] Appel SJ, Jones ED, Kennedy-Malone L. (2004) Central obesity and the metabolic syndrome: implications for primary care providers. J Am Acad Nurse Pract 16, 8, 335-342.

[2] Ashwell MA, LeJeune SRE, McPherson K. (1996) Ratio of waist circumference to height may be better indicator of need for weight management. British Medical Journal 312, 377.

[3] Berg AH, Scherer PE. (2005) Adipose tissue, inflammation, and cardiovascular disease. Circ Res 96, 939-949.

[4] Despres, J, Moorjani, S, Lupien, PJ, Tremblay A, Nadeau A, Bouchard C. (1990) Regional distribution of body fat, plasma lipoproteins, and cardiovascular disease'. Arteriosclerosis 10, 4, 497-511.

[5] Grundy SM, Cleeman JI, Daniels SR, Donato KA, Eckel RH, Franklin BA, Gordon DJ, Krauss RM, Savage PJ, Smith SC Jr, Spertus JA, Costa F (2005) Diagnosis and management of the metabolic syndrome: an American Heart Association/National Heart, Lung, and Blood Institute Scientific Statement. Circulation 112, 2735-2752.

[6] Klein S, Allison DB, Heymsfield SB, Kelley DE, Leibel RL, Nonas C, Kahn R. (2007) Waist circumference and cardiometabolic risk: a consensus statement from Shaping America's Health: Association for Weight Management and Obesity Prevention; NAASO, The Obesity Society; the American Society for Nutrition; and the American Diabetes Association. Am J Clin Nutr 85, 1197–1202.

[7] Kupusinac A, Doroslovački R, Malbaški D, Srdić B, Stokić E (2013) A primary estimation of the cardiometabolic risk by using artificial neural networks. Comput Biol Med 43, 6, 751-757.

[8] Rutter MK, Meigs JB, Sullivan LM, D'Agostino RB, Wilson PW. (2005) Insulin resistance, the metabolic syndrome, and incident cardiovascular events in the Framingham Offspring Study. Diabetes 54, 11, 3252-3257.

[9] Shamai L, Lurix E, Shen M, Novaro GM, Szomstein S, Rosenthal R, Hernandez AV, Asher CR. (2011) Association of body mass index and lipid profiles: evaluation of a broad spectrum of body mass index patients including the morbidly obese. Obes Surg 21, 1, 42-47.

[10] Stevens J, Katz EG, Huxley RR. (2010) Associations between gender, age and waist circumference. Eur J Clin Nutr 64, 6-15.

[11] Stokić E, Tomić-Naglić D, Djerić M, Jorga J. (2009) Therapeutic options for treatment of cardiometabolic risk. Med Pregl 62 Suppl 3, 54-58.

[12] Stokić E, Brtka V, Srdić B. (2010) The synthesis of the rough set model for the better applicability of sagittal abdominal diameter in identifying high risk patients. Comput Biol Med 40, 9, 786-790.

Session 9.

Biotechnology

FLUORESCENCE SPECTROSCOPY, COLORIMETRY AND NEURAL NETWORKS IN DISTINGUISHING DIFFERENT TYPES OF HONEY

Krastena Nikolova[1], Diana Tsankova[1], Tinko Evtimov[2]
[1]University of Food Technologies, Plovdiv, Bulgaria,
[2]Plovdiv University "Paisii Hilendarski", Plovdiv, Bulgaria
e-mail: kr.nikolova@abv.bg

Abstract: The aim of the article is to investigate the optical properties of Bulgarian honey in regard to the potential of honey discrimination on the base of its botanical origin. Samples from three types of honey (acacia, linden, and honeydew) are measured by a fluorescence spectrometer recording emission from 350 to 800 nm with excitation at 370, 395 and 405 nm. Principal components analysis (PCA) is used for reducing the number of inputs (wavelengths) and for a proper visualization of the experimental results. A combination of fluorescence emission spectra with some colorimetric parameters (CIELab) is used for training data of a neural network (a multilayered perceptron) with backpropagation learning algorithm. The good accuracy of the proposed neural network based honey classifier is confirmed by a validation test carried out in MATLAB environment.
Key words: fluorescence spectroscopy, honey discrimination, PCA, artificial neural network

INTRODUCTION

Honey is a mixture of sugars (70-80 %) and water (10-20 %) containing a large number of minor constituents. The main sugars found in honey are the monosaccharides, fructose and glucose [10]. Honey is known to be rich in enzymatic and non-enzymatic antioxidants, including glucose-oxidase, catalase, flavonoids, ascorbic acid, phenolic acids and carotenoids [1, 2]. Its composition depends highly on the type of flowers as well as the climatic conditions [19].
Production of natural honey is a laborious process, which is time consuming and involves a lot of cost. Therefore honey is often subject to falsification by adding sugar and other impurities. Furthermore, the botanical and geographical declaration of the origin seems to be one of the fundamental aspects of the honey quality that affects its commercial value [13, 17]. So in order to prevent fraud in the labeling, it should be developed a means of distinguishing between different types of honey.
At the current stage of knowledge, a reliable authentication of floral origin of honey can be achieved by a global interpretation of sensory, pollen and physicochemical analyses carried out by an expert [11, 14, 15]. The content of different phenolic compounds is recognized to well reflect the type of honey and its quality, because phenolic acids and flavonoids are inherent chemical markers of the floral origin [12, 17]. Unfortunately, the most of these methods are generally too time-consuming, complex, and labour intensive for quality control application or require very specialized personnel to interpret the results.
In addition, most of the analytical techniques involve some kind of sample pre-treatment. The advantages of the technique of spectroscopy (visible, near and middle infrared, fluorescent) with respect to other methods are the non-invasive approach, the relatively easy and quick data acquisition. The principal advantages of fluorescence spectroscopy, pointed out by almost all authors, are its rapidity and sensitivity [16] (100–1000 times more sensitive than other spectrophotometric techniques [14, 15]).
Food contains many different fluorophores, whose signals overlap and make it impossible to measure the concentration of a single compound. Nevertheless, the shape of normalized fluorescence spectra in combination with multivariate statistics can be used to characterize and identify different food [14, 15], including different types of honey.
Due to the correlation of incoming data, statistical classification methods (linear discriminant analysis, naive Bayesian classifier, and so on) encounter some computational difficulties such as 'badly scaled or close to singular matrix'. Artificial neural networks overcome these problems at processing raw data and can be used for multivariate analysis to create more accurate classifiers [6].
The purpose of this study is to investigate the optical properties of Bulgarian honey and the possibility of recognizing its botanical origin using fluorescence spectroscopy in right-angle fluorescence mode.

Spectroscopic data obtained undergo subsequent statistical processing including principal components analysis (PCA), which is used for reducing the input space dimension and visualizing the clusters formed by different types of honey. An artificial neural network (NN) with Backpropagation (BP) learning algorithm is proposed to classify honey in appropriate classes related to its floral origin. The performance of the neural calibration model is confirmed by leave-one-out-cross validation test in MATLAB environment.

MATERIAL AND METHODS

Honey spectrum acquisition

Thirty-two samples of three different types of Bulgarian honey (acacia – 8 samples; linden – 10 samples; and honeydew – 14 samples) were purchased from supermarkets (Lexie, Kaufland, Piccadilly) and from private producers. Before spectral measurement, the honey samples were placed in a water container at 50^0C until the soluble substances fully dissolved. Then the samples were annealed at room temperature (25-26^0C).
The fluorescence spectral characteristics of the honey were taken with a fiber optic spectrometer (AvaSpec-2038, Avantes) with sensitivity in the (200-1100) nm range. The sources used to measure the fluorescence spectra are 370 nm, 395 nm, 405 nm light emitting diodes (LEDs). The resolution of the spectrometer is about 8 nm for a 200 μm input slit. An optical fiber with a diameter of 200 μm is used to bring light to the probe and to measure the scattered and fluorescent light. A collimator with a lens of an aperture D = 5 mm is used to gather more light and send it to the receiver.
Generally, with classical right-angle fluorescence spectroscopy, the measurements are carried out in dilute solutions where the absorbance is below 0.1 [14, 15]. At a higher absorbance rate, the fluorescence intensity decreases due to the inner filter effect. In that case the front-face fluorescence spectroscopy is more suitable for use. In the presented study, in order to measure the fluorescence spectra of honey (especially dark honeydew honey) without dilution, the cuvette holder was modified as follows. The first probe (optical fiber) was placed between two glass slides, which were fixed by a threshold, consistent with the diameter of the probe. The second probe (LEDs) was fixed on the upper glass, 90^0–angle to the first and the minimum distance between them. Honey was located between the two slides. The resulting emission spectra with excitation at 370 nm, 395 nm, 405 nm were normalized by dividing with the maximum intensity value of the respective excitation signal.

Colour, β-carotene and water content measuring

The following measurements were determined according to the methods of the European Honey Commission [5]. All measurements were performed at room temperature. Colorimetric study of honey was made using a software package VISIONlite ColorCalc for spectrophotometer Helios Omega. It was used mode 'Advanced', i.e. calculations were performed in the range of 380 nm -780 nm (instead of ‘Basic’ mode: 400 nm – 700 nm). The honey samples were placed in a cuvette 10 mm x 10 mm (Recommendations on uniform color spaces, 1971) and the color parameters in CIELab colorimetric system were measured.
The β – carotene was calculated by using the transmission spectra in the visible region and values for color parameters by software program developed specially for Lovibond PFX 880 from the producer.
The water content was determined by measuring the refractive index of honey at room temperature with Abbe’s refractometer. The data were corrected at 20^0C and values were obtained using methods adopted by the International Honey Commission [5].

Principal components analysis [8, 9]

The aim of the method is to reduce the dimensionality of multivariate data (e.g., wavelengths) whilst preserving as much of the relevant information as possible. PCA is a linear transformation, that transforms the data (observations of possibly correlated variables) to a new coordinate system such that the new set of variables, *the principal components*, are linear functions of the original variables. PCs are uncorrelated, and the greatest variance by any projection of the data comes to lie on the first

coordinate, the second greatest variance on the second coordinate, and so on. This is achieved by computing the covariance matrix for the full data set. Then, the eigenvectors and eigenvalues of the covariance matrix are computed, and sorted according to decreasing eigenvalue [8, 9].
All the principal components are orthogonal to each other. The full set of principal components is as large as the original set of variables. Usually the sum of the variances of the first few principal components exceeds 80% of the total variance of the original data [18].
In this study, the first two PCs are used mainly for the purposes of visualization.

Artificial neural network based classifier

It is well known that artificial neural networks with a feedforward multilayered structure are universal function approximators [4, 7]. One classification task can be easily reduced to a task for approximation. Let the classifier of honey be implemented as a neural network with a feedforward structure and Backpropagation (BP) learning algorithm. The neural network consists of $n + 3$ inputs (n is the number of wavelengths included in the emission spectrum characteristics of the honey), 3 outputs and 2 hidden layers. The three additional inputs are designed for the 3 colorimetric indicators (parameters L, a and b) of the CIELab system. The proposed combination of fluorescent emission spectra with the three colorimetric parameters of CIELab system aims to increase the accuracy of predicting the floral origin of honey. The three outputs of the network correspond to the three classes of honey: acacia, linden and honeydew honey. The two hidden layers contain neurons with 'tansigmoid' activation function (hyperbolic tangent), and the activation function of the three output neurons is 'logsigmoid' [3].
The method of the PCs is applied to one of the emission spectra (Ex. 370 nm), extended by the three colorimetric parameters L, a and b (total $n + 3$ inputs). The resulting $n + 3$ PCs are used as input training samples for the neural network. The supervisor supplies the network's output with the following three combinations: '1 0 0', '0 1 0' or '0 0 1', depending on whether the input receives the data for the classes 'acacia', 'linden' or 'honeydew', respectively. BP is a gradient-based learning algorithm, that minimizes the sum squared error between the real and required input of the NN. The leave-one-out-cross-validation test is used to validate the NN-based honey classifier.

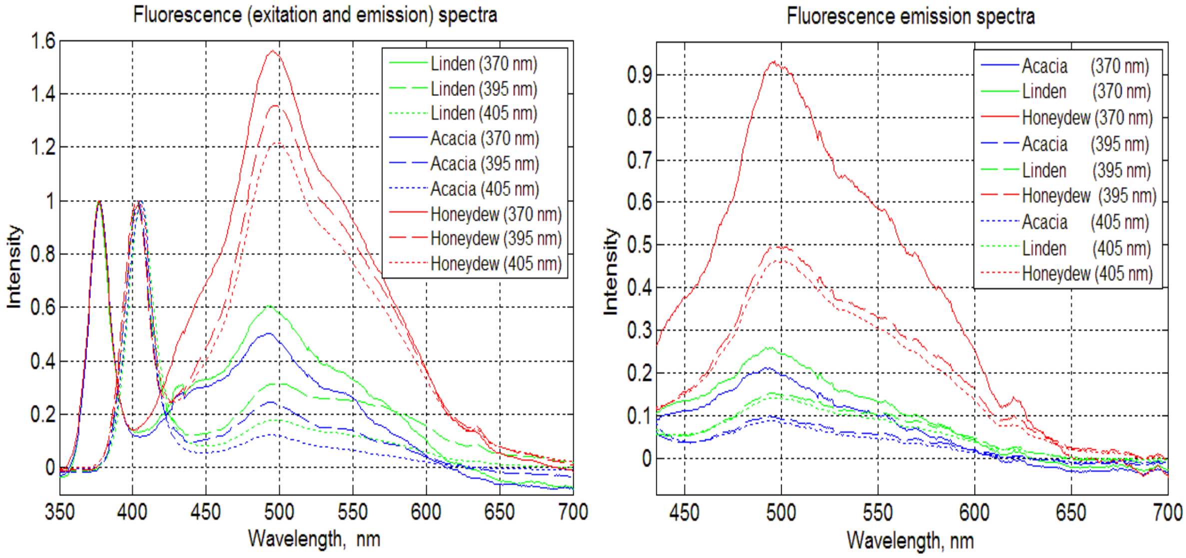
RESULTS AND DISCUSSION

Fluorescence spectra, colour, β-carotene and water content of honey

The normalized fluorescence spectra of a random sample from the three types of honey (acacia, linden, and honeydew) with wavelengths ranging in visible domain under excitation at 370 nm, 395 nm, and 405 nm are shown in Fig.1a. The first maxima (with magnitude 1) correspond to the excitation signals, and the second maxima – to the emission spectra's significant values. The averaged fluorescence (emission) spectra of the three classes of honey (acacia, linden and honeydew) at 370 nm, 395 nm and 405 nm excitation are shown in Fig.1b.
Generally, for each type of honey the emission with the highest intensity was obtained at the excitation wavelength of 370 nm, and the lowest intensity - at 405 nm. The honeydew honey had the highest intensity of emission in respect to the other types of honey, and the acacia honey – the lowest intensity. The mean values of the wavelengths with maximum emission varied from 476 nm to 502 nm, under standard deviation from 1.4 nm to 28.9 nm.
Table 1 shows the mean values and standard deviations of the water content, β-carotene and the CIELab colour parameters related to the different classes (types) of honey. Moisture content is an important quality parameter that influences the shelf life of honey [5]. It ranged between 13.92% and 18.90% for all 32 samples presented and it was below the upper limit of 20% set by the relevant EU directive.

NN-based model for classification of honey- calibration and testing

Since the intensity of emission spectra of the three types of honey is greatest at excitation of 370 nm (Fig.1b), only the spectral characteristics at this excitation were used for the synthesis of a honey's classifier. PCA was carried out in order to visualize data from different honey samples and to identify their similarities and differences. Using PCA, the spectral dimensionality was reduced to a small number (two) of principal components. The scores scatter plot of the 1st and 2nd PCs is shown in Fig.2a, where samples from classes ‘Acacia’, ‘Linden’ and ‘Honeydew’ are marked with circular, triangular and squared symbol, respectively. It is evident that the samples form three clusters (acacia, linden and honeydew), which are overlapped. Here, determining the type of honey is based solely on the inscription on the label by the manufacturer, i.e. trusting the manufacturer. The two PCs suitably visualize the honey’s spectra, but the information contained in them is not enough to properly distinguish different types of honey. Therefore PCA was applied to a combination of fluorescence spectra characteristics and the three indicators (*L*, *a*, *b*) of the colorimetric system CIELab. In this case the first two PCs explain as high as 94.27 % of variance of the combined data (76.21 % for PC-1 and 18.06 % for PC-2). The result (Fig. 2b) shows a better distinguishing between different types of honey, with the exception of a few overlapping samples of classes ‘acacia’ and ‘linden’.



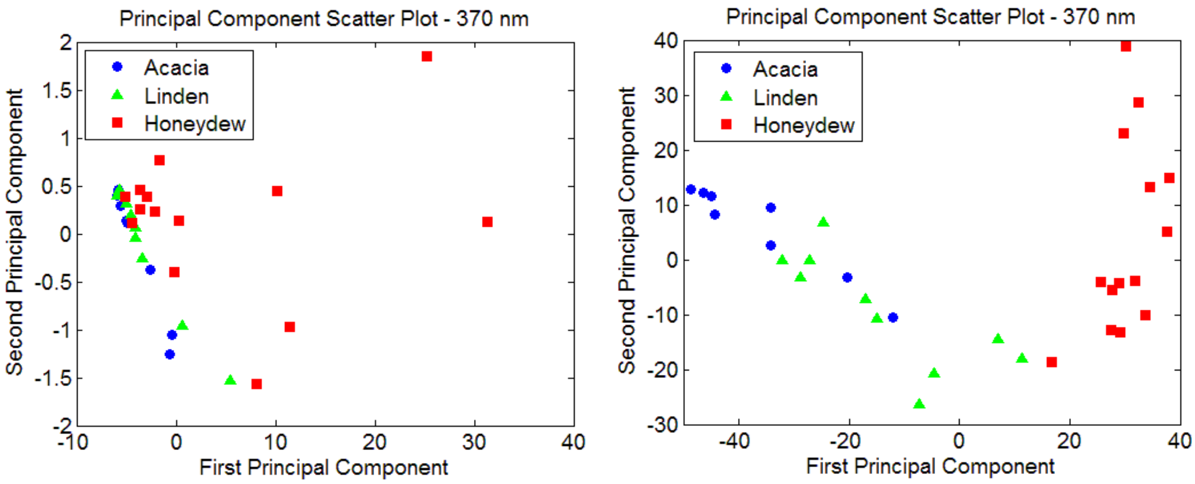
(a) (b)

Figure 1. Fluorescence spectra at excitation of 370 nm, 395 nm and 405 nm: (a) excitation and emission spectra for one sample from the three types of honey; (b) the average emission spectra of the three classes of honey (acacia, linden and honeydew).

Table 1. Water content, β-carotene, and colour parameters of honey

		Acacia honey		**Linden honey**		**Honeydew**	
		Average value	Standard deviation	Average value	Standard deviation	Average value	Standard deviation
Water content, %		16.30	1.17	16.50	1.08	15.97	0.95
β- carotene		7.11	2.58	15.53	10.24	18.52	21.46
CIE-Lab Values (Ill. D65 / 10 deg Observer / 380-780 nm)	L	92.45	5.46	85.35	6.63	51.27	12.80
	a	0.29	1.78	3.05	4.78	27.94	5.83
	b	32.01	15.00	57.65	16.72	74.54	11.63

The neural classifier was trained using the values of all PCs, obtained by PCA applied to the enriched data (spectral characteristics of fluorescence + colour parameters *L*, *a*, *b*). The number of neurons in the first and second hidden layers of the neural network was selected heuristically - 500 and 250, respectively. The efficiency of the neural network classifier was confirmed by leave-one-out-cross-validation test (in MATLAB environment [3]), the result of which is shown in Fig. 3 and Table 2. As evident in Table 2, 2 samples from observed class 'acacia' are predicted wrong as 'linden', while 3 samples from class 'linden' – as 'acacia'. The model predicts 27 out of 32 samples correctly. 84.4% prediction accuracy (75% class 'acacia', 70% class 'linden', and 100% class 'honeydew') is achieved.



(a) (b)

Figure 2. PCA of: (a) the honey's fluorescent spectra (b) a combination of the honey's fluorescent spectra and CIELab's parameters

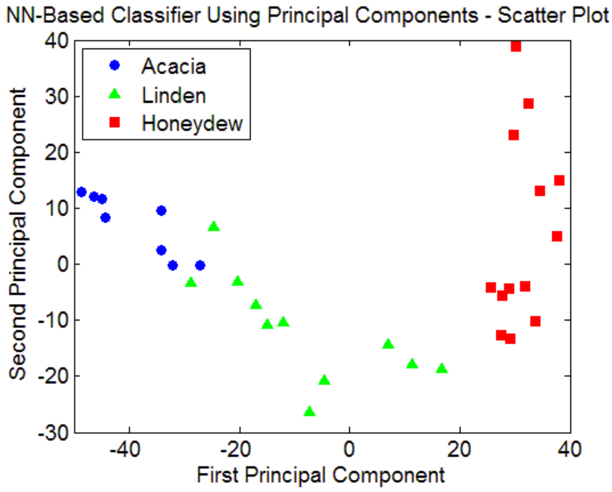


Figure 3. PCA based visualization of leave-one-out-cross-validation test of the proposed neural network based classifier of honey

Table 2. Discrimination accuracy of NN-based model

		Predicted Class by PC-NN			
		Acacia	Linden	Honeydew	
Observed Class	Acacia	6	2	0	8
	Linden	3	7	0	10
	Honeydew	0	0	14	14
		9	9	14	

CONCLUSION

In this article the optical properties of Bulgarian honey were investigated in regard to the potential of honey discrimination on the base of its botanical origin. The fluorescence spectra combined with the colorimetric parameters of CIELab were used for training the neural network based classifier. The classifier shows a good prediction accuracy, 84.4%, determined by the 32 leave-one-out-cross-validation tests. The neural network is open for new honey samples which will precise the clustering and maybe will improve the performance of the honey's floral origin predictor. Future work will include a comparative analysis of the proposed neural network classifier and some popular statistical classifiers, such as those based on a linear or a quadratic discriminant analysis, as well as the use of fluorescence spectra with excitation and emission in the UV region.

ACKNOWLEDGEMENTS

The paper presents research and development, supported by Scientific Fund of Internal Competition of the University of Food Technologies – Plovdiv under the Research Project No.7/14-H.

REFERENCES

[1] Aljadi A. M., Kamarrudin M. Y., Evaluation of the phenolic contents and antioxidant capacities of two Malaysian floral honeys, Food Chemistry, Vol.85, pp.513-518, 2004.
[2] Batrusaityte V., Venskutonis P.R., Ceksteryte, V., Radical scavenging activity of different floral origin honey and beebread phenolic extracts, Food chemistry, Vol.80, pp.249-254, 2007.
[3] Beale, M.H., Hagan, M.T., Demuth, H.B., Neural Network Toolbox™, User's Guide, The MathWorks Inc., 1992-2015. https://www.mathworks.com/help/pdf_doc/nnet/nnet_ug.pdf
[4] Blum, E.K., Li, L.K., Approximation theory and feedforward networks, Neural Networks, Vol.4, pp.511-515, 1991.
[5] Bogdanov S., Martin P., Lullmann C., Harmonised methods of the European honey commission, Apidologie, pp.1-59, extra issue, 1997.
[6] Chen, L., Wang, J., Ye, Z., Zhao, J., Xue, X., Vander Heyden, Y., Sun, Q., Classification of Chinese honeys according to their floral origin by near infrared spectroscopy. Food Chemistry, Elsevier Ltd, Vol.135, No.2, pp.338-342, 2012.
[7] Hornik, K., Stinchcombe, M., White, H., Multilayer feedforward networks are universal approximators, Neural Networks, Vol.2, pp.359-366, 1989.
[8] Hotelling, H., Analysis of a Complex of Statistical Variables into Principal Components. Journal of Educational Psychology, Vol.24, No.6 & 7, pp.417–441 & pp.498–520, 1933.
[9] Jolliffe, I. T., Principal Component Analysis. Second ed. Springer Series in Statistics. New York: Springer-Verlag New York, 2002.
[10] Nagai T., Inoue R., Inoue H., Suzuki N., Scavenging capacities of pollen extracts from Cistus ladaniferus on autoxidation superoxide radicals, hydroxyl radicals and DPPH radicals. Nutrition Research, Vol.22, pp.519-526, 2002.
[11] Persano Oddo, L., Bogdanov, S., Determination of Honey Botanical Origin: Problem and Issues. Apidologie, Vol.35 (special issue), pp.2-3, 2004.
[12] Pyrzynska, K., Biesaga, M., Analysis of phenolic acids and flavonoids in honey. Trends in Analytical Chemistry, Vol.28, pp.893–902, 2009.
[13] Robbins, R. J., Phenolis acids in foods: An overview of analytical methodology. Journal of Agricultural and Food Chemistry, Vol.51, pp.2866–2887, 2003.
[14] Ruoff, K., Authentication of the Botanical Origins of Honey, A Dissertation for the degree of Doctor of Sciences, University of Helsinky, p.32, 2006.
[15] Ruoff, K., Karoui, R., Dufour, E., Luginbuhl, W. , Bosset, J.O., Bogdanov, S., Amado, R., Authentication of the botanical origin of honey by front-face fluorescence spectroscopy. A preliminary study. J Agric Food Chem. Vol.53, No.5, pp.1343-1347, 2005.
[16] Sádecká J., Tóthová J., Fluorescence spectroscopy and chemometrics in the food classification − a review. Czech J. Food Sci., Vol.25, pp.159–173, 2007.
[17] Sergiel, I., Pohl, P., Biesaga, M., Mironczyk, A., Suitability of three-dimensional synchronous fluorescence spectroscopy for fingerprint analysis of honey samples with reference to their phenolic profiles, Food Chemistry, Vol.145, pp.319–326, 2014. http://dx.doi.org/10.1016/j.foodchem.2013.08.069
[18] Statistics Toolbox™ User's Guide, R2014a, The MathWorks, Inc., 1993–2014.
[19] Tarboush, A., Kahtani, A., El-Sarrage, M.S., Floral type identification and quality of some honey types, Food Chemistry, Vol.46, pp.13-17, 1993.

OPTIMIZATION OF FERMENTATION MEDIUM COMPOSITION FOR LIPASE PRODUCTION BY *RHIZOPUS ARRHIZUS* DURING SUBMERGED FERMENTATION

Hristina Strinska[1], Valentina Dobreva[1], Boriana Zhekova[1], Georgi Dobrev[1]
[1]University of Food Technologies, Plovdiv, Bulgaria
e-mail: hstrinska@gmail.com

Abstract: In order to decrease the price of the final product alternative sources of organic nitrogen – fish meal and cottonseed meal were examined. The highest lipase activity (5459.71 U.dm^{-3}) was achieved by using fermentation medium with cottonseed meal in concentration of 30.0 g.dm^{-3}. This activity was about 20% higher than the control with tryptone. The new fermentation medium was optimized by central composite design 2^3. A mathematical model was developed which was used to predict final lipase activity 7076.57 U.dm^{-3} by using 4.0 g.dm^{-3} corn starch, 30.0 g.dm^{-3} cottonseed meal and 10.3 g.dm^{-3} ammonium phosphate. The results were confirmed by three experiments with average lipase activity 6631.00 U.dm^{-3} which is close to the predicted one.

INTRODUCTION

Lipase (triacylglycerol hydrolase) is an enzyme which catalyzes the hydrolysis of triacylglycerol and in the absence of water – reactions of esterification and transesterification. Lipases are enzymes with great application in many industries. They find application as additives in food, fine chemicals, detergent, cosmetics, pharmaceuticals, leather and biomedical assays. Additionally, lipases have an important application in bioenergy, especially in biodiesel production. That is the reason for the great interest in lipase production [1].

The source of nitrogen is of a great importance for lipase production. Scientists are interested in finding cheap and pervasive materials. Widely used in biotechnological practice are: peptone [11], yeast extract [8] and so on. Thirunavukarasu et al. use fish meal for lipase production from *Cryptococcus* sp. MTCC 5455 [10]. Yang et al. use soybean meal as source of organic nitrogen for biosynthesis of lipase from *Rhizopus arrhizus* [12].

Bioconversion of agricultural residues for lipase production is of a great importance mainly due to their low cost, accessibility and nutrient compositions [1]. D'Annibale et al. and Brozolli et al. use olive-mill wastewater for a production of extra-cellular lipases by *Candida cylindracea* NRRL Y-17506 [3, 4]. Asses et al. also use olive-mill wastewater for lipase production by *Geotrichum candidum* [2].

The aim of this study is investigation of alternative materials (cottonseed meal and fish meal) as sources of organic nitrogen and optimization of fermentation medium composition for biosynthesis of lipase from *Rhizopus arrhizus* using response surface methodology.

MATERIAL AND METHODS

Microorganism Maintenance and Storage

The studied *Rhizopus arrhizus* strain used in this study was provided by Biovet® Peshtera. It was grown in the following medium, g.dm^{-3}: malt extract, 10.0; yeast extract, 4.0; glucose, 4.0; agar-agar 20.0. pH was adjusted to 7.0. The strain was cultivated at 28°C for 14 days and stored at 4°C.

Vegetative Inoculum Preparation

0.5 cm^3 spore suspension (2×10^8 spores.cm^{-3}) was added to 100 cm^3 sterilized (at 121°C for 30 min) medium with pH 7.0 with the following composition (g.dm^{-3}): glucose, 30.0; peptone, 20.0; $MgSO_4.7H_2O$, 0.5; KH_2PO_4, 1.0; $NaNO_3$, 1.0; $CaCO_3$, 1.0. The strain was cultivated on a rotary shaker (180 min^{-1}) at 28°C for 24 h.

Submerged Cultivation

Submerged cultivation was carried out in 500 cm^3 flasks containing 100 cm^3 medium with composition corresponding to the aim of the study. pH of the medium was adjusted to 7.0, then the medium was sterilized at 121°C for 30 min. 5.0 cm^3 vegetative inoculum was used for inoculating each flask and cultivation was carried out at 28°C for 64 h at a rotary shaker (180 min^{-1}).

Influence of organic nitrogen sources

For studying the influence of organic nitrogen sources fermentation medium with composition ($g.dm^{-3}$) was used: corn starch, 10.0; nitrogen source, 10.0-30.0; $NH_4H_2PO_4$ 7.1; $(NH_4)_2C_2O_4$, 1.0; $MgSO_4$, 1.49 и KCl, 1.89. The cultivation process was performed according to the procedure described above.

Response surface methodology

Central Composite Design (CCD) was employed for optimization of the medium composition and to study the interaction between: corn starch, cottonseed meal and $NH_4H_2PO_4$. For this study fermentation medium with the following composition was used ($g.dm^{-3}$): corn starch; cottonseed meal; $NH_4H_2PO_4$; $(NH_4)_2C_2O_4$, 1.0; $MgSO_4$, 1.49 и KCl, 1.89. Each parameter was studied at five different levels (-1.682, -1, 0, +1, and +1.682).

Table 1. Values of independent variables at different levels of the optimal composite design 3^2

Independent variables	Levels				
	-1.682	**-1**	**0**	**+1**	**+1.682**
X_1 Corn starch, $g.dm^{-3}$	1.6	5.0	10.0	15.0	18.4
X_2 Cottonseed meal, $g.dm^{-3}$	13.2	20.0	30.0	40.0	46.8
X_3 $NH_4H_2PO_4$, $g.dm^{-3}$	2.3	4.0	6.5	9.0	10.7

A matrix of 17 experiments with four factors was generated. The lipase activity was taken as the dependent variable or response (Y). According to the obtained results a regression analysis was accomplished and a quadratic regression model was expressed as follows:

$$\hat{Y} = b_0 + \sum_{i=1}^{m} b_i . x_i + \sum_{i=1, j=i+1}^{m} b_{ij} . x_i . x_j + \sum_{i=1}^{m} b_{ii} . x_i^2 \qquad (1)$$

Where Ŷ is the response variable, b_0, b_j, b_{ij}, b_{ii}-the regression coefficients of the model, and x_i and x_j-coded levels of the independent variables [7].
The cultivation process was performed according to the procedure described above.

Lipase assay

Lipase activity was measured by spectrophotometric method using p-nitrophenyl palmitate as substrate buffered with Tris-HCl pH 9.0 [6]. Reaction mixture with 2.4 cm^{-3} of freshly prepared substrate and 0.1 cm^{-3} enzyme was incubated for 15 min at 35°C and the reaction was stopped by adding 1 cm^3 plumbous acetate. After centrifugation absorbance was measured at 405 nm. One unit of enzyme activity was defined as the amount of enzyme that released one µmol of p-nytrophenol per minute under the assay conditions described.

RESULTS AND DISCUSSION

In a previous study it was discovered that the most appropriate organic nitrogen source for lipase production by *Rhizopus arrhizus* during submerged fermentation was tryptone [5]. Because of its high cost experiments for changing triptone with cheaper products (cottonseed meal and fish meal) were prepared.

The influence of the two components on lipase biosynthesis was studied (Table. 1). As seen from the table when cottonseed meal was added at concentration 30 g.dm^{-3} lipase activity 5459.71 U.dm^{-3} was achieved, which was about 20% higher that the control with tryptone (4540.35 U.dm^{-3}). As seen from the results the fish meal strongly inhibited lipase biosynthesis.

Table 2. Influence of organic nitrogen sources on lipase activity in the fermentation broth

Organic nitrogen sources	Concentration, g.dm^{-3}	Lipase activity, U.dm^{-3}
Tryptone	6.6	4540.35
Cottonseed meal	10.0	2000.49
	20.0	3945.47
	30.0	5459.71
Fish meal	10.0	329.41
	20.0	246.52
	30.0	464.61

In order of optimization of the fermentation medium a planned mathematical experiment 2^3 was accomplished for defining the optimal concentrations of corn starch, cottonseed meal and ammonium phosphate (Table 3).

Table 3. Central composite design 2^3

№	Codded values			Lipase activity, U.dm^{-3}	
	X_1	X_2	X_3	Y^a	$\hat{Y}$
1	1	1	1	5102.61	4364.61
2	-1	1	1	8512.85	8693.68
3	1	-1	1	2155.25	2124.92
4	1	1	-1	2249.89	3158.84
5	-1	-1	1	6838.37	6191.16
6	-1	1	-1	3426.13	3718.21
7	1	-1	-1	3439.65	3520.57
8	-1	-1	-1	2817.73	3817.11
9	1.682	0	0	2398.61	2393.12
10	-1.682	0	0	6647.09	6282.76
11	0	1.682	0	5511.41	5254.75
12	0	-1.682	0	3568.09	3454.57
13	0	0	1.682	5511.41	6371.76
14	0	0	-1.682	4592.05	3361.50
15	0	0	0	4483.89	5691.89
16	0	0	0	6836.37	5691.89
17	0	0	0	5889.97	5691.89

[a] results are a mean value of three replications
X_1 – corn starch;
X_2 – cottonseed meal;
X_3 – $NH_4H_2PO_4$.

The results from the regression analysis are presented in Table 4. The ANOVA table partitions the variability in the composite plan into separate pieces for each of the effects and then tests the statistical significance of each effect. In this case, two effects had P-values less than 0.05 – X_1 and X_3, indicating that they were significantly different from zero at the 95.0 % confidence level. As seen from the table none of the interaction effects were significant.

Table 4. Regression analysis results

Effect	Coefficient	Standard error	P-value
Average	5691.89	821.70	
X_1	-1156.40	630.75	0.0105
X_2	535.19	630.75	0.1406
X_3	894.96	630.75	0.0297
$X_1.X_2$	-65.71	824.11	0.8785
$X_1.X_3$	-942.43	824.11	0.0622
$X_2.X_3$	650.35	824.11	0.1656
X_1^2	-478.69	765.82	0.2578
X_2^2	-472.78	765.82	0.2631
X_3^2	-291.77	765.82	0.4749

The significant effects were clearly presented in Paretto Chart (Figure 1).

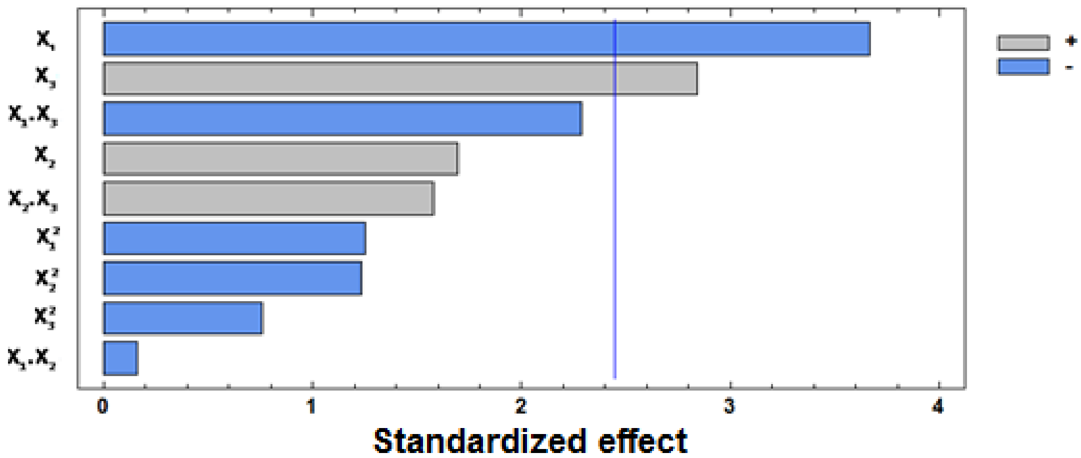


Figure 1. Paretto chart.

Standardized Pareto Chart (Fig. 1) is a histogram with the effects plotted in decreasing order of their significance. The vertical line through the chart depends on the value of alpha and the significant factors extend beyond that line. As seen from the chart the most significant effect was the corn starch concentration followed by the ammonium phosphate concentration.

The R-squared statistic of the model was 85.11%. The standard error of the estimate showed the standard deviation of the residuals to be 1165.4. The mean absolute error (MAE) of 566.36 is the average value of the residuals. In this case Durbin-Watson statistic is 2.5 which showed that the model has negative correlation.

As a result of the central composite design the following mathematical model was developed (2):

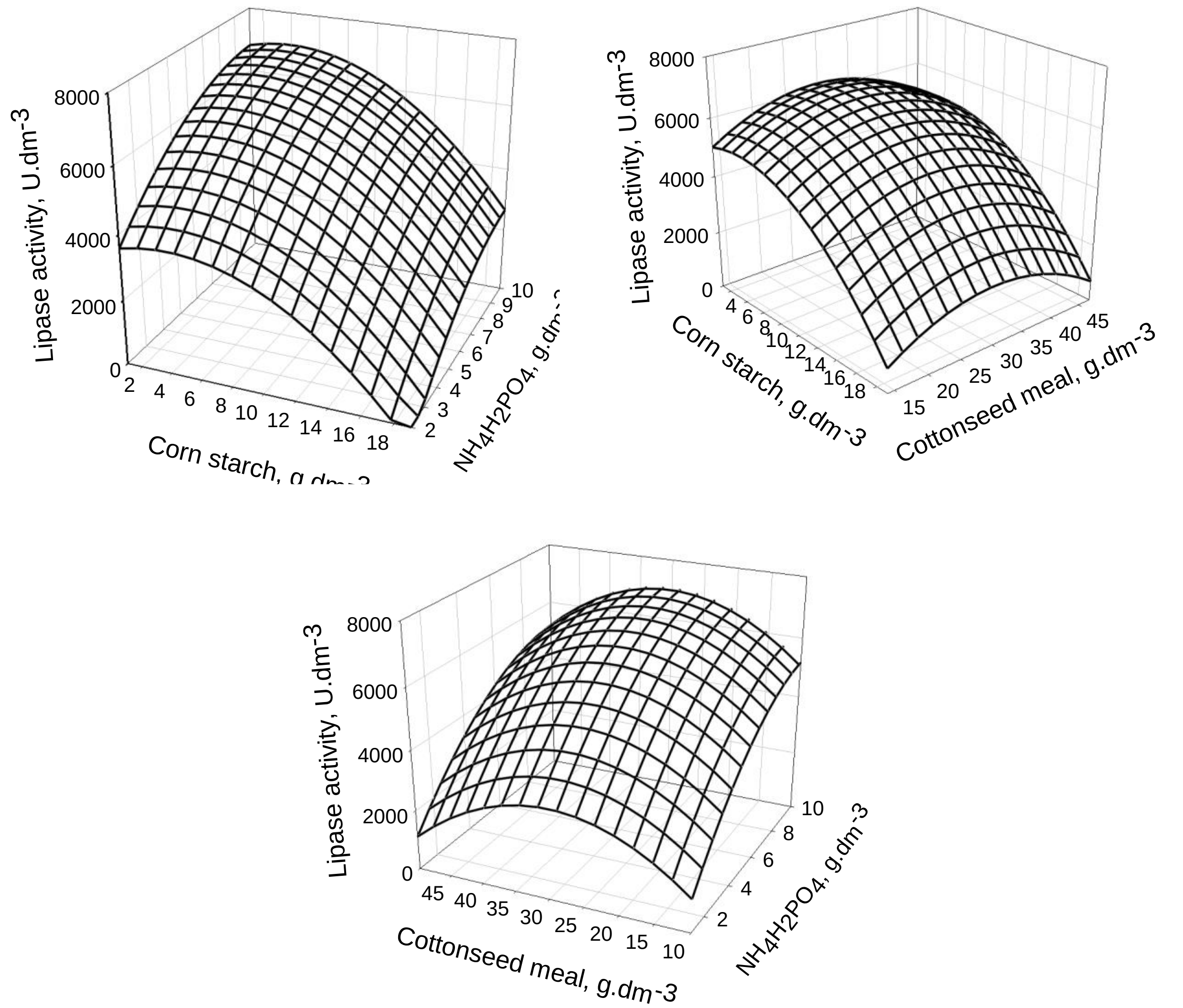
$$\hat{Y} = 5691.89 - 1156.40.X_1 + 894.96.X_3 - 478.69.X_1^2 - 472.78.X_2^2 - 291.77.\ X_3^2 \qquad (2)$$

The model was studied and maximum lipase activity 5966.75 $U.dm^{-3}$ was predicted when the three of the components were added in the fermentation medium in concentrations corresponding to codded values X_1=–1.2, X_2=0 and X_3=1.5. When the values were decoded the concentrations of the component were established to be as follow: corn starch – 4.0 $g.dm^{-3}$, cottonseed meal – 30.0 $g.dm^{-3}$, ammonium phosphate – 10.3 $g.dm^{-3}$.

Figure 3a reveals the interaction effect of corn starch and ammonium phosphate concentration when the concentration of cottonseed meal was fixed at optimal value. As seen from the figure when the corn starch concentration was high, the influence of ammonium phosphate was not substantially. It can also be noticed that there was an optimum of corn starch concentration about 4.0 $g.dm^{-3}$ and when the it was higher than 6.0 g.dm^{-3} lipase biosynthesis was strongly inhibited. Those results don't correspond with our previous research with corn starch as carbon and tryptone as organic nitrogen sources when was found out that simultaneously increasing of corn starch and tryptone concentrations lead to enhancement of lipolytical activity. In that case when the concentration of the carbon source was higher than 10 g.dm^{-3} there was not inhibition of lipase activity but slight enhancement [9]. The reason for inhibition by high concentration of corn starch when using cottonseed meal was possibly in the complex composition of this organic nitrogen source and interaction between these two materials.

On Figure 3b is represented the interaction effect between the carbon and organic nitrogen sources. It can be noticed that in the optimal corn starch concentration there were also an optimum of cottonseed meal concentration.

The interaction effect of cottonseed meal and ammonium phosphate (Figure 3c) reveals that great importance of ammonium phosphate. It also shows that there was no interaction effect between the two components as for every concentration of $NH_4H_2PO_4$ the variation of the cottonseed meal has a



c.

Figure 3. Responses surface plot **a.** Corn starch and $NH_4H_2PO_4$; **b.** corn starch and cottonseed meal; **c.** cottonseed meal and $NH_4H_2PO_4$

CONCLUSION

In order to decrease the price of the final product alternative sources of organic nitrogen – fish meal and cottonseed meal were examinated. It was established that cottonseed meal was appropriate organic nitrogen source while fish meal strongly inhibited lipase biosynthesis. The new fermentation medium was with complex component composition. That led to the need of optimization by using central composite design 2^3. A mathematical model was developed which was used to predict final lipase activity 7076.57 U.dm^{-3} by using 4.0 g.dm^{-3} corn starch, 30.0 g.dm^{-3} cottonseed meal and 10.3 g.dm^{-3} ammonium phosphate. The results were confirmed by three experiments with average lipase activity 6631.00 U.dm^{-3} which is close to the predicted one.

REFERENCES

[1] Abdelmoez, W., Mostafa, N.A., Mustafa A., Utilization of oleochemical industry residues as substrates for lipase production for enzymatic sunflower oil hydrolysis, Journal of Cleaner Production, Vol.59, pp. 290-297, 2013.

[2] Assay, N., Ayed, L., Bouallagui, H., Ben Rejeb, I., Gargouri, M., Use of *Geotrichum candidum* for olive mill wastewater treatment in submerged and static culture, Bioresource Technology, Vol.100, pp. 2182–2188, 2009.

[3] Brozzoli, V., Crognale, S., Sampedro, I., Federici, F., D'Annibale, A., Petruccioli, M., Assessment of olive-mill wastewater as a growth medium for lipase production by *Candida cylindracea* in bench-top reactor, Bioresource Technology, Vol.100, pp. 3395–3402, 2009.

[4] D'Annibale, A., Giovannozzi Sermanni, G., Federici, F., Petruccioli, M., Olive-mill wastewaters: a promising substrate for microbial lipase production, Bioresource Technology, Vol.97, pp. 1828–1833, 2006.

[5] Dobrev, G., Strinska, H., Zhekova, B., Dobreva, V., Delchev, N., Influence of the fermentation medium composition on lipase production by *Rhizopus arrhizus*, Bulgarian Journal of Agricultural Science, Vol.20, No. 1, pp. 42-45, 2014.

[6] Kaushik, R., Saran, S., Isar, J., Saxena, R.K., Statistical optimization of medium components and growth conditions by response surface methodology to enhance lipase production by *Aspergillus carneus*, Journal of Molecular Catalysis B: Enzymatic, Vol.40, pp. 121-126, 2006.

[7] Kishan, G., Gopalakannan, P., Muthukumaran, C., Thirumalai Muthukumaresan, K., Dharmendira Kumar, M., Tamilarasan, K., Statistical optimization of critical medium components for lipase production from *Yarrowia lipolytica* (MTCC 35), Journal of Genetic Engineering and Biotechnology, Vol.11, pp. 111–116, 2013.

[8] Rajendran, A., Thangavelu, V., Statistical experimental design for evaluation of medium components for lipase production by *Rhizopus arrhizus* MTCC 2233, LWT - Food Science and Technology, Vol.42, pp. 985–992, 2009.

[9] Strinska, H., Dobreva, V., Zhekova, B., Dobrev, G., Optimization of starch and tryptone concentrations in medium composition for lipase production by submerged fermentation of *Rhizopus arrhizus* using response surface methodology, International Journal of Biochemistry Research & Review, Vol. 5, No. 3, pp. 178-186, 2015.

[10] Thirunavukarasu, K., Purushothaman, S., Gowthaman, M.K., Nakajima-Kambe, T., Rose, C., Kamini, N.R., Utilization of fish meal and fish oil for production of *Cryptococcus* sp. MTCC 5455 lipase and hydrolysis of polyurethane thereof, Journal of Food Science and Technology, Vol.50, No.9, pp. 5772-5780, 2015.

[11] Wang, D., Xu, Y., Shan, T., Effects of oils and oil-related substrates on the synthetic activity of membrane-bound lipase from *Rhizopus chinensis* and optimization of the lipase fermentation media, Biochemical Engineering Journal, Vol.41, pp. 30–37, 2008.

[12] Yang, X., Wang, B., Cui, F., Tan, T., Production of lipase by repeated batch fermentation with immobilized *Rhizopus arrhizus*, Process Biochemistry, Vol.40, pp. 2095–2103, 2005.

IMMOBILIZATION OF *RHIZOPUS ARRHIZUS* LIPASE ON POLYACRYLONITRILE MEMBRANES

Hristina Panajotova[1], Valentina Dobreva[1], Boriana Zhekova[1], Georgi Dobrev[1]
[1]University of Food Technologies, Plovdiv, Bulgaria
e-mail: angelovatina84@yahoo.com

Abstract: *Rhizopus arrhizus* lipase was immobilized onto the polyacrylonitrile (PAN) ultrafiltration membranes by adsorption and activated by amidination reaction. Effects of immobilization parameters including pH, enzyme concentration and coupling time were evaluated to obtain the best reaction conditions. The highest activity was recorded at the operation conditions of 3 h coupling time at pH 4.0 using optimal enzyme concentration of 0,33U. After enzyme immobilization, the storage stability was improved significantly, and the immobilized *R. arrhizus* lipase still retained 87.6% of its initial activity.
Key words: *Rhizopus arrhizus*, membranes, immobilization, lipase.

INTRODUCTION

Lipases (triacylglycerol hydrolases) are an important group of enzymes and they find use in a variety of biotechnological fields such as food, dairy, detergent and pharmaceutical industries. Lipases are largely produced by microorganisms and specifically fungi lipases play a vital role in commercial ventures [12]. Lipases are glycerol ester hydrolases that catalyze the hydrolysis of triglycerides to free fatty acids and glycerol. Besides this, they are also efficient in various reactions such as esterifications, transesterifications and aminolysis in organic solvents [1].
As biocatalysts, the enzymes exhibit a number of advantages such as high level of catalytic efficiency and high degree of selectivity, including chemical-, regio- and stereoselectivity. However, various practical problems in enzyme applications exist, for example, high cost and instability. To overcome these problems, enzymes are often immobilized onto insoluble or solid support‘s and this has been regarded as a useful strategy to improve their thermal and operational stability and recoverability**.** Immobilized enzymes are defined as “enzymes physically confined or localized in a certain defined region of space with retention of their catalytic activities, and which can be used rapidly and continuously**”**, [6].
An immobilization of enzymes on solid carriers can be achieved using a broad variety of chemical and physical methods. They include adsorption or attachment of lipase on the surface of the carrier by week forces, such as van der Walls, hydrophobic interactions or dispersion forces, entrapment or encapsulation in a polymeric matrix, covalent attachment onto solid carrier and cross-linking method.
For enzyme immobilization the support materials have a great impact on the performance of the immobilized enzymes. The improvement of biocatalytic efficiency can be achieved by manipulating the supports structure, [3]. Among various supports, polyacrylonitrile (PAN) polymers have attracted intense attention due to a variety of their excellent characteristics, which include high strength, abrasion resistance, thermal stability, and resistance to bacteria, and photo irradiation. However, the relative poor hydrophilicity prevent the PAN from some potential applications, [7]. The excellent biocompatibility create a specific microenvironment for the enzymes and thus benefit the enzyme activity [14]. The hydrophobicity of the carrier has been found to show significant influence on lipase activity after immobilization. The activity of lipase is increased when the enzyme is selectively adsorbed on hydrophobic supports, because lipases can recognize the surfaces similar to those of their natural substrates and they suffer interfacial activation during immobilization, [13].
In the present study, the immobilization conditions, including time, concentration of lipase and pH were investigated in order to determine the optimal conditions for increase in immobilized *R. arrhizus* activity. Subsequently, the operation stabilities of the immobilized enzyme were investigated in detail.

MATERIAL AND METHODS

Materials

The studied *Rhizopus arrhizus* strain was provided by Biovet® Peshtera and produced as described previously [5]. PAN membrane, p-nitrophenyl palmitate (p-NPP) were purchased from Sigma. All other chemicals were of analytical grade and were used without further purification.

Lipase immobilization

Lipase was immobilized by adsorption on PAN membranes. They were cut into 1 cm^2 pieces. The membranes were immersed into 2.5ml lipase solution (1mg/ml lipase containing 0,33U) at 25°C with shaking at 255rpm. After the adsorption process, enzyme loaded membrane was removed from the solution and then dried for 24h at room temperature. The amount of the immobilized lipase was determined by the lipase activity difference of the initial and final lipase solutions. To achieve a reliable result, each test was repeated three times at least. Efficiency was calculated as following:
Immobilization efficiency (%) = (Active bound enzyme/Theoretically bound enzyme) x 100 where: Active bound enzyme % = I/A x 100; Theoretically bound enzyme % = (A-B)/A x 100; A = initial lipase activity (U/ml) ; B = unbound lipase activity (U/ ml); I = immobilized lipase activity (U/cm^2)

Effect of incubation time on lipase activity

To determine the optimal time of incubation for maximum activity of immobilized enzyme, the PAN membrane was incubated in reaction mixture 2.5ml (1mg/ml lipase providing 0,33U) lipase solution for 1-8 hours.

Effect of enzyme concentration on lipase activity

To determine the effect of lipase concentration on the activity of the immobilized enzyme, the following amount of enzyme was used: (0,16; 0,33; 0,66; 0,99; 1,32; 1,65) U. The incubation time was 3 hours. The activity of immobilized lipase was determined as described above.

Effect of immobilization pH on lipase activity

The effect of pH on the activity of the immobilized lipase was studied by immersing the PAN membrane into lipase solution with pH (50 mM phosphate buffer) ranging from 3 to 10 at 20°C for 3 hours and then determining their activities.

Reusability and storage stability of immobilized lipase

For the reusability test, the immobilized lipase was subjected to a hydrolytic reaction with p-NPP solution for 15 min. After each reaction run, the immobilized lipase preparation was removed and washed with phosphate buffer (50 mM, pH 8.0) solution to remove any residual substrate on the membrane. The initial activity of immobilized *R. arrhisus* lipases was taken as 100%.
The storage stabilities of immobilized *R. arrhizus* lipases were studied by incubating immobilized enzymes dry at 4 ^{o}C and then determining the activity performance at different incubation days.

Surface modification of PAN membrane

The PAN membrane was activated by using the amidination reaction and then employed to immobilize *R. arrhizus* lipase with covalent binding.
Polyacrylonitrile membranes were cut in 1cm^2 pieces and washed with distilled water. The immobilized lipase onto PAN membrane was immersed in 5 ml anhydrous ethanol and hydrogen chloride gas was then bubbled through the mixture to produce the corresponding imidoester derivatives. After 30 min at 0°C the membrane was removed and washed several times with 50 mM phosphate buffer with pH 8.0 Then the activated membrane was used for immobilization at the same conditions as described above.

Enzyme activity assay

Lipase activity was measured by spectrophotometric method using p-nitrophenyl palmitate (p-NPP) as substrate in aqueous media buffered with Tris-HCl pH 9.0. The reaction mixture, containing 2,4 ml 0,8 mM substrate and 0,1 ml of enzyme solution for free lipase or 2,5 ml 0,8 mM substrate and 1cm^2 immobilized enzyme, was incubated for 15 min at 35°C. Then 1 ml saturated solution of plumbous acetate was added to stop the reaction. After centrifugation absorbance was measured at 410nm. One unit (U) of lipase activity was defined as the amount of lipase to generate 1,0 μmol of p-NP per minute under this experimental condition.

RESULTS AND DISCUSSION

Effect of process parameters on immobilization efficiency and activity

Optimal conditions for maximum enzyme activity differ for immobilized enzymes depending on the type of the support, method of activation, and method of immobilization.

Effect of incubation time on immobilization and catalytic activity

The immobilization time, being an important factor for *R. arrhizus* lipase immobilization, had major influence on the optimal immobilization (Figure 1). This was observed in a broad range, from 1 to 8h. As can be seen from Figure 1, a significant amount of enzyme was bound to the support within the first hour, whereas the lipase activity continued to increase significantly as shown by a higher amount of immobilized enzyme, and reached maximum values within 3 hours. The next experiments were carried out at the optimum incubation time of 3 hours.

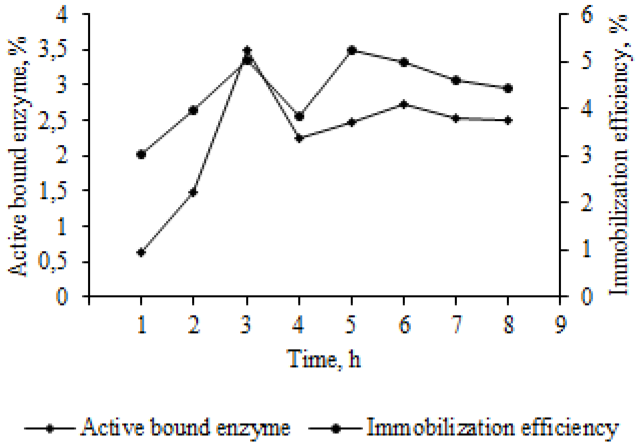


Figure1. Effect of incubation time onto lipase activity

Effect of enzyme concentration on lipase adsorption

The effect of enzyme concentration on lipase adsorption is shown on Figure 2. It can be observed that the lipase activity first increased along with the initial increase in enzyme concentration. After reaching the concentration of 0,33U activity (0,1 % lipase solution) the enzyme activity and immobilization yield gradually decreased. The increasing enzyme concentration can lead to formation of multilayer of adsorbed enzyme, thereby limiting the substrate diffusion and preventing the substrate to reach the active enzyme site.

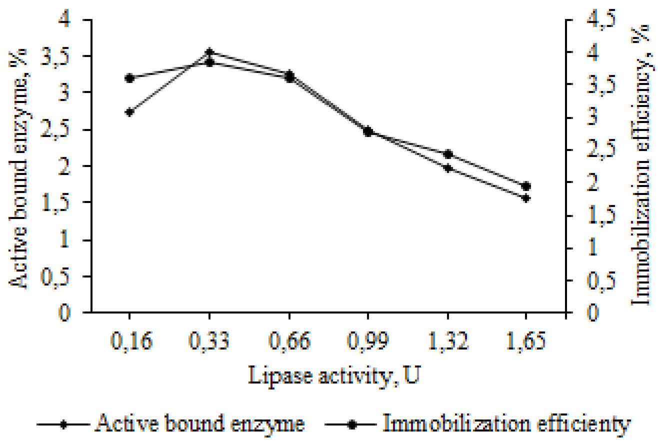


Figure 2. Effect of enzyme concentration on immobilization efficiency and lipase activity

Additionally maximum enzyme loading around the concentration of 0,1 % lipase solution (0,33U activity in reaction mixture) was calculated. The next experiments were carried out at the optimum enzyme concentration.

Effect of media pH on immobilization and catalytic activity
The variation of the active bound enzyme and immobilization efficiency for the immobilized lipase with the pH for immobilization is given in Figure 3. It can be seen that the maximum activity was obtained when the enzyme was immobilized at pH 4.0. The next experiments were carried out at the optimum pH media.

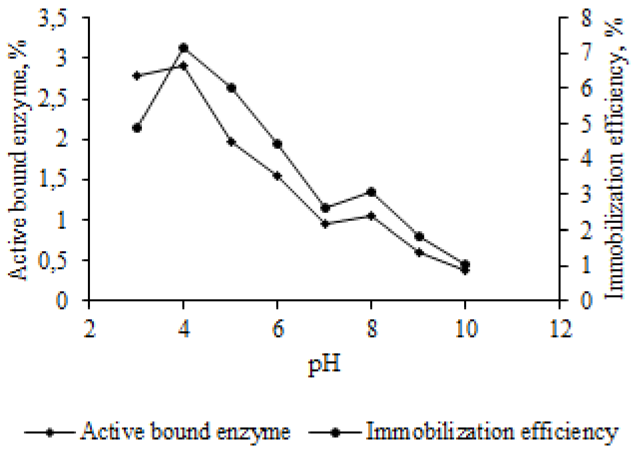


Figure 3. Effect of pH on immobilization process

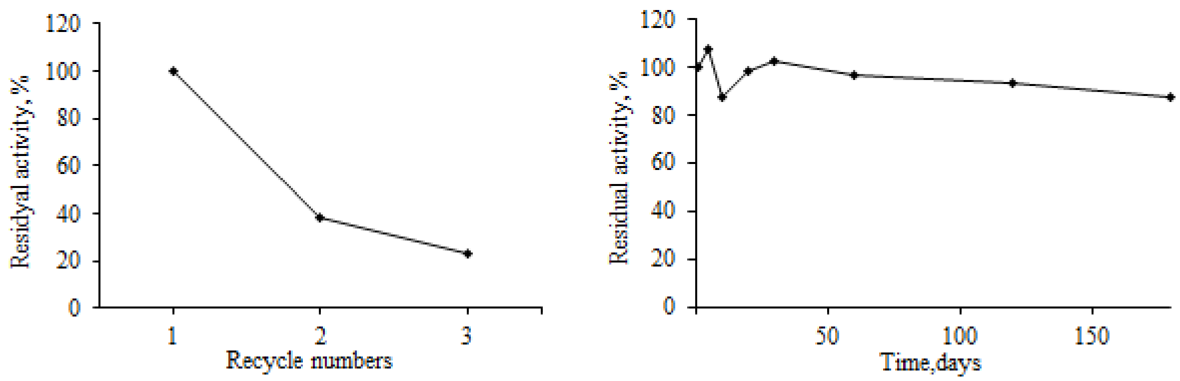
It is clear that pH of the immobilization media had a significant effect on enzyme activity and immobilization yield. Generally, it is expected to obtain the highest activity of immobilized enzyme at around the optimum pH level, and for *R. arrhizus* lipase it is about pH 7-9. But results indicated that the highest immobilization efficiency was at pH 4.0. This can be explained with the isoelectric point of the enzyme. Relevant studies said that the immobilization of the proteins on the solid supports is usually maximally obtained at the isoelectric point of the enzyme [2], [4], and it is known that the isoelectric points of serine hydrolases are generally between pH 4 and 6 [8].
In order to reduce the risk of enzyme leakage from the support, the PAN membrane was modified and covalently bound with the enzyme by amidination reaction.The nitrile groups of PAN were first activated in ethanol by hydrogen chloride to produce an imidoester derivative, followed by reacting with enzyme-containing solution for conjugation with the amino groups of lipase. This procedure provides a simple yet effective method for covalently attachment of enzyme to inert PAN. Table1 shows the activity of the immobilized enzyme on modified and unmodified PAN membrane under optimum reaction conditions. It can be seen that the lipase activity and immobilization efficiency on modified PAN membrane is higher than on the unmodified one. The reason could be the large number of amino groups in activated PAN membrane which are potential reactions sites for covalent coupling with enzyme.

