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Original scientific paper

DEVELOPMENT OF SYSTEM FOR DISPLACEMENT MEASUREMENT OF A CANTILEVER BEAM WITH STRAIN GAUGE SENSOR

Dejan Šiškovski, Zlatko Petreski, Goce Tasevski

Institute of Mechanics, Faculty of Mechanical Engineering,
"Ss. Cyril and Methodius" University in Skopje,
Karpoš II bb, P.O. box 464, 1001 Skopje, Republic of Macedonia
siskovskidental@yahoo.com

A b s t r a c t: In this paper, strain gauge based experimental system for displacement measurement of a cantilever beam was developed. The system comprises strain gauge sensors, signal conditioning module and data acquisition unit. Two strain gauges installed at the beam surface are connected in Wheatstone half-bridge configuration. Signal conditioning process is described in details along with the procedure for signal processing. Eventually, experimental investigations were conducted to verify the analytical gained results and certain conclusions were drawn.

Key words: cantilever beam; strain gauge; Wheatstone bridge; signal conditioning

РАЗВОЈ НАСИСТЕМ ЗА МЕРЕЊЕ НА ПОМЕСТУВАЊА НА КОНЗОЛНА ГРЕДА СО МЕРНА ЛЕНТА КАКО СЕНЗОР

А п с т р а к т: Во овој труд, развиен е експериментален систем за мерење на поместувања на конзолна греда врз основа на мерна лента. Системот се состои од мерни ленти како сензори, модул за кондиционирање на сигналите и единица за аквизиција на податоците. Две мерни ленти кои се инсталирани на површината на гредата се поврзани во конфигурација на Витстонов полу-мост. Процесот на кондиционирање на сигналот е опишан во детали, заедно со процедурата за процесирање на сигналите. На крајот, извршени се експериментални испитувања за да ги верифицираат аналитички добиените резултати и извлечени се одредени заклучоци.

Клучни зборови: *к*онзолна греда; мерна лента; Витстонов мост; кондиционирање на сигнали

INTRODUCTION

Measurement of mechanical structure parameters is very important issue in engineering research since they are exposed to different loads. If loads exceed their residue limits may cause inadmissible deformation or permanent damage to the structure that might endanger safety exploitation. Therefore, it is necessary to periodically measure and test the parameters, such as stress and strain of the responsible parts from the mechanical structures.

A wide variety of techniques exists for measuring strain or deformation [1,2] but the most frequent method is with a strain gauge which converts force, pressure, tension, weight etc., into a change in electrical resistance [3].

The advantages of using strain gauges are the small size and very low mass, excellent linearity over wide range of strains, low and predictable thermal effects, high stability with time, lack of moving parts and very small hysteresis [4]. Although the strain gauge is inexpensive and relatively easy to use, care must be exercised to ensure it is properly bonded to specimen, aligned in the direction of measurement, less sensitivity to temperature, and more importantly the lead wire resistance, the excitation source and the accuracy of other components used in the signal conditioning circuit [5].

Resistance changes in strain gauge are very small and they need to be measured with a suitable electrical circuit. Because of its outstanding sensitivity, the Wheatstone bridge circuit [6] is the most frequently used circuit designed to convert small changes in resistance to changes in voltage.

This paper presents the designing steps of a system for displacement measurement of a cantilever beam at any point, pressed by an acting force at their end point. In that context, section 2 describes the developed system and all necessary phases for its implementation, supported by theoretical background. Experimental verification of the system is made in section 3, while in the final section 4 certain conclusions are brought regarding the realized system.

MEASUREMENT SYSTEM ARCHITECTURE

The conceptual design of the system architecture for displacements measurement of a cantilever beam is presented in Figure 1, given by block diagram.

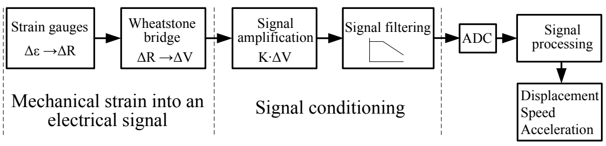

Fig. 1. Block diagram of the measurement system.

Whole structure from the proposed system can be divided into 3 main segments. The first segment consists of a cantilever beam on which two active strain gauges as sensors are installed combined with a Wheatstone half-bridge. This section enables mechanical strain conversion into a proportional electrical signal. The next step that is carried out in part two refers to the signal conditioning matter because the signals produced by the half-bridge are not immediately suitable for data acquisition. This stage is necessary in order to be able to move towards further signals processing, that is done in the third section.

Conversion of mechanical strain into an electrical signal

Figure 2 shows long and thin cantilever beam of uniform rectangular cross section, exposed under an acting force F attached at a distance l from the fixed point.

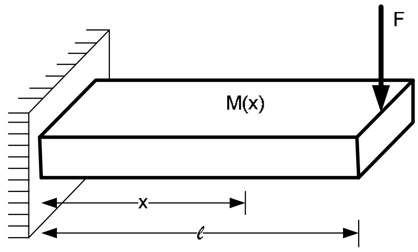

Fig. 2. Cantilever beam exposed under an acting force F

The magnitude of the bending moment at a given point along the cantilever beam can be expressed by the well known equation [7]:

$$M_{(x)} = F\left(l - x\right). \tag{1}$$

Distribution of the normal stresses in a given section depends only upon the value of the bending moment M in that section and the geometry of the section (moment of inertia). Therefore, the sizes of the normal stresses along the beam, at the most distant segments from the elastic curve, where $y = h/2$, shall be derived as follows:

$$\sigma_{(x)} = \frac{6 \cdot F\left(l - x\right)}{b \cdot h^2}. \tag{2}$$

In the area of elasticity of the materials, Hooke's law is valid, thus by its substitution in equation (2), the strain of the cantilever beam at any distance x can be determined as:

$$\varepsilon_{(x)} = \frac{6 \cdot F\left(l - x\right)}{E \cdot b \cdot h^2}. \tag{3}$$

Starting from the basic differential equation of the elastic curve [7], taking into consideration equation (1) and after double integration, the displacements of the cantilever beam for any distance x, resulting from the applied force F attached at their end point are obtained by the equation:

$$y_{(x)} = -\frac{F \cdot x^2\left(3l - x\right)}{6 \cdot E \cdot I}. \tag{4}$$

From equation 3 it could be conclude that major stresses and strains appear at the anchored point of the cantilever beam. Next equation 5 derives from the equations 3 and 4.

$$y_{(x)} = -\varepsilon_{(x_m)} \frac{x^2\left(3l - x\right)}{3h\left(l - x_m\right)}. \tag{5}$$

It determines the displacements for any location x of the cantilever beam, depending on the measured strain at a location x_m.

The conversion of mechanical strain into an electrical signal is performed by using strain gauge sensors. Because of their increased sensitivity in the vicinity of the fixed point, strain gauges were placed at distance x_m = 30 mm from that point, as shown in Figure 3.

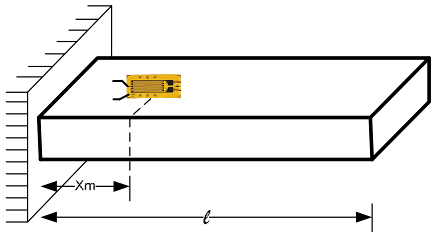

Fig. 3. Installation of the strain gauges

The strain can be tensile or compressive, as distinguished by a positive or negative change in the nominal resistance of the gauge. When used in a Wheatstone bridge configuration, this property of the strain gauge is exploited to convert the change in resistance of the strain gauge to a voltage that corresponds to the strain applied [6].

Wheatstone half bridge shown in Figure 4 is composed of two 100 Ω resistors and two active strain gauges of 6/120LY11 type from HBM.

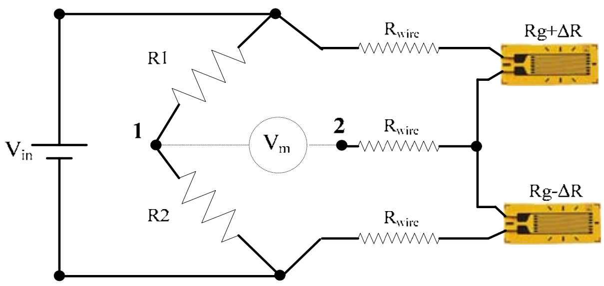

Fig. 4. Half-bridge with three wires

In this configuration the strain gauges are connected with three wires. Two of them are used to carry the excited voltage up to the strain gauges while measurements are performed through the third wire which is popularly called "sense".

Taking into account the effects of the resistance of the wires and the resistance change that occurs in the strain gauges under stress, the relationship between the measured voltage V_m and the strain ε, in the case where $R_1 = R_2 = R_g$, can be expressed as:

$$\frac{V_m}{V_{in}} = -\frac{1}{2}\frac{G_F \cdot \varepsilon}{\left(1+\frac{R_{wire}}{R_g}\right)}. \qquad (6)$$

Because the length of the wires used in the experiment are very short, resistance R_{wire} is very small, thus the term $(1 + R_{wire}/R_g)$ from equation 6 can be neglected. Therefore, the dependence between beam displacements and the measured voltage V_m from the bridge is obtained when equation 6 is added in the equation 5, given by:

$$y_{(x)} = -\frac{V_m}{V_{in}}\frac{2x^2(3l-x)}{3h\cdot G_F(l-x_m)}, \qquad (7)$$

where: h and l are height and length of the beam and G_F is the gauge factor.

Signal Conditioning

The expected maximum displacements of the cantilever beam are between the ranges of ±15 mm. According to equation (7), the measured voltage from the bridge V_m will be between the ranges of ±0.55 mV. As data acquisition equipment NIRio9636 is used, containing of 16-bit ADC converter with range of ±10 V. For these reasons, the signal must be amplified more than a thousand times. This way resolution increases and the signal/noise ratio improves. Figure 5 shows the entire process of signal conditioning in the time domain, displayed on an oscilloscope.

Figure 5a, shows the real signal from the bridge when the beam freely oscillates with its first natural frequency of 9 Hz. It may be noted that the noises that appear in the signal are multiple greater than the signal of interest and they are in range between ±10 mV. First step to remove these noises is the differential amplifier, which is suitable for amplification of very small signals in the range of millivolts. Figure 6 shows the amplification of a signal that is contaminated with noise, through a differential amplifier.

Due to the “inverting” input characteristic, the induced voltage that appears in the wires will be annulled after the amplification. Figure 5b shows the amplified signal by the differential amplifier by 47 times so improvement of the signal/noise ration can be noticed. For further amplification of the signal two “inverting” amplifiers are used with amplification factors of 47 and 5. As the last step in the signal conditioning process is the application of low-pass filter. Figure 5c shows the filtered signal with a total amplification by factor $K = 11045$ times. The values for the resistor and capacitor from the low-pass filter are taken as $R = 900\ \Omega$ and $C = 10\ \mu\text{F}$ hence the cut-off frequency of the filter has been chosen almost twice the value of the first natural frequency of the beam i.e. 17.7 Hz.

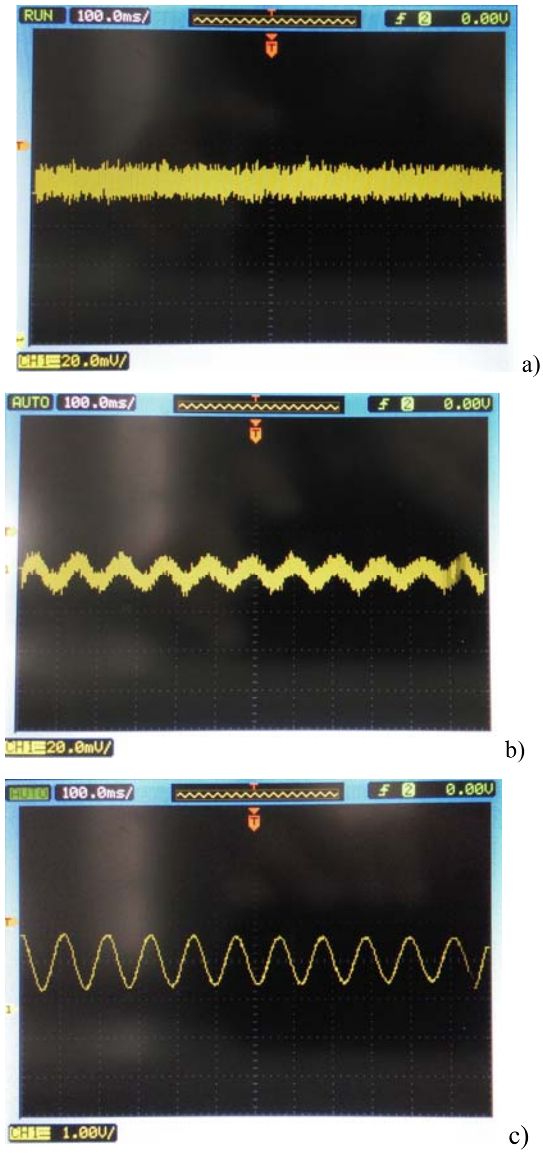

Fig. 5. Signal conditioning

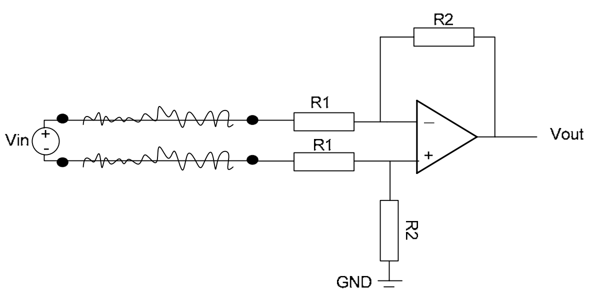

Fig. 6. Differential amplifier

At this frequency the amplitude of the output signal relative to the amplitude of the input signal will be reduced for –3 db, while the phase delay will be –45°. The transfer function of the low-pass filter will be:

$$\frac{V_{out}}{V_{in}} = \frac{1}{0{,}009 \cdot s + 1}\ . \tag{8}$$

Figure 7 shows the Bode diagram of the transfer function of the filter.

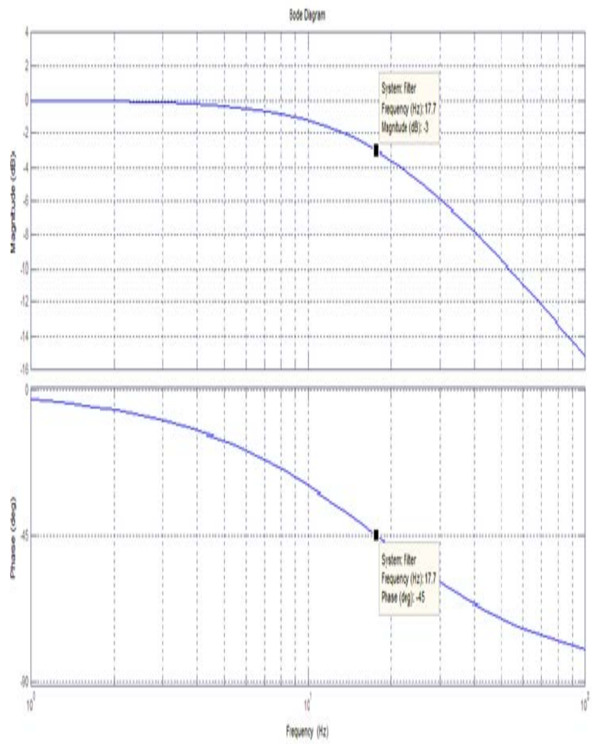

Fig. 7. Bode diagram of the low-pass filter

Signal Processing

Once completed the process of signal conditioning, data acquisition and converting of the signal into physical quantity are the next necessary steps. Knowing that the V_{out} voltage measured by the data acquisition equipment is equal to $V_{out} = K{\cdot}V_m$, by replacing this expression in equation (7) the dependence between the maximum displacement of the beam and voltage V_{out} is obtained. From there, a new coefficient C_P derives by which the measured voltage is converted into physical size-displacement. This coefficient can be calculated for any location x of the cantilever beam, so in case when measuring the displacement of the end point of the beam (x = l), C_P can be determined as:

$$C_P = \frac{4 \cdot l^3}{3 \cdot V_{in} \cdot K \cdot h \cdot G_F \left(l - x_m\right)} = 2,441 \text{ mm/V}. \quad (9)$$

According to this, the relation of maximum displacement of the beam as a function of voltage V_{out} can be written as:

$$y_{\max} = 2,441 \cdot V_{out} \text{ mm}. \quad (10)$$

Starting from the equation 4, taking into account also the expression 10, another coefficient C_F can be determined as:

$$C_F = 0,002441 \frac{3EI}{l^3} = 0,113 \text{ N/V}. \quad (11)$$

From here, the relation between the force and the output voltage V_{out} can be set as:

$$F = 0,113 \cdot V_{out} \text{ N}. \quad (12)$$

EXPERIMENTAL VERIFICATION

Verification of coefficients C_P and C_F is carried out by experimental measurement with 6 test masses of 5, 10, 15, 20, 25 and 30 g which are placed at the end point of the beam. The whole experimental setup of the developed system for measuring the displacements of a cantilever beam is given by Figure 8.

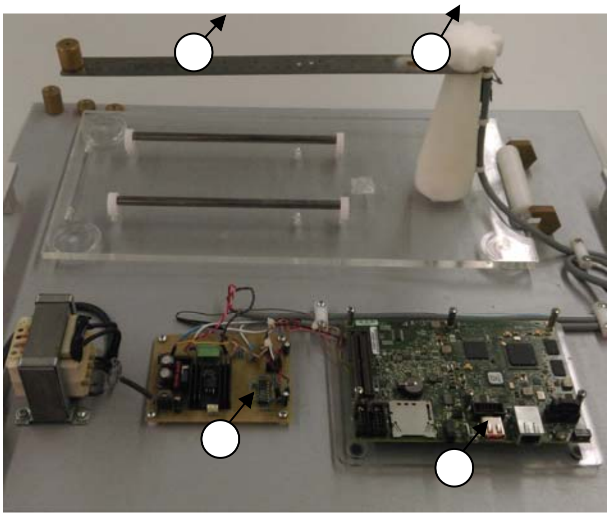

Fig. 8. Experimental setup of the system
1) Cantilever beam, 2) Strain gauge,
3) Signal conditioning module, 4) data acquisition unit

During the measurement, the cantilever beam is set in a horizontal position and the masses are converted as acting forces. Figure 9 shows a diagram where output voltage V_{out} is measured in relation to the displacements of the beam, while Figure 10 present dependence between voltage V_{out} and the acting forces. From the diagrams it may be noted linear relationship among voltage, force and displacements.

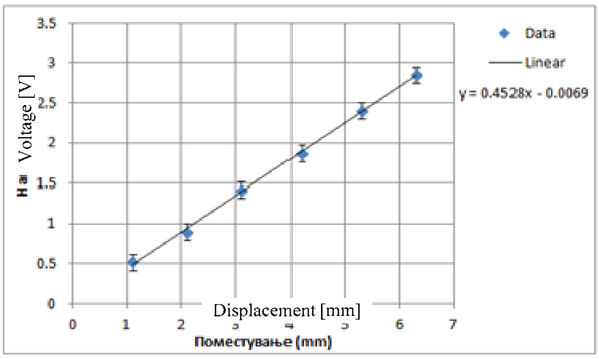

Fig. 9 Relations between voltage and displacements

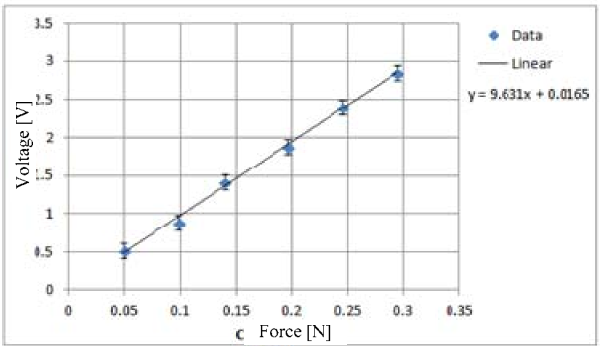

Fig. 10. Relations between voltage and forces

Using the method of least squares, linearization is performed in terms of displacement and force and after certain mathematical operations the following expressions are obtained:

$$y_{\max} = 2.2 \cdot V_{out} \text{ mm}. \quad (13)$$

$$F = 0.103 \cdot V_{out} \text{ N}. \quad (14)$$

Table 1 shows the coefficients C_P and C_F obtained by analytical and experimental way.

Table 1

Analytical and experimental values of the coefficients C_P and C_F

Coefficient	Analytical values	Experimental values
C_P	2,441 mm/V	2,2 mm/V
C_F	0,113 N/V	0,103 N/V

CONCLUSIONS

A strain gauge based system for displacements measurement of a cantilever beam was developed in this paper. The design procedure requires knowledge of mechanical engineering area, electrical engineering in terms of conversion and signals conditioning as well as data acquisition equipment capabilities. The applicability of the developed system can be perceived by inserting the equation 12 in equation 10 where it can directly be determined the displacements value of the cantilever beam depending on the applied forces.

Certain experimental tests were carried out on the cantilever beam in order to verify the obtained analytical results of the proposed system. The results given in Table 1 indicate sufficiently close values for the coefficients C_F and C_P hence with this developed system, deformations of the cantilever beam can be measured quite accurately. Differences in analytical and experimental results owed to certain imperfections in the constituent components of the measurement system.

By differentiating the signals obtained from the displacements, velocity and acceleration of the cantilever beam can be determined. Hence, with certain modifications and adjustments in the designed measurement system, these signals can be used as feedback in a closed loop control system for vibration measurement.

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Original scientific paper

HIGH-VOLTAGE TRANSFORMER NOISE MEASUREMENTS

Atanas Nastev[1], Zlatko Petreski[2]

[1]*AD MEPSO, Maksim Gorki No.4 1000 Skopje, Republic of Macedonia*
[2]*"Ss. Cyril and Methodius" University in Skopje, Faculty of Mechanical Engineering, Karpoš II bb, P.O. box 464, 1001 Skopje, Republic of Macedonia*
atanas.n@hotmail.com

A b s t r a c t: This paper presents the results from the noise measurements of a high voltage 300 MVA transformer. The results from the substation noise measurements are compared with the results from the measurements made at the FAT and the impact noise of the cooling system in the overall noise of the transformer is demonstrated as well. There is also an analysis of the impact of noise on employees in the substation on daily and weekly basis. The main sources of noise in the transformer are the magnetic core, the connectors, the tap-changer and the transformer cooling system.