Table 1. Immobilization efficiency and activity of immobilized lipase on PAN membrane

	Total enzyme, U	**Unbound enzyme, U**	**Active bound enzyme, U**	**Active bound enzyme, %**	**Theoretically bound enzyme,%**	**Immobilization efficiency, %**
Lipase immobilized on PAN membrane	0,33	0,026	0,0117	3,55	92	3,85
Lipase immobilized on activated PAN membrane	0,33	0,11	0,0177	5,38	66	8,15

The results on Table 1. shows that the percentage of theoretically bound enzyme is higher than that of the active connected, which is usually explained by the difficult access to the substrate to the immobilized enzyme, and diffusion limitations. As a result of such reactions the interaction between the substrate and the active site of the enzyme was blocked, which led to reduced activity of the immobilized lipase.
Another possible reason for loss of activity is the oil-water interface, which determines lipase action. Due to an opposite polarity between the enzyme (hydrophilic) and their substrates (lipophilic), lipase reaction occurs at the interface between the aqueous and the oil phases. Hence, interfaces are the key spots for lipase biocatalysis and appropriate site for modulating the lypolisis [11]. The multiple covalent bonds between the enzyme and the carrier might reduce the interface which can decrease the lipase activity, as shown in several studies, [9], [10]. The relatively poor activity of PAN-adsorbed lipase also can indicate that rather incomplete interfacial activation was achieved. Thus, there seems to be room for further improvement of lipase adsorption methodology to achieve more efficient interfacial activation.

Reusability and storage stability of immobilized lipase
For industry application,the characterization of reusability is one of the important key features, which can make the immobilized enzyme superior to the free one. The effect of repeated use on the activity of immobilized *R. arrhizus* lipase is shown in Figure 4(a). The immobilized enzyme retained 23% of its initial activity after 3 repeated cycles. The activity decrease could be attributed to the inactivation of the enzyme caused by the denaturation of the protein, or because of high loss of enzyme due to leakage.



(a) Residual activity (b) Storage stability

Figure 4(a,b). Reuse stability and storage stability of the immobilized lipase onto PAN membrane

In addition, the immobilized lipases were kept dry at 4°C for 30 days, and their retained activities were tested periodically to examine the storage stability. As shown in Figure 4 (b), the retained activity of the immobilized lipase was kept close to 100% even after 180 days. It indicated that the immobilized lipase onto unmodified membrane has good storage stability. The same experiments for reusability and storage stability were made with the immobilized lipase onto modified PAN membrane under optimal conditions, and it was considered that the enzyme had no stability and reusability. The immobilized enzyme has no activity after first recycle and it was inactivated after 24 h of storage.

CONCLUSION

In this study, it was shown that immobilization conditions significantly influence the immobilization process of lipase on PAN membrane. The parameters affecting the enzyme activity and stability were determined. The results revealed that the optimum process parameters were 0,33U lipase concentration, pH 4.0 for 3 hours coupling time. Lipase immobilization provides enhanced enzyme storage stability, maintaining 87,6 % of its initial stability after 180 days. Immobilized lipase showed low residual stability, which was mostly due to the enzyme leakage. In order to prevent the enzyme loss, the membrane surface was modified by means of amidination reaction. The lipase immobilized onto modified PAN membrane displayed higher activity and immobilization efficiency, but no stability in aqueous media. Nevertheless, the practical applications of lipases are in organic reaction media. Additionally, storage stability is an advantageous property for the continuous use of this enzyme in industrial applications.

REFERENCES

[1] Babu Joseph, Pramod W. Ramteke,George Thomas, Cold active microbial lipases: Some hot issues and recent developments, Biotechnology Advances Vol. 26: No.457–470, 2008.

[2] Höök, F, Rodahl, M, Kasemo, B and Brzezinski, P, Structural changes in hemoglobin during adsorption to solid surfaces: effects of pH, ionic strength, and ligand binding. Proc Natl Acad Sci U S A, Vol.95:12271-6, 1998.[5] H. Strinska, B. Zhekova, V. Dobreva, G. Dobrev, Response surface methodology optimization of precess parameters for lipase production by Rhizopus, First National Conference of Biotechnology, Vol.100, No. 4,pp.32-40, 2014.

[3] H. T-umturk, N. Karaca, G. Demirel, and F. Sahin, "Preparation and application of poly(N,Ndimethylacrylamide-co-acrylamide) and poly(N-isopropylacrylamide-co-acrylamide)/k-Carrageenan hydrogels for immobilization of lipase,"International Journal of Biological Macromolecules, vol. 40, No.3, pp. 281–285, 2007.

[4] Koutsoukos, PG, Mumme-Young, CA, Norde, W and Lyklema, J (1982). Effect of the nature of the substrate on the adsorption of human plasma albumin. Colloids and Surfaces Vol. 5:93-104.

[5] H. Strinska, B. Zhekova, V. Dobreva, G. Dobrev, Response surface methodology optimization of precess parameters for lipase production by Rhizopus, First National Conference of Biotechnology, Vol.100, No. 4,pp.32-40, 2014.

[6] Kenthorai Raman Jegannathan and Sariah Abang, Denis Poncelet, Eng Seng Chan and Pogaku Ravindra, Production of Biodiesel Using Immobilized Lipase, Critical Reviews in Biotechnology, Vol.28: pp.253–264, 2008.

[7] Liu X.;Chen H.;Wang C.C.;Qu R.J.;Ji C.N.;Sun C.M.;Zhang Y.;Synthesis of porous acrylonitrile/methyl acrylate copolymer beads by suspended emulsion polymerization and their adsorption properties after amidoximation; J. Hazard. Mater., Vol. 175, pp.1014-1021, 2010.

[8] Mala B.Rao, Aparna M. Tanksale,Mohini S. Ghatge, Vasanti V. Deshpande, Molecular and Biotechnological Aspects of Microbial Proteases, Microbiology and Molecular biology reviews Vol. 62, No.3, pp. 597–635,1998.

[9] Patrick Adlercreutz. Immobilisation and application of lipases in organic media, Chem. Soc. Rev., Vol.42, pp. 6406-6436, 2013.

[10] P.Desnuelle, P. Savary, Specificities of lipases, J. Lipid Research. Vol.4 No.4, 1963.

[11] P. Reis, K. Holmberg , H. Watzke, M.E. Leser, R. Miller, Lipases at interfaces: A review, Advances in Colloid and Interface Science 147–148 (2009) 237–250.

[12] R. Gupta . N. Gupta . P. Rathi, Bacterial lipases: an overview of production, purification and biochemical properties, Appl Microbiol Biotechnol Vol.64: pp.763–781, 2004.

[13] Roberto Fernandez-Lafuente, Pilar Armisén, Pilar Sabuquillo, Gloria Fernández-Lorente, José M. Guisán, Immobilization of lipases by selective adsorption on hydrophobic supports, Chemistry and Physics of Lipids, Vol.93,No.1-2, 1998.

[14] Sadana A. Protein adsorption and inactivation on surfaces. Influence of heterogeneities. Chem. Rev., Vol. 92: No.1799–818, 1992.

HIGH PRESSURE DENSITIES OF n-ALKANE+ALCOHOL SYSTEMS

Ali A. Abdussalam [1,2], Gorica R. Ivaniš[1], Ivona R. Radović[1], Mirjana Lj. Kijevčanin[1]
[1]University of Belgrade, Faculty of Technology and Metallurgy, Belgrade
[2]Aljabel - Algharbi University, Faculty of Engineering, Gharyan, Libya
e-mail: mirjana@tmf.bg.ac.rs

Abstract: This work reports densities, isothermal compressibilities and isobaric thermal expansion coefficients for the pure n-heptane, n-octane and ethanol at temperatures from (288.15 to 413.15) K and at pressures up to 60 MPa. The same properties were determined for the binary mixtures n-heptane+ethanol and n-octane+ethanol over the temperature range (293.15 to 373.15) K and at pressures ranging from (0.1 to 40) MPa. Highly precise densimeter DMA HP was used for density measurements. The obtained results indicate an absence of molecular interactions between compounds and less effective packing of a mixture comparing to pure components.
Key words: high pressure density, isothermal compressibility, isobaric thermal expansion coefficient, n-heptane, n-octane, ethanol

INTRODUCTION

In order to reduce the greenhouse gases, especially CO_2 emissions, the incorporation of non-fossil compounds in automotive fuels is of high interest nowadays. Worldwide, mixtures of ethanol and conventional gasoline are used due to many positive aspects of ethanol application: it has a good "well to tank" CO_2 emission balance since it is extracted from the biomass, high n-octane number (108), high heat of vaporization, broader flammability limits and higher flame speeds, [1], [2]. On the other hand, linear alkanes are typical gasoline constituents so as thermodynamic and mechanical properties of liquid alkane + alcohol mixtures are of great interest, especially at elevated pressure and temperature conditions.
This work reports results of the density measurements of pure n-heptane, n-octane and ethanol at temperatures from (288.15 to 413.15) K and at pressures up to 60 MPa. Also, densities of binary mixtures (n-heptane+ethanol) and (n-octane+ethanol) were determined over the temperature range (293.15 to 373.15) K at pressures ranging from (0.1 to 40) MPa. Modified Tait equation was applied to correlate density data. From p, ρ, T, x data of liquid mixtures valuable derived properties are calculated, e.g. isothermal compressibilities and isobaric thermal expansion coefficients. All these properties are essential for the design, operation, control and optimization of industrial processes.

MATERIAL AND METHODS

Materials

The chemicals in this work were used as received without further purification. n-Heptane was supplied from Sigma-Aldrich, while n-octane and ethanol were the products of Merck, all having the mass fraction purities ≥ 0.99. Chemicals were degassed prior to measurements.

Apparatus

The liquid densities of pure compounds and its binary mixtures at different pressures and temperatures were experimentally studied using an Anton Paar DMA HP density measuring cell coupled with an Anton Paar DMA 5000 vibrating tube densimeter. The measuring device was explained in details in our previous work, [3].
The apparatus was used to measure the oscillating period over the temperature range (288.15 to 413.15) K and at pressures from (0.1 to 60) MPa. Each selected temperature was controlled with an integrated Peltier thermostat with the stability within ±0.05 K. A pressure generator, model 50-6-15 from High Pressure Equipment Co. (HiP), was used to set and control the pressure in the system; acetone was applied as a hydraulic fluid, [3]. Pressure in the system was measured using a pressure

transducer WIKA, S-10, Alexander Wiegand GmbH&Co. The maximum value of the sums of deviation and expanded measurement uncertainty is ± 0.1815 % in relation to the full range.

The period of the tube vibration τ, was determined with a digital counter whilst the vibrating period was displayed to seven significant digits. The collected data (period of oscillation of U-tube, cell temperature and pressure) were transferred from DMA HP to DMA 5000 by connecting S-BUS interfaces. The APSoftPrint software program (a Microsoft Excel Add-In) was used to read out and transfer the measured values from DMA 5000 to a PC.

The procedure of Comuñas et al., [4] has been employed to calibrate the Anton Paar DMA HP densimeter and described in details elsewhere, [3]. Having in mind the uncertainties of pressure, temperature and period of oscillation measurements, the overall uncertainty in the reported densities is estimated to be 1.7 $kg\cdot m^{-3}$ in the temperature range 288.15-363.15 K and 2.7 $kg\cdot m^{-3}$ at temperatures 373.15-413.15 K.

Mixtures were prepared gravimetrically using a Mettler AG 204 balance with a precision $1\cdot 10^{-7}$ kg. The uncertainty of the mole fraction calculation was less than $\pm 1\cdot 10^{-4}$. The excess molar volume was calculated with the average uncertainty $\pm 4\cdot 10^{-6}\ m^3\cdot kmol^{-1}$.

Density modelling

Experimental values of densities were fitted by Tait equations. This correlation involves fitting parameters a_i, b_i and c_i and relates density ρ with temperature T and pressure p in a polynomial form according to the eqs. (1) to (4), [5]

$$\rho(T,p)=\frac{\rho^{\mathrm{ref}}(T)}{1-C(T)\ln\left(\dfrac{B(T)+p}{B(T)+p^{\mathrm{ref}}}\right)} \tag{1}$$

$$\rho^{\mathrm{ref}}(T)=\sum_{i=0}^{2}a_iT^i \tag{2}$$

$$B(T)=\sum_{i=0}^{2}b_iT^i \tag{3}$$

$$C(T)=\sum_{i=0}^{2}c_iT^i \tag{4}$$

where ρ^{ref} is density at reference pressure p^{ref} that is chosen to be 1 MPa. In our case the parameter C is treated as temperature independent.

Derived thermodynamic properties calculation

From density data valuable derived properties can be calculated. Here, excess molar volume, V^E isothermal compressibility, κ_T and isobaric thermal expansion coefficient, α_p were determined.

$$V^{\mathrm{E}}=\sum_{i=1}^{n}x_iM_i\left\lfloor\left(\frac{1}{\rho}\right)-\left(\frac{1}{\rho_i}\right)\right\rfloor \tag{5}$$

In eq. (5) x_i denotes the mole fraction of a component i in a mixture; M_i its molecular weight and ρ and ρ_i are the measured densities of a mixture and a pure component i, respectively.

Isothermal compressibility describes the pressure effect on density at constant temperature as follows, [5]

$$\kappa_T=\frac{1}{\rho}\left(\frac{\partial\rho}{\partial p}\right)_T \tag{6}$$

Incorporation of the eq. (1) in eq. (6) leads to

$$\kappa_T=\frac{C(T)}{\left(B(T)+p\right)\left(1-C(T)\ln\dfrac{B(T)+p}{B(T)+p^{\mathrm{ref}}}\right)} \tag{7}$$

Isobaric thermal expansion coefficient expresses the temperature influence on a fluid density at constant pressure and can be calculated by using the following equation, [5]

$$\alpha_p = \frac{1}{\rho}\left(\frac{\partial p}{\partial T}\right)_\rho \left(\frac{\partial p}{\partial \rho}\right)_T^{-1} = -\frac{1}{\rho}\left(\frac{\partial \rho}{\partial T}\right)_p \qquad (8)$$

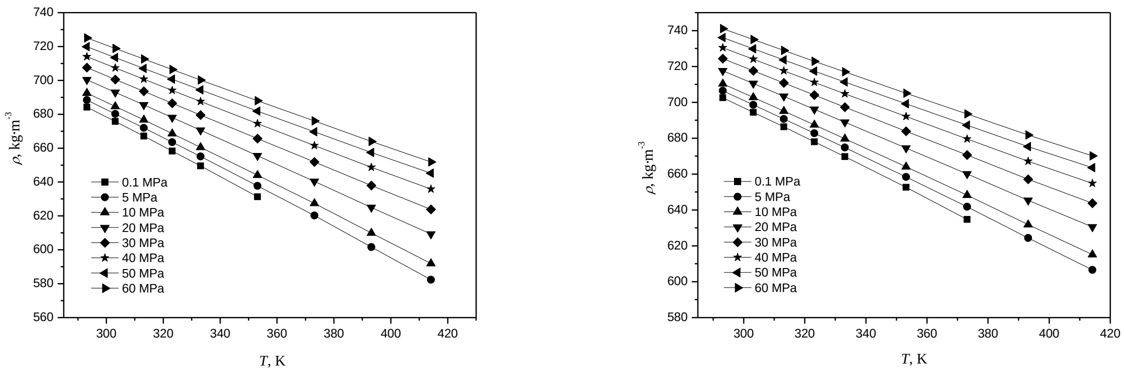
The following expression can be derived combining eqs. (1) and (8)

$$\alpha_p = \frac{-\rho^{\mathrm{ref}\,\prime}(T)}{\rho^{\mathrm{ref}}(T)} - \frac{C(T)\dfrac{B'(T)(p^{\mathrm{ref}}-p)}{(B(T)+p)(B(T)+p^{\mathrm{ref}})} + C'(T)\ln\dfrac{B(T)+p}{B(T)+p^{\mathrm{ref}}}}{\left(1 - C(T)\ln\dfrac{B(T)+p}{B(T)+p^{\mathrm{ref}}}\right)} \qquad (9)$$

where $\rho^{\mathrm{ref}\,\prime}(T)$, $B'(T)$ and $C'(T)$ are derivatives of parameters defined in our previous work, [5].

RESULTS AND DISCUSSION

Figure 1 shows measured densities of the pure n-heptane and n-octane as a function of temperature at different pressures. Figure 2 represents three-dimensional variation of densities vs. temperature and pressure for ethanol.



a) b)

Figure 1. Densities of the pure a) n-heptane and b) n-octane as a function of temperature at different isobars.

Figures 1 and 2 demonstrate that densities are decreasing in the following order: ethanol>n-octane>n-heptane. As temperature increases a pure compound density decreases almost linearly at investigated temperature and pressure ranges. Contrarily, density increases with increasing pressure. The variation of density versus pressure at lower temperatures is practically linear, while it slightly deviates from straight line at temperatures higher than 353.15 K.

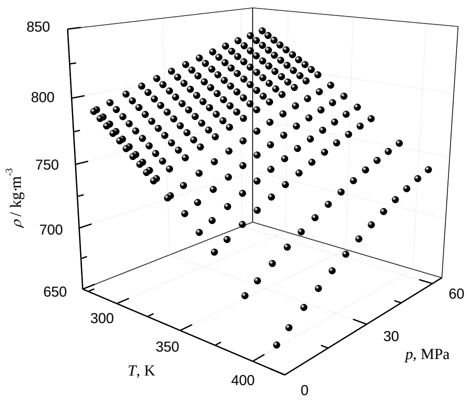
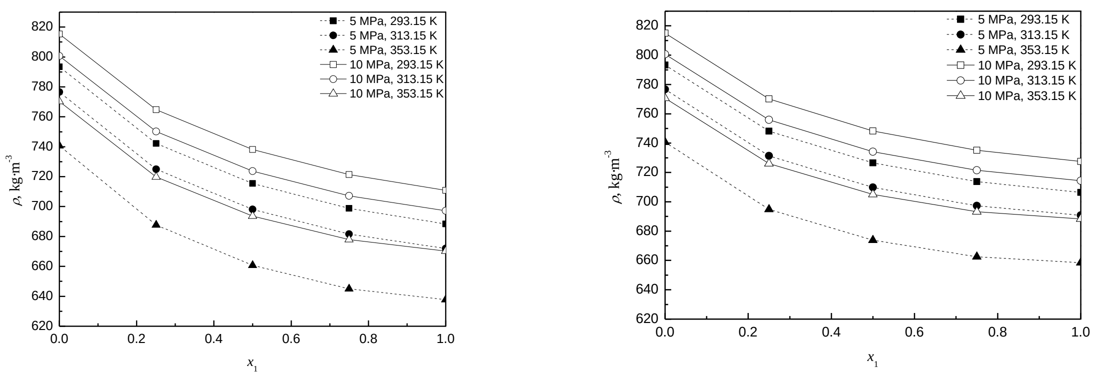


Figure 2. 3D diagram of densities of the pure ethanol as a function of temperature and pressure.

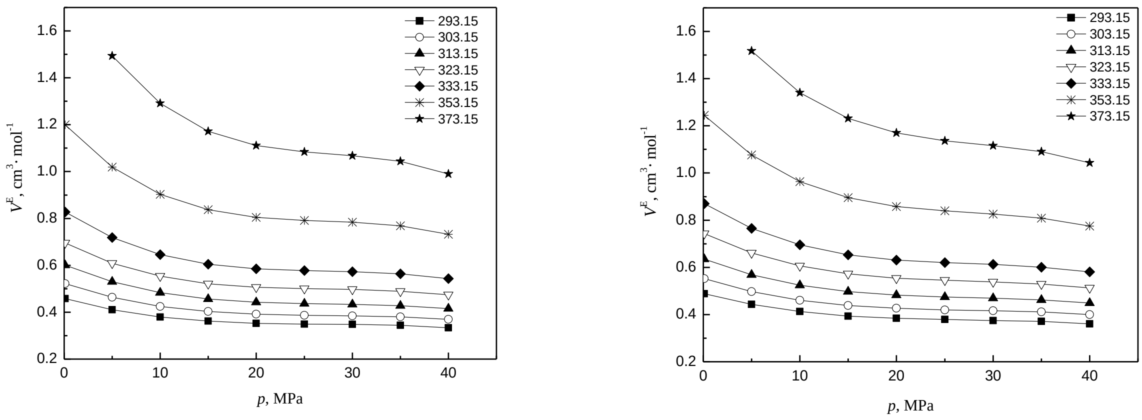
Figure 3 depicts temperature and pressure influence on the densities of the investigated binary mixtures. Densities decrease as temperature increases, particularly between 313.15 and 353.15 K. Density vs. x function monotonically increases with increasing ethanol concentration along nonlinear dependence.



a) b)

Figure 3. Experimental densities (ρ) vs. mole fraction (x_1) for the a) n-heptane (1) + ethanol (2) and b) n-octane (1) + ethanol systems at 5 MPa (full symbols) and 10 MPa (empty symbols) for selected isotherms: ■, □, 293.15 K; ●,○, 313.15 K; ▲, Δ 353.15 K.

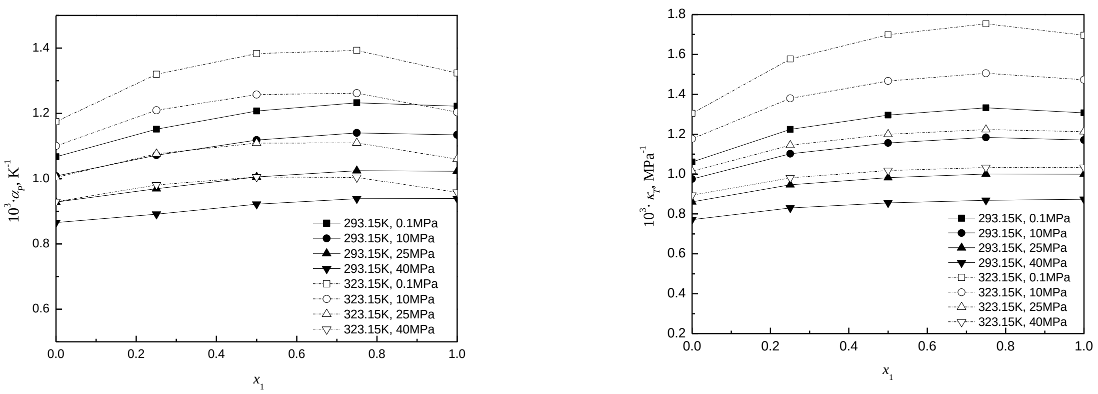
Figure 4 depicts changes of excess volume of equimolar n-heptane+ethanol and n-octane+ethanol mixtures vs. pressure for different isotherms. As temperature increases excess volume also increases, noticeably at 353.15 and 373.15 K. Contrarily, the pressure raise causes a mixture compression, e.g. excess volume decrease. However, the influence of pressure change is more pronounced up to around 20 MPa. At higher pressures excess molar volumes become almost constant. Both mixtures containing alcohol show positive deviation from ideal behaviour, which usually indicates an absence of molecular interactions between components and poorer packing between dissimilar compounds. Ethanol molecules form self-associates connected by hydrogen bonds. The addition of n-heptane or n-octane to pure ethanol influences the weakening or breaking of hydrogen bonds.
Figures 5 and 6 depict changes of isothermal compressibility, κ_T and isobaric thermal expansivity, α_p with pressure and temperature for the analyzed binary mixtures.



a) b)

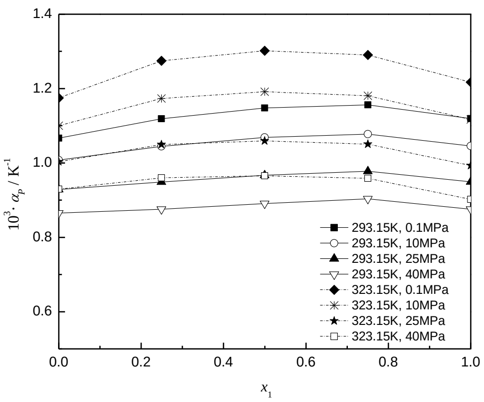
Figure 4. Excess molar volume (V^E) vs. pressure (p) for the equimolar binary mixtures: a) n-heptane (1) + ethanol (2) and b) n-octane (1) + ethanol (2) at different isotherms.

As Figures 5 and 6 demonstrate, pure compounds isothermal compressibility and isobaric thermal expansivity decrease in the following order: n-heptane>n-octane>ethanol within the investigated p, T range. Both κ_T and α_p increase with temperature increase and decrease as pressure increases. However, difference between pure compounds compressibility diminishes with increasing pressure. Also, the temperature influence on isothermal compressibility reduces as pressure increases (from atmospheric to 40 MPa). It is evident that κ_T and α_p vs. x curves show non-monotonical behavior at 323.15 K. n-Octane is slightly more expansive than ethanol at lower pressures and temperatures, but at higher temperatures and pressures becomes less expansive than ethanol. Also, higher expansivity and compressibility of a mixture than for the pure compounds is typical.

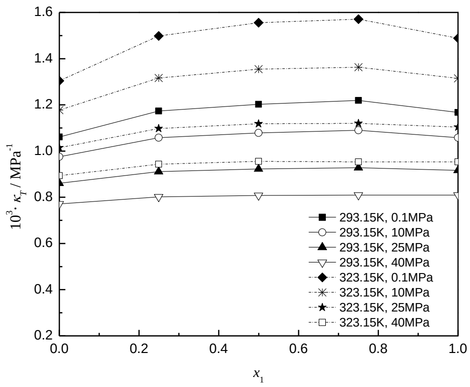


a) b)

Figure 5. a) Isobaric thermal expansivity (α_p) and b) isothermal compressibility (κ_T) vs. mole fraction of n-heptane (x_1) for n-heptane (1) + ethanol (2) system at different pressure and temperature conditions.



a)



b)

Figure 6. a) Isobaric thermal expansivity (α_p) and b) isothermal compressibility (κ_T) vs. mole fraction (x_1) for n-octane (1) + ethanol (2) system at different pressure and temperature conditions.

Higher thermal expansivity in a mixture coupled with the positive excess molar volumes for n-heptane+ethanol and n-octane+ethanol mixtures can be explained as a less effective packing of the compounds within the mixture and breaking of the hydrogen bonds between ethanol molecules, which results in an increase in the free volume. At higher temperatures this effect is even more pronounced, e.g. both excess volume increases and thermal expansivity of a mixture is getting higher compared to those of the pure compounds. On the contrary, as pressure increases excess volume decreases due to the shortening of the distance between compounds and decrease of the free volume, [6].

CONCLUSION

Densities, excess molar volumes, isothermal compressibilities and isobaric thermal expansion coefficients for the pure n-heptane, n-octane and ethanol and for the binary mixtures of n-heptane+ethanol and n-octane+ethanol at high pressures and temperatures are analyzed. A volume expansion occurs when ethanol is mixed with n-heptane or n-octane. Additionally, higher thermal expansivity in mixtures compared to the pure compounds points to disruption or the weakening of hydrogen bonds between ethanol molecules and less effective packing of the compounds in mixtures.

REFERENCES

[1] Balat, M., Global bio-fuel processing and production trends, Energy Explor Exploit, Vol. 25, pp.195–218, 2007.

[2] Jeuland, N., Montagne, X., Gautrot, X., Oil & Gas Science and Technology - Rev. IFP, Vol. 59, pp. 559-570, 2004.

[3] Ivaniš, G., Tasić, A., Radović, I., Djordjević, B., Šerbanović, S., Kijevčanin, M., An apparatus proposed for density measurements in compressed liquid regions at the pressures 0.1-60 MPa and the temperatures 288.15-413.15 K. J. Serb. Chem. Soc. Vol. 80, pp. 1073–1085, 2015.

[4] Comuñas, M. J. P., Bazile, J., Baylaucq, A., Boned, C. Density of Diethyl Adipate using a New Vibrating Tube Densimeter from (293.15 to 403.15) K and up to 140 MPa. Calibration and Measurements, Engineering, Vol. 53, pp. 986–994, 2008.

[5] Ivaniš, G., Tasić, A., Radović, I., Djordjević, B., Šerbanović, S., Kijevčanin, M., Modeling of density and calculations of derived volumetric properties for n-hexane, toluene and dichloromethane at pressures 0.1–60 MPa and temperatures 288.15–413.15 K, J. Serb. Chem. Soc., 2015. Accepted for publication

[6] Watson, G., Zéberg-Mikkelsen, C. K., Baylaucq, A., Boned, C., High-pressure density measurements for the binary system ethanol + n-heptane, J. Chem. Eng. Data, Vol. 51, pp. 112-118, 2006.

PRODUCTION OF FATTY ACIDS METHYL ESTERS FROM WASTE MATERIALS

Sofija P. Miškov[1], Mirjana Lj. Kijevčanin[1], Ivona R. Radović[1]
[1] University of Belgrade, Faculty of Technology and Metallurgy, Serbia
e-mail: ivonag@tmf.bg.ac.rs

Abstract: Biodiesel production utilizing biowaste as raw material reduces the capital costs and environmental problems related to biowaste disposal. In this investigation, biodiesel was synthesized in a heterogeneous transesterification reaction utilizing used cooking oil and methanol as reactants and eggshell raw material as a calcium-oxide catalyst source. Calcination was carried out at 800ºC for 4h. Transesterification was conducted at 65 ºC. High yield of fatty acids methyl esters was obtained while densities and viscosities of analyzed biodiesel samples were in accordance with recommended standard values.
Key words: biodiesel, heterogeneous transesterification, eggshell, used cooking oil

INTRODUCTION

Fuels produced from renewable recourses and/or biowaste are seen as a potential option for oil crisis and environmental problems solution. Legal demands imposing the amount of 10 vol. % of biofuels in the transport sector by 2020. overlapped with environmental issues concerning biowaste disposal, have clearly defined sustainable biodiesel production as scientific and industrial priority. On the other hand, the concerns related to the biodiesel production from food crops imposed need for non-food biodiesel sources (second generation biodiesel), e.g. used cooking oils or waste animal fats. In European union the total waste cooking oil capacity is estimated to significant amount of 700 000–1 000 000 t/year.
The biodiesel production plants are mostly utilizing traditional technology of fatty acids methyl esters (FAME) production. FAMEs, main constituents of biodiesel, are usually produced in transesterification reaction, which can be conducted using homogenous or heterogeneous catalyst, the use of lipases, alternative reaction treatment like application of ultrasound or supercritical conditions, etc. Typical transesterification reaction can be carried out at moderate temperature (65°C) and atmospheric pressure with no significant capital costs and very high yield of product, [1].
The application of homogeneous catalyst gives high yield of biodiesel although with many disadvantages. The main drawbacks are related to environmental issues and no possibility of the catalyst reuse. The biodiesel production with homogenous catalyst is usually followed with biodiesel washing, which generates large amounts of wastewater that must be treated before disposal. On the other hand, heterogeneous catalyst is easily separable, recyclable and does not create wastewater, [1].
Solid base oxides, such as CaO, MgO, ZnO, BeO, lanthanum and zeolite have been used as heterogeneous catalysts. Among above mentioned mostly used is CaO since it has shown a good catalytic performance in transesterification reaction, [1]. It is low soluble in methanol so it is easily separable after reaction, it is cheap and environmentally friendly. Moreover, it can be produced from industrial food waste as a raw material, which disposal makes problems all over the world. The main biowaste sources of calcium-oxide are eggshells, bones or mollusk shells where it exists as calcium-carbonate.
In this work biodiesel was synthesized from used cooking oil (UCO) as a feedstock while the catalyst was prepared from eggshell waste as a raw material. Raw eggshell was characterized using thermo-gravimetric analysis/differential scanning calorimetry (TGA/DSC), while characterisation of prepared catalyst was carried out using Brunauer-Emmett-Teller method (BET). Transesterification was conducted at 65 ºC, with 15:1 methanol/oil molar ratio and 5 wt.% of catalyst loading.

MATERIAL AND METHODS

Recycled oil

Biodiesel investigated in this work was synthesized by transesterification reaction from used cooking oil (UCO) collected from restaurants in Serbia.
Chemical composition of UCO was determined using gas chromatogram with flame ionic detector (GC-FID 6890, Agilent) Colum: CP-Sil 88 (100m × 0.25 mm, film thickness 0.2μm). Table 1 shows weight ratio of fatty acids that are mainly present in UCO as well as water and free fatty acids (FFA) content. Based on data reported in papers [2], [3], it can be assumed that cooking oil used here is a mixture of sunflower and palm oil. Amount of free fatty acids and water is in accordance with previously suggested limits, [4].

Table 1. Chemical composition of used cooking oil[a]

Fatty acid components	wt%
Palmitic	8.38
Stearic	3.42
Oleic	33.40
Linoleic	50.52
FFA content	0.82
Water content	0.06

[a] fatty acids present in traces are not shown

Catalyst preparation and characterization

Raw chicken eggshells were collected from local factory, washed with water and dried for 24h at 70°C. Dry eggshells were grinned in a mill, after which they were kept in closed jars. Thermal behavior of raw eggshell was determined using a SDT Q600 instrument, (TA Instruments). Differential Scanning Calorimetry and Thermogravimetric analysis were performed under a nitrogen flow of $100 cm^3 min^{-1}$ with linear temperature programming at 10 $°C min^{-1}$ in the temperature range of 25–1000°C.
Calcination of eggshells was carried out at temperatures 800°C. Prepared catalyst was analysed using Brunauer–Emmett–Teller (BET) technique. The BET surface area of the catalyst was measured using Micrometrics ASAP 2000 instrument, after out gassing in vacuum at 110°C.

Transesterification procedure

The transesterification reaction was conducted using the heterogeneous CaO based catalyst produced from chicken eggshell. The molar ratio of methanol (Ficher Chemical, 99.99 mass%) to oil was 15:1, while the catalyst was added with a weight content of 5% (catalyst/oil weight ratio). Transesterification reaction was conducted in a batch reactor at 65°C. Catalyst and methanol were mixed in a reactor until stationary conditions were achieved under methanol reflux. Preheated oil was added into the reactor and reaction was carried out for 2h. After cooling, FAME and methanol were separated from glycerol and catalyst by centrifuge and stratified in a separating funnel. Methanol was evaporated in a rotary evaporator. FAME was filtered through double filter paper.

FAME characterization

The content of fatty acids in FAME was analyzed using gas chromatography with flame ionization detector model Varian 3400. Density and viscosity of FAME was determined using an Anton Paar DMA 5000 digital vibrating and Stabinger viscometer (model SVM 3000/G2).

RESULTS AND DISCUSSION

TGA/DSC and BET analysis

Figure 1 shows weight loss (green line) and endothermic peak (blue line) that occurs at temperatures around 800°C, which corresponds to the results reported previously, [5]. This loss is attributed to decomposition of $CaCO_3$ and out gassing of CO_2. Organic compounds and water are lost at temperatures below 400°C. Consequently, 800°C was chosen as an optimal temperature for calcination.

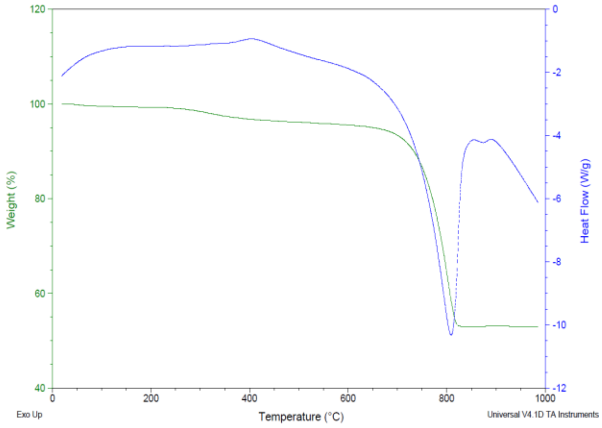


Figure 1. TGA and DSC curves of raw eggshell

Table 2 collects the results obtained using BET analysis of the prepared catalyst (CaO_{800}).

Table 2. BET analysis

Sample	S_{BET}, m^2g^{-1}	V_{total}, cm^3g^{-1}	$V_{mesopores}$[a], cm^3g^{-1}	$V_{micropores}$, cm^3/g^{-1}	$D_{median\ mesopores}$, nm	D_{max}, nm
CaO_{800}	2.706	0.00740	0.00721	0.0009	11.49	3.94

[a] $V_{mesopores}$ - mesopores volume; $V_{micropores}$ – micropores volume; $D_{median\ mesopores}$ – median mesopores diameter, D_{max} - maximum diameter

According to presented table 2, parameters, e.g. total pore volume, mesopores volume, median mesopores diameter and maximum pore diameter, are relatively high for CaO_{800} sample. Volume and mesopores distribution are presented in figure 2 for CaO_{800} sample, where pore volume is presented with black squares and pore size distribution is presented with red line. Pores are mostly in a range of 3 to 7 nm and they form majority of total pore volume.

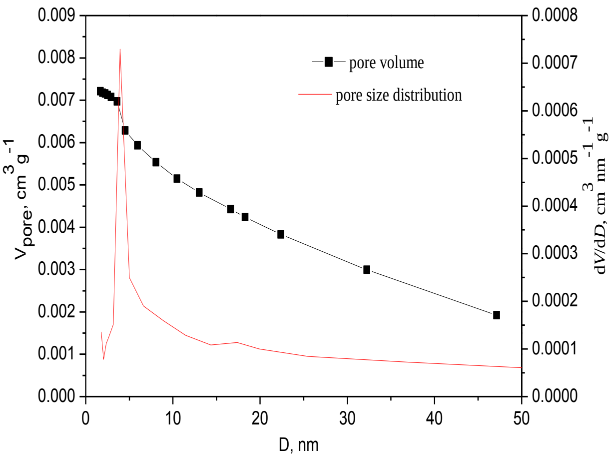


Figure 2. Volume and mesopores distribution of sample CaO_{800}

Biodiesel composition

Catalyst calcined at 800°C gave very high yield of fatty acid methyl ester, almost 99 wt%. Viriya et al., [5] reported that optimum calcination temperature is 800°C, while higher calcination temperatures cause severe sintering of catalyst particles, resulting in suppressed smaller active sites and consequently smaller biodiesel yields.

Table 3. Biodiesel composition[a]

Sample	FAME wt%	MG wt%	DG wt%	TG wt%
UCO_{800}	98.88	0.33	0.25	0.54

[a] T_{calc} -calcination temeperature; FAME – fatty acid methyl ester; MG – monoglyceride; DG – diglyceride; TG - triglyceride

It was suggest that the basest sites are in the interior of catalyst, since surface of the catalyst shows low porosity. Analyzing the pore size distribution and pore volume from figure 2, it can be concluded that most of the pores are micropores, having the diameter 4 nm. These micropores generate pore volume ranging from 0.007 to 0.008 $cm^{3} g^{-1}$. Khemthong et al., [6] reported that derived eggshell is dense material due to its very low surface area and pore volume with very high basic site density which makes it active for transesterification reaction. Besides, it is important to point out that activation of catalysts just before the reaction plays important role in biodiesel yield, since remove of gaseous water molecules creates high porosity, [7].
Densitiy and viscosity of FAME were measured and compared to standard values. Density and viscosity of utilized FAME is lower. It was expected since the amount of fatty acid methyl esters in this sample was higher and fatty acid methyl esters are less dense and viscous than glycerides. Sample UCO_{800} (883.757 kgm^{-3}) meets the density standards ASTM D6751 and EN 14214, which recommend the range of 860-900 kgm^{-3} at 288.15 K. According to ASTM D6751 standard biodiesel kinematic viscosity at 313.15 K should be in range 1.9-6.0mm^2s^{-1}, while by EN 14214 acceptable range is 3.5-5.0 mm^2s^{-1}. UCO_{800} having the kinematic viscosities 4.9567 mm^2s^{-1} is on the upper limit of EN 14214 standard and fits the ASTM D6751 standard, [1].

CONCLUSION

FAME were synthesized in heterogeneous transesterification reaction from used cooking oil and methanol. CaO based catalyst was produced by calcination of hen eggshells at 800ºC and analyzed using TGA/DSC and BET analyses, that led to conclusion of appropriate calcination temperature. High yield of fatty acids methyl esters (about 99 wt.%) was achieved when catalyst was prepared at 800 ºC. Measured density and viscosity met global standards. High yield of fatty acids methyl esters confirm that biodiesel can be efficiently produced from biowaste in heterogeneous transesterification reaction.

REFERENCES

[1] Leung, D. Y. C., Wu, X., Leung, M. K. H., A review on biodiesel production using catalyzed transesterification, Appl. Energy, Vol. 87, pp.1083–1095, 2010.
[2] Ma, F., Hanna, M. a., Biodiesel production: a review1Journal Series #12109, Agricultural Research Division, Institute of Agriculture and Natural Resources, University of Nebraska–Lincoln.1. Bioresour. Technol., Vol. 70, pp.1–15, 1999.
[3] Yan, S., Kim, M., Salley, S. O., Ng, K. Y. S., Oil transesterification over calcium oxides modified with lanthanum, Appl. Catal. A Gen., Vol. 360, pp.163–170, 2009.
[4] Kouzu, M., Yamanaka, S. Y., Hidaka, J. S., Tsunomori, M., Heterogeneous catalysis of calcium oxide used for transesterification of soybean oil with refluxing methanol, Applied Catalysis A: General, Vol. 355, pp.94–99, 2009.

[5] Viriya-Empikul, N., Krasae, P., Nualpaeng, W., Yoosuk, B., Faungnawakij, K., Biodiesel production over Ca-based solid catalysts derived from industrial wastes, Fuel, Vol. 92, pp.239–244, 2012.

[6] Khemthong, P., Luadthong, C., Nualpaeng, W., Changsuwan, P., Tongprem, P., Viriya-empikul, N., Faungnawakij, K., Industrial eggshell wastes as the heterogeneous catalysts for microwave-assisted biodiesel production, Catal. Today, Vol. 190, pp.112–116, 2012.

[7] Hu, S., Wang, Y., Han, H., Utilization of waste freshwater mussel shell as an economic catalyst for biodiesel production, Biomass and Bioenergy, Vol. 35, pp.3627–3635, 2011.

OPTIMIZATION OF CAPACITY OF BIOGAS COGENERATION SYSTEM FOR AN INTEGRATED PIG FARM

Marko Mančić[1], Dragoljub Živković[1], Milena Todorović[1], Milena Jovanović[2], Milan Djordjević[3]
[1]University of Niš, Faculty of Mechanical Engineering, Aleksandra Medvedeva 14, Niš, Serbia
[2] University of Niš, Faculty of Occupational Safety in Niš, Čarnojevića 10a, Niš, Serbia
[3]University of Priština, Faculty of Technical Sciences, Kosovska Mitrovica
e-mail: markomancic@masfak.ni.ac.rs

Abstract: In this paper, energetic and financial annual balance of a livestock farm is performed. The results of the balance are used to determine current energy costs at the farm, properties of its energy demands, as well as potentials for on-site production of biogas. Dynamic annual performance model of the farm is created using TRNSYS software, and used for Genopt optimization of the farms energy supply. A generic model of a biogas fired cogeneration system based on an internal combustion engine and heat storage tank system to determine economic benefits of cogeneration. Investment costs are calculated as function of engine power and heat storage volume. Power of the cogeneration system and volume of its heat storage are optimization variables. The goal function is based on net present value, where energy savings and cash flows are affected by the simulated annual performance of the cogeneration system. Results of optimization obtained using Trnsys-Genopt are presented and discussed in the paper.
Key words: Optimization, cogeneration, biogas, livestock farm, net present value, energy savings.

INTRODUCTION

Biogas is a mixture of gasses, where methane (CH4) accounts for two thirds and carbon dioxide for one third of the volume of the mixture. Apart from methane and carbon di oxide, the volume of biogas consists of other gasses with significantly lower shares. Biogas is a renewable energy source which can be produced using livestock production manure and energy crops. Production and utilization of biogas is especially significant for reduction emission of methane, the gas which increases the greenhouse gas effect (with intensity 23 times higher than carbon dioxide). Also, when biogas is used as a fuel, apart from electricity, heat is typically produced, thus contributing to improved energy efficiency. Additional positive effects achieved by anaerobe fermentation of the manure is the reduction of odor and prevention of pollution of land and ground waters [1]. In addition, it is feasible to achieve positive socio-economic effects, encourage rural development and better exploit human and material resources on a local level.

Production of biogas on livestock farms is recognized as a measure for improved waste management and energy supply improvement in the literature [1-10]. A recent research indicated that agricultural production is the hot spot of life cycle of food products, where impact of waste management systems in pig farming and environment impact are analyzed, but energy supply systems are omitted from the research [1]. Multiple environmental benefits in different sectors have been recognized from the Danish farm experience with centralized biogas plants from the 1970's until now: it generates renewable energy, it enables the recycling of organic waste, it can play a role in manure distribution and storage and improve the veterinary aspects of manure, it can reduce fertilizer use, and it contributes to the reduction of the greenhouse gas methane [2]. The composition of input substrate affects methane and biogas yield, and can be further used to produced heat, steam and electricity [3]. In an economical analysis of available biogas production technologies in Sweden and utilization of biogas for production of heat, combined heat and electricity (CHP) and vehicle fuel, CHP option showed favorable economic feasibility, but also highest sensitivity to the tested parameters [4]. Comparison of eight waste to energy technologies in today's energy systems showed that utilization of organic waste in manure based biogas production provides cheaper CO_2 reduction than incineration, and utilization of biogas for CHP provides the lowest CO_2 reduction cost [5].

Produced biogas may be utilized in many ways. Methane accounts for 60[%]-80[%] in the composition of biogas, with a heating value of 23040 KJ/m^3. Since the ratio of methane in the

composition of natural gas is approximately 98[%], and heating value of natural gas is 33350 KJ/m^3, we can conclude that the heating value of 1 m^3 of natural gas is approximately 45[%] higher than that of the biogas. Biogas can be used to produce electricity, as boiler fuel or for refrigeration equipment. Most of the equipment which uses natural gas, propane or butane, can also use biogas as fuel.
In this paper, possibilities for biogas cogeneration are analysed through a case study of an intensive pig farm. Energy performance data of the farm are collected and used to determine potential for on-site biogas production. The data is used to model energy demands of the farm, and a biogas fired cogeneration system in Trnsys software. Techno-economic Trnsys/Genopt optimization is performed to determine optimal size of the internal combustion engine biogas cogeneration plant.

DETERMINING ENERGY DEMANDS AT THE FARM

Energy consumption at the case-study farm analyzed in the paper is represented by heating and electricity demands. Electricity consumption data was collected for a period of 3 years, and average monthly values are presented in Figure 1. Heat is supplied by two 750[kW] boilers, to animal housing buildings, an office building and sanitary hot water system. Mass flow rates and temperatures of water supply and return, and water supply to the animal housing and office buildings were measured using Greyline PT400 mass flow rate sensor and TESTO 831 temperature sensor. Temperature of the main supply pipeline was read from an existing thermometer in the boiler house. The following temperatures were read at the time of the measurement (Fig. 1): main supply pipeline temperature 90[^{o}C], temperature at inlet for heating buildings 81.2[^{o}C], temperature at office building inlet and SHW heating 74.5[^{o}C], temperature at main return pipeline 71.6[^{o}C].

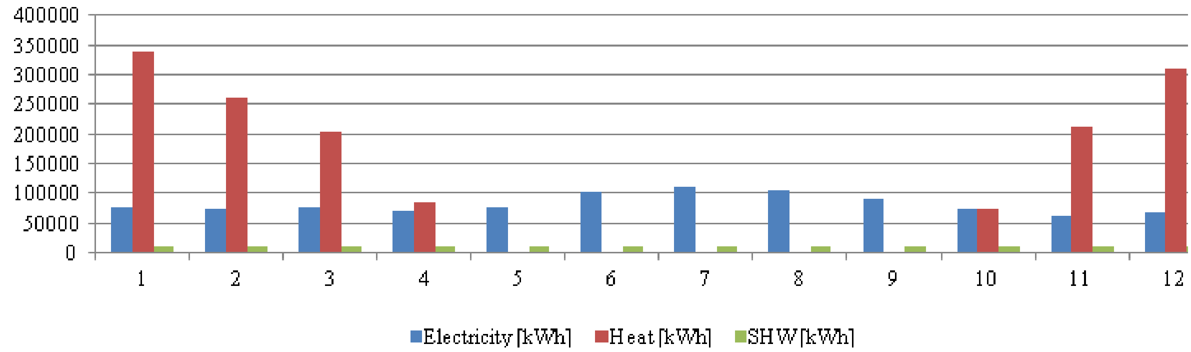


Figure 1. Annual energy demands at the farm

Total annual heat consumption of the system, together with the distribution losses was found equivalent to 2270[MWh]. Specific energy indicator consumption per animal head was calculated and compared to the benchmark values [6]. Results are presented in Table 1. Cost of kWh of supplied heating is calculated based on annual coal consumption during heating season, as fuel cost [12] in [€]; and the cost of electricity is taken from the available annual data, as average cost per kWh. With the indicator values close to the average benchmarks, the case study farm can be considered a typical representative of an intensive pig farm.

Table 1. Calculated energy indicators compared to benchmark values

Indicator	Unit	Value	Benchmark value
Water consumption	m^3/head/year	1.19	1.825 (partly slated floor) 0.07-0.3 (Breeding and finishing farms)
Electricity consumption	kWh/head/year	43.43	42.7 (Integrated farms)
Thermal energy consumption	kWh/head/year	49.28	43.74 (Integrated farms)
Total energy consumption	kWh/head/year	92.72	83-124 (over 450 sows/year) 41-147 (over 2100 piglets/year)

Based on the obtained energy demand results, alocation of energy costsa at the farm was performed, where average values of consumed heat resulted in 10.125 [€/MWh], based on the average annual demand with respect to average fuel purchase cost [12], and, the average value of electricity of 61.97 [€/MWh] was calculated based on average annual electricity cost data. The ratio of heat in the total annual energy demand of 69.3[%], was found, and the ratio of electricity in total annual energy demand of 30.37[%] was calculated. Looking at energy cost data, 72.5[%] of energy costs can be attributed to electricity costs, and 27.5[%] to heat costs.

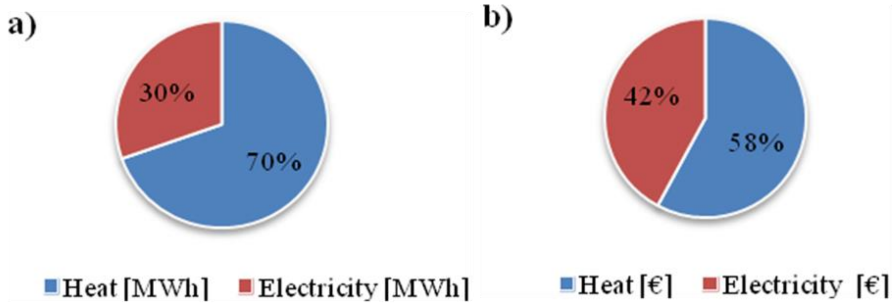


Figure 2. Ratio of heat and electriciy in:
a) total annual energy demand of the farm, (b) annual energy costs

Generally, quantities of manure, sludge and urine generation are difficult to measure, and therefore they were estimated according to daily values [6] per animal and average livestock count for the farm. Possible methane production was calculated using average values for methane yield from the literature [7]. Biogas potential was calculated based on the theoretical amounts of biogas produced per unit of fresh pig slurry a produced slurry calculated for the average type and number of animals at the farm [7, 8]. Total animal count at the farm is 17780 in achieved in four turns, 17.45[%] of which are suckers, 44[%] are finishers, 29.2[%] wieners, and 2.88[%] are sows and gilts. Apart from animal growth, the farm is in the business of agricultural crop farming on 390[ha] surrounding the farm, which represents additional potential for using organic waste for biogas production on the one hand side, and a place for utilization of fertilizer, a by-product of biogas production on the other hand side.
Available slurry for methane production is estimated to 74.6 [t] per day, and a biogas yield of 27.5 [m^3] of biogas per *t* of fresh slurry [9], annual methane yield is estimated to 450242.1[m^3]. For this estimation, a ratio of methane in produced biogas of 60[%] is assumed [10]. An economic analysis of available biogas production and utilization in Sweden rated combined production of heat and electricity (CHP) as a favorable biogas utilization technology [4]. According to estimated annual methane production capacity, a CHP unit could be used to cover base heating loads and produce electricity. In order to obtain a valid permit for selling electricity, average annual efficiency of 85[%] for the cogeneration unit has to be insured [11]. Profitability of cogeneration is improved when the system is operated throughout a year, with utilization of both heat and electricity. In addition to heat supplied to the buildings, heat produced by the cogeneration module can be utilized in the process of fertilizer production for drying the digestate, a byproduct of the process of biogas production.

OPTIMIZATION OF THE BIOGAS COGENERATION SYSTEM

Although biogas could be used in gas fired boilers to meet local heat demands, in an economic analysis of available biogas production and utilization technologies in Sweden utilization of biogas for combined production of heat and electricity (CHP) was among the top rated solutions [10]. According to estimated annual methane production capacity, a CHP unit could be used to cover base heating loads and produce electricity.

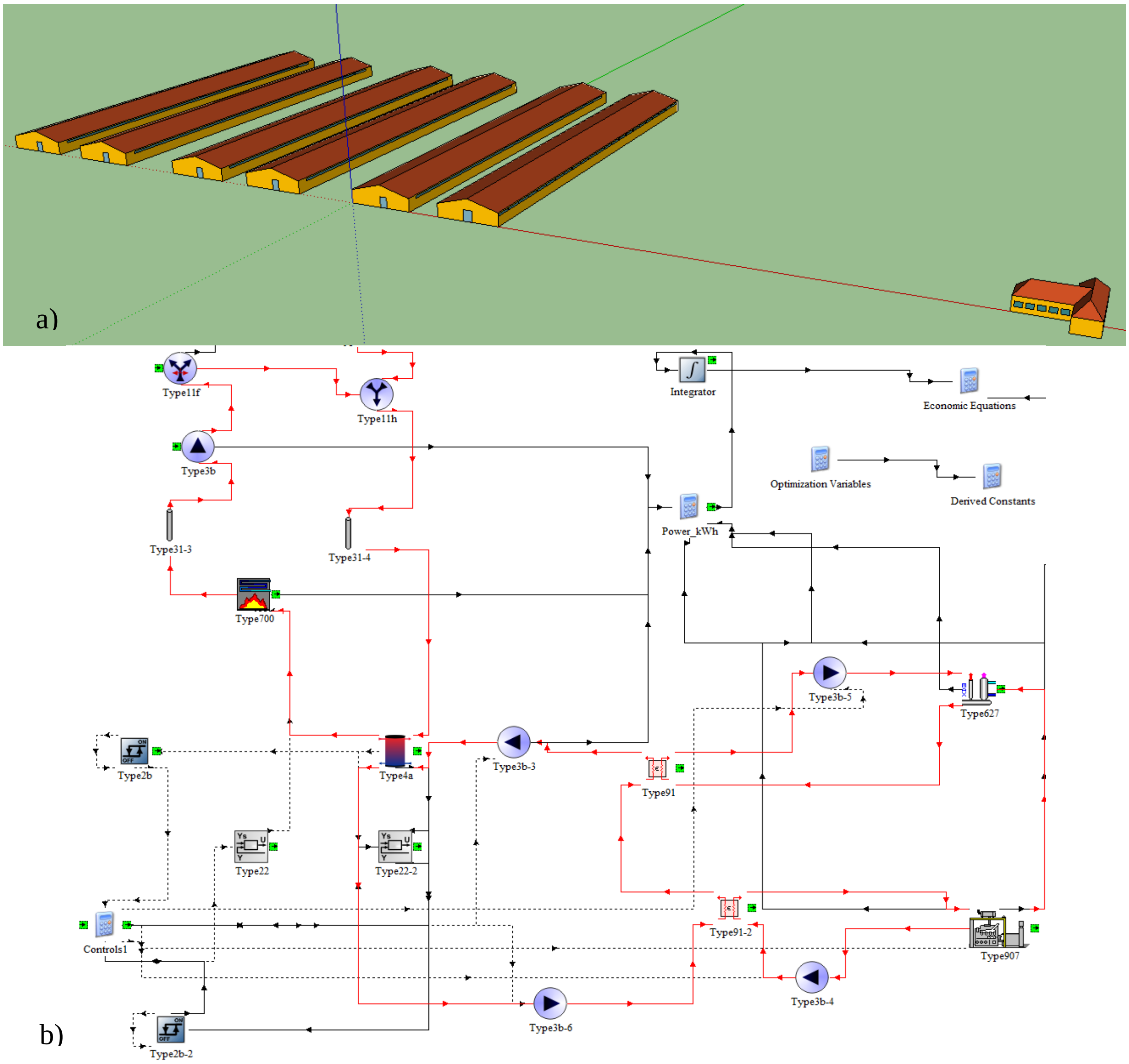


Figure 3. TRNSYS model of the case study farm:
a) TRNSYS 3D multizon model, b) biogas cogeneration system model

A comparison of possible prime movers for small scale cogeneration installations including Solid Oxide Fuel Cell (SOFC), Polymer Electrolyte Membrane Fuel Cell (PEMFC) Engine and Internal Combustion Engine (ICE) [21] and gas-turbine [21-23] was conducted, showing the comparison of their efficiencies and investment costs. According to the simulations and evaluations [24] Stirling engine is most efficient, closely followed by the Reciprocating IC engine. Gas turbine based trigeneration configurations with absorption chillers with and without heat storage, are optimized and confronted to conventional systems in [25, 26]. Green-house gas emission indicators and estimations relevant for CHP plants and comparison to conventional plants [27] show that emission reduction greatly depends on the technology adopted for system integration. CHP technologies fuelled by gas can provide quite good GHG emission reduction, in the range from about 20[%] (for small scale gas turbines) up to about 35[%] (for ICEs and CCs). Also ICEs prove to exhibit good potential emission reduction performance [28]. Based on the literature performance review, SOFC and PEMFC seem better suited for smaller system integration, hence ICE is chosen for further analysis.
A dynamic annual performance model of the farms energy demands is created and couplet with the BCHP model in Trnsys software. The modeled BCHP plant exports electricity directly to the grid, while waste heat for the engines jacket water and flue gas heats a heat storage tank, which is further used for heating animal housing buildings. The system is equipped with a gas fired boiler, which is

engaged when available heat from the heat storage is insufficient for maintaining room temperature above 16 [°C].
For the CHP produced electricity, an export price of 123.1[€/MWh$_e$] [12] was accounted for. According to literature review [13, 14], investment cost for the biogas CHP plant I_{BCHP} is estimated according to installed power for electricity production of the CHP P_{CHPe} module as:

$$I_{BCHP}[€] = -1.09 P_{CHPe}[kW] + 3602 \tag{1}$$

The model takes advantage of a heat storage tank, with the capital investment I_{HS} determined as a linear function of the storage volume capacity and unit cost factor, as per eq. 2:

$$I_{HS}[€] = 400 V_{HS}[m^3] \tag{2}$$

The performance of the modeled ICE with change of its part load ratio (PLR) is given in table 2.

Table 2. Part load ratio performance data of the simulated ICE (fraction of nominal value)

Part Load Ratio	Mech. Eff.	Elect. Eff.	Waste Heat to Jacket Water	Waste Heat to Oil Cooler	Waste Heat to Exhaust	Waste Heat to Aftercooler	Waste Heat to Environment
0.4	0.338	0.921	0.311	0.07	0.532	0	0.087
0.5	0.35	0.932	0.314	0.071	0.526	0.013	0.076
0.6	0.359	0.936	0.314	0.071	0.521	0.026	0.068
0.7	0.365	0.939	0.314	0.07	0.517	0.037	0.061
0.75	0.367	0.939	0.313	0.07	0.515	0.043	0.059
0.8	0.368	0.939	0.313	0.07	0.513	0.048	0.056
0.9	0.368	0.939	0.31	0.069	0.512	0.057	0.052
1	0.364	0.939	0.307	0.068	0.514	0.065	0.047

Net present value function of the biogas cogeneration system project was used as the goal function for optimization, with the economic lifecycle set to 12 years, the period equal to the duration of a typical contract for electricity export with the feed-in tariff price. In order to determine the net present value of a project, determination of the net annual cash flow is of high importance, which in this case is defined by cost savings achieved by utilization of the proposed system. Net annual savings achieved by application of the biogas cogeneration system in the analyzed case study of a pig farm are determined by: 1) available organic waste which could be used for biogas production and therefore running the cogeneration module, 2) cost of produced biogas is considered negligible, since the initial capital investment cost and annual maintenance costs are treated independently, 3) in periods without sufficient amount of produced biogas, the cogeneration system can utilize natural gas with the common market cost. Cost saving achievable by selling produced fertilizer are not considered in this paper, it is assumed that all of the produced fertilizer can be applied to the agricultural crop farming performed at the farm. Integration of the net annual cash flows, and project profitability parameters of the biogas cogeneration project is performed in TRNSYS software, so that the dynamic performance of the system during a typical meteorological year affects fuel consumption, and therefore project profitability and the goal function. The following parameters were calculated [15]:

$$B = \sum B_t P_e - \Delta C_e \tag{3}$$

Where: B-total annual savings; B_t – energy savings for one year (t=1…n); ΔC_e - exploitation cost change.
Net present value NPV:

$$NPV = \sum_{0}^{n} B_t / \left(1 + d^t\right) \tag{4}$$

Where: d – discount rate; n – estimated project lifetime, B – annual net cash flow (revenue).
Simulated BCHP performance in interaction with the simulated energy demand performance in each time step for a typical meteorological year. The presented economic parameters strongly depend on the simulated fuel consumption and fuel costs. Initial cost of the ICE cogeneration module is

determined as per eq. (1), whereas heat storage tank cost is assumed as an average cost of 400[EUR/m^3]B of tank volume. TRNSYS/Genopt optimizations were conducted using negative value of NPV as optimization goal function, where the minimum of the negative value of NPV for 12 years of the project, in the given domain is the optimal point.

OPTIMIZATION METHODS

In this paper, Genopt software was used as the optimization tool, with Trnsys software running in batch mode. Output values of the given TRNSYS optimization variables obtained through the dynamic simulations of the system were used as inputs for the optimization process. For optimization purposes, the Hooke Jeeves algorithm was used [20] Hooke Jeeves algorithm to determine the goal function minimum point.

Hooke Jeeves optimization algorithm

Hooke and Jeeves algorithm [20] divide the algorithm in an initial exploration
(I), a basic iteration (II), and a step size reduction (III). (I) and (II) make use of so-called exploratory moves to get local information about the direction in which the cost function decreases. Let $\Delta x^i \in R$ be the step size of the i-th independent parameter, and $e_i \in R^n$ assume we are given a base point, called the resulting base point x_r and its function value, $f_p \triangleq f(x_r)$, then we make a sequence of orthogonal exploratory moves. To do so, we set $i = 0$, and assign:

$$f_p \leftarrow f_r, \tag{5}$$

Otherwise, we assign:

$$\Delta x^i \leftarrow -\Delta x^i \tag{6}$$

$$\mathrm{x_r} \leftarrow \mathrm{x_r} - 2\Delta \mathrm{x^i e_i} \tag{7}$$

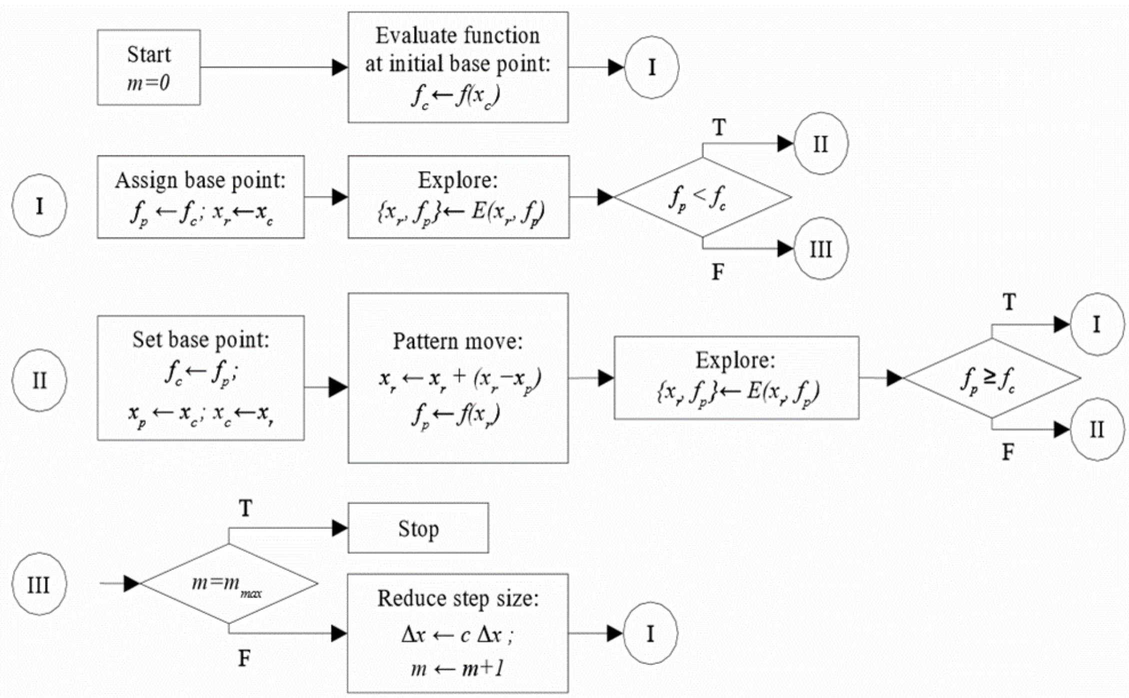


Figure 4. Hooke Jeeves optimization [20]: (I) initial iteration, (II) exploration and (III) step size reduction.

Evaluate $f(x_r)$ and assign $f_r \leftarrow f(x_r)$. f this exploration reduced the cost function, we apply $f_p \leftarrow f_r$ (6). otherwise, we reset the resulting base point by assigning

$$x_r \leftarrow x_r - \Delta x^i e_i \tag{8}$$

so that the resulting base point has not been altered by the exploration in the direction along e_i. Therefore, if any of the exploration moves have been successful, we have a new resulting base point x_r, and a new function value $f_p = f(x_r)$. asign the (probably new) resulting base point x_r he same procedure is repeated along the next coordinate direction (i.e., along e_i), until an exploration along all coordinate vectors $e_{i,} i \in \{1, \ldots, n\}$ has been done.

Na At the end of then exploratory moves, we have a new resulting base point x_r f and only if at least one of the exploratory moves led to a reduction of the cost function. Hooke Jeeves algorithm, with the initial iteration (I), general search (II) and step size reduction (III), is presented in fig 3.

RESULTS

For the created model of energy demand and BCHP plant based on an ICE engine with performance described in table 2, Genopt opimizations were conducted to determine the optimal size of the BCHP plant, i.e. the optimal power of the ICE and the optimal volume of the heat storage tank. Energy and fuel costs are considered constant. A discount rate of 5[%] was used in economic evaluation Hooke Jeeves algorhytm was used for optimization. The convergence was reached and pinpointed the solution. A BCHP plant of 500 [kW] with 100[m^3]of heat storage is the optimal solution is obtained using Hook Jeeves algorhytm, after 40 iterations. Optimization results are presented in fig. 5.

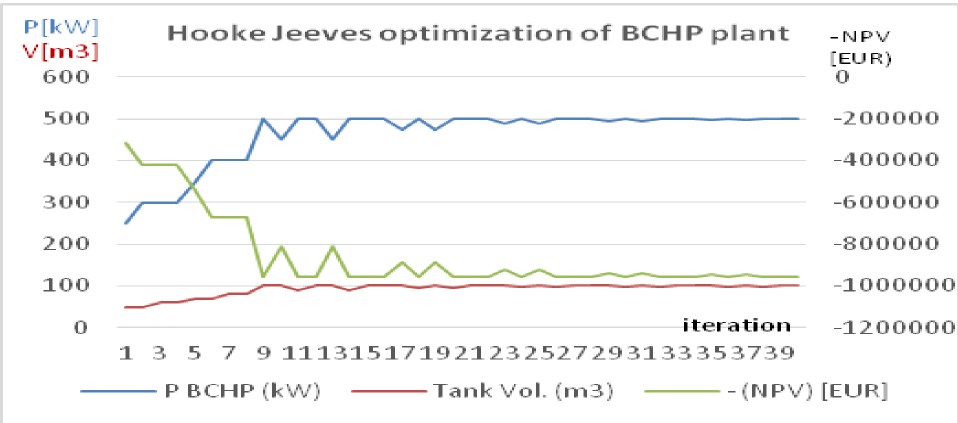


Figure 5. Optimization results obtained Hooke Jeeves algorithm

CONCLUSION

In this paper, a literature review technologies with positive effects on the environment, used at livestock farms, were presented. Based on the review, it can be concluded that utilization of organic farm waste for biogas production can be considered the best option for waste treatment, and combined heat and power production and biogas powered cogeneration technologies can be considered best in terms of energy supply of the farm. Effects of application of biogas cogeneration system for a case study of a large intensive pig farm with capacity of 20000 heads per year in four turns. Based on the energy performance data of the farm, it was concluded that the analyzed farm can be considered a typical representative of its type. Based on the acquired energy consumption and energy cost data, it was concluded that approximately heat consumption represents 70[%] of the total farms energy consumption, and approximately 30[%] of the farms energy annual costs. The cause of such energy consumption and cost ratios are the current tariffs of electricity and fuel used for heating.

Based on the acquired energy system data, a dynamical model of the farms energy demand was created using TRNSYS software, which consists of the multizone model of the farms buildings, main supply pipeline model, air convection heating model and the model of biogas fired cogeneration system with a boiler for peak loads. After determining net annual cost savings achievable by application of the proposed biogas cogeneration system, and net present value of the biogas cogeneration project as function of the simulated annual behavior of the system with a given capacity, a Genopt optimization of the system capacity was performed. Net present value function for 12 years was used as the goal function. Optimal solution was obtained and it represents one third of the presently installed heating power at the farm, and envisages utilization of a huge heat storage unit. Optimization was performed using the Hooke Jeeves optimization algorithm and Genopt software.

ACGNOWLEDGEMENT

This paper was done in the framework of project III 42006 - “Research and development of energy and environmentally highly effective polygeneration systems based on using renewable energy sources” and project TR 33015 – “Research and development of a Serbian zero-net energy house” (2011-2014), both financed by the Republic of Serbia Ministry for Education and Science.

REFERENCES

[1] Aleksić S., Pantelić V., Radović Č., Livestock Production Present Situation And Future Development Directions In Republic Of Serbia, Biotechnology in Animal Husbandry, Vol 25, No. 5-6, pp 267-276, 2009.
[2] M. Meul, F. Nevens, D. Reheul, G. Hofman, Energy use efficiency of specialised dairy, arable and pig farms in Flanders, Agriculture, Ecosystems and Environment Vol. 119, 2007, pp135–144.
[3] Poritosh Roy, Daisuke Nei, Takahiro Orikasa, Qingyi Xu, Hiroshi Okadome, Nobutaka Nakamura, Takeo Shiina, A review of life cycle assessment (LCA) on some food products, Journal of Food Engineering 90 (2009) 1–10.
[4] R.P.J.M. Ravena, K.H. Gregersen, Biogas plants in Denmark: successes and setbacks, Renewable and Sustainable Energy Reviews, 11, pp. 116–132, 2007.
[5] P. Weiland, “Biogas production: current state and perspectives”, Appl Microbiol Biotechnol, pp.849-860, 2010.
[6] L. M. Svensson, K. Christensson, L. Bjornsson, Biogas production from crop residues on a farm-scale level: is it economically feasible under conditions in Sweden?, Bioprocess Biosyst Eng, 28: 139–148, 2005.
[7] S. Prasertsana, B. Sajjakulnukitb, Biomass and biogas energy in Thailand: Potential, opportunity and barriers, Renewable Energy 31, pp. 599–610, 2006.
[8] D. Živković, M. Mančić, V. Stefanović, S. Pavlović, Biomass In Serbia – Resources, Barriers And Possible Solutions, II International Conference IEEP 2012, Zrenjanin, Serbia, 2012.
[9] M. Münster, H. Lund, Comparing Waste-to-Energy technologies by applying energy system analysis, Waste Management 30, pp.1251–1263, 2010.
[10] S. Pipatmanomai, S. Kaewluan, T. Vitidsant, Economic assessment of biogas-to-electricity generation system with H2S removal by activated carbon in small pig farm, Applied Energy 86, pp.669-674, 2009.
[11] Best Available Techniques (BAT) Reference Document for the Intensive Rearing of Poultry and Pigs, European Commission, Draft 2, 2013.
[12] http://www.jppeu.rs/wp-content/uploads/2014/01/lubnica _cenovnik.doc (1/16/2016)
[13] M. Lambic, Solarne tehnologije:toplotni i fotoelektricni sistemi, AGM knjiga d.o.o. 2013.
[14] Biogas postrojenje – uputstvo za izradu prethodnih studija opravdanosti sa primerom za jedno biogas postrojenje, Republika Srbija, AP Vojvodina, Pokrajinski sekretarijat za energetiku i mineralne sirovine, Novi Sad, 2012

[15] Uredba o uslovima i postupku sticanja statusa povlašćenog proizvođača električne energije, na osnovu člana 56 zakona o energetici (Službeni glasnik RS, br. 57/11, 80/11 - ispravka 93/12 i 124/12)
[16] Uredba o merama podsticaja za povlašćene proizvođače električne energije, na osnovu člana 59. stav 6, Zakona o energetici (Službeni glasnik RS, br. 57/11, 80/11 - ispravka 93/12 i 124/12)
[17] Biogas-Messprogramm II–61 Biogasanlagen im Vergleich. Fachagentur Nachwachsende Rohstoffe e.V., Gülzow.
[18] M. Nill, R. Wilfert, Kurzfassung des Endberichtes für da DBU Projekt 15071: Biogasgewinnung aus Gülle, organischen Abfällen und aus angebauter Biomasse – Eine technische, ökologische und ökonomische Analyse. Institut für Energetik und Umwelt gGmbH, Leipzig, 2004.
[19] V. Karamarkovic, M. Matejic, Lj. Brdarevic, M. Stamenic, B. Ramic, Handbook for preparing energy efficiency projects in municipalities, Belgrade, 2008, Ministry for mining and energy of Republic of Serbia
[20] M. Witter, GenOpt, Generic Optimization Program, Lawrence Barkley National Laboratory, Barkley, CA94720, 2011
[21] Adrian Bryan de Bruyn Integration of Combined heat and power generators into small buildings A transient Analysis approach, A theses presented to University of Waterloo in fulfillment of the thesis requirement for the degree of Master of Science in Mechanical Engineering (2006), Waterloo, Ontario, Canada,
[22] H.I. Onovwiona, V.I. Ugursal Residential cogeneration systems: review of the current technology, Renewable and Sustainable Energy Reviews, 10 (2006), p389–431
[23] P.A. Pilavachi , Mini- and micro-gas turbines for combined heat and power, Applied Thermal Engineering, 22, (2002) , p 2003–2014
[24] Pierluigi Mancarella, Gianfranco Chicco, Assessment of the greenhouse gas emissions from cogeneration and trigeneration systems. Part II: Analysis techniques and application cases, Energy, 33 (2008), p 418–430
[25] Gianfranco Chicco, Pierluigi Mancarella, Assessment of the greenhouse gas emissions from cogeneration and trigeneration systems. Part I: Models and indicators, Energy, 33(2008), p 410–417
[26] E. Teopa Calva, M. Pico´n Nu´n˜ez , M.A. Rodrı´guez Toral, Thermal integration of trigeneration systems, Applied Thermal Engineering, 25 (2005), p 973–984
[27] Sergio Arosio, Manfredo Guilizzoni, Francesca Pravettoni, A model for micro-trigeneration systems based on linear optimization and the Italian tariff policy, Applied Thermal Engineering, 31 (2011), p 2292-2300

Session 10.

Reengineering and project management

RESOURCE CONSTRAINED PROJECT SCHEDULING PROBLEM: AN ANALYTICAL APPROACH

Furkan UYSAL[1], Selçuk Kürşat İŞLEYEN[2], Cihan ÇETİNKAYA[3], Nazmiye ÇELİK[3]
[1]Part Time Faculty, Civil Eng., Atilim University, Kızılcaşar Mahallesi, İncek , Ankara, TURKEY
[2]Department of Industrial Eng., Gazi University, Gazi Üniversitesi Rektörlüğü, 06500, Ankara, TURKEY
[3]Department of Industrial Eng., Gaziantep University, 27310 Şehitkamil, Gaziantep, TURKEY
e-mail: cihancetinkaya@gantep.edu.tr

Abstract: In project management, accurate planning and effective scheduling are critical for the performance of any organization. There are a variety of project scheduling problems in the literature, but "The Resource-Constrained Project Scheduling Problem (RCPSP)" is the most well-known NP-Hard problem in project scheduling. The problem consists of executing a group of activities limited by resource constraints. Precedence relationships force some activities to begin after the finalization of others. In addition, every processing activity requires a predefined amount of resources, which are available in limited quantities in every time unit. Thus, a special real case of project scheduling problem: "Resource Constrained Project Scheduling Problem" (RCPSP) is considered in this study. A new mathematical model is developed and the efficiency of the mathematical model is tested with standard test instances, also its performance is compared with baseline solutions. The easily applicable proposed model is shown to give good results and still valid for most of the project scheduling problems.

Key words: Project scheduling, resource constraint, mathematical model.

INTRODUCTION

Effective project scheduling changes an organization's frame in business life. The project scheduling problem date back to 1969 (Pritsker et all 1969) and it has been comprehensively researched in the literature. Among all related literature in scheduling problems, Resource Constrained Project Scheduling Problem (RCPSP) is a more practical case in most of the projects -where the aim is to find an optimal scheduling of a set of activities within a network- while precedence and resource constraints are not violated. In this type of problems, two constraints are modeled. Known as technological constraints, the precedence constraints force an activity to be started within an imposed time frame after all of its predecessors is completed. Directly related to the cost of a project, resource constraints force an activity to consume a limited amount of resources. Given the resource and precedence constraints, more than one schedules can be generated which would have different project durations-some are longer while some are shorter- and the best option is selected which ultimately serves as a baseline schedule.
In this paper, RCPSP is taken for granted as a practical model of project scheduling problem and it is modeled with an analytical approach and related literature is given. Mathematical model is tested with standard test instances and performance is compared with baseline solutions.

RCPSP

The objective of RCPSP is to determine a start date for each activity in such a way that precedence and resource constraints are satisfied, and the project duration is minimized. As RCPSP is NP-hard in the strong case (Blazewicz et al. 1983) it can be solved by exact methods only for small projects. Hence, many researchers have proposed heuristic and meta-heuristic methods for the solution of the RCPSP. RCPSP include deterministic durations and resource demands. There are basically three solution methods to the problem. Exact methods used for finding the optimal schedule but not appropriate to complex problem sets. Heuristics are fast and often provide adequate solutions, but they

do not usually provide high quality solutions. Meta-heuristics are capable of finding high quality solutions but sometimes they are time consuming.
Exact methods date back to zero-one integer programming approach of Pritsker et al. (1969). Other researches are enumeration methods such as branch and bound algorithm of Christofides et al. (1987), mathematical model of Mingozzi (1998) and another zero-one approach by Patterson et al. (1974). Moreover, a detailed survey of exact methods can be found at Kolish and Padman (2001) and Ozdamar and Ulusoy (1995). Project scheduling hand book of Demeulemeester and Herroelen (2002) gives comparable studies between different analytical methods. Due to the NP-Hard environment of the problem, it can be solved by exact models only for small sized problem instances up to 60 activity networks. Therefore, most of the solution techniques are focused on other two groups: heuristics and meta-heuristics. Heuristics are rule of thumbs which can serve as good solution routines in a polynomial time. Most heuristics are rules that are tailored to fit for specific types of problems. They may be deterministic and stochastic whether the same results can be found at each iteration or not. The heuristic studies for the RCPSP date back to Kelley (1963) with a schedule generation schema (SGS). SGS is at the hearth of heuristics and meta-heuristics as well as it is a heuristic itself. Priority-rule-based heuristics (PR-H) use a SGS in order to build a schedule. Priority rule is used for selecting the nominee activities from the activity set. PR-H can be classified according to criteria it employs, i.e. network, time and resource based rules. If PR-H generates a single solution it is called single pass method, if it generates more than one schedules, it is called multi pass methods (Kolish and Hartman, 1999). PR-H can be applied to get one solution at a time. As an example of heuristics see Hartman et al. (2000), where Late Finish Time (LFT) and Worst Case Slack (WCS) rule is used in experiments on test of algorithms performances. Davis and Patterson (1975) tested various heuristic sequencing rules on RCPSP with the total project minimization objective function. Backward forward improvement method (Li and Willis, 1992) is a special improvement method that is based on scheduling with same SGS and heuristics, in reverse time direction. Another method is selecting more than one heuristics in a random manner which can be found at Storer et al., (1992).
Meta-heuristics are higher level heuristic methods which can be applied for different type of problems without being specific for one specific type of problem. The meta-heuristics are included variety of methods such as genetic algorithms (GAs), simulated annealing (SA), tabu search, particle swarm optimization (PSO) and ant colony optimization (ACO) which mimic a natural phenomenon in order to find a global optimum in a large search space. Among all meta-heuristics, GAs have a large variety of application areas. It is a population-based and stochastic search algorithm based on evolutionary computation principles inspired by the Darwinian principles of natural selection (Holland, 1975). Examples of other meta-heuristics are tabu search algorithm (Thomas and Salhi, 1998), simulated annealing (Bouleimen and Lecocq, 2003), neighborhood search (Fleszar and Hindi, 2004), genetic algorithm (Hartmann, 2002), ant colony optimization (Merkle et al., 2002), particle swarm optimization (Chen et al., 2010). Also there are hybrid algorithms that combine one or more algorithm together (Valls et al.,2008; Tseng and Chen, 2006). Kolish and Hartmann (2006) and Hartmann and Kolish (2000) give detailed comparison of heuristics and meta-heuristics under different objective functions.
Apart from analytical approaches, most of the software developers provide practical software packages to engineers. MS Project and Primavera are very common and an educational software RESCON (http://econ.kuleuven.be/rescon, last accessed at 13.01.2013) can be downloaded with free of charge. Nevertheless, these software packages give limited solutions to the RCPSP and efficiency of these algorithms is low.

A Mathematical Model of RCPSP

Since mathematical model gives insight behavior of the problem itself, a mathematical model is given in this section. Considering the previous works mathematical model of the problem is regenerated for this problem is as follows;
A finite set which includes activities $N = \{1,2,\cdots,n\}$ and activity relations $A = \{(i, j) : i, j \in N\}$ is given. If $(i, j) \in A$ that means activity j cannot start before i is finished. In addition, resources

$k \in K$ is given, the availability of resource k is shown as R_k and resource usage of activity j is defined as $r_{j,k}$ $(0 \le r_{j,k} \le R_k)$

Parameters

$G=(N,A)$ Graph with arcs and activities
$N=\{1,2,\cdots,n\}$ set of activities
$A=\{(i,j)\, i,j \in N\}$ set of precedence relations
K: $k=1,2,\cdots,K$ set of resources
R_k : Limits of resource k
$r_{j,k}$: Resource usage of activity j from resource k
p_i : Processing time of activity i
M : A big number

Variables

s_i : Start time of task i
c_i : Finish time of task i
$C_{\max}$: Finish time of last dummy activity
$x_{i,j}$: If start time of task i is smaller than finish time of task j than $x_{i,j}=1$, otherwise $x_{i,j}=0$. That is;

$$x_{i,j}=\begin{cases}1 & ,s_i<c_j\\ 0 & ,o.w.\end{cases}$$

$h_{i,j}$:If start time of task i is larger or equal than start time of task j $h_{i,j}=1$, otherwise $h_{i,j}=0$. That is:

$$h_{i,j}=\begin{cases}s_j \le s_i \Rightarrow 1\\ o.w. \Rightarrow 0\end{cases}$$

$z_{i,j}$: If start time of task i is between the start time and finish time of task j $z_{i,j}=1$, otherwise $z_{i,j}=0$. That is:

$$z_{i,j}=\begin{cases}s_j \le s_i < c_j \Rightarrow 1\\ o.w. \Rightarrow 0\end{cases}$$

Where $y_{i,j}$, $t_{i,j} \in \{0,1\}$

Constraints

$s_j \ge p_i + s_i$	$\forall (i,j) \in A$	(1)
$c_i = p_i + s_i$	$\forall i \in N$	(2)
$C_{\max} \ge c_i$	$\forall i \in N$	(3)
$s_i \ge c_j - M * y_{i,j}$	$\forall (i,j) \notin A$ and $i \ne j$	(4)
$x_{i,j} \ge 1 - M*(1-y_{i,j})$	$\forall (i,j) \notin A$ and $i \ne j$	(5)
$s_i \le s_j - 1 + M * t_{i,j}$	$\forall (i,j) \notin A$ and $i \ne j$	(6)
$h_{i,j} \ge 1 - M*(1-t_{i,j})$	$\forall (i,j) \notin A$ and $i \ne j$	(7)
$z_{i,j} \le (x_{i,j} + h_{i,j})/2$	$\forall (i,j)$	(8)

$$z_{i,j} \geq x_{i,j} + h_{i,j} - 1 \qquad \forall(i,j) \tag{9}$$

$$\sum_j r_{j,k} * z_{i,j} \leq R_k - r_{i,k} \qquad \forall(i,k) \tag{10}$$

$$Min\, C_{\max} \tag{11}$$

Constraint (1) states that processing time of activity j should be greater than processing time of activity i plus its duration. Finish time of any activity is determined with (2) and (3) is used for determining the last task finish time, (4)-(9) is used for determining the task ongoing in same time periods, (10) is an upper limit of resources in order to restrict the total resource usage.

Proposed mathematical model is solved with Gurabi 5.0 solver on Python 2.7 interface. Model is tested with standard test instances of PSPLIB [24]. 30 and 60 activity networks are tested which is totally 960 test instances. I7-2670QM, 2.2 GHz computer is used on Windows 7 operating system which has 4 GB RAM. Time limit was 300 seconds for J30 sets and 1000 seconds for J60 sets. All problem sets were solved with mathematical model and %94.5 of J30 sets and %73 of J60 sets were solved optimally. Results are tabulated at Table 1 and Table 2.

Table 1. Number of Optimally Solved Sets and Average Computation Time

Problem Set Type	Number of Optimally Solved Sets	Average Computation Time (sec)
J30	454	14.3
J60	351	19.9

Sets that cannot be solved by our model is tested with known optimum results. It depicts optimum only by %2.68.

Table 2. Comparison of Results That Cannot Be Solved Optimally By Model (J30 Sets)

	Problem No	**Upper Bound of Model (This Study)**	**Optimum**	**Deviation (%)**
1	J309_2	92	92	0
2	J3013_1	61	58	5,17
3	J3013_2	68	62	9,68
4	J3013_3	80	76	5,26
5	J3013_4	73	72	1,39
6	J3013_5	73	67	8,96
7	J3013_6	68	64	6,25
8	J3013_7	83	77	7,796
9	J3013_8	108	106	1,89
10	J3013_9	71	71	0
11	J3013_10	64	64	0
12	J3014_2	54	53	1,89
13	J3014_7	50	50	0
14	J3025_5	72	72	0
15	J3029_1	86	85	1,18
16	J3029_2	90	90	0
17	J3029_3	79	78	1,288
18	J3029_4	105	103	1,948
19	J3029_6	98	92	6,528
20	J3029_7	74	73	1,37
21	J3029_8	86	80	7,5
22	J3030_10	53	53	0
23	J3041_10	99	99	0
24	J3045_2	125	125	0
25	J3045_6	129	129	0
26	J3046_7	60	59	1,69
	Average			**2.68**

For comparison mix integer programming by Patterson (1984) is used with J30 problem instances setting up the time limit as 500 seconds. This model is accepted as efficient model in the literature. %97 of J30 sets were optimally solved by the model in 500 seconds.

CONCLUSION

Briefly, in this study The Resource Constrained Project Scheduling Problem is surveyed and a new mathematical model is proposed for the problem. Mathematical model and its validity are tested with a "30 and 60 activity" network. All problem sets were solved with mathematical model and %94.5 of J30 sets and %73 of J60 sets were solved optimally. Since model serves a more practical case for most of the projects, it can easily be applied in practice. Considering the problem is an NP-Hard problem, the model can be inefficient for large problem instances. Therefore, heuristics and meta-heuristics can be used for large problem instances. Also cost minimization, or profit maximization can be used as objective functions. For future study, we are aiming to add "stochastic demand" to this study which has not been researched in the literature before.

REFERENCES

[1] Blazewicz, J., Lenstra J. K. ve Rinnooy Kan A.H.G., (1983) "Scheduling Projects to Resource Constraints: Classification and Complexity", Discrete Applied Mathematics, 19995, 11-24.

[2] Bouleimen K., Lecocq H., (2003) "A new efficient simulated annealing algorithm for the resource-constrained project scheduling problem and its multiple modes version." European Journal of Operations Research, Volume 149, 268–281.

[3] Christofides N., Alvarez-Valdes R., Tamarit J.M., (1987) "Project scheduling with resource constraints: a branch and bound approach", European Journal of Operational Research, Volume 29, No:3,262–73.

[4] Demeulemeester, E., ve Herroelen, W., (2002), "Project scheduling – A research handbook". Vol. 49 of International Series in Operations Research & Management Science. Kluwer Academic Publishers, Boston.

[5] Fleszar K., Hindi K., (2004), "Solving the resource-constrained project scheduling problem by a variable neighborhood search." European Journal of Operational Research, Volume 155, 402–413.

[6] Hartmann S., (2002), "A self-adapting genetic algorithm for project scheduling under resource constraints." Naval Research Logistics, Volume 49, 433–448.

[7] Hartmann S., Kolisch R., (2000), "Experimental evaulation of state-of-the-art heuristics for the resource-constrained project scheduling problem.", European Journal of Operational Research, Volume 127, No 2, 394-407.

[8] Kolisch R., Hartmann S., (2006), "Experimental investigation of heuristics for resourceconstrained project scheduling: An update.", European Journal of Operational Research, Volume 174,No 1, 23–37.

[9] Kolisch R., Sprecher A., (1997), "PSPLIB - A project scheduling problem library: OR Software - ORSEP Operations Research Software Exchange Program" European Journal of Operational Research, Volume 96, No 1, 205-216, Data available from http://129.187.106.231/psplib/

[10] Kolish R. ve Padman R., (2001), "An Integrated Survey on Deterministic Project Scheduling" OMEGA Volume 29, 249-272.

[11] Li S., Jia Y., Wang J.A, (2012), "discrete-event simulation approach with multiple-comparison procedure for stochastic resource-constrained project scheduling", International Journal of Advanced Manufacturing Technology, Volume 63, No 1, 65-76.

[12] Merkle D., Middendorf M.,Schmeck H., (2002), "Ant colony optimization for resource-constrained project scheduling." IEEE Transactions on Evolutionary Computation, Volume 6, 333–346.

[13] Mingozzi, A., Maniezzo V., Ricciardelli S., Bianco L., (1998), “An Exact Algorithm For The Resource-Constrained Project Scheduling Problem Based On A New Mathematical Formulation”, Management Science, Volume 44, 715–729.

[14] Ozdamar L., Ulusoy G., (1995), “A survey on the resource constrained project scheduling problem, IIE Transactions, Volume 27, 574-586.

[15] Patterson J.H. ve Huber W. D.A (1974), “Horizon-Varying, Zero-One Approach to Project Scheduling”, Management Science , Volume 20, No. 6, 990-998.

[16] Patterson J.H., (1984), “A Comparison of Exact Approaches for Solving the Multiple Constrained Resource, Project Scheduling Problem” Management Science , Volume 30, No 7, 854-867.

[17] Pritsker, A., Allan, B., Watters, L.J., Wolfe, P.M., (1969) “Multiproject Scheduling With Limited Resources: A Zero-One Programming Approach”, Management Science, Volume 16, 93–108.

[18] Thomas P.R., Salhi, S., (1998), “A tabu search approach for the resource constrained project scheduling problem”, Journal of Heuristics, Volume 4, 123–139.

[19] Tseng L.Y., Chen S.C., (2006.), “A hybrid metaheuristic for the resourceconstrained project scheduling problem.” European Journal of Operational Research, 175, 707–721.

[20] Valls V., Ballestin, F., Quintanilla S., (2008), “A hybrid genetic algorithm for the resource-constrained project scheduling problem.” European Journal of Operational Research, Volume 185, 495–508.

TECHNICAL AND FINANCIAL MANAGEMENT COMPONENT COMPLEX TECHNICAL SYSTEMS

Zlatko Lacković[1], Milan Ivanović[2], Ivana Šadrk Nukić[1]
[1]Josip Juraj Strossmayer University of Osijek, Faculty of Civil Engineering, Osijek
[2]Panon – Think tank for strategic studies – Osijek
e-mail: zlackovic@gfos.hr

Abstract: The article considers the connection between computer science and mathematics in order to manage complex technical processes. First, it cites the example of the technical management of the change in information technology. After that states the conceptual design of monitoring costs for individual business and manufacturing stages. Everything is directed toward maximum efficiency of business and production processes.
Key words: management, technology, organization, costs

INTRODUCTION

Operation of complex technical systems, in modern conditions, strong support can give information technology. Bearing in mind the special features of complex technical systems, the use of information technology in the business requirement, without which it can not effectively operate in all positions, especially in process management. In addition, should take into account the success of information technology as an important factor of success of the total business of the company, given the current following facts: [4,1]

- explosion of knowledge and information technologies,
- speed, connectivity and value added has become a key source of success,
- Information is a strategic weapon of companies,
- information becomes a fundamental function of the company,
- enterprises need computer literacy,
- geo-strategic importance of information technology is growing.

Analyzing of the previous facts and consideration of the role of IT in business enterprises, it can be concluded that everything goes very quickly from production to product distribution. This conclusion largely applies to every technical manufacturing or service system, but the implementation is different for individual activities. Besides informing the strategic weapons each, a particularly complex technical system, for the following types of impacts: [3,178]

- Information Technology installed in an increasing number of new products
- creating new products is inconceivable without information technology.
- information technology alter the business relationship.
- information technology permanently affect a redefinition of activities
- all the effects of information technologies allow reducing operating costs.
- Information resources are becoming the most important business.

The application of information technology requires a certain computer literacy of all the participants. This applies primarily to the technical understanding and skills of information technology application. In particular, it is important to use and interpret information, but also an understanding of the effects of computerization. Therefore, participants in the business have to be trained for it, especially in the applied sense.
Given the nature of engineering management should take into account the most important pieces of information technologies that support business or manufacturing and service process. Ideally technical managers objectively have a firm, primarily to productive operations in the technical and cost terms.

ELECTRONIC PROCESS CONTROL

Managing production or service process is one of the most important tasks of engineers-managers. In fact, it is a situation when you should use polytechnic knowledge in order to manage the technique and technology, and take into consideration of all economic, in particular the cost components, for maximum performance. In this regard will continue to be considered one of the known technical approach to managing complex technical systems. After that they may identify economic, especially the cost components arising from the functioning of the technical reliability of the system. One of the known systems by which you can manage complex production or service process is a programmable logic controller generally recognized as the PLC. [5,1] The association cited a programmable logic controller is defined as "a digital electronic device that uses a programmable memory for memory commands which is required for carrying out specific functions such as logic functions, counting, timing, calculation, in order to manage different types of devices and processes via analog and digital input-output module".

Programmable logic controllers (PLCs) are industrial computers whose hardware and software elements specially adapted to work in an industrial environment, and that can be easily programmed and installed in existing industrial systems.

The complete system, PLC driven controller, according to Figure 1 consists of:

- The input devices, such as switches, buttons, sensors, etc..
- input module, which is part of the PLC and using this module is receiving signals from input devices.
- Logical Unit (CPU), which is the brain of the PLC controller, and consists of a central processing unit and memory.
- In the process of the accommodation program and data, and it controls the operation of the entire system.
- output module, which is also part of the PLC. Through this module can receive signals to control individual output devices.
- output devices, such as relays, lamps, motors contactors, valves etc.

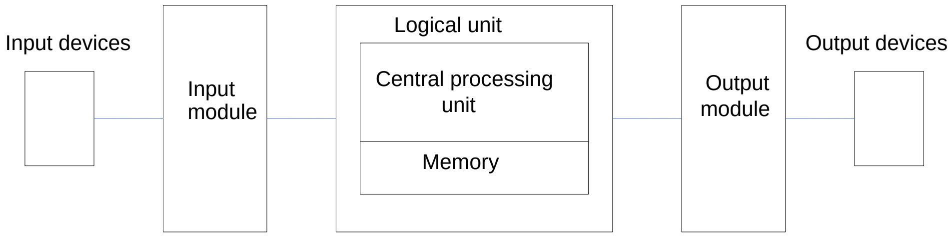


Figure 1. The basic elements of the programmable logic controller [2,180]

PLC is, essentially, a microprocessor device that uses a programmable memory to remember order requiring the performance of specific functions, such as performing logic functions, timers, counters, timing functions, mathematical calculations, with the aim of managing different types of devices and systems via digital and analog input and output modules. PLC device is different from general-purpose computer system that it has no external memory (discs), as well as a number of elements of standard input / output equipment. In addition, its operating system is simpler and provides fewer opportunities alongside a general purpose computer.

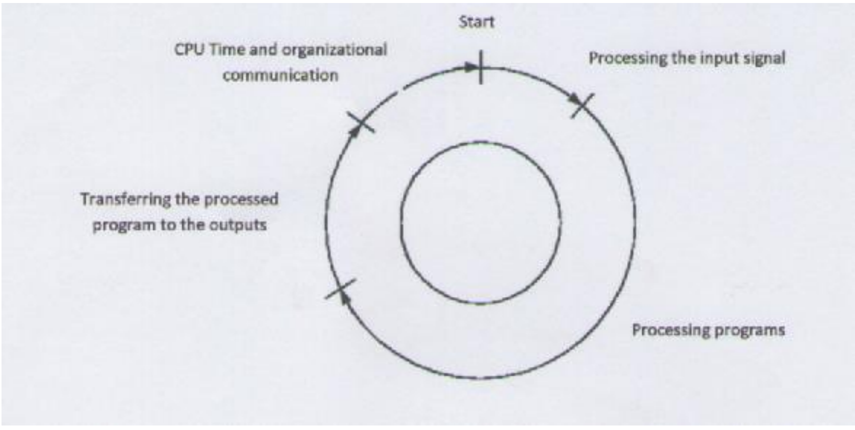


Figure 2. Functioning [2,183]

According to Figure 2. - The cycle begins processing the input signal within which the PLC reads the contents of input lines (registers input modules). The readout data is transferred in a specific area of memory (image input). Then he activated the program of the cycle in which the processor executes programming instructions governing the proper arithmetic-logic functions. Data (operands) used in programming commands are taken from memory and from the area designated as image input and processing results are placed in a special area of memory (image output). It is important to point out that in the execution of program commands the data are not taken directly from the input modules or results directly mounted on the output modules, but the program exchanges data only with the memory.
Upon completion of the part of the cycle for processing programs, operating system PLC unit by transferring the data to the output lines (registers output modules). This creates the impression that the PLC all operations specific program carried out at the same time. The fourth part of the cycle is intended for realization of the exchange of data with devices that are connected to the PLC. After that, the operating system brings PLC in the maintenance phase in which the updated internal timers and registers, performs memory management as well as other activities related to the maintenance of the system. Depending on the type of the embedded microprocessor input and output are performed at a cycle time of the order of milliseconds. The duration of your treatment program will depend on the size of the program.

COST MANAGEMENT COMPONENT

These considerations are oriented towards technical aspects, because that is the main task of the manager of every technical system. However, it should be noted that in every technical system of economic phenomena major factor efficiency. Specifically, it should be noted that the functioning of each system has certain costs that are particularly increased in stages downtime or poor functioning, all of which ultimately may reduce the effectiveness of not only production but also the business system as a whole. Therefore, it is necessary to analyze, besides the technical functionality, the cost per individual phases, as to be able to investigate the causes and take measures to reduce the delays and other causes of non-functioning. Therefore, it is necessary, within the technical management of the system, parallel to monitor the progress of costs throughout all phases of the procurement of inputs, production and distribution of output, and it can be used already mentioned program as shown in Figure 3. Therefore, it is on track costs in the procurement stage, and at all stages of production and distribution costs of products to customers.

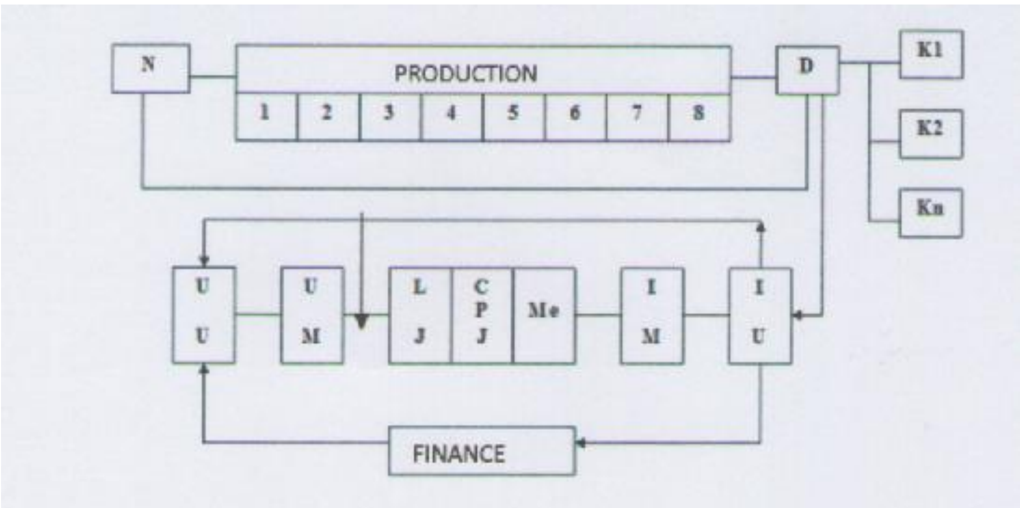


Figure 3. Manage of the operation and costs of complex technical systems [2,185]

Legend:
N - procurement, D - Distribution, K1 to Kn - customers, UU - input device, UM - input module, LJ - logical unit, CPJ - central processing unit, Me - memory, IM - output modules, IU -Output device

Display in Figure 3 suggests that the manager of a complex technical system must connect several specific components of management. As the manager of the technical system does not deal with the general business policy of the wider business system, its role is primarily to ensure the efficiency of the production process. This refers to the acquisition, production and distribution, where the main objectives of ensuring reliable operation and minimize costs. Sami costs can be programmed and monitored by applying the elements of pure phases djelidbene calculations. [1,122]
If the above calculations adapted to the respective application, able to plan, monitor and analyze all costs by stages, not only of production, but the whole process from procurement to distribution. In addition to the cost of the whole process, we should note the fact that the costs of operation (exploitation) opposed the reliability of the system. This means that the role of technical manager to constantly trying to find a balance between maximum reliability and minimum operating costs and maintenance. That can certainly help information system that brings together, in terms of value, technical and cost aspects of managing complex technical system. Precise determination and analysis in terms of value can be carried out using mathematical methods with the use of network planning. The movement of output relative to the input can be displayed to productive funkacijom and costs by applying mathematical methods.
The figure 4 shows one technical process of the three production lines or any other complicated technical operation. In each line are shown ways in which the process of formation of costs in a limited time. The formation costs over time are shown respective function. Each operation is displayed so that it can be seen that the mathematical functional expression shows progress of the physical and technical processes. For example, in line 1, which is marked with the function y1 first operation takes place linearly with the shift. In other operations, clearly has other effects on costs and their movement shows the corresponding functions or diagrams. At the end of the process we have, for example, the installation of a complex product that is also displayed with the corresponding functions.

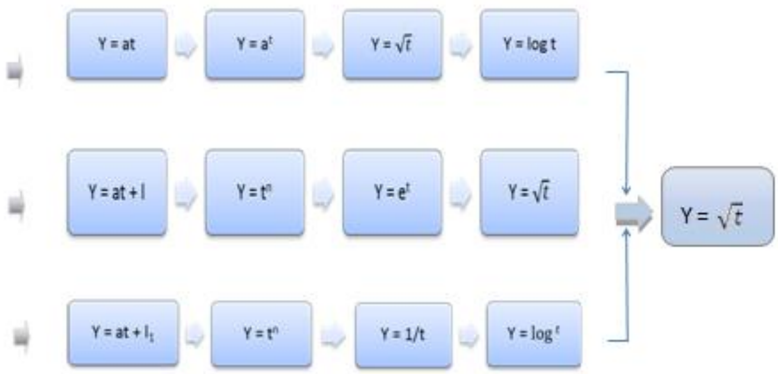


Figure 4. Production or other complex technical process [3,224]

Movement of costs can be calculated by solving the set of all functions by using Laplace transformations. First, calculate the individual cost of integrating it through algebraic theorems of the form summarizing all costs on lines and operations. They are after integration and calculation taking into account the time constraints and the cost of the final operations marked with y4 obtain total costs. Figure 5 is a conceptual design of improvised movement of costs in a complex technical process shown functions Y1, Y2 and Y3, which represent processes that occur at the same time. At the end of the process takes place in the final process that represents its real function? 4. Using La Placeovu transformation and the corresponding theorems linearity and additional impact of linear nature can be set calculations of content, such as in this case, the cost of each operation costs of all lines of production processes and the overall costs of the entire process. Calculation of individual lines and the cost of the process are calculated by integrating with the application of Laplace transformation. [7,5]

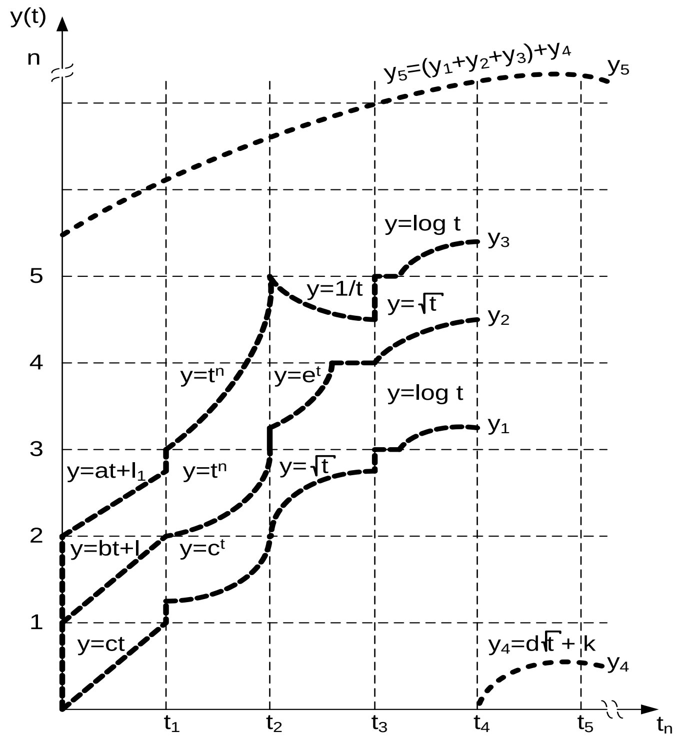


Figure 5. Diagram of operating costs in a complex technical process [3,225]

The use of models and tools such as the Laplace transform is used to serve you when the argument of a function is also a function with the presence of other conditions for the use of this model.

CONCLUSION

From the above considerations may be taken over the concluding thoughts. First of all this is the necessity of the use of information technology in technical systems. This is especially true for process management in a technical sense. Thanks to the possibilities related to the modulation and processing information all technical processes can be monitored and cost. In this way, using suitable mathematical models, ensures the technical reliability of the technical and economic efficiency of the process in a complex technical system.

REFERENCES

[1] Karić, M., Ekonomika poduzeća, Ekonomski fakultet, Osijek, 2006., str. 122.
[2] Lacković,Z., Inženjerski menadžment, Elektrotehnički fakultet, Osijek, 2008.
[3] Lacković,Z., Upravljanje tehničkim procesima, Akademija tehničkih znanosti Hrvatske, Osijek, 2015.
[4] Srića, V. i dr., Menadžerska informatika, MEP Consvet, Zagreb, 1999..
[5] www.nema.org/about/contact. NEMA (The Natonal Electrical Manfactures Association),
[6] www.tri-plc.com
[7] www.pfri.unri.hr

INDUSTRIAL MANUFACTURING SYSTEM DESIGN. WORKPLACE LAYOUT OPTIMISATION

Vasile Alexa[1], Sorin Aurel Raţiu[1], Imre Kiss[1], Vasile George Cioată[1]
[1]Politehnica University of Timişoara, Faculty of Engineering Hunedoara
e-mail: vasile.alexa@fih.upt.ro

Abstract: In order to optimally place an industrial manufacturing system, we should consider more options, from which we choose the optimal variant based on a set of efficiency indicators assessing the main features of all possible variants. The organisation and management of the manufacturing activity in the enterprise depend directly on the type of production. In this paper, we are going to present a method to emplace the workplaces according to the succession of various groups of workplaces, based on the production links.
Key words: production, optimization, technological flow, workplace

INTRODUCTION

The industrial manufacturing system design is based on the concept of *optimality* that presupposes that a system operates under extremisation conditions *(minimisation or maximisation* of an economic efficiency function), e.g. minimisation of the production cost or maximisation of the profit.
The industrial manufacturing system, as a complex system, is characterised by the following features:
» it actively interacts with the environment, in order to create an effective ambience in which operates with maximum profitability;
» the industrial manufacturing system structure is adaptable to all conditions arising during operation;
» it uses the previous experience to optimise its current and future activity.
Industrial production system design methodology comprising the steps, fig. 1:

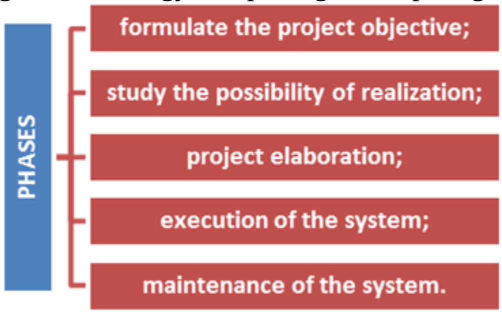


Figure 1. Phases of designing a production system

A production system has at least five subsystems, figure 2:

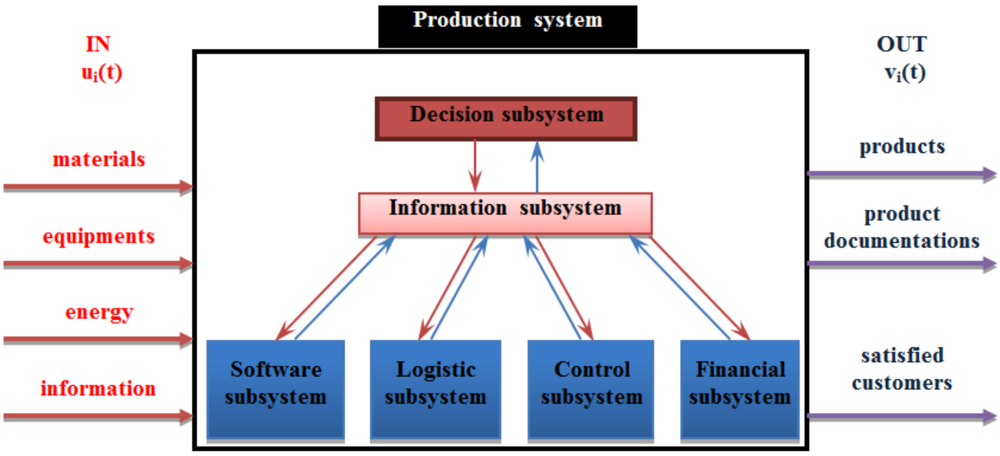


Figure 2. The structure of the production system

OPTIMISATION MATHEMATICAL MODEL

The forecasting of the development and optimisation of the industrial manufacturing systems is made using *mathematical models,* linear or nonlinear, depending on the complexity of the phenomena and the variation range of the variables describing the state of the manufacturing systems with *discrete or continuous structure.*

The mathematical model can be developed in systemic conception and can evolve from a workplace, productive unit, and national industrial or economic branch.

The mathematical models can be *synthetic models* or *specific models*, both applicable to manufacturing systems optimisation with feedback.

The systemic approach involves treating the design subject as a well-defined system. Therefore, the item that in a certain context can be just a component of a system, in a different context it can be considered as a given system. For example, a manufacturing unit can be considered a system which has, as subsystems, the production departments, workshops, workplaces, and in the context of an industrial branch it is considered to be a subsystem.

The industrial system represents a group of elements (people, materials, equipment’s) forming a whole, which interact and operate for achieving a common goal.

The study of the optimal layout of a manufacturing system must include many variants, of which we shall choose the *optimal variant* based on a system of efficiency indicators which assesses the main features of all possible variants.

The optimisation requires the existence of an *objective function* and a *restriction system.* The function presented in equation (1) represents the *objective function*.

Next, using the comparative analysis, we are going to adopt the optimal variant, i.e. the one which, for the same technical conditions and capacity, when only the layout differs, it ensures the construction and operation of the manufacturing system with minimum costs. We shall quantify the factors influencing the decision-making process, i.e. transport distances, quantities, specific costs, investments costs, etc.

A linear mathematical model for establishing the optimal location of an enterprise within a homogeneous manufacturing branch, using as optimisation criterion the *minimisation of transport, manufacturing and investment costs*, might have the following objective function:

$$\min F(x) = \min(\underbrace{\sum_{i=1}^{E+N}\sum_{j=1}^{C} C_{ij}X_{ij} + \sum_{k=1}^{M}\sum_{i=1}^{E+N} D_{ki}X_{ki}}_{\text{Transport costs related to products + raw materials}} + \underbrace{\sum_{i=1}^{E+N}(P_iY_i + S_iZ_i)}_{\text{Manufacturing costs}} + \underbrace{\sum_{i=1}^{E+N}(E_nI_i + E'_nI'_i)}_{\text{Investment costs}}) \tag{1}$$

using the following notations:

- $i=1, \ldots, E+N$
  - E - number of existing manufacturing units
  - N - number of new manufacturing units that are going to be built
- $j=1, \ldots, C$
  - C - number of points of consumption
- $k=1, \ldots, M$
  - M - number of raw material sources
- C_{ij} - transport cost of the finished product unit from the manufacturing centre i to the consumption centre j;
- X_{ij} - quantity of finished products transported from the production centre i to the consumption centre j;
- D_{ki} - transport cost of the raw material unit from the source k to the manufacturing centre i;
- X_{ki} - raw material quantity transported from the source k to the manufacturing centre i;
- Y_i - production volume that corresponds to the existing manufacturing units;
- Z_i - production volume estimated for the new manufacturing units;
- P_i - manufacturing cost of the product unit obtained from the existing manufacturing units;

- S_i - manufacturing cost of the product unit obtained from the new manufacturing units;
- E_n - economic efficiency indicator of the investment volume I_i from the existing manufacturing units, E;
- E'_n - economic efficiency indicator of the investment volume I'_i from the new manufacturing units, N.

The restriction system consists of a system of equations and inequalities, as follows:

$$\sum_{i=1}^{E+N} X_{ij} = B_j \, , \tag{2}$$

where: B_j is the consumption requirement in the point of consumption *j*.

$$\sum_{j=1}^{C} X_{ij} = Y_i + Z_i \tag{3}$$

The signification of equation (3 is that the quantity produced and transported to point C must not exceed the production volume afferent to the units E+N.

$$\sum_{k=1}^{M} X_{ki} = Y_i + Z_i \tag{4}$$

The signification of equation (4) is that the raw material quantity, transported from a point *k* to the manufacturing centre *i*, must be equal to the requirement of raw material to be used for obtaining the production volume afferent to the units E+N.

The previous restriction system is supplemented by a system of inequalities:

$$\begin{cases} 0 \le Y_i \le C_{pE} \\ 0 \le Z_i \le C_{pN} \\ 0 \le V_k \le W_{kM} \end{cases} \tag{5}$$

where: W_{kM} is the production capacity of the raw material source *k*;
V_k is the production volume afferent to the raw material source *k*.

The signification of equation (5) is that the production contracted from the units E must not exceed their production capacity. The equation (5) has the same significance as the equation referring to the new production units, N.

The non-negativity conditions: $\begin{cases} x_{ij} \ge 0 \\ x_{ki} \ge 0 \end{cases}$

This optimisation problem is solved using the *linear programming.*

THE TECHNOLOGICAL FLOW. THE LINK METHOD

It is used in the functional workplace layout, to establish the succession of the various workplace groups of the same type.

The **production link** is the connection between two workplaces located successively.

The main criterion

- Determination of the number of links established between two workplaces, i.e. the flow of materials between the various workplaces
- The workplaces are placed so that on the shortest routes to be moved the highest quantities of materials, and on the longest routes to be moved the lowest quantities

In the company, there are 40 specialised workplaces:

- 5 precision automatic presses
- 1 industrial washing machine
- 1 vibratory finishing machine
- 3 manual presses
- 2 packaging machines (ATIS)
- 2 polishing machines

Note the operations performed by these machines with:

A	B	C	D	E	F
•stamping	•scouring	•finishing	•assembly	•packing	•polishing

Following the above operations, we analyze manufacturing of 4 products P1, P2, P3, P4, running in the production hall:
Flow of each milestone will be the one in Figure 3. Transport of 4 parts, between workplace is performed using transport containers, whose capacity is influenced by the size of these items.

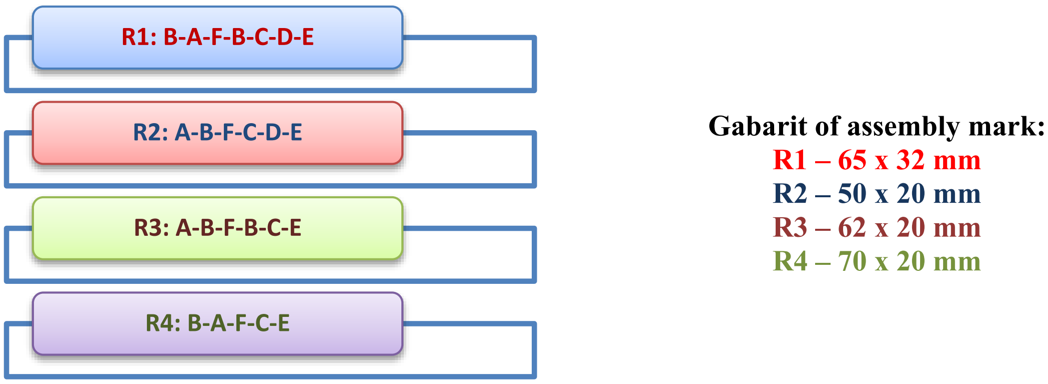


Figure 3. The technological flow of four assembly mark

STEP 1
Drawing links table is to establish links of production for each product to be processed on the machines to be placed on the surface of production.
For this builds a table, which will be the end product names manufactured columns, each column having two sub-columns.
Sub columns name will be the name of workplace (W) of the succession process flow and production links (PL) for each product (table 1).

Table 1. Table of the production link

R1		R2		R3		R4	
W	PL	W	PL	W	PL	W	PL
B	BA	A	AB	A	AB	B	BA
A	AF	B	BF	B	BF	A	AF
F	FB	F	FC	F	FB	F	FC
B	BC	C	CD	B	BC	C	CE
C	CD	D	DE	C	CE	E	
D	DE	E		E			
E	*		⊗		Δ		∅

STEP 2
Drawing table traffic intensity is the second step of the method links represented by a triangular table, whose columns and lines will be called workplaces to be located (table 2).
At the intersection of the lines will be marked with columns corresponding production links products to be processed.

STEP 3
This stage production sited in the center of the top three workplaces busiest - in our case workplaces B, C and F.
In the center of the production will be placed jobs B, C and F, in descending order of the number of links production traffic intensities table (figure 4).

Table 2. Table of the traffic intensity

	A	**B**	**C**	**D**	**E**	**F**
F	* ∅	* Δ Δ ⊗	⊗ ∅			**8**
E			Δ ∅	* ⊗	**4**	
D			* ⊗	**4**		
C		* Δ	**8**			
B	* ⊗ Δ ∅	**10**				
A	**6**					

STEP 4

Analysis of the possibilities of locating other workplaces, in descending order of the number of links in production, compared to workplaces already located.

a) After workplaces B, C, F, workplace placement follows A.

AB + AC =4+0 =4
AC + AF =0+2 =2
AF + AB =2+4 =6

The workplace A will be located in front of BF side because it has the most links production (figure 5).

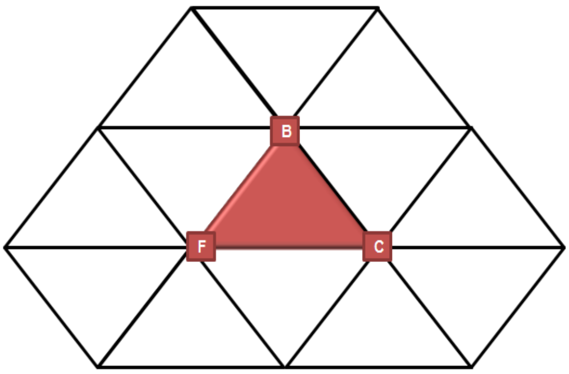


Figure 4. *Placing first three workplaces in descending order*

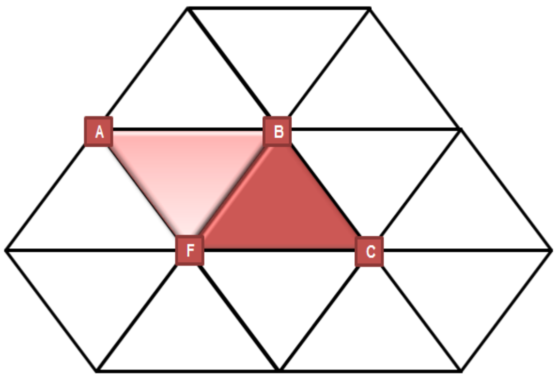


Figure 5. *Placing workplace A*

b) The next workplace to be placed on the surface of the production work will be D. Analysis of the possibilities location:

DB+DC=0+2=2
DC+DF=2+0=2
DF+DA=0+0=0
DA+DB=0+0=0

Workplace D will be located either in front edge BC or before side FC, because they have the most links production. Agreed to place it front side FC (figure 6).

c) Follow workplace E, which will be located in the production area according to the following calculations:

EB+EC=0+2=2
EC+ED=2+2=4
ED+EF=2+0=0
EF+EA=0+0=0
EA+EB=0+0=0

The workplaces E side will be placed in front of BC (figure 7).

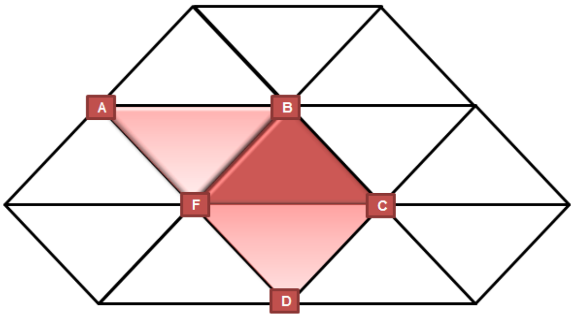


Figure 6. *Placing workplace D*

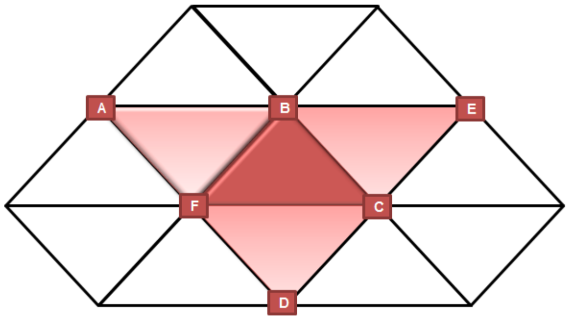


Figure 7. *Placing workplace E*

Table 3. Rules for placing equipment

No. crt.	Distance	Dimensione [m]
1	The maximum width of the free zone in front of the machine for the corridor movement	**0.3**
2	The distance between the machine and the pylon, wall or heating elements when not working or service place	**0.4**
3	The distance between two machines in parallel or in two simple benches, which have one workplace (operator).	**0.8**
4	Distance between two machines in parallel between the two benches or double, which have two working places (back to back two operators)	**1.4**

CONCLUSION

Develop mathematical model of a production system consists of:

» definition of variables input-output systems;
» determining subsystems;
» flowcharts developing functional systems and subsystems;
» determining the operating conditions of the systems and subsystems;
» establish interrelation between subsystems;
» establishing total system performance.

The method links provide a theoretical scheme of location of employment, it must, however, take into account the requirements of specialists in technology, in terms of providing the lightness required for some jobs and proximity vents and installations ventilation workplaces which release emissions.