Key words: trsnsformer; transformer noise; transformer cooling; system noise measurement

МЕРЕЊЕ НА БУЧАВАТА НА ВИСОКОНАПОНСКИ ТРАНФОРМАТОР

А п с т р а к т: Во овој труд се претставени резултатите од мерење на бучавата на високонапонски трансформатор со моќност од 300 MVA,. Воедно, е направена споредба на резултатите од мерењеата на ниво на бучава во трафостаница, со резултатите од (ФАТ) при фабричкиот прием, и прикажано е влијанието на бучавата од системот за ладење во вкупното ниво на бучава на трансформаторот. Притоа направена е анализа на влијанието на бучавата врз вработените во трафостаницата на дневно и неделно ниво. Главни извори на бучава кај трансформаторот се клемите, магнетното јадро, системот за ладење на трансформаторот и системот за регулација на напонот.

Клучни зборови: трснсформатор; бучава на трансформатор; систем за ладење на трансформаторот; мерење на бучава

INTRODUCTION

According to the Regulations on safety and health at work for employees exposed at risk of noise, there are noise levels, which shouldn't be exceeded at the work place, or if the noise can not be prevented, proper safety equipment should be ensured to reduce the noise levels. The methods and apparatus should be adapted to the prevailing conditions, particularly taking into account the characteristics of the noise to be measured, the duration of exposure, ambient factors and the characteristics of the measuring apparatus. The high voltage transformers which will be discussed in this paper are used in substations of the energy distribution and transmission grid, production plants and large industrial facilities. This paper presents the measurement and analysis of the noise level of the three-phase transformer with power of 300 MVA connected to a 400 kV grid with transformation to low voltage of 110 kV. A factory acceptance test for the subject transformer has been performed in Zagreb by Siemens.

TRANSFORMER NOISE SOURCES

The noise level is very important operational feature of the transformer which is measured by final test at the factory acceptance. The method of sound pressure or measuring the sound intensity is used as prescribed by the standards IEC 60.076-10 (2001) and IEEE Std C57.12.90 (2006). The measured values must meet the permitted noise level according to NEMA-National Electrical Manufacturers Association Standards TR1 (1998), or some special requirements in accordance with the regulations of the National grid. The average noise level of a 300 MVA transformer is about 82 dB, while in Figure 1, the permited noise level is given according to the power of the transformer.

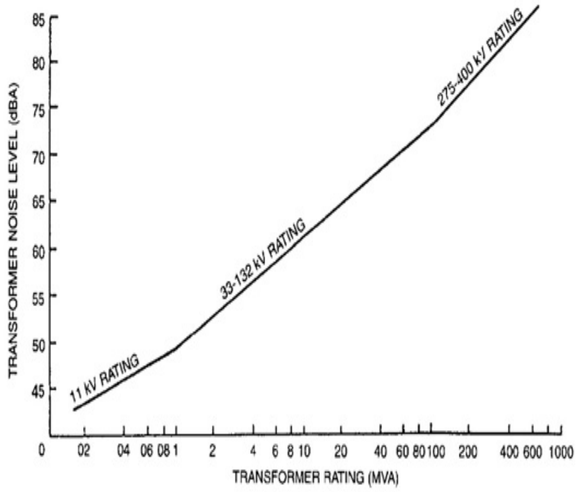

Fig. 1. Average transformer noise level

The sources of noise are divided into main and secondary. The main sources of transformer noise are: magnetic core, clams, tap changer, and cooling system for the transformer.

Outside noise sources also contribute to the overall noise. In practice those are some other transformers or the equipment which is located nearby and is usually 1.5–2 dB. Additional ambient noise occurs if the transformer is near a frequent highway and when the noise frequency is 500 Hz, it can reach up to 6 dB. Other factors or secondary sources of noise that contribute to the total noise level would be the current and voltage harmonics and residual magnetization. A characteristic of these sources is that they are more powerful, i.e. they contribute to greater noise during operation of the transformer outside.

TAP-CHANGER

The tap-changer (RS) can directly increase the noise, especially if there is a reduction of the high voltage side of the transformer. This causes the tap-changer of the nominal position (7) to increase, and thus increase the noise level. The correlation between the relative position RS and the voltage is presented in Table 1.

Table 1

Features of the transformer and other parameters during the process of measuring

Type		ARZD 300000 – 420/2	
Winding		VN-HV	NN-LV
	RS		
	1	420000	112326
Rated voltage V	7	400000	115000
	17	370000	121571
Type of cooling		ODAF	
Rated power MVA		300	
STN-STW		10500	
Data load on the transformer during the measurement:			
Voltage (kV)		111	
Current of side (A)		371	
Active power (MW)		65	
Reactive power (VAr)		32	
Dimensions of trafnsformatorot (m)			
Length		9,71	
Width		3.28	
Height		3,44	
Wind speed 14 km/h			
Time 9:20 hour			
Дата 17. 06. 2015			

TRANSFORMER COOLING SYSTEM

The Cooling system ODAF (Oil directed air forced cooling), which is an advanced version of OFAF, is used in the transformer shown in Figure 2, where the measurements were taken. In accordance with the standards, the following scheme for marking the type of cooling system is accepted: In character 1, fluid for contact with the windings and the core (O – oil, L – liquid, and A – air), 2 – way of contact of the fluid with the windings and the core (N – natural, D – direct, F – forced), 3 – cooling system which is in contact with the outside environment (A – air, G – gas and W – water) 4 –

way od contact of the fluid with the outside environment (N – natural, D – direct, F – forced).

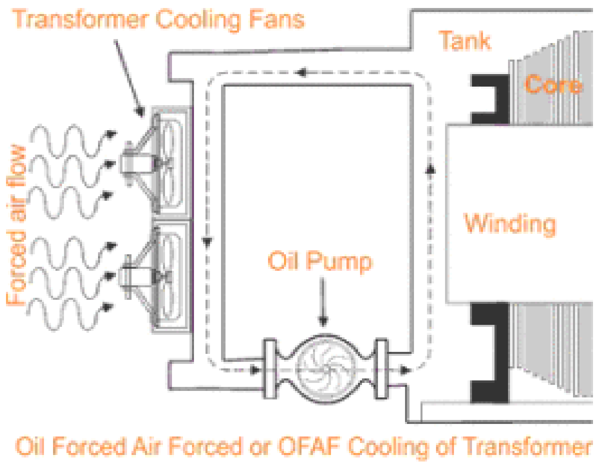

Fig. 2. Transformer cooling system

RESULTS FROM THE NOISE MEASUREMENT

For the purposes of this paper, outside measurements of the transformer were taken and compared with the results measured in a laboratory – factory acceptance test (FAT). In accordance with the procedure for measuring transformer noise of the standard IEC 60076-10 [2], during the measurement the following principles were taken into account: The minimum number of measurement points is 6, while 8 (Figure 3) and 37 in factory testing are used for the paper. They are performed on two height levels (1/3 and 2/3 of the height of the transformer), as the height of the transformer exceeds 2.5 m. Otherwise, if the height of the transformer does not exceed 2.5 m, the measurements are taken at half the height of the transformer. Namely, in external transformer operating conditions, the measurements are performed in two modes, i.e., with engaged 2/8 fans (mode 1) and 8/8 for the cooling system (Mode 2). The measurements were taken at the substation Skopje 1 – Butel with the instrument Bruel & Kjaer Type 2250.

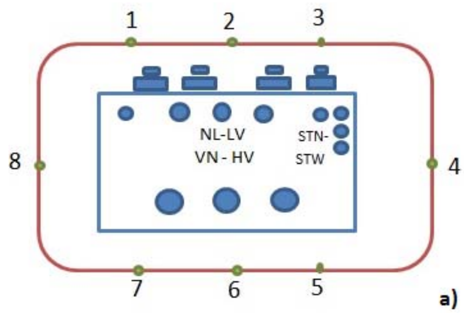

Fig. 3. Measuring points schedule for measuring the transformer noise

From the substation measurement results (Table 2) the maximum intensity of 83, 9 dB noise is obtained with all fans engaged in the cooling system of the transformer. The biggest difference of 10.8 dB between the two modes of operation appears in the measuring point 3. That is the result of the operating modes of the transformer, when the first mode of operation fan near the point 3 is not engaged (Figure 4). The Table 2 also shows the values of measurements made at the factory acceptance in the same measuring points as the measurement in the substation. The measurement of FAT are taken with the engaged 8/8 fans, idle and at 100% rated voltage and at 1/3 of the height of the transformer. The results obtained from the FAT measurements with the measurements taken in the substation demonstrate no significant difference between them, and they are shown in Figure 5.

Table 2

Results of the transformer noise measurement

Mode 1	2 of 8 engaged fans							
Measuring points	1	2	3	4	5	6	7	8
1/3 of the height – dB A	79,8	73,4	71,4	64,4	67,7	66,1	65,7	70,3
2/3 of the height- dB A	78,3	73,7	70,9	65,1	63,8	67,4	66,7	68,8
Mode 2	8 of 8 engaged fans							
1/3 of the height- dB A	81,8	81,7	80,8	71,6	68,1	69,3	65,2	69,6
2/3 of the height- dB A	79,9	83,9	81,7	68,3	68,4	70,1	65,4	70,6
FAT	8 of 8 engaged fans							
1/3 of the height- dB A	79,8	81	79,4	70,3	70,3	68,6	70,1	70
2/3 of the height- dB A	81,8	81,8	79,6	70,4	70,1	69,1	68,1	70,3

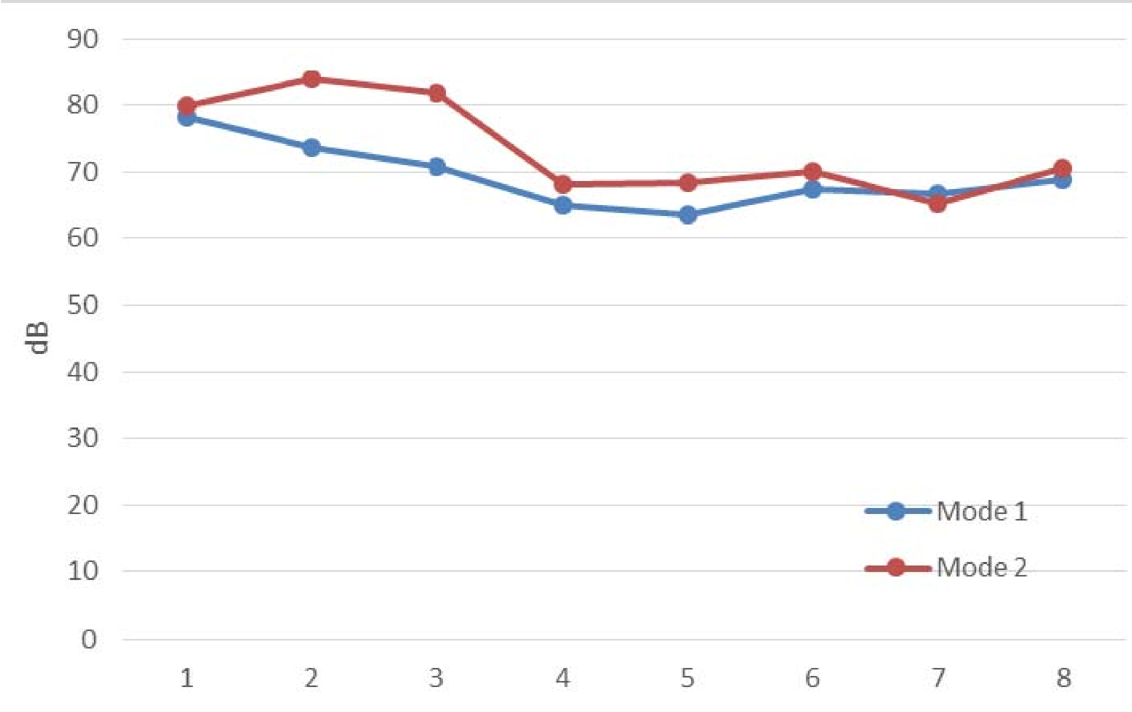

Fig. 4 Results of measurements in the substation in both modes of operation

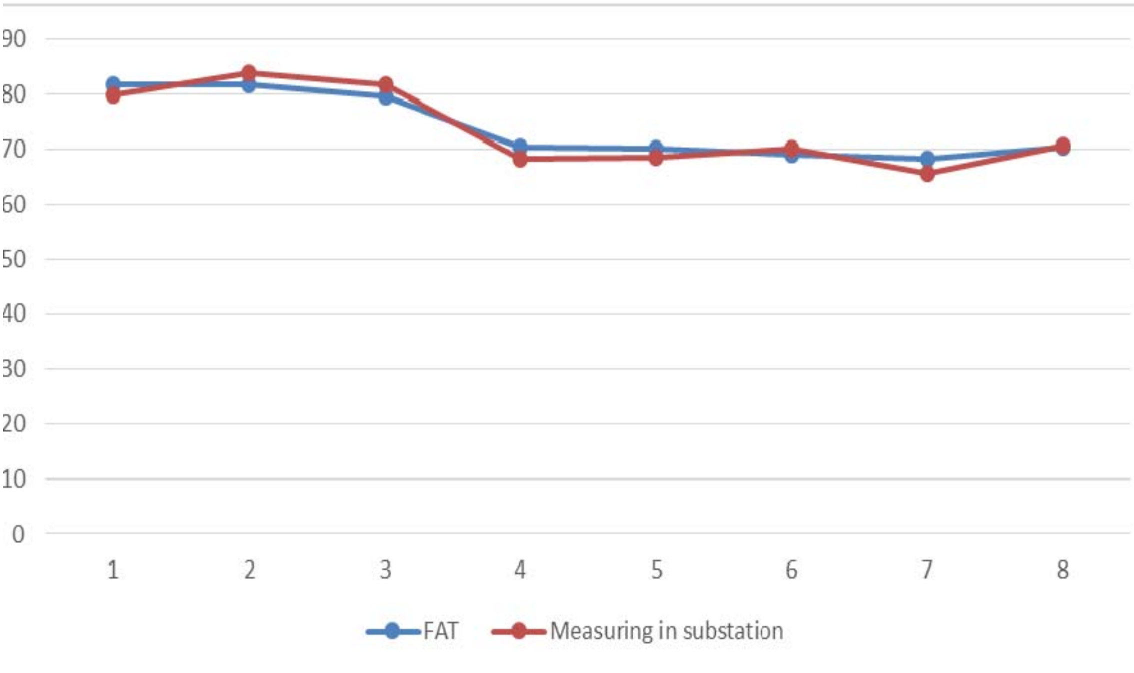

Fig. 5. Comparison between the results of FAT and the substation measurements

DAILY AND WEEKLY LEVEL OF NOISE EXPOSURE

Two types of daily and weekly levels of exposure have been measured for this paper, i.e. the medium and maximum daily and weekly exposure. To determine the daily noise level, it is necessary to know the exposure time of the employee for a period of 8 hours. The workload of an employee who has an assignment to periodically inspect the transformer or some other type of assignment near the transformer, lasts up to 2 hours, twice a week.

For the remaining of the time, the same employee is exposed to office noise, which in accordance with the standards, must not exceed 40dB. If we take the highest value of 83.9 dB, generated by the transformer, according to equation 1, we see the maximum daily level of employee exposure Lep, *d* of 76 dB. For calculating the weekly exposure level, we used equation 2 and received the maximum weekly level of employee exposure *Lep, w* of 72 dB. While in the calculation of weekly exposure, when an employee does not perform tests on the transformer, it demonstrated a daily exposure level of 40 dB. To determine the average daily and weekly exposure levels, as an input parameter we used the average noise value LpA0, which was obtained according to formula 1.3 and is LpA0 = 75 dB. According to the calculations we have obtained, the average daily exposure of an employee is 69 dB and the weekly exposure is 65 dB.

$$\log d = Lep, d = 10 \cdot \log \frac{1}{9}\left(t_1 \cdot 10^{\frac{L_1}{10}} + t_2 \cdot 10^{\frac{L_2}{10}}\right) \quad (1)$$

where:

Lep, *d* – is daily exposure level dB

t – Time of exposure (h)

L – noise level in dB

$$Lep, w = 10 \cdot \log\left(\frac{10^{\frac{Lep,d_1}{10}} + 10^{\frac{Lep,d_2}{10}} + 10^{\frac{Lep,d_3}{10}} + 10^{\frac{Lep,d_4}{10}} + 10^{\frac{Lep,d_5}{10}}}{5}\right) \quad (2)$$

$$L_{pA0} = 10 \lg\left(\frac{1}{N}\sum_{i=1}^{N} 10^{0,L_{pAi}}\right) \quad (3)$$

where:

Lep,w – Weekly noise exposure dB

N – Number of measurement points

L_{pAi} – Measurement in a certain point

According to the standard ISO 1999: 1990, point 3.6, the daily noise level must not exceed the value of 85 dB, and the weekly noise level must not exceed 87 dB.

CONCLUSION

From the conducted research, measurement and analysis, we can conclude that many factors influence the noise level. However, the impact of the cooling system is greater, i.e., when comparing the results in both modes of operation, a difference of maximum 10.8 dB can be noticed. From the measurements we have obtained maximum noise level of 83.9 dB, while from the calculation of maximum daily exposure of 76 dB and weekly exposure of 72 dB, we can conclude that the daily level of noise, generated by the transformer and the other equipment nearby, is within the permitted limits, in accordance with the Regulations.

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Original scientific paper

AIR POLLUTION FROM PUBLIC TRANSPORTATION: THE CASE OF SKOPJE

Dame Dimitrovski[1]**, Vanja Djinlev**[2]

[1] ***"Ss. Cyril and Methodius" University in Skopje****, Faculty of Mechanical Engineering,*
Karpoš II bb, P.O. box 464, 1001 Skopje, Republic of Macedonia
[2]*School of Industrial and Information Engineering, Politecnico di Milano, Italy*
dame.dimitrovski@mf.edu.mk

A b s t r a c t: The general trend of constant increase of vehicle's number and the environmental degradation has led many researchers and academics to model the air pollution deriving from transportation.Using the Tier 3 model developed by the European Environment Agency, this paper outlines the tail – pipe emissions from the two public urban transportation companies in Skopje, Macedonia. Namely, both the publicly owned company - JSP and the privately owned company – Makeskpres Prevoz were analysed and the results are shown hereinafter. In the end, this paper outlines the difference between higher and lower EURO emission standards in terms of pollution quantity deriving from urban bus transport.

Key words: public transportation; pollution; Tier 3

ЗАГАДУВАЊЕ НА ВОЗДУХОТ ОД ЈАВНИОТ ПРЕВОЗ: СЛУЧАЈ СКОПЈЕ

А п с т р а к т: Трендот на постојан пораст на бројот на возила и загадувањето на животната средина предизвикува перманентен интерес на инстражувачите за моделирање на загадувањето на воздухот кое потекнува од транспортот. Со употреба на TIER 3 нивото на CORINAIR медодологијата, развиена од Европската агенција за животна средина, овој труд ги разработува издувните емисии од јавниот автобуски транспорт во Скопје, Македонија,вклучувајќи ги ЈСП и Макекспрез Превоз. Во овој труд се истакнати бенефитите од упореба на повисоки Еуро норми за издувната емисија од јавниот автобуски превоз.

Клучни зборови: јавен превоз; загадување; TIER 3

INTRODUCTION

In today's highly connected and transport – dependent societies, a huge focus is put on the environmental impact that transport means have. Preserving the environment not only benefits current generations, but ensures a safe habitat for future generations as well. In line with this, Skopje, the capital of Macedonia, along with many other highly populated cities in Macedonia, is facing a serious air pollution problem. Being the largest city by territory and inhabitants, Skopje is struggling with the high concentration of pollutants such as nitrous oxides, carbon dioxide, but especially with theabove – average concentration of particulate matter emissions (PM2.5 and PM10) in the winter periods, possibly affecting more than 60% of the population [1]. The hourly, daily and yearly concentrations of particulate matter are almost always above the critical value, as it is presented in Figure 1 [2]. The flat line at the bottom of the graph represents the limit value while the other lines represents the measured values of PM10 concentrations in 5 measuring stations spread across different parts of Skopje, from 27.10.2015 to 26.11.2015.

As urban transport stands for one of the main contributors in the urban air pollution, it has been in the focus of many academics and scholars, especially the particulate matter (PM) emissions, since many evidences confirm the negative effect on human and environmental health it has [3].

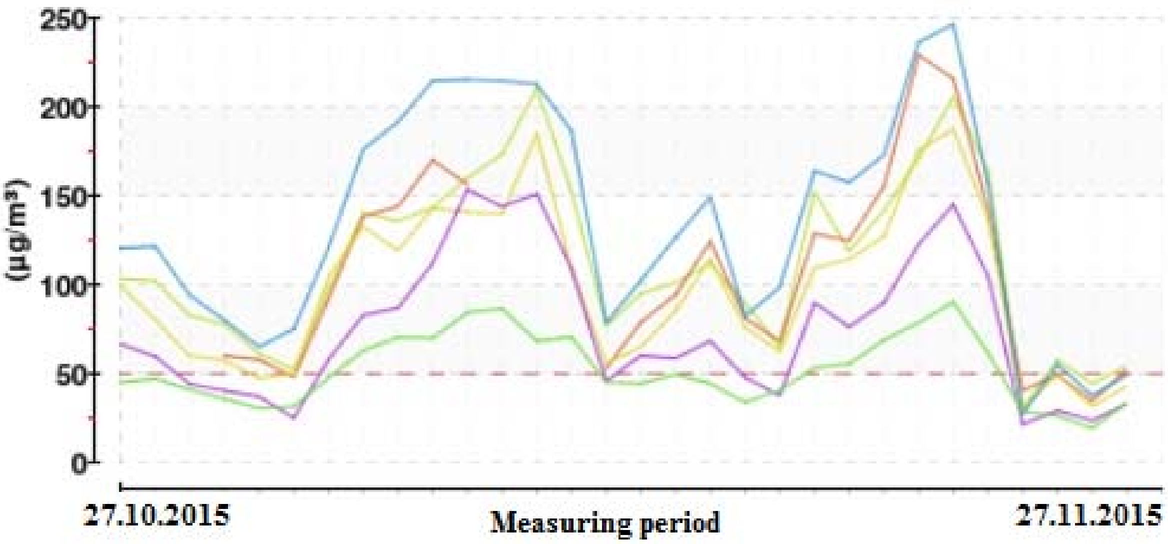

Fig. 1. Measured values of PM10 at 5 measurement points from 27.10.2015 to 26.11.2015

In the attempt to quantify and analyse Skopje's urban public transport air pollution, a study has been undertaken to calculate the hot particulate matter (PM) emissions from the public transport service on Skopje's territory. For that purpose, the 2013 European Environmental Agency's (EEA) "exhaust emissions from road transport" guidebook [4] was used, and the results are presented in this paper hereinafter.