REFERENCES

[1] Popa, H., Managementul şi ingineria sistemelor de producţie, Editura Politehnica Timişoara, 2001.
[2] Alexa, V., Hărău, C., Microeconomie. Aplicaţii, Editura Mirton, 2005.
[3] Abrudan, I., Cândea, D., Managementul Sistemelor de producţie, Editura Dacia, Cluj Napoca, 2002.
[4] Badea, F., Managementul producţiei, Editura ASE Bucureşti, 2002.
[5] Battini, D., Faccia, M., Persona, A., Sgarbossa, F., New methodological framework to improve productivity and ergonomics in assembly system design, International Journal of Industrial Ergonomics, vol.4, p.30-42, 2011

MULTI-CRITERIA ANALYSIS FOR ESTIMATION OF COSTS FOR INJURIES AND DISEASES AT WORK

Tale Geramitchioski[1], Vangelche Mitrevski[1], Vladimir Mijakovski[1], Ljupco Trajcevski[1]
[1]University St. Kliment Ohridski, Technical Faculty, Bitola, Macedonia
e-mail: tale.geramitcioski@uklo.edu.mk

Abstract: Republic of Macedonia is a country where employees in every type of industry are everyday facing various risks of injury and sometimes even death. Inadequate working conditions, constant economic pressure, complicated internal and external political events, inability of the social partners to fight for their role in the society are just some of the many justifications of various investors that are involved in the process of creating additional value to the projects. For that purpose, in 2007, Republic of Macedonia like the rest of the EU countries implements the European Directives regarding safety and health at work. That means all organizations must follow the given standards and regulations of safety and health at work such as: applying appropriate employee training, conducting regular medical examinations to the employees, preparing elaborate for risk assessment for each workplace, monitor and test the equipment and the machines that are used in everyday process of work. Costs that may arise in the event of an accident at work can present great burden to the budget of a project in every given industry leading to unforeseen financial losses, loss of time and important human resources, and therefore it may result with ending the working project.
Key words: safety, health, costs, risk assessment methodology

INTRODUCTION

International Labor Organization, in a study regarding health and safety at work in the US, 2003, says that death and disease arising from the cost of workplace have much exposure to more risks in society. There is no way to know what role have these studies played in the social consensus that led to the formation around proactive protection policies at work in most industrialized countries, but their importance in the public domain and the resources continually allocated to update and improve them both indicate that they have the power to motivate.
Harberger and Jenkis (2002) define cost-benefit analysis as a sum of tools for directing decisions on whether to take certain course of action or not. Pearce (1988); Snell (1997); Preez (2004) define cost-benefit analysis as methodology for estimate of the costs and benefits enabling development of numerous comparisons and forecast of benefits and costs that should be considered or measured in order to sum them. There are great number of different definitions and views about cost-benefit analysis.
The original theoretical basis for the cost – benefit analysis, as a technique for economic assessment of public investments was laid in 1930 when US engineering corps created methodology for justification of Congress' projects (Lagas, 1999). First system usage of cost – benefit analysis happened in USA in relation to investment programs for water resources in Northern America in 1930s. It was noted that the mass public expenditure undertaken for the development of selected river valleys and public benefits of such schemes are considered unreliable. Since the 1930s, cost - benefit analysis is a popular tool for evaluating public sector projects and is one of the oldest techniques that have been developed in the US to assess the implications of alternative schemes on water resources, by which its application has spread rapidly on various activities in the public sector in all parts of the world.
The same process can be seen on national level. Every industrialized country has national legislation and adheres to international conventions that force protection of health and safety of own workforce, though advocates of safety at work have found it useful to demonstrate the economic costs of the decline in work. "Safety in numbers", one of the highest profile publications of the International Labor Organization (ILO) in the field of safety at work, suggests that 4 percent of global income is lost due to occupational injuries and diseases, discovery quoted around the world numerous times.

MULTI-CRITERIA ANALYSIS

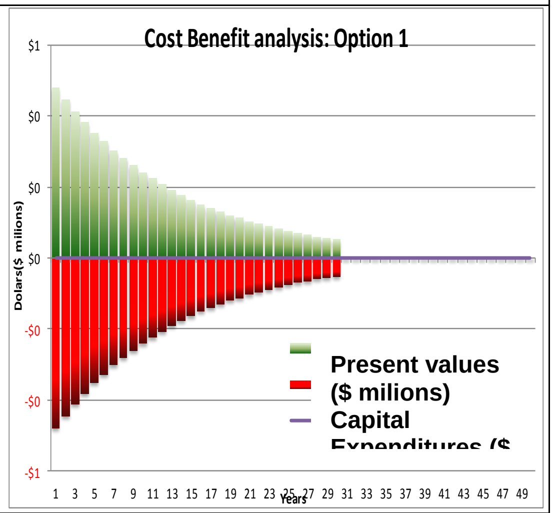
Theoretical design of the cost - benefit analysis by different types of benefits, security research and direct / indirect costs of accidents is implemented into the software. Different types of costs incurred from accidents caused by the fault of the employer in a particular industry as a consequence of avoiding adherence to the measures and principles set by management for Safety and Health at Work are also presented. These costs might be key in economic endurance of the project itself. Based on that, the costs from this character are distributed in two groups: costs incurred to improve the safety of workers and reducing the risk of accident and costs incurred as a result of injury to a worker due to violation of standards of safety and health at work.
Due to the need for unification of the respective benefits and costs in Cost-Benefit analysis in program Cost-Benefit-Analysis.xls, costs are defined as:
Costs 1, Costs 2, ... Costs 5, while benefits as Benefit 1, Benefit 2,... Benefit 5. They can be, for example, costs caused by production cuts due to worker injury or disease at work, medical expenses, legal fees etc., while the benefits can be to reduce accidents, reduce medical cases, increase productivity, reduced sick leaves etc. Input parameters for analysis are given in next Table:

	Option 1 < example 1 >	Option 2 < example 2 >	Option 3 < example 3 >	Option 4 < example 4 >
Estimation period (years)	30	30	30	30
Capital expenditures	$0	$2.000.000	$30.000.000	$55.000.000
Whole life costs	$15.000.000	$17.000.000	$45.000.000	$70.000.000
Cost -Benefit analyses				
Present Value of profit	$5.849.716	$7.604.631	$39.841.423	$47.718.390
Capital Expenditures	$5.849.716	$7.849.716	$35.479.345	$43.903.348
Benefit-cost ratio	1,00	0,97	1,12	1,09
Net Present Value	$0	-$245.085	$4.362.077	$3.815.042
Multi-criteria analysis of non-material expenses				
Criteria 1	1,50	2,50	2,50	2,50
Criteria 2	1,25	2,25		1,50
Criteria 3	0,60	0,90	1,20	1,20
Criteria 4	0,40	0,30	0,50	0,80
Weighted rating	3,8	6,0	4,2	6,0

In the model itself, four different examples are presented and at the end, multi-criteria analysis of non-material costs and fees, if any, are shown, where four different criteria are defined.

Example 1.

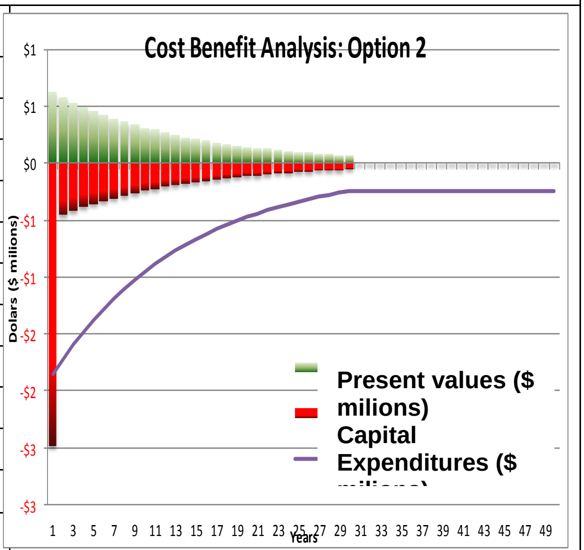
Cost Benefit Analysis	Investment proposal
Option 1:	**Example 1**
Key assumptions	
Discount rate (%)	8,00%
Periodic assessment (years)	30 years
Summary results of the analysis	
Capital expenses per 10 years	$0
Whole life costs	$15.000.000
Present Value of benefits	$5.849.716
Present value of costs	$5.849.716
Benefit-cost ratio	1,00
Net present value	$0



Years	**2015**	**2025**	**2035**	**2045**
Discounted factor (half-year)	0,96225	0.44571	0.20645	0.10328
Discounted factor (at beginning of year)	1,00000	0.46319	0.21455	0.10733
Benefit 1	$100.000	$100.000	$100.000	$100.000
Benefit 2	$100.000	$100.000	$100.000	$100.000
Benefit 3	$100.000	$100.000	$100.000	$100.000
Benefit 4	$100.000	$100.000	$100.000	$100.000
Benefit 5	$100.000	$100.000	$100.000	$100.000
Total Benefits (half-year)	$500.000	$500.000	$500.000	$500.000
Present Value of benefits (hals-year)	$481.125	$222.854	$103.225	$51.638
Present Value of benefits	$5.849.716			
Costs 1	-$100.000	-$100.000	-$100.000	-$100.000
Costs 2	-$100.000	-$100.000	-$100.000	-$100.000
Costs 3	-$100.000	-$100.000	-$100.000	-$100.000
Costs 4	-$100.000	-$100.000	-$100.000	-$100.000
Costs 5	-$100.000	-$100.000	-$100.000	-$100.000
Total Costs (half-year)	-$500.000	-$500.000	-$500.000	-$500.000
Capital costs (at beginning of year)	$0	$0	$0	$0
Total costs	-$500.000	-$500.000	-$500.000	-$500.000
Total capital costs	$0			
Overall cost of living	-$15.000.000			
Present value of costs (half-year)	-$481.125	-$222.854	-$103.225	-$51.638
Present value of costs (at beginning of year)	$0	$0	$0	$0
Present value of costs (at current year)	-$481.125	-$222.854	-$103.225	-$51.638
Present value of costs	-$5.849.716			
Net cash flow	$0	$0	$0	$0
Net present value (at current year)	$0	$0	$0	$0
Cumulative NPV	$0	$0	$0	$0
Data to draw the graph:				
Year	0	10	20	30
Present Value of benefits ($ milions)	$ 0.481	$ 0.223	$ 0.103	$ 0.052
Present value of costs ($ milions)	- $ 0.481	- $ 0.223	- $ 0.103	- $ 0.52
Cumulative net present value ($ milions)	$ -	$ -	$ -	$ -

Example 2

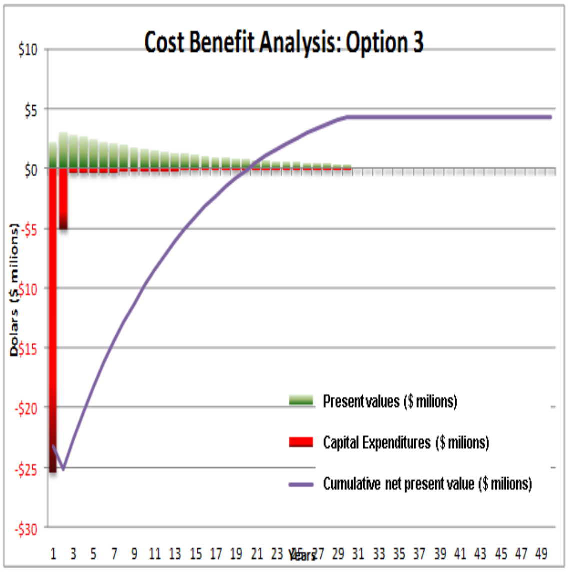
Cost Benefit Analysis	**Investment proposal**
Option 2:	**Example 2**
Key assumptions	
Discount rate (%)	8,00%
Periodic assessment (years)	30 years
Summary results of the analysis	
Capital expenses per 10 years	$2.000.000
Whole life costs	$17.000.000
Present Value of benefits	$7.604.631
Present value of costs	$7.849.716
Benefit-cost ratio	0.97
Net present value	-$245.085



Years	**2015**	**2025**	**2035**	**2045**
Discounted factor (half-year)	0,96225	0.44571	0.20645	0.10328
Discounted factor (at beginning of year)	1,00000	0.46319	0.21455	0.10733
Benefit 1	$250.000	$250.000	$250.000	$250.000
Benefit 2	$100.000	$100.000	$100.000	$100.000
Benefit 3	$100.000	$100.000	$100.000	$100.000
Benefit 4	$100.000	$100.000	$100.000	$100.000
Benefit 5	$100.000	$100.000	$100.000	$100.000
Total Benefits (half-year)	$650.000	$650.000	$650.000	$650.000
Present Value of benefits (hals-year)	$625.463	$289.710	$134.192	$67.129
Present Value of benefits	$7.604.631			
Costs 1	-$100.000	-$100.000	-$100.000	-$100.000
Costs 2	-$100.000	-$100.000	-$100.000	-$100.000
Costs 3	-$100.000	-$100.000	-$100.000	-$100.000
Costs 4	-$100.000	-$100.000	-$100.000	-$100.000
Costs 5	-$100.000	-$100.000	-$100.000	-$100.000
Total Costs (half-year)	-$500.000	-$500.000	-$500.000	-$500.000
Capital costs (at beginning of year)	-$2.000.000	$0	$0	$0
Total costs	-$2.500.000	-$500.000	-$500.000	-$500.000
Total capital costs	-$2.000.000			
Overall cost of living	-$17.000.000			
Present value of costs (half-year)	-$481.125	-$222.854	-$103.225	-$51.638
Present value of costs (at beginning of year)	-$2.000.000	$0	$0	$0

Present value of costs (at current year)	-$2.481.125	-$222.854	-$103.225	-$51.638
Present value of costs	-$7.849.716			
Net cash flow	-$1.850.000	$150.000	$150.000	$150.000
Net present value (at current year)	-$1.855.662	$66.856	$30.967	$15.491
Cumulative NPV	-$1.855.662	-$887.146	- $438.535	- $ 245.085
Data to draw the graph:				
Year	0	10	20	30
Present Value of benefits ($ milions)	$ 0.625	$ 0.290	$ 0.134	$ 0.067
Present value of costs ($ milions)	- $ 2.481	- $ 0.223	- $ 0.103	- $ 0.052
Cumulative net present value ($ milions)	- $ 1.856	- $ 0.887	- $ 0.439	- $ 0.245

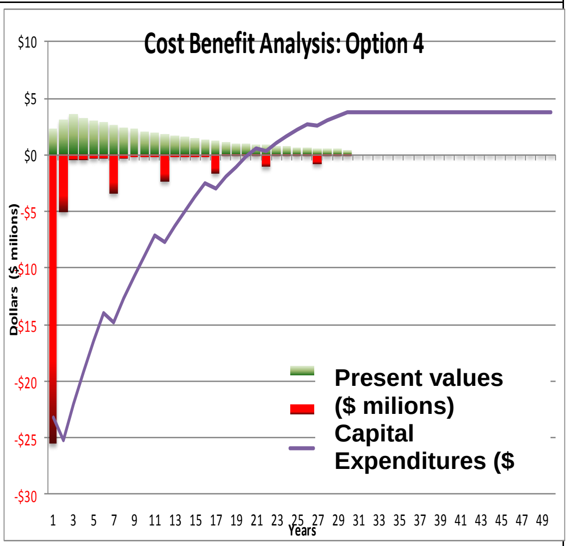
Example 3

Cost Benefit Analysis	**Investment proposal**			
Option 3:	**Example 3**			
Key assumptions				
Discount rate (%)	8,00%			
Periodic assessment (years)	30 years			
Summary results of the analysis				
Capital expenses per 10 years	$30.000.000			
Whole life costs	$45.000.000			
Present Value of benefits	$39.841.423			
Present value of costs	$35.479.345			
Benefit-cost ratio	1.12			
Net present value	$4.362.077			
Years	**2015**	**2025**	**2035**	**2045**
Discounted factor (half-year)	0,96225	0.44571	0.20645	0.10328
Discounted factor (at beginning of year)	1,00000	0.46319	0.21455	0.10733
Benefit 1	$400.000	$800.000	$800.000	$800.000
Benefit 2	$1.000.000	$1.000.000	$1.000.000	$1.000.000
Benefit 3	$100.000	$100.000	$100.000	$100.000
Benefit 4	$100.000	$100.000	$100.000	$100.000
Benefit 5	$750.000	$1.150.000	$1.500.000	$1.500.000
Total Benefits (half-year)	$2.350.000	$3.500.000	$3.500.000	$3.500.000
Present Value of benefits (hals-year)	$2.261.289	$1.559.978	$722.572	$361.466
Present Value of benefits	$39.841.423			
Costs 1	-$100.000	-$100.000	-$100.000	-$100.000

Costs 2	-$100.000	-$100.000	-$100.000	-$100.000
Costs 3	-$100.000	-$100.000	-$100.000	-$100.000
Costs 4	-$100.000	-$100.000	-$100.000	-$100.000
Costs 5	-$100.000	-$100.000	-$100.000	-$100.000
Total Costs (half-year)	-$500.000	-$500.000	-$500.000	-$500.000
Capital costs (at beginning of year)	-$25.000.000	$0	$0	$0
Total costs	-$25.500.000	-$500.000	-$500.000	-$500.000
Total capital costs	-$30.000.000			
Overall cost of living	-$45.000.000			
Present value of costs (half-year)	-$481.125	-$222.854	-$103.225	-$51.638
Present value of costs (at beginning of year)	-$25.000.000	$0	$0	$0
Present value of costs (at current year)	-$25.481.125	-$222.854	-$103.225	-$51.638
Present value of costs	-$35.479.345			
Net cash flow	-$23.150.000	$3.000.000	$3.000.000	$3.000.000
Net present value (at current year)	-$23.219.837	$1.337.124	$619.347	$309.828
Cumulative NPV	-$23.219.837	-$8.479.130	- $493.084	$ 4.362.077
Data to draw the graph:				
Year	0	10	20	30
Present Value of benefits ($ milions)	$ 2.261	$ 1.560	$ 0.723	$ 0.361
Present value of costs ($ milions)	- $ 25.481	- $ 0.223	- $ 0.103	- $ 0.052
Cumulative net present value ($ milions)	- $ 23.220	- $ 8.479	- $ 0.439	$ 4.362

Example 4

Cost Benefit Analysis	**Investment proposal**
Option 4:	**Example 4**
Key assumptions	
Discount rate (%)	8,00%
Periodic assessment (years)	30 years
Summary results of the analysis	
Capital expenses per 10 years	$55.000.000
Whole life costs	$70.000.000
Present Value of benefits	$47.718.390
Present value of costs	$43.903.348
Benefit-cost ratio	1.09
Net present value	$3.815.042



Years	**2015**	**2025**	**2035**	**2045**
Discounted factor (half-year)	0,96225	0.44571	0.20645	0.10328

Discounted factor (at beginning of year)	1,00000	0.46319	0.21455	0.10733
Benefit 1	$400.000	$1.200.000	$1.200.000	$1.200.000
Benefit 2	$1.000.000	$1.000.000	$1.000.000	$1.000.000
Benefit 3	$100.000	$500.000	$500.000	$500.000
Benefit 4	$100.000	$100.000	$100.000	$100.000
Benefit 5	$750.000	$1.150.000	$1.500.000	$1.500.000
Total Benefits (half-year)	$2.350.000	$4.300.000	$4.300.000	$4.300.000
Present Value of benefits (hals-year)	$2.261.289	$1.916.545	$887.731	$444.087
Present Value of benefits	$47.718.390			
Costs 1	-$100.000	-$100.000	-$100.000	-$100.000
Costs 2	-$100.000	-$100.000	-$100.000	-$100.000
Costs 3	-$100.000	-$100.000	-$100.000	-$100.000
Costs 4	-$100.000	-$100.000	-$100.000	-$100.000
Costs 5	-$100.000	-$100.000	-$100.000	-$100.000
Total Costs (half-year)	-$500.000	-$500.000	-$500.000	-$500.000
Capital costs (at beginning of year)	-$25.000.000	$0	$0	$0
Total costs	-$25.500.000	-$500.000	-$500.000	-$500.000
Total capital costs	-$55.000.000			
Overall cost of living	-$70.000.000			
Present value of costs (half-year)	-$481.125	-$222.854	-$103.225	-$51.638
Present value of costs (at beginning of year)	-$25.000.000	$0	$0	$0
Present value of costs (at current year)	-$25.481.125	-$222.854	-$103.225	-$51.638
Present value of costs	-$43.903.348			
Net cash flow	-$23.150.000	$3.800.000	$3.800.000	$3.800.000
Net present value (at current year)	-$23.219.837	$1.693.691	$784.507	$392.449
Cumulative NPV	-$23.219.837	-$7.177.333	-$583.604	$ 3.815.042
Data to draw the graph:				
Year	0	10	20	30
Present Value of benefits ($ milions)	$ 2.261	$ 1.917	$ 0.888	$ 0.444
Present value of costs ($ milions)	- $ 25.481	- $ 0.223	- $ 0.103	- $ 0.052
Cumulative net present value ($ milions)	- $ 23.220	- $ 7.177	$ 0.584	$ 3.815

CONCLUSIONS

One of the more difficult things for every industry is planning the amount of expenses that will be spent in the sector of health and safety of workers during execution of their assigned tasks over certain period of time. Cost- benefit analysis is one kind of methodology to assess the costs and benefits that

helps to make numerous comparisons and predictions of benefits and costs that should be taken into account.
Methodology for estimation of costs for one company in a cases of accident or professional disease at work, type of costs, how to achieve cost reduction and how to anticipate these costs, is developed and presented in this article. For this purpose, a program that measures costs and makes analysis of the profitability for investing in the safety and health at work, is developed.
The final results of the analysis (output criteria) are given in the Table:

		Option 1		Option 2		Option 3		Option 4	
		Example 1		**Example 2**		**Example 3**		**Example 4**	
Criteria	**Weight criterion**	**Contribution (0 – 10)**	**Weight index**	**Contribution (0 – 10)**	**Weight index**	**Contribution (0 – 10)**	**Weight index**	**Contribution (0 – 10)**	**Weight index**
Criteria 1	50,0 %	3	1,50	5	2,50	5	2,50	5	2,50
Criteria 2	25,0 %	5	1,25	9	2,25	0		6	1,50
Criteria 3	15,0 %	4	0,60	6	0,90	8	1,20	8	1,20
Criteria 4	10,0 %	4	0,40	3	0,30	5	0,50	8	0,80
Total	**100,0 %**	**16**	**3,8**	**23**	**6,0**	**18**	**4,2**	**27**	**6,0**

Through examples of studies by other authors, we have seen other similar methodologies for calculating costs in a case of accidents or occupational diseases and methods for analyzing the parameters involved in building these methodologies and cost-benefit analysis to examine the effect of preventing the creation of pre - conditions to reduce the risk of accident or occupational disease at work.
However, no matter how much we strive to improve the conditions related to safety and health at work, well implemented system for safety and health at work and yet continue to have accidents and injuries at work, which in turn lead to a increased costs associated with safety and health of the employees. The methodology developed in this article can be applied in many industries and is expected to lead to significant material savings to companies in respect of payment of damages to employees, damages by occupational diseases, attorney fees and court costs, etc. Action plan for implementation of the planned activities will be relieved from time interruptions due to accidents and diseases, will bring savings in terms of loss of material damage due to delays in the deadlines for implementation, etc.

REFERENCES

[1] Oxenburgh, M. & Marlow, P. (1996) The Productivity Assessment Tool: Computer Based Cost Benefit Analysis Model for the Economic Assessment of Occupational Health and Safety Interventions in the Workplace. Journal of Research-ECON Proceeding
[2] Elias Okede Ikpe MSc, DEVELOPMENT OF COST BENEFIT ANALYSIS MODEL OF ACCIDENT PREVENTION ON CONSTRUCTION PROJECTS , PhD dissertation, Wolverhampton University, Great Britain, 2011
[3] Beatson, M. and M. Coleman., International Comparisons of the Economic Costs of Work Accidents and Work-Related Ill-Health, in J. Mossink and F. Licher (eds.) Costs and Benefits of Occupational Safety and Health: Proceedings of the European Conference on Costs and Benefits of Occupational Safety and Health 1997
[4] Marjolein de Weerd (TNO); Rory Tierney (Matrix); Birgit van Duuren-Stuurman (TNO); Evelina Bertranou (Matrix), *Estimating the cost of accidents and ill-health at work: A review of methodologies*, European Risk Observatory, 2014
[5] Snell, M. (1997) *Cost-Benefit Analysis for Engineers and Planners*. Thomas Telford Ltd UK

THE OPTIMIZATION OF SCHEDULING PROBLEMS USING METAHEURISTIC METHODS – A BRIEF REVIEW

Mića Đurđev[1], Mijodrag Milošević, Dejan Lukić, Jovan Vukman, Goran Jovičić
[1]University of Novi Sad, Faculty of Technical Sciences, Novi Sad, Serbia
e-mail: mdjurdjev@live.com

Abstract: Production scheduling represents one of the most significant functions within manufacturing system. Its main purpose is to allocate operations of each job to available machines in manufacturing environment at particular times. Scheduling problems with larger dimensions usually belong to the class of NP hard combinatorial problems and are considered to be one of the most difficult combinatorial problems in operations research. This paper is focused on scheduling problems in different manufacturing systems including job shop, flow shop, parallel machines and single machine scheduling. Further, the paper also covers the most common optimization criteria and aspects of some metaheuristic methods as efficient approaches for solving scheduling problems.
Key words: scheduling, optimization, metaheuristics, job shop

INTRODUCTION

Production scheduling is considered to be one of the most significant functions in manufacturing system. It is focused on allocating operations for each job to appropriate machine in manufacturing environment and finding the best sequence of operations while minimizing some optimization criteria like makespan, flow time or total job tardiness. Scheduling activity in industry has a great impact on cost reduction, utilization of resources, increased productivity, customer satisfaction and competition advantage [5]. Academic research in the field of scheduling is primarily being aimed on finding efficient algorithms for generating optimal scheduling plans for different manufacturing environments. Single machine, parallel machines, flow shop and job shop enviroments are the most common where job shop scheduling represents one of the most frequently studied and also one of the hardest problems in literature [10]. Besides that, different scheduling models can be found in literature, including static and dynamic models, where static considers set of jobs that do not change over time, in contrast to dynamic model where new jobs constantly appear over time [2]. There are also deterministic models which assume conditions known with certainty, and stohastic models that are subject to different sources of uncertainty, like machine breakdowns, unknown processing times, unexpected job releases and etc. Most of scheduling problems with larger dimensions belong to the class of NP hard combinatorial problems, although there are some types of simpler scheduling problems that are solvable in polynomial time [10]. Metaheuristic methods, like genetic algorithm or simulated annealing, are frequently studied methods used for solving various types of hard combinatorial problems that include scheduling problems as well.
According to introductory information, this paper is organized in the following way. Different manufacturing environments that are considered when finding optimal scheduling plans are briefly analized in the second chapter. Most common time based criteria as well as scheduling constraints commonly used in literature are represented in the third chapter. The fourth chapter gives short review of some metaheuristic implementations used for efficient solving of scheduling problems. Conclusion is given in chapter five.

MANUFACTURING ENVIRONMENTS IN SCHEDULING PROBLEMS

Scheduling problems are defined by particular manufacturing environment, or the configuration of manufacturing resources on shop floor. In this chapter, some well-known scheduling environments are shortly analyzed and represented. There are the following ones [11, 10]:

- Single machine scheduling – usually named as single machine sequencing problem which is the simplest of all the cases of enviroments. It also represents a special case when solving some problem in much difficult environment. Single machine problem is based on defining optimal route of operations on particular single machine. Sequencing and resource allocation activities within this scheduling model are not distinguished and the allocation of one machine is completely determined by sequencing activity.

- Parallel machine scheduling – a simple setting where the effects of parallelism are presented. Jobs are available for processing on any one of the m parallel identical machines in environment, or maybe on any machine that belongs to some given subset. Example of Gantt chart for parallel machine scheduling with 2 machines is represented on Figure 1.

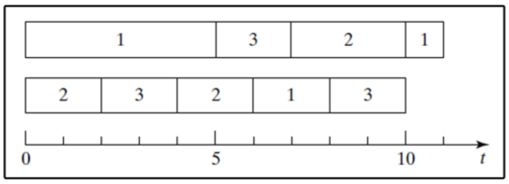


Figure 1. Gantt chart for parallel machine problem [10]

- Flow shop scheduling – Like job shop, flow shop scheduling is among most common scheduling environments studied in the literature. Machines in the flow shop are arranged in the series. The most important characteristics of this type of manufacturing system is that the sequence of operations is the same for all the machines, and jobs can visit each machine only once. Figure 2 illustrates Gantt chart for flow shop problem with 2 machines on Y axis. More complicated than this problem is flexible flow shop where the sequence of job operations is the same for all jobs but there is more than one available machine for each operation.

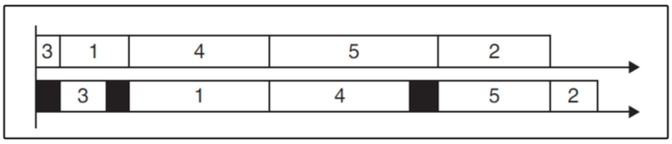


Figure 2. Gantt chart for flow shop problem [2]

- Job shop scheduling – The hardest problem of all scheduling problem, as said earlier. This problem has the very large number of possible alternatives. That is because each job has different predetermined route and capability to visit each machine more than once. Figure 3 illustrates example for job shop scheduling problem with three machines. Even more complicated problem is flexible job shop scheduling problem where each operation can be performed on any machine in in the system.

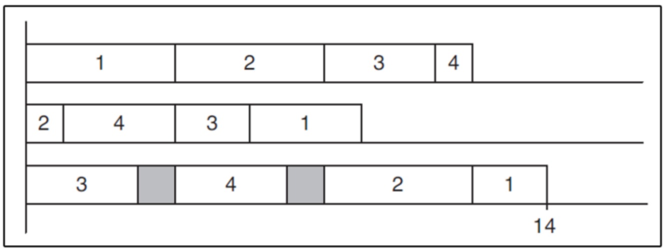


Figure 3. Gantt chart for job shop problem [2]

SCHEDULING CONSTRAINTS AND OBJECTIVES

Scheduling problems are commonly described by triplet $\alpha|\beta|\gamma$, where α stands for production environments defined in previous chapter, β field gives detail about processing constraints and γ provides details about objective to be minimized/maximized [10].
Most frequently used processing constraints and restrictions in literature are the following ones[10]:

- Release dates – This constraint defines release date of the job j. It means that job j cannot start its processing before particular time defined by this constraint. Otherwise, when release date is not entered in constraint field, jobs can start at any time.
- Preemptions – This is common constraint for dynamic scheduling models. Preemptions are interruptions in short. Jobs could be interrupted for the purpose of processing another job on that machine. After finishing, preempted job can continue its processing on same machine. Schedules with no preemptions are known as non-delay schedules.
- Breakdowns – Machine breakdowns that can occur. It implies that machine may not be available for processing continuously.
- Precedence constraints – This constraint is common for process planning as well as for scheduling problems. It means that there are priorities among jobs. Some jobs, one or more, should be completed before another can start its processing. There are special forms of precedence constraints. They are usually represented on graph or network.

Examples of some commonly used objective functions are [10]:

- Makespan – It is maximum completion time of all jobs in the system. Minimization of the makespan represents the most frequently used objective in the literature.
- Maximum lateness – This objective defines the maximum violation of the due dates.
- Number of tardy jobs – It assumes the minimization of the number of jobs that are tardy – jobs that exceed its completion period.
- Mean flow time – In considers the minimization of total time that job spends in the system, including processing and idle time.

It is also worth mentioning that scheduling problems studied in academia are quite simplified in contrast to problems in practice. Assuming that fact there are some assumptions that are frequently mentioned by authors who deal with this type of combinatorial problems. In this paper some assumptions for job shop scheduling problems are given [4]:

- Each machine can process only one job at a time;
- No preemptions are given; each operation is performed until its completion;
- Jobs cannot visit the same machine twice;
- The processing times for each job are known;
- There are no precedence constraints among operations of different jobs;

Among these assumptions the one more important fact is that many practical problems consider more than one optimization criteria which increase its difficulty even more. As already stated, scheduling problems belong to the class of NP hard combinatorial problems. Many authors dealt with a lot of different types of scheduling problems considering various constraints and objectives in mentioned environments. Next chapter gives a short overview of optimization methods with focus on metaheuristic approaches as one of the most efficient methods for solving these types of combinatorial problems.

METAHEURISTIC APPROACHES FOR SCHEDULING PROBLEMS

Optimization methods for solving hard combinatorial problems can be divided into exact and approximate methods [7]. Exact methods, like branch and bound algorithm or dynamic programming, are the most reliable methods for finding optimal solution and they can be applied to some small instances of difficult problems. Their greatest drawback is time required to solve hard combinatorial problems. Johnson's algorithm is famous exact method for solving scheduling problems with smaller sizes. On the other side, approximation based methods, where metaheuristic methods belong, represent the extremely efficient approaches with capability of finding enough good (near optimal) solutions for large sized problems in reasonable time.
Metaheuristics can be classified by many aspects. Here, single solution and population based metaheuristics will be shown like given in [7]. Among most popular single solution-based metaheuristics for scheduling problems are simulated annealing and tabu search. They are usually used in hybridization with another method in order to improve the search. Genetic algorithm, ant colony

optimization and particle swarm optimization are popular population-based metaheuristics used for scheduling problems where genetic algorithm represents the most common one.
In the literature, as already stated, job shop scheduling problem is most widely studied problem of this type. In the paper [3] detailed literature review of artificial intelligence based metheuristics for job shop scheduling problems is given. Some of AI metaheuristic methods are shortly presented below with some implementation examples.
Genetic algorithm (GA) is popular search metaheuristic developed by John Holland in 1970s [8]. GA is based on principles of Darwin's process of natural selection and genetics. It uses operators like selection, crossover and mutation to improve the search space and give good individuals. Modern GA approaches found in literature are usually focused on some significant modifications of GA or combinations of GA with other metaheuristic method or rule (hybrid approach). This is due to the fact that problem sizes and complexity in practice forces authors to develop more efficient and more versatile algorithms that will prove capable of finding optimal or near optimal solutions.
A new GA for solving flexible job shop scheduling problem (FJSSP) with minimization of makespan is given in [6]. Authors created new chromosome representation scheme called "permutation job" and adopted different strategies for crossover and mutation. The particular FJSSP is partial which considers that each operation of a job can be performed on one of a given subset of M machines. Developed algorithm proved efficient on a scheduling problem situation in drug manufacturing company that considers 10 jobs and set of 31 machines. New GA also showed its superiority and efficiency in comparing with other approaches for some benchmark problem data given in table 1. N*m denotes the number of jobs (n) and number of machines (m), while C_m stands for best makespan for each problem. Results are shown only for new GA algorithm that was coded in Matlab environment. Convergence curve that shows decrease of makespan and Gantt chart for problem data Mk01 are shown on Figures 4 and 5.

Table 1. Results of problem data (incomplete)[6]

Problem	n*m	NGA C_m
Mk01	10*6	37
Mk02	10*6	26
Mk03	15*8	204
Mk04	15*8	60
Mk05	15*4	173
Mk06	10*15	67
Mk07	20*5	148
Mk08	20*10	523
Mk09	20*10	307
Mk10	20*15	212

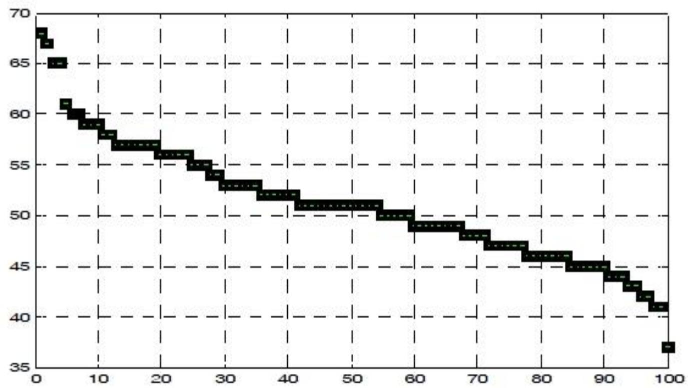


Figure 4. Convergence curve for Mk01[6]

Hybrid model for solving job shop scheduling problem (JSSP) is given in [9]. The developed model incorporates both GA and TS (Tabu search) metaheuristics. Complementary strengths such as global parallel search of GA and local optimum avoidance of TS are well exploited in purpose of solving JSSP. Hybrid genetic tabu search algorithm showed excellent results and proved optimality for 48 out of 51 benchmark problems found in the literature. Of even greater importance is the fact that this model found far superior solutions in quality and computing time in comparison to the current systems used in real life environments, namely, in steel mill sector and automobile windscreen processing industry. Machine layout with available machines in shop environment at steel mill industry sector are shown in Fig. 6. The objective of this problem was minimization of the makespan. Computational time ranged from 0,10 to 48 minutes depending on problem size and model parameters.
Particle swarm optimization (PSO) is a metaheuristic method inspired from swarm intelligence. It mimics the social behaviour of natural organisms such as birds or fish in search for food. Main

operators in this algorithm are particles and their velocities and positions [7]. In the paper [1] Branch&Bound and PSO are introduced for solving job shop problem with no-wait constraint with minimization of the makespan. The main characteristic of this problem is exclusion of job or machine interruptions. PSO algorithm was applied for 40 instances of job shop problem and compared with other methods in the literature where good results were obtained.

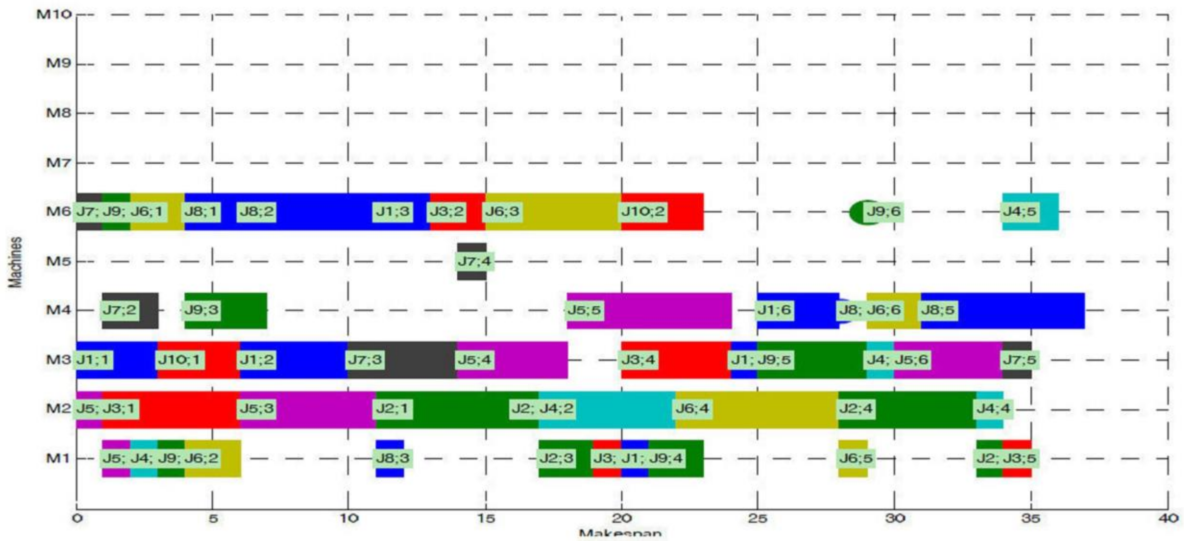


Figure 5. Gantt chart for Mk01 problem with 10 jobs and 6 machines [6]

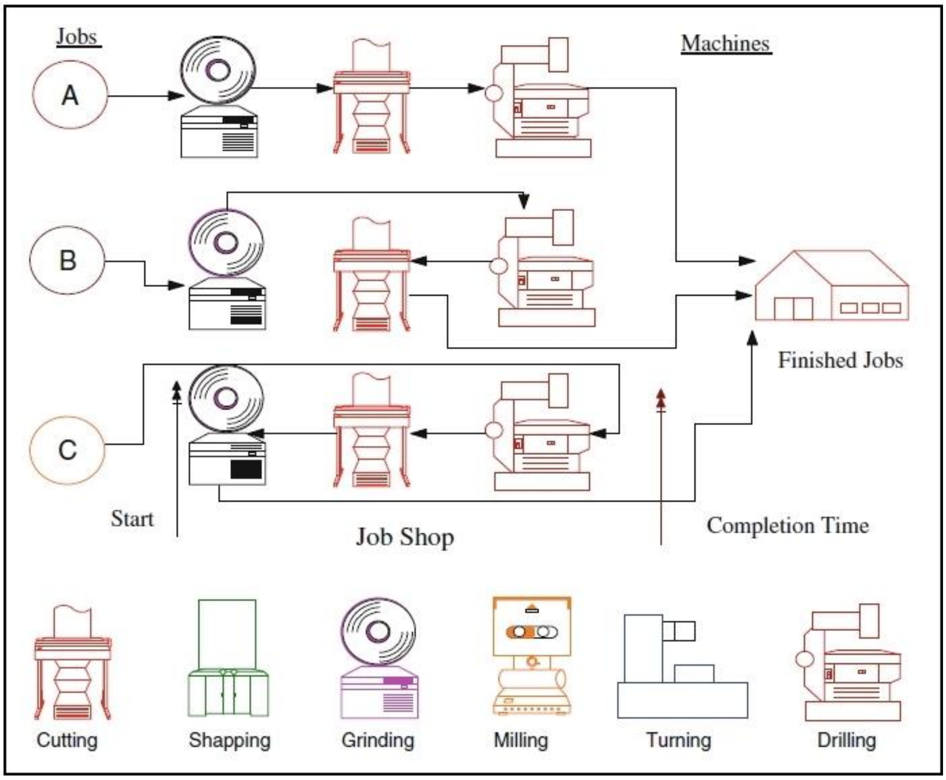


Figure 6. Machines and machine layout in steel mill work shops [9]

Ant colony optimization (ACO) algorithm is popular metaheuristic that mimics the behaviour of natural ants in finding the optimal path between the nest and food source [11]. The chemical trail called pheromone is most important operator of ACO algorithm which memorizes characteristics of good solutions found by ants [7]. Some implementations of ACO can be found in review paper [11].

CONCLUSION

The goal of this paper was to give a brief review of production scheduling optimization problem and some efficient metaheuristic approaches for finding optimal or near optimal solutions. Due to its combinatorial nature, large numbers of scheduling problems are very difficult to solve. The scope of this paper covered three basic elements of scheduling problem notation. The first element was manufacturing environment, where single machine, parallel machines, flow shop and job shop scheduling environment are shortly presented. Most popular scheduling constraints and objectives used in literature are specified as the second and third element of the problem. The last chapter was focused on most popular metaheuristic methods, such as genetic algorithms, particle swarm optimization and tabu search, with some examples in modern literature.

ACKNOWLEDGEMENT

This paper is part of a research on project "Modern approaches to the development of special bearings in mechanical engineering and medical prosthetics," TR 35025, supported by the Ministry of Education and Science, Republic of Serbia.

REFERENCES

[1] AitZai, A., Benmedjdoub, B., Boudhar, M., Branch-and-bound and PSO algorithms for no-wait job shop scheduling, Journal of Intelligent Manufacturing, Springer, 2014.
[2] Baker, K.R., Trietsch, D., Principles of Sequencing and Scheduling, John Wiley & Sons, Inc., Hoboken, New Jersey, 2009. ISBN 978-0-470-39165-5.
[3] Calis, B., Bulkan, S., A research survey: review of AI solution strategies of job shop scheduling problem, Journal of Intelligent Manufacturing, Springer, 2013.
[4] Cheng, R., Gen, M., Tsujimura, Y., A tutorial survey of job-shop scheduling problems using genetic algorithms—I. representation, Computers & Industrial Engineering, Vol. 30, pp. 983-997, Elsevier Science Ltd, 1996.
[5] Dhingra, A.K., Multi-Objective Flow Shop Scheduling Using Metaheuristics, PhD thesis, Department of Mechanical Engineering, National Institute of Technology Kurukshetra, India, 2006.
[6] Driss, I., Mouss, K.N., Laggoun, A., A new genetic algorithm for flexible job-shop scheduling problems, Journal of Mechanical Science and Technology, Vol. 29, pp. 1273-1281, Springer, 2015.
[7] El-Ghazali, T.: Metaheuristics: From Design to Implementation, John Wiley & Sons, Inc., New Yersey, 2009, ISBN: 978-0-470-27858-1.
[8] Holland, J.H.: Adaptation in Natural and Artificial Systems, University of Michigan Press, Ann Arbor, MI, 1975.
[9] Meeran, S., Morshed, M.S., A hybrid genetic tabu search algorithm for solving job shop scheduling problems: a case study, Journal of Intelligent Manufacturing, Vol. 23, pp. 1063-1078, Springer, 2012.
[10] Pinedo, M.L.: Scheduling – Theory, Algorithms and Systems, 3rd edition, Springer-Verlag, New York, 2008, ISBN 978-0-387-78934-7.
[11] Tavares Neto, R.F., Godinho Filho, M., Literature review regarding Ant Colony Optimization applied to scheduling problems: Guidelines for implementation and directions for future research, Engineering Applications of Artificial Intelligence, Vol. 26, pp. 150-161, Elsevier, 2013.

HUMAN RESOURCES OF LOCAL GOVERNMENT OF THE REPUBLIC OF SERBIA IN WASTE MANAGEMENT

Neda Nikolić[1], Srecko Ćurčić[1], Aleksandra Gajović[1]
[1] University of Kragujevac, Faculty of Tehnical Sciences Čačak, Serbia
e-mail: neda.nikolić@ftnkg.ac.rs

Abstract: This paper discusses the importance of human resources of local governments in improving the process of waste management. The observation of environmental protection as a comprehensive system of values of economic, environmental and social elements of a nation implies the existence of human resources that will bring cultural identities closer and contribute to the improvement of waste management in local environments. With a well-planned systematization of jobs and coordinated work of employees engaged in waste management the mentioned elements would become complementary and there would be greater efficiency. The paper presents the results that show that waste management activities are not a priority matter or are part of a series of environmental activities of individual local governments.
Key words: waste management, human resources, local governments

INTRODUCTION

Waste management is an important segment of Environmental Management. Bearing in mind the aspirations of the Republic of Serbia towards full membership of the European Union, there is a need for change in this sector. Modern trends dictate adjustments of local governments towards a new approach and an emphasis on different potentials, not only the economic ones, but also to those resources that can be environmentally oriented. Human resources of local governments are insufficiently used in the waste management process and thus future plans should be directed towards the contribution of employees in this segment of the environment. It is estimated that Serbia needs 10.6 billion euros by the end of 2030 for the harmonization of environmental protection standards with those of the European Union. [6] Paragraph 8.2.3. of the National Waste Management Strategy until 2020 indicates the significant extent of private sector involvement in ensuring proper waste management. The emphasis is placed on the separation and recycling of hazardous and non-hazardous waste. It is believed that this step would not be of great importance unless action of financing such participants in this process is taken. To this purpose, the Ministry of Agriculture and Environmental Protection announced a competition for the award of incentives for recycling companies and operators engaged in processing and re-use of waste as secondary raw material, which lasts until the end of January 2016. This is one of the indicators that Serbia is taking planned steps towards improving waste management. Also, the drafting of the new Agenda, the implementation of which will start in September 2015, is in the process. Agenda will have 17 primary and 169 specific global goals of sustainable development for the period of the next 15 years. [2] One of the topics will be environmental and global warming. Agenda 21 has clearly defined principles that have not found proper application in practice. Taking into consideration the causes of global warming, proper disposal waste will be considered as a starting point of the solutions. In this process, there is more interaction between participants. So, waste management means creating a system of values in which the financial and social capital are partners and not the competitors to the environment. For this reason, state must direct the improvement of waste management towards enlarging the social capital in addition to improving all other conventional resources and capital. [1]

Social responsibility of recycling centers is very important. It is in their core activity, as well as in promoting environmental protection and encouragement of legal entities and individuals for recycling, through various activities and privileges. In this regard, we can say that recycling centers play one of the most important roles in terms of conservation and environmental protection, and this can be inferred from the environmental policy. By applying strategies and laws, by working on continuous improvement of its employees, encouraging cooperation with businesses, individuals and non-governmental organizations, recycling companies represent an important link between pollutants and the roads to adequate protection of the environment. Their importance and role can be more substantial than defined in the National Strategy until 2020. The participation of operators in the disposal and storage of waste is defined in this strategy by the role of operator of facilities for storage and waste disposal and processing system operators. Contemporary trends in waste management include continued competitive initiatives and voluntary improvement of standards not only in regional centers, but also with small operators who are on their way to adapt to the ecological and economic area of the European Union.

The Regional Centers for Waste Management

The Regional Waste Management Plan defines a number of local government units in accordance with the common goals of waste management. The legislation mandates that they be inhabited by at least 200 000 inhabitants and that their collective action be verified and approved by the relevant ministry. [5]

Table 1. The participation of the local government of Lučani in the regional center for waste management [5]

Local government that initiated the construction of a regional center for management of municipal waste	Municipalities that make up the Regional Centre for Waste Management	Number of inhabitants (2002)	Waste amount t/annum. (2009)
Užice	Bajina Bašta, Požega, Arilje, Ivanjica, Čajetina, Kosjerić, Čačak, Lučani, Ljubovija	378.668	91.516

The waste management strategy of local governments frequently ignores the small operators, which brings a host of problems in practice. The projected amount of waste in the local government unit of Lučani, which should be disposed of at a regional landfill "Deep", built on the basis of the Regional Plan of all participants (Table 1), is considerably oversized in relation to the amount of waste transported to the regional landfill. One part of the fault is caused by the poor assessment and neglect of the amount of waste processed by small operators at the local government level. It is envisaged that by the end of 2020 the municipality of Lučani will have produced 3666 tons of waste, which represents an increase compared to 2009 when 2,582 tons of waste were produced. This information should influence the awareness and the increased efficiency of recyclers in this municipality, both in terms of prevention of environmental pollution and profit views.

Table 2. The quantities of municipal waste produced annually in Serbia and projections for 2020 [5]

	Local government	Population according to the census of 2002	Quantity of waste produced in 2009, t	Projected amount of waste produced in 2020,t
The Morava District				
72nd	Gornji Milanovac	46.092	13.191	18.731
73rd	Ivanjica	34.279	3.816	5.420
74th	Lučani	23.189	2.582	3.666
75th	Čačak	116.534	33.392	47.417

One should bear in mind that in addition to the population there are a number of companies that also generate both municipal and industrial waste. According to the Law on the disposal of waste, Article 26 each company (legal entity) that is engaged in the processing of waste and generating 200kg of hazardous or 100 tons of non-hazardous materials per annum during their operations, is actually a producer of waste.

The hierarchy of waste management, as well as EU policies on waste, is a representation of the significance of the processes, from the least to the most suitable option. The basis is the dumping of waste, followed by the return of energy, recycling, reuse, minimization and prevention at the top as the most acceptable pyramid of options. When we apply this picture to the state of waste movements in Serbia, it is clear that we are at the level of the least acceptable option, which is not itself realized as it should have been. It takes a lot of work and training to meet the conditions for gradual growth and success. The primary starting point for this is prevention. In countries that are EU members, paper, glass and non-ferromagnetic metals are produced from recycled materials - 50% paper, 43%glass in particular. These types of recycling already function in the Republic of Serbia and more emphasis should be given to them having the percentage of production of these products in the EU in mind. [5]
Defining the problems that arise in protecting the environment at a local and regional level based on the gap between small operators and regional requirements, it is necessary to influence the improvement of their mutual cooperation. The essence of the removal of such errors and omissions is reflected precisely improving the work of local governments in managing waste. Employees who deal with this problem are the proponents of a healthy, coordinated and balanced cooperation between local governments and its small operators with regional plans, and finally of the national aspirations of joining the European Union. Unfortunately, some local governments do not look upon nor interpret environmental protection as a comprehensive process of its sustainable development. Looking at the isolated segments of environmental protection, and waste management in particular, mistakes are inevitable regardless of the overall value system. Skilled human resources at the level of local government involved in these tasks proved to be questionable in many cases. However, in those local governments where a position in waste management exists, there has been much greater success in relation to local governments then where there are none.

THE RESULTS OF WASTE MANAGEMENT AT THE LEVEL OF LOCAL GOVERNMENTS

Based on research conducted in 2015 at the level of 145 local governments of the Republic of Serbia[1] on the organization of human resources in environmental protection, the results related to waste management have been singled out.

Table 3. Organization of waste management of local governments of The Republic of Serbia depending on their size

		The size of a local government by population								
		< 20 000	< 60 000	< 100 000	< 150 000	> 150 000	Σ f	χ^2	df	p
Whether at the level of local government at its current systematization of jobs there are positions intended for waste management?	f yes	11	17	5	5	5	43	17.206	4	0.002*
	f no	36	19	2	4	0	61			
Whether at the level of local government at its current systematization of jobs there are positions intended for waste management?	f yes	11	17	5	5	5	43	17.206	4	0.002*
	f no	36	19	2	4	0	61			

* at level 0.01of significance

[1] The local governments of Kosovo and Metohija were not covered in this research solely due to the impossibility of implementing the questionnaire and not due to questioning or prejudging their respective statuses.

Each local government wanting to achieve sustainable development, and to improve waste management accordingly, would have to utilize and engage human resources. Unfortunately, by analyzing the survey results, it is clear that in many of them there is no workplace dedicated to working with waste management. Assuming that planning such a workplace depends on the size of the local government, the $\chi 2$ test was made at level 0.01 of significance. From Table 3 it can be seen that there is a significant correlation between these two variables and the chi-square test is statistically significant at the "intersection" with the size of local government.

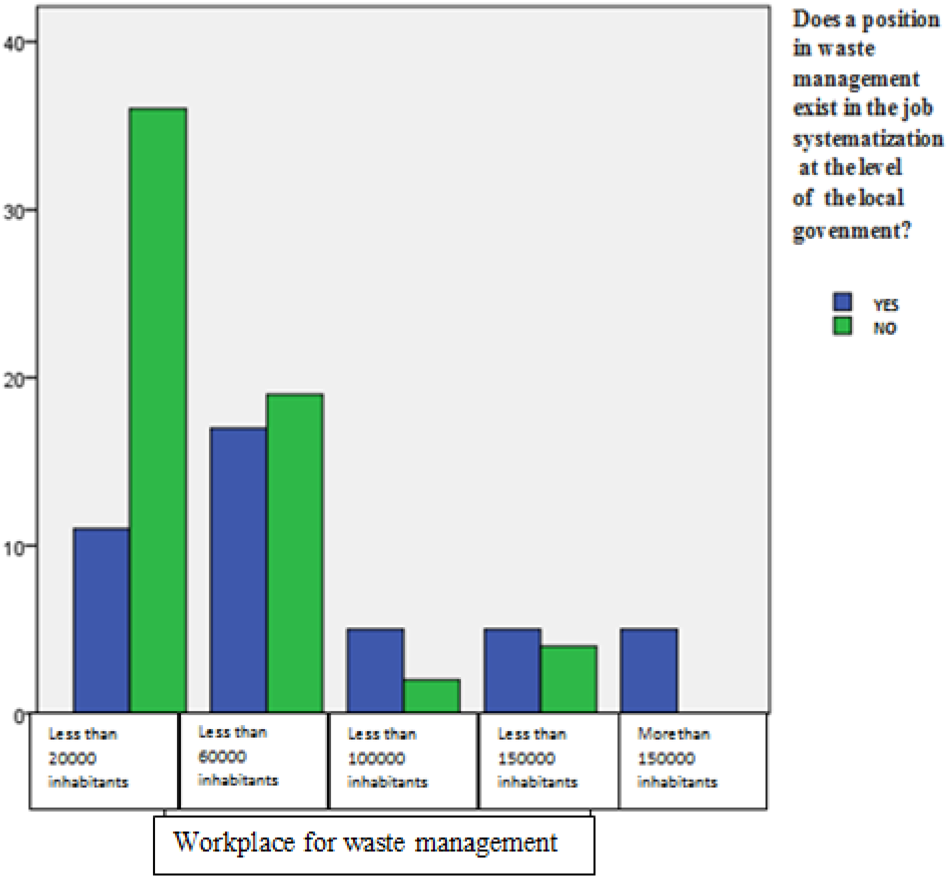


Figure 1. Representation of the workplace intended for waste management by the majority of local governments

The graph (Figure 1) shows as evident that within the local governments of up to 20 000 inhabitants a small number of those local governments have a planned workplace for waste management in their job classifications. With the growing size of the local government and the population as the most important category in the generation of waste, the need for human resources that will be employed in waste management contributes to its successful disposal. It is interesting that all local governments with 150 000 inhabitants have a job intended for waste management.

CONCLUSION

It is clear that there is no basis solid enough to be a supporting pillar for further work and development of waste management. Differences in local governments determine the differences in the approach to waste management. The legislative framework is a roadmap and guidance, but the system of values should be strengthened by social capital, the starting point of which would be human resources. Each local government should plan the introduction of a workplace intended for a waste management in order to coordinate the work of small operators, the economy and population in accordance with regional and national goals.

REFERENCES

[1] Bajac M., Jovanović Dj., Matavulj M., The Education of Socially Responsible Managers, Quality 1-2, 2009., Belgrade
[2] Chamber of Commerce of Serbia
[3] Petrović N., Environmental Management, Faculty of Organizational Sciences
[4] Radosavljevic J., Đorđević A., “Landfill and disposal of municipal waste”, Monograph, University of Niš, Niš 2012.
[5] The Waste Management Strategy of Serbia until 2020.
[6] http://www.politika.rs/rubrike/Politika/Treba-nam-106-milijardi-evra-za-dostizanje-ekoloskih-standarda-EU.lt.html

ACKNOWLEDGEMENT

This paper was created as the result of the project entitled : The Research of Cogeneration Potential in Municipal and Industrial Power Plants of the Republic of Serbia and the Possibilities of Revitalization of the Existing and Construction of New Cogeneration Plants (III 42013), which is funded by the Ministry of Education, Science and Technological Development of the Republic of Serbia, research cycle 2011-2014(2015).

CAPACITIES OF LOCAL SELF GOVRENMENTS IN SERBIA FOR ENVIRONMENTAL PROTECTION DEVELOPMENT – CASE STUDY

Nedeljko Ćurić
Standing Conference of Towns and Municipalities, Belgrade, Serbia
e-mail: nedeljko.curic@skgo.org

Abstract: In the past more than decade the process of strategic planning and programming was embedded into the public administration procedures at all levels, from national to local. From the other side, it is strong need for procedure and national legislative *harmonization* with EU Directives on strategic, but also on project level in the area of environmental protection (with time and resources consuming investments). In this paper the capacity of LSGs in the sample of 20 programme budgeting for 2015.analysis, conjunction with of planned project of environment protection with the identified projects in action plans of local strategic documents will be presented, with recommendations for improvement.
Key words: programme budgeting, project, strategic planning

INTRODUCTION

The chapter 27 – Environmental Protection is one of the most complex negotiation chapter in EU accession because of high implementation costs, complex institutional framework and administrative capacities at all level improvement necessity
The main principles of environmental protection investment managing are:
- Concentration of resources on the most expensive sectors,
- EU requirements fulfilment on the lowest price,
- Public funds allocation to the public infrastructure with high priority
- Cooperation toward cost reduction
- Phase approach during the implementation,
- IPA II funds reallocation on the priority infrastructure needs (70% on water and 30% on communal solid waste)
- Long term planning in order to improve investment cycle,
- Active participation in project preparation

The approximate costs

Table 1. Total investment costs by sectors

Sector	Investment costs (million €)
Drinkable water / National approximation strategy in the environmental protection	2.000
Waste Water Treatment / draft of the plan for water protection	4.962
Communal Solid Waste / specific implementation plan for Directive of landfill	918
Total investment costs	7,880

The main activities related to cost approximation are:
- The Draft of the Strategy of water management on the territory of the Republic of Serbia and Water Pollution protection Plan which identifies agglomerations and gives precise implementation costs in the Water area,

- The development of the Specific Implementation Plan for Directive of landfills
- The development of other sectors' documents is in progress, and supposed to be adopted by the end of 2015

The goals of national strategies of the sectors: Communal Solid Waste, Waste Water and Remediation are:

- To construct Regional centres for solid waste management in accordance to the Directive for landfills 99/31/EU and relevant Serbian legislative,
- To expand percentage of households connected to the public sewerage network to 65% of inhabitants until 2019.
- To ensure communal waste water treatment (in the settlements where organized water supply and significant influence on the recipients exist as well as water quality in sensitive areas)
- To ensure revitalization and normal operation of the existing waste water treatment plants in the settlements,
- Existing dumps with the highest risk on the environment pollution, sanitation and location of "black points" with historical pollution with hazardous waste.

The preparation of planning and project documentation – experiences, so far:

- Luck of prepared project documentation is one of the main obstacle for IPA funds absorption
- It is need to strength of the capacities and awareness at all levels institutions for project documentation
- Project documentation has to be prepared in accordance to Serbian legislative as well IPA funds

MATERIAL AND METHODS

Assessment of 20 local programme budgets[1] for 2015

Assessment of 20 local programme budgets for 2015 on the basis of parameters identified and data collected was performed in SCTM in the period March-July. The overall objective of was: to assess compliance between selected Local Self Governments / LSGs' local budgets targeted and Methodology of Program Budgeting Implementation issued by Ministry of Finance in February 2014 in terms of usage of defined list of programmes and programme activities.

Within the scope of support provided to LSGs in programme budgeting and strategic planning, SCTM fulfilled following activities during 2015 with objective of improving programme budgeting (PB) process for 2016 and strategic planning:

1. Screening of the implementation of strategic planning process in 20 selected LSGs based on the evidence of implementation of strategic documents with regards to budget spending for the relevant timeline (March 2015);
2. Screening of the implementation of programme budgeting with regards to the compliance with the proposed PB structures, objectives and indicators for 20 targeted LSGs (March 2015) ;
3. Assessment and revision of SCTM recommended PB programme/programme activities' goals and indicators and provision of recommendation for their improvement (JulyApril 2015);
4. Field work with LSGs on enforcement of PB and SP -

SLAP information system

SLAP Information System is a database, structured collection and pre-evaluation/scoring tool of municipal infrastructure projects, It allows the municipalities to present their infrastructure priorities

[1] The programme budgets system was implemented for the first time for the budget for 2015 of all levels: national, provincial and local. SCTM was appointed by the Ministry for Finance of the Republic of Serbia for technical support LSGs in programme budgeting, especially in programmes' programme activities' unique goals and indicators determination. More at: http://www.skgo.org/reports/details/1542

by registering projects within a strategic framework set by relevant line ministries. The database can be accessed online and has been managed by the Standing Conference of Towns and Municipalities (http://www.slap.skgo.org) since 2008 and financially supported by European Union.
The main purpose of SLAP is to facilitate identification and prioritization of municipal and intermunicipal infrastructure projects in a transparent and efficient manner and in line with the national strategic framework. Main features of the information system include:

- Continuous and sustainable system of presenting municipal infrastructure projects;
- Top-down approach: central level sets up policy and criteria for selecting priorities;
- Bottom-up approach: LSGs identify and present the priorities;
- Sector based approach: relevance of sector strategies and support to their implementation;
- Flexibility: available online, reporting, grading. Possibility to extend to monitoring and implementation in the future;
- Transparency: evaluation of projects using objective criteria, based primarily on relevance and quality, while taking project maturity into account.

Table 2. The status of project submitted to SLAP as per October 2015[2]

Sector	Number of projects	Investment (mill €)
Communal solid waste	18	251,15
Waste water	29	727,31
Water supply	8	174,38
Tourism	9	56,81
Industrial zones, including technological parks	17	95,49
Energy – public buildings	3	0,17
TOTAL:	**84**	**1.305,31**

RESULTS AND DISCUSSION

Based on the mentioned Analysis the following graph shows average percentage of 20 LSGs' budget relocation in the 15 programmes and average percentage of projects. The following LSGs budget was analysed: the Cities: Zrenjanin, Novi Sad, Vranje, Valjevo, Sremska Mitrovica, Novi Pazar, and the Municipalities: Trgoviste, Koceljeva, Kula, Trstenik, Lucani, Backa Topola, Gornji Milanovac, Ada, Aleksinac, Paracin, Knic, Kovin, Knjazevac, Golubac

[2] Up to now, 19 projects from SLAP have been selected for financial and technical support by EU. The list of financed projects are on www.misp-serbia.rs. 25 project was selected by Environmental protection fund in October 2011. The average amount of investment of those projects is about 10 million of Euro

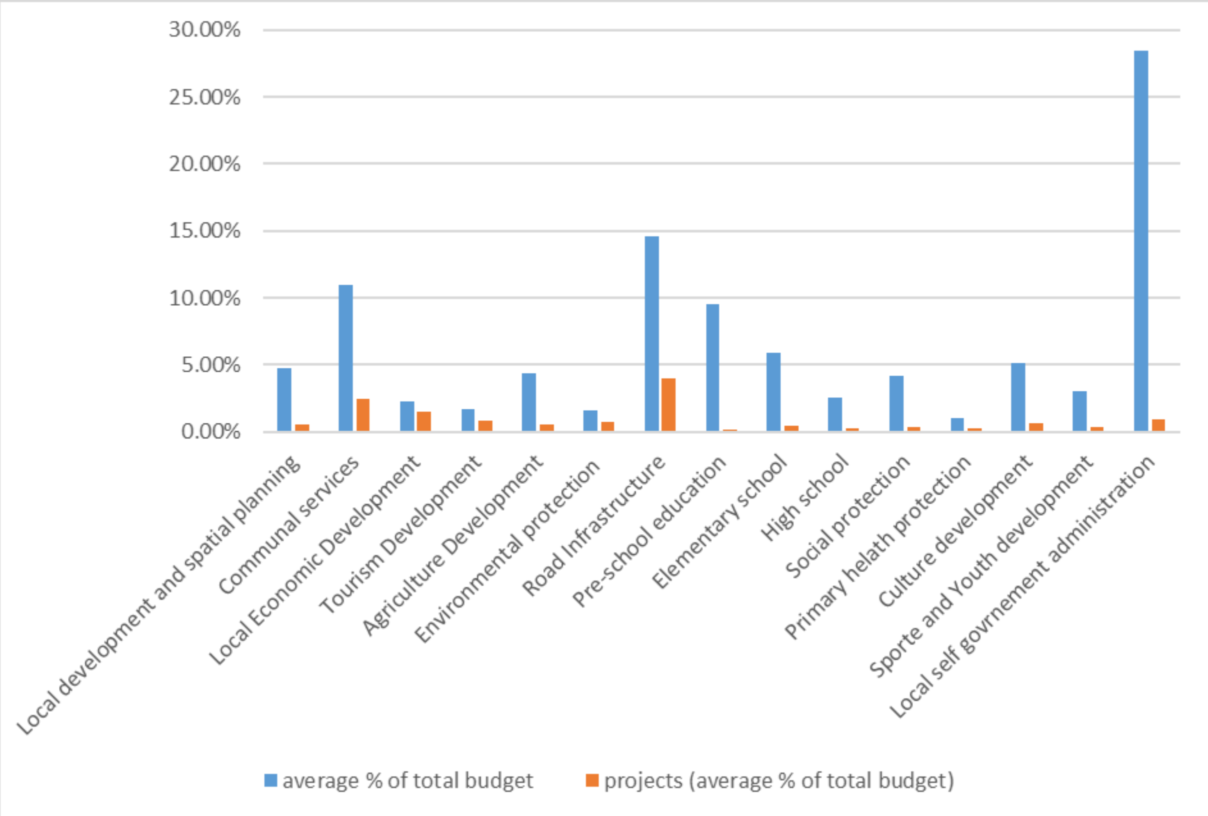


Figure 1. Average budget appropriation for different programs

The average budget appropriation to the programmes Environmental Protection is relatively small (less than 5% with smaller portion of budget for projects). For the Programme Communal Services average budget appropriation is in the third place, but relatively with small appropriation to the projects. The biggest budget appropriation for projects goes to the Road infrastructure, approximately equal of the sum of portion of Environmental protection and Communal Services. Generally the distribution of the budget to the projects in area of environmental protection at LSGs level, is not sufficient toward requirements of the EU accession and present limited absorption capacity at local level.
Comparing the list of identified projects in programme budgets with projects from action plans of local development strategies the conclusion is: For the projects of the Environmental protection area of the local action plans of the strategic document, in average 4.24% of budget selected LSGs allocate, which is twice bigger then appropriation for the Programme Environmental Protection and approximately the same portion for the Programs: Communal services and Environmental protection together.
According to previous data, the proportion of budget reallocation of the LSGs budged to the programs of Environmental protection and Communal Services is not balanced refer to the estimated approximate costs (the most higher costs are related to the sectors: Communal Solid Waste, Waste Water Treatment, and Water Supply and Industrial pollution.
So, the needs for synchronization of local processes of budget and strategic planning at local level and with national level is obvious and urgent.

CONCLUSION

Considering that goals and priorities of the strategy development documents from all levels of governance is achieved by the *projects*, and that 60% of all activities related to environment protection will be realized on the local level and under responsibility of LSGs, it can be concluded that the processes of local strategic, financial planning has to be improved in order to increased it' efficiency and effectiveness. The source of data for local *strategic*, *capital* and *programming budgeting* in the area of environmental protection is the same: the project documentation. Since, the comprehensive data on project documentation is embedded into SLAP data base structure, SCTM will promote it as *unique* data source for the similar planning and programming purpose. By that way. LSGs will be motivated to input and update data on their projects, regularly, which ensure data base for strategic planning at ministry level and IPA 2 programming.

REFERENCES

[1] National Approximation Strategy for Environmental Protection, Official Gazette R.SR. 55/05, 101/07, 65/08 and 16/11)
[2] Methodology for Programme Budgeting preparation, Standing Conference of Towns and Municipalities, 2014.
[3] SLAP project pipeline of municipal infrastructure project in Serbia
[4] Ćurić, N., Odadžić, B., Odadžić, D., Primena SLAP sistema za operativno opštinsko planiranje, Energetic technology, 2011
[5] Ćurić, N., SLAP project pipeline of municipal infrastructure project in Serbia, International Conference on Applied Internet and Information Technologies, 2012

NEW EU NRMM EMISSION REGULATION AND ITS EFFECT TO SERBIAN INDUSTRY AND ENVIRONMENT

Slobodan Janković[1], Vladimir Šinik[1], Velimir Petrovic[2]
[1]University of Novi Sad, Technical Faculty "Mihajlo Pupin", Zrenjanin, Serbia
[2]IMR Institute, Belgrade, Serbia
e-mail: sjankovic@eunet.rs

Abstract: The paper deals with on-going changes in non-road mobile machinery (NRMM) vehicles' legislation procedure which would enable reduction of exhaust emission from the NRMM engines. The new regulation regarding NRMM emission has been lunched by EU and Serbia has been warned against the exigent steps toward harmonization of the local regulations. The paper gives in detail view of the nowadays limit levels of the emission from NRMM in Serbia along with the limits of the pollutants which NRMM will have to meet at the end of the harmonization process.
Two aspects of this process are extremely important. Firstly, at the end of the process Serbia would have emission of the controlled pollutants from NRMM dozens times less than nowadays. The PM (particle meters) emission will be reduced for 34 times or more, NOx emission will corresponds to 23 times less value, etc. The second aspect which paper highlights is the economical aspect. Potential and certain implication of the NRMM emission upgrade is that Serbian industry and agriculture can face dramatic impact. The paper analyses the possible strategies which would enable Serbian industry and agriculture to minimize the new investments and increase of operational costs in fulfilling the new emission regulations.
Key words: Engines, Exhaust emission, NRMM pollutants, EU regulation.

INTRODUCTION

In the EU commission staff document related to the enlargement strategy and main challenges in 2013-2014 it is highlighted that "Serbia … has … to align its legislation with the acquis (which means the "EU acquis") in a number of areas, including emissions of pollutants from non-road engines…". To enable good understanding of this issue it is important to highlight its background and to see what strategy can be implemented in Serbia to enable environment protection along with protection of domestic industry and agriculture. The general overview of ecological, technical an economical aspects related to the introduction of emission complained CI (Compression-Injection) NRMM engines (actually, diesel engines for NRMM), is given in this chapter.
Since 1995, as the result of intention for clear environment, CI engines manufacturers significantly reduced the level of exhaust emission. The main intension was in reduction of diesel particulars matters (DPM or PM) and NOx (mono-nitrogen oxides i.e. NO and NO_2). In addition CO and HC have been significantly reduced, too.
The CI NRMM engine's emission reduction is the result of many technical measures implemented on the engines. At the beginning of the process of emission reduction the main intension was toward reduction of the visible pollutants which are in correlation to PM. Actually, PM has been always indirectly controlled, even before the first regulation related to the CI engines emission has been lunched by EPA (Environment Protection Agency from USA), UN ECE (United Nations Economic Commission for Europe) and EU Commission. At that time it was controlled as level of smoke and all OEM producers has intended to declare their products as low smoke products. Subsequently, as result of the intension for minimizing impact to the environment the engine producers continued the efforts toward reduction of NOx emission Co and HC, too. Based that the first here noted pollutant (PM) is directly correlated with the quality of burning process, producers introduced different measures to enable higher injection pressure, better fuel spray, preventing fuel to come to the contact with piston and especially liner's walls (based that liners are with the much lower temperature), etc. That was possible with, that time, existing technology.
Introducing higher technical level solution for emission reduction and more expensive engines (based on introduction of the new subsystems) corresponds to the interest of EU and USA engine industry and markets. Actually, more expensive engines are more affordable to the western market customers and the higher level of technology was available with the industry in well-developed countries, only.

As the result, the developing countries find themselves in position to follow the latest EPA, ECE and EC regulation with a delay and with intention to introduce lower exhaust emission levels once when its industry interest became capable to deliver appropriate solutions, only. Consequently, understanding EPA and EC NRMM diesel engine emission regulation and its levels is crucial (see the next chapter).

ANALYSES OF THE EMISSION REGULATION AHEAD OF SERBIA

Serbia is looking to harmonize its regulation with EU. This means that exhaust emission levels for agricultural tractors (AGT) have to be in line with the: (i) European framework directive for AGT 2003/37/EC, (ii) EU directive for emission of gaseous and particulate pollutants by engines intended to power agricultural or forestry tractors 2000/25/EC and (iii) EU directive relating to measures against the emission of gaseous and particulates pollutants from internal combustion engines to be installed in non-road mobile machinery 97/68/EC.
All noted directives have been amended many times with the final results that the level of the allowed emission became stricter. In EU the level of emission has been upgraded from the Euro Stage I to Euro Stage IV (in USA from EPA Tire 1 to EPA Tire 4) and it is strictly dependable of engine power range.
The first European legislation which regulates emissions from CI non-road mobile equipment was lunched at the end of 1997 with implementation date from, 1.1.1999. That was NRMM Euro stage I,

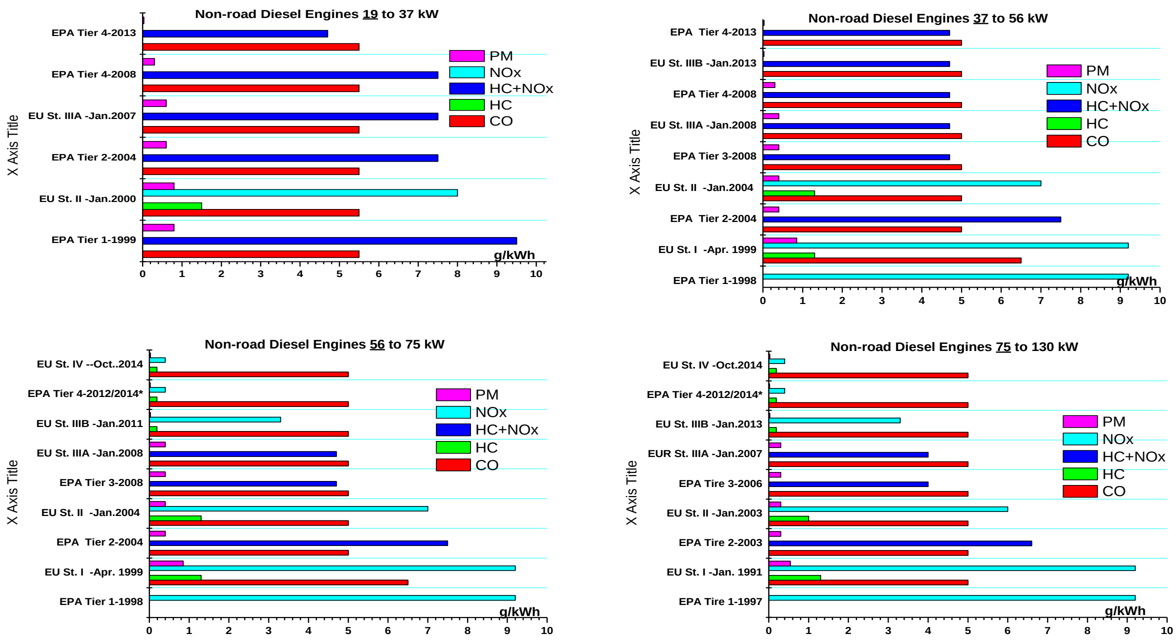


Figure 1. Analyses of the progress of EU regulations for exhaust emission from CI non-road mobile machinery engines with cross-reference to the EPA regulations (underlined power values are included in the particular power range(s)).

also known as »non-road vehicle« Euro Stage I. As it is given in Fig. 1 Stage I was implemented only to the diesel engines with power of 37 kW or higher.

The following issues have to be highlighted in NRMM Euro Stage I:

- Implemented only to the NRMM engines with power of 37 kW or higher,
- Limits for all pollutants are significantly higher than what can be found in USA norms i.e. EPA Tier 1,
- PM limit level is 1.8 to more than 2.1 times higher than EPA Tire 1 limit values,
- Testing as per heavy duty steady stay test cycle (NRSC - Non-Road Steady Cycle as per ISO8178-C1)
- Testing fuel with CN 45-50 and sulphur (mass) content 0.1 to 0.2%.

It is important to be noted that based on Regulation on technical and other requirements for the fuels (Serbian' Official Gazette 64/2011) fuel for diesel engine D2S is with sulphur (mass) content of 0.2% i.e. the same content as test fuel for Euro Stage I and Euro Stage II.
In the subsequent Euro stage II the main changes are as follows:

- Limits for all pollutants more close to these given in USA norms i.e. EPA corresponding tire,
- PM and NOx limit levels for approximately 30 % les then in the Stage I,
- Testing as per heavy duty steady stay test cycle (NRSC - Non-Road Steady Cycle as per ISO8178-C1) mandatory (not changed from the Stage I),
- Testing fuel with Sulphur (mass) content 0.1 to 0.2% (not changed from the Stage I).

Euro Stage III A, III B and IV introduce the following important changes:

- Limits for all pollutants mainly the same as USA norms i.e. EPA corresponding tire,
- PM and NOx limit levels significantly reduced. PM level reduced from (in the Stage II) allowed level of 0.3-0.6 g/kWh (depends on the engine power range) to 0.025 g/kWh!
- NRTC (Non-road transient test cycle) as per ISO 8178-4 became mandatory (Stage III B and IV).This enables emission to be measured more close to the real service load condition but makes significant impact to the price of testing installation.
- CoP (Conformity of Production) i.e. checking that the conformity of engines serial production became more strict.
- Introduction of the Deterioration Factor (DF) and Emission Durability Period (EDP). EDP has been established at the level of EDP = 5000h (for engines with power ≤ 37 kW) and EDP = 8000h (for all other engines). This is very important change in the emission regulation which has to insure authorities that emission of the engine, during expected engine service life, will not significantly excide (5 to 10% depending of the pollutant) the limit values mandatory during engine type homologation/certification.
- Test fuel with very low sulphur (mass) content: 300 mg/kg for Stage IIIA and 10 mg/kg for the Stage IIIB and IV.

FEASIBLE STRATEGY FOR SERBIA – COST AND BENEFITS FROM HARMONISATION OF THE NRMM EXHAUST EMISSION REGULATION WITH EU

There are two important aspects for Serbian agriculture and industry in harmonizing with nowadays EU regulations for CI NRMM engines. The first one is the cost and benefit for the agriculture and industry while the second is the local administration strategy in harmonizing regulations. Delay in implementation of the latest EU directives is significant and obvious. But, delay has one important reason. That is the protection of the state's economic interests.
Without implementation of exhaust emission regulations, the local governments has relaxed farmers and enabled them to use AG tractors with low purchasing price as well as with very low operational cost. AG tractors which don't meet Stage I (power ≥ 37 kW) or Stage II (19 kW ≤ power < 37 kW) are with

- Low price,
- Low operation cost which is at the same level as many years back and
- With specification which enable use of D2S fuel.

It is true that ecological effects from CI engines which don't complain the latest emission regulations are very negative, but, it is obvious that economical interest is with the higher priority i.e. dominant.
The very important aspect is also that CI NRMM OEM producer(s) are not capable to easy improve specification of their products. Consequently, introducing more strict emission regulations will »kill« domestic IC NRMM engines and AG tractors industry.
The aspect noted in previous paragraph is quite obvious. Actually, upgrading of the existing engines to the actual emission norms will ask for:

- Very serious redesigning the engine families,
- Introducing different subsystems on the engines such as:
    - New FIE (mechanical with higher pressure for engines 19 kW ≤ power < 37 kW and CR for engines with power ≥ 37 kW

- EGR (exhaust gas recirculation) or/and cooled EGR,
- DOC (diesel oxidation catalyst) which enables reduction of: (i) organic fraction of diesel particulates (SOF), (ii) carbon monoxide (CO) and gas phase hydrocarbons (HC), where the oxidation of gas phase HC can be described as by following reaction:

$$\text{Hydrocarbons} + O_2 = CO_2 + H_2O, \quad (1)$$

oxidation of SOF (soluble organic fracture) compounds can be discribed as:

$$C_nH_{2m} + (n + m/2)O_2 = nCO_2 + mH_2O \quad (2)$$

and oxidation of carbon monoxide to carbon dioxide can be discribed as:

$$CO + ½O_2 = CO_2 \quad (3)$$

- DOC with DPF (diesep aprticle filter) or
- DOC and SCR (sective catalytic reduction of NOx by nitrogen compounds, such as *ammonia* or *urea*) where after urea decomposition

$$CO(NH_2)_2+H_2O \rightarrow 2HN_3 + CO_2 \quad (4)$$

the following rections in SCR reductions (at temperature 150 do 550˚C) of NOx hepen:

$$4NO + 4NH_3 + O_2 = 4N_2 + 6H_2O \quad (5)$$
$$NO + NO_2 + 2NH_3 = 2N_2 + 3H_2O \quad (6)$$
$$2NO_2 + C = 2NO + CO_2 \quad (7)$$
$$4NH_3 + 3O_2 = 2N_2 + 6H_2O \quad (8)$$

- POC (Particle oxidation catalysts) to enable

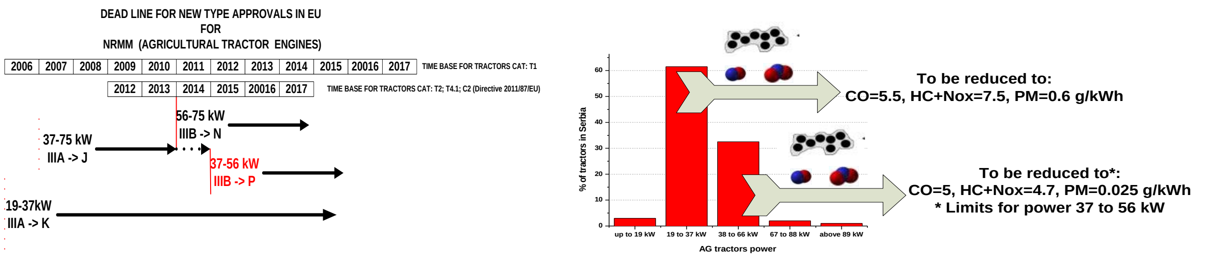
$$C + 2\ NO_2 \dashrightarrow CO_2 + 2NO \quad ^{\text{at 250 to 450 ˚C}} \quad (9)$$

- Introducing implementation of demanding CoP procedures,
- Introducing the new production lines, etc., etc.

All of this will enable engines which will meet Euro Stage IIIA (19 kW ≤ power < 37 kW) and engines which will meet Euro Stage IIIB / IV (engines with power ≥ 37 kW) but the cost aspect will be very critical. Estimated price of upgrading the engines (design cost, only) will be at the range of 2 annual turnovers of the domestic CI NRMM engine producer(s). The overall cost for lunching production will be more than 10 times the annual turnovers. Based, on economic aspects that scenario looks critical. But, it has to be noted that the main problem is not total amount of the investment. The main problem is related to the annual turnover of the local producer(s) which is at the extremely low level. Consequently, the main limitation is related to the low financial capability of the local NRMM engine industry which is in strong correlation with its market shear.
Cost- benefit analyses has to take in consideration the time which local industry has to harmonize their products with EU emission regulations. That aspect looks more optimistic and promising if the chosen strategy will be appropriate. Serbia has minimum 4 to 5 years to find itself in position when it will have to harmonize local regulations with EU regulations. Let see what has to be achieved in that time.
As it can be seen in Fig. 2 the engines up to 37 kW (Cat. K) has been from the 2006 at mandatory emission level defined as Stage IIIA. In category K that level is with moderate limit levels of pollutants. The PM limit is 0.6 g/kWh, only while the NOx+HC limit is 7.5 g/kWh, only. Based on nowadays available technology these limit values can be achieved without after-treatment of the exhaust gases. That open possibility for domestic producer(s) to meet the limits with the design

upgrade of the existing engine families and with implementation of more advanced mechanical FIE, only.

Consequently, it looks as realistic and possible achievement for the local industry to meet European norms for CI NRMM engines in power range below 37 kW. Based that ~ 61.5 % of all tractors in Serbia are in that power range it is extremely important and from cost-benefit aspect crucial to meet the EU norms in that power range. As it was noted above the cost for that action can be moderate while the benefits, through preventing import, providing job for local industry, protecting spear parts market and providing to the farmers AG tractors at very reasonable price, will be extremely high.



a) b)

Figure 2. a - Time base for new emission levels from NRMM in EU, b - Percentage AG tractors in service in Serbia according to its power range and reduction of controlled pollutants from NRMM from Euro Stage I to Euro Stage IIIB for NRMM engines with power ranges of interest for Serbia.

The Euro Stage IIIA in category K (19 kW ≤ power < 37 kW) will stay in power even after 2017. Consequently, the positive financial effects of the meeting IIIA regulations in this category will stay for a reasonable long time (EU still didn't declare any amendment to emission regulations in this category).

The financial effects from export can also significant. Local products in this category are with very competitive prices and with good background at the markets of surrounding countries where export, based on emission regulations have been stopped. Croatia and Slovenia have joined the EU and, because of that, they implemented the new regulations. As the result the local industry lost these markets. Macedonia upgraded the regulations with the intention to harmonize them with EU. Romania, as the member of EU, also implemented the latest emission regulations and, based on economic problems, closed local AG tractor industry. Consequently, many »old« markets can be again activated with possibilities for export to some other markets which were not dumped in the past (Romania, Bulgaria, Greece, etc.)

From ecological point of view the benefits will be absolutely at the same level as in other EU countries and Serbia will protect the local environment exactly same way as the environment is protected in well-developed western countries including EU, USA, Japan, etc.

Based on noted above, it looks very logical and cost effective to make investment in meeting EU legislation norms for IC NRMM engines in category K.

The status in the categories above 37 kW is different. In the categorise P (37 kW ≤ power < 56 kW) and N (56 kW ≤ power < 75 kW) there are approximately 32.5 % of the total ~ 411,000 AG tractors (consequently, Serbia has ~ 93 % of all tractors or ~ 382,000 tractors in power range from 19 kW to 75 kW).

Ecological aspect is these categories are extremely important. In spite of much less number of the tractors with power above 37 kW, based on their higher power range, the emission from them is close to equal to the emission from cat. K engines (~ two times higher power but two times less in numbers). It can be concluded that ecological approach will show that engines cat. P and N are of the same importance as engines cat. K. But, nowadays regulation in P and N categories are stricter (see Fig. 1) based that that they have to meet Euro Stage IIIB level of emission with PM = 0.02 to 0.025 g/kWh and approximately 2 time less level of NOx pollution than what is allowed for K category. Consequently, meeting the norms in these categories will give great ecological effect.

Unfortunately, Euro Stage IIIB is not easy to meet and asks for serious investments in designing absolutely new engine families, distributing low sulphate fuel to the fuel stations in agricultural farms etc. It will be very difficult to compensate the tremendous investment in production IIIB engines with revenues from the export. The reason is strong competition in the market in this power range as well as difficulties in establishing new engine families in new markets.

The strategy in categories above 37 kW can vary depends on the local government intention in this industrial segment but with the low level of local market protection (as it is nowadays), it will be very difficult to enable to domestic producers to meet IIIB requirements. As it is, the local market is very open for importing CI NRMM (customs duty ~ 10%, but for importing from some countries the duty is negligible) and AG tractors (customs duty ~ 15% but for importing from some countries the duty is negligible as for the engines).

It is obvious that serious effort from the local government as well from the local NRMM industry has to be done for solving ecological as well as economic aspects related to the improvement of emission norms for CI NRMM engines which are in use in Serbian agriculture.

CONCLUSION

In detail analyses of the ecological, economical and technical aspects related to the harmonizing Serbian regulation for NRMM emission with European norms shows the following important results. Firstly, based on the permanent claims from EU regarding status of Serbian NRMM emission regulation, Serbia has to start harmonization in this field with EU. It is expectable that harmonisation, which means full alignment of the local norms with EU regulations, would have to be finalized within 4 to 5 years.

Secondly, humanization process will have important positive effects to the all ecological aspects based that the difference between Serbian and EU regulation in this field is very large. Consequently, once when the regulations would be harmonized, Serbia will have emission of the controlled pollutants from NRMM dozens times less then nowadays. For example, particle meters (PM) emission will be reduced 34 times or more, NOx emission would be reduce for 23 times or more. But this harmonization will cause economic impact to the Serbian NRMM industry and agriculture, too.

The main economic effect to agriculture will be in increase of the expenses for new NRMM as well as higher operational cost of NRMM. The dominant effect to the local NRMM industry can be loosing of domestic market.

As it came out in the paper’s analyses, the negative financial effects can be significantly reduced with reasonable and moderate, investment in local industry to enable it to stay with high local market shear in category of IC engines for NRMM up to 37 kW. But, that investment must be done on-time and with synchronized timing with local emission regulation progress. For higher power NRMM the investment must be significantly higher and more accurate import regulations, together with improvement of the emission regulations, must be implemented.

REFERENCES

[1] Bari Saiful: *Diesel Engine - Combustion, Emissions and Condition Monitoring,* InTech Europe, Rijeka, Croatia, 2013

[2] Census of Agriculture 2012, *Agriculture in the republic of Serbia,* Statistical Office of the Republic of Serbia, Belgrade, Serbia 2013.

[3] Pereda-Ayo B., González-Velasco J., NOx Storage and Reduction for Diesel Engine Exhaust Aftertreatment, InTech Europe, Rijeka, Croatia, 2013

[4] European Commission Directive 2011/72/EU, Brussels, EU, 2011

[5] European Commission Directive 2011/87/EU, Brussels, EU, 2011

[6] European Commission Directive 2014/43/EU, Brussels, EU, 2014

CREDIT RISK MANAGEMENT IN DOMESTIC BANKS WITH FOCUS ON RISKS IN THE CONSTRUCTION

Marina Bugarčić[1], Marina Milovanović[1], Jasmina Perišić[1], Ljiljana Radovanović[2], Marko Ristić[3]
[1]Faculty of Entrepreneurial Business of the UNION "Nikola Tesla" University, Belgrade, Serbia
[2]University of Novi Sad,Technical Faculty "Mihajlo Pupin", Đure Đakovica bb, Zrenjanin, Serbia,
[3]Institute Goša, 35 , Milana Rakića str., Belgrade, Serbia,
e-mail: bugarcicm.vbps@gmail.com

Abstract: Risks incurred by the bank in its operations are liquidity risk, credit risk, market risk (interest rate risk, currency risk and changes in market prices of securities, financial derivatives and commodities), the risk exposure of banks, investment banks' risks, risks that relating to the country of origin of the person to whom the bank is exposed, operational risk, legal risk, reputation risk and strategic risk. In the last two decades, occupies an important place risk management, as the leading concepts of organizing and directing the business activities of banks, and within it the key position taken by the issue of credit risk. In fact, credit risk is higher than any other and therefore the first one in the category of risk. In the narrowest sense of that risk is included in the daily operation of the bank.
Key words: Bank portfolio, Credit portfolio, Credit Risk, Credit scoring system

INTRODUCTION

On modern financial markets, financial institutions are exposed to numerous risks, ranging from lack of business diversification and propensity to in risky - and profitable arrangements - until the earthquake in stock markets and the global financial crisis. Increased requirements for systematic management and control of risk, have their roots in the fact that today's business strategy is based on three important factors: money, time and risk. In this regard, reports of financial institutions are the most important sources of information on the activities of financial institutions, or companies, in the area of identifying and taking measures of risk management [5].
There are many factors that affect the growth the uncertainty, such as: changes in interest rates, changes in deposits, the inability of the debtor to repay the loan, deregulation, moral hazard, as well as the entry of banks into tasks that previously were not traditional banking. In addition, the globalization of banking operations and trends of mergers and acquisitions of major banks, forcing the management of the bank to identify the most important risks. This is primarily to systemic risks, particularly the risks stemming from the lack of knowledge of business to an unknown geographically remote areas and markets [1].
Unlike traditional commercial banking, investment banking strong expansion in modern economy significantly affected the expansion of the range of risks to which banks are exposed in their operations. This applies primarily to banks that operate globally, IE. Not only in domestic but also in the international financial markets [4]. The global economic crisis, which escalated in 2008, only confirms this paper.
Globalization and instability of the financial market, as well as increased competition between banks, require banks to introduce innovation in their business, as well as risk management. The present time calls for a new philosophy and the new approach in solving business problems with the banks, as well as the assessment of business risks, prior to entering into certain business financial ventures. Bank in modern financial terms operates in an environment of other banks, customers and the economy as a whole, all of which brings an element of risk in the banking business. The risks that banks face are unavoidable and must be evaluated, controlled and financially neutralized by in order not to endanger whole business of the bank.

The prediction is always a matter of evaluation of future events. Unanticipated changes and unforeseen events cause uncertainty. Uncertainty is a major risk factor.
Basically, the risk could be defined as the possibility of not achieving the expected rate of return on the basis of placing funds, and that will result in the loss of a job. Below are some definitions of risk [2]:

1. The probability of loss or exposure to risk,
2. The danger that can result in the loss,
3. Assets or individual exposed to loss,
4. The withdrawal from actual losses,
5. Psychological uncertainty in relation to loss,
6. The loss of the potential amount of money supply,
7. The deviation of the real losses and so on.

Summarized above, increased exposure to one of the financial risks can significantly contribute to increasing the impact and other risks due to their interrelationship between, and the effect of synergy.

MATERIALS AND METHODS

Managing risks in the construction industry are a continuous process and should include all phases of the construction project. The main objective of risk management in the construction industry is to identify risk factors for the particular project and to develop a risk management plan, in order to minimize the possibility of occurrence of risk events and its bad influence on the realization of the construction project. The largest responsibility for identifying risks, analysing and responding to them in the investor and his team to manage risks. The various phases through which the project have their own specificity, are connected to each other and require a special approach to risk management. Construction project in its evolution goes through several phases and in each of them is possible to identify a number of potential risks or adverse events whose outcome could have a negative impact on the successful completion of the project.
It would be very difficult to make a list of all the risks that arise in construction projects regardless of size, type, the content and specifics of individual projects. For a quantitative analysis of a large number of risks would never be enough information, while the qualitative analysis of a large number of risk was a time consuming process due to the large number of decisions that these risk management should have made. The list of risks which are analysed in some phase of the construction project is formed so that the list of risks that are common to all construction projects adds to the list of risks associated with the project.These risks are determined after a study of potential sources of risks associated with the project, adverse events that carry a risk, and the adverse effects that would occur if the undesirable scenario materialize.
The risk management process always begins by recognizing the risk. Identifying risks can be considered the most important phase of risk management. The aim is to draw up lists of significant risk for a certain project. To make this list first thing that had to be done, in our paper we investigated potential sources of risk, adverse events that carry a risk, and the adverse effects that will happen. For example, the source of risk as weather, events are extremely poor weather conditions, and the effect of the delay in execution of works due to extremely poor weather conditions. In the list of the most important risks it is necessary to conduct a qualitative risk assessment, which is done by a brief description of each risk. The description must be clear in order to avoid intrusion with long risks. After they are removed, the risks should be classified in categories in order to identify sources of risk. Categories include a larger number of risks. Once the sources are defined for each risk it is necessary to determine the adverse event that will produce this risk. This is particularly important due to the later definition of risk response. Among the risks, there is often mutual relationship that needs to be defined. It is now possible to determine the probability of each risk occurrence of the risk and its impact on the project and make a description of the order of priority of risk management. After a qualitative risk assessment and measures taken risk response is observed risk for the time in which will establish Probably that is in response to the risk of any new risks.

RESULTS AND DISCUSSION

Given that our enterprises operate in an environment which is not customary to first carry out the planning, profitability of investment, and then to proceed with the implementation of the same, therefore the risks of investing are significantly higher (**Fig. 1**).

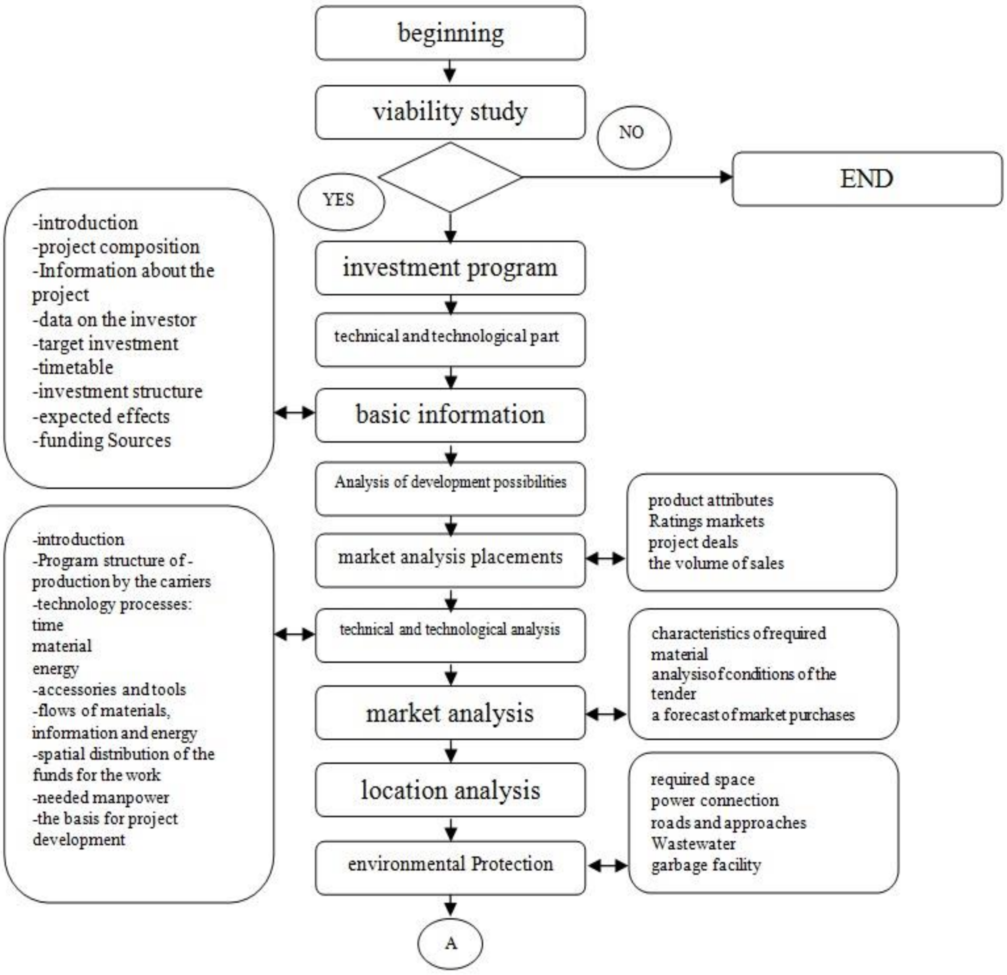


Figure 1. Scheme of investment activities

Due to All listed above it is necessary to make an investment program, and after that start with the implementation of the same. Investment study is a complete investment program, made by the latest technology and components in accordance with the existing economic and legal system at the time of programming. The investment program is a study containing all the essential elements of the investor, the investment and the possible effects of investment in the use for a certain period of time.

The investment program is essential to the investor for two basic purposes. First, it is the basic document for making the investment decision on the basis of an analysis of the conditions and the effects of the realization of the investment and its use in a given time, usually in the first five years or the shortest in the repayment of loans. Then, the investment program is an integral part of the demand for credit, to search for co-financiers, foreign investment and other similar activities in determining "financial structure", that is the source and terms of financing investments and the beginning of its use. And in the conditions when the investor is able to properly repay the loan and the other conditions for participation in the enterprise, it is customary to elaborate the basic information in the form of the investment program. Depending on the object of the investment and its complexity, the investor organizes the development of programs in the own production or hire a professional institution, or qualified persons [6]. The investment program should be adapted to the purpose of the investment. The structure of the investment program depends on:

- Technical and technological characteristics of the structure,
- Location of the building,
- Regulations that are binding on the regulation of fees for: city construction, land, ensuring electrical energy, remote heating and a telephone connector.

Preparation of construction, rental of premises, compensation at the site, a temporary communications facilities, etc., are all "other expenses" of the investment. Project Engineering, fees, costs of technical examination and similar costs together, all this belongs to the other expenses to be displayed on the form of the invoice in the investment program.
When projects are finished and estimates upon basic subjects of investment, it is easy to draw up an overview of the total investment. In addition to the formation of total cost, it is useful to express the value of the building and through the measurement unit constructed building. In our conditions, it is customary for such measures adopted m^2 of living space constructed building.

CONCLUSION

Risk Management, today represents one of the most attractive jobs in the global financial market. This creativity can be expressed by the weight loss avoided, or achieved additional revenue of companies. Scientific and technical progress lead to distortions of market relationships, creating an increasing risk of adjusting all faster rhythm of innovation capital-intensive character. Such conditions require a different system of decision-making based on well-prepared, timely and accurate information. The market economy involves the free operation of supply and demand of goods and services, labour and money within a country and beyond. Under modern conditions, market forces operate outside the boundaries of a country. Free operation of economic laws should be regarded, because each country has its own law and economic constraints [3]. In such a market, companies offer their own products and services. In such circumstances, there is no longer a guarantee for anyone to be able to sell their products and services at the planned price. Products and services are mainly intended for unknown buyer. This method of selling has always been associated with business risk. The risk is always present, may be smaller or larger, but is still present. Our social environment in the transition period, which led to general uncertainty in all areas, has created such conditions that generally can benefit people who are prone to risk. If we define financial risk as volatility or instability yields, which leads to unexpected losses in money-value, then one can argue that higher volatility causes higher risk. The phenomenon of risk in banks and non-banking companies, must be explained in many aspects, in order to manage it as successfully as possible. Banks are increasingly forced to resort to a variety of innovations in order to survive the risky banking market.
The continuous process of realization of its development goals is forcing every company to invest, to enter their own or borrowed accumulation and go consumption possible today, to ensure themselves a new consumption and make new investments tomorrow. This is an organization forced to invest because investment is the only way of implementing development goals.

ACKNOWLEDGMENTS

This paper is the result of research within the project TR 34028, which is financially supported by Ministry of Education, Science and Technological Development of Serbia, Messer Tehnogas and PD TE – KO Kostolac.

REFERENCES

[1] Bjelica, V., Bankarstvo, teorija i praksa, “Atlas”, Novi Sad, pp.265, 2001.
[2] Cirovic, M., Bankarstvo, Bridge Companz, Beograd., pp. 272, 2001
[3] Cirovic, M., Bankarstvo, Bridge Companz, Beograd., pp.74, 2001.
[4] Đukić Đ.„Upravljanje rizicima i kapitalom u bankama“, No.2, pp.21, 2011.
[5] Eric, D., Finansijska trzista i instrumenti, „Cigoja stampa“, No.2, Beograd, pp. 187, 2002.
[6] Vujicic D., Dr. Nerandzic B., Dr. Perovic V., Prirucnik za investicije., Stylos.,pp.65, 2008.

THE DEBT CRISIS IN DEVELOPING COUNTRIES

Marina Bugarčić[1], Marina Milovanović[1], Jasmina Perišić[1], Ljiljana Radovanović[2], Marko Ristić[3]
[1]Faculty of Entrepreneurial Business of the UNION "Nikola Tesla" University, Belgrade, Serbia
[2]University of Novi Sad, Technical Faculty "Mihajlo Pupin", Đure Đakovica bb, Zrenjanin, Serbia,
[3]Institute Goša, 35, Milana Rakića str., Belgrade, Serbia,
e-mail: bugarcicm.vbps@gmail.com

Abstract: This paper describes how developing countries tend to have limited internal sources of revenue. If they fail to use their long, productive to mobilize investment and create new opportunities for employment, they are eventually faced with the dilemma of lower income levels than their impact on capacity utilization, which will lead to inability of debt servicing. All this makes it difficult for developing countries to receive unconditional assistance from donor agencies, and increased country risk. This handicap is forcing governments that are unable to pay off debt, to rely more on domestic borrowing. However, the increase in domestic borrowing leads to the increase of domestic interest rates, which in turn leads to slow down in the economy.
Key words: debt crisis, debt, industry, investments.

INTRODUCTION

Like every economic category, public debt affects the development of a country positively and/or negatively. There are three propositions about the positive effects of public debt on the development of a country.

The first proposition refers to the fact that the government debt is a way of raising funds in order to achieve a balance between revenue and expenditure. With the development of the economy of a country, the national financial functions are increasing, so that governments have problems with a lack of financial resources, especially for investment. In this context, the debts can be a convenient way to fill these gaps.

The second proposition of the positive impact of debt on the economy refers to the possibility of adjusting the industrial structure of the country, regional structure, as well as promoting the stable development of the national economy. Basically, the external debt is usually applied to finance investment projects and programs, such as: energy and infrastructure programs of the World Bank. This applies particularly to the possibility suppression of poverty, where projects are specifically designed towards promoting the development of economically lagging regions. These measures can contribute to economic development and thus preventing huge financial and social gaps between different regions and social classes. In addition, these measures will help to achieve social stability. From this point of view, the public debt is useful for adjusting the industrial structure of the country, and thus to achieve a stable national development, which can be achieved by government measures in the field of national development planning, which implies a strict control of foreign investments.

Finally, the third positive effect of public debt on the economy is that debts help improve liquidity in the domain of international payments. In other words, international loans could have a direct impact on international income of the country, by giving foreign currencies enhances the country's ability to pay and the strengthening of international liquidity, giving the government a chance for more productive investments. The development of key infrastructure sectors, and strengthening the export industry, may contribute to the adjustment of the domestic industrial structure towards reaching the desired level of competitiveness. Also, this contributes to increasing the production of import substitutes to reduce imports and thereby increase foreign exchange reserves of the country. Finally, these measures can help to improve production and export capacity, and the capacity of international payments of a country. The negative effect of debt on the development of the country occurs in cases when public debt exceeds a specific level. The excessive debt can affect growth through restricting the level of productivity and the weakening of investment growth, which is considered the "dark side" of external debt. This refers especially for developing countries, who may have difficulties to achieve sustainable economic growth. Therefore, the governments of these countries should undertake a rigorous control over the expansion of its fiscal deficit. In contrast, if the public debt has become unsustainable, economic prosperity is impossible. Specifically, it should be bear in mind that the growth of debt implies a higher current account deficit, which leads to an imbalance of debt of the country, regardless of the fact whether it is a public debt or guaranteed economy debt.

MATERIALS AND METHODS

There are three theories about the consequences of the budget deficit and public debt: Keynesian, Ricardian and neoclassical school. The common characteristic is that they mainly consider the situation of origin deficit due to the reduction in tax revenue, and not due to an increase in public spending (although the Keynesian school in the original version of observing the effects of the increase in public spending on change of employment and output, and only later the effects of a reduction in tax revenue). Generally speaking, inequality attitudes on the deficit and public debt stems from dissimilar assumptions underlying the models of different schools [9].

According to the doctrine of the classical economy deficit and public debt phenomena are justified only in exceptional conditions and short-term needs for public expenditure, while their continued existence is justified only in the case of financing productive capital projects whose rate of return is higher than the rate of interest on borrowings. According to the belief of classical economists, there was little difference between state borrowing and borrowing by private individuals. Each type of debt is used exclusively for harmonization of flows of revenues and expenditures in time.

The neoclassical school is based on the assumption that people have a limited life span and that the generations overlap, and that in all periods there is a balance in the market. Budget deficits increase the overall life by shifting consumption taxes on future generations. If the economical resources are fully utilized, and increasing consumption necessarily implies a reduced savings. The situation on the capital market is changing, and the interest rate must rise in order to market came into balance once again. Deficits of a permanent nature, thereby "crowd out" private accumulation of capital, which has devastating consequences for economic growth [2].

The Keynesian school chronologically precedes neo-classical, and it is based on the premise that timely deficits have more favourable effects on well-being. However, there are situations in which stimulation of aggregate demand caused by a deficiency has adverse effects. Such is, for example. Situation of full employment and fixed money supply, when the increased demand for money leads to higher interest rates and a decline in investment. Accordingly, the Keynesian school the opportunity for deficit has positive or negative effects, depending on the state of the economy. This means that Keynesian theory was not able to politicians that universal recommendations, and that they themselves should recognize the situation in which is economy, in order to take appropriate measures [5].

The Ricardian school assumes that successive generations are associated with the voluntary and unselfish transfer of resources. This implies that the consumption is function resources of taxpayers and their descendants. The deficits only postpones the payment of taxes, leaving it for future generations, while the discounted present value of taxes and public expenditure is equal, which means that the deficit of previous generation leaves resources unchanged. Consumption, as a function of resource generation, does not change under the influence of tax changes. In other words, the policy of fiscal deficit has no impact on real economic size.

Ricardian school starts with the hypothesis of neutrality of debt, and is based on the following, very restrictive assumptions: 1) the time horizon of the citizens / taxpayers is infinite, 2) differences in tax burdens motivate citizens on intergenerational transfers based on altruism, 3) consumers are rational and farsighted, 4) capital markets are either perfect, or on them there is a specific fault, 5) taxes are lump (lump-sum), 6) use of the deficit cannot create values, and 7) public spending cannot be infinitely financed by borrowing. Given that these assumptions do not correspond to reality, and that the hypothesis of neutrality of debt cannot be sustained unless we abandon any of these assumptions, it is considered that the Ricardian school can not give good directions for the conduct of specific budgetary policy [1].

Neoclassical and Keynesian paradigms may be quite good supplement, especially if they are treated as two different aspects of the analysis of fiscal policy. Decomposition of deficit to its permanent and temporary component, it can be concluded that neoclassical analysis examines the effects of permanent deficits, while Keynesian considers the impact of temporary deficits that are being taken to stabilize cyclical fluctuations around equilibrium with full employment. In other words, the neoclassic considers lower debt preferential from the standpoint of the average national savings, but allowing temporary deficits in the service of the government to stabilize the economy close to balance [3].
From the theoretical point of view, it seems that neoclassical analysis is based on the least restrictive conditions and that describes most realistic reality. Considering the impact of deficit on the economy, neoclassics believe that the key question is whether the deficit is temporary or permanent. In fact, if consumers focus on their life spending, reduction of the deficit caused by the increase in the tax burden will, according to neoclassic, result in a greater drop in demand if consumers believe that this reduction is permanent. In this case, the government's attempts to achieve a balance with greater savings can reduce demand so that it will cause a recession. On the other hand, neoclassic feel that the impact of ongoing deficit of any sign for the economy, depends on the degree of economic development and economic goals. That is, if the private savings are insufficient to achieve a desirable level of capital accumulation, then the state must pursue a permanent surplus.
The main lack of these theories is that they study of the effects of deficit and public debt on economic activity generally ignore: (a) the method of financing the deficit (by issuing debt or monetary financing); (b) the cause of the deficit (increased government spending or a reduction in tax revenue); (c) the structure of tax revenues and the structure of government spending; (d) the period in which they are carried deficit financing (except neoclassical distinguishing between permanent and temporary deficits); (e) whether exogenous policies are anticipated or non-anticipated. From this point of view, considering the impact of higher deficit on economic activity starts from the fact that, in order to evaluate the effect of fiscal policy on aggregate demand, it is necessary to create a model of the economy, and specify the reference policy (in relation to which some policy can be called expansive or restrictive) [4].

DISCUSION AND CONCLUSION

For the debt crisis in developing countries, caused by bad debt risk management, the international community has designed several solutions:

(1) The mechanism on debt rescheduling (SDRM) [7],

After the Argentine crisis, the IMF proposed sovereign debt restructuring mechanism (SDRM) in 2001. The by establishing international bankruptcy court, similar to insolvency statute for companies that national governments may request the convening of an international higher. This panel is responsible for negotiations with private creditors to come to an agreement on debt restructuring. If a majority of creditors reach an agreement, the rest of the creditors have to respect that.
Another feature of this proposal is to limit lawsuits to suspend debt repayments. This means that when debtors and creditors reach Agreement on debt rescheduling, debtors temporarily stop paying back a debt, and creditors can not take legal action.

(2) Collective action clause, CAC [6],

After a discussion about politics of sovereign debt restructuring, the United States with other G-10 countries and the US Treasury Department proposed a new approach that is more market-oriented than towards the restructuring of debt. It was not a replacement of the existing mechanism of restructuring, but supplement it. Collective action clauses can be avoided by rent-seeking countries exhausted and wars, which are a possible restructuring that are related by unanimous consent and complete information model of sovereign debt. Since 2003, the majority of newly issued sovereign debt, introducing collective action-clause. The argument for the CAC that the competition between bondholders will be crucial in terms of resolving debt problems.

(3) Codes of conduct, CGC

Code of Conduct was proposed by the Bank of France and the Institute of International Finance [10]. This proposal is supposed to ensure acceptable solution, which can cover a variety of interests and views of all interested parties. CGC does not replace either one of the two previous documents, but is complementary to them. Common principles are: regular dialogue based on trust between the debtor and creditors; transparency of information; Meetings of interested stakeholders; comparable treatment of different creditors; economic and financial conditionality to debt rescheduling; exchange of information on the load between the different actors; the re-establishment and strengthening of normal financial relations between creditors and debtors. The observance of the principles of standardization makes debt restructuring fast and tidy, but also provide more favourable treatment of debtors in relation to creditors.

(4) Solution of the Institute of International Finance

In June 2004, the Institute of International Finance has developed "Principles for stable capital flows and fair debt restructuring in emerging markets" for countries that rely too heavily on international financial capital, such as Brazil, Mexico, Turkey and South Korea, in order to take precautionary measures in resolving the debt crisis [8]. In comparison with the CGC, this solution is more appropriate.

The main principles of the draft that the debtor must carry "ideal economic policy", such as monetary, exchange rate and debt management policy. In addition, it requires the support of the public support of the legal system and the creation of the investment environment, but also the obligation of the debtor to share economic and financial information in the region. The creditor must work to improve its investment policy and risk management, including multi analysis of economic and fiscal policy of the country's debt. Financial institutes, in particular the IMF, should provide information on international macro-economic fundamentals, the optimal debt structure, as well as financing for both sides participating in the restructuring of sovereign debt.

ACKNOWLEDGMENTS

This paper is the result of research within the project TR 34028, which is financially supported by Ministry of Education, Science and Technological Development of Serbia, Messer Tehnogas and PD TE – KO Kostolac.

REFERENCES

[1] Arrau, P. (1990). How Does the Debt Crisis Affect Investment and Growth? International Economics Department, The World Bank. (http://www-wds.worldbank.org/servlet/WDS ContentServer/WDSP/IB/1990/04/01/000009265_3960929014431/Rendered/PDF/multi 0page .pdf).

[2] Bernheim, D. B. (1989). A Neoclassical Perspective on Budget Defici. Journal of Economic Perspectives, vol. 3, No. 2,; Spring 1989., p 55-72, http://www.jstor.org/discover/ 10.2307/ 1942669?uid=2&uid=4&sid=21101739672263.

[3] Bernheim, D.B. op. cit.

[4] Buiter, W. (1986). Structural and Stabilization Aspects of Fiscal and Financial Policy in the Dependent Economy. NBER Working Paper #2023. (http://www.nber.org/papers/w2023.pdf)

[5] Can Keynesian Economics Reduce Boom-Bust Cycles. (http://www.investopedia.com /articles/economics/08/keynesian-economics.asp #axzz1jnZqhnfz.)

[6] Collective Action Clauses: Recent Progress and Challenges Ahead, Sergio. J. Galvis, Angel L. Saad, 2004., https://www.questia.com/library/journal/1G1-132298680/collective-action-clauses-recent-progress-and-challenges

[7] http://www.unescap.org/sites/default/files/Implementing%20the%20monterrey%20consensus%20in%20asia%20and%20the%20pacific.pdf

[8] IMF, SDRM, http://www.thefreedictionary.com/Monetary , i MONTERREY CONSENSUS in Asia and the Pacific, (2008)

[9] Principles for Stable Capital Flows and Fair Debt Restructuring in Emerging Markets, 2004 "http://www.icmagroup.org/ICMAGroup/files/78/78c3b39e-a582-431c-91d9-09bdaf0a46c8.PDF"

[10] Tempelman, H. J. (2005). James M. Buchanan on Public-Debt Finanse. The Independent Review, v., X, n. 2, Winter 2005, ISSN 1086-1653, p. 435-449. http://www.independent.org/pdf/tir/tir_11_03_06_templeman.pdf.

[11] Towards a voluntary Code of good conduct for Sovereign Debt Restructuring, Banque de France, FSR, June 2003., http://www.banque-france.fr/fileadmin/user_upload/banque_de_france/publications/Revue_de_la_stabilite_financiere/etud7_0603.pdf

Session 11.

Process management

THE Datafit ANALYSIS OF BRIQUETTES MANUFACTURING PROCESS FROM FINE AND PULVEROUS FERROUS WASTES

Sorina Serban[1], Teodor Heput[1], Simion Jitian[1], Imre Kiss[1]
[1.]University Politehnica Timisoara, Faculty of Engineering Hunedoara, Hunedoara, ROMANIA
e–mail: sorina.serban@fih.upt.ro

Abstract: Reintroduction into the economic circulation of products/small and powdery ferrous wastes lead to reduction of water/air/soil pollution levels. Every tone of ferrous waste recovered and returned to steel production circuit leads to an economy of investments and operating costs. The paper approaches the problem of fine and pulverous wastes recovery from mining and steel industry. In fact, our research carried out shows that wastes can be used to produce briquettes.
Key words: pollution, environment, steel industry, usage, wastes, briquetting, the Datafit analysis

INTRODUCTION

Nowadays, among the main materials consumed worldwide (wood, steel, cement, and plastic), steel is in the first place and will still be there in the future. Steel and iron used as materials in many industrial fields, have the property to be recovered from manufactured products after their usage, regardless of period of time corresponding to those products´ life. During ferrous metallurgy processes by which iron ore is converted to steel (iron and steel) and continuing with the manufacturing processes of these products, there are different forms of iron and steel scrap that results, having the generic name ferrous scrap. The steel industry uses large quantities of materials both in primary and secondary development process. The raw material used for primary development process in steel industry is iron ore [1,2,10,11,13]. Exploitation of iron ore deposits which are subjected to concentration operations, leads to obtaining fine grained iron concentrates which makes the process of agglomeration very difficult.
From steel industry activities derive a wide range of wastes, that can be categorized as recyclable wastes (ferrous and nonferrous wastes) and storable wastes, as well (slag, sludge, tar, oils). On the platform of a steel mill virtually all sectors contribute to the pollution of at least one environmental factor. Most frequent, ferrous scrap results from the steel industry while processing iron and steel, from industries where steel products are processed or used as such, and from the ferrous part recovery process. Ferrous scrap in the steel industry may be pulverous, deriving from exhaust gas treatment plant, from steel processes, or may be pieces, deriving from steel and iron making processes. The flow of production in steel industry generates, on a continuous basis, wastes containing iron and carbon, in quantities directly proportional to the output. Within the manufacturing process, in addition to the main product there are sometimes secondary products, and there are always wastes: pulverous (powdery), small (fine) or large sizes, containing utile components like carbon, iron and alloying elements. Ferrous scrap can and should be reused, in their entirety, within steel industry. In fact, the pulverous ferrous wastes can be processed by pelletizing and the fine and pulverous ones by agglomerating and briquetting technologies. Every tone of ferrous scrap recovered and returned to steel production circuit leads to an economy of investments and operating costs. Romanian steel industry is currently experiencing technological gaps regarding the collection, transport, storage and, especially, the use of all categories of waste.

LABORATORY EXPERIMENTS

Briquetting is the method by which pieces of spherical, oval or rectangular forms are obtained from fine/small and pulverous waste during compressing operations on specialized equipment, followed by a drying–roasting process in order to increase their mechanical characteristics [5–13].Briquetting applies to pulverous wastes (powder resulting from dedusting plants) and also to fine products obtained by precipitation. For waste briquetting (at 50–60^{0}C) inorganic binders are used (limewash, Na_2SiO_3) and sometimes organic binders (sulphite liquor, heavy tars etc.) Briquetting operation consists of:
≡ preparation, mixing and homogenizing waste with binder to ensure optimum moisture and granulation;

≡ compression of the mixture;
≡ hardening;
≡ transport and storage of briquettes.

Mixing and homogenization of the mixture is performed in mixture drums, screw mixers, paddle mixers. Compression is performed on presses with rotating cylinders and piston presses. Hardening is performed by cooling and sintering.

Experiments on the production of briquettes were conducted within the laboratory of the Doctoral School of the Faculty of Engineering Hunedoara, University Politehnica Timişoara, Determination of waste chemical composition was carried out in the laboratories of ArcelorMittal Hunedoara Company.

To obtain briquettes, the raw material is subjected to fine grinding, which usually is performed in ball mills. Wastes which are substandard in terms of grain size are ground with these mills. Recipes with pulverous wastes are prepared. Homogenization of waste is done manually or in mixing plant with the addition of binders, and to obtain briquettes, the press is equipped with a mold chosen in accordance with the type of desired briquette. The proportions of wastes were determined in 13 recipes, compliance with these recipes is mandatory in order to obtain briquettes with appropriate quality standards [5–13].

Table 1. The used wastes and the composition of briquetting recipes (%)

Wastes type	Composition of briquetting recipes, [%]												
	R1	R2	R3	R4	R5	R6	R7	R8	R9	R10	R11	R12	R13
Steel dust (P.O.)	40	36	33	30	27	24	20	17	15	13	8	5	2
Agglomeration–furnaces dust (P.A.F.)	30	33	36	39	42	45	48	51	54	57	60	63	66
Galvanic sludge 1 (N.G.–O)	2	2	3	4	5	6	7	5	6	6	5	7	8
Galvanic sludge 2 (N.G.–B)	8	9	7	7	6	4	5	6	5	4	7	5	4
Red mud from bauxite refining (N.R.)	10	10	10	10	10	10	10	10	10	10	10	10	10
Graphite powder (G)	2	2	2	2.5	2.5	3	3	3.5	3.5	4	4	4.5	4.5
Bentonite powder (B)	4	4	3.5	3.5	3.5	3	3	3	2.5	2.5	2.5	2	2
Limewash powder (V)	4	4	4.5	4	4	4	4	3.5	4	3.5	3.5	3.5	3.5

Table 2. Chemical composition of the recipes, (%)

	R1	R2	R3	R4	R5	R6	R7	R8	R9	R10	R11	R12	R13
Fe_2O_3	37.16	40.26	39.66	36.47	40.08	36.10	39.20	43.15	33.57	38.42	40.02	34.73	36.02
SiO_2	16.95	17.52	15.70	19.30	18.29	18.01	18.58	17.28	16.84	16.52	18.68	11.15	10.37
ZnO	10.82	8.47	8.56	9.54	8.42	9.76	8.40	9.13	9.47	8.76	5.81	16.99	16.73
CaO	10.56	9.42	10.64	9.92	11.23	11.62	10.32	11.56	11.08	10.96	9.56	7.57	7.44
Al_2O_3	7.16	7.40	10.14	8.55	7.68	6.1	9.14	8.14	8.33	7.54	7.26	2.80	2.43
Na_2O	4.10	4.80	3.75	4.66	3.80	5.16	7.23	4.13	4.20	5.32	6.12	7.33	7.67
MgO	2.47	2.13	2.04	2.19	2.27	1.41	1.57	1.15	2.08	1.89	2.37	2.60	2.56
MnO	1.63	1.28	1.37	1.44	1.41	1.13	1.08	1.04	1.33	1.62	1.13	2.20	2.14
P_2O_5	1.54	1.87	1.18	1.21	1.21	1.10	1.93	1.34	1.45	1.28	3.11	2.41	2.53
Other oxides	7.6	6.8	6.9	6.7	5.6	9.6	2.55	3.08	11.65	7.69	5.9	12.0	12.0

Recipes composition and chemical composition of briquettes obtained were displayed in **Table 1** and **Table 2** [10,11]. Once the briquettes are obtained, they are subjected to hardening processes after a diagram heating/holding/cooling, and then dried and tested to determine the qualitative characteristics (compression tests to determine resistance to cracking, crushing and grinding interval).

For recovery of small and pulverous wastes as briquettes from steel industry, energy and mining, we considered the following wastes: agglomeration–furnaces dust, steel dust, galvanic sludges (two different types) and red mud from bauxite refining (bauxite residue). As binder for the manufactured briquettes we considered the following three types of powdery materials: limewash, bentonite and graphite [5,6,10–13].