OVERVIEW OF SKOPJE'S URBAN TRANSPORTATION COMPANIES

There are two urban bus transportation companies in Skopje, one of which is publicly while the other one is privately owned. The information needed for successful execution of the Tier 3 emission model about the publicly owned transportation company (JSP Skopje) was gathered through the Access to information of public character and by using JSP Skopje's official website [5]. Since the last changes in the vehicles' technologies, was made in 2013, the following Table 1 depicts the gathered information that characterizes JSP Skopje's transportation fleet.

The daily average distance driven by the buses and minibuses is 132.63 kilometres while the total daily distance covered by the 401 vehicles is 53184.8 kilometres. 96.26% JSP Skopje's vehicles use diesel while the remaining 3.74% use compressed natural gas (CNG). On the territory of Macedonian's capital, the publicly owned transportation company has 39 city bus lines, with a total length of 568.7 kilometres and with 2742 daily departures.

Table 1

Number of JSP Skopje's buses and minibuses divided by the fuel and the EURO emission standard

	EURO emission standard	Number of vehicles	Fuel
Buses	Pre-EURO	13	Diesel
	EURO 1	19	Diesel
		15	CNG
	EURO 2	29	Diesel
	EURO 5	298	Diesel
Minibuses	EURO 3	11	Diesel
	EURO 5	16	Diesel
Total number of vehicles		401	

On the other hand, the privately owned transportation company Makekspres prevoz has 100 city buses that use diesel fuel complying with the EURO 2 emission standard [6]. The daily average distance covered by these buses is 171.94 kilometres per bus, while the total daily distance driven is 17194.2 kilometres. On Skopje's territory, the privately owned transportation company has 7 bus city lines with total length of 74.3 kilometres, with a total of 1604 daily departures.

The number of bus lines, bus lines length and the number of daily departures of Makekspres prevoz is given in Table 2.

Table 2

Number of bus lines, bus lines length and number of daily departures – Makekspres prevoz

Bus line number	Number of daily departures	Distance covered (km)	Daily distance covered (km)
9	250	7.8	1950
12	264	11.8	3115.2
18	28	10	280
19	260	12	3120
20	270	7	1890
22	270	13.2	3564
23	262	12.5	3275
Total	1604	74.3	17194.2

Beside the vehicles' characteristics which include the average load (taken to be 50%), EURO emission standard and the slope of the road that the vehicles are driving on (taken to be 0), the last needed information for completing the model are the speed profiles. For that purpose, several main streets and boulevards were recorded and analysed, focusing the driving patterns of the buses and minibuses.The observed transportation vehicles' speed profiles characterized by the average speed on a given distance segment driven is given in Table 3.

Table 3

Speed profiles of the urban transportation companies

Average speed	15 km/h	30 km/h	45 km/h
Distance segments	3	2	1
JSP Skopje	66.3	44.2	22.1
Makekspres prevoz	85.9	57.3	28.7

The Tier 3 model developed by the European Environment Agency represents the most comprehensive, highly advanced transportation emission estimation model developed according to the COPERT transportation emission software [7]. Contrary to the Tier 1 and Tier 2, the Tier 3 emission model takes into account several influencing variables and factors that have a direct correlation with the amount of tailpipe emission.

QUANTIFYING THE EMISSION FROM PUBLIC TRANSPORTATION USING TIER 3

One of the main purposes of this paper is to quantify the tailpipe emission from the urban transportation sector in order to better understand, manage and develop future policies to ensure urban air quality and promote clean habitat for all Skopje's citizens. Having said this, the paper examines emission of four different air pollutants: carbon monoxide (CO), hydrocarbons (HC) that also include the non-methane volatile organic compound (NMVOC), nitrous oxides (NOx) and particular matter emission (PM) ranging from $PM_{0.1}$ to PM_{10} (0.1–10μm). All of the corresponding emissions are based on complex functions in which the speed is the main contributor, as shown in Table 4 for every different vehicle category and EURO emission standard. The main difference between Tier 3 and Tier 1–2 is the fact that the emission per kilometre in Tier 3 is a variable taking into account the vehicles' speed, while Tier 1 and 2 use constantemission factors (emission per kilometre).

When it comes to the emission from buses that use CNG as a fuel, emissions from this type of fuel per kilometre are constant, having the following values:

– CO = 8.4 g/km
– NOx = 16.5 g/km
– HC = 7 g/km
– PM = 0.02 g/km.

The values of the terms [a], [b], [c], [d], and [e], found in the emission functions are given in Appendix 1 of this paper, while the term [x] represents the average vehicle speed. The next two figures (Figure 2 and Figure 3) represent the difference in hydrocarbons (HC) and particular matter (PM) emissions between buses complying with EURO 2 and EURO 5 emission standards.

Table 4

Emission functions for corresponding vehicle category

Vehicle category	EURO Emission Standard	Polluting substance	R^2	Emission function
Minibus	Euro III	CO	0.9786	(a+(b/(1+exp((((-1)*c)+(d*ln(x)))+(e*x)))))
Minibus	Euro III	HC	0.9923	(a-(b*exp(((-1)*c)*(x^d))))
Minibus	Euro III	NOx	0.9935	((a*(x^b))+(c*(x^d)))
Minibus	Euro III	PM	0.9805	(1/(((c*(x^2))+(b*x))+a))
Minibus	Euro V	CO	0.9831	((a*(x^b))+(c*(x^d)))
Minibus	Euro V	HC	0.9662	(1/(((c*(x^2))+(b*x))+a))
Minibus	Euro V	NOx	0.9945	(a+(b/(1+exp((((-1)*c)+(d*ln(x)))+(e*x)))))
Minibus	Euro V	PM	0.93	(((a*(x^3))+(b*(x^2))+(c*x))+d)
Bus	Pre-EURO	CO	0.985	((a*(b^x))*(x^c))
Bus	Pre-EURO	HC	0.992	(a+(b/(1+exp((((-1)*c)+(d*ln(x)))+(e*x)))))
Bus	Pre-EURO	NOx	0.9489	((a*(b^x))*(x^c))
Bus	Pre-EURO	PM	0.9919	((a*(b^x))*(x^c))
Bus	Euro I	CO	0.9595	exp((a+(b/x))+(c*ln(x)))
Bus	Euro I	HC	0.9926	(a+(b/(1+exp((((-1)*c)+(d*ln(x)))+(e*x)))))
Bus	Euro I	NOx	0.9524	exp((a+(b/x))+(c*ln(x)))
Bus	Euro I	PM	0.9704	(a-(b*exp(((-1)*c)*(x^d))))
Bus	Euro II	CO	0.9638	(a+(b/(1+exp((((-1)*c)+(d*ln(x)))+(e*x)))))
Bus	Euro II	HC	0.9913	(a+(b/(1+exp((((-1)*c)+(d*ln(x)))+(e*x)))))
Bus	Euro II	NOx	0.9703	(a+(b/(1+exp((((-1)*c)+(d*ln(x)))+(e*x)))))
Bus	Euro II	PM	0.9056	((a*(b^x))*(x^c))
Bus	Euro V	CO	0.9803	((a*(b^x))*(x^c))
Bus	Euro V	HC	0.9555	(1/(((c*(x^2))+(b*x))+a))
Bus	Euro V	NOx	0.9927	(((a*(x^3))+(b*(x^2))+(c*x))+d)
Bus	Euro V	PM	0.9388	(((a*(x^3))+(b*(x^2))+(c*x))+d)

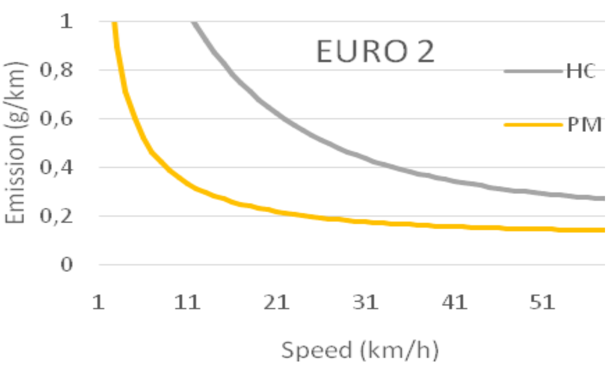

Fig. 2. HC and PM emission from EURO 2

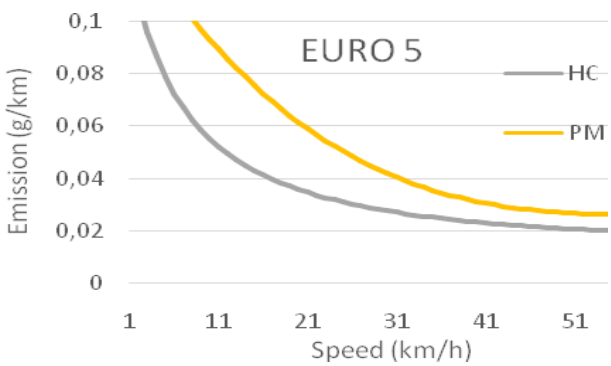

Fig. 3. HC and PM emission from EURO 5

OBTAINED RESULTS

The following Table 5 summarizes the yearly pollution from the two urban transportation companies in Skopje, expressed in kilograms and tonnes.

As it can be seen from the Table 5, even though JSP Skopje has more than four times of the number of buses that Makekspres prevoz has, the emission from the publicly owned company does not have the expected ratio of increased emissions. This is due to the fact that JSP Skopje has buses equipped with newer engine technologies that comply with higher EURO emission standards, while the privately owned company operates buses that comply with the EURO 2 emission standard.

Table 5

Total yearly emissions from JSP Skopje and Makekspres prevoz

	Polluting substance	(kg)	(t)
JSP Skopje	CO	56497.14	56.49714
	NOx	158315.3	158.3153
	HC	4486.891	4.486891
	PM	2121.768	2.121768
Makekspres prevoz	CO	15350	15.35
	NOx	71888.54	71.88854
	HC	3679.399	3.679399
	PM	1310.345	1.310345

Even though the emissions of carbon dioxide and nitrous oxides are higher from JSP buses, the difference in the hydrocarbons and particulate matter between the two companies is negligible – the difference between the two components deriving from the two transportation companies is not so high, as it can be seen on the next Figure 4.

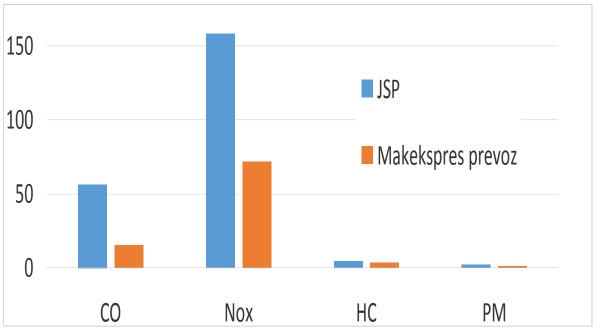

Fig. 4. Emissions from JSP and Makekspres prevoz on a yearly basis

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APPENDIX 1

Variables' values used in the emission functions

Group	EURO emission standard	Polluting substance	a	b	c	d	e
Minibus	Euro III	CO	0.899459	7.183872	0.763839	0.266598	0.074516
Minibus	Euro III	HC	326.9623	-1.77098	40.11213	-0.57716	0
Minibus	Euro III	NOx	0.1937	-1.11707	0.062562	1.045782	0
Minibus	Euro III	PM	1.039816	0.283529	-0.00207	0	0
Minibus	Euro V	CO	22.06167	-0.74272	653.3497	-3.06231	0

Group	EURO emission standard	Polluting substance	a	b	c	d	e
Minibus	Euro V	HC	1.531019	43.33872	-0.08747	0.278846	0.048564
Minibus	Euro V	NOx	8.910442	1.75025	-0.01376	0	0
Minibus	Euro V	PM	-3.1E-07	5.67E-05	-0.00351	0.091263	0
Bus	Pre-EURO	CO	88.8909	1.004227	-0.90032	0	0
Bus	Pre-EURO	HC	98.22963	1.004036	-0.58595	0	0
Bus	Pre-EURO	NOx	0.606168	55.46745	-0.62208	0.71474	0.031641
Bus	Pre-EURO	PM	17.18303	1.005766	-1.01061	0	0
Bus	Euro I	CO	2.331993	4.438456	-0.49678	0	0
Bus	Euro I	HC	3.33372	3.408691	-0.35825	0	0
Bus	Euro I	NOx	0.296803	13.45681	-0.50689	0.592877	0.03545
Bus	Euro I	PM	0.208818	-1.27059	0.129244	0.824252	0
Bus	Euro II	CO	0.891023	5.135665	5.531722	2.067282	-0.00269
Bus	Euro II	HC	3.909356	177.7604	-0.40546	0.856693	0.000712
Bus	Euro II	NOx	0.221885	5.374086	0.205943	0.604381	0.042126
Bus	Euro II	PM	2.154895	1.010949	-0.82731	0	0
Bus	Euro V	CO	32.14341	0.999161	-0.756	0	0
Bus	Euro V	HC	-4.7E-05	0.010398	-0.76477	20.94568	0
Bus	Euro V	NOx	6.875489	1.206806	-0.00772	0	0
Bus	Euro V	PM	-4.8E-07	8.81E-05	-0.00546	0.138985	0

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Original scientific paper

MANAGAMENT OF THE SISTEMS FOR MUNICIPAL SOLID WASTEN IN URBAN AREAS

Vančo Donev[1], Vladimir Arsov[2], Dame Dimitrovski[1]

[1]"Ss. Cyril and Methodius" University in Skopje, Faculty of Mechanical Engineering,
Karpoš II bb, P.O. box 464, 1001 Skopje, Republic of Macedonia
[2]OILCO KDA, Limited liability partnership company for transport.
Str. 10 No.152 Miladinovci – Ilinden. Skopje, Republic of Macedonia
vancho.donev@mf.edu.mk

A b s t r a c t: Managing with hard structure communal waste these days is more and more important not just for the countries but as well as for the companies too, from the aspect of possibility for extra (additional) profit and by its efficient work process through minimizing (reducing) their cost. Besides the protection of the environment, also as one of the motives for implementing this adequate system for the hard structure communal waste is the realization of the aspirations of the Republic of Macedonia for joining the European Union according to the standards of the European Union referring to managing of different types of waste. The future of successful organizations and countries that have aspirations to join the European Union lays in the proper and correct approach in managing the hard structure communal waste.

Key words: thermal treatment; solid waste management; incineration; pyrolysis; composting; recycling; zero waste; clean production

МЕНАЏМЕНТ НА СИСТЕМИТЕ ЗА ЦВРСТ КОМУНАЛЕН ОТПАД ВО УРБАНИ СРЕДИНИ

А п с т р а к т: Менаџментот со цврст комунален отпад е од се поголемо значење не само за државите, туку и за претпријатијата од аспект на можноста за дополнителен профит и по ефикасно работење на самите претпријатија, преку минимизирање на трошоците. Покрај заштита на животната средина, како еден од мотивите за воведување на ефективен и ефикасен менаџмент за управување со отпад, односно соодветен третман на цврстиот комунален отпад е и остварувањето на аспирациите на Република Македонија за влез во Европската Унија, што е во тесна зависност со запазување на регулативата и стандардите на ЕУ, кои се однесуваат на менаџментот со различните видови отпад. Иднината на успешните организации, градови и земји аспиранти за влез во Европската Унија лежи во правилниот пристап на управување и третман на цврстиот отпад.

Клучни зборови: термички третман; менаџмент со цврст комунален отпад; инсинерација; пиролиза; компостирање; рециклирање; отстранување на отпадЧ чисто производство

SOLID WASTE MANAGEMENT

Solid waste management system

Waste is any substance or object that belongs to the categories of waste in the list of wastes that the generator or the owner throw away, intends to throw away or is required to throw away. Solid waste management system includes determination of current situation of creation, collection, transportation, reuse, minimization and recycling of municipal solid waste, thermal treatment of municipal solid waste characterization of municipal solid waste and removal (disposal).

Treatment, recovery and recycling of the solid waste – Waste composting and anaerobic digestion are not in practice in Macedonia. Activities for recovery and recycling of municipal waste are very limited, with no organized approach and without licenses for waste handling. Practically there is no initiative at the local level to organize selection and recycling of usable municipal solid waste. Small private companies are mostly dealing with usage of useful fractions of municipal solid waste. Reprocessing of many kinds of materials with a potential for recycling is financially unsustainable under present conditions. The market of paper and cardboard is divided into two parts: one part (about 20%) is organized by the paper factory with application of "collection points", and the other part is collected by the informal sector. The paper factory does not use all collected fractions of paper and cardboard, due to the market restrictions.

Incinerating facilities – Within the sanitary landfill Drisla, that serve the area of the City Skopje, it's been installed two-chamber incinerator for medical waste and it's been in function since 2000. The capacity of the installation is 0.2 t/h, working temperature is 800/1000 degrees and installation is not equipped with a system to clean the liquid gas. Estimation is that approximately 35% of the total amount of hazardous waste from healthcare institutions in Macedonia is burning.

Recycling – Reprocessing of waste it's been done on a different kind of products, such as paper, hard plastic and foils, which are included and the wastes of the end-users. Activities for waste solving are struggling to complement the reprocessing capacity in the country, despite some of the products which the market prices can cover the transportation costs are exported.

Problems and obstacles in the system for solid waste management. A review and analysis of the key problems related to the existing waste management situation in Macedonia show that the main problems and obstacles are focused almost on all areas related to the development of the waste management system and its role in the society:

– Policy and legislative framework,
– Institutional/organisational arrangements,
– Human resources/capacity,
– Financing/cost recovery and investments,
– Stakeholder awareness and communication,
– Data availability/reporting,
– Waste avoidance and reduction,
– Waste recovery and recycling,
– Waste segregation, storage, collection and transport,
– Waste treatment/processing,
– Final disposal of waste and remediation of environmental burdens,
– Impact on public health and living/natural environment with the potential impact on the Macedonian economy.

The analysis of these problem areas shows that the present waste management situation in Macedonia can be characterised as sub-standard regarding human and financial resources, insufficient and inefficient regarding monitoring, as well as hampered by political and social lacks (like execution of enforcement, stakeholders consultations, public awareness) resulting in various dysfunctional systems in society and in many related negative effects on the environment and public health.

Basic principles for development of Macedonian solid waste management system – The basic principles for development of the Macedonian solid waste management system, it represent the main priorities as starting points to implement the measures of the National waste management plan:

The principle of **solving waste problems at their source** means the direct or shared responsibility of the waste holder/generator for waste throughout its entire lifetime, to control and collect individualy waste streams, to register their quantities and characteristics and to provide such treatment and disposal operations that are according to regulations, acceptable from the environmental and from the economic aspect. Additional responsibility is given to the manufacturers-waste generators, which are only able to prevent the generation of the production waste, to recover the process energy from waste streams, to organise recovery/utilisation of end-of-life products and to minimise the quantities and hazardous potential of waste to be disposed of.

The system should also provide **separate collection of waste** according to their hazardous characteristics, according to their point-source or dispersed-source generation and, according to intention of further management, which shall be acceptable from the environmental and economic aspect. Special priority attention shall be paid to the separation of hazardous and nonhazardous waste streams at source and to the separate final disposal of those streams.

A collection network with the intention to utilise valuable constituents of end-of-life products that is based on the "producer's responsibility" principle, shall be organised by the manufacturers, importers, distributors and retailers of products and by the specialised service enterprises.

As the waste may represent secondary raw material, sustainable waste management means an optimal utilisation of potential resource of waste as a substitute for **non-renewable natural resources** taking into account economic, environmental and social aspects.

The network of the collection, storage and pre-treatment facilities for special waste streams shall be planned on the basis of results of feasibility studies where available markets for recyclable material and end-of-life products or for some of their fractions shall be taken into account, optionally within the country or in some of the neighbouring countries. It is necessary to build new infrastructure for waste management collection, treatment and final disposal of solid waste at the regional level which will cover more than 200,000 inhabitants.

The capacities for collection, storage and pretreatment for specific waste streams and used products must be planned based on the results that will be obtained from the feasibility studies, where there are markets for materials that can be recycled and for used products.

The territory of the Republic of Macedonia represents a national value and the basis for economic and social development of the country, it requires rational and environmentally safe use of land intended for agriculture, manufacturing activities and for settlements, as well as rational use and protection of water resources, soil as well as natural and cultural heritage.

Landfill represents the most undesirable option in the waste management hierarchy but it is the unavoidable disposal option for the unusable part of generated waste or for waste residues after various recovery, recycling and treatment processes. Residual waste may disposed of in landfills only as stabilised, non-reactive material or it shall be pre-treated prior to landfill in order to stabilise the waste, to minimise the deposition volume and to reduce the mobility of harmful and hazardous substances as well as their emissions by emissions to air and by leaching water out of the landfill facilities.

Remediation of contaminated sites – "hotspots", i.e. industrial contaminated areas and non-compliant municipal and industrial landfills, may significantly contribute to the reduction of negative impacts on human health, agricultural land, biodiversity and natural environment and not finally, on the quality of the food products on the Macedonian and other markets. The priority of closing and/or remediation of such environmental burdens depend on detected risks and/or on direct impacts on the water and soil environment and on the nearby placed settlements.

THE ROLE OF THE WASTE MANAGEMENT STRATEGY IN THE REPUBLIC OF MACEDONIA

The Waste Management Strategy reflects the national policy in waste management and represents the basis for preparation and implementation of an integrated and cost-effective waste management system. With this strategic document, the Republic of Macedonia defines the fundamental directions in waste management for the coming twelve year period, on the basis of recognition of serious impacts to the living and natural environment caused by improper waste management at present and in the past, and it determines the fundamental directions of the gradual waste management system set-up based on the hierarchy of the main principles of waste management and on the main principles of sustainable use of natural resources.