The quality characteristics the resistance to crushing and the resistance to cracking of obtained briquettes, are calculated. With the data obtained, we conducted several dependencies that demonstrates the influence of the composition of briquetting load on these indicators, using Datafit and Matlab programs.

Firstly, in our matematical analysis, we plotted in Datafit program the variation in resistance to cracking and resistance to crushing of obtained briquettes, according to the proportion of the small and pulverous wastes used in the recipes (steel dust, agglomeration–furnaces dust, galvanic sludges). The obtained mathematical correlations, the regression equations (polynomial regression model type: y = a + b·x1 + c·x12 + d·x13 + e·x14 + f·x15 + g·x2 + h·x22 + i·x23 + j·x24 + k·x25) and the regression surfaces are shown in the **Figures 1–6**. Conveniently, these models are all linear from the point of view of estimation, since the regression function is linear in terms of the unknown parameters a, b, ... Therefore, for least squares analysis, the computational and inferential problems of polynomial regression can be completely addressed using the techniques of multiple regression, done by treating x, x2, ... as being distinct independent variables in a multiple regression model.

RESULTS OF THE Datafit ANALYSIS

DataFit is a simple and efficient science and engineering tool that simplifies the tasks of data plotting, regression analysis (curve fitting) and statistical analysis. The data were processed in DataFit programs to obtain correlations between the main characteristic of the obtained briquettes – resistance to crushing and resistance to cracking – and the proportion of components in the recipe (small and pulverous wastes quantities).

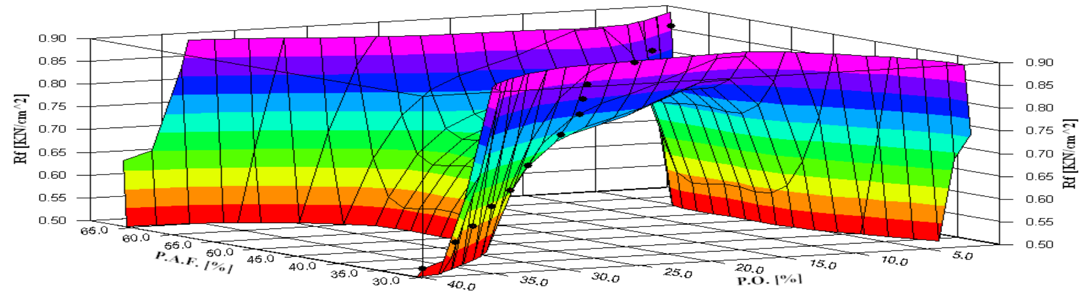


Figure 1. The regression surface determined by the briquettes resistance to crushing depending on the proportion of steel dust and agglomeration–furnaces dust (the coefficient of multiple determination: R^2=0.9996349716, the polynomial regression equation coefficients are: a=–205.6158; b=23.8851; c=–1.0830; d=0.02397; e=–0.0002; f=1.1140; g=0.7284; h=–0.0802; i=0.0041; j=–0.0001; k=9.2884)

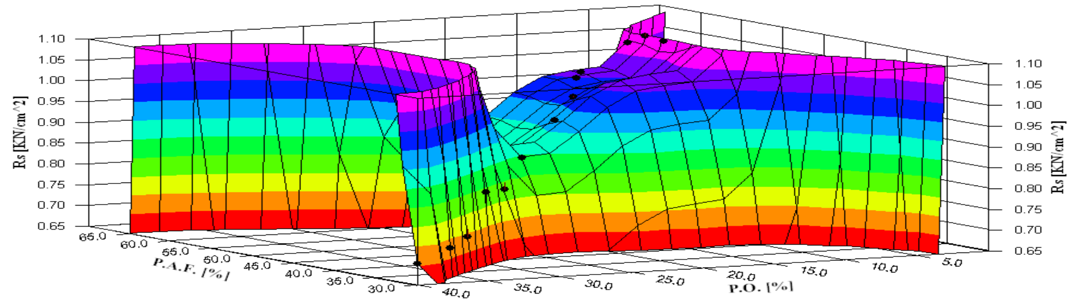


Figure 2. The regression surface determined by the briquettes resistance to cracking depending on the proportion of steel dust and agglomeration–furnaces dust (the coefficient of multiple determination: R^2=0.9920884722, the polynomial regression equation coefficients are: a=440.0762; b=–51.3919; c=2.3642; d=–0.0530; e=0.0006; f=–2.5292; g=–1.9088; h=0.2059; i=–0.0105; j=0.0002; k=–2.2424)

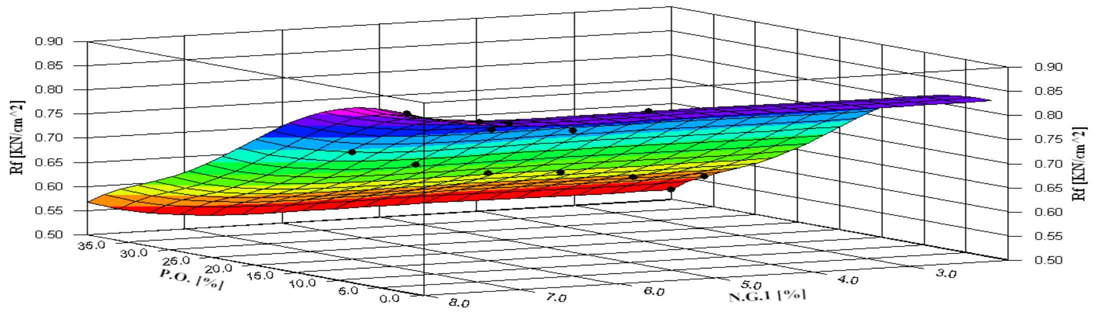


Figure 3. The regression surface determined by the briquettes resistance to crushing depending on the proportion of steel dust and galvanic sludge 1 (the coefficient of multiple determination: R^2=0.9996578109, the polynomial regression equation coefficients are: a=0.8178; b= –0.0009; c=0.0004; d=–0.0001; e=2.4959; f=–2.6265; g=0.0215; h= –0.0186; i=0.0065; j=–0.0010; k=0.0001)

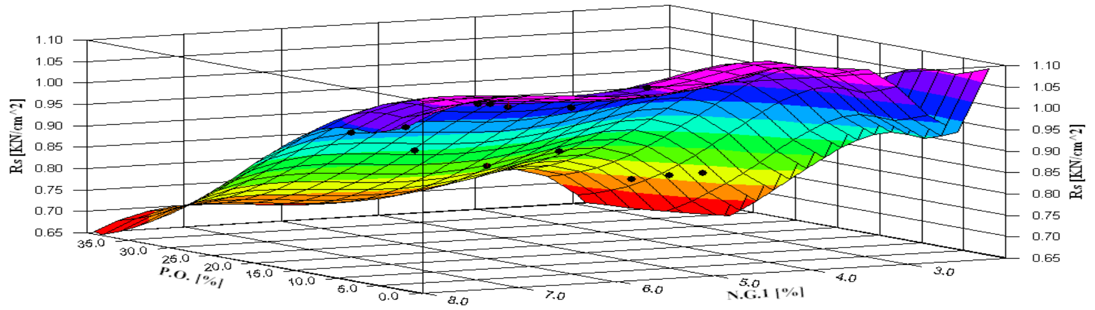


Figure 4. The regression surface determined by the briquettes resistance to cracking depending on the proportion ofsteel dust and galvanic sludge 1 (the coefficient of multiple determination: R^2=0.9975716124, the polynomial regression equation coefficients are: a=18.0641; b=2.3436; c=–2.8285; d=1.5497; e=–0.3915; f=0.0364; g=–70.6418; h=107.5958; i= –78.7594; j=27.8951; k=–3.8446)

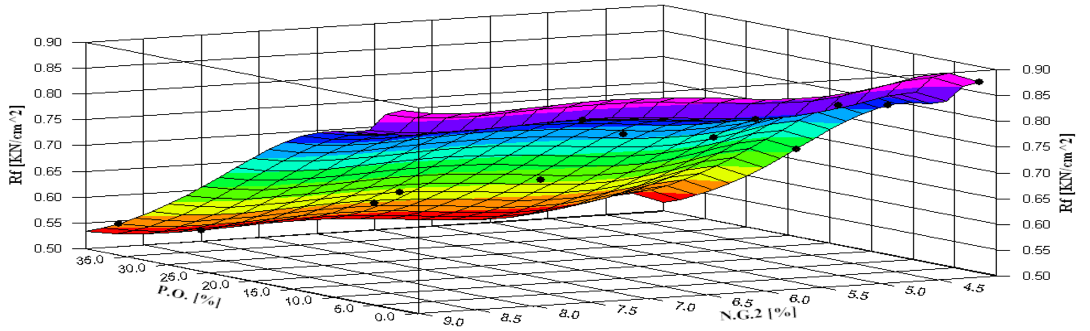


Figure 5. The regression surface determined by the briquettes resistance to crushing depending on the proportion of steel dust and galvanic sludge 2 (the coefficient of multiple determination: R^2=0.9999509001, the polynomial regression equation coefficients are: a=–244.5798; b=2.6814;c= –3.0316; d=1.5452; e=–0.3655; f=0.0321; g=693.4561; h=–780.7115; i=436.4224; j=–121.1669; k=13.3702)

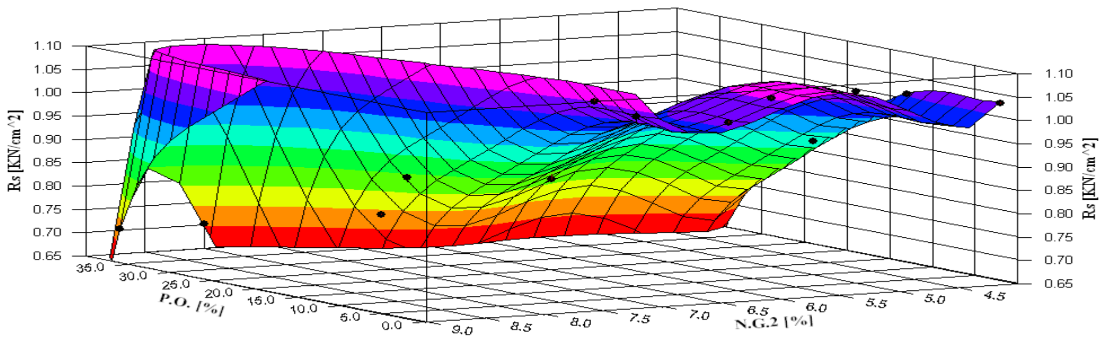


Figure 6. The regression surface determined by the briquettes resistance to cracking depending on the proportion of steel dust and galvanic sludge 2 (the coefficient of multiple determination: R^2=0.9968434407, the polynomial regression equation coefficients are: a=116.5405; b=–0.0161;c=0.0036; d=–0.0003; e=0.0001; f=–1.2262; g=–101.6929; h=35.1393; i=–5.9538; j=0.4944; k=–0.0161)

The accuracy of DataFit has been verified with the Statistical Reference Datasets Project of the National Institute of Standards and Technology (NIST). DataFit is a science and engineering tool that simplifies the tasks of data plotting, regression analysis (curve fitting) and statistical analysis. With the combination of the intuitive interface, online help and wide range of features, it is a tool that is used effectively by both engineers and scientists.

CONCLUSIONS

Waste recycling represents one of the economic solutions of environment ecology. In this sense the group of authors has made a series of experimentations regarding their transformation in used products in the iron-and-steel industry. To obtain the products in forms of briquettes many series of receipts have been tested and according to qualitative characteristics of the obtained products the processing receipts have been chosen.
The data obtained has been processed in Datafit program, which that allowed the establishing of optimal domains of variations of the technological parameters in view of obtaining some products with superior technological characteristics.
The paper presents results of research on the strength of briquettes obtained from recycled ferrous wastes – through resistance to crushing and the resistance to cracking –, research conducted to acknowledge the following two technical problems:

- the alteration of the experimental briquettes resistance, in accordance with the quantity of various ferrous wastes (steel dust, agglomeration–furnaces dust, galvanic sludges) used for the experimental recipes preparation;
- the influence upon the resistances of some chemical compounds from materials recovered by briquetting.

As a result of analyses performed on products obtained by processing small and pulverous wastes from industrial steel and mining areas and the experiments conducted in the laboratory stage, we consider the following:

- the studied small and pulverous wastes (steel dust, agglomeration–furnaces dust, galvanic sludges) can be processed by using the available technology like briquetting and can be reintroduced into the steel circuit with minimum investment costs;
- reintroduction of small and pulverous wastes into economic circuit has both economic and ecological effects, by releasing the occupied terrains (ponds, landfills, disused buildings) in case of deposited wastes, vacancy of areas for waste resulting routinely on technology flows.

Taking into consideration the existing local conditions, as a result of the strong economic restructuring, a large amount of pulverous and small ferrous wastes remained, it is necessary to intensify the wastes recovery process, both because it represents a source of iron, poor raw material, and because of technological and ecological considerations. We consider that can be processed both the wastes resulted in technological flows and those deposited in ponds or landfills.
For Romania the recovery of ferrous wastes represents a priority for the durable development strategy because the natural resources of some raw materials categories are poor or insufficient and the resources can substitute part of the raw materials with significant low costs. Comparatively with the practice and the world wide manifested tendencies, the Romanian industry registers gaps in the powder wastes collection, transportation and storage area, as well as in that of the recovery technologies area by their recycling or reusing. Thereby, the approach of the superior recovery of small and powder ferrous wastes problem was considered necessary and convenient.

References

[1] CIOCAN, A., Turning waste generated in small and powder metallurgy, National Publishing Group Publishing, Bucharest, 2003.

[2] CONSTANTIN, N., NICOLAE, M., GEANTA,V., BUTNARIU, I., LEPADATU, G., Processes and alternative technologies in steel, PRINTECH, Bucharest, 2009.

[3] CONSTANTIN, N., NICOLAE, M., RUCAI, V., Research regarding the physical and chemical characteristics of pre–reduced iron ores the analysis of the possibilities of their use in the iron and steel elaborating process, International Conference – Prereduced products and Europe, Milano – Italia, 1996, 230–239.

[4] *** Pollution Prevention and fighting in the steel making, energy and mining industry areas through the recycling of small–size and powdering Wastes, Program PN2–Consortium–CO, Research Project nr.31–098/2007.

[5] HEPUŢ, T., SOCALICI, A., ARDELEAN, E., ARDELEAN, M., CONSTANTIN, N., BUZDUGA, R., Recovery of ferrous waste and small bulk, Politehnica Publishing House, Timişoara, 2011

[6] El–HUSSINY, N.A., SHALABI, M.E.H., A self–reduced intermediate product from iron and steel plants waste materials using a briquetting process, Powder Technology, Volume 205, Issues 1–3, 2011, 217–223

[7] STRANGE, R., Method of making briquettes and product, JCS Industries, 1981

[8] FORD, G.W Jr., Process for recovering iron from iron–rich material, Covol Technologies, 1994

[9] VALENTI, N., Formed briquettes, process for forming the same and process for utilizing the same in the manufacture of metals, Ohio & Pennsylvania Fuels Co, Ltd., 1991

[10] TODORUT, A.S., SOCALICI, A., Recovery of powdery waste results from technological flows in siderurgy, International Journal Of Systems Applications, Engineering & Development, Issue 3, Volume 6, 2012, 251– 258

[11] TODORUŢ, A., HEPUŢ, T., Broadening of raw materials in the steel industry, by recycling wastes, International Conference on Energy, Environmental and Chemical Engineering, Paris, France, ISSUE 71, 2012, 1466–1472.

[12] ROBINSON, R., Recycling of metallurgical by–products within integrated iron and steelmaking, Lulea University of Technology, 2004

[13] ȘERBAN, S.G., HEPUȚ, T., Ferrous wastes recovery possibilities in the area of steel industry – experiments in the laboratory phase on the briquettes production from fine and pulverous wastes, Acta Technica Corviniensis – Bulletin of Engineering, Fascicule 3 / 2015 [July–September], 49–56

THE Matlab ANALYSIS OF BRIQUETTES MANUFACTURING PROCESS FROM FINE AND PULVEROUS FERROUS WASTES

Sorina Serban[1], Teodor Heput[1], Simion Jitian[1], Imre Kiss[1]
[1.]University Politehnica Timisoara, Faculty of Engineering Hunedoara, Hunedoara, ROMANIA
e–mail: sorina.serban@fih.upt.ro

Abstract: In most industrialized countries pollution of air, water and landscape has a common cause: discharge of manufacturing wastes in the environment without a real concern of avoiding it. Measures needed to combat pollution require considerable investment and significant operating expenses, especially in the steel industry. In the industrial sector, in most cases, in addition to the main product, there are one or more products which can be returned to the steel circuit after a quick processing. By combining economic imperative to maximize the recovery of scrap with the social aspect of action to combat environmental pollution in order to restore and maintain the ecological balance, a particular attention must be paid to waste recovery problem. The paper approaches the problem of fine and pulverous wastes recovery from mining and steel industry.
Key words: pollution, environment, steel industry, usage, wastes, briquetting, Matlab analysis

INTRODUCTION

The alteration of global ecosystems, because of consumption and production, shows how important is the process of rethinking the use of natural resources by the economy and society. For industry, the problem of managing the recovery (recovery, recycling) is an environmental and economic priority [4,12,13]. For human communities and natural ecosystems in the steel industry and mining sites, pollution and risk do not disappear with the cessation of mining and processing of minerals, furthermore, it continues, the sites remain sources of pollution and risk. Wastes contain substances resulting from industrial activity where they are produced and disposal of these wastes from the production cycle is achieved by a proper recovery: recovery and / or disposal for recycling and stabilization/solidification for storage in landfills [10,11,13].

Recovery includes the collection, transport, storage, selection and processing of certain waste, which can be returned to a flow sheet by internal and/or external recycling. Internal recycling (direct recycling) consists of reintroducing the recovered industrial wastes in the same flow sheet that generated them, and external recycling (reuse) is the industrial activity that reintroduces the recovered waste in a flow sheet that is completely different from the one which generated it. By combining economic imperative to maximize the recovery of scrap with the social aspect of action to combat environmental pollution in order to restore and maintain the ecological balance, a particular attention must be paid to waste recovery problem [5–13].

LABORATORY EXPERIMENTS

Briquetting is the method by which pieces of spherical, oval or rectangular forms are obtained from fine/small and pulverous waste during compressing operations on specialized equipment, followed by a drying–roasting process in order to increase their mechanical characteristics [5–13].Briquetting applies to pulverous wastes (powder resulting from dedusting plants) and also to fine products obtained by precipitation. For waste briquetting (at 50–60^{0}C) inorganic binders are used (limewash, Na_2SiO_3) and sometimes organic binders (sulphite liquor, heavy tars etc.).

Experiments on the production of briquettes were conducted within the laboratory of the Doctoral School of the Faculty of Engineering Hunedoara, University Politehnica Timişoara. Determination of waste chemical composition was carried out in the laboratories of ArcelorMittal Hunedoara Company.

To obtain briquettes, the raw material is subjected to fine grinding, which usually is performed in ball mills. Wastes which are substandard in terms of grain size are ground with these mills. Recipes with pulverous wastes are prepared. Homogenization of waste is done manually or in mixing plant with the addition of binders, and to obtain briquettes, the press is equipped with a mold chosen in accordance with the type of desired briquette. The proportions of wastes were determined in 13 recipes, compliance with these recipes is mandatory in order to obtain briquettes with appropriate quality standards [5–13]. Once the briquettes are obtained, they are subjected to hardening processes after a diagram heating/holding/cooling, and then dried and tested to determine the qualitative characteristics (compression tests to determine resistance to cracking, crushing and grinding interval).

For recovery of small and pulverous wastes as briquettes from steel industry, energy and mining, we considered the following wastes: agglomeration–furnaces dust, steel dust, galvanic sludges (two different types) and red mud from bauxite refining (bauxite residue). As binder we considered the following three types of powdery materials: limewash, bentonite and graphite [5,6,10–13].

Using the Matlab program, we plotted the dependencies between the same correlation parameters, presented in **Figures 1–6**. In fact, in this mathematical experiment using the Matlab, we verified the regression equations obtained in Matlab (through the coefficients of multiple determination of the same type of equations), and we plotted the regression surfaces and, additionally, the correlation diagrams for the proportion of the small and pulverous wastes used in the recipes which assure the optimal resistance to crushing and the resistance to cracking of the obtained briquettes.

RESULTS OF THE Matlab ANALYSIS

Although polynomial regression is technically a special case of multiple linear regression, the interpretation of a fitted polynomial regression model requires a somewhat different perspective. The goal of polynomial regression is to model a non–linear relationship between the independent and dependent variables (technically, between the independent variable and the conditional mean of the dependent variable). In this sense, the experimental data were processed in the Matlab programs. We plotted the regression surfaces and the correlation diagrams between the briquettes main characteristics and the small and pulverous wastes quantities proportion.

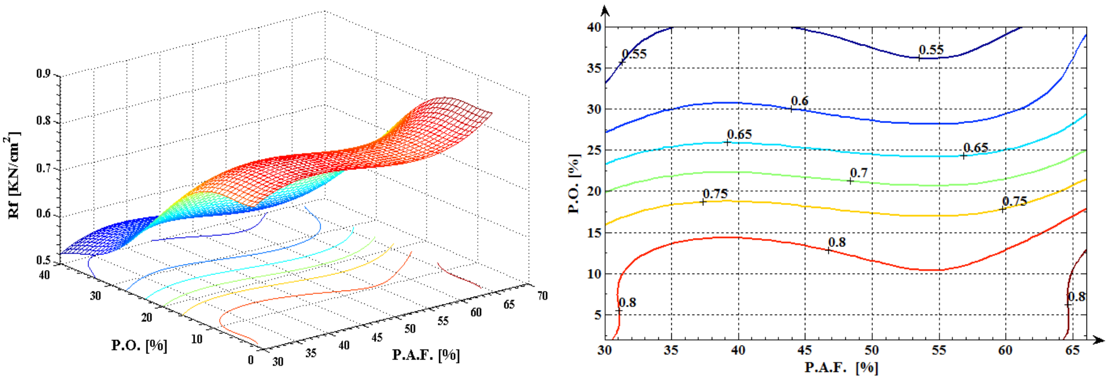


Figure 1. The regression surface and the correlation diagrams determined by the briquettes resistance to crushing depending on the proportion of steel dust and agglomeration–furnaces dust (the coefficient of multiple determination: R^2=0.9994282003)

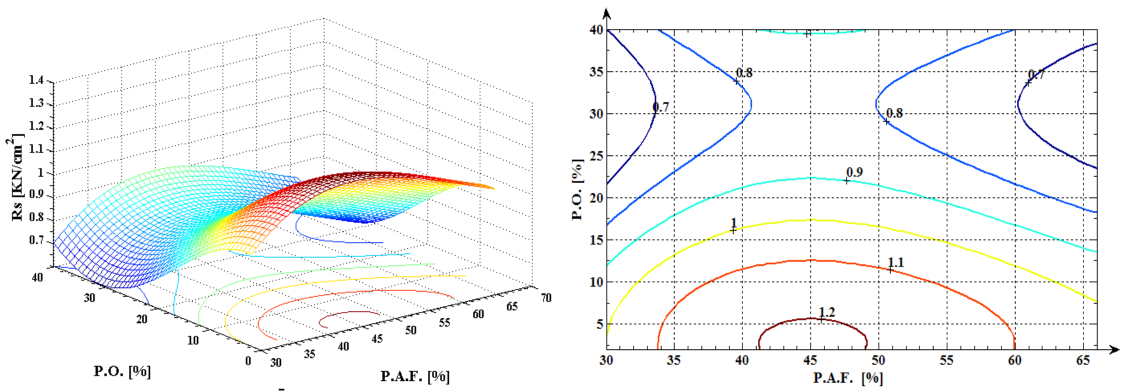


Figure 2. The regression surface and the correlation diagrams determined by the briquettes resistance to cracking depending on the proportion of steel dust and agglomeration–furnaces dust (the coefficient of multiple determination: R^2=0.9910367990)

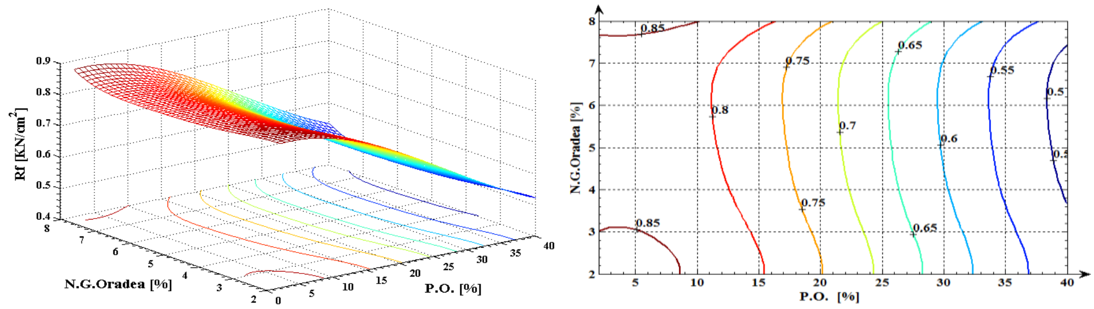


Figure 3. The regression surface and the correlation diagrams determined by the briquettes resistance to crushing depending on the proportion of steel dust and galvanic sludge 1 (the coefficient of multiple determination: R^2=0.9994749743)

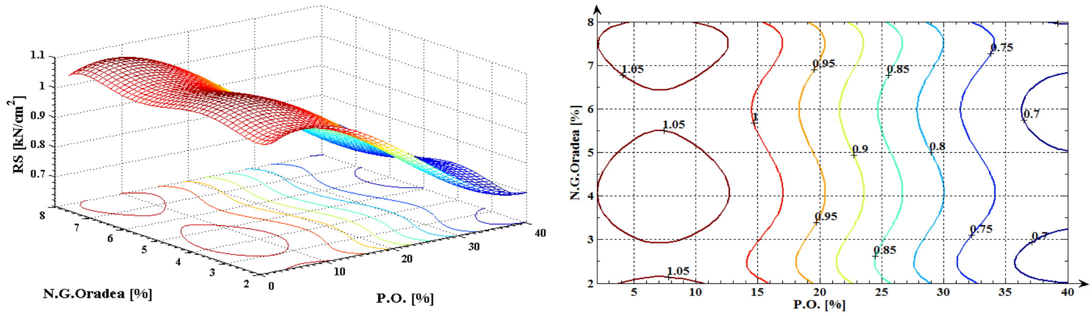


Figure 4. The regression surface and the correlation diagrams determined by the briquettes resistance to cracking depending on the proportion of steel dust and galvanic sludge 1 (the coefficient of multiple determination: R^2=0.9941040618)

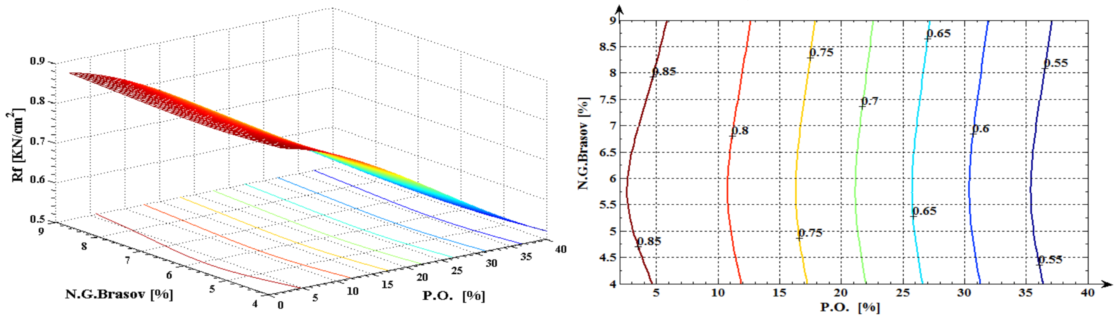


Figure 5. The regression surface and the correlation diagrams determined by the briquettes resistance to crushing depending on the proportion of steel dust and galvanic sludge 2 (the coefficient of multiple determination: R^2=0.9971393267)

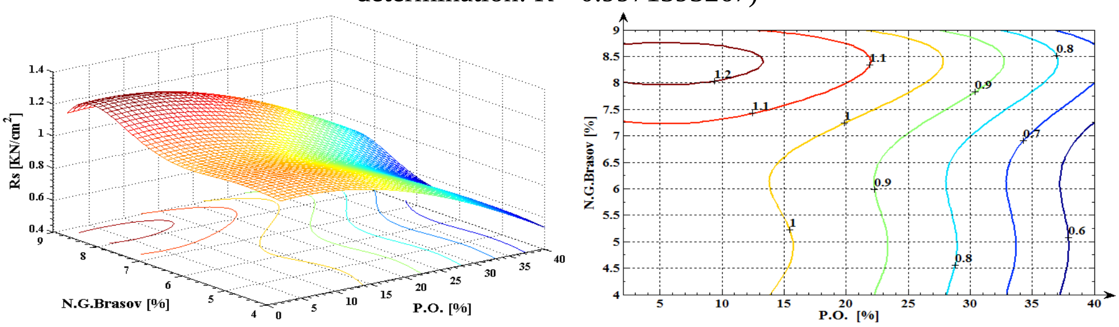


Figure 6. The regression surface and the correlation diagrams determined by the briquettes resistance to cracking depending on the proportion of steel dust and galvanic sludge 2 (the coefficient of multiple determination: R^2=0.9956932644)

CONCLUSIONS

As a result of analyses performed on products obtained by processing small and pulverous wastes from industrial steel and mining areas and the experiments conducted in the laboratory stage, we consider the followings:

- the studied small and pulverous wastes (steel dust, agglomeration–furnaces dust, galvanic sludges) can be processed by using the available technology like briquetting and can be reintroduced into the steel circuit with minimum investment costs;
- reintroduction of small and pulverous wastes into economic circuit has both economic and ecological effects, by releasing the occupied terrains (ponds, landfills, disused buildings) in case of deposited wastes, vacancy of areas for waste resulting routinely on technology flows.
- the results of the experiments lead to the conclusion that the analyzed wastes can be processed by briquetting (to provide mechanical strength characteristics superior to those minimum values for this method), this method allows recovery of waste with high variation limits in terms of grain size (desirably under 2 mm);
- technological alternatives presented have the advantage of offering solutions for all waste generated ferrous powder, regardless of the content of iron and non-ferrous elements, resulting in current technology flows, as well as those stored in ponds and waste dumps.
- analysis of these technologies provides environmental treatment of these types of waste allowed to be noted that for Romania is a particularly important issue because there is an amount of them deposited as dumps and continues to generate higher amounts.

We consider that can be processed both the wastes resulted in technological flows and those deposited in ponds or landfills.

References

[1] CIOCAN, A., Turning waste generated in small and powder metallurgy, National Publishing Group Publishing, Bucharest, 2003.

[2] CONSTANTIN, N., NICOLAE, M., GEANTA,V., BUTNARIU, I., LEPADATU, G., Processes and alternative technologies in steel, PRINTECH, Bucharest, 2009.

[3] CONSTANTIN, N., NICOLAE, M., RUCAI, V., Research regarding the physical and chemical characteristics of pre–reduced iron ores the analysis of the possibilities of their use in the iron and steel elaborating process, International Conference – Prereduced products and Europe, Milano – Italia, 1996, 230–239.

[4] *** Pollution Prevention and fighting in the steel making, energy and mining industry areas through the recycling of small–size and powdering Wastes, Program PN2–Consortium–CO, Research Project nr.31–098/2007.

[5] HEPUŢ, T., SOCALICI, A., ARDELEAN, E., ARDELEAN, M., CONSTANTIN, N., BUZDUGA, R., Recovery of ferrous waste and small bulk, Politehnica Publishing House, Timişoara, 2011

[6] El–HUSSINY, N.A., SHALABI, M.E.H., A self–reduced intermediate product from iron and steel plants waste materials using a briquetting process, Powder Technology, Volume 205, Issues 1–3, 2011, 217–223

[7] STRANGE, R., Method of making briquettes and product, JCS Industries, 1981

[8] FORD, G.W Jr., Process for recovering iron from iron–rich material, Covol Technologies, 1994

[9] VALENTI, N., Formed briquettes, process for forming the same and process for utilizing the same in the manufacture of metals, Ohio & Pennsylvania Fuels Co, Ltd., 1991

[10] TODORUT, A.S., SOCALICI, A., Recovery of powdery waste results from technological flows in siderurgy, International Journal Of Systems Applications, Engineering & Development, Issue 3, Volume 6, 2012, 251– 258

[11] TODORUŢ, A., HEPUŢ, T., Broadening of raw materials in the steel industry, by recycling wastes, International Conference on Energy, Environmental and Chemical Engineering, Paris, France, ISSUE 71, 2012, 1466–1472.

[12] ROBINSON, R., Recycling of metallurgical by–products within integrated iron and steelmaking, Lulea University of Technology, 2004

[13] ŞERBAN, S.G., HEPUŢ, T., Ferrous wastes recovery possibilities in the area of steel industry – experiments in the laboratory phase on the briquettes production from fine and pulverous wastes, Acta Technica Corviniensis – Bulletin of Engineering, Fascicule 3 / 2015 [July–September], 49–56

PROPORTIONAL-INTEGRAL-DERIVATIVE (PID) CONTROLLER EQUIPPED LFC OF MULTI-AREA INTERCONNECTED POWER SYSTEM

K.Jagatheesan[1], B.Anand[2], Nilanjan Dey[3], Amira S. Ashour[4], Valentina E. Balas[5]
[1]Dept. of Electrical and Electronics Engineering, Mahendra Institute of Engineering and Technology, Namakkal, Tamilnadu, INDIA
[2]Dept. of Electrical and Electronics Engineering, Hindusthan college of Engineering and Technology, Coimbatore, Tamilnadu, INDIA
[3]Dept. of CSE, Techno India College of Technology, Kolkata, INDIA
[4]Department of Electronics & Electrical Communications Engineering, Faculty of Engineering, Tanta Univ., EGYPT. College of CIT, Taif University, KSA
[5]Faculty of Engineering, Aurel Vlaicu University of Arad, ROMANIA
E-mail: jaga.ksr@gmail.com

Abstract: The current study presents the Proportional-Integral-Derivative ((PID) controller for Load Frequency Control (LFC) of interconnected multi-area power system. Ant Colony Optimization (ACO) technique is employed to tune PID controller parameters using three different objective functions. The proposed design is implemented in two areas equal thermal power system. It comprised appropriate Generation Rate Constrain (GRC) non-linearity. Comparison simulation results showed that the Integral of Time Absolute Error (ITAE) objective function based PID controller gives a superior controlled response. Besides testing the effectiveness of the Hydrogen Aqua Electrolyzer (HAE) unit in the LFC of two area interconnected power system. Simulation results established the efficiency of using ITAE objective function based ACO-PID controller and the HAE unit equipped power system. It was proved that the power system equipped HAE energy unit takes superior time settling of 17.9 seconds with minimum 0.0012 peak overshoot and 0.012 peak undershoot, compared to power systems without HAE unit.
Key words: Ant Colony Optimization (ACO) technique, Load Frequency Control (LFC), Objective functions, Proportional-Integral-Derivative ((PID) controller

INTRODUCTION

The main aim of Load Frequency Control (LFC) is to maintain the power balance between total power generation with total load demand, to give superior quality and more reliable power to consumers. The load demand is not a constant value as it varies with time due to large industrial growth and technology. Consequently, load changes affect the system parameters, such as the system frequency, tie-line power flow between connected areas and area control error. Therefore, LFC keeps the system frequency of the predetermined value to regulate the power generating unit based on the Area Control Error (ACE). Keeping the system frequency value nearly equal to zero for continuous adjustment of the active power value leads to matching the total power generation with the total load demand [1-2]. Recently, several natured inspired meta-heuristic algorithms have been introduced to solve the optimization problem in Load frequency control of single/multi-area interconnected power system. such as Firefly Algorithm (FA) [3], Cuckoo Search (CS) algorithm [4], Teaching learning Based Optimization (TLBO) [5], hybrid Particle Swarm optimization-Pattern Search (hPSO-PS) [6] and Modified Harmony Search Algorithm (MHSA) [7].
Teaching-learning based optimization algorithm based fuzzy-PID controller was implemented in two area interconnected non-reheat thermal power system in [3]. The performance of the proposed technique was compared to recently developed algorithms, such as genetic Algorithm (GA), Lozi map based chaotic optimization algorithm (LOA), pattern search (PS) and Simulate Annealing (SA) based PID controller for the same power system. In addition, the authors carried out a robustness test by varying the system parameters from their nominal value.
Chaine and Tripathy [4] considered the Integral controller and super conducting Magnetic Energy Storage (SMES) unit to present the automatic generation control of two areas interconnected reheat

thermal power system with GRC non-linearity. The controller parameters and SMES unit parameters were optimized by using the Cuckoo Search (CS) optimization technique with different objective functions.
Sahu *et al*. implemented the Fuzzy Proportional-Integral (PI) controller in the Automatic generation Control (AGC) of two area non reheat thermal power systems [5]. The fuzzy PI controller gain values were optimized by employing hybrid Particle Swarm Optimization and Pattern Search (hPSO-PS) algorithm. The superiority of the proposed approach was demonstrated by comparing its results to the Bacterial Foraging Optimization Algorithm (BFOA), Genetic Algorithm (GA), Conventional Ziegler Nichols (ZN), Differential Evolution (DE) algorithm, hybrid BFOA and Particle Swarm optimization (PSO) based PI controllers.
In [6], the PI/PID controller equipped multi-area non-reheat thermal power system was discussed. The PI/PID controller parameters were optimized by considering firefly algorithm with the ITAE objective function. The proposed approach effectiveness was tested by considering the parameter variation test. The performance was compared to the GA, BFOA, PSO, ZN and DE tuned controller performance.
Shivaie *et al*. [7] discussed the LFC of two area interconnected hydrothermal power system by considering the PID controller. The controller parameters were optimized Modified Harmony Search Algorithm (MHSA) based on the ITAE objective function.

Aim and contributions of this work

The main aim and contribution of this work as follows:

1. To design ACO-PID controller for LFC of two area power system with GRC non-linearity.
2. To consider three different objective functions in the design of the PID controller.
3. To improve the performance of the investigated power system in view of the HAE energy unit.

Paper organization

The remaining sections the current work was organized as follows: the investigated power system model was presented in the “Power System Model” section, the suitable controller was designed in the “Design of PID controller” section, the simulation results and discussion were analyzed in the “Simulation Results and Discussions” and finally conclusion about the proposed work is given in the “Conclusion” section.

POWER SYSEM MODEL

The interconnected multi-area power system consists of several control areas that connected via tie-lines. Figure1 demonstrates the transfer function model of the two area interconnected power system with GRC non-linearity [8].

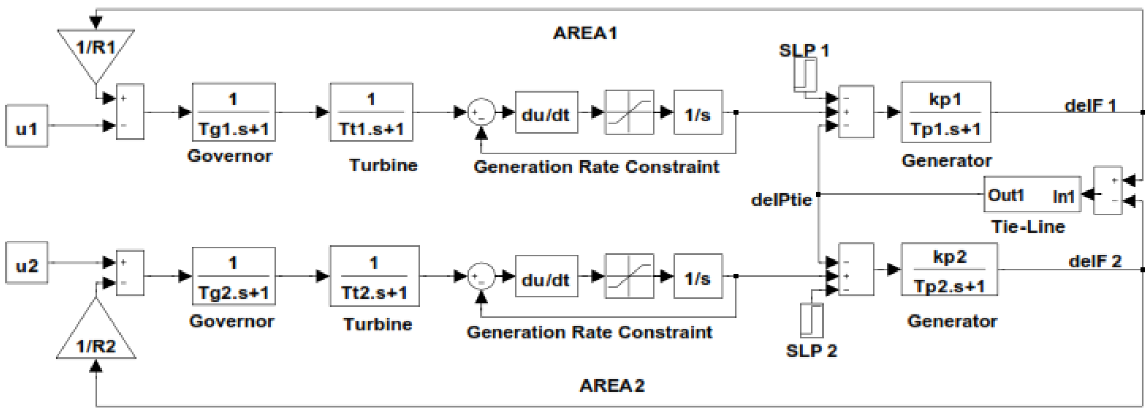


Figure 1. Two area interconnected power system with GRC non-linearity

In fig.1, u_1 and u_2 represent the control input to the power system; B_1 and B_2 denote the frequency bias factor in p.u MW/Hz; R_1 and R_2 refer to the self regulation parameter for the governor in p.u. Hz; Tg_1 and Tg_2 represent the speed governor time constant in seconds; Tt_1 and Tt_2 are the steam chest time constant in seconds; Tp_1 and Tp_2 are the power system time constant; Kp_1 and Kp_2 are the load frequency constant (Tp=2H/f*D, Kp=1/D); delF1 and delF2 are the frequency deviations in area 1 and area 2; respectively. Additionally, DelPtie is the deviations in tie-line power flow between the control areas of the interconnected power system.

Each power generating unit consists of suitable governor, turbine, and GRC non-linearity and power generator unit, to carry the own load and keep system stability constant during normal power system operation. When there is a sudden load disturbance occurs in any one of the interconnected power system, it affects total system frequency and tie-line power flow between control areas. The LFC adjusts the frequency deviations and tie-line power deviations into zero for keeping stability of the interconnected power system.

The thermal power generating unit is equipped with non-reheat turbine. The Generation Rate Constrain (GRC) non-linearity of 3% per min was considered for the thermal areas. The transfer function of aqua electrolyser and fuel cell is given by [9]:

$$G_{AE}(S) = \frac{K_{AE}}{1+ST_{AE}} \tag{1}$$

$$G_{FC}(S) = \frac{K_{FC}}{1+ST_{FC}} \tag{2}$$

Where, K_{AE}, T_{AE}, K_{FC} and T_{FC} are the gain and time constant values of aqua electrolyser, gain and time constant of fuel cell; respectively. Chemical energy of fuel (hydrogen) was converted into electrical energy with help of static conversion device (Fuel cell). The Aqua electrolyser is an additional device used for load leveling.

Nominal Parameters of power system and HAE unit

The nominal parameter values of interconnected two area thermal power system [10-12] are as follows:

$T_{t1}=T_{t2}=0.3s$
$T_{g1}=T_{g2}=0.2s$
$R_1=R_2=2.4$ Hz pu^{-1}MW
$B_1=B_2=0.425$ p.u MW/Hz
$K_{p1}=K_{p2}=120$ Hz pu$_{-1}$MW
$T_{p1}=T_{p2}=20s$
$T_{12}=0.0707$ MW rad^{-1}

While, the data for Hydrogen Aqua Electrolyser [9] is given by:

$K_{AE}=0.002$
$T_{AE}=0.5s$
$K_{FC}=0.01$
$T_{FC}=4s$

DESIGN OF PID CONTRLLEER

Proportional-Integral-Derivative (PID) controller

The control of frequency deviations and tie-line power flow deviations between interconnected power systems are controlled by implementing PID controller in each area. The transfer function of PID controler is given by [10-11, 14]:

$$G_{PID}(S) = K_p E(S) + \frac{K_p}{T_i S} E(S) + K_d E(S) \tag{3}$$

Where K_p, K_i and K_d are the Proportional, Integral and Derivative gain values; respectively. While, the error signal is denoted by E(s). The inputs to the contrllers are area controll error given by:

$$ACE_1 = B_1 \Delta f_1 + \Delta P_{tie} \tag{4}$$

$$ACE_2 = B_2 \Delta f_2 - \Delta P_{tie} \tag{5}$$

Where, ACE_1 and ACE_2 are the area control error of area 1 and 2; respectively. Δf_1 and Δf_2 are the frequency deviation in area 1 and 2; respectively, ΔP_{tie} is the tie-line power deviations. The PID controllers output are u1 and u2, which given as control input to the power system called reference power setting ($\Delta P_{ref1}, \Delta P_{ref2}$).

$$\Delta P_{ref1} = u_1 = -K_i.ACE_1 - \frac{K_P}{T_i}\int ACE_1 - K_d T_d \frac{d}{dt} ACE_1 \tag{6}$$

$$\Delta P_{ref2} = u_2 = -K_i.ACE_2 - \frac{K_P}{T_i}\int ACE_2 - K_d T_d \frac{d}{dt} ACE_2 \tag{7}$$

The controller parameters were optimized by considering meta-heurastic optimization algorithm. In the modern meta-heurastic algorithm optimization process, the objective funtion is first designed based on the required specification and constraints. Based on the previous literature the objective functions to be considered are the Integral Square Error (ISE), Integral Absolute Error (IAE) and Integral Time Absolute Error (ITAE). The expression of the objective functions are depicted in the following expressions [10-12, 14]:

$$IAE = \int_0^t |ACE_i|\, dt \tag{8}$$

$$ITAE = \int_0^t t.|ACE_i|\, dt \tag{9}$$

$$ISE = \int_0^t (ACE_i)^2\, dt \tag{10}$$

Ant Colony Optimization (ACO) technique

During the food searching process of real ants, intially all the ants are spread randomly around the surroundings of the nest. Ants are communicated each other, without any visual cues. During the return trip after completion of the food searching tour, ants store the pheromone chemical on the ground. The strength of chemical is based on the quality and quanity of the food source, which is more usefull for other ants to follow the shortest path to get good quality food source. The chemical stored in the remaining path having minimal concentration and it is easly evaprated. This natural behavior of real ants are inspired by many researchers to develop Ant Colony Optimizaation (ACO) optimization algorithm. The ACO algorithm was developed by Dorigo's and collegues during the year 1990's. The expression for transition probabilty, pheromone versus heuristic information and pheromone depositated values are given as follows [11-14]:

The transition probability from town *i* and *j* for the k_{th} ant as follows:

$$p_{ij}(t) = \frac{\tau_{ij}(t)^{\alpha}(\eta_{ij})^{\beta}}{\sum_{j \in nodes} \tau_{ij}(t)^{\alpha}(\eta_{ij})^{\beta}} \tag{11}$$

$$\eta_{ij} = \frac{1}{d_{ij}} \tag{12}$$

$$\tau_{ij}(t+1) = (1-\rho)\,\tau_{ij}(t) + \sum_{\substack{k \in colony\ that \\ used\ edge\ (i,j)}} \frac{Q}{L_k} \tag{13}$$

Where P_{ij} is the probability between the town *i* and *j*

τ_{ij} is the associated pheromone with the edge joining towns *i* and *j*,
d_{ij} is the distance between the two towns *i* and *j*,
Q is a constant,
A and β are constants that find the relative time between pheromone and heuristic values on the decision of the ant,
L_k is the length of the tour performed by K_{th} ant,
ρ is the evaporation rate,

In the present work, the initialization parameters (Number of ants, pheromone (τ), evaporation rate (ρ), and number of iterations) were selected to give better result as provided by Omar *et al*. in [13]. The parameters values were chosen as: Number of ants=50, pheromone (τ) =0.6, evaporation rate (ρ) =0.95 and number of iterations=100. The ACO optimization technique optimized PID controller parameters values are given in the Table 1.

Table 1. PID controller parameters

	PID controller gain value					
	K_{P1}	K_{I1}	K_{D1}	K_{P2}	K_{I2}	K_{D2}
ISE	0.91	0.45	0.78	0.95	0.8	0.95
IAE	0.81	0.96	0.97	0.98	0.99	0.64
ITAE	0.97	0	0.95	0.94	0.98	0.35
With HAE	0.99	0.49	1	1	1	0.43

SIMULATION RESULTS AND DISCUSSIONS

This section demonstrates the application of the proposed approach based PID controller for LFC of two area power system considering different objective functions, besides including the application of HAE energy unit. The controller parameter values of different objective functions and conditions are given in table 1.

Comparisons of ACO-PID controller with different objective function

A performance comparison of different objective functions is demonstrated by considering one percent Step Load Perturbation (1% SLP) in area 2. Figs. 2-3 and Figs. 5-6 show the areas frequency devotions and area control errors; respectively. Fig.4 illustrates the response of tie-line power flow deviation between the connected areas. In these mentioned figures, the solid line indicates the response of ISE objective function based ACO-PID controller response, dotted line represents the IAE objective function based ACO-PID controller response and the solid bold line shows the response of power system with ITAE objective function based ACO-PID controller response.

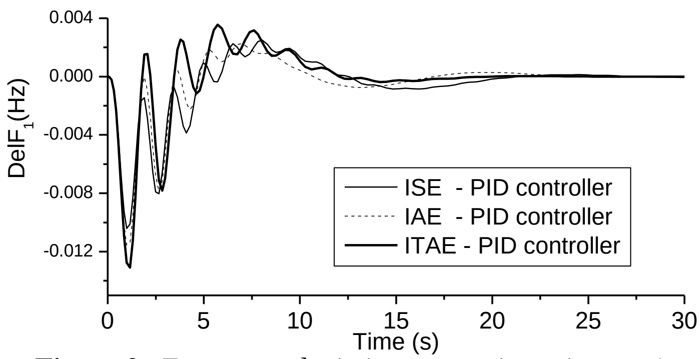


Figure 2. Frequency deviation comparisons in area 1

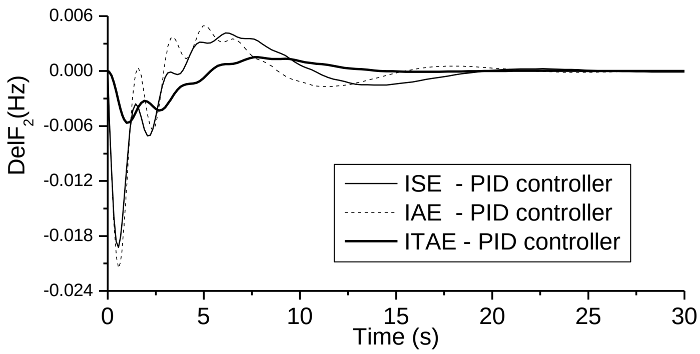


Figure 3. Frequency deviation comparisons in area 2

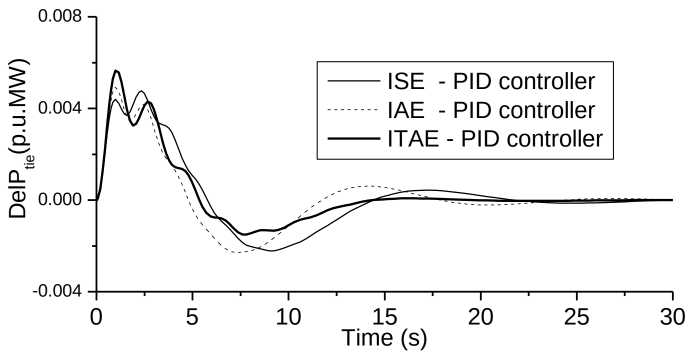


Figure 4. Tie-line power deviation comparison

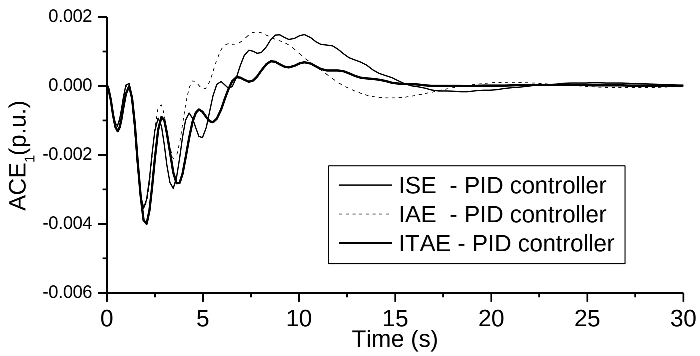


Figure 5. Area control error of area 1

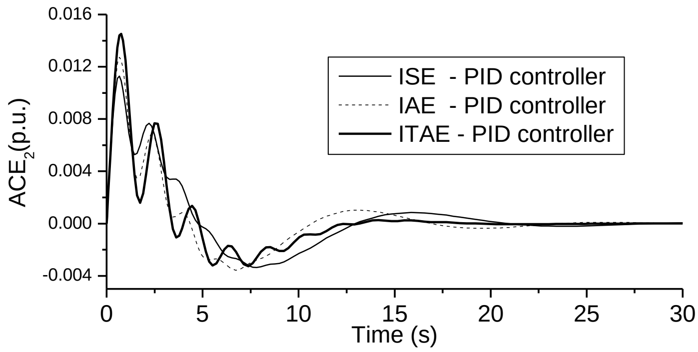


Figure 6. Area control error of area 2

It is evident that ITAE based ACO-PID controller provided better control response compared to IAE, ISE based ACO-PID controller.
Figure 7 demonstrates the settling time comparison in the delF1, while Table 1 shows comparisons of different controllers' performance.

Table 2. Performance comparions of diffrent controllers

	Frequency Deviation in area 1		
	Settling Time (s)	Peak Overshoot (Hz)	Peak Undershoot (Hz)
ISE	22.72	0.0007	**0.01**
IAE	22.25	**0.0004**	**0.01**
ITAE	**18.75**	0.0015	0.013

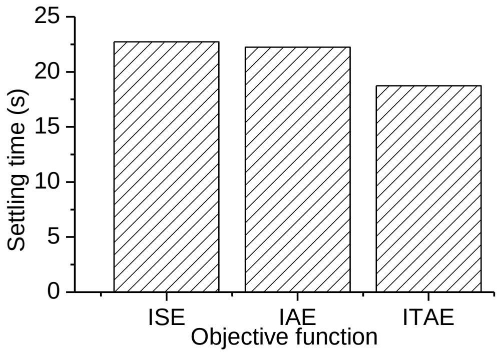


Figure 7. Settling time comparison (in delF1)

From the Fig.7 and Table 2 it is evident that the ITAE based controller has the superior performance. It takes 18.75 seconds for settling, which is much better compared to other two objective based controllers, even it has the higher peak overshoot and peak undershoot as shown in Figs 8 and 9.

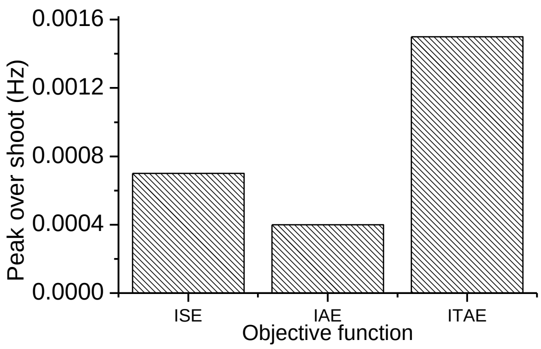


Figure 8. Peak over shoot comparison (in delF1)

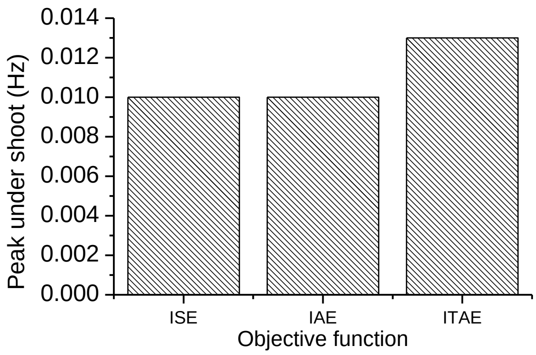


Figure 9. Peak over shoot comparison (in delF1)

Figures 8 and 9 demonstrate that the peak overshoots and undershoots for the system response is effectively reduced by the ISE and IAE objective functions based ACO-PID controller.

Performance of HAE unit

Simulation results verified the effectiveness of the Hydrogen Aqua Electrolyzer (HAE) unit in the LFC of two area interconnected power system. The results include a comparison performance that consider the ITAE objective function and 1% SLP in area 2. The frequency deviations in area 1, tie-line power flow between connected areas and area control errors are depicted in figs.10-12; respectively.The solid lines show the response of power system with HAE energy unit, while the dashed lines show the response of system without HAE unit. A numerical values of the time domain specifications are given in the Table 3.

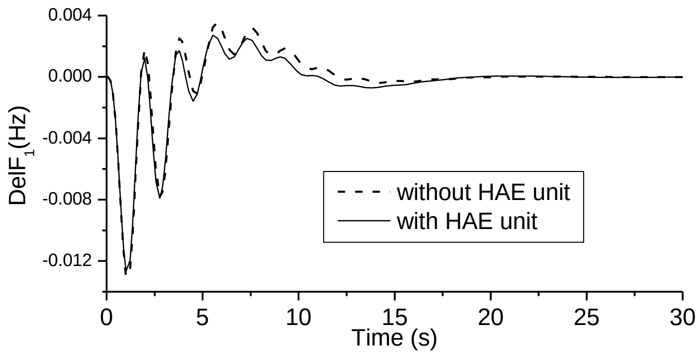


Figure 10. Frequency deviation comparisons in area 1

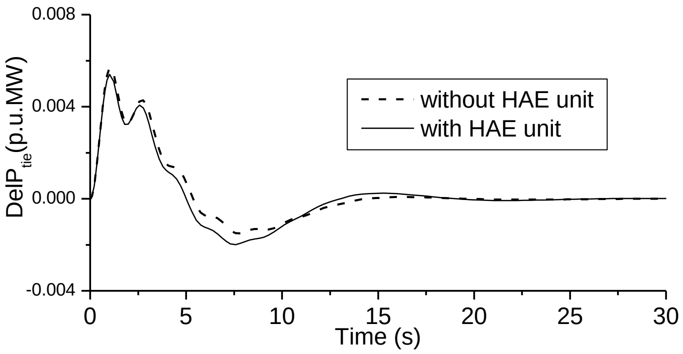


Figure 11. Tie-line power deviation comparison

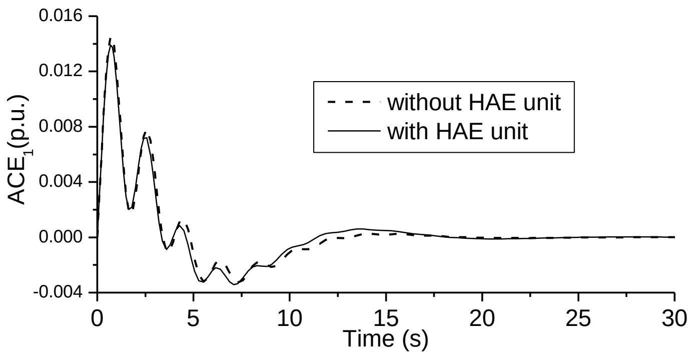


Figure 12. Area control error in area 1

Table 3. Performance of investigated system with and without HAE unit

	Frequency Deviation in area 1		
	Settling Time (s)	Peak Overshoot (Hz)	Peak Under shoot (Hz)
Without HAE	19.86	0.0017	0.013
With HAE	**17.9**	**0.0012**	**0.012**

From figs.10-12 response and the numerical values in table 3, it is unconscious that the HAE energy unit equipped system effectively diminishes the peak shoots and settling time in the response compared to system without HAE unit. The HAE energy unit takes 17.9 seconds for settling with minimum 0.0012 peak overshoot and 0.012 peak undershoot.

CONCLUSION

The proposed work designs the Proportional-Integral-Derivative (PID) controller for Load Frequency Control (LFC) of multi-area interconnected thermal power system with Generation Rate Constraint (GRC) non-linearity and different objective functions. The effectiveness of the Integral Time Absolute Time (ITAE) objective function based Ant Colony Optimization (ACO) technique optimized PID controller was proved by comparing Integral Square Error (ISE) and Integral Absolute Error (IAE) objective function based ACO-PID controller.

In addition, the performance of the system was improved by adding Hydrogen Aqua Electrolyzer (HAE) energy unit in both areas of the power system, which achieved less settling time with minimum overshoot and undershoot peaks. Simulation result was established the ITAE based ACO-PID controller and HAE unit equipped power system feasibility.

REFERENCES

[1] Dianwei Qian, Jianqiang Yi, Xiangjie Liu., Design of reduced order sliding mode governor for hydro-turbines, 2011 American control conference on O’Farrell Street, San Francisccco, CA, USA, June 29-July1, 2011, pp:5073-5078.

[2] Xiangjie Liu, Xiaolei Zhan, Dianwei Qian., Load frequeny control considering generation rate constraints, Proceedings of 8th world congress on Ontelligient Control and Automation, July 6-9, 2010, China, pp:1398-1401.

[3] Saroj Padhan, Rabindra Kumar Sahu, Sidhartha Panda, Application of firefly algorithm for load frequency control of multi-area interconnected power system, Electric Power Components and Systems, Vol.42, pp: 1419-1430, 2014.

[4] Sabita Chaine, M.Tripathy, “ Design of an optimal SMES for automatic generation control of two-area thermal power system using cuckoo search algorithm,” Journal

of Electrical Systems and Information Technology, Vol.xx, pp: xxx-xxx, 2015 (In Press)

[5] Binod Kumar Sahu, Swagat Pati, Pradeep Kumar Mohanty, Sidhartha Panda, Teaching-learning based optimization algorithm based fuzzy-PID controller for automatic generation control of multi-area power system, Applied Soft Computing, Vol.27, pp:240-249,2015.

[6] Rabindra Kumar S ahu, Sidhartha Panda, G.T.Chandra Sekhar, A novel hybrid PSO-PS optimized fuzzy PI controller for AGC in multi area interconnected power systems, Electric power and energy systems, Vol.64, pp.880-893, 2015.

[7] Mojtaba Shivaie, Mohammad G.Kazemi, Mohammad T.Ameli, A modified harmony search algorithm for solving load-frequency control of non-linear interconnected hydrothermal power systems, Sustainable Energy Technologies and Assessments, Vol. 10, pp.53-62, 2015.

[8] Anand.B, Ebenezer Jeyakumar.A., Load Frequency control with Fuzzy logic Controller considering Non-Linearities and Boiler Dynamics, ACSE, vol.8, pp;15-20.2009.

[9] Francis.R, Chidambaram.I.A, Optimized PI+ load-frequency controller using BWNN approach for an interconnected reheat power system with RFB and hydrogen electrolyser units, Electric power and Energy systems, Vol.67, pp:381-392, 2015

[10] Jagatheesan, K. Anand, B., Nilanjan Dey , Ebrahim, M.A, Design of Proportional-Integral-Derivative controller using Stochastic Particle Swarm Optimization technique for single area AGC including SMES and RFB units, Proceedings of the Second International Conference on Computer and Communication Technologies: IC3T 2015, Vol.2, pp:299-309, 2015.

[11] Jagatheesan, K. Anand, B. and Nilanjan Dey, Automatic generation control of Thermal-Thermal-Hydro power systems with PID controller using ant colony optimization, International Journal of Service Science, Management, Engineering, and Technology, Vol.6, pp: 18-34, 2015.

[12] Jagatheesan K, Anand B, Performance Analysis of Three Area Thermal Power Systems with Different Steam System Configurations considering Non Linearity and Boiler Dynamics using Conventional Controller, proceedings of 2015 International Conference on Computer Communication and Informatics (ICCCI -2015), Jan. 08 – 10, 2015, Coimbatore, India.pp:1-8.