The Waste Management Strategy is a document on the aims and development of measures, with the primary intention of overcoming the unacceptable environmental situation with regard to impacts of improper waste management on the air, water, soil and natural environment as well as public health, with the follow-up intention to reach complete control over generated waste streams, to reduce the waste quantities and hazardous potential, to achieve the optimal material/energy recovery and final disposal of waste by means of the optimal and contemporary system of new infrastructure facilities and with the final intention to introduce cleaner production technologies and sustainable management of natural resources and waste, as well as to reduce emissions of greenhouse gases arising from waste. Waste is not only a generator of impacts to the environment, but may also be recovered and reused. All recovery phases of waste fractions usable for the production of new goods or energy represent the preservation of non-renewable natural resources However, secondary raw material recovered from waste streams and Waste Management Strategy of the Republic of Macedonia intended for material recycling and energy production need to find their market.

Simultaneously, waste management represents in all process phases of collection, material and energy recovery a potential of new employment in service and production activities. All members of a society shall take corresponding responsibility of waste because they appear as holders and producers of waste in three contradictory roles – taking care of the quality of the environment, health and quality of life particularly for the coming generations on both a global and local level, generating waste and polluting the environment in daily activities and consuming of goods and services. This is the reason a special status is given to waste issues and the success and efficiency of the implementation of the waste management strategy depends, beside the necessary capital investments and space related limitations, above all on the correct balance of legal, institutional, organisational, sociological and in particular economical/financial instruments.

MEASURES AND ACTIVITIES THAT SHOULD BE TAKEN AT THE LEVEL OF THE CITY SKOPJE

A) Information and education

Waste prevention is essentially based on the level of information and education the population about the value of waste and dangers coming from himself and his direct connection with the depletion of natural resources.

An activity that arises is education and prevention of waste in schools by making a brochure/picture book and organise training for teachers and students. Providing training for education on prevention in administration institutions of the City and the municipalities within the City and providing training for the NGOs.

B) Donating actions

Donating actions of clothes and stuff, with small volume organized by the City of Skopje in cooperation with municipalities and non-governmental organizations of the City of Skopje.

Donor actions in schools, about textbooks, reading books and notebooks.

C) Expanding the service of the public enterprise Communal Hygiene SKOPJE in rural parts of the the municipalities within the City of Skopje

Implement procedures for including the rural parts, providing vehicles, elaboration of a scheme etc.

Can be considered three alternatives as follows:

1. Communal Hygiene SKOPJE to include with its service these places.

2. Municipalities within the City of Skopje to establish its own public enterprise "collecting and transporting" of mixed municipal waste.

3. Service to be organized as a public – private partnership with a private operator

D) Establishing ownership of containers for waste disposal of legal and physical entities that prepare food (catering facilities – restaurants, hotels etc.)

Surveying the caterers for the size of the container which is needed, providing containers, elaboration of a scheme for collecting containers, informing the caterers for the scheme of collection and start the scheme.

This measure would relieve common containers and care for the hygiene, functioning and maintenance of containers would divert from the service provider to the user. This measure will significantly contribute at improving the condition of the public hygiene in the city.

E) Home composting

Making a brochure for home composting, delivering the brochure about composting with the receipt for waste in the urban area, and through the municipalities/local communities in rural areas to all households that have a yard larger than 50 square meters, making composters and organazing a trainings for composting.

F) Selective collection of cardboard – sticker

Cardboard – sticker i.e. boxes in which products are delivered to commercial and catering facilities significantly contribute to the inefficiency of the system for collection and transportation of mixed municipal waste in urban part of the town, i.e. this type of waste is the main cause of insufficient use of the volume of containers and vehicles on one side and scattered waste around the containers on the other side.

G) Establishment of stock market of used items

Experience of countries who have achieved good results in waste prevention actions, thats register objects which for a generator are potential waste with which he should handle and make costs, to be used by entities that are using these items.

This effective measure can be implemented by setting a tool for direct intercommunication of bidders and claimants of used items.

RECOMMENDATIONS FOR FURTHER IMPROVEMENT

According to the fact that the solid waste management system in urban areas is almost at its lowest level from the aspect of the hierarchy of waste treatment, we will mention the following recommendations for further improvement of the current situation:

– Political will and understanding. It is mandatory to have political agreement on the importance of functional and sustainable management of municipal solid waste;

– Intercommunication between the City, municipalities, NGOs and all other public and private institutions;

– Using the experiences from other countries and cities in Europe and the world;

– Making analysis and starting a pilot project for an individual home composting and centralized composting in schools, larger public green areas from several households and companies with own green areas;

– Reconstruction and modernization of the fleet in Communal Hygiene Skopje, installing GPS systems for tracking the vehicles, on the use of the tank-cistern, the degree of compaction and reduce the fuel consumption;

– Performing technical improvements of the sanitary landfill Drisla;

– Manage of the illegal dumps: monitoring, cleanup and remediation;

– Organization and strengthening of the capacities of the structures which will be included in the implementation of the solid waste management system;

– For a successful project it is important to have a good team and team leader with capacity to lead the operation ahead;

– Change the method of payment for waste collection. By changing the method of payment it is necessary to establish a stimulating measures for those who provide primary selection, and punishable measures for those who will not select the waste.

– Opening more centers for collection and recycling of waste;

– Performing education on prevention of waste in schools and public institutions;

– Ownership of the containers for waste disposal of the legal and physical entities (like the model in New York).

First and basic is to provide and implement an effective and efficient system for collection and safely treatment of the municipal solid waste, to solve the first step, and it is the waste management, then to move towards increasing the ambitions, are to achieve high levels of recycling, incineration, reuse, etc. Path to success is a step by step.

CONCLUSION

These days one of the most important things in the world is the protection of the environment. In modern conditions of living the cycle of material moving in the nature is disturbed, and because of that she is no longer in a position to decompose the waste that the human is generating enormously everyday.

For this purpose is developed a special scientific – engineering discipline – SWM (solid waste management). Primary aim of this discipline is to create as little as possible waste and, secondly, the waste to be extracted and used as much as possible. By returning of the solid waste in the production process of materials is achieved savings of energy and raw materials and it is equally important for the pollution reduce of the environment.

The systems for solid waste management in the urban areas, is a hard work job that needs to be continuously improved in order to fulfill the expected results. If the aspires are the systems of solid waste management in urban areas be as efficient and effective of course it should include and the structures for communication with the public (audience):

– Publishing of general information of waste problems;
– Establishing a system for communication with the generators of waste in the manufacturing sector;
– Creating a system for public relations.

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Original scientific paper

CHANGES OF THE MOTOR OILS CHARACTERISTICS DURING EXPLOITATION AS A INDICATOR OF IC-ENGINE FUNCTIONALITY
(CASE STUDY)

Ljupčo K. Bogdančeski[1], Dame M. Dimitrovski[2]

[1]*Makpetrol AD Skopje, Division for Standardization, Quality and Ecology, Sv. Kiril i Metodij 4, 1000 Skopje, Republic of Macedonia*
[2]*Faculty of Mechanical Engineering, University "Ss. Cyril and Mathodius" in Skopje, Karpoš II bb, P.O. box 464, 1001 Skopje, Republic of Macedonia*
ljubebog@yahoo.com

A b s t r a c t: This paper presents a research of the part of the major physical and chemical characteristics of motor oils in several stages. Three types of motor oils are investigated: fully synthetic motor oil, partly synthetic motor oil and mineral motor oil. In addition there is a tabular, graphical representation and comparing the tested parameters of unused oils and oils during their exploitation in the IC engine. Also there is analysis of the need for motor oil replacement in accordance with vehicle manufacturer recommendation in correlation with the deterioration of certain characteristics and the replacement period prediction without negative consequences for the IC engine and its functionality.

Key words: motor oils; characteristics; researching; exploitation; deterioration; replacement

ПРОМЕНАТА НА КАРАКТЕРИСТИКИТЕ НА МОТОРНИТЕ МАСЛА ВО ТЕКОТ НА ЕКСПЛОАТАЦИЈАТА, КАКО ИНДИКАТОР НА НЕГОВАТА ФУНКЦИОНАЛНОСТ
(ЕКСПЕРИМЕНТАЛНА СТУДИЈА)

А п с т р а к т: Во овој труд направено е истражување на дел од битните физичко-хемиски карактеристики на моторните масла во неколку фази. Истражувани се 3 вида моторни масла: целосно синтетичко моторно масло, делумно синтетичко моторно масло и минерално моторно масло. Даден е табеларен и графички приказ, како и споредба на испитуваните параметри на неупотребуваните масла и маслата во текот на нивната експлоатација во моторот. Исто така, направена е и анализа за потребата од нивната замена согласно препораките од производителот на возилото во содејство со истрошеноста на поедините карактеристики, како и предвидувања за периодот на замена без последици по моторот и неговата функциоанлност

Клучни зборови: моторни масла; карактеристики; истражување; експлоатација; истрошеност; замена

INTRODUCTION

The working conditions of tribomechanihal elements are very complex and mostly determined by the characteristics of the oils. The complexity of the conditions is determined by the temperature of the elements in contact, the oil temperature, the external load, respectively specific pressure in the contact area, the dynamic character of the contact and the transmission of power etc. [1, 3].

During the use of tribomehanichal elements, the properties of all elements could be changed. Hard elements suffer physical changes, but oil-physical and chemical changes. The rate of degradation processes and the changes of all elements of the system, depends on the overall conditions under which works tribomechanihal system. Because, wear and friction (both main tribological processes), of all of tribomechanihal elements (and oil) are taking place under the same circumstances, there can be established a functional connection between them and working conditions. It is actually a factor that is based on diagnostic of oil condition, and through it and the diagnostic of condition of parts of the mechanical system.

The wear of hard elements of the system is a slow process and therefore difficult to monitoring, and very often difficult to stop and disassembled the whole system and measure the wear. The checking the change of physical and chemical characteristics of the oil is much easier and simpler way. It is only necessary to find a correlation between the changes of the individual elements. This can be achieved by observing (experimentation) in a typical system. It is necessary to have a laboratory equipped and professionally trained personnel. The laboratory analysis must be exactly made, and its results will not be valid if the sample of oil is not taken in accordance with the standards and in clean bottle. Because of this it must strictly follow the rules for sampling:

– the sample mast be taken nearly before the filter, sump or pump,

– not to take a sample from the "dead" lines or valves,

– before taking a sample, its necessary to establish circulation and operating temperature,

– to take into clean and dry containers and properly marked, and

– the place of sampling must be cleaned before taking the sample.

Chemical composition and properties of bae oil, chemical composition and properties of additives are modificated during the exploitation of engine oil, and that means that the chemical composition of the oil in general is modificated, as a result of contamination and degradation. The most significant contaminants in engine oil are: degradation products in base oil, degradation products in additives, the metal particles which arising from the material, hard particles in the oil from entering the environment, water and products of fuel combustion.Contamination of oil products from its own degradation, unburned fuel products due to incompletely burnt fuel and contaminants from different backgrounds are occur during the exploitation the oil in engine.The type, performance and lineage of contaminants indicate the nature and extent of changes. For example: husky particles of metal point indicate of wear, grain particles of different sizes indicate of material fatigue. Analysis of the chemical composition of metal particles indicates of tribomechanical system elements wear. There are many opportunities so that it could be contaminated and degrade. Contamination and degradation of the oil during its exploitation cannot be prevented, but can slow down, which is important for the oil and mechanical system. The speed and the level of degradation of the oil is proportional of the speed and degree of contamination. Therefore, it is important to prevent the rapid contamination of the oil before and during of its exploitation. Spectrum of contaminants of the oil is very wide. Each contaminant influence destructive of the oil, diminishing physical-chemical and working characteristic, and as a final consequence-reduced the oil`s and mechanical system`s life. On the oil path, starting with his production until to end users, there are a range of possibilities for contamination and degradation, sometimes to the point of uselessness. Possible contaminants include: gasoline, diesel fuel, other oils, water, dust and other environmental contaminants. Because, fuels and oils are transported by road and tank wagons, sometimes previous transported fluid is not completely unloaded, so that residue contaminates the next transport. Very often, remains of the water after washing the vehicle which is very destructive impacts the oil.

Preventive measures are: professional and regular cleanliness of vehicles before loading and binding control oil quality before unloading (appearance, color, odor, density, water content, flash point, viscosity). When the oil is pouring into the buyer`s storage tanks may cause to oil contamination, if the equipment is contamination. During storage, if tank filter for day-night "breathing" is damaged, through it can penetrate dust, sand or similar abrasive materials. Therefore, the filter must often be controlled and if it is necessary to replace him. In the storage tanks space there is moisture. By changing the temperature, moisture condenses, flows down the walls and collected at the bottom of storage tank. In contact with oil, condensed water can be easily and quickly degrade the oil and make it unusable even before its application. Preventive measure is to fixing temperature of the oil to about 40 °C by installation of heaters and moisture cannot condense. However, the water level in storage tank should be monitored regularly and if necessary to drain.

Exploitation investigations are getting the best performance for applications properties of motor oils.

MATHERIALS AND METHODS

Testing of the vehicle

Monitoring lubricant performance in application is the main task of a servicing laboratory. It consist of determining the physico-chemical properties of the lubricant samples supplied from the application spots, based on which it is possible to evaluate the given lubricant`s condition, and hence also to provide the user with a recommendation on how to furtherly handle the lubricant.[5]

The tests were done on 4 vehicles (Tab. 1). All vehicles have catalytic converter, except one vehicle with a diesel engine and they use fuels without sulphur. One vehicle is tested during application without pour more of oil.On the other vehicle, after taking the sample for testing, pour more an oil just as much a extracted quantities of oil. On the rest of the vehicles, after taking samples for physical and chemical analysis overall residual oil in the crankcase is replaced by fully unused engine oil.

T a b l e 1

Testing vehicle

Vehicle	Mngine	Oil	kw	Type of vehicle	Number of testing	Passed km	Duration (months)
Honda civic 1.8	gasoline	synthetic	106	passenger	3	18000	12
Citroen saxo 1.5 d	diesel	semi sythetic	42	passenger	3	11000	12
Iveco Eco Daily	diesel	mineral	126	commercial	3	30000	8

Motor oil testing

This article presents the results of exploitation analysis of the synthetics, semisynthetic and mineral lubricants. Table 1 provides the basic properties of unused synthetic and semi synthetic motor oil, and meet the following specifications:

API SN/CF ACEA A3/B4-10 MB-229.5 GM LL-B-025 VW 502.00/505.00 Porsche A-40

API SL/CF ACEA A3/B3 MB-229.1 VW 500.00/505.00

API CI-4/SL MB-228.3 VOLVO VDS-3 MAN M3275

In total it was 9 testing, and the data of testing are shown in Tables 2 and 3. During the test, the vehicles passed between 3300 and 30000 km in different periods from 8 to 12 months. In all tests was represented city driving and driving out of the city, apropos prevailed mixed type of driving. Were used as a fuel two types of fuels: Unleaded petrol 95 octanes and Diesel.

Physical and chemical properties of the oils

During the tests were taken samples of used oils from vehicles in the amount of 150 cm^3. Subject of studies in used oils were the same parameters that were listed in unused oil (Tables 2, 3 and 4) in order to make a comparison.

T a b l e 2

Testing results of unused synthetic motor oil and during his exploitation

Property	Units	Grade specification 5W-40 SN/CF			
		Unused	after 7000 km	after 14000 km	after 18000 km
Kinematic viscosity at 40 ^oC	mm^2/s	77.85	65.34	62.27	60.24
Kinematic viscosity at 100 ^oC	mm^2/s	13.46	12	11	11
Viscosity index	–	177	183	188	189
COC Flash point	^oC	204	195	180	178
Pour point	^oC	–40	–35	–32	–32
Density at 15 ^oC	g/ml	0.8549	0.8576	0.8625	0.8667
TBN	mg KOH/g	12.2	10.1	7.2	5.2

Table 3

Testing results of unused semi synthetic motor oil and during his exploitation

Property	Units	Grade specification 10W-40SL/CF			
		Unused	after 3300 km	after 8000 km	after 11000 km
Kinematic viscosity at 40 °C	mm^2/s	101	99.61	95.73	92.38
Kinematic viscosity at 100 °C	mm^2/s	14.9	14.66	14.23	13.82
Viscosity index	–	154	153	153	150
COC Flash point	°C	231	220	218	200
Pour point	°C	–40	–30	–30	–30
Density at 15 °C	g/ml	0.8671	0.8731	0.8756	0.8729
TBN	Mg KOH/g	9.25	8.5	8	6.5

Table 4

Testing results of unused mineral motor oil and during his exploitation

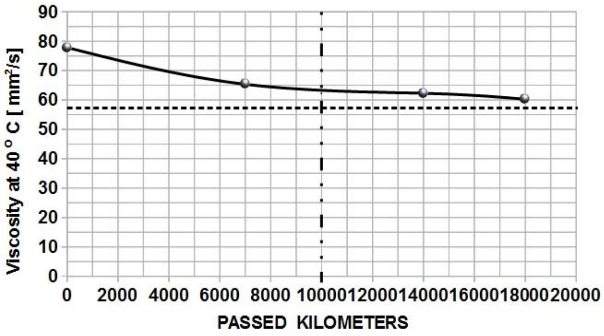
Property	Units	Grade specification 15W-40 CI-4/SL			
		Unused	after 21000 km	after 23000 km	after 30000km
Kinematic viscosity at 40 °C	mm^2/s	121,20	106,5	105	102
Kinematic viscosity at 100 °C	mm^2/s	15,37	14,31	14	13,17
Viscosity index	–	132	138	133	135
COC Flash point	°C	231	225	222	217
Pour point	°C	–21	–21	–15	–14
Density at 15 °C	g/ml	0,8848	0,8892	0,8903	0,8996
TBN	mg KOH/g	10,6	10,6	10,1	7,4

Testing results of the oils characteristics during exploitation

Synthetic motor oil – As a synthetic motor oil in this testing it was used a motor oil with API SN/CF ACEA A3/B4-10 MB-229.5 GM LL-B-025 VW 502.00/505.00 Porsche A-40 specifications in Honda civic 1.8. Have been made 4 testing during 12 months-3 testing during exploitation and 1 on unused oil before we fill it in the engine.Motor oils was sampling after passed 7 000, 14 000 and 18 000 km. With last sampling, motor oil was completely replaced.There were analysed 4 characteristics and the resultsare present on Figure 1. During the test driving it was used combined test system – driving in and out urban environment.

Semi synthetic motor oil – As a semi synthetic motor oil in this testing it was used a motor oil with API SL/CF ACEA A3/B3 MB-229.1 VW 500.00/505.00 specifications in Citroen saxo 1.5 d. Have been made 4 testing during 12 months-3 testing during exploitation and 1 on unused oil before we fill it in the engine.Motor oils was sampling after passed 3300, 8000and 11000 km. With last sampling, motor oil was completely replaced.There were analysed 4 characteristics and the results are present on Figure 2. During the test driving it was used combined test system – driving in and out urban environment.

Mineral motor oil – As a mineral motor oil in this testing it was used a motor oil with API CI-4/SL MB-228.3 VOLVO VDS-3 MAN M3275 specifications in Iveco Eco Daily. Have been made 4 testing during 8 months-3 testing during exploitation and 1 on unused oil before we fill it in the engine.Motor oils was sampling after passed 21 000, 23 000and 30 000 km. With last sampling, motor oil was completely replaced.There were analysed 4 characteristics and the results are present on Figure 3. During the test driving it was used combined test system – driving in and out urban environment.



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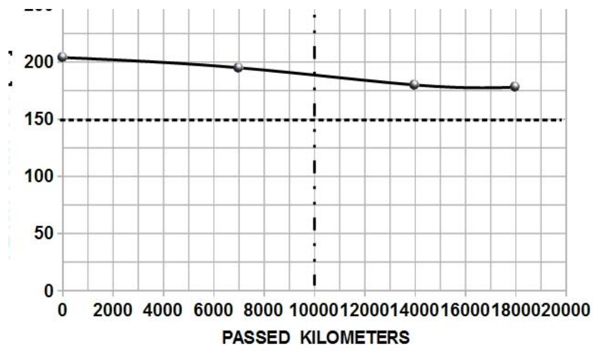

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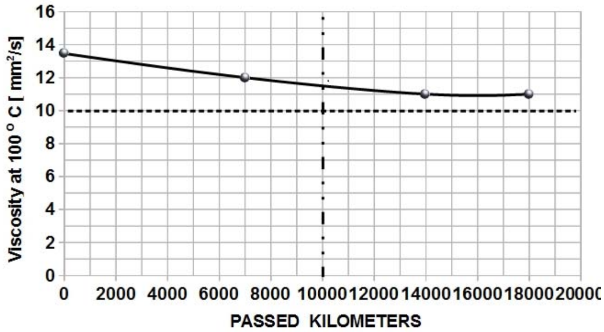

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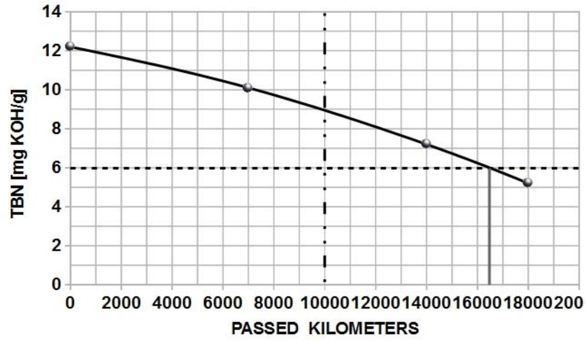
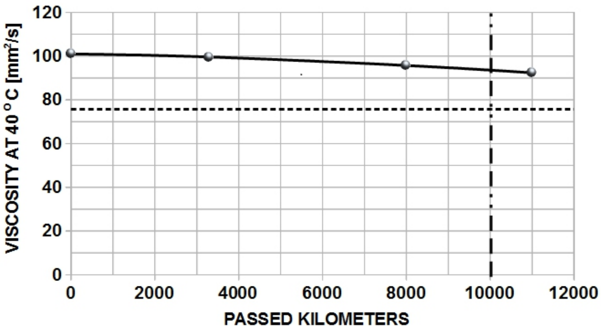


1d)

Fig. 1. Changing of properties of synthetic Mmotor oil during exploitation



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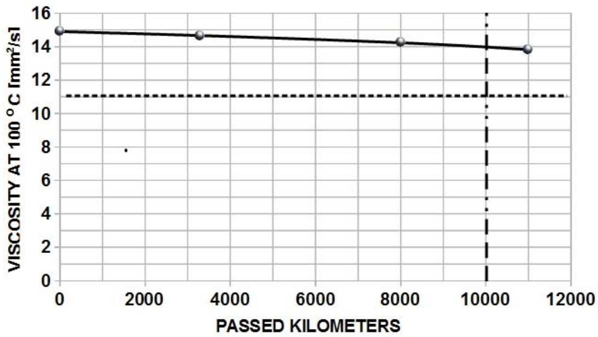

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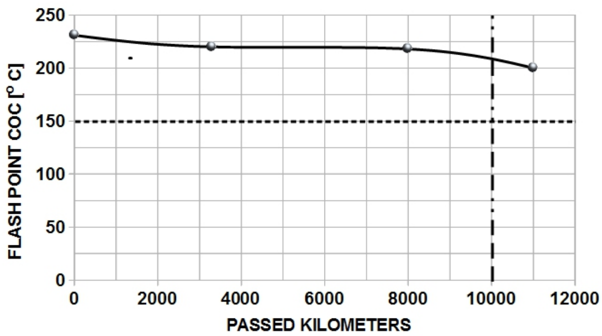

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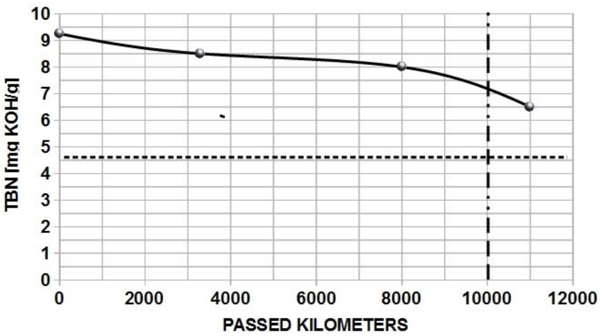

2d)

Fig. 2. Changing of properties of semi synthetic Motor oil during exploitation

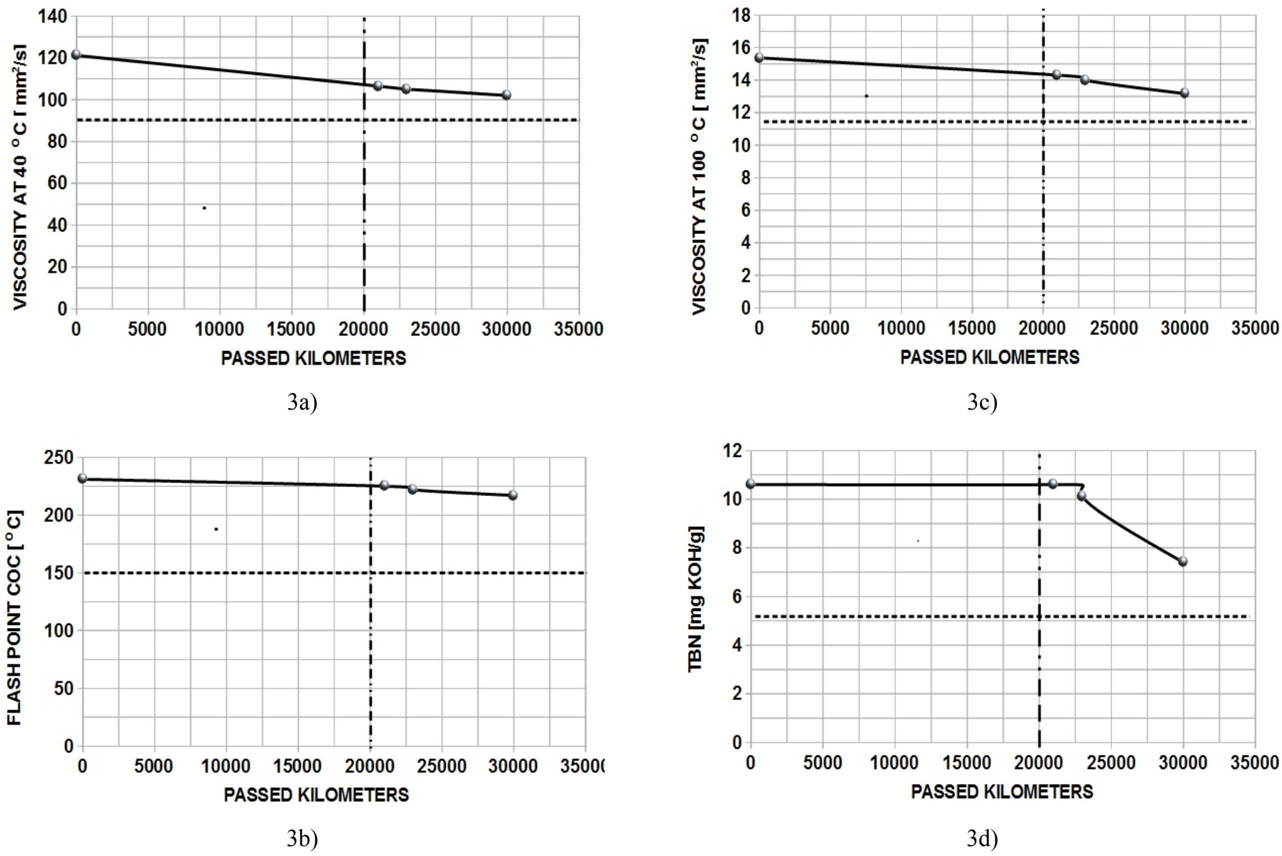

Fig. 3. Changing of properties of mineral Motor oils during exploitation

RESULTS AND DUSCUSION

Interpretation of oil analyzes in exploitation is a complex activity because the analysis of individual parameters are interconnected. With the exploitation investigations one can get the best view in oil properties [2, 4].

From the images it is visible the reduction of viscosity in all three tested oils. Reducing the value of the viscosity of the oil, leading to a reduction in its pressure and therefore can not provide sufficient flow to all parts of engine, and particularly to bearings that are most distant from the oil pump. In addition, the thickness and consistency of oil film becomes smaller than required and can not provide a cavitation lubrication. The oil film weakens and brokenes lead to increased noise and to spending on metal surfaces. Because of the reduced viscosity less seal between the piston rings and cylinder occurs, resulting in a slow start and lower compression. All this things contributes to a limited reduction of viscosity of max. 25% of the initial value or the viscosity of the oil before being placed in the engine (dotted line in the diagram of the picture).

With vertical dot-dash lines marked in the charts boundary suggested by the vehicle manufacturer are defined then much mileage is necessary to replace the engine oilcompletely. From diagrams it is notable that although the viscosity is reduced far from the critical value.But not only reducting of the viscosity should be a reason for changing the oil.

The flash point is the lowest temperature to which to heat the oil in a situation in which the released vapors will ignite instantly if offered an open flame without permanently burning. It is expressed in the OS and is considered a measure of volatility and significant for transport and storage due to the threat of fires. The permissible drop in the flash point is 25% of its initial value or minimum OS 150. By flash point is determined in the presence of fuel oil. The presence of fuel oil can be associated with poor performance in injectors.The flash point is reduced if the oil has a certain amount of fuel, due to partial wear of piston-cylinder assembly, as inconvenient or set system fuel injection.

The Figure 1 shows diagrams of the flash point in the exploration of synthetic motor oil, which is noticeable continuous decrease after spending 13 000 kilometers, after which comes to its stabilization.

Figure 2 shows the continuous reduction of the flash point in semi-sintetic motor oil after spending 8 000 km that comes after its stabilization.

In the flash point for mineral oil minimal reduction throughout the tested period (Figure 3).

Given that the graph indicates that the flash point is still far from critical values (25% of the initial value) and bearing in mind the recommendations of the vehicle manufacturer for the replacement of oil, they are in good condition exploitation. In any case, the fuel oil may reflect poorly on the motor for long periods, primarily due to the worsened performance of the oil or its deteriorated lubricating properties – which could reflect on the engine and its work.

Overheads pool number (Total Base Number – TBN) is defined as a measure of alkalinity origin of all matter in the oil that demonstrates basic reaction. It is expressed in mgKOH/g sample of the oil. It is equivalent to the amount of acid required to neutralize all basic substances in a sample of one gram of oil [8].

High temperatures in the engine lead to the formation of deposits and deposits of vital parts, especially in the video area. As a consequence of this may come diminishing mobility, ie conglomeration of piston rings. Deposits continue moving into coke that abrasive act on the desktop of the cylinders and as a consequence we have the appearance of polished surface. For detergent additives are carriers of the base reserve by reducing their spending total pool number (TBN).

Fastest spending detergent additives, and thus sharply reduce the value of TBN occurs often in frequently moving and stopping or driving a short distance (urban cycle), thus failing to achieve the operating temperature of the engine. In these conditions of cold engine it comes to creating large amounts of deposits, resins and smoke that lower TBN, and lead to rapid clogging of the oil filter. Disperzantnite additives tasked then wrapped finest particles (contaminants) to hold dispersed and thereby prevent their conglomeration and sedimentation.

From Figure 3d it can be noted that the intersection of the test curve and the rights to the minimum allowable value for TBN, shows us the mileage (16 500 km) to which the oil has not had to be replaced. With further use of engine oil TBN value falls below the value of 50% compared to the initial value, which in technical terms means that it is no longer able to neutralize harmful acids-to the extent they are not dangerous to metal surfaces engine. The oil had to be replaced after spending 16 500 km. In any case identified 16 500 km represent more mileage compared to the recommendations of the vehicle manufacturer, which is a good economy and an additional benefit for the environment. The remaining value of TBN oils and their momentary replacement is far from their critical value, which means that they could remain in the engine further use.

CONCLUSION

There is an optimal time when the motor engine oil should be replaced, and it depends on many factors: the state of the engine, engine oil quality, the driving, the climatic conditions etc. If oil is not replaced at the right time, there is a risk of corrosive action of individual acidic components on vital engine parts and diminishing lubricity of engine oil appears, and as a consequence there is an intensive spending on metal surfaces [6]. On the other hand, premature replacement is not economical, and further pollute the environment. The best solution is determining the period of replacement of oil based on the condition of the oil and the condition of the engine [7].

The general conclusion is that, thanks to the examinations of specified types of motor oils, which were examined in this paper the general recommendation is that oilshould not be replaced so early as it isrecommended by the manufacturer, because the analysis showed that they are in good condition and could beexploited after recommended mileage.For the large bus flat or large car flat it is better to check the oil from time to time and to find the real millage for replacement in order to save money and to save the environment.

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Original scientific paper

SELECTION AND ANALYSIS OF COMBINED COGENERATION PLANT OF NATURAL GAS FOR HEATING THE CITY OF BITOLA

Suzana Zikovska[1], Slave Armenski[2]

[1]*ELEM Macedonian PowerPlanrs, Branch Rek Bitola,*
Novacki pat b.b., 7000 Bitola, Republic of Macedonia
[2]*Department of Thermal Engineering, Faculty of Mechanical Engineering,*
"Ss. Cyril and Methodius" University in Skopje,
Karpos II b.b. P.O. Box 464, 100 Skopje, Republic of Macedonia
zikovska@yahoo.com

A b s t r a c t: The basis for initiating this research was based on the latest achievements in the development of energy technologies, such as: efficiency, energy saving and ecology. In this research, the findings from some previous research in this area had been used, especially for cogeneration plants with natural gas as an energy source for combined production of electricity and thermal energy. A selection of the drive motor in the plant cogeneration was done, depending on the defined needed heat for the city of Bitola. According the curve of the hourly temperature of the outside air for the city of Bitola and the heat consumption, analysis of the thermal cogeneration plants was made in terms of: combined steam-gas cycle to produce heat for heating in the range between (80-200) MWt and a cycle with steam turbine with regulated subtraction.

Key words: cogeneration; electricity and heat efficiency; saving energy; natural gas

ИЗБОР И АНАЛИЗА НА КОМБИНИРАНА КОГЕНЕРАТИВНА ПОСТРОЈКА НА ПРИРОДЕН ГАС ЗА ТОПЛИФИКАЦИЈА НА ГРАДОТ БИТОЛА

А п с т р а к т Основата за отпочнување на ова истражување се базираше на најновите достигнувања во развојот на енергетските технологии, како што се: ефикасноста, заштедата на енергија и екологијата. Во ова истражување искористени се сознанијата од досегашните истражувања во оваа област, особено за когенеративните постројки со природен гас како извор на енергија за комбинирано производство на електрична и топлинска енергија. Извршен е избор на погонскиот мотор во постројка за комбинирано производство во зависност од дефинираната потребна топлинска енергија за градот Битола. Согласно кривата на средната часовна температура на надворешниот воздух за град Битола и топлинскиот конзум, направена е анализа на термоенергетски когенеративни постројки на: комбиниран паро-гасен циклус за добивање на топлина за греење во опсег меѓу (80-200) MWt и циклус со парна турбина со регулирано одземање.

Клучни зборови: когенерација; електрична енергија и топлина; ефикасност; заштеда на енергија; природен гас

INTRODUCTION

The development of the energy technologies, can be reduced to meet the requirements of efficiency, economy, saving the energy resources, ecology and flexibility.

Today, the problems of environmental nature in the use of the most exploited energy resource, the coal, are enormous and becoming more serious due to the stricter environmental norms. For this reason, efforts are made to reduce the emission of carbon compounds CO and CO_2, nitrogen oxides, sulfate compounds NO_X and SO_2.

Another problem that arises and becomes particularly serious is the limited quantities of coall which is the major energy resource in Macedonia used in electricity production.

Analyzing the application of the energetic resources in Europe and in the whole world in general, as well as the benefit from them, it is confirmed that the use of the natural gas as a fuel in the construction of new thermal power plants with a combined production of energy or cogeneration plants for combined production of natural gas grows more and more.

In accordance with the benefits of the cogeneration plants in the world today, more and more organizations are dealing with the promotion and implementation of co-generation. Accordingly, in 2001 in Brussels, the European organization for the promotion of co-generation (The European association for the Promotion of Cogeneration or part EDUCOGEN) was established [9], [10].

In this regard the development and the implementation of cogeneration plants is different in different countries and depends on the economic and the industrial development, the available fuel, the climate conditions, etc.

In the countries with colder climates, cogeneration is most often used for heating or satisfying the needs of heat for heating and hot water for the population.

The Fig. 1 shows the application of cogeneration in certain countries in Europe [1].

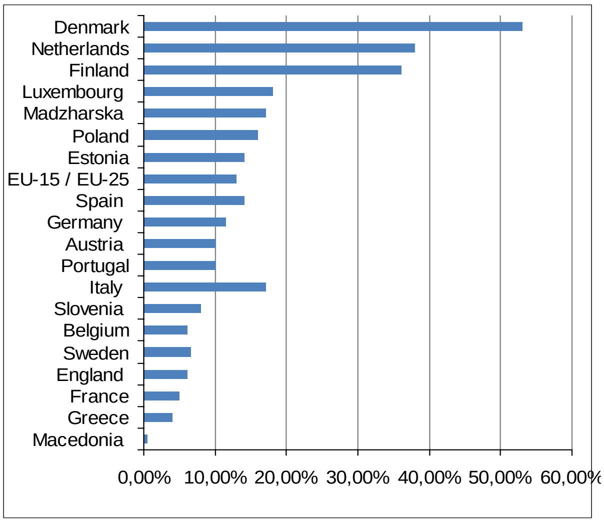

Fig. 1. Participation of co-generation in the total electricity production in Europe

The average amount of electricity produced from cogeneration plants is about 15% and there is a trend of steady growth. The very percent in some countries can be seen on Fig. 1 [1], [8].

The development and the implementation of cogeneration plants is different in different countries, and depends on the economic and industrial development, available fuel etc. From the diagram can be seen that Macedonia has the lowest rate of participation of the cogeneration in the process of electricity production. The results of the survey in terms of energy and environmental effects of the implementation of cogeneration for the combined production of electricity and thermal energy to natural gas confirm the need for greater and more intensive use of this type of plant and the introduction of natural gas in a big way in the energy sector in the Republic Macedonia.

DEFINING THE CRITERIA FOR SELECTING COGENERATION PLANT

In order to select and fully exploitate the cogeneration plants during the year, the following conditions must be taken into account: the need for heat, the power factor load or the working hours during the year, profile setup of the electricity and the thermal energy [2], [3].

The heat consumption for heating of a settlement are defined on the basis of external minimum design temperature for the respective place. Based on data processing of the meteorological measurements of the outdoor air between 1996–2010 years the city of Bitola, in Table 1, the numerical values of the relative length of the duration of temperature intervals during the heating season and heat capacity are presented [4].

This means that the average load during the heating season is 23.4% and the average heat load during the heating period is 46800 kW. According to the table the number of hours the plant would reach is 4320th. The diagram of the coefficient of the thermal load is shown in Figure 2.

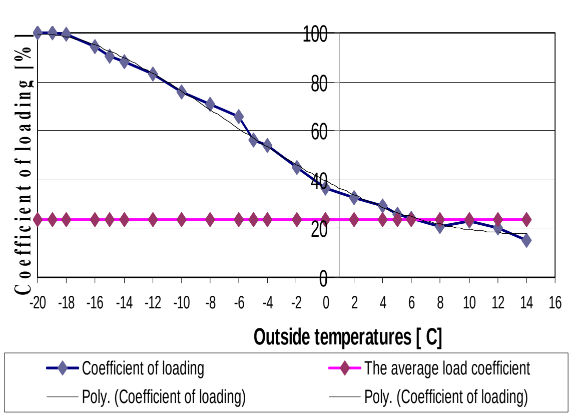

Fig. 2. Diagram of the thermal load coefficient depending on external temperatures

Table 1

Relative length of duration of the temperature ranges in the heating season, and heat capacity

Item number	Temperature interval °C	Relativna length of duration day	Relativna length of duration Hour	Thermal load %	Thermal power kW
1	< (–18)	0.2	5	100	200000
2	(–18) to (–15)	0.7	17	100 – 90.72	200000 – 181449
3	(–15) to (–10)	2.7	65	90.72 – 75.92	181449 – 151843
4	(–10) to (–5)	6.9	166	75.92 – 56.3	151843 – 112647
5	(–5) to (0)	25.9	622	56.3 – 36.4	112647 – 72749
6	(0) до (+5)	55.6	1334	36.4 – 25.9	72749 – 51711
7	(+5) до (+10)	62.1	1490	25.9 – 23.3	51711 – 46521
8	(+10) до (+12)	20.9	502	23.3 – 18.6	46521 – 37216
9	> (+12)	4.5	108	18.6 – 0	37216 – 0
	Total / Average	180	4320	23.4	46800

The analysis of the assessment of the potential and the real heat consumption (in Bitola and it is surrounding) show that it is 110/200 MWt [4]. It would be considered as a variable size in the range of 80 to 200 MWt. That will be the basis for defining the optimal conditions for technically possible and economically feasible solution for cogeneration plant that will be used for combined production of electricity and heat.

COMBINED PRODUCTION OF ENERGY WITH NATURAL GAS

For determining the most favorable solution, it is necessary to perform a preliminary analysis of cogeneration plants for electricity and heat production.

The preliminar analysis and simulation of a combined process in different regimes (in the range of 80 to 200 MWt) of heat, is carried out according to the technical solution combined cogeneration plant of natural gas as the picture 3[rd] [5], [7].

In order to select the most suitable solution, what is initially needed is the determination of the change in the output power and the necessary heat for heating with steam turbine for combined production, for different modes of heat production in accordance with the change in outside temperature.

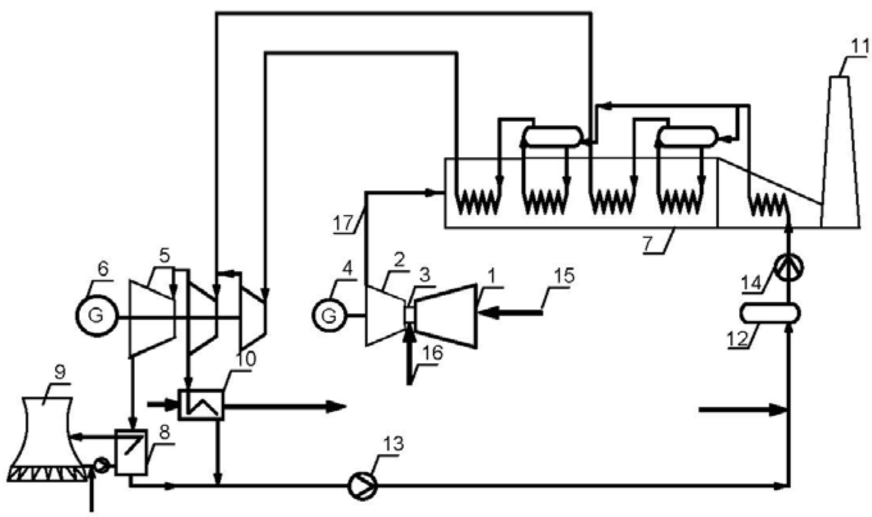

Fig. 3. Principled scheme of combined cogeneration plant
1) a compressor; 2) Gas turbine; 3) Combustion chamber; 4–6) Generators; 5) Condensation steam turbine; 7) Steam Generator; 8) condenzer; 9) Cooling tower; 10) District heating exchanger; 11) chimney; 12) Feed water tank; 13) condensates pumps; 14) feed water pumps; 15) air; 16) fuel; 17) output gases; 18) Dstrict heating water

The change of the power of the steam turbine at different modes is represented in the diagram in Figure 4.

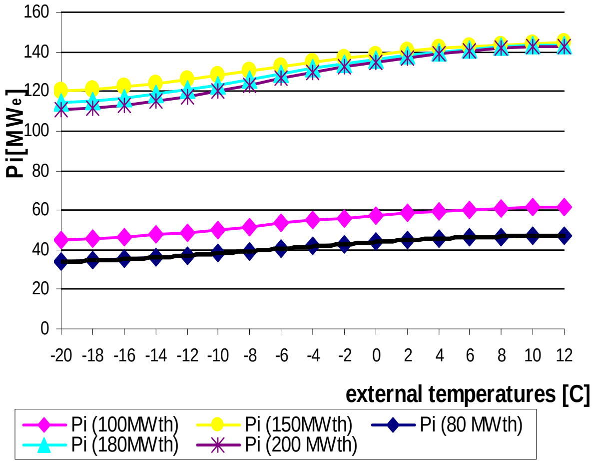

Fig. 4. Diagram of the change of the power turbine of the outside temperature

With the change and the growth of the external temperature, the necessary heat for heating is being changed as well. What is that change in different modes can be seen from the diagrams presented in Figure 5.