[13] M.Omar, M.Soliman, A.M.Abdel Ghany, F.Bendary, Optimal tuning of PID controllers for hydrothermal load frequency control using Ant colony optimization, International journal of Electrical Engineering and Informatics, Vol.5, pp: 348-354, 2013.

[14] Jagatheesan, K. Anand, B., Nilanjan Dey, Amira S. Ashour, Artificial Intelligence in Performance Analysis of Load Frequency Control in Thermal-Wind-Hydro Power Systems, International Journal of Advanced Computer Science and Applications, Vol. 6, pp: 203-212, 2015.

PROJECT MANAGEMENT OF WASTE ALKALI: OVERVIEW OF POSSIBLE SOLUTIONS

Aleksandra Aleksić[1], Radoslav Mićić[2], Jasna Tolmač[2]
[1]Department for development and investition, NIS Gazprom Neft, Novi Sad, Serbia
[2]University of Novi Sad, Technical Faculty "Mihajlo Pupin", Zrenjanin, Serbia
e-mail: aleksandra.v.aleksic@nis.eu

Abstract: Disposal, handling and treatment of waste materials that are hazardous and harmful one of the main problems of the refineries. A solution of sodium hydroxide (NaOH) in refinery processing is used for the removal of hydrogen sulphide (H_2S) or a mercaptan (R-SH) from various hydrocarbon streams. The product of the reaction between mercaptan and excess of NaOH is waste lye. Worn lye is most problematic among the entire industrial waste disposal. This paper is focused on methods of reducing, reusing and recycling of waste lye.
Key words: Refining, waste alkali, disposal

INTRODUCTION

A solution of sodium hydroxide (NaOH) is used in refinery processing for removal of hydrogen sulphide (H_2S) or a mercaptan (R-SH) from various hydrocarbon streams. Since mercaptans react with excess of NaOH obtained solution after this reaction product of the reaction is called waste lye.
The waste lye is classified as a D003 (reactive sulfides) or as hazardous waste (US Resource Conservation and Recovery Act - RCRA) because it contains high concentrations of toxic substances, such as phenols and hydrogen sulfide [1]. These substances have a negative impact on conventional biological treatment and after neutralization and dilution since it is toxic for the bacteria used in such processes. Current environmental regulations have a major impact on the design of systems for the purification of waste alkalis and conventional disposal methods, disposal in deep wells or discharged into the aquatic environment (oceans) are becoming environmentally unacceptable [2].
The quality of waste alkali varies from refinery to refinery [3, 4]. It is possible that in the waste alkali locate and trace of special catalyst. Worn alkali typically has a pH>12, and the sulfide concentration higher than 2-3 wt%, depending on the source. The waste sulphite alkali can be classified as a group of phenolic naphthenic or waste sulphide liquors depending on the content of phenols, sulfides and free NaOH. The content of the phenol can vary from 240 g/L phenol, 2 to 25 g/l of sulphides, from 5 to 30 g/l of mercaptans and 5 to 18% of free NaOH. Apart from these substances may be found and ammonia, cyanide, together with mono and poly-aromatic nitrogen and sulfur components. The waste alkali may also contain phenols, mercaptans, amines, and other organic compounds, the alkali-soluble or alkali to form emulsion [5]. The main chemical reaction in the process, which include extraction and regeneration are as follows below. The reaction with the sodium hydroxide with the formation of mercaptans and mercaptides of sodium:

$$RSH + NaOH \rightarrow RSNA + H_2O$$

The oxidation of sodium mercaptides, and the formation of disulfide and sodium hydroxide:

$$RSNa + 1/4\ O_2 + 1/2\ H_2O \rightarrow RSSR + NaOH$$

As the alkalinity of the waste liquids is reduced, and the capacity for the extraction of mercaptan increases. When disulfides accumulate to a few milligrams per liter, the content of OH^- falls below 5%, so a fraction of the solution purified and restored. Other causes of spending are the accumulation of mercaptans, Na_2S, phenolic compounds, emulsified oil, thiosulfate, carbonate and Fe^{+2} residues (precipitants). Selection of the best modes of treating of waste alkali is a critical task, especially in meeting the overall standards and needs, related to waste management. The development of these technologies usually initiated by environmental regulatory constraints related to emissions and discharges of certain waste materials [6]. These include the principle of waste management hierarchy, with good qualities and cons of each possible solution (Fig. 1).

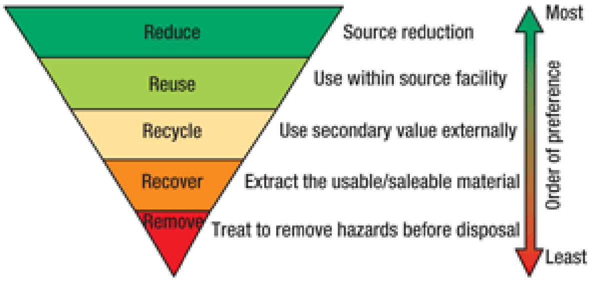


Figure 1. The hierarchy of handling waste lye [12]

Characterization of contamination sources and their segregation

Typical processes in the oil industry that generates waste alkali are:

- caustic washing of light hydrocarbons from the atmospheric distaillation unit;
- preparation of raw materials on plants for isomerization and polymerization;
- thermal/catalytic cracking processes;
- caustic washing of middle distillates,
- processes of extraction/sweetening of mercaptans.

By converting a caustic to the acidic component into the inorganic/organic sodium salts such as sulfides, carbonates, mercaptides, disulfide oils, phenolates, cresolates and naphthenates. During this process, the caustic substances are used usually in a concentration of 5-20%, which depends on the type of raw material and types of processes. Since treated acidic components are with a great range of boiling points, the composition of waste alkali varies depending on the operating temperature of the process for caustic treatment [7]. In order to facilitate proper treatment, various waste streams should be systematized on the basis of the dominant pollutant:

- Sulfide: primarily sulphides (scrubber of stright-run hydrocarbons originates from ADU)
- Phenolic: phenols, cresols and xylene with sulphides (scrubber of gases and gasoline as a product from cracking unit)
- Naphthenic: naphthenic acid (scrubber of mercaptans - extraction of middle distillates).

Table 1. The systematization of waste streams on the basis of the dominant pollutants

Components	**Characterized waste stream**		
	sulphide	phenolic	naphthenic
Sodium-hydroxide (%wt)	2-10	10-15	1-4
The inorganic sulfides, S (wt%)	0,5-4	0-1	0-0,1
Mercaptides, S (wt%)	0,1-4	0-4	0-0,5
Cresylic acid, (% wt)		10-25	0-3
Naphthenic acid, (% wt)			2-15
Carbonates, (% wt)	0-4	0-0,5	
pH	13-14	12-14	12-14
Free oily substances	Varies up to 20% in the untreated raw material		

a) Reducing the quantity

Reduction the generation of waste material is the first and the most desirable step. During the design process for the caustic treatment, most preferable is to generate as small as possible amount of the waste lye, while maintaining the desired efficiency of the process. The following measures will help to achieve this goal.

b) Processes without the use of alkali

The elimination of spent lye can be achieved by utilisation of processes that do not use alkali. These processes are based on the technique of injecting ammonia and catalytic processes with a solid catalyst, which are most suitable for the processes of oxidation of mercaptans.

c) Multi-stage caustic wash

Two degrees wash (scrubbing), the first with a weak and the second with a strong alkali enables enhanced alkali utilization. The first stage allows easier removal of most of the hydrogen sulphide (H_2S), while the second stage is polishing in order to obtain maximum efficiency in removing contaminants. For these alternatives must be weighed the capital investment cost against saving lye during treatment.

d) Increasing the percentage of lye

Generation of waste lye can be minimized by using a stronger lye which, as far as possible, and thereby prevents the penetration of the acidic components in the hydrocarbon product. How much power lye can be used may be determined on the basis of analytical data and operating experience.

e) More efficient regenerative system

In many cases, the amine treatment is preceded by caustic washing. The provision of an efficient design/operation of these regenerative units, which can remove a large amount of H_2S, provides a reduction in the load on the plant for caustic washing unit, thereby decreasing the amount of waste.

f) The choice of maximum strength lye

When it is possible to select, maximum volume lye, thereby the water content is reduced as well amount of dissolved organic pollution.

g) The technique of non-dispersion mass transfer

Extraction of naphthenic acids is limited by the tendency of emulsion formation. This is prevented with higher concentration of alkali in the units which provide dispersive caustic mixing. Film-contact techniques can overcome these limitations which allows the use of stronger alkalis and savings in the use and generation of waste lye.

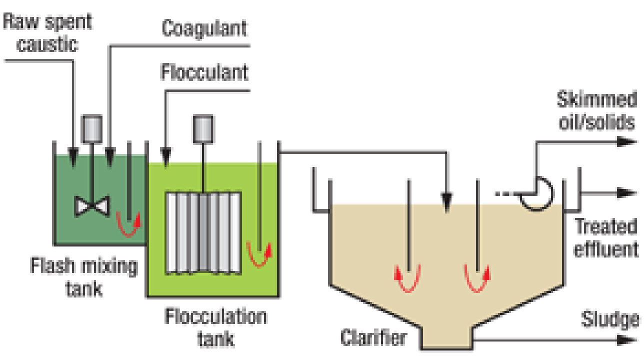


Figure 2. Flow diagram of a typical plant for chemical treatment of waste alkali [12]

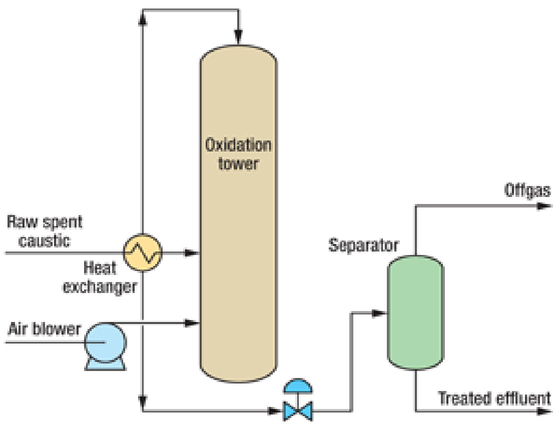


Figure 3. Flow diagram of the plant for treatment of waste alkali by wet oxidation [12]

RE-USE OF WASTE ALKALIS ON THE SAME OBJECT ON WHICH IS GENERATED

After reduction of the amount of generated of waste alkali, the next step is to identify possible options for its re-use, on the same facilities. Segregation of waste alkali, based on the type of contaminants, been using this approach, because mixing different types of caustic wastewater can lead to the formation of compounds that are not suitable for reuse [8]. Potential reuse of waste alkali is a function of its alkalinity, a measure of free NaOH residues and contaminants such as sodium phenolate (Na_2S) and other sodium salts of weak acids. There is a high potential opportunity for applications which are reused instead of purified fresh lye. To optimize the application for reuse, it is necessary to understand the chemistry of the process operating conditions of the system and the impact of caustic pollutants that occurs on that system. Potential reusability of the lye and exchange for the use of fresh lye are described in the paper.

a) The neutralization of desalted water

Desalting process removes salt and other impurities, such as sediments from the bottom and water from crude oil before fractionation. Depending on the crude to be treated, alkali is injected into the desalter in order to maintain the optimum pH (generally 7-8), and thus neutralize the acidity of the crude, to maximize the de-emulsification. It is used diluted caustic solution, usually 2-3% by weight, in order to maintain a low level of salt and limit the emulsification, which is due to naphthenic acids present in the raw material. Naphthenic waste alkali stream is not recommended for repeated use, or sulfide stream also, due to the lack of sufficient alkalinity. In contrast, the phenol waste stream lye is effective because it is neutralized by naphthenic acids, thereby forming the phenols that are soluble in the feed.

b) Corrosion control of atmospheric distillation column (ADU)

Durring atmospheric distillation the base - alkali is often introduced in the raw material to reduce corrosion that is caused by hydrochloric acid (HCl) formed by hydrolysis of calcium and magnesium chloride, which remains in the residual water from the crude oil desalter. Phenolic waste alkali can be used in these applications, as well as effluent spent naphthenic bases, because sodium-naphthenates reacting with HCl.

c) Adjusting the pH in salt water from the desalter

If the pH control in desalter can not provide a minimum alkalinity leaving salt water, it can lead to corrosion of downstream equipment (valves and pipes). The injection of lye in the rising line of salt water is therefore required. For this purpose suits worn phenolic bases.

d) Internal reuse

Most of the processes for oxidation of mercaptan in the section of the extraction commonly used alkali with higher strength (20° Be), thus favoring the removal of mercaptans. Base with smaller strenght (10° Be) is used in operation of prewashing, due to lower solubility of Na_2S.

Spent alkali which is discharged from the extraction section has a relatively low content of sulphide and it can be used upon dilution in a pre-wash unit. Such regenerative processes are more effective in reducing the amount of spent lye in relation to a one-pass process (once-through).

e) Needs for wastewater treatment

The alkaline solution is normally dosed upstream from the unit for the chemical and biological treatment, in order to maintain the pH value in the preferred system. Since phenol and naphthenic content if their content in the controlled borders, successfully solve by bio-treatment, phenol and naphthenic streams of spent lye are suitable for reuse. Sulphide streams pose a problem because of its smell. Accordingly, phenolic flows are best for reuse, then naphthenic, while sulphide have little possibility of reuse.

OUT RECYCLING FACILITY (USE OUT OF THE REFINERY)

Another option for reuse spent alkalis is a possibility of recycling and this possibility should be investigated. In addition, recycling is currently successfully used in several refineries in the US and Canada. This methods may require further tretment or additional equipment within the facilitie, depending on needs and establishment of the facility for the re-use/recycling (outside the refinery) [9, 10].

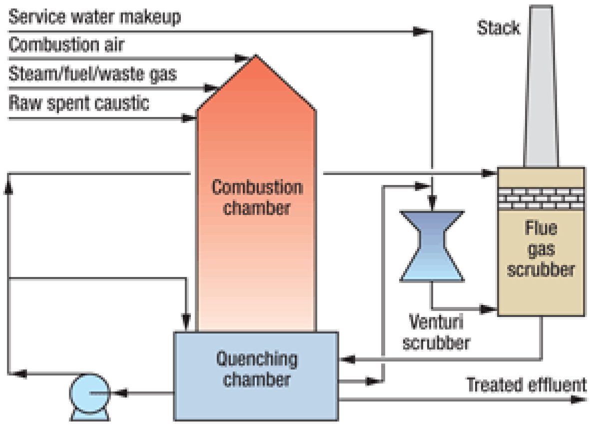


Figure 4. Flow diagram of the incineration plant [12]

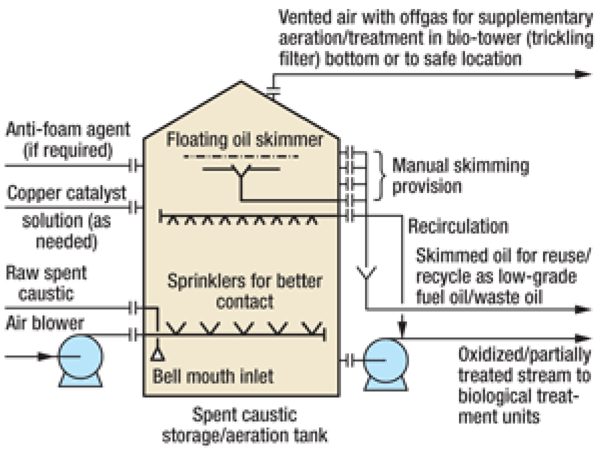


Figure 5. Flow diagram of atmospheric plant [12]

In these applications problem may be in handling and transportation. If so, the exhausted alkali can be sold to specialized companies that carry out transport and distribution. Potential opportunities include recycling plants for processing of pulp and paper, leather industry, mining, wood preservatives and paint industry.

Within processing plants there may be options for the separation of useful substances, in particular the pure base, sulfide salts, phenols and naphthenic acids. These materials can be used as raw material for the production of phenolic resins, herbicides, solvents, wood preservatives, dryer in the production of paints and inks, additives, fuel etc. However, this approach needs proper cost-benefit analysis before deciding to use it. New techniques, such as membrane and electrolytic processes have promising trends [11].

CONCLUSION

Disposal, handling and treatment of waste materials is one of the main problems of the refineries due to the nature of the waste, having in mind that are dangerous and harmful. Sources that generate waste lye are different because during the neutralization and disposal generate various types of organic and inorganic acid waste, such as carbon dioxide (CO_2) sulfides, carbonates, mercaptans, phenols and naphtenates. These components are acidic and must be removed to avoid corrosion of equipment and contamination. Conditions can be a bit more complicated since in waste streams, there may be some content of oil components.

There are different methods for treating waste alkalis and they include: chemical precipitation, neutralization, oxidation, chemical oxidation reagents, wet oxidation, catalytic oxidation and incineration. These processes are on a daily basis improved. Each method offers certain advantages; the method used will depend on the composition of the waste, the size and configuration of the facility that generates waste and limit the toxicity of subsequent biological treatment of waste materials.

REFERENCES

[1] William D. C. and Rothschild, Wet air oxidation of spent caustics. The Nat. Environ. J. 4(6), pp. 16–19, 1994.

[2] Grover R. and Gomaa H. M., Proven technologies manage olefin plant's spent caustic. Hydrocarbon Process. 72(9), pp. 61–71, 1993.

[3] Dando, D. A., and Martin D. E., A guide for reduction and disposal of waste from oil refineries and marketing installations, CONCAWE Report No. 6/03, 2003.

[4] Veerabhadraiah. G., and Haldar, A., Aiming towards Pollution Prevention and Zero Discharge in Petroleum Industry, Proceedings of AIChE Spring Conference, Atlanta, 2000.

[5] US Dept. of Energy, Energy and Environmental Profile of the US Petroleum Refining Industry, 2007.

[6] Sarkar, G. N., Utilization of the Spent Caustics Generated in the Petroleum Refineries in the Crude Distillation Unit, 5th Intl. Conference on Stability and Handling of Liquid Fuels, The Netherlands, 1994.

[7] API, Category Assessment Document for Acids and Caustics from Petroleum Refining, US EPA, 2009.

[8] Sarkar, G. N., Utilization of the Spent Caustics Generated in the Petroleum Refineries in the Crude Distillation Unit, 5th Intl. Conference on Stability and Handling of Liquid Fuels, The Netherlands, 1994.

[9] Ahmad, W., Neutralization of Spent Caustic from LPG Plant at Preem AB Goteborg, Department of Chemical and Biological Engineering, Chalmers University of Technology, Sweden, 2010.

[10] Mamrosh, D., C., Beitler, K., Fisher and Stem, S. "Consider improved scrubbing designs for acid gases," Hydrocarbon Processing, January 2008.

[11] Falqi, F. H., Miracle of Petrochemicals: Olefins Industry, 2009.

[12] http://www.hydrocarbonprocessing.com

ECONOMIC BENEFITS FROM THE USE OF METHOD OF TRIPLE RINSING AFTER APPLICATION OF PLANT PROTECTION PRODUCTS

Una Marčeta[1], Jelena Tasovac[2], Olivera Paunović[1], Mila Zakin[1], Sanja Stanisavljev[1]
[1]University of Novi Sad, Technical Faculty "Mihajlo Pupin", Zrenjanin, Serbia
[2]"Agro Klek", Klek, Serbia
e-mail: una.tasovac@tfzr.rs

Abstract: Since the beginning of pesticides application, there has been a problem of disposal of packaging after their use. Although the area is now regulated by law, we are aware of the fact that a large number of individual users of pesticides handle packaging negligently. Serbia has about 4.25 million hectares of arable land, where during chemical treatment several tons of pesticides are used and afterwards an enormous amount of waste packaging remains. The aim of this paper is to present financial loss that occurs due to residue of pesticides in packaging if proper rinsing is not carried out, and possibly raise the awareness of end-users of plant protection products in terms of proper use and safe disposal of packaging.
Key words: plant protection products, pesticide containers, method of triple rinsing

INTRODUCTION

Plant Protection Products (PPP) are active substances and preparations containing one or more active substances whose role is to protect plants and plant products against harmful organisms (pests) and prevent their effect [1]. Packaging materials reach the market together with plant protection products and after use of PPP become waste that is often categorized as hazardous waste. Only the containers which are washed three times can be classified as non-hazardous waste [2]. It is important to raise awareness about proper treatment of packaging waste from PPP, from manufacturers to end-users, to whom economic viability, unfortunately, represents the basic stimulus for undertaking prescribed measures after the use of pesticides.

Packaging of Plant Protection Products

Management of packaging of plant protection products must be in compliance with environmental goals that have become increasingly important in the context of social concerns relating to environmental protection. In the packaging industry since the 1980s of the last century emphasis has been put on safe and sustainable management of packaging waste from plant protection products throughout Europe, where it is viewed as a potential valuable resource. [3]

Rinsing packaging after used PPP

Rinsing packaging after used PPP is a simple process and it is the basis for all further activities. The main objective is to secure that waste packaging contains minimum concentration of active substance and make sure it is harmless to human health and the environment, and, on the other hand, its economic impact is undeniable. [4]
Classification of waste containers of PPP depends on the amount of hazardous substances that remain in the bottle after being washed according to the EWC where the lowest limit is 0.1% w/w of the total amount of a composition in the bottle, and relates to a highly toxic material [5]. Within the EU there is a different approach to classification of washed waste packaging, with at least one third of countries classifying these containers as dangerous. In some countries it is not possible to obtain data because this problem has not yet been examined by competent institutions. This level of inconsistency across Europe has great current and future consequences on programs for collection and reuse of packaging of PPPs. [4]
Method of triple rinsing stands out as the simplest and most widely applied method for rinsing, which removes more than 99.99% contaminating residue in a package [6]. Results of numerous studies have

shown that the amount of active substance in properly rinsed packaging remains below the limit of 0.1% w/w of the bottle, which is set by the EWC. Classification of packaging as non-hazardous allows easy and controlled environmental conditions for disposal, recycling and energy gain, and in addition it reduces costs of disposal and provides opportunities for economic profit and new workplaces. [5] When the contents of the package is poured into a sprayer and allowed to drain, 2% of the original amount of the preparation still remains in it. This means that application of recommended method of rinsing can save money since the amount of agent used increases by 2%. [7]

MATERIAL AND METHODS

The research was carried out in Agricultural Cooperative 'Agro Klek' and possible losses are presented on the example of two preparations of the same active substance and same formulation of different manufacturers. The basic characteristics of the preparations tested are given in Table 1.

Table 1. The basic characteristics of the preparations tested

Preparation	Formulation	Type of pesticide	Packaging	Price per bottle
ZEAZIN – Chemical Agrosava	SC	herbicide	1 l	715 RSD
REZON – Galenika Fitofarmacia	SC	herbicide	1 l	744 RSD

Table 2. defines the purpose of each preparation as well as active substance (content in litre of preparation), recommended application rate, and annual consumption of products in the Cooperative

Table 2. Purpose of preparation, active substance (content in litre of preparation), recommended application rate, and annual consumption of products

Preparation	Active substance (content in litre of preparation)	Application rate	Annual consumption in the Cooperative
ZEAZIN – selective herbicide used to control broadleaf and reduction of narrow-leaved weeds in corn	terbuthylazine (500 g/l)	2.0 l/ha	900 l
REZON - herbicide used to control annual broadleaf weeds in corn crop and sunflower	terbuthylazine (500 ± 25 g/l)	1.5 – 2.0 l/ha	900 l

These preparations, in packaging of 1 litre, were selected because of the type of formulations in which, due to their physical and chemical properties, there is a significant residue of products in packaging, and because these preparations are used to treats large area of land (900 ha in one production year) in AC 'Agro Klek'.

Weighing of emptied bottles in a sprayer without rinsing and weighing of the same bottles upon application of triple washing was performed, so that based on the difference of mass, information about weight of the residual mixture in the bottle could be obtained, if it was not adequately rinsed. Digital scale with technical precision of 0.01g was used for measurements (six reps). Rinse of packaging was done according to the WHO (World Health Organization) guidelines [7]. Based on the obtained mass of the preparation remaining in the bottle, percentage of that residue in relation to the total weight of the filled bottles was calculated, as well as the financial loss per bottle and annual financial losses if triple rinsing was not applied.

RESULTS AND DISCUSSION

Results of measurements showing loss for the preparations of same formulations, with the same active ingredient and volume of packaging and from different manufacturers are given in Figure 1. and in Table 3.

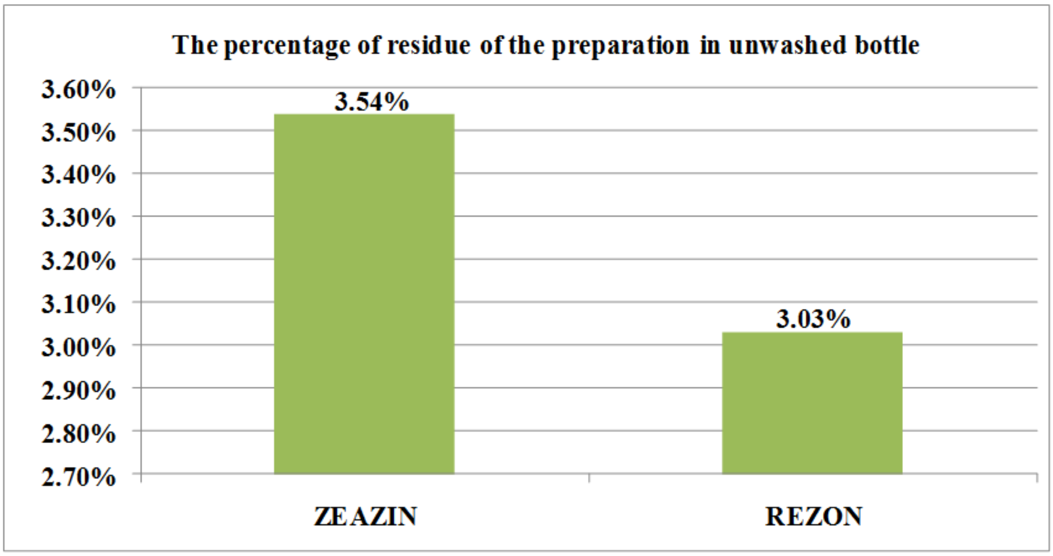


Figure 1. The percentage of residue of the preparation in unwashed bottle

Results presented in Figure 1 show that the percentage of residue for the preparation ZEAZIN is 3.54% and for the preparation REZON 3.03%. Difference in percentage of residue of preparations in a bottle without rinsing is only 0.51%.
Information about financial loss per unwashed bottle is shown in Table 3.

Table 3. Financial loss per unwashed bottle

Preparation	Pakaging	Price per bottle [RSD]	Financial loss per unwashed bottle [RSD]
ZEAZIN	1 l	715	25.31
REZON	1 l	744	22.54

Table 3 shows that financial loss per unwashed bottle for preparation ZEAZIN is RSD 25.31, and for preparation REZON is RSD 22.54, indicating very little difference of RSD 2.77. Based on obtained data it can be concluded that the percentage of preparation residue in a bottle is directly proportional to financial loss per unwashed bottle. Thus, for preparation ZEAZIN percentage of residue in a bottle is greater than the percentage of residue for preparation REZON, so the loss for unwashed bottle of preparation ZEAZIN is higher as compared to preparation REZON although the price of preparation ZEAZIN is lower.

CONCLUSION

The percentage of residue of the preparation in unwashed bottle can be affected by physical and chemical properties of active substances as well as their proportional share in one liter of preparation. Physical and chemical properties of the solvent and their proportional share in the finished composition also have their impact. The type, number and proportional share of inactive substances (substances with no significant pesticidal properties) with liquid forms of the formulation, may also affect the percentage of residue. Of physical and chemical properties of the preparation, density of preparation significantly affects its retaining on walls of a bottle and therefore the percentage of residue of the preparation in unwashed bottle [9].

Shown financial losses per tested unwashed bottle of preparation may seem minor, but when put into function with quantity of product used per hectare and the number of acres treated in the Cooperative during a production year, then the loss takes on greater significance. Loss on level of the Cooperative for preparation ZEAZIN would amount to RSD 22,779.00 a year if washing was not applied, which represents the value of 31.86 l of preparation. For preparation REZON annual loss would amount to RSD 20,286.00 or 27.27 l of preparation. This information leads to conclusion that application of proper rinsing of packaging generates saving of preparation ZEAZIN sufficient for treatment of 15.93 ha of corn, and of preparation REZON for 13.64 ha of corn.

Results presented in this paper should highlight the benefits of using rinsing of packaging, primarily financial benefits, and thus stimulate users of pesticides to properly treat waste packaging.

REFERENCES

[1] Commission of the European Communities. COM(2002) 349 final. Communication from the Commission to the Council, the European Parliament and the Economic and Social Committee towards a Thematic Strategy on the Sustainable Use of Pesticides, Brussles.

[2] EPA. 2012. Good practice guide for empty pesticide containers. Environmental Protection Agency

[3] ECPA. 2007. Crop Protection Plastic Containers. The case for a nonhazardous waste classification. European Crop Protection Association.

[4] Huyghebaert B, Mostade O, Sawa J. 2004. Management of empty pesticides containers. TEKA. Commission of motorization and power industry in agriculture 3: 117-126.

[5] Briassoulis D, Hiskakis M, Karasali H, Briassoulis C. 2014. Design of a European agrochemical plastic packaging waste management scheme - Pilot implementation in Greece. Resources, Conservation and Recycling (87): 72–88.

[6] CropLife International. 2004. Container Management: Safe and effective disposal of emptycrop protection product containers, Brussels, Belgium.

[7] FAO/WHO. 2008. Guidelines on Management Options for Empty Pesticide Containers. In: International Code of Conduct on the Distribution and Use of Pesticides, Food and Agriculture Organization of the United Nations. Rome: World Health Organization.

[8] Janjić V. 2005. Fitofarmacija, Beograd.

[9] Mollet H., Grubenmann A. (2001): Formulation Technology – Emulsions, Suspensions, Solid Forms. WILEY-VCH Verlag GmbH, Weinheim. New York. Chichester. Brisbane. Singapore. Toronto.

Session 12.

Student papers

NEED FOR REENGINEERING AND ITS IMPLEMENTATION AT NOKIA

Antonija Kadarijan
University of Novi Sad, Technical Faculty "Mihajlo Pupin", Zrenjanin, Serbia
e-mail: antonijakadarijan@gmail.com

Abstract: In this paper, we will present the concept of reengineering, which means its definition and the most frequent reasons for its implementation. Reengineering seeks to establish a new beginning of the old business concept, and companies that set up this model, are designed to resist all those crisis situations and issues that are common in today's way of doing business. Successful implementation of reengineering opens new objectives of the company and creates a new philosophy of company management. Nokia has gone through a process of reengineering and therefore is listed as an example, which presents reengineering and effectiveness of its application in a natural way.
Key words: reengineering, new business concepts, Nokia.

INTRODUCTION

The concept of reengineering, as we know, is linked to the name of Michael Hamer (Adamovic& Seifert, 2004). This approach was first mentioned in the 90's in the last century. The definition of this concept that is generally accepted and almost universal, and whose founder also is Hamer, states (Adamovic& Seifert, 2004): Reengineering is the fundamental rethinking and radical redesign of business processes to achieve dramatic improvements in performance. Definition of reengineering contains keywords, which defines the nature of reengineering, and these are (Adamovic& Seifert, 2009):
Primarily - answering fundamental questions such as,, Why are we doing this/that? " Or,, Why do we do it this way? ', management needs to determine the reasons for the implementation of re-engineering;
Radically- refers to the implementation of radical changes and ignore all the existing procedures;
Dramatically-reengineering involves dramatic leaps in improving business efficiency;
Process- often happens that employees are the most oriented to fulfilling their own duties and responsibilities in the company, but not on the process. Focusing on the entire process is a key activity in implementing reengineering.
Reengineering is expressing the need for redesign of all those operating guidelines, which were part of the business of a company and their rejection, in order to achieve some new business ventures, completely new methods and new ways of doing business. The product,, new beginnings', as often there is a custom to say in the literature, should encourage business activity, to contribute to the betterment of the business in terms of acquiring or improving competitive advantage, increase profits and others. The need for re-engineering occurs with the advancement of technology, which with itself, among other things, brought about a rapid change, with which it is often difficult to keep pace. From the companies that seek to maintain its own competitive advantage is expected to continuously monitor all changes in
all areas of business. In regard to this, the author (Seifert, 2008), also lists the most common reasons that influence the need for implementation of reengineering, which are:

1. the rapid changes taking place in the world;
2. customers or consumers who are becoming more demanding;
3. the competition, which is becoming sharper.

These are the most common problems that companies face in the course of its operations, and the implementation of the re-engineering seeks to overcome these and all other business problems, by an entirely new philosophy of business management. Very similar situation happened to company,, Nokia ', so the specific reasons for upcoming of such a phenomena will be covered in this paper, as well as that of the total costs of reengineering,, the recovery' 'of the company in finding new business solutions. Thus, the application of reengineering means also the realization of new company goals, a new ambition and a new system of functioning business.

THE REFERENCE TO THE BUSINESS - SUCCESSES AND FAILURES

World famous brand ‘Nokia’ is a Finnish company that once was the world's largest mobile phone manufacturer. Founded in 1966, and the success of the company was ahead of Motorola and Samsung with 23% of market share (https://sh.wikipedia.org). Numerous models of this brand phones have been very widely distributed and known to consumers of all age limits.

A large number of consumers especially remembers the famous Nokia 3310, which is still, according to its various specifications, considered as one of the best phones ever. At a time when technology telephone suit current technological advances, this model has had a very stable market dominance. The year of „victory“ of this model and the year when the company had the most success was the year of 2000(https://sh.wikipedia.org). Likewise, 2005 was a year of good business results, when they amounted to 34.19 billion euros, with a growth rate of 16% (https://sh.wikipedia.org). The company then sold 265 million units of mobile phones (https://sh.wikipedia.org). The big attraction at the time was the game on a mobile phone ‘The Snake’, also known to the general population, which also marked the growth and progress of the giant.

It is important to emphasize the business segments in which the company has focused during the most successful years of its work - Nokia has excelled in the foreground speed and flexibility and a healthy working environment in the company. Reference (Janićević, 2008) points out that job satisfaction, is particularly important for the successful performance of the job, where the most significant factors are suggested pleasant working conditions and relationships with colleagues, as well as clear and stable organizational structure. Top management of Nokia has always worked to build better relations with its employees, in order to achieve that the entire ‘business pyramid’ exudes a friendly presence and a relationship based on mutual respect (https://sh.wikipedia.org). Investments are focused on market research, the marketing activities which pulled millions of euros, on attracting new customers, whose number, once grew enormously. In this way, the company had the eternal desire to present itself as an innovator, whose success is guaranteed in the long run, and also, as the telecommunications giant whose accomplishments continue and seemingly can not stagnate. Enormous business successes are made by Nokia brand, which was not the follower, but the followed leader on the market.

This phenomenon was evident until a few years ago, but these changes in the market are proving their speed of occurrence and that success is not easy to keep. On the contrary, it takes years of hard work for the sake of business satisfaction, and only a few moments to stagnation and crisis. Thus, in particular, sometimes the telecommunications giant and most recognizable brand, now holds only 3% percent of the total world market(http://www.b92.net) - which is (there is no need to emphasize), so little compared to its Best business days.

Often in the allegations, which proved to be true, the emergence of Apple and Android phone is stated as the main reason for the crisis of the company. For the leaders of this company, this was the fact that at first they did not want to believe, as Nokia has always been able to adapt and that entrances and exits from many different jobs (paper, electricity, rubber boots). Especially interesting is the fact that in the nineties, when it began a sudden increase in the success of Nokia, CEOs decided to get rid of everything else except communications (http://www.b92.net) - this testifies to the potential and power of conglomerate.

However, there was a problem in business at Nokia, and it was why it did not succeed. This means insufficient guidance on producing products that consumers want to buy. Here is where the biggest flaw in the business that occured was hiding. Nokia was engineering company, which was missing more skills in marketing management in the sense that it did not directed their marketing and productive forces enough to the products, which in a given time and period should serve the purpose of customers, and not to exceed technological possibilities. This is evidenced by the fact (http://www.b92.net) that in 1996 Nokia was the company that produced the mobile phone touch screen with the ability to use the Internet, at which point it had not yet arrived ‘massive use’.

There is another flaw. Specifically, Nokia has always been truly a hardware company, considerably more than software one, and its engineers were experts in making devices, but not in the creation of programs that run these devices (http://www.b92.net). In this way, the company underestimated the

importance of the software, which is included even applications that are supposed to operate on smartphones. By comparison, Apple's experts on software and hardware looked alike, where both segments implied two equally important parts. In addition, the company failed to grasp the importance of software, Nokia has indirectly underestimated the importance of the transition smartphones - and this was, when we lookck now, a classic move by the company that was trapped in its glorious past. Management was fooled by previous 2007 results, as the company has not made the most profit from its smartphones (http://www.b92.net),so this is probably what drifted it apart of dedicating to them. Having known that it was used to their success in many years earlier, the introduction of smartphones at that time, which again was a mistake, was considered a high risk to be taken.
As far as the market changes rapidly occurring and how each move is very important, where their former results may be an encouragement but not eternal guiding star in the business, testifies failure of Nokia. The company has overestimated the strength of its brand, and believe that the averaged what was a late entry into the era of smartphones, will be able to cope with competition. For years after the success of the iPhone, Nokia was still confident that the superior design of hardware will win the customers. It certainly was not the case, because the time we live in is such that the high-tech era taught people to expect constant innovation. When it happens that companies drop out from of the race or just have difficulties to catch up, users will not hesitate to punish. Late and inadequate-this combination proved deadly for Nokia.

REENGINEERING AT NOKIA AND NEW STEPS IN BUSINESS

Nokia has definitely entered a stage when reengineering is badly needed. The aforementioned gaps are certainly authentic and are very strong reasons why the company has entered into crisis. From references (Adamovic& Seifert, 2009), which gave Herman, according to the most common situations for the occurrence of the crisis in the company, which have passed through the operations of Nokia, and they perform:

1. when existence of enterprise is threatened (profit decrease in Nokia, less productivity);
2. when a company does not have enough time to make some important decisions (stagnation of manufacturing smartphones, tardiness for its competitors);
3. when items or activities are suddenly and significantly changed (technology is changing day by day, and any deviation from any change is fatal both for any company, and the Nokia);
4. When there is no agreement about the way out of the crisis (at least present in the company Nokia, but a longer period of stagnation was allowed before acting).

Yet another feature indicates that it is time to introduce reengineering of the company. And, that's when you do not realize the correspondence between planned and realized. Just such a situation occurred this brand. The data from 2011 show that Nokia announced a huge loss with the drastic drop in sales smartphone devices –that is the price the company paid for falling behind its competitors, and the results are shown as well. Selling of samrtphones in that year fell by a whopping 32%, respectively to 2.37 billion euros (http://onlinetrziste.com). Another evidence of discrepancies between profits and losses of the company, is the fact that the company reported a total loss in 2011 of 487 million euros, while profit was 295 million euros in one quarter of that year, plus the reported loss per share of 0.10 euros (http://onlinetrziste.com). Just a year earlier, the company had earnings per share, which in 2010 amounted to 0.06 euros (http://onlinetrziste.com).More than clear that reengineering is the only solution.
Beginning of the creation of new organizations is 2013 (http://www.svet.rs). Then Microsoft bought Nokia's mobile division as well as all of its patents. Nokia was sold for 7.2 billion euros (http://www.jutarnji.hr), where Microsoft will become the owner of one of the largest manufacturers of mobile phones. Complete transaction was done in the first quarter of 2014 (http://onlinetrziste.com). In this way, the brand and the company did not stop to exist, but by entering into membership with Microsoft, it's got other dimensions, and turned their business in a new direction, which certainly reflects the presence of reengineering. This is an example of the company, which in a relatively short time had to cope with radical changes, adopted quickly and as completely changed the course of its business. Reengineering in the Nokia opens new goals and new business vision. Nokia we remember was the embodiment of the power of mobile phones recognizable by the long-term quality, great

design, pleasant to the eye and long term use. It is an era that is behind this brand, perhaps most remained as a beautiful memory as the image that we want to achieve in new products at another branch.Just in accordance with the foregoing, the leaders of Finnish companies require that the company is not dead and that the brand continues to lives, turning to some new challenges and ventures.

In 2014, the public accessed the information that the current Nokia is not in poor condition and is to prepare for a completely new business focus. This will include telecommunications infrastructure, HERE Maps and navigation systems (http://www.b92.net) .Also, the segment of interest and production will be directed to the project development 5G network, which cradle of implementation is also Finland (http://www.b92.net). President of Nokia's Board of Directors, Risto Silasma, presented as a second transaction best step for the advancement of the Nokia brand, and its shareholders (http://www.b92.net). In this process of the transaction, Microsoft will take the Asha brand and license a new Nokia brand, which suggests that Nokia still has its own brand, and it provides Microsoft with an opportunity to expand their services using their phones as a platform for Windows Phone. (http://www.b92.net). Nokia will certainly keep their patents and merger of the two companies lies in the fact that Nokia Microsoft issued ten-year license for use, while Microsoft will give Nokia the right to use patents HERE services(http://www.b92.net). About this successful cooperation is also saying the fact that the leaders think about the ongoing cooperation, at which beginning of joint operations was invested more than 250 million euros (http://www.b92.net).

Since the practical experience shows that almost 70% of typical actions performed in the reengineering does not produce results in a short time (http://www.crnarupa.singidunum.ac.rs), Nokia boasts excellent cooperation with Microsoft and, such an action, in a given situation, was the best for the company.

CONCLUSION

Reengineering is the process, whose knowledge is required in the operations of each company, as both opportunities and threats in the market is very uncertain phenomenon. It often happens that the leading giants in the global market fold down and that their their business is a question matter. Then begins the process by which it reaches for an entirely new philosophy of business and completely new targets. Many companies falter and fail that manifests on their business processes for some time, realize dramatically, which is a lack of reengineering. Like all the good in life which has to be waited and built, so we haveoperation of reengineering coming with some new experiences and winning new customers, for which Nokia is expected to win and amaze as it could and did in its best days.

REFERENCES

[1] Adamović, Ž., Sajfert, Z., (2004.), Reengineering, University of Novi Sad, Tehnical faculty ,, Mihajlo Pupin'', Zrenjanin, str. 7.
[2] Adamović, Ž., Sajfert, Z., (2009), Reengineering second edition, University of Novi Sad, Tehnical faculty ,, Mihajlo Pupin'', Zrenjanin, str. 9-10.
[3] Sajfert, Z., (2008.), Management of changes, University ofNoviSad, Tehnicalfaculty ,,MihajloPupin'', Zrenjanin, str. 91.
[4] Janićević, N., (2008.), Organisational behaviour, Data Status, Beograd, str 92.
[5] http://www.crnarupa.singidunum.ac.rs/ , dr Milenko Heleta, Basics of reengineering part III, 2009.
[6] https://sh.wikipedia.org 30.06.2015
[7] http://www.b92.net 04.09.2013.
[8] http://onlinetrziste.com 21.07.2011.

MONITORING OF IONIZING RADIATION

Aleksandra Felbab[1], Olivera Paunović[1], Bogdana Vujić[1]
[1]University of Novi Sad, Technical Faculty "Mihajlo Pupin", Zrenjanin, Serbia
e-mail: aleksandrafelbab@yahoo.com

Abstract: Radon is a radioactive inert gas with no color taste and smell formed from the decay of two radioactive chemical elements uranium and thorium. The formation of malignant diseases in humans due to the presence of radon is a consequence of ionization in cells, resulting in disfunction of a group of cell. In order to take adequate measures to reduce the harmful effects of radon and protect human health, it is necessary to monitor concentration levels of radon indoors. Considering that on the territory of Serbia is currently implementing the actions of measuring radon in homes, the aim of this study is to investigate the level of consciousness and knowledge of citizens about radon, its sources and harmful effects. Also one of the aims was to raise consciousness of the need to improve health and the environment protection. This paper describes a study that included 62 people interviewed. People were divided into two groups. One group of tested people encompassed students of primary and secondary schools, while other group of tested people included working age population. The questions are divided into four groups and included the following: *knowledge of the basic properties of radon, knowledge of the harmful risks and ways of protection from ionizing radiation, and ways of raising awareness about the importance of preserving the environment.* The survey confirmed the hypothesis set at the beginning of the study. It was concluded that there is a correlation of years and professional qualifications of the respondents about the knowledge of basic characteristics and ways of protection of ionizing radiation. On basis of the results it can be concluded that the respondents of all ages, qualifications half aware of the need of continuous education and raising awareness about the importance of preserving and improving the environment.
Key words: radon, monitoring, education, ionizing radiation

INTRODUCTION

Radon is a radioactive inert gas with no color taste and smell formed from the decay of two radioactive chemical elements uranium and thorium. In nature, there are 23 isotopes of radon, and the most dangerous for the environment and human health is 222Rn, which is represented with a share of 80% of all radon isotopes [1]. The physical elimination half-life of radon is 3,824 days. During this process α particles are emited. This type of particles has high level of ionisation, which can couse cell disfunction and cancer. It has been determined that it is much more harmful for human health if particles of radon are directly inhaled. [2]. The concentration of radon in the air of outdoor open space is small while radon in indoors air can reach high values. Studies have shown that radon can be found even in drinking water but to a much lower level than in the indoor air [3]. The main source of radon in the indoor air is the soil where the facility is built. Radon inside the building reaches out of the crack in the land, building materials and air vents. Concentration levels of radon indoors depend primarily on the type and characteristics of the soil. Thus, in the facilities of countries where there are sedimentary land like Germany, Netherlands, Polish, UK, there are lower concentrations of radon, while the facilities in countries where land is granite such as Austria, Czech Republic and Finland is present a higher concentration of radon [4]. Also, indoors concentration of radon depends on the mobility of the radon in the soil, speed diffuse radon through different materials, characteristics of building materials [5]. An example of material for the construction of buildings for the presence and concentration of radon are considerably higher levels of this element in the closed rooms of the buildings constructed of blocks which are the basic characteristics of porosity and ventilation [6]. Weather and time of day can affect the amount of radon. For example, early in the morning radon concentration is a maximal due to the inversion of the temperature, which prevents the vertical air flow which leads to an extremely stable atmosphere. Radon gas is heavier than air so the highest concentrations can be detected on the ground floor [7]. Twenty-first century brings a modern technology that under the present circumstances leads to a reduction of human activities and increased the number of hours spent indoors, it can lead to a potentially higher exposure to radon. Because of all these facts, the International Agency for Cancer conducted a survey in Europe, North America and China where, after the case studies, came to many conclusions about radon as a dangerous element for the population. One of more important assumptions that is confirmed that radon greatly contributes to lung cancer and leukemia [8]. Recent research conducted in Europe, Asia and North America have shown that radon is the leading cause of lung cancer and leukemia. According to data from 2010, European emissions of this gas is 12% of total world emissions radon [9]. Therefore, the World Health Organization (WHO) suggests that it is necessary to establish a legal framework for the population protection from radon [10] . In Serbia, there is a legal framework that regulates the field of ionizing radiation. According to the Ordinance on the limits of exposure to ionizing radiation emergency levels of exposure to radon in homes is equal to the annual average concentration of 200 Bq/m^3 in the air of new buildings and 400 Bq/m^3 in the air existing buildings [11]. Compared to the EU, these levels are aligned, but it is necessary to revise and set new limit values in order to improve living conditions, exposures radon and preservation of human health. With the aim of establishment of concentration levels, tracking trends and determining measures to reduce the impact of radon on human health, it is nessesery to perfor monitoring in enclosed spaces [12]. In Serbia, the first studies that were related to the measurement of the concentration of radon in indoor premises was carried out on the territory of APV 2003 [13]. The study included 1000 locations in all 45 municipalities in Vojvodina. Measurements were repeated in 2004 and covered 1000 locations in 45 municipalities, provided that the measurements are repeated at locations where the previous campaign measurements recorded elevated concentrations of radon. After the implementation of the monitoring made the first radon map for Vojvodina (Figure 1)

Figure 1. Radon map of Vojvodina in period December 2004 – March 2005 [13]

The Agency for Protection against Ionizing Radiation and Nuclear Safety and the National Program of radon measurement is re-established monitoring of concentration levels of radon in the territory of Serbia, which will be implemented during 2015 and 2016 [15]. Monitoring of radon indoors is performed using a device that is necessary to locate and households the aim of this paper is to examine what is the of familiarity of the population with negative effects of radon on human health, radon sources, as well as the reasons for its increased concentrations. Indirect objectives are to raise knowledge about the impact ionizing radiation and radon on human health, especially on the part of the population that gave no consideration to this problem. Also, one of the aims is to inform the population of the harmful effects and the measures to be taken in order to reduce the level of radon indoors, and therefore adverse effects.

MATERIAL AND METHODS

Research Area

The survey was conducted in the city of Zrenjanin, the administrative center of the Central Banat district in the city that has a population of 76,511, in the municipality of a population of 123.362. The total area of the municipality is 1324 km^2 [16]. The results of measurements of radon concentrations that were implemented during 2005, in the city, showed mean values of radon of 123 Bq/m^3, while the concentration levels on the territory of municipality were from 9 to 293 Bq / m3 (Table 1).

Table 1. Voncentration of radon in the municipality of Zrenjanin in 2005 [13]

Serial number.	Place	Activity concentration of radon Bq/m^3
1.	Zrenjanin	123
2.	Kumane	216
3.	Melenci	59
4.	Aradac	293
5.	Tomaševac	111
6.	Perlez	90
7.	Stajićevo	9
8.	Lukićevo	203
9.	Lazarevo	38

Based on these results, it can be concluded that the area in the city of Zrenjanin belongs to an area with low levels of natural radioactivity as its value for the most part does not exceed the legal time frame (Figure 1 and Table 1).

Hypotheses research

The main hypothesis – There is a correlation years and professional qualifications of the respondents about the knowledge of basic characteristics and ways of protection of ionizing radiation

Hypothesis No. 1: Knowledge of the respondents employed in the chemical and pharmaceutical industry about the harmful effect upon ionized radiation

Hypothesis No.2. Knowledge of respondents about how to protect their businesses from the damaging effects of ionizing radiation

Hypothesis No. 3. The children during their schooling do not acquire a clear picture of the hazards brought by ionizing radiation and methods for their protection

Hypothesis No. 4. Adequate motivation through various training seminars and promotes a greater proportion of respondents in training to raise environmental awareness and improvement of the environment

The method of investigation

Data were collected by questionnaire in which he stated that the survey is anonymous and the results will be used exclusively for research.

The questionnaire consisted of 4 groups of questions:

1. Knowledge of the basic properties of radon,
2. Knowledge of the harmful effects of radon,
3. Methods for preventing and reducing the risk of ionizing radiation, and
4. Methods of raising awareness about the importance of preserving the environment

RESULTS

The study included people of various age, gender and occupation, so due to specific issues gain a clearer picture of the level of knowledge about the properties of radon, under-utilization and ways of protection from ionizing radiation or radon. It should be noted that the study included primary and secondary schools, covering the most vulnerable part of the population.

The study involved two groups of responses:

1. 42 surveyed people aged employees and students (over 22)
2. 20 children interviewed in primary and secondary schools (10-16 years).

Table 2. Age structure I group

Age limit	Obtuseness (%)
22- 25 years	12%
25-35 years	24%
35-45 years	35%
45- 55 years	5%
55-65 years	12%
65 years	12%

Table 3. Structure of respodents and groups of qualifications within the I gropu

Qualification	Obtuseness (%)
III skilled worker	- **10%**
IV secondary education (4 years)	- **17%**
The highly skilled worker	- **17%**
VI (VI1 and VI2) higher education (and university level)	- **10%**
VII1 Higher Education	- **36%**

Table 4. Structure respondents to success in school within the II group

Student achievement	Zastupljenost
Enought	**2%**
Good	**10%**
Very good	**29%**
Excelent	**59%**

Based on the analysis of data and groups it was found that most respondents younger age (22 to 25 years) is not aware of even the basic characteristics of radon, but 72% of respondents pointed to the harmful effects of ionizing radiation that causes one of malignant diseases, allergies, anemia, skin diseases and leukemia. Also, the group of respondents aged 35 to 45 yeras according to the companies and organizations whose employees they are, very rarely mentioned the impact of the measures of protection against the harmful effects of this element. On the other hand, respondents between the ages of 45 - 55 years and of 55 - 65 years, point out that in their companies was performed to improve the protection of workers from the effects of ionizing radiation (Figure 2).

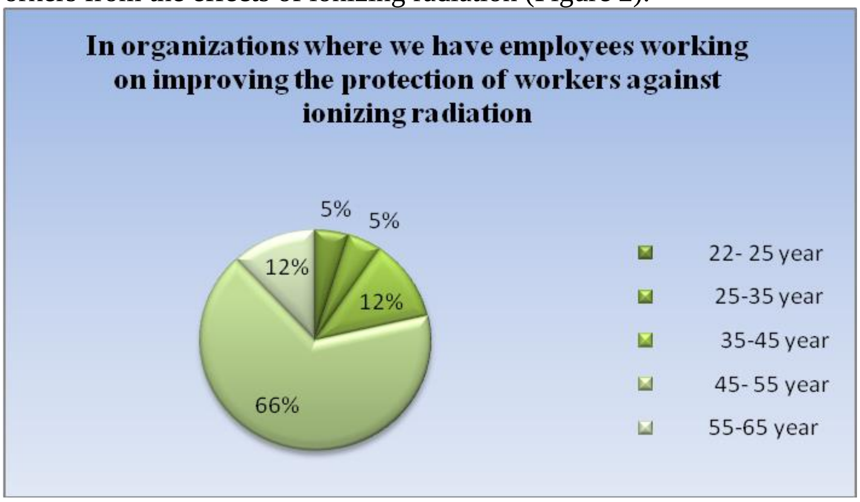


Figure 2. Improving the protection of workers from the effects of ionizing radiation

Even 71% of respondents said they agree that it is necessary to have a specific education about protection against ionizing radiation, which was found to have sufficient consciousness about the nessesity of education (Figure 3). Study group, which included elementary and secondary school (group II) made up the majority of students receiving a great success (59%). This group of respondents pointed out that so far very few have had the opportunity to learn from their teachers about the impacts and ways of protection from ionizing radiation. The fact of is that the 73% of subjects in primary and secondary schools, are not sufficiently aware of how these elements can have harmful effects on their health (Figure 4).

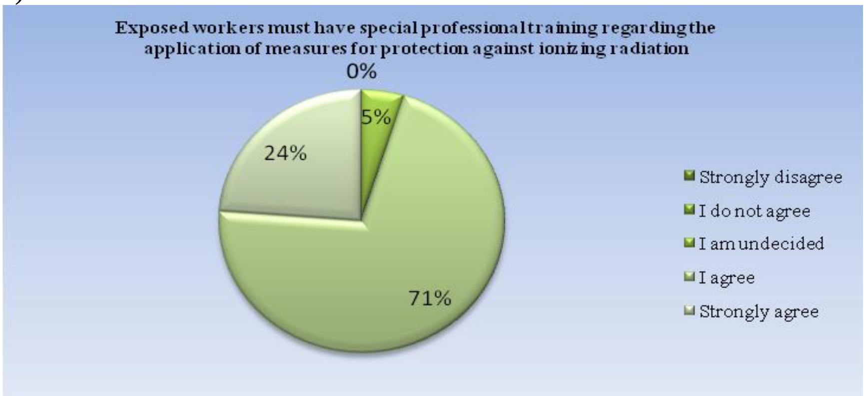


Figure 3. Continued high awareness among employees about the needs of education

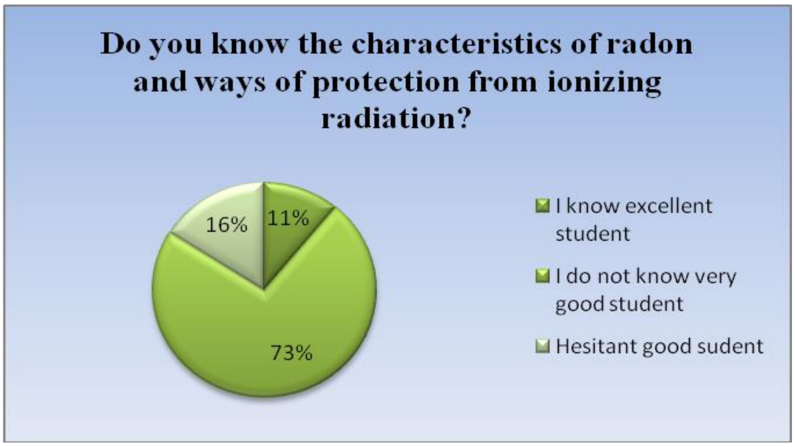


Figure 4. Knowledge of the basic characteristics and ways of protecting group II surveyed people

Within the group of questions about the importance and ways of raising awareness on environmental preservation, respondents aged over 65 years old consider that in the previous period because of the growing pollution necessary to take strict measures to improve the general quality of life. The percentage of 95% of respondents in their organizations are perfect places to feel that increasingly encourages the preservation of the environment as part of their work organizations, and 5% of respondents who are holding an executive position emphasizes that encourages its employees to constant improvement in the environmental protection. Respondents of all ages mostly agree with the fact that it is present on the Internet an adequate amount of information on the hazards of radiation. The percentage of 62% of respondents believe that the knowledge is individual and depends on us. Also, more respondents (82%) agree or fully agree with the fact that the persons who work with sources of radiation susceptible to malignant diseases.

CONCLUSION

Taking into account that the radon, a radioactive element that is present in the household due to the ground structure, type of construction materials and other factors very harmful to human health, causing malignant fall sick planning and leukemia, it is necessary to carry out regular monitoring of concentration levels of this element in enclosed spaces. On the territory of APV in the period between 2003 and 2005 carried out radon measurements in enclosed areas, whereby the first Radon map also made during 2015. The Agency of Protection against Ionizing Radiation and Nuclear Safety of Serbia continues measurement of radon in the indoor environment on the territory of Serbia. In order to examine the level of knowledge and awareness about radon, its resources, adverse effects and ways of protection, in the city of Zrenjanin, the survey was conducted, which included a total of 62 subjects (group aged 22- 65 years, and group II pupils Mid-sized and primary schools). The research results within the second group of respondents indicate that most of them are not familiar even with basic adhesive labels radon but that there is a high enough awareness of the needs of education. While the research results within the second group of respondents indicate that students during their education have little opportunity to improve and update their knowledge in the field of ionizing radiation, as well as during their education do not acquire a clear picture of the preventive measures for protection against ionizing radiation. Based on survey results entire led to the general conclusion that it is necessary to work on more training and public awareness of ways to protect the basic properties and characteristics of ionizing radiation and of radon, which would permanently radio and health of the population. The results obtained during the research, suggest that citizens need to be constantly motivated and show them the importance of improving environmental protection.

REFERENCES

[1] Vitorović Dragomir, “Hemijska tehnologija” Naučna knjiga Beograd, 1980.
[2] Cvetković Ružica: Hemijsko inženjerska termodinamika, Niš: Izdavačka jedinica Univerziteta, 1996
[3] Predrag Osmokrović, „ Osnovi nuklearne fizike“ Akademska misao, Beograd, 2008
[4] http://www.biomedicinskaistrazivanja.com/prethodni-brojevi/godiste-3-broj-1-jun-2012/
[5] Tatić Vujadin “ Patologija za studente više medecinske škole“ Medika graf 2004.
[6] Mitrović Vladimir, „ Arhitektura XX veka u Vojvodini“ Akademska knjiga 2010.
[7] Savić Ivo,” Ekologija i zaštita životne sredine”, Zavod za udžbenika, Beograd, 2013.
[8] http://www.cancerresearchuk.org/about-cancer/find-a-clinical-trial
[9] Bishop, Charles E, „Radon-hazard potential of Beaver basin area, Beaver County, Utah“ (Special study), Unknown Binding, 1998
[10] http://ec.europa.eu/priorities/energy-union/index_hr.htm
[11] Pravilnik o granicama izloženosti jonizujućem zračenju (Službeni list SRJ br 32/1998.)
[12] Fajnman Ričard, “ Neobična teorija svetlosti i materije”, Heliks, 2011.
[13] https://www.pmf.uns.ac.rs / I.Bikit, J.Slivka, M.Vesković, N.Žikić-Todorović, E.Varga, S.Forkapić, D.Mrđa, J.Hansman, T.Jeftić, “Izveštaj o monitoringu koncentracije radona u zatvorenim prostorijama na teritoriji Vojvodine 2003/2004 godine“ Novi Sad 2004.
[14] http://www.ekourb.vojvodina.gov.rs/ аутоматски-мониторинг-квалитета-амбијенталног-ваздуха
[15] http://cosmic.ipb.ac.rs/ http://147.91.87.156/radon/
[16] webrzs.stat.gov.rs/WebSite/public/PageView.aspx?pKey=711&URL=http://pod2.stat.gov.rs /ElektronskaBiblioteka2

SELECTION OF LUBRICANTS FOR LUBRICATION OF MEHANICAL TRANSMISSIONS

Ivan Lukić
University of Novi Sad, Technical faculty „Mihajlo Pupin“ Zrenjanin, Serbia
e-mail: ivanlukić64@gmail.com

Abstract: In this paper are shown basic procedures and instructions with spreadsheets, technologies of lubricating mechanical transmissions from the aspect of maintenance. Lubricants that are used in these procedures are presented in the applicable standards: SRPS, AGMA, and SAE gradation. This study covers lubrications of standard transmissions which include: outdoor and indoor gear transmissions.
Key words: Mechanical transmission, Lubrication, Lubricants for lubrication.

INTRODUCTION

Since friction represents one of the constituent elements of all mechanical joints and it can never be completely annul it affects all mutual movements of the objects that are in contact with each other. Since this work defines the topic that relates to mechanical transmissions where during the coupling of gears as well as during movement of coupled gears friction is inevitable factor, it can never be completely annul. The basic task of lubricants in this composite system of mechanical transmissions is that it enables not only lubrication and reduction of wear of contact surfaces of teeth in the gear that will enable longer and more stable operation, but also another function of lubricants beside its role of enabling less friction is dissipation of heat that occurs during the teeth friction with each other while power is transmitted. Although lubricant should reduce wear and tear of coupled gear elements, their teeth, it cannot completely provide maximum reduction of friction, friction will always be somewhere present but in certain minimum quantities which depend on the selection of lubricants, this relates especially to gear parts that are not fully exposed to the lubricating agent i.e. areas that are not fully or only some part coated with lubricant where due to centrifugal force and due to rotation leads to poor retention of lubricants, this applies to the tooth flanks where we have the greatest friction due to rotation. Most often in these segments of transmission unfavorable element is slightly dampened surface which leads to the occurrence of increased friction, and that causes wearing and tearing of the flanks that have crucial influence on the occurrence of termination of transmission. In order to alleviate these occurrences lubricant injection is inserted under pressure between gear teeth especially in those gears that are turning in high speed.