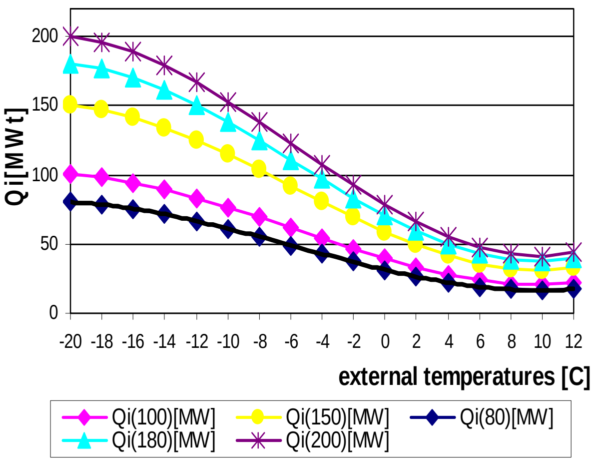

Fig. 5. Diagram of the change of the heat for heating from the outside temperature

From the diagrams in Figure 4 and 5 it is clear that at very low temperatures (–18°C and lower project), the heat consumption is at maximum level, which results in a decline in the production of electricity. However, the coefficient of utilization of the plant for that mode is the highest. But as the outdoor temperature grows, the need for heat for heating in the heating system is reduced at the expense of the production of electricity is increasing, but the use of energy in the plant is decreasing. So for temperatures above 12ºC, when there is no need for heat for heating, the coefficient of utilization of the block is low and the same as the condensing mode.

There are more modes between these two conditions, according the external design temperature and the amount required for heating. Further research will aim at finding an optimal solution of plant cogeneration of electricity and heat.

ANALYSIS METHOD OF COMBINED PRODUCTION FACILITY AND TECHNICAL PERFORMANCES

Preliminary to choose a technically feasible and optimal energy efficient solution for plant production of electricity and heat, we use the method of comparative analysis of the proposed technical solutions.

For this purpose the technical performance such as energy efficiency and energy savings are being analysed, with three possible technical solutions for the production of electricity and heat [13], [14].

Separate production of electricity and heat in a thermal power plant and the boiler heating system.

Cogeneration steam turbine with regulated seizure of steam for the heating system.

Cogeneration plant with a combined cycle with gas turbine and condensation steam turbine with regulated steam subtraction.

Energy efficiency

The energy efficiency is one of the most important technical performances and it is calculated by the following equation [10]:

$$\eta = \eta_{ea} + \eta_{tha} = \frac{P_{ea} + Q_{tha}}{Q_{ga}}$$

where is:

P_{ea} – Net power output of the system used annually

Q_{th} – Useful heat output of the cogeneration system annually,

Q_{ga} – Used heat from the fuel cogeneration system annually.

The diagram in Figure 6 also shows the size of the overall efficiency of the three considered systems that produce electricity and heat for heating depending on the required heat for heating, at the combined cogeneration gas (CCP), cogeneration steam turbine (CST) and a separate production (SP) of the two types of energy, during the heating season.

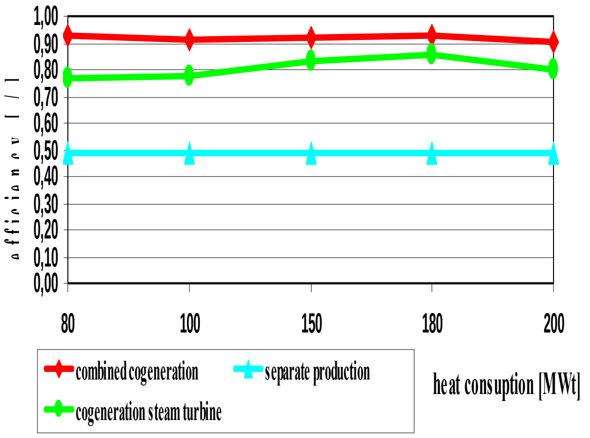

Fig. 6. Diagram of dependence of efficiency of cogeneration and separate production

The diagram clearly shows that the highest efficiency is achieved when the CCP of the natural gas for all heats in the analyzed range is 80 – 200 MWt).

This means that the performance of the CCP is an objective function that will significantly affect the process of choosing the CCP natural gas, with optimal production of heat for heating. The factor of energy saving FESR.

In order to find the most suitable solution for cogeneration plant operation, it is necessary to calculate and analyze the factor of fuel saving at combined cogeneration of natural gas. This factor is calculated by the following equation [10]:

$$FESR = \frac{Q_{gs} - Q_{gc}}{Q_{gs}}$$

where is:

Q_{gs} – The total energy of the fuel at separate production electricity and thermal energy;

Q_{GC} – The total energy of the fuel when producing electrical and heat energy at cogenerative plant.

In order to have a real understanding of the benefits of energy savings of fuel, it is necessary to compare the process of separate production of electricity and the thermal energy (SP - CCGP) at various heat loads. How does the factor of saving fuel reacts during the heating season and at the same time depending on the outside temperature ,can be seen in the diagram in Figure 7.

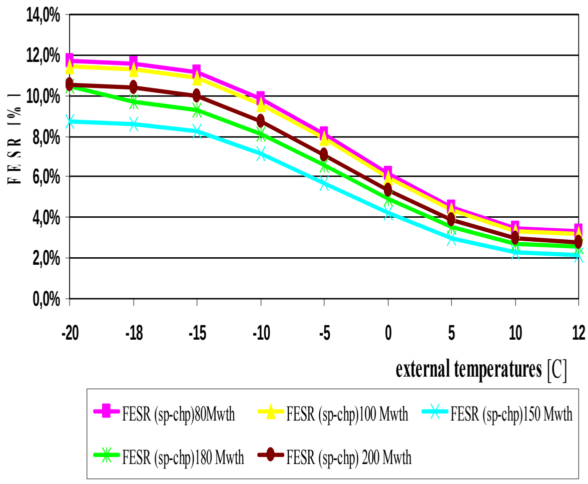

Fig. 7. Diagram of fuel saving cogeneration

From the diagram in Figure 7 it can be clearly seen that the greatest fuel savings can be achieved in combined cogeneration natural gas in heat energy production of 80 to 100 MWth.

Also the saving is on the highest level when CCP at very low temperatures when the coefficient of thermal load is at its hughest level.

The work of the CCP at very low temperatures clearly illustrates the advantage in terms of energy savings of fuel compared to a separate production where the necessary heat for heating is produced in boilers.

The dependence of the percentual saving of fuel, cogeneration of electricity and heat in CCP of natural gas compared with separate production of electricity and heat depending on the generated thermal energy is represented in the diagram of Figure 8.

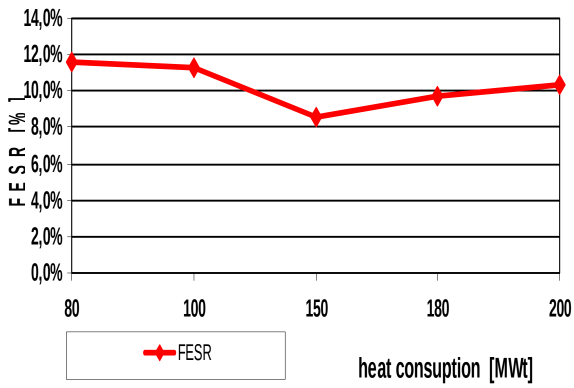

Fig. 8. Diagram of the dependence of fuel savings of heat consumption

From the analysis done so far , we come to the conclusion that the energy savings from fuel at CCP natural gas is higher compared to the SP and it is placed from 9 to 12% in CCP with different capacity [11], [12].

CONCLUSION

Based on the surveys of external conditions for for the city of Bitola (1996–2010) and the estimated heat consumption of 110/200 MWt, different calculations and technical analysis of the various cogeneration are being performed. In doing so, the following conclusions are brought:

- The average coefficient of thermal load for the city of Bitola from 23.4% in the analyzed period is defined.
- An analysis of all the possible criteria for determining the type of combined heat and power cogeneration plant to natural gas it is performed. Thus all analyzes, calculations and simulations are made for a wide range of thermal loads 80 to 200 MWt.
- The results received in the numerical analysis show higher overall efficiency of the CCP of the natural gas and 0.928 which is for 89% higher in terms of the efficiency at separate production, or 7.9% compared to steam turbine cogeneration.
- The analysis of the results in the CCP that meet the predefined conditions (maximization of total efficiency and maximization the factor for saving fuel), for the type of plant a CCP is chosen at maximum heat for heating of 80 MWt.The work of the plant is a function of a coefficient of heating.

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Short communication

AUTOMATION IN AN AEROBIC CONTINUOS SYSTEM FOR TREATMENT OF TECHNOLOGIC WASTE WATERS FROM MEAT INDUSTRY

Dejan Kordoski

[1] *Institute of Hydrotechnics, pneumatics amd automation, Faculty of Mechanical Engineering, "Ss. Cyril and Methodius" University in Skopje*
Karpoš II bb, P.O. box 464, 1001 Skopje, Republic of Macedonia
lester@t.mk

A b s t r a c t: The full implementation of the process of automation in an aerobic continuous system for treatment of technologic waste waters from meat industry, is based on real time monitoring, analysis and control of niche of complex chemical, physical and biological parameters. The principal goal is to provide continuous, unobstructed and effective operation of the station for waste water treatment. With the use of automation in the process of waste water treatment it's expected to achieve higher efficiency and productivity of the technology, as well as decrease in the use of human resources.

Key words: automation; waste water treatmentl aerobic continuous system; meat industry

АВТОМАТИЗАЦИЈА НА АЕРОБЕН КОНТИНУИРАН СИСТЕМ ЗА ПРЕЧИСТУВАЊЕ НА ТЕХНОЛОШКИ ОТПАДНИ ВОДИ ОД МЕСНА ИНДУСТРИЈА

А п с т р а к т: Целосната имплементација на процесот на автоматизација во аеробен континуиран систем за пречистување на технолошки отпадни води од месната индустрија е базирана на моментално следење, анализа и управување на низа комплексни хемиски, физички и биолошки параметри. Главната цел е да се овозможи континуирано, непречено и ефикасно работење на станицата за пречистување на отпадни води. Со употребата на автоматизација во процесот на пречистување на отпадни води, се очекува да се постигне поголема ефикасност и продуктивност на технологијата за пречистување, како и намалување во употребата на човечки ресурси.

Клучни зборови: автоматизација; пречистување на отпадни води; аеробен континуиран систем; месна индустрија

INTRODUCTION

Meat processing industry produces products and semifinished products from animal processing. This is accomplished through a niche of technologic and commercial operations, standardized and compliant with food safety regulations. From these technologic processes large amounts of by-products are created in a form of solid and liquid waste from organic origin, which must be treated in order to be harmless and acceptable for the ecologic environment.

Waste waters from meat industry are divided into two groups: faecal and technologic.

Treatment and recycling of faecal waters is best achieved in cogeneration plants through capturing and storing of methane. Onsite reuse of the fuel cuts energy expenses for water heating in the industrial complex. Estimated capacity of methane from different fractions of waste from the meat processing industry is displayed in Table 1 [1]:

Treatment of technologic waste waters obtained from sanitation of work surfaces, equipment and floors are processed in waste water treatment facilities. The composition and characteristics of the technologic waste waters from meat industry varies depending on the part of the plant or technological process from where it originates.

Table 1

Estimated capacity of methane gathered from different fractions of the waste from meat processing industry

Substract	Capacity of Methane mg CH_4/kg dry organic matter
Stomach content	300
Water for stomach flushing	280
Faeces	650
Remains from capturing fats	710
Floating solids	700
Household waste	330

The usual composition and characteristics of the technologic waste from meat industry is displayed in Table 2 of [2]:

Table 2

Composition and characteristics of waste from meat processing industry

Parameters	Value
Moisture, (%)	69,45
Total solids, (%)	30,55
Volatile solids (% of total solids)	87,95
Nonvolatile solids (% of total solids)	12,05
Organic Carbon, (%)	23,32
Total N, (%)	2,71
P, (mg/g)	4,19
K, (mg/g)	9,9
COD, (mg/L)	1.000 – 6.000 (max 20.000)
BOD_5, (mg/L)	1.000 – 4.000 (max 10.000)
Temperature, (˚C)	20 – 35

Technologic waste waters seldom have a constant composition, because they depend on the [3]:

- Part and type of the production process;
- Quality of the meat;
- Type of the product;
- Speed of sanitation of the floors and the type of equipment;
- Speed of mixing of the waters;
- Amount and temperature of water used for sanitation etc.

Treatment of technologic waste waters from meat industry can be achieved by using any of the following three technologies [4]:

- Aerobic – in presence of oxygen;
- Anoxic – in absence of oxygen, in presence of nitrates or nitrites;
- Anaerobic – in absence of oxygen, nitrates and nitrites.

The specifics of the technologic waste waters is suitable for aerobic biological treatment, because of its organic pollution and constituent well degradable matter. Aerobic continuous system is ergonomically acceptable for use of larger meat processing industries, it is economical in construction and exploitation, low maintenance costs as well as low energy demand.

AUTOMATION OF AEROBIC CONTINUOUS SYSTEM FOR TREATMENT OF WASTE WATERS IN MEAT INDUSTRY

With the extensive development of digitalization, implementation of automation in technologic processes in all industrial sectors becomes essential.

Automation in the process of treatment of waste waters from meat industry can't be designed in exactly defined cycles ahead, because of changes in the structure of the influent and changes in its flow; hence real time following of a niche of parameters is a necessary requirement, in order to have fresh data on the condition and characteristics of the influent. Analysis of the gathered data is processed in an expedite manner, followed by quick actions and control, because of the continuous flow of the influent, and the commitment to preserve uninterrupted efficiency of the facility.

The parameters gathered and cycles of control depend on the process of the treatment, as follows:

- The cycle of the control of the collecting shaft and the first sedimentation tank depends on the level of the influent in the tank, as well as the sedimentation of solid particles on the bottom and the amount of floating fat. Depending on the operations of the unit for separation of solid particles, the influent can be passed to the next operation.
- The cycle of the separation of the solid particles from the influent depends on the type of equipment used for this action, and is usually specified by the manufacturer of the equipment. The number and capacity of the

equipment should satisfy the entry parameters of the flow at the entry in the collecting shaft.

- Right after separation of the solids, in the DAF tank soluble and insoluble fat are measured and the adequate amount of HCl is added to break down the fat and to achieve successful flocculation. Floating fat is gathered with a scraper into another tank, and when a certain level is reached a pump would be activated to transport the broken down fat. Depending on the concentration of the soluble fat, and the residue from the filtration process, the amount of air brought into the DAF tank is controlled. When certain level of sediment particles on the bottom of the tank is reached, another pump is activated to transport the solids.
- In the neutralization tank pH levels are monitored, and the dosage of NaOH, which aligns the pH levels of the influent to neutral.
- After the alignment of the pH levels, amount of influent that can be received by the equalization tank is brought in. The equalization tank is strictly connected to the control of the influent flow in the downstream processes.
- In the anoxic tank concentrations of N and P are measured, as well as the concentration of the bacteria present that govern the reduction.
- In the biologic reactor the following parameters are monitored: BOD_5, COD, carbon organic matter in the influent, oxidation of ammonia, removing of N and P, depending on the requirements of the quality of the effluent.
- The excess sludge from the biologic reactor is transported to the sedimentation tanks. When lower values for the bacteria in the anoxic tank are obtained, a part of the sludge is transported in the anoxic tank, another part is transported to the tanks for drying, and a small part is kept as a reserve for the anoxic tank.
- The effluent from the drying tanks and the sedimentation tank is finally neutralized with a treatment with NaOCl, which can be done in a harmonized manner depending on the recipient of the effluent.

In order to assure adequate monitoring, analysis, operation and control of this information it is required to design and construct an intelligent system with instant sampling and laboratory analysis of the condition of the influent. To achieve this, probes are placed into all processes of the influent treatment which measure: chemical compounds, organic matter, flow, pH, temperature, density, levels of the influent in the separate processes etc. Data received by the probes is analysed by programmed software, and accordingly takes autonomous operations and control. The size and the speed of the intelligent system is designed to be sufficient and efficient, depending on the amount of information processed and stored at any time of the operation of the facility [5].

In order to achieve continuous and uninterrupted operation of the waste water treatment facility, implementation of control procedures for remote control, or control through IoT, serve as a back up variant to the autonomous regime when maintenance is required.

CONCLUSIONS

Automation of the processes for: gathering data, analysing and control; enhances the efficiency and productivity of a waste water treatment facility in the meat industry.

By creating autonomous gathering of real time data and instant analysis of the condition and the characteristics of the influent, as well as control of operations, the use of human resources is significantly reduced.

Backup mechanisms for remote control, or control through IoT, are placed in order to achieve uninterrupted operation of the waste water treatment facility during maintenance.

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Original scientific paper

EFFECT OF CO-SOLVENT ON BIODIESEL PRODUCTION

Slavčo A. Aleksovski[1], Goran Srbinoski[2], Biljana Veleska Chapragoska[3]

[1]Faculty of Technology and Metallurgy, "Ss. Cyril and Methodius" University in Skopje
P.O. Box 580, MK-1001 Skopje, Republic of Macedonia
[2]Rudnička 32, 6250 Kičevo, Republic of Macedonia
[3]Department of Criminalistic Technique, Ministry of Interior Affairs,
Dimče Mirčev bb, 1000 Skopje, Republic of Macedonia
slavcho@tmf.ukim.edu.mk

A b s t r a c t: The main problem of transesterification reaction is that the reactants (oil and alcohol) are not readily miscible. This leads to a longer reaction time and higher product costs. Introducing a mixing solvent agent (co-solvent) generates an oil-dominant one-phase system in which the mass transfer is improved, the reaction is faster and higher extant of reaction. In this study, ultrasound-assisted base catalyzed transesterification of used cooking oil in a batch conditions and in the presence of co-solvent (n-hexane and biodiesel) was analyzed. The experiments have been carried out with a molar ratio of oil to methanol 1:6, 0.7 wt.% of KOH to oil, 1:1 volume ratio of co-solvent to methanol and temperature 65°C. The reaction time was varied as 15, 30 and 60 minutes. Also, the reaction of transesterification was conducted without using of co-solvent. Fourier Transform Infrared Spectroscopy (FTIR) analysis was used to determine methyl esters content in a biodiesel.

Key words: biodiesel; ultrasound; co-solvent; used cooking oil; transesterification

ЕФЕКТ НА КО-РАСТВОРУВАЧ ЗА ДОБИВАЊЕ НА БИОДИЗЕЛ

А п с т р а к т: Основниот проблем на реакцијата на трансестерификација е дека реактантите (масло и алкохол) не се мешаат лесно. Ова води кон долго време на реакција и повисока цена на чинење на производот. Воведувањето на растворувач за мешање (ко-растворувач) генерира еднофазен маслено доминантен систем во кој е подобрен преносот на маса, ракцијата е побрза а досегот на реакција е поголем. Во овој труд, анализирана е ултразвучната базно катализирана трансестерификација на употребувано масло за готвење во шаржни услови и во присуство на ко-растворувач (н-хексан и биодизел). Експериментите беа изведени со молски однос на масло со метанол 1:6, 0.7 мас.% на KOH спрема масло, 1:1 волуменски однос на ко-растворувач со метанол и температура 65°C. Времето на реакција беше менувано како 15, 30 и 60 мин. Исто така, реакцијата на трансестерификација беше изведена без употреба на ко-растворувач. За определување на содржината на метил естри во биодизел беше употребена Фуриер Трансформирана Инфрацрвена Спектроскопска (FTIR) анализа.

Клучни зборови: биодизел; ултразвук; ко-растворувач; употребувано масло за готвење; трансестерификација

INTRODUCTION

The reaction of transesterification (Figure 1) is a known process to produce fatty acids methyl esters (FAME) from vegetable and animal based oil. The reaction generally is carried out in a batch type processor at 60°C temperature and 1 at pressure. However, since the reaction of fatty acids with methanol is reversible, the reaction comes to equilibrium before a complete conversion of the oil. This is why an extent amount of methanol is added to the reaction mixture, in order to shift the equilibrium to product side [1].

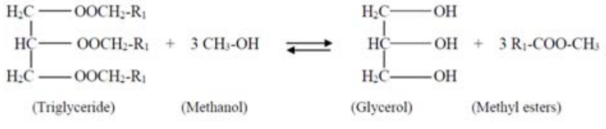

Fig. 1. Reaction of transesterification

This reaction proceeds via three consequtive reversibile reactions where mono- and diglycerides are intermediates and their presence in the final product (biodiesel) is considerable. The reaction produces two liquid phases: alkyl esters and crude glycerol fraction (the heavier liquid). Among the alcohols that have been used to produce biodiesel, methanol is the one of most used. It is polar and shortest chain alcohol and is a relatively inexpensive [2]. Transesterification reaction can be catalyzed by both homogeneous (alkali and acid) and heterogeneous catalysts. The most used alkali catalysts are NaOH and KOH. Alkali-catalyzed transesterification of vegetable oils proceeds faster than acid-catalyzed reaction. The problem associated with the homogeneous catalyst are the high consumption of energy, form unwanted soap byproduct by reaction of the free fatty acids (FFA) and expensive separation of the homogeneous catalyst from the reaction mixture [3].

The reaction of transesterification is associated with another problem which is that the reactants (oils and alcohols) are not readily miscible because of their chemical structures. The mass transfer between two phases becomes a significant factor that affects the reaction rate. Oil disperses in the methanol medium, so the rate of collision of the glyceride and the methoxide (the mixture of methanol and the alkaline catalyst – KOH or NaOH) molecules become slower. This lowers the rate of collision of the molecules and also the rate of reaction causing longer reaction times, higher operating expenses, higher capital investments and consequently higher product costs [4]. This reaction system is a two phase, where mass transfer limitations due to immiscibility of the reactants determines, the overall reaction rate at the beginning of the reaction. This problem can be overcome by using vigorous mechanical agitation, enhanced reaction temperature and using co-solvents. The breakage of alcoholic reactant into a fine drops emulsion in the vegetable oil by intensive mixing increases interfacial area and mass transfer rate [5]. The enhanced reaction temperature increases both, miscibility of the reactants and the reaction rate constants [6].