BASIC PROPERTIES OF LUBRICANTS AND TYPES OF LUBRICATION OF THE GEAR TEETH

For lubrication of the gear teeth we apply following types of lubricants: solid lubricants in gear teeth that are moving at speeds of up to 3 (m/s), technical greases in gear teeth that are moving at speeds of up to 2.5 (m/s), oils (mineral and synthetic) [4]. In order to perform correct selection of lubricants for gear teeth, it is necessary to classify the characteristics of lubricants in order to make lubricating process optimal. These features include: stability in exploitation i.e. to retain its chemical and physical properties when changing flow velocity, operating temperature and pressure, to have good lubricating properties, good thermal conductivity, and small change in viscosity with temperature and pressure change in working range that is resistant to the occurrence of foam and emulsion, to have good resistance to oxidation and aging, that is less active toward rubber, metals, plastics and that is free of solid impurities. Besides already defined characteristics that lubricant needs to fulfill for his correct choice in gear and sprocket lubrication technology we must take in to account following characteristics which include: rate of air separation that shows at which speed the air bubbles will appear on the surface of the liquid (oil) for lubrication, property of a working fluid to bubble i.e. speed of breaking the bubbles separated on the surface of lubricating liquid in the form of foam. Lubrication is a procedure that reduces friction and wear of the material by introducing lubricant between the surfaces in relative moving. It includes the following activities: cleaning-rinsing of the sliding surfaces, switchboards installation lubricants, aggregate for lubricant supply (pumps, filters), checking of the condition of the lubricant, filling the lubricant, replacement of lubricants, regulation of spent oil and other [5]. Depending of what is the mutual relationship of the surfaces that are moving as well as the manner in which this has been achieved we distinguish the following types of lubrication: hydrodynamic, hydrostatic, elastic hydrodynamic, boundary lubrication.

CORRECT SELECTION OF LUBRICANTS FOR LUBRICATION OF THE MECHANICAL TRANMISSIONS BY ACCORDING STANDARDS

Correct choice of lubrication plays very important role at the mechanical power transmissions because proper selection of lubricants will not only reduce friction and wear butt will also preserve coupled system from numerous failures that may occur by using inadequate lubricants. So we can say that there are following lubricating agents for open and closed systems of transmission. In open systems for lubrication of mechanical transmissions are mainly used two lubrication systems for lubrication of cogs and gear with oil. Those systems are: system of sinking sprocket teeth in the oil bath and injection system i.e. system that brings oil under pressure by means of nozzles in between teeth of the sprocket. During lubrication by immersing sprocket with its bottom part dives in to the oil bath so that the depth of immersion is 1-5 of the sprocket module. This kind of immersion is used for high speeds of sprockets up to 15 (m/s) [1]. Lubricating oil injection is used for higher gear speeds and the advantage of this method of lubrication is reflected in constant circulation of the same oil in the lubrication system. This method significantly reduces oil consumption. In order for this lubrication system to function it is necessary to include following basic components: a drive unit for providing a permanent oil circulation (circulation pump), cooling system for circulating oil (refrigerator), a pipe system with fittings for flow circulating oil (thermometer, manometer). For proper lubrication of the gear teeth in this manner, it is necessary to ensure that the operating temperature does not exceed the value of 60 - 80 ºC, because higher temperatures lead oil to rapid aging. For lubrication of closed gear transmissions in technical systems with low speed of revolution liquid fat is used. The amount of fat is determined according to the measures of the gear while the mod of lubrication is performed continuously. Recommendations for the choice of lubricating oil in the gear teeth are characterized by oil viscosity depending on the power and speed of the mechanical gear. (Chart 1) [2] Displays the review of characteristics. The above mark is valid for lubricating all types of gear in the technical systems in general mechanical engineering. An oil change should be performed after every 1000 – 5000 operating hours, depending on the type of the gear load. During the running of the system oil change should be performed after every 20 – 30 working hours. In addition to the basic table that is listed on the choice of oil for manual transmission the recommendation is given and the selection of lubricants for open gear drives according to standard SRPS:B:H3.270-274. . (Chart 2) [2] Presents the characteristics. Recommendations for choice of lubricant and grease type for gear transmission on the technical systems are defined according to standard ISO. (Chart 3) [2] Provides an overview of characteristics. For lubrication of mechanical power transmitters for motor vehicles, mining and construction machinery, agricultural machines are used recommendations for the selection of lubricants that are shown in (Chart 4) [2]. (Chart 5) [2] Shows approximate value of motor oil gradation and oil for gearboxes and differentials according to SAE. (Chart 6) [2] Division of oil for closed gear transmissions was performed that conform to the ISO groups from 46 to 1000.

Table 1. Oil viscosity data η (Pa s /50ºC) for lubrication of the gear teeth [2]

circumferential velocity of the gear (m/s)	**Ft / (b-mn) Ft-circumferential force on the sprocket, mn-modul of gears**		
	12,5	12,5-30	30
0.5	0,135	0,274	0,410
0.5-2	0,720	0,135	0,274

Notice: Oils that are used for lubrication gears are alloy (oils with the addition of EP additives) that is for strong loads and higher capacity hypoid oils.

Table 2. Recommendations for choice of lubricant and grease type gear trains on technical systems [2]

Types of lubricants	**Methods of lubrication**
Bitumen based lubricants	Manual lubrication, brush
Lubricants with solvents that result in a solid film after evaporation	Manual or automatic, with spraying
High viscosity oils with EP additives	Dripping, spraying, continuously or intermittently

Table 3. Recommendations for lubrication of mechanical power transmitters for motor vehicles, rudarko construction machinery, agricultural machines [2]

Lubrication oil designations	**Viscosity at 40ºC**	**Viscosity index**	**Ignition point ºC**	**Pour point ºC**
ISO L – CKC 68	68	95	220	-25
ISO L – CKC 100	100	95	220	-20
ISO L – CKC 150	150	95	220	-18
ISO L – CKC 220	220	95	230	-15
ISO L –CKC 320	320	95	235	-12
SAE gradation				
80 W	11	90	165	-27
80-90 W	14	95	180	-27
85-90 W	17	95	180	-19
85-140 W	26	90	200	-12
90 W	18	90	180	-19
140 W	31	80	210	-12

Notices: This is the group of high quality oils with EP Additives that are used for industrial gear transmissions that work in temperature range from 15 -120ºC.They are used for lubrication of heavily loaded gear of all types of gear teeth and the load.

Table 4. Recommendations for lubrication of mechanical power transmitters for motor vehicles, rudarko construction machinery, agricultural machines [2]

Vehicles	**Mechanical gear transmissions**	**Automatic gear transmissions**	**Diferential (hypoid) transmissions**	**Differential gear (conical with arched sprockets, worm)**
Passenger vehicles	SAE 80 (EP)* SAE 90 (EP) or multigrade	Fluids for automatic transmissions ,ATF	SAE 90 (EP) or multigrade	-
Duty vehicles	SAE 80 (EP)* SAE 90 (EP) or multigrade	SAE 80 (EP) for semi automatic transmissions,ATF fluid for automatic transmissions	-	SAE 140 or multigrade

Notice: When choosing EP additives we must consider compatibility with the materials from which are made the elements of the transmission.

Table 5. Approximate value of gradation of motor oil and gear oil and differentials according to SAE viscosities [2]

SAE gradation (SAE number)	Engler degree °E	Viscosity grade name
For motor oil SAE		
10 W (winter conditions)	2,5-3,35 / 50°C	Very light, winter
20 W (winter conditions)	3,35-6,75	Light, winter
30 W (winter conditions)	3,34-6,62	Light
40 W (winter conditions)	6,62-9,84	Medium
50 W (winter conditions)	9,84-14,20	Heavy
-	14,20-21,80	Very heavy
For gearbox and differential oil SAE		
75 W	3,0-4,0 / 50°C	Very light
80 W	7,0-10,0	Light
90 W	12,0-25,0	Medium
140 W	3,4-5,6 / 100°C	Heavy
250 W	Above 5,6	Very heavy

Notice: SAE is determined, for winter conditions at 0°F, and at 210°F with other oils

Table 6. The division of oil for closed toothed gear [2]

AGMA number	ISO viscous group	AGMA number	ISO viscous group
1 EP	46	6,6 EP	320
2,2 EP	68	7comp,7 EP	460
3,3 EP	100	8 comp,8 EP	680
4,4 EP	150	8A comp	1000
5,5 EP	220	-	-

Notice: All of the oils contain additives against corrosion and oxidation groups 7comp, 8 comp and 8A comp contain from 3 do 10 % fatty oils.

Table 7. The division of oil for closed toothed gear [2]

Axial distance (mm)	Type of the auger transmission	Auger revolutions number (ob/min)	AGMA number Temp. environment °C		Auger revolutions number over (ob/min)	AGMA number Temp. environment °C	
			-10 do 15	10 do 15		-10 do 15	10 do 15
Do 150	Cylindrical globoid	700 700	7 comp 8 copm	8 comp 8A comp	700 700	7 comp 8 copm	7 comp 8 copm
150 – 300	Cylindrical globoid	450 450	7 comp 8 copm	8 comp 8A comp	450 450	7 comp 8 copm	7 comp 8 copm
300 – 450	Cylindrical globoid	300 300	7 comp 8 copm	8 comp 8A comp	300 300	7 comp 8 copm	7 comp 8 copm
450 – 600	Cylindrical globoid	250 250	7 comp 8 copm	8 comp 8A comp	250 250	7 comp 8 copm	7 comp 8 copm
Above 600	Cylindrical globoid	200 200	7 comp 8 copm	8 comp 8A comp	200 200	7 comp 8 copm	7 comp 8 copm

PHASES OF LUBRICATION

Since lubrication represents very important segment in functioning of the mechanical transmission system its maintenance will enable long and unhindered operation without cancellations mainly cause by wear and tear of the gear flanks and other constituent elements. Lubrication planning is based on a set of stages that enables preventive maintenance of the mechanical transmissions. This set of activities should enable reliable and available operation of the mechanical transmissions in a given time period. Following maintenance phases are [3]:

Phase 1, inspection: Inspection of the entire technical system that requires lubrication i.e. determining what needs to be lubricated.

Phase 2, planning: Determine when to perform lubrication, i.e. assess the frequency of lubrication.

Phase 3, lubrication program: There are four main source of information for the development of a good lubrication program. Sources are:

- Manufacturer of the technical system;
- Manufacturer of lubrication;
- Other users of the technical system;
- Own experiences

Phase 4, implementation of the lubrication program: It is always the best for one person to be in charge for the maintenance of the technical system and to carry responsibility. Tasks for such a person would be:

- Establishing group for lubrication and an accurate accounting of the work program.
- The definition, organization, premises when performing lubrication activities.
- The division of responsibilities by individuals.
- The training of the lubricants.
- Providing a balanced supply of lubricant from the storage.
- Establishment of feedback to monitor irregularities and improvement of products.
- Development of computerized lubrication program and maintenance control system.
- Motivating staff that conducts lubrication to check the equipment before carrying out maintenance activities.

CONCLUSION

The main task of this study is to provide single cover basic characteristics of lubricants for mechanical transmissions in general mechanical engineering. Tabular views are selected according to the characteristics of the gear, and they clearly show the basic characteristics of lubricants as well as to serve all personnel in the maintenance of technical system that they in their operational practice meet and lubrication technology for easier operation.

REFERENCES

[1] Ž. Adamović, S. Stefanović, Lj. Josimović, O.Momčilović, N. Jevtić, G. Jovanov, Podmazivanje mašina, OMO, Beograd, 2003.
[2] Zbornik radova osme internacionalne koferencije o tribologiji,Beograd ,2003.
[3] Ž. Adamović ,Totalno održavanje ,Tehnički fakultet ,,Mihajlo Pupin" , Zrenjanin,2005.
[4] S. Veriga , Mašinski elementi III, Prenosnici, Mašinski fakultet, Beograd, 1993.
[5] A. Vulić, Prenosnici snage, Skripta, Mašinski fakultet, Niš, 1992.

BENEFITS OF IMPROVING THE MODERN METHOD OF DRYING IN FOOD INDUSTRY

Aleksandra Felbab[1], Ivan Palinkaš[1]
[1]University of Novi Sad, Technical Faculty "Mihajlo Pupin", Zrenjanin, Serbia
e-mail: aleksandrafelbab@yahoo.com

Abstract: This paper deals with the drying as one of the technological operations in food processing industry. Modern technologies allow us to use a large number of appliances which are dried matter. Their increased use therefore contributes to increased adverse risks. The final goal is to promote modern methods and presentation of economic and environmental advantages that their improvement and training give. Alternative and modern drying technology contribute to higher profitability in the food industry. In our country it is necessary to work on better and better promotion of the drying system by solar energy and it should be encouraged to use alternative energy sources. Due to the fact that this method does not have a detrimental impact on health people and the environment, energy efficiency is at a maximum.
Key words: drying food, alternative energy, energy efficiency

INTRODUCTION

One of the first simplest methods of preservation is drying By the use of solar energy. Marco Polo in his writings with research travel spoke with pride about his method. Followed by a number of other research. Researchers like Nicholas Aspert, Olson, Gall Borden leave a big mark in the history of drying technology. Great innovation in food technology the fifties of the twentieth century brings Peebles, process instantiation. Wanting to dry the product, and whilst maintaining the same quality. Internationally recognized experts from different fields in the book "Blue Drying Technology" includes an overview of all the important aspects of the drying material. They are dedicated to the processing of modern methods of infrared radiation, microwaves, powerful forces ultrasound, oscillating magnetic field. Aiming to improve the qualitative value of the dried product, energy-saving, and reduce drying costs, and thus increase profits.[1] Nordic scientists believe it is necessary to perfect modern drying methods in those parts of the world where economic resources are very limited. It is necessary to create drying systems with alternative and renewable energy sources. The development of solar energy in Serbia is based mainly on winning production devices application for low-temperature conversion of solar radiation into heat.[2] The choice of method of drying primarily affects the shape of the particles to dry - if the matter is a fine grained, unitary, fiber, liquid or solid form as well as the amount of matter. (Table 1.)

Table 1. Possible use of certain types of dryers depending on the characteristics of raw materials

Characteristics of raw materials	Liquids			Powders		The solid			Solid bodies
	Dissolved	Puree	Pastes	Centrifuge	Filter	Powder	Granules	Fibres	
Convective dryers									
Fluidized bed	*	*		*	*	*	*	*	*
With sprinkler	*	*	*						
With tunnel				*	*	*	*	*	
Conductive dryers									
With drums	*	*	*						
Rotational				*	*	*	*		
With tunnel				*	*	*	*		*

It is also important to take into account the prices of dried matter. They must not neglect ergonomics driers. Modern kilns in a constructive sense, should meet ergonomic requirements and to be cognizant of environmental protection. Because of all these facts, it is very important to determine for what we want to use the dryer. Different methods of wide special methods, tunnel, chamber, or drying in a vacuum are just some of the traditional methods that can be used to dry the material. Recent research shows that increasingly developed modern and more efficient technologies that suppress the traditional ways of drying. For this reason it is necessary to work on creating energy efficient systems in our country. Food technology represents a significant role in economic development, constantly developing new facility for economic efficiency.

TRADITIONAL METHODS OF DRYING

The process of dehydration water was used since ancient times. Inhabitants of the Middle East and Asia have water from the foods removed by evaporation in the air, fuming, and drying in the sun. Traditional method that we now want to revive and advance. Drying dairy products experiencing its expansion in the twentieth century. Research shows that at the same time develop other ways of drying out in the dairy industry and in the entire food industry. Innovation drying on the rollers and spray-drying enabled the raw materials and manufacturing various products of high quality. Great strides in industrial applications is the emergence of ultrafiltration and electrodialysis. [3] It was to save energy and at the beginning of the twentieth century introduced multistage evaporators with continuous operation. At a time when in the fields of international technology appear findings of American membranes. Years back nanofiltration experiencing expansion in the food industry. The main advantage of the traditional method of spray drying is to preserve the quality and multiple efficiency. The process is very fast and requires minimal labor. Yet this great advantage also brings with it a number of disadvantages from a reduction in the quality of dried products over large energy losses. Therefore, when planning the fuel supply should primarily take into account the best possible utilization methods of natural drying or possibly on the use of free sources of waste heat. Traditional methods also include natural drying and drying with the help of technical means for heating.

Natural and technical drying

The natural drying dry falls to the ground, which is carried out by flowing air at ground distributed materials. The second method is a natural warming drying self-heating. For technical drying are typical drying systems including ventilation cooling, ventilation drying, drying with hot air, hot air drying. Compared with ventilation drying applications drying with hot air leads to significantly better effects. Methods technical drying characteristics for rotary kilns, dryers with a stirrer, strip and driers circulation or continuous-drying.[4] These methods are most suitable because they can cause great losses. To achieve better effects of this method it is necessary to work on their constant training. In the food industry many types of processes are represented as drying which is shown in FIG. (Figure 1)

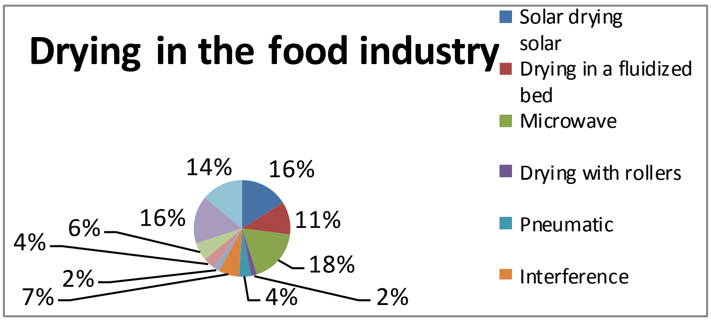


Figure 1. Drying in the food industry

Chamber tunnel and rotary kilns

The chamber drying kilns smaller unitary material (plastics, grain, crystal, textile materials ...) Parts chamber kilns are Bases, lese, steam pipes, drainage channels and crafts butterfly). (Figure 2) The Chambers shall be well insulated to minimize heat loss. The lack of such dryers is that drying takes a long time, have very little effect and drying of raw material is uneven. Tunnel kilns these are indirect drying chambers with forced convection. Characteristics of this dryer is that they are used for drying large quantities of materials. Rotating kilns make long slanting cylinders that slowly rotate small and bulk material. Drying food products requires very careful selection of dryers. These methods are not considered by us eat more preferred because it turned out that during the drying requires changes in store, acting on their physiology, influencing the aroma, in some segments may have impact on the nutritional value of foods. Create big losses because of which they are also viewed as much less efficient in relation to modern methods of drying in the food industry.

Figure 2. Chamber and tunnel dryers [5]

Drying with rollers thick and liquid materials

Today, the rollers drought many substances: resins, coatings, adhesives, as well as groceries. Most of the dried products in the food industry this method is obtained by drying. The advantage of this dryer is discontinuous in their work, because in this way reduces energy consumption. One of the binding to some technical issues is the question of heating rollers which are usually heated by steam which is one of the more expensive procedures.[6] The quality of the finished product dried on the rollers depends not only on temperature and duration of drying and the temperature of the incoming raw materials as well as its degree of concentration, coating thickness and uniformity of the raw material on the rollers. For warming roll is used a dry saturated steam temperature to 150 ° C, which is supplied to the interior of the roller through a shaft.[7] The speed of rotation of rolls is particularly important because of it depends on the thickness of the layer applied and the duration of contact materials with hot surface of the rollers. The removal of condensed vapor is carried out continuously, the pump at the other end of the roller shaft. In the food industry drying stodgy material is made by mixing it also represents one of the more expensive ways with large losses and reduced profitability.

MODERN METHODS OF DRYING

It is the most rational production where there is no waste, one in which the raw materials and energy is completely used. Such technology is safe for the environment.[8] However, every day there is a burgeoning and consumers are becoming more educated and more informed. They begin to evaluate how ecological characteristics of the RTD and those economically viable for them. The imperative of modern economy becomes rational use of natural non-renewable resources and environmental protection as well as to the RTD must be unique, affordable and convenient to all interested consumers, depending on the domain of their production. In food technology start to use the spectrum of solar energy, wind energy and biofuels. The advantages of this system are manifold which can be seen on the display next picture. (Figure 3) Systems of drying, filtration demineralization, conservation and storage of food in increasingly use renewable sources. Research shows that companies are increasingly applied technology solutions that save resources and are environmentally sound. Innovation, which appeared in the course of 2014 is the development of automated continuous flow dryers for fruits, vegetables and herbs are based on the principles of energy efficiency. Also present on our market for energy efficient kilns that use solar energy and biofuels. Today, if we are to succeed in their business sphere it is necessary to comply with many aspects. It is necessary to increasingly develop computer programs for the food industry. These methods shorten the procedures, the financial means at need to invest is diminishing. Improving Traditional methods of spraying to expand the product range with higher earnings. Cost becomes bigger and minimizing waste.

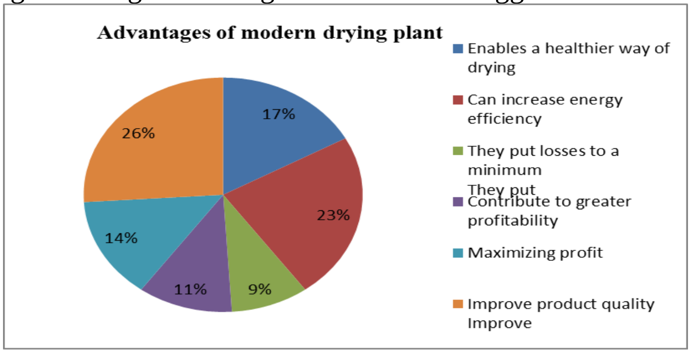


Figure 3. Advantages of modern drying plan

Drying with radiation and ultrasound

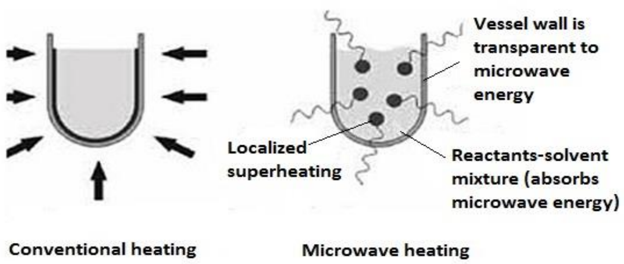
Drying with infrared radiation in a highly automated vacuum dryers where energy consumption is very small. In addition to the usual method for preserving foods increased application is the use of radiation. Radiation is defined as a method of propagation of energy in the form of electromagnetic waves. Irradiation is the effect of radiation exposure to food and thus the surrender of part of or the entire energy consumption. Warming foods can be carried out infrared rays. The range of the infrared radiation is from 10-3 to 1.5 • 10-6 m. Infrared rays passing through the food are absorbed, pour energy store, which is why it is heated. Infrared heating has a number of advantages compared to conventional heating methods.[9] There is, first of all, to the shorter heating time, uniform heating, less changes in the quality of ingredients, there is no loss of solvent from food, simplicity and energy saving equipment. Infrared heating can be used in various processes in the food industry. Mainly used for drying foods. Efficiency of UV radiation depends on the number and type of microorganisms, as well as the intensity of the radiation. With the health aspect is important to establish that in the irradiated foodstuff no toxic products. In principle, the absorbed radioactive energy leads to a variety of chemical reactions, and can not exclude the possibility of creating some harmful compounds. However, based on numerous studies, conducted in the United States and England, based on animal feeding was observed that irradiated foods containing any type of harmful compounds. But with the health aspects of this this type of dried represents an inadequate way. Why are the World Health Organization set norms that food irradiated to 1 kGy considered healthy and harmless for human consumption and food irradiated doses above 1 kGy should be tested for the presence of toxic compounds. Drying ultrasound is one of the cheaper and more cost-effective methods. High power ultrasound and low frequency (f = 20 to 100 kHz) is considered one of the more effective methods. Shortens drying time foods and thus comes to big energy savings. The quality of the dried the dried product this method is very high and can preserve all of its original features. However, with half of Health experts also stress detrimental for the characteristics of the human body, and a similar extent as for the method of irradiation.

Microwaves for heating material in other drying systems

The development of technology today allows the combination of different methods of drying. Drying is one of the most suitable methods for preserving foods. The use of microwaves in the food industry today considerably widespread and can be very efficient and cost-effective energy. Microwave heating occupies an increasingly important place in drying systems, because of their advantages over other energy sources. The manner of conventional and microwave heating is shown in the following figure. (Figure 4) Microwave technology began to develop during the Second World War. During the research period the magnetron and sources of radar radiation occurs first microwave oven in 1954.

Microwave radiation belongs to the group of electromagnetic radiation the wavelength λ = 0,01-1nm. Microwave radiation leads to the acceleration of chemical reactions, there are three types of microwave effects: thermal, specific and non-thermal.[10] Microwaves us provide increased Energy efficiency. When drying us this fact is very important because the drying of an operation which requires a large energy consumption. Warming microwave energy takes place throughout the volume of the product to be dried, which is more efficient because it saves time and energy. The fact that the product is quickly dried to a lesser extent, affects the quality of dried foods. It is believed that the combination of conventional and microwave drying or a combination of the microwave drying and drying in vacuo can improve the quality of the dried food.

Figure 4. Conventional and microwave heating [11]



Solar drying systems

Renewable energy has been used and the name of the permanent energy sources, energy sources whose reserves are constantly or cyclically renewed. The name itself suggests that consumption of these energy resources does not exceed the rate at which they are updated. There are also non-renewable resources are fuels whose reserves are estimated at tens or even hundreds of years until their creation took tens of millions of years. Renewable energy comes from three main sources: solar energy, nuclear fission, gravitational energy. The sun is the largest source of energy on earth. Solar energy is obtained from sunlight. Solar energy is used for a long time for the evaporation of salt from the sea, drying heating system. Technologies used for the utilization of solar energy in the AI may be divided into active and passive. The technology is classified as active solar panels and solar collectors, while passive classified orientation of houses or buildings during construction in order to improve air circulation and increase the utilization of sunlight for lighting. Solar energy can be used in different ways and used as: electrical, thermal, mechanical or chemical energy. The simplest way for the utilization of solar energy collecting thermal energy in the form of hot water or hot air. Solar dryer using solar energy on the principle of electromagnetic radiation in the spectrum of global solar radiation over the radiation in the visible infrared region. [12] The advantage of this dryer is that they are mobile and easily adaptable to all weather conditions may be used and additional sources of heat heaters, biomass enables better absorption of energy. Their operation includes the following phases prepared material is spread in a layer of uniform thickness on the trays that are made of aluminum or stainless steel. Exact agree on mobile carts that are on wheels. Particularly directed flow of hot air which is heated by the solar collector is carried out dry. The removal of excess moisture is achieved naturally and additional fan through a vent pipe. The warm air from the solar collectors is fed into the dryer through the exhaust chamber. All of regulation given temperature and humidity is done using automated electronics can work on the principle of air circulation equipped with thermal groups as a subsidiary system. Dryers are lightweight constructions made from natural materials with a high degree of automation.[13] The drying process takes place in a healthy and safe manner. (Figure 5) SMAT to solar driers are the most effective method of drying out the aspects of health care pro- and with the economic and environmental. Meet all HVAC features and what is the biggest characteristic that losses of heat placed at a minimum.

Figure 5. Solar dryer [14]

CONCLUSION

Innovations in technology require high investments for which seldom works on new patents. The pursuit of modern equipment is increasingly growing. Companies are increasingly taking into use of modern technologies. Contemporary knowledge about the physiology of nutrition indicate the growing importance of agricultural raw materials, or their derivatives in the daily diet in humans. It is necessary to work on finding the most effective ways for their processing and storage. Modern systems of drying foods must meet the criteria of quality dried products, must have energy efficiency certificates. In a constructive manner and for the increasingly must meet ergonomic requirements, but that when it takes into account environmental protection. World Health Organization put the focus on finding the most appropriate solutions in the field of food industry with the proviso that they do not have bad influences on human health. It is necessary to work on the improvement of traditional drying method. One of the more effective traditional method is to spray drying system is widespread during the twentieth century. It is necessary to revive and improve. It is very cost-effective, energy efficient and is thus not harmful to the human body. It is also very important to improve and work on constantly perfecting new methods of microwaves, ultrasound radiation is necessary to find adequate solutions to reduce their harmfulness. Solar drying systems belong to the most efficient method of drying the twenty-first century, both in food and in other industries as well as numerous studies have shown. They do not have a detrimental impact on human health and the environment, energy efficiency is at a maximum. The range of benefits that this method gives a broad why it is necessary in our country to allocate certain funds for the its improvement, promotion and continues to work on incentives to producers in their manufacturing centers introduced just this drying systems.

REFERENCES

[1] Evangelos T., Arun M. S., Modern Drying Technology, London, 2014.
[2] Lambić M., Pekez J., „Uporedni tehno-ekonomski pokazatelji toplotnih i fotonaponskih solarnih instalacija nominalnih snaga 2kW“, OMO 2015, Zbornik radova, ISBN 978-86-84231-39-2; COBISS.SR-ID 215839244, Beograd, 2015., Izdavač: Institut za istraživanja i projektovanja u privredi.
[3] Baras J., Prehrambena tehnologija, Zavod za udžbenike i nastavna sredstva, Beograd 1989.
[4] www.modernhealthcare.com
[5] www.tehnologijahrane.com
[6] Cvijanović S., Končar-Đurđević S., Cvijanović R., „Mašine i aparat“i, Zavod za užbenike i nastavna sredsva Beograd,1989.
[7] Tratnik Lj., Mijatović I., Upotreba jonskih izmenjivača za demineralizaciju slatke surutke, Zagreb 1987.
[8] Đorđević D., Ćoćkalo D. Osnove Marketinga, Tehnički fakultet „ Mihajlo Pupin“ Zrenjanin 2010.
[9] Valent V., Sušenje u procesnoj industriji, Tehnološko-metalurški fakultet, Beograd 2001
[10] Baloš S., Uticaj mikrotalasnog zračenja na mehaničke karakteristike PMMA biopolimera, Novi Sad, 2009
[11] Kaluđerski S. Cvejanov S. Tošić B., Prehrambena tehnologija, Zavod za udžbenike, Beograd, 2008.
[12] http://www.mikonsusare.rs
[13] Ćirić D. Primena solarne energije za sušenje lekovitog bilja, Fakultet tehničkih nauka, Novi Sad 2005
[14] www.bif.rs

THE USE OF BIOGAS FROM THE BIOMASS ON FARMS AND ENVIRONMENTAL PROTECTION

Slađana Borić[1], Sanja Stankov[1], Jasna Tolmač[1]
[1]University of Novi Sad, Technical Faculty "Mihajlo Pupin", Zrenjanin, Serbia
e-mail: sladjana.boric@hotmail.com

Abstract: This work represents a review of biogas production on farms. The development of purer and renewable resources of energy represents today the crucial question for the solution of mentioned problems. Biomass, which includes vegetation and trees as well as biologically solid bodies, animal and agricultural leftovers, organic fractions of communal waste and some kinds of industrial waste, shows up as a promising option for its world potential in means of its availability, more efficient conversion and ability to produce carbon-dioxide (CO_2) on neutral basis. Biogas is a mixture of methane (CH_4), carbon-dioxide and some other compounds, in smaller amount. Biogas is a renewable resource and helps climate preservation and protection of limited resources.
Key words: biomass, production, biogas, farm

INTRODUCTION

The energy crisis from the beginning of 1970's and other numerous economic and ecological reasons have made many countries to take certain steps in order to save energy and use it rationally [1]. Due to continuous growth of global energy use, an important challenge has arisen: by the end of 2050, non-renewable resources such as coal, oil, gas and nuclear energy will have been replaced with new, renewable, ecological, pure, natural resources of energy such as sun, wind, water flows and biomass. In addition to that, the use of fossil fuels causes many problems in protection of local environment such as: atmospheric pollution, acidification of ground and emission of gases with greenhouse effect [2]. The development of pure and renewable energy resources is the crucial question today for solving stated problems. Biomass, which includes vegetation and trees, as well as biological solid bodies, animal and agricultural leftovers, organic fractions of communal waste and some kinds of industrial waste, shows up as a promising option for its world potential in means of its availability, more efficient conversion and ability to produce and use carbon-dioxide (CO_2) on neutral basis. Biomass is an all-round energy resource, it generates not only the electric energy, but also the health and it can additionally be used for the production of biofuel, biogas. Contrary to fossil fuels, the combustion of biomass does not increase the amount of carbon-dioxide (CO_2) in the atmosphere and, thus, it has a positive effect on local environment [3]. One of the most important renewable energy resources, if not the most important is the biomass because of the amount of energy periodically renewed and relatively small cost of production. The great advantage of biomass is reflected in obtaining alternative ecological fuels; one of possible solutions more imposing is biodiesel and biogas, fuel that is based on plant processing and waste oils [4].

1. Biomass

By biomass we imply biodegradable fragments of a product, waste or agricultural leftovers, as well as forest waste and the waste of related industries, biodegradable fragments of industrial and communal waste. The Directive 2009/28/EC stipulated by the European parliament defines biomass as: *"Biodegradable fragment of a product, waste and biological leftovers in agriculture (both of plant or animal origin), forestry and related sectors such as fishing and aquaculture, and biodegradable fragments of industrial and communal waste".*
Biomass represents a biodegradable energy resource and by its aggregate structure, we can group it into:

- stiff biomass (briquetted biomass, pelleted biomass),
- liquid biomass (bioethanol, biomethanol, biodiesel),
- gaseous biomass (biogas).

Biomass is predominantly made of carbon, hydrogen and oxygen. Energy content of particular biomass types is often expressed through Low Heat Level (LHV). LHV depends on the moisture content in biomass, as well as on the hydrogen content in fuel. The real level of biomass LHV with familiar moisture content can be calculated from LHV level of dry biomass according to the following equation [5]:

$$\mathrm{Hu}(w) = \mathrm{Hu}(wf)(100 - w) - 2{,}44w/100$$

where:
Hu(w) - LHV (u MJ/kg) with particular content of moisture in biomass,
Hu(wf) - LHV completely dry biomass,
w – the content of moisture in percents, constant 2,44 of heat of water evaporation.

2. Biogas as a product of biomass

Biogas represents a mixture of methane (CH_4), carbon-dioxide and some other compounds in smaller amount.

Table 1. "The content of biogas"

Component Chemical formula	Chemical formula	Volume percentage %
Methane	CH_4	50-70
Carbon dioxide	CO_2	20-40
Nitrogen	N_2	<3
Hydrogen	H_2	<3
Ammonia	NH_3	<1
Aerated water	H_2O	1-5
Hydrogen-sulphide	H_2S	<1

The heat power of biogas depends directly on methane. The content of methane depends on the type of raw material which is applied in anaerobic process. When put in digester, more than half of stiff raw material is turned into gas. The gas is supersaturated with water; therefore a large amount of moisture is removed with gas. From raw material suspension to the stadium of leftover, total loss is about 20%. The rest can be used as excellent manure because it contains ingredients that are important for plant growth: nitrogen, phosphorus and potassium.
Biogas is created through anaerobic digestion of biomass, actually from:

- leftovers in agriculture (slurry, excrement from livestock and poultry raising farms, silage),
- biomass leftovers originated from the primary processing of agricultural products (which do not contain dangerous materials),
- other biomasses which do not contain dangerous materials, leftovers and animal parts.

Anaerobic digestion is a process in which biodegradable material is being degraded because of oxygen absence. The technology of biogas is not applicable on all farms, although it can be a profitable and convenient method for getting the energy and protecting the local environment in processing animal leftovers. This technology is especially convenient for farms which have a huge amount of waste. The production of biogas is based on the anaerobic breakdown of organic materials. During this starting anaerobe period, bacteria absorb the oxygen and, by doing that, they use the oxygen. After the disappearance of oxygen, the process of breakdown begins. The amounts and the characteristics of organic materials that arise in this way can differ a lot. The characteristics of soluble materials on farms depend on climate conditions, the type of agriculture, the type of reared animal, the type of waste collection.

3. The possibility of heat and electric production from biogas on farms

One of the natural products of anaerobic digestion is biogas which typically contains between 60 to 70 percent methane, 30 to 40 percent carbon dioxide, and trace amounts of other gases [6]. The biogas produced on farms from manure and agricultural waste can be applied for covering the heat needs of farm itself, for heating up the rooms, for hay and grain drying. Biogas surplus depends on factors such as: the capacity of assembly, the types of raw materials being submitted to anaerobic breakdown, season, and climate conditions. Because of all these possibilities, it is necessary to develop annual plan of production and consumption for each farm. On countryside farms with small number of livestock, biogas can be produced in smaller assemblies and to be used for covering an important part of energy needs of households.

Figure 1. "The review of simple biogas system with associated equipment"

The use of biogas for production of electric energy is becoming more intense and economic thanks to development of devices which are used in that purpose. There are many types of power generating sets for production of electric energy with different power, from 80-350 kW [7]. According to so far experiences, lower limit for economic use of biogas in electric energy production is at 100 kW engine strength (1m^3 of biogas gives about 1,7 to 1,9 kW of electric energy). Relying on the given data about average production of organic materials of manure and the production of biogas in m^3/kg of organic materials of manure, the Table 2. is defined.

Table 2. "The summary table of possible production of electric and heat energy on standard farms"

1-4 Possible production of heat from biogas on the standard farms.				5-7 Possible production of electricity from biogas on the standard farms.		
1	2	3	4	5	6	7
MJ/day	MJ/h	MW	kW	kWh	kwh /day	kWh/year
607,2	25,3	0,0070277	7,03	2	48	17520
400,2	16,67	0,0046	4,6	1,4	33,6	12264
1269,6	52,9	0,0147	14,7	4,5	108	39420
3047,04	126,96	0,03526	35,26	10,6	254,4	92856

The complex usage of biogas energy makes the production of biogas more perspective and more rational. The system which should be developed for biogas production should be able to produce an optimal amount of biogas out of raw material in a technically optimal and economic way with possible fusion of energetic, agro economic, ecological and esthetical. The basic condition for forming constructive characteristics of biogas production assembly is to carry out the previous investigative materials. They refer to reliable characterization of substrates, on establishing technological parameters for anaerobic fermentation process. The results of these researches should give the answer about: the amount, the texture of substrates, fulfilling the conditions for successful navigation of anaerobic fermentation process, the conditions that are needed for optimal process flow and material balances (substrate, product and biomass) during the process and the amount and the structure of the final products of decomposition.

3.1. The phases of biogas system

A typical biogas system is made of following phases:

1. Induction of manure – premix,

2. Anaerobic digester,
3. The storage of leftovers,
4. The system for manipulating the biogas,
5. The use of gas.

Induction of manure – Livestock farms which use the manure managing system for its collecting and storage in order to fulfill sanitary, ecologic and operative criterions. The manure is collected and stored in firm, liquid or half-firm condition. *Digester* – it is a part of the manure managing system in which the expansion of bacteria that degrade the manure and produce biogas is optimized. The selection of the appropriate type of digester depends on the projected manure managing system for particular farm. *The storage of leftovers* – The products of anaerobic digestion is biogas and leftovers. The leftover is the stabilized organic solution which has the same value as the manure. The storages are needed for stationing the leftover because it cannot be used during the whole year. *The system for manipulating the biogas* – This system transports the biogas from digester to the consumer and engine or boiler. This system contains pipeline, gas pump, gas recorder and condensate drainage. The biogas produced in digester is located under impermeable lid which covers the digester. The biogas is brought out with gas pump or fan which is connected at the end of collecting pipe. Gas recorder is used to control the flow. Warm biogas cools while passing through pipes and water steam condensates. Formed liquid is discharged through sink for condensate. *The use of gas* – The produced biogas can be used in many ways. Biogas contains 60-80% of methane in its structure with methane's heat value of about 23040 KJ/m^3. Regarding that the percentage of methane in natural gas is about 98% and that its heat power is about 33350 KJ/m^3, we come to the conclusion that the heat power of 1m^3 natural gas is higher than the heat power of biogas for about 45%. Biogas can be used for the production of electric energy, as the fuel in the boiler or in the cooling equipment. The most of the equipment that uses the natural gas, propane or butane, can also use biogas as its fuel.

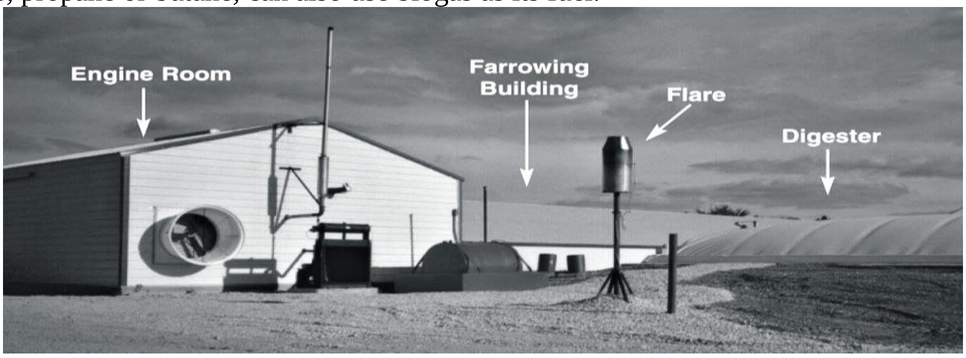


Figure 2. "The look of the farm which uses the biogas"

4. The protection of the local environment from the aspect of use of biogas on a farm

In some European countries, we have different approaches in using the biogas technology. While some countries use biogas technology for processing wastewater, other ones use it for increasing the value of organic manure. After the anaerobic digestion, about 25-40% of organic dry material is transformed into methane and carbon-dioxide. This reduction improves the quality of manure. The amounts of components which cause unpleasant smell is also reduced, the amount of weed and the use of pesticides is reduced. Many farms have noted the increase of crop after the usage of digested manure. Measurements have shown that the crop has increased for 2-3% in comparison with the crop when unprocessed manure was used. Methane is the second most important gas which causes the generation of the greenhouse effect in the world. The emission of methane appears in every anaerobic process of organic material. It is estimated that the emission of methane from agriculture contributes with 33% to the greenhouse effect. About 7% comes just from animal waste products which is about 20-30 million of tons of methane per year. By anaerobic treatment of animal waste, renewable resource is used which has the following effect on climate: the usage of renewable resource reduces CO_2 emission because the use of fossil fuels is decreased (1 m^3 replaces 0.5 kg of oil and in this way, the emission of CO_2 is reduced for 2.6 kg). In developing countries, smaller biogas assemblies reduce the consumption of forest resources for energy derivation in households and they decrease the destruction of forests and ground degradation which has its consequences in climate disasters (floods, etc.). Biogas is a renewable source and helps in climate and limited resources preservation.

CONCLUSION

Small and medium assemblies in European countries make 70% of existing assemblies and 80% of annual growth. Regarding that liquid phase of manure has the largest effect in biogas production, this assemblies should primarily be built in pig farms. In the biggest cow and chicken farms there are technical-technological and economic conditions for the construction these assemblies. With medium-term and long-term development plans, the development and the construction of biogas assembly should also be planned. The first step should be the construction of test assembly in the region which has a developed livestock production. The protection of the local environment, as well as energy saving has a growing significance and, from that point the construction of biogas assemblies has a large perspective. At the level of government institutions, there should be the support for this type of production and energy use. That support would be reflected through various stimulating methods like the subvention of production and the equipment for biogas production and use on livestock farms.

REFERENCES

[1] Tolmač, D., Prvulović, S., Tolmač, J., "Racionalizacija potrošnje energije u industriji", Univerzitet u Novom Sadu, Tehnički fakultet "Mihajlo Pupin", Zrenjanin, 2014.
[2] Klass, DL., "Biomass for Renewable Energy and Fuels", Encyclopedia of Energy, 2004.
[3] Jovanović, B., Parović, M., "Stanje i razvoj biomase u Srbiji", Jefferson Institut, Beograd, 2009.
[4] Demirbas A., "The Importance of Bioethanol and Biodiesel from Biomass", Energy Sources, Part B: Economics Planning and Policy, No 3., 177 – 185, 2008.
[5] Carić, M., Soleša, D., "Biomasa kao obnovljiv izvor energije i tehnologija za proizvodnju biogasa - Priručnik za petodnevni kurs", DAI, Agencija za konsalting, Leskovac, 2014.
[6] EPA, "Managing Manure with Biogas Recovery Systems Improved Performance at Competitive Costs", The AgSTAR Program, 2002.
[7] Stanković L., Zaharijev Z., Kovačević S., "Uređaji za proizvodnju biogasa", Poljoprivredni fakultet, Novi Sad, Biogas-teorija i praksa, Donji Milanovac, 1985.

THE INFLUENCE OF ALLERGENIC POLLENS AS NATURAL CONTAMINANT

Sanja Stankov[1], Slađana Borić[1], Jasna Tolmač[1]
[1]University of Novi Sad, Technical Faculty "Mihajlo Pupin", Zrenjanin, Serbia
e-mail: sssanja89@gmail.com

Abstract: The pollution of environment is one of very important risky factors in modern society. The impact of polluted air on the phenomenon of respiratory symptoms is being monitored since 1930. Because of its negative and harmful impact on humans' health, pollen was characterized as a contaminant found in nature. One of the ways to help the persons who are allergic to pollen is to organize and to enforce continuous measurement of the pollen concentration in the air. It is important to be familiar with time and spatial distribution, as well as to know types of aero allergenic pollens in order to form the calendar of pollen and to follow its condition.
Key words: pollution, protection of environment, air pollution, human health, pollen.

INTRODUCTION

The observation of allergenic pollen was conducted for the first time in Serbia in 2002, in Federal weather center. In modern world, the characteristics of polluted air are different because the standard shows that the level of standard contaminants is lower than in previous years. "Pollen traps" are devices that are being used in Europe for already 20 years in order to measure the concentration of allergenic pollens in air. One measured area covers about 30-50 kilometers in its diameter, depending on the orography of the terrain. There are many diversified networks of stations which measure the concentration of pollen in European Union nowadays [1]. Besides Belgrade, which has two measuring spots, other towns which have installed "traps" are: Novi Sad, Subotica, Požarevac, Kruševac, Kragujevac and Čačak. In order to gain better image of the concentation of allegenic pollen in our country, we need to have at least 15 more measuring spots.
The pollen of some plants which has a negative impact on human health is classified as „natural" air contaminant. The World Health Organization (WHO) directs on the necessity of monitoring of pollen which is suspended in the air; the reason for this is that aeropollen is an important cause of allergic reactions in the past 50 years. The results of monitoring enable further research, diagnostification, prevention and treatment of pollen allergies.

NATURAL CONTAMINANT

The law about air quality has defined pollen as natural contaminant. The establishment of state monitoring of detecting allergenic pollen is conducted in the Agency for protection of the local environment [2]. In modern world, considerable attention is dedicated to allergenic pollens as frequent topic in ecology and health. Plant pollen is one of the most important natural allergens which can be found in air. Pollen grains cause allergic reactions in every fifth human (pollen sneezing, bronchitis, dermatitis, conjunctivitis, and so on). In case of continuous and perennial exposed to high concentrations, one part of human population becomes ill of bronchial asthma and chronic bronchitis. The World Health Organization has warned that different types of allergic reactions in humans will be the illness of modern society in 21st century [3].
There are 24 identified types of pollen. Some of them are ambrosia, wormwood, nettle, poplar, alder, maple, willow, ash, birch, walnut, oak, hazel, pine, hemp grass. The International Association for Aerobiology (IAA) has defined a time period when continuous sampling is conducted. When we observe the climate in our country, this period begins around February 1st when hazel tree and alder tree start to bloom. This period lasts until the beginning of November when the fluorescence of wormwood and ambrosia ends.

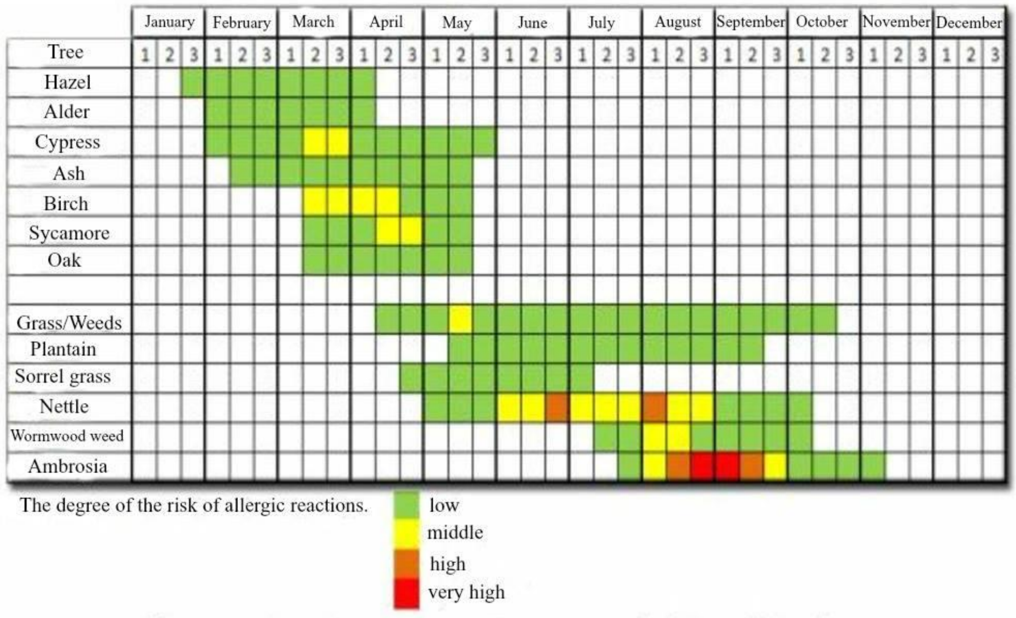


Figure 1. “The calendar of risk degree for generation of allergic reactions”

In time of vegetative growth period, there are numerous pollen grains of different plants in the air. The pollen particles are so fine that they can be almost invisible. Smaller pollen grains (whose size is about 30-50 microns) easily get in respiratory airways and, in touch with respiratory airways mucous the whole series of biochemical reactions begins. The result of these reactions is the release of mediators, the chemical substance.

By the impact of these substances on particular tissues and cells, the symptoms of allergic reactions appear. Every year, more and more people on our planet become susceptible of these substances.

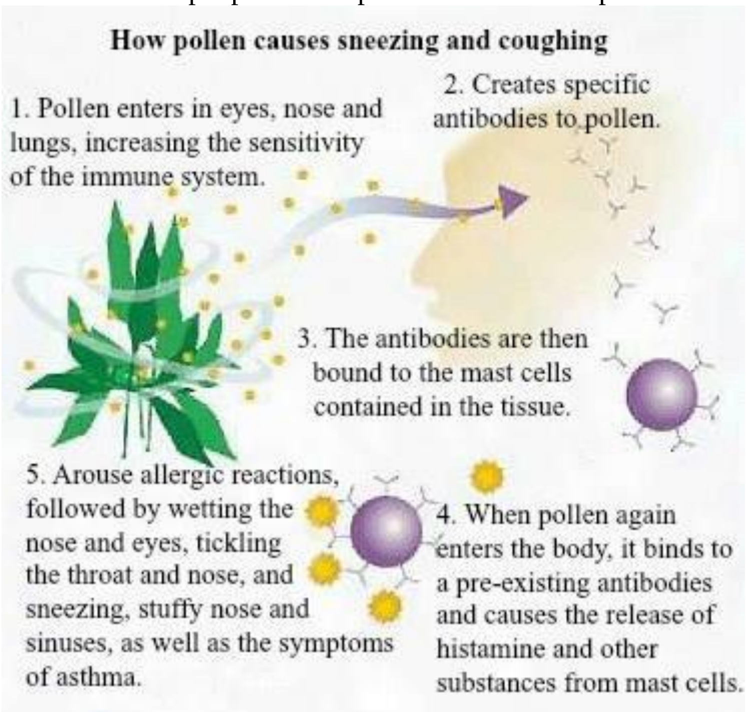


Figure 2. “The impact of pollen on sneezing and coughing”

The concentration of pollen is designed for one day, one week, decade, month, season and the whole year, for each plant individually [4]. In order to help the persons who have problems with pollen allergies, the Agency for Protection of local environment has made the territorial cover.

The measurement covers three seasons of fluorescence:

1. The season of the fluorescence of ***trees*** which begins with the fluorescence of hazel tree and alder tree (lasts from February until the beginning of May).
2. The season of the fluorescence of ***grass***; this period is characterized by the fluorescence of pines and lime-tree (lasts from May until the second decade of July).
3. The season of the fluorescence of ***weed*** which is the most important allergen in the season of weed fluorescence (lasts from the second half of July until November).

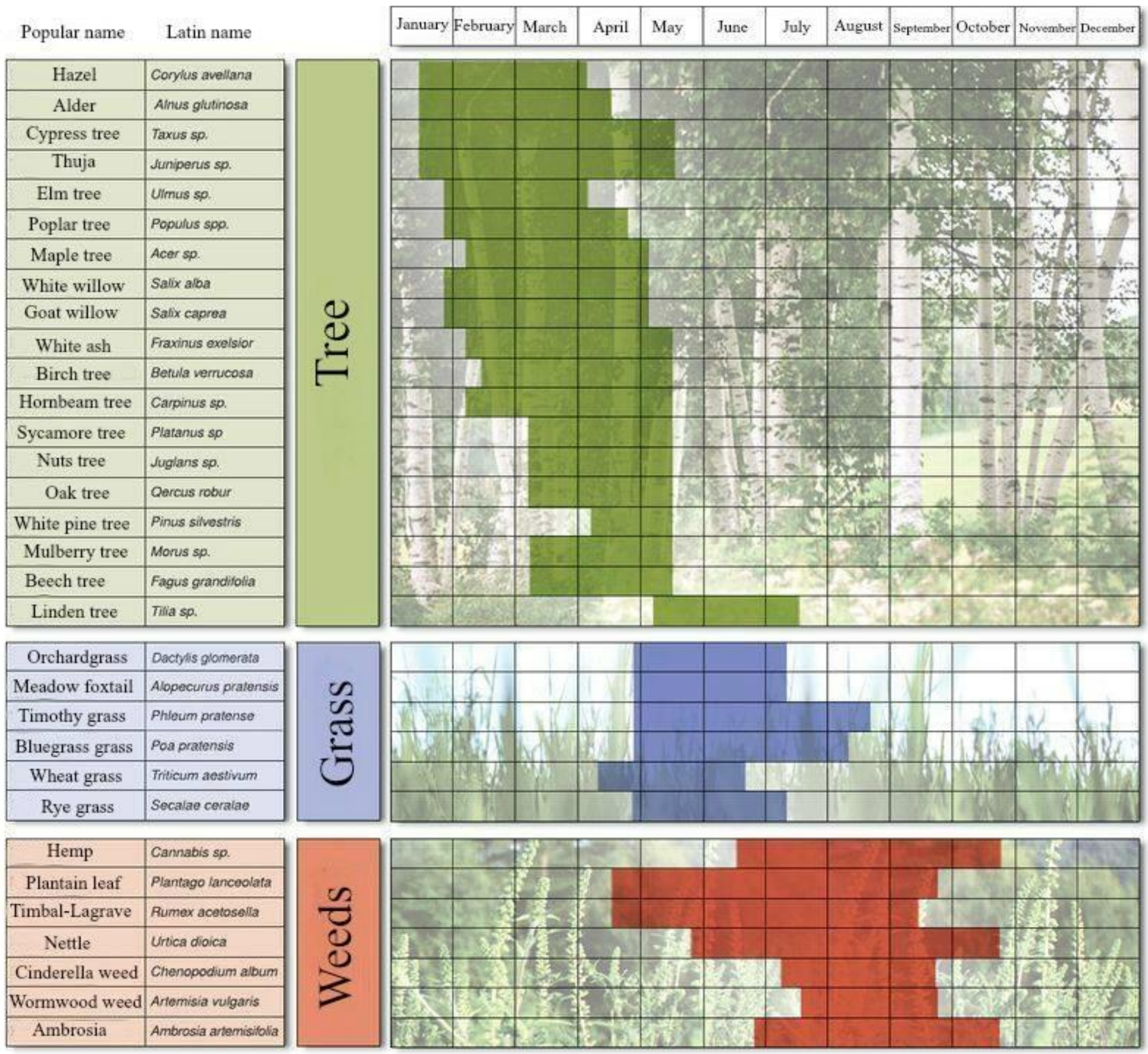


Figure 3.“Observation of allergenic pollen by calendar”

Aeropollen is continuously mustered by volumetric method. The gathered data are expressed as concentrations (the number of pollen grains in m^3 of air). The marginal value for tree and grass pollens is 30 grains in $1m^3$ of air. The marginal value for weed pollen is 15 grains/m^3 of air. When pollen reaches a particular state of ripeness, the emission of pollen occurs with help of the meteorological mechanism of wasteful. Higher air temperature, lower air humidity and windy time are the most favorable conditions for pollen emission. Also, the increased concentrations of carbon-dioxide in atmosphere have the influence on the increased production of pollen, and warmer summers lengthen the season of pollination.

AMBROSIA ARTEMISIIFOLIA

Ambrosia artemisiifolia is the largest weed allergen whose origins are in North America. It appeared in Europe in the middle of 19th century when it was brought together with seminiferous clover. The first data about ambrosia dates from 1953. From the surroundings of Sremski Karlovci, Petrovaradin and Novi Sad, this weed allergen begins to spread aggressively all over Vojvodina towards south. It owes the power to inhabit different habitats to its adaptability.

According to the observation of aero pollen and allergic diseases caused by it, which was conducted all around the world, it is established that ambrosia pollen is responsible for 50% of all allergies caused by aeropollen, and that this pollen is the strongest allergen among all pollens.

Ambrosia can be characterised as the plant of habitats that are temperate humid, neutrophil, nitrogen-rich, organic-matter-poor, loose, lit up and very warm; it can inhabit saline biotopes, too [5], although it is aterophita which enables it to survive unfavorable periods in the form of seed. The period of fluorescence lasts from July to October. The germination begins when ground gets warm and it lasts until the harvest of wheat. On wasted and unploughedlands, it can germinate even until the end of September.

A ten-year observation of pollen concentration in measurement spot in Belgrade, the location Zeleno Brdo, shows the following data: the total amount of pollen during every year, the lenght of pollination by days and total amount of pollen in period from August until September.

Year	Total amount of pollen	The lenght of polination by days	Total amount of pollen in period from August until September
2005	1954	96	1741
2006	4553	101	4460
2007	4210	122	4038
2008	4267	127	3512
2009	2886	92	2761
2010	5662	98	5559
2011	3882	107	3762
2012	3661	97	3590
2013	4183	95	4106
2014	2782	77	2746

Figure 4. “The data for ambrosia for 10 year-period for the location Zeleno Brdo – Beograd“

Geographical diffusion of ambrosia on the territory of Republic of Serbia in 2014, based on overall measured amount of pollen of this plan in all stations in National network for air quality control, shows that this plant can be most frequently found in the Northern parts of Serbia (even five times more frequent than in other parts). Ambrosia now grows in many town green areas and can be seen almost near every countryside road.

The risk of allegic reactions can vary from year to year, depending in climate factors and anthropogenic influences (the unkempt of ground which becomes crowded with weed, etc). Because of its huge impact on work capability and because of overall protection of health, it is necessary to work on its destruction.

AIR QUALITY IN REPUBLIC OF SERBIA IN 2014

The assessment of air quality is conducted once a year for each previous year and this is stipulated by the Law of air protection [6], and is carried out on the basis of an average annual concentrations of polluting material and the concentration of suspended particles PM_{10} (defined by gravimetric method). The Agency for protection of local environment has realized an operative monitoring of air quality on the territory of Republic of Serbia with more than 90% of valid and available data; this is the consequence of a non-defined budget limit. The covered data show that there have been some limit exceeds of marginal and accepting values.

- ***In the zone Serbia,*** air was clean or slightly polluted (except the town Kragujevac territory where air was abstemiously polluted and the territory of the town Valjevo where air was exceedingly polluted).
- ***In agglomerations Novi Sad, Niš, Pančevo and Kosjerić*** air was clear or slightly polluted.
- ***In agglomeration Belgrade*** air was abstemiously polluted.
- ***In agglomerations Smederevo, Užice and Bor*** air was exceedingly polluted.

Each zone represents a part of Republic of Serbia with defined borders, determined in order to assess and manage air quality which makes a characteristic functional environment according to air quality control, maintenance and/or development [7]; a zone with more than 250,000 people is considered an agglomeration.
In the same period, 68,8% of population in Republic of Serbia had clean or slightly polluted air. During that period, 31,2% of population had the quality of air which needs improvement. The Government spending in 2014 were 0,3% of gross national product (GNP) for all the costs for the „protection of the local environment“; this represents reducement in comparison with 2013 when these costs were 0,4% of GNP.
As in previous years, in 2014 the dominant pollen in all stations was the ambrosia pollen. It had the highest concentration in Kula and Novi Bečej while the birch pollen had the highest concentration in Subotica and the grass pollen in Bečej. Insufficient control of aggressive weed – ambrosia had an important role in development of its high concentration.

CONCLUSION

The calendar of allegenic pollen's presence is of great importance for allergic persons as well as for doctors allergists who coordinate the patients' treatments and medicament therapy. During 2014, the ambrosia pollen was dominant. From the aspects of health protection, continuous trading of the concentration of pollen grains is of huge importance because these data are necessary to help in prevention with sensitive persons and they contribute to more efficient patient treatment; it enables to improve the work of municipal and urbanistic services on destroying grass and weed which cause allergic diseases; we get an insight of needs to introduce a legal regulative including an international as well.

REFERENCES

[1] http://www.musicar.rs/alergeni/
[2] The Republic of Serbia Ministry of Agriculture and Environmental Protection "ANNUAL REPORT ON THE STATE OF THE AIR QUALITY IN THE REPUBLIC OF SERBIA IN 2014." Agency for Environmental Protection, Belgrade, 2015., http://www.sepa.gov.rs/download/VAZDUH2014.pdf
[3] CENTER FOR HYGIENE AND HUMAN ECOLOGY "REPORT ON THE RESULTS OF MEASUREMENTS POLEN IN THE TERITORY OF THE CITY OF PANČEVO AND ENVIRONMENT 2012.", Department of Public Health Pančevo
[4] http://www.musicar.rs/alergeni/
[5] http://www.musicar.rs/alergeni/
[6] The Republic of Serbia Ministry of Agriculture and Environmental Protection "REPORT ON THE STATE OF THE ENVIRONMENT IN THE REPUBLIC OF SERBIA", The Agency for Environmental Protection, 2014., http://www.sepa.gov.rs/download/Izvestaj2014.pdf
[7] "LAW ON AIR PROTECTION" ("Off. Gazette of RS", no 36/2009)