Boocock et al [7] have been proposed a model which included a cyclic solvent introduced into the reaction mixture which makes both the oil and methanol miscible. Therefore, this homogeneous single phase reaction medium leads to a very fast reaction when compared to conventional time of reaction. Complete reaction is possible in only couple of minutes. After the reaction is finished, the added co-solvent must be removed from the final reaction mixture. But, excessive addition of co-solvent into the reaction mixture could reduce both rate of reaction and methyl esters yield as a result of the dilution effect on the reagents [8].

In this study, ultrasound-assisted base catalyzed transesterification of used cooking oil and methanol in a batch conditions and in the presence of co-solvent (n-hexane and biodiesel) was analyzed. The reaction was performed in a laboratory reactor in the presence of KOH as a catalyst and isothermally at 65°C. The other reaction conditions were: molar ratio of oil to methanol 1:6, catalyst concentration 0.7%wt. to oil and 1:1 volume ratio of co-solvent to methanol. The reaction time was varied as 15, 30 and 60 minutes. In addition, the reaction was performed in the absence of co-solvent.

EXPERIMENTAL WORK

A. *Materials*

Used cooking oil and methanol as a reagent, potassium hydroxide as a solid catalyst and two types of co-solvents (n-hexane and biodiesel) were used in these experiments. Methanol (99,5% p.a. quality) and KOH – pellets (85% p.a. quality) were purchased from "Alkaloid" – Skopje, R. Macedonia. The used n-hexane (98% p.a. quality) was product of "Carlo Erba – Divisione Chimica Milano", Italy. The used biodiesel (96.79% methyl esters content) as a co-solvent was obtained in previous laboratory experiments. The neutralized used cooking oil (Kolid Company, R. Macedonia) was with yellow color and specific odor and it was the following characteristics:

- Molecular mass (890 g/mol)
- Density at 18°C (0.920 g/cm^3)
- Kinematic viscosity at 40°C (19.4091 mm^2/s)
- pH (6.75)
- Acid value (0.167 mgKOH/g)

Fig. 2. Used cooking oil (neutralized)

B. *Equipment*

The equipment in which the reaction was performed consisted of laboratory glass reactor (250 ml) equipped with a water-cooled reflux condenser immersed in an ultrasonic cleaning bath (ULTRASONIC CLEANER DC150H; dimensions: 30 x 16 x 14cm) operating at constant irradiation frequency of 40 kHz frequency. The bath was filled with distilled water and heating at 65^{o}C. The equipment for experiments is shown in Figure 3.

Fig. 3. Laboratory equipment for ultrasound-assisted biodiesel production

C. *Experimental procedure*

The oil and methanol were used as a reagent in the reaction of transesterification to study the effect of co-solvent presence on the reaction time. The one-step reaction was performed isothermally at 65^{o}C in batch conditions using ultrasound at a constant irradiation frequency of 40 kHz. The molar ratio between oil and methanol was 1:6 and the catalyst concentration was 0.7%wt. of the weight of used cooking oil, previously optimized. The amount of co-solvent used in the experiments was in volumetric ratio 1:1 with the required amount of methanol. The reaction time was varied as 15, 30 and 60 minutes. In comparison, reaction of transesterification was conducted at the same conditions without using of co-solvent.

Initially, neutralized used cooking oil (100 ml) and required amount of co-solvent were placed into the reactor, round bottom glass flask, equipped with a water-cooled reflux condenser. Then the reactor was immersed into the heated ultrasound water bath at 65^{o}C. While the oil and the co-solvent were mixed, the required amounts of potassium hydroxide and methanol were fed into another glass vessel. The vessel was placed into the ultrasonic bath until all the catalyst was solved. Next, the prepared alcohol/catalyst solution was quickly added into the reactor and reaction time was started. After the reaction time was finished the products mixture was placed into a separating funnel in which two separate layers were formed, upper esters layer and lower glycerol layer (Figure 4).

Fig. 4. Methyl esters (upper) layer and glycerol (lower) layer in the separating funnel

After phase separation, the crude biodiesel was methanol and n-hexane (co-solvent) regenerated into rotavapor, shown in Figure 5. Methanol and n-hexane regenerated biodiesel was dry washed and analyzing, Figure 6. During using of biodiesel as a co-solvent only methanol was regenerated.

Fig. 5. Methanol and n-hexane regeneration

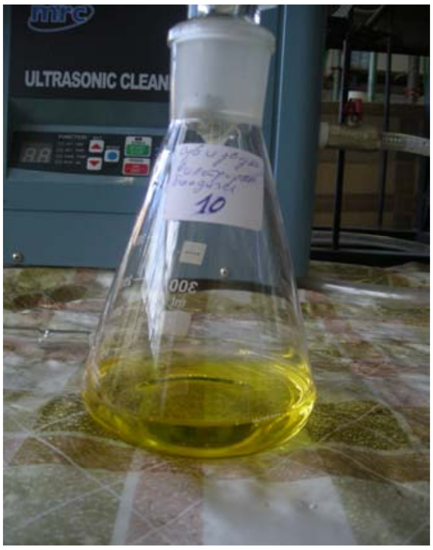

Fig. 6. Final purified biodiesel

D. *Analysis of the final biodiesel*

The methyl esters content in the final biodiesel was determined by Fourier Transform Infrared analysis using FTIR – HATR Perkin Elmer 100 type spectrophotometer with suitable software Perkin Elmer Spectrum Express. Figure 7 shows typical FTIR spectrum of biodiesel obtained from used cooking oil and methanol by ultrasound-assisted transesterification in the presence of co-solvent (n-hexane).

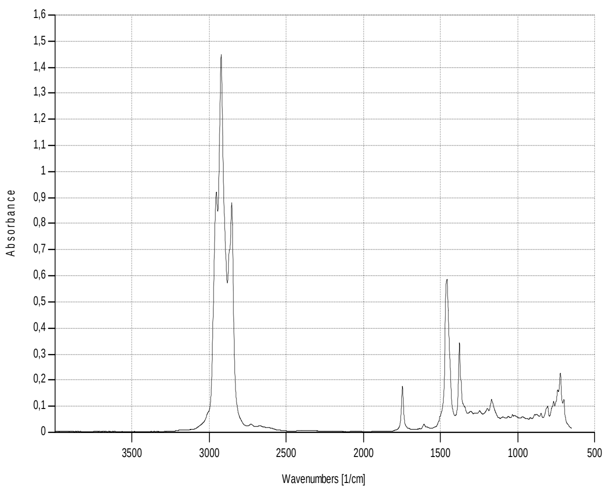

Fig. 7. Typical FTIR spectrum of biodiesel obtained by ultrasound-assisted transesterification of used cooking oil and methanol in the presence of n-hexane as a co-solvent

RESULTS AND DISCUSSION

Analyzing and processing the obtained FTIR spectra the methyl esters content in the samples was calculated. The results are shown in Table 1.

Table 1

Exp. No	Co-solvent	Reaction time (min)	Methys esters content (%)
0	–	60	94.90
1	n-hexane	15	97.38
2	n-hexane	30	96.99
3	n-hexane	60	97.07
4	biodiesel	15	97.11
5	biodiesel	30	96.97
6	biodiesel	60	96.61

Molar ratio = 1:6 mol/mol; Catal. conc.= 0.7 %wt. to oil

A plot of the reaction time versus the conversion efficiency (methyl esters content) in the presence of co-solvent for these reaction conditions is illustrated in figure 8.

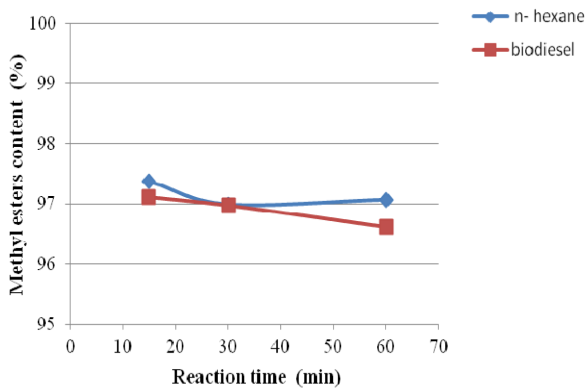

Fig. 8 Effect of reaction time on methyl esters content in the presence of cosolvents (n-hexane and biodiesel). Reaction conditions: molar ratio oil/methanol 1:6, catalyst concentration 0.7%wt, temperature 65°C, volume ratio |co-solvent /methanol 1:1

The graph shows that the highest methyl esters content in the final biodiesel was obtained when the reaction time was the shortest (up to 15 minutes) and it was 97.38% and 97.11% for n-hexane and biodiesel as a co-solvent, respectively. Increasing the reaction time from 15 minutes up to 60 minutes leads to reduced methyl esters yields of 0.3 to 0.5%. This indicates that the transesterification reaction in the presence of co-solvent was already complete within 15 minutes and the further extension of the reaction is nothing else but the loss of energy, time and methyl esters yield. Longer reaction time favors the feedback reaction that leads to reduction of the conversion of tryglicerides into a methyl esters. Comparing to final methyl esters yields, n-hexane proved to be a little more efficient than biodiesel as a co-solvent. On the other hand, it was necessary the n-hexane to be regenerated from the crude biodiesel that was not the case with the biodiesel as a co-solvent. The biodiesel, which initially was added as a co-solvent into a reaction mixture, later will be used as a fuel together with the newly formed methyl esters as a reaction product. In these experiments, the separation of esters and glycerol phase in the separating funnel was carried out more quickly when n-hexane was used as a co-solvent. After methanol regeneration, the crude biodiesel obtained from experiments from the numbers No.1 and No.4 (there the reaction time was the shortest and the yield was the highest) was the most transparent.

Figure 9 shows a plot of the reaction time versus the methyl esters content in the presence and in the absence of co-solvents.

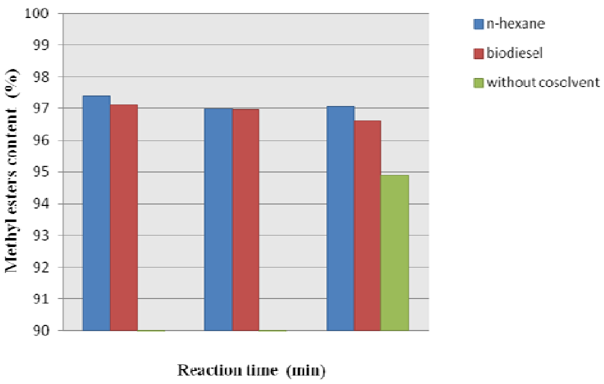

Fig. 9 .Effect of reaction time on methyl esters content in presence and in absence of co-solvents. Reaction conditions: molar ratio oil/methanol 1:6, catalyst concentration 0.7%wt, temperature 65°C, volume ratio co-solvent /methanol 1:1

The obtained results showed that the use of co-solvents in ultrasound-assisted transesterification process dramatically shortens the required reaction time, from 60 to 15 minutes. Unless a shorter time, the obtained methyl esters yields were higher by 1.7 to 2.5% compared with experiment carried out without using co-solvent (94.90%). This study confirmed positive effect of co-solvents (n-hexane and biodiesel) on the KOH – catalyzed methanolysis of used cooking oil, which was attributed not only to the better miscibility of the reactants but also to the better mass transfer as the result of the self-enhancement of the interfacial area. In the reaction without use of co-solvents the mass transfer resistance is limited in the first few minutes and the rate of chemical reaction is very low. The results show that biodiesel obtained in the presence of n-hexane and biodiesel as co-solvents in laboratory conditions achieved European quality standard (EN 14214) which refers to the minimum methyl esters content in biodiesel (96.5%). Single-stage transesterification without use of co-solvent do not achieved the required standard for safe use of biodiesel and probably it should be carried out as a two-step process.

Many researchers have investigated the transesterification of various oils in the presence of co-solvents, establishing various operating conditions for those oils. Boocock et al. [7] recommended the use of tetrahydrofuran as the best co-solvent and approximately 1.25 vol/vol of methanol being required for miscibility at the oil/methanol ratio of 1:6 and a temperature of 23°C. According to Guan et al [9], dimethyl ether as an environmentally friendly solvent could replace tetrahydrofuran as a co-solvent for the transesterification process. Dabo et al [10] used tetrahydrofuran as a co-solvent for the transesterification of *Jatropha curcas* seed oil with methanol in the presence of NaOH as a catalyst. They obtained an optimum yield of 98% at these reaction conditions: 1:4 oil-to-methanol molar ratio, 1:1 cosolvent-to-methanol volume ratio, 0.5%wt. to oil catalyst concentration, reaction time of 10 minutes, temperature of 40°C and 200 rpm stirring speed. Guan et al. [8] used several co-solvents (tetrahydrofuran, dimethyl ether, diethyl ether and methyl tertiary butyl ether) for the transesterification of sunflower oil and methanol at room temperature of 25°C. They found that dimethyl ether was the best one. At molar ratio 1:6, they found that the oil was almost complete converted into methyl esters after 20 minutes reaction while only approximately 78% conversion was reached in the absence of co-solvent. Park et al. [11] have suggested the use of methyl esters (biodiesel) as a co-solvent. In their experiments they used soybean oil and methanol as a reagents and KOH as a catalyst. The reaction conditions were: molar ratio 1:6, catalyst concentration 0.8%wt. to oil, agitation speed 300 rpm, 20 minutes reaction time and temperature of 60°C. The amount of methyl esters as a co-solvent introduced initially was 0, 5 and 10%wt. to oil. Thanh et al. [12] used acetone as a co-solvent for the transesterification of vegetable oils (waste cooking oil, canola, catfish and *Jatropha curcas* oil) with methanol in the presence of KOH as a catalyst. The optimal conditions were: molar ratio 1:4.5, catalyst concentration 1.0%wt, 25%wt. acetone and 25°C reaction temperature. The conversion of vegetable oils to methyl esters exceeded 98% after 30 minutes. Pena et al. [13] studied the effect of three alkaline catalyst (CH_3ONa, NaOH and KOH) and hexane as a co-solvent on the methanolysis of castor oil. They concluded that CH_3ONa leads to considerably higher methyl esters content than the other catalysts and using co-solvent methyl esters content increases up to 96.5%. Encinar et al. [14] tasted various co-solvents (diethyl ether, dibutyl ether, tert-butyl methyl ether, diisopropyl ether, tetrahydrofuran and acetone) for the transesterification of rapeseed oil and methanol in the presence of KOH as a catalyst. The best results were obtained at a molar ratio oil to methanol of 1:9, catalyst concentration 0.7%wt to oil, a molar ratio co-solvent to methanol 1:1, an agitation rate of 700 rpm and a temperature of 30^{o}C. Among the tasted co-solvents, dimethyl ether and tert-butyl methyl ether showed best results.

CONCLUSIONS

In the present study, ultrasound-assisted base-catalyzed transesterification of used cooking oil and methanol in the presence of co-solvents (n-hexane and biodiesel) was investigated. For comparison, reaction of transesterification was conducted without using of co-solvent. The following conclusions were drawn from this research work:

► Ultrasound-assisted transesterification in the presence of co-solvent for the production of biodiesel was found to be fast and very promising method. Introducing a solvent makes the reactants, oil and methanol, to be miscible. This homogeneous single phase reaction medium leads to a very fast reaction compared to conventional reaction times. For the short time, reaction was transformed from mass transfer limited to kinetic controlled reaction.

► Biodiesel obtained in processes that were used ultrasound and co-solvents reaches high levels of methyl esters in a very short time (to 15 minutes) that meets European quality standard EN 14214 for content of methyl esters.

► Using n-hexane as a co-solvent in the process of methanolysis slightly higher methyl esters yields were obtained compared with biodiesel as a co-solvent. After the reaction is finished n-hexane needs to be regenerated from the mixture which further increases the production cost. That is not the case when biodiesel is used as a co-solvent.

► Shorter reaction times using co-solvents makes the process energy saving and increases the production capacity.

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Original scientific paper

THE OPTIMIZATION OF BIODIESEL PRODUCTION BY ULTRASOUND ASSISTED REACTION

Goran Srbinoski[1], Slavčo A. Aleksovski[2], Biljana Veleska Čapragoska[3]

[1]Rudnička 32, 6250 Kičevo, Republic of Macedonia,
[2]Faculty of Technology and Metallurgy, "Ss. Cyril and Methodius" University in Skopje, Karpoš II bb, P.O. box 580, 1001 Skopje, Republic of Macedonia
[3]Department of Criminalistic Technique, Ministry of Interior Affairs, Dimce Mircev bb, 1000 Skopje, Republic of Macedonia
slavcho@tmf.ukim.edu.mk

A b s t r a c t: Biodiesel usually is obtained by two step reaction of transesterification using energy extensive process due to the low solubility of methanol into the oil. Ultrasound assisted biodiesel production is a relatively new promising method which can overcome this problem. In this study, the ultrasound assisted base catalyzed reaction of biodiesel production from used cooking oil in a batch conditions was analyzed. The effects of the most relevant variables, amount of catalyst, reaction time and the molar ratio oil/alcohol, were analyzed. Transesterification of the used cooking oil has been carried out in one step with a molar ratio of oil to methanol 1:4.5, 1:6, 1:9 and 1:12; percent of catalyst 0.5, 0.7 and 1.0% wt of KOH to oil and 65°C temperature. The reaction time was varied as 20, 40, 60 and 90 min. The methyl esters content in the biodiesel was determined by FT-IR (Fourier Transform Infrared Spectroscopy) analyst.

Key words: biodiesel; used cooking oil; ultrasound, transesterification

ОПТИМИЗАЦИЈА НА ДОБИВАЊЕ БИОДИЗЕЛ СО УЛТРАЗВУЧНА РЕАКЦИЈА

А п с т р а к т: Биодизелот обично се добива со двостепена реакција на трансестерификација со користење на голема количина на енергија како резултат на малата растворливост на метанолот во маслото. Добивањето на биодизел со ултразвук е релативно нова ветувачка метода која може да го надмине овој проблем. Во овој труд, анализирано е каталитичкото добивање на биодизел од употребувано масло за готвење со ултразвук во шаржни услови. Анализирани се ефектите на највлијателните варијабли, количина на катализатор, време на реакција и молски однос масло/алкохол. Трансестерификацијата на употребуваното масло за готвење е изведувана во еден степен со молски односи на масло и метанол 1:4.5, 1:6, 1:9 и 1:12; процент на катализатор 0.5, 0.7 и 1.0% мас. сметано на KOH спрема масло и 65°C температура. Времето на реакција е менувано како 20, 40, 60 и 90 мин. Содржината на метил естри беше определена со FT-IR (Фуриер Трансформирана Инфрацрвена Спектроскопија) анализатор.

Клучни зборови: биодизел; употребувано масло за готвење; ултразвук; трансестерификација

INTRODUCTION

Biodiesel is less toxic, biodegradable, sulfur free, reduces carcinogenic air toxins (particulate matter, unburned hydrocarbons, carbon monoxides and sulfates) by 75–90% compared to fossil diesel. It can be used in any compression ignition engine without major modifications [1, 2]. Biodiesel fuel is defined as the alkyl esters of long chain fatty acids, which fulfills certain standards. Biodiesel usually is obtained by the reaction of transesterification or alcoholysis of natural triglycerides (TG) such as vegetable oils, animal fats, waste fats and greases, waste cooking oils (WCO) with short-chain alcohols, usually methanol or ethanol. In a typical biodiesel reactor, oil or fat (triglyceride) is converted to fatty acid methyl esters (FAME) and a co-product glycerol (GL) via a catalyzed chemical reaction (transesterification). It is widely accepted that the conversion of oil to FAME in the reactor proceeds via three consecutive reversibile reactions [3]. These reactions are as folows:

$$\text{Triglyceride} + \text{Methanol} \Leftrightarrow \Leftrightarrow \text{Diglyceride} + \text{FAME} \quad (1)$$

$$\text{Diglyceride} + \text{Methanol} \Leftrightarrow \Leftrightarrow \text{Monoglyceride} + \text{FAME} \quad (2)$$

$$\text{Monoglyceride} + \text{Methanol} \Leftrightarrow \text{Glycerol} + \text{FAME} \quad (3)$$

The overall reaction is:

$$\text{Oil} + 3\text{Methanol} \Leftrightarrow \text{Glycerol} + 3\text{FAME} \quad (4)$$

The reactant intermediates, diglycerides (DG) and monoglycerides (MG), appear in small concentrations during the reaction and are considerable contaminants in the final product, biodiesel. The products of the transesterification reaction, FAME and glycerol, are immiscible and separate out forming two layers. To complete the reaction, 3:1 molar ratio of alcohol to oil is stoichiometrically needed. In practice, the molar ratio of alcohol to triglycerides needs to be higher to drive the equilibrium to a maximum ester yield. In the reaction of transesterification the most used are alkaline catalysts which include KOH, NaOH, potassium and sodium methoxide [4]. The most important variables that influence on the extant and reaction rate are the type and concentration of catalyst, the reaction temperature, the molar ratio of alcohol to oil, the reaction time, the agitation intensity and purity of reactants, which mean that the water and free fatty acids content negatively affect to the final yield of methyl esters [5].

The triglyceride and alcohol phases are not miscible and form two liquid layers upon their initial introduction into the reactor [6]. The less-dense phase has the catalyst dissolved in the alcohol, whereas the other contains the oil or fat. The reaction between these species can occur only in the interfacial region between the liquids, as alkaline catalysts are essentially insoluble in the oil phase. Vigorous mixing is required to increase the area of contact between the two phases [4]. The reaction of methanolysis is heterogeneous during the whole course, so combination of different chemical and physical processes will affect its kinetics. In the studies of methanolysis reaction kinetics, three regimes are well-recognized: an initial mass transfer controlled regime (slow) followed by a chemically controlled regime (fast), and a final regime close to equilibrium (slow) [3, 7, 8].

The contact between the two phases is usually improved by intensive mechanical agitation, especially at the industrial level, but some researchers have tried to overcome this problem by applying ultrasound irradiation. Influence of ultrasound on transesterification reaction is of purely physical nature. Formation of fine emulsion between oil and alcohol due to micro turbulence generated by cavitation bubbles generates enormous interfacial area, which accelerates the reaction [9]. Ultrasound is the process of propagation of the compression waves with frequencies above the range of human hearing. Ultrasound frequency ranges from 20 kHz to 10 MHz [10]. In the biodiesel production process, ultrasound at low frequency (20 – 100 kHz) is mostly applied. In the ultrasound-assisted methanolysis, the formation, growth and implosive colapse of micro bubbles (known as ultrasonic cavitation) induced acoustically in the bulk of the liquid phase increase the mass transfer between the phases by supplying both heating and mixing. Cavitation causes a localized increase in temperature at the phase boundary and provides the mechanical energy for mixing and the required activation energy for initiating the methanolysis reaction. The colapse of the cavitation bubbles disrupts the phase boundary and causes emulsification by ultrasonic jets that impinge one liquid to another. These effects speed up the methanolysis reaction rate and shorten its duration, while high final yields of biodiesel are usually achieved [11, 12].

In this study, used cooking oil and methanol were used as a feedstock for ultrasound-assisted biodiesel production process. The transesterification reaction was catalyzed with solid base catalyst, KOH. The process was carried out in a batch conditions and isothermally at 65^{o}C. Ultrasound with constant irradiation frequency of 40 kHz was applied. The aim of this work is to optimize the most relevant variables that affecting the transesterification process (amount of catalyst, reaction time and molar ratio between oil and alcohol). Waste biomass (cellulose, hemycellulose and lignin) is a renewable energy source that can be converted to solid, liquid and gas fuels via process of pyrolysis. The process is performed at high temperature (400-600^{o}C) and in the absence of oxygen. The bio-oil is a potential fuel that can partially replace the others conventional petroleum fuels. Bio-oil as a fuel can overcome problems with expensive petroleum fuels and solve the environmental problems. Also, it can be used as chemical synthesis source. Bio-char has several applications, such as domestic solid fuel, activated carbon, additive, fertilizer etc. Obtained bio-gas can also be used as a fuel.

EXPERIMENTAL WORK

A) Materials

Used cooking oil, methanol and solid catalyst KOH were used in these experiments. Methanol (99,5% p.a. quality) and KOH - pellets (85% p.a. quality) were purchased from "Alkaloid" - Skopje, R. Macedonia. The oil (Kolid Company, R. Macedonia) was transparent with yellow color and specific odor. The properties of used cooking oil (neutralized) are shown in table 1.

Table 1

Propeties of used cooking oil

Property	Value
Molecular mass (g/mol)	890
Density at 18^{o}C (g/cm^{3})	0,920
Kinematic viscosity at 40^{o}C mm^{2}/s)	19,4091
pH	6,75
Acid value (mg KOH/g)	0,167

B) Equipment

The reaction of transesterification was performed in a laboratory reactor (250 mL) equipped with a reflux condenser which was immersed in an ultrasonic cleaning bath (ULTRASONIC CLEANER DC150H; dimensions: 30 x 16 x 14 cm) operating at constant irradiation frequency of 40 kHz. The bath was filled with distilled water. The temperature of the bath was maintained constant by a thermostat at 65^{o}C. The laboratory equipment is shown in Figure 1.

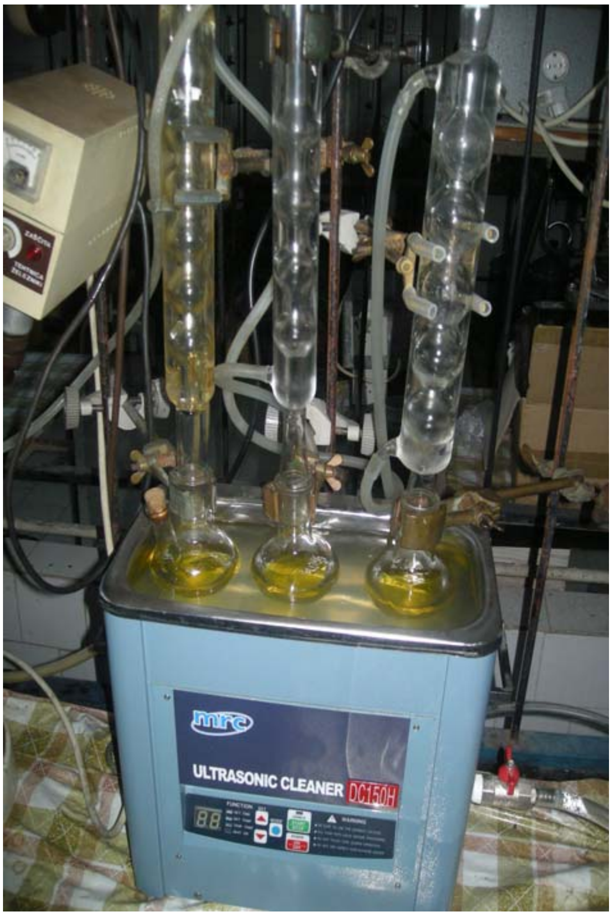

Fig. 1. Laboratory equipment for ultrasound assisted biodiesel production

C) Experimental procedure

Methanol and used cooking oil were used as a raw material to study the effect of low frequency ultrasound on biodiesel production at constant temperature (65^{o}C) using molar ratio of oil to methanol ranging from 1:4.5, 1:6, 1:9 and 1:12, and the quantity of alkali catalyst from 0.5%, 0.7% and 1.0% (wt/wt) of the weight of used cooking oil. The reaction time in the experiments was varied as 20, 40, 60 and 90 minutes. Used cooking oil (100 ml) was placed into the reactor (dry round bottom three-necked glass flask) equipped with a water-cooled reflux condenser. Then the reactor was immersed into the ultrasound water bath at 65^{o}C. Potassium hydroxide and methanol were fed into another three-neck glass vessel. The vessel was placed into the ultrasonic bath until all the catalyst was solved. Next, the prepared alcohol/catalyst solution was quickly added to the flask with oil heated at 65^{o}C and reaction was timed. When the reaction was finished, the reactor mixture was allowed to settle in separating funnel to get two separate layers of biodiesel and glycerol (Figure 2).

Next, separated crude biodiesel was methanol regenerated into rotavapor (heated into a water bath at 70 - 80°C under vacuum conditions for 30 minutes), and dry washed using cellulose and magnesium silicate adsorbents.

D. Analysis of the final biodiesel

The obtained final biodiesel from all experiments was analyzed by Fourier Transform Infrared Spectroscopy (spectrophotometer type FTIR - HATR Perkin Elmer 100) using suitable software PerkinElmer Spectrum Express. Figure 3 shows typical FTIR spectrum of biodiesel obtained from used cooking oil and methanol by ultrasound-assisted transesterification.

Fig. 2. Glycerol and esters phase separation

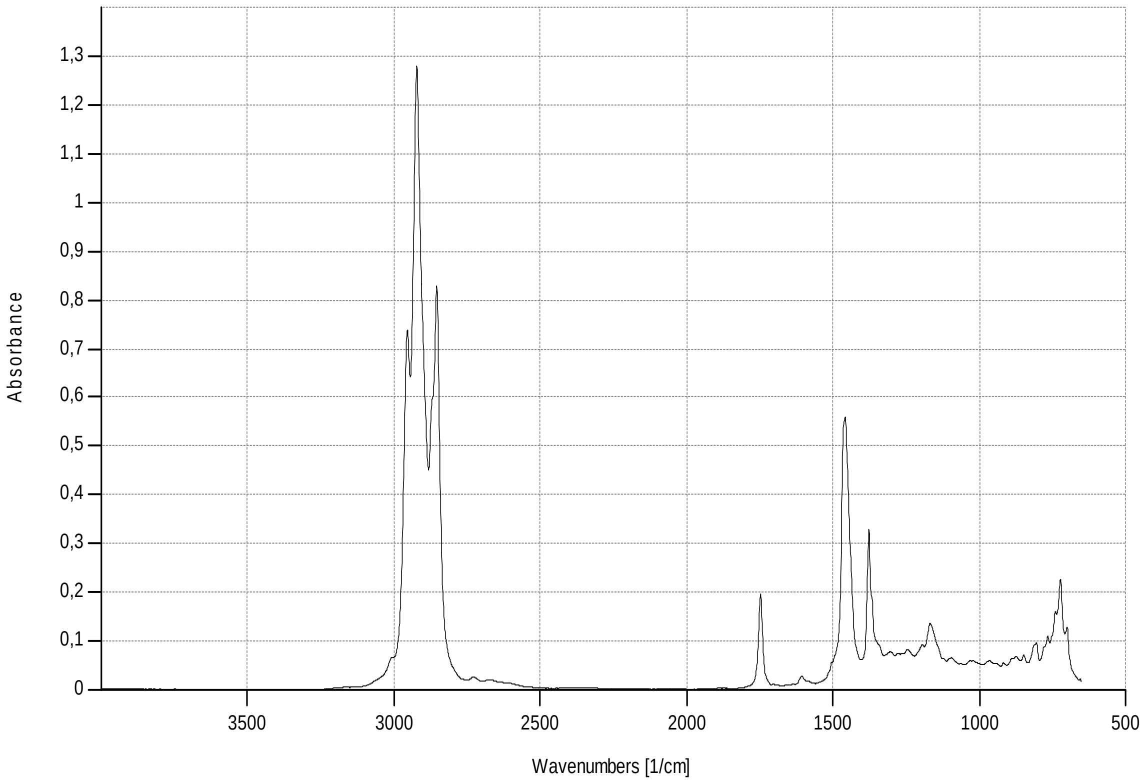

Fig. 3. FTIR spectrum of obtained biodiesel

RESULTS AND DISCUSSION

During the reaction of transesterification the effects of molar ratio oil to methanol, catalyst concentration and reaction time have been analyzed, as well as equilibrium conversion. Two step (2x30 min) transeterification with mechanical stirring was also conducted. Processing the obtained spectra, the methyl esters content in the final biodiesel was estimated. The results are shown in Table 2.

These obtained results were the basis for optimization of the most relevant variables that affecting ultrasound-assisted batch transesterification process.

Table 2

Methyl esters content and reaction conditions

Exp.No.	Molar ratio (oil/methanol)	Catalyst concentration (%wt. of oil)	Reaction time (min)	Methyl esters content (%)
0*	1:6	0.7	2x30	96.79
1	1:6	1.0	60	95.75
2	1:6	0.7	60	94.90
3	1:6	0.5	60	94.49
4	1:4.5	0.7	60	92.48
5	1:9	0.7	60	94.07
6	1:12	0.7	60	91.88
7	1:9	0.7	20	91.42
8	1:9	0.7	40	95.37
9	1:9	0.7	90	93.91

*conventional mechanical mixing

A) Effect of catalyst concentration

The concentration of the catalyst is an important parameter on the rate of reaction and equilibrium conversion of methyl esters. In these experiments three catalyst loadings of 0.5%, 0.7% and 1.0% (wt/wt) of the weight of used cooking oil are used. The other reaction conditions molar ratio oil to alcohol 1:6, reaction time of 60 minutes and reaction temperature of 65°C were kept constant. A plot of the catalyst concentration versus the conversion efficiency (methyl esters content) for these reaction conditions is illustrated in figure 4.

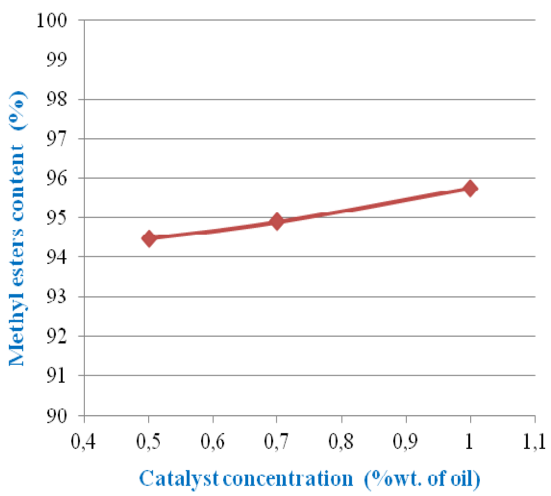

Fig. 4. Effect of amount of catalyst on methyl esters content. Reaction conditions: molar ratio 1:6, reaction time 60 minutes and reation temperature 65°C

It can observe that increasing the amount the catalyst from 0.5% to 1.0% wt. leads to higher methyl esters content. On the other hand, larger quantity of catalyst formed soaps and create difficulties in the biodiesel washing process. Both phases, methyl esters and glycerol, after a few hours of separation, were most transparent when the amount of catalyst was 0.7% wt of oil. At a 0.5% wt of oil catalyst concentration, there was a visible presence of non reacted fatty acids. For these reasons, the catalyst concentration of 0.7% wt. was adopted to be optimal for this process.

Noureddini et al. [6] reported that higher catalyst concentration increase the solubility of methyl esters in the glycerol phase of the final product. As a result, a significant amount of methyl esters remains in the glycerol phase after the phase separation. There are a number reports about optimal catalyst concentration in the ultrasound-assisted transesterification processes. Hingu et al. [13] have studied the effect of ultrasound at low frequency (20 kHz) on methanolysis of used cooking oil in the presence of KOH as a catalyst and reaction tempertature of 45°C. They obtained best result at 1%wt. catalyst amount. Babajide et al. [14] reported a highest yield of methyl esters in biodiesel production process from used cooking oil and methanol when the amount of KOH as a catalyst was 0.75%wt. to oil and reaction temperature of 30C. The applied ultrasound in the process was at 24 kHz frequency. Pal et al. [15] have studied methanolysis of non edible vegetable oil in the presence of KOH as a catalyst, ultrasound at 28.5 kHz frequency and reaction temperature of 50 - 60°C. They reported about optimal catalyst concentration of 0.75%wt. Santos et al. [16] used soybean oil and methanol for transesterification process in the presence of NaOH as a catalyst. The reaction was performed at ambient temperature and atmospheric pressure and applied ultrasound was at 40 kHz irradiation frequency. Optimal catalyst concentration of 0.2%wt, was reported. Wu et al. [17] have studied transesterification of camelina sativa seed oil and methanol in the presence of KOH as a catalyst and 55°C temperature. They used ultrasonic bath (40 kHz) for the process. They reported about 1.25%wt. optimal catalyst concentration.

B) Effect of molar ratio

Although the stoichiometric molar ratio between the tryglyceride and methanol for transesterification is 1:3, in practice, the higher molar ratio needs to push the equilibrium right to higher equilibrium ester content. The excess of methanol is minimized backward reaction. The experiments were conducted with molar ratios of 1:4.5, 1:6, 1:9 and 1:12 while the other reaction conditions were kept constant: catalyst concentration of 0.7%wt. to oil, temperature of 65°C and reaction time of 60 minutes. A plot of the molar ratio oil to methanol versus the methyl esters content for these reaction conditions is illustrated in Figure 5.

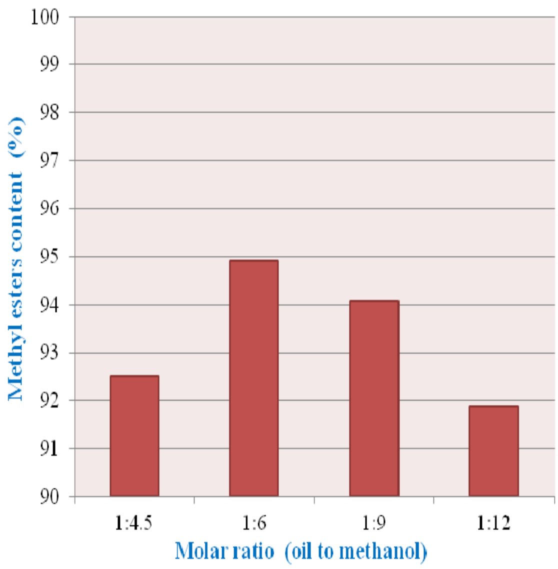

Fig. 5 Effect of molar ratio on methyl esters content. Reaction conditions: catalyst concentration 0.7%wt., reaction time 60 minutes and reaction temperature 65°C

This figure shows that highest methyl esters content in the biodiesel was obtained when the molar ratio oil to alcohol is between 1:6 and 1:9 (94.90% and 94.07% respectively). This indicates that the optimum molar ratio between oil and alcohol for this process is 1:6. At molar ratio 1:4.5 the quantity of methanol is not enough to obtain higher methyl esters content (92.48%). On the other hand, excess amount of used methanol (molar ratio 1:12) gives minimal yield (91.88%) due to the lower rate of reaction. Except the low concentration of methyl ester, the use of large quantities of methanol makes problems with the separation of glycerol fraction because the methanol is polar alcohol and acts as an emulsifier.

In the case of ultrasound-assisted base transesterification in batch conditions, optimal molar ratios between 1:6 and 1:9 are the most mentioned in the literature. Hingu et al. [13], Babajide et al. [14] and Pal et al. [15] have founded that the highest methyl esters yield was obtained at molar ratio 1:6. Santos et al. [16] reported in their study that optimal molar ratio was 1:9. Wu et al. [17] in their experiments have founded that optimal molar ratio was 1:8.

C) Effect of reaction time

The reaction time is also too important variable for triglyceride conversion in to methyl esters and to obtain maximum yields. The reaction time depends on a lot of the process temperature. To determine the optimum reaction time for this process, the experiments were conducted at four different times: 20, 40, 60 and 90 minutes. The other reaction conditions were kept constant: molar ratio between oil and methanol 1:9, catalyst concentration 0.7%wt. to oil and reaction temperature of 65°C. A plot of the reaction time versus the methyl esters content in biodiesel for these reaction conditions is illustrated in figure 6. The figure shows that the highest methyl esters content in the final biodiesel (95.37%) was obtained at 40 minutes reaction time. Increasing the reaction time from 40 to 60 minutes leads to decrease in methyl esters content for 1.30% (from max. 95.37% to 94.07%). The further increase in reaction time from 60 to 90 minutes leads to slight decrease in the methyl esters yield (from 94.07% to 93.91%). In this case, the optimal reaction time was 40 minutes. When the reaction time was under optimal 40 minutes, reduced yield of methyl esters were as a results of incomplete conversion of triglycerides into methyl esters. Otherwise, when the reaction time was over optimal 40 minutes, lower methyl esters yield was obtained as a result of feedback reaction in which the methyl esters react with glycerol and formed triglycerides.

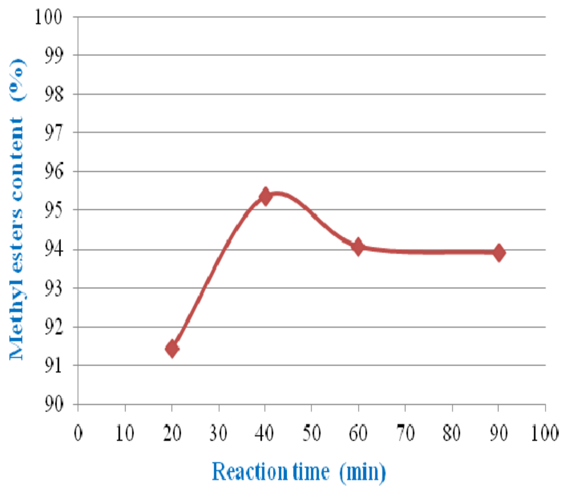

Fig. 6 Effect of reaction time on methyl esters content. Reaction conditions: catalyst concentration 0.7%wt., molar ratio 1:9 and temperature 65°C

In the case of ultrasound-assisted transesterification in batch conditions, some researches [13 - 17] reported about optimal reaction time between 30 and 50 minutes. For example, Babajide et al. [14] and Santos et al. [16] in their experiments have found that optimal reaction time was 30 minutes. Hingu et al. [13] and Pal et al. [15] reported about 40 minutes optimal reaction time. In the experiments made by Wu et al. [17] the optimal reaction time was 50 minutes.

CONCLUSIONS

In the present study, the transesterification reaction of used cooking oil and methanol in the presence of solid base catalyst (KOH) and batch conditions using ultrasonication was investigated and optimized. Based on the obtained results these conclusions can be made:

♦ The use of ultrasound at low frequency in biodiesel production process is a good alternative of mechanical mixing of the two phases, oil and alcohol.

♦ It is a little difference between methyl esters content obtained with one step ultrasound assistance and two step process using mechanical mixing.

♦ One step transesterification process significantly reduces total processing time, increasing the capacity plant and lower power consumption.

♦ The optimum conditions for this process were molar ratio of oil to methanol 1:6 using 0.7%wt. KOH as a catalyst and 40 minutes reaction time.

♦ To obtain higher equilibrium methyl esters content than classical two-step process using mechanical mixing (>96.79%), the ultrasound-assisted process must be conducted as a two-step process.

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TECHNICAL DIAGNOSTICS, MODERN TECHNOLOGY FOR PREVENTIVE SYSTEM MAINTENANCE

Vančo Donev[1], Goce Stefkovski[2]

[1]*Faculty of Mechanical Engineering, "Ss. Cyril and Methodius" University in Skopje, Karpoš II bb, P.O. box 464, 1001 Skopje, Republic of Macedonia*
[2]*JSC Macedonian Powel Plants - Branch HPS "Treska"*
vancho.donev@mf.edu.mk

A b s t r a c t: The paper entitled "Management of maintenance with emphasis on technical diagnostics in function of reducing the costs of exploitation" is a result of long experience and research in the field of maintenance of hydro power plant. During the maintainance process there are some difficulties and shortcomings in technical diagnostics of complex systems that are part of the hydro power plant. Lately there has been a great interest for optimization of systems, hence the need for a study of this issue in order to increase the reliability of hydro energy system while using less resources.

Key words: management of maintenance; technical diagnostics; costs of exploitation; maintenance of hydro power plant; optimization of systems; reliability of hydro energy

ТЕХНИЧКА ДИЈАГНОСТИКА, СОВРЕМЕНА ТЕХНОЛОГИЈА НА ПРЕВЕНТИВНОТО ОДРЖУВАЊЕ НА СИСТЕМИТЕ

А п с т р а к т: Трудот под наслов “Менаџмент на одржување со посебен осврт на техничка дијагностика во функција на намалување на трошоците во експлоатација “ е резултат на повеќегодишно искуство и истражување во областа на одржување во хидроелектрана. При одржувањето на хидроелектраната се појавуваат тешкотии и недостатоци при техничката дијагностика на сложени системи кои се составен дел на хидроелектраната. Во последно време во светски рамки се јавува се поголема заинтересираност за оптимизација на системите, па оттука произлегува и потребата за проучување на оваа проблематика со цел да се зголеми доверливоста на хидроелектраната во енергетскиот систем во услови на користење помалку средства

Клучни зборови: менаџмент на одржување; техничка дијагностика; трошоците во експлоатација; одржување во хидроелектрана; оптимизација на системите; доверливоста на хидроелектраната

INTRODUCTION

Diagnostics is a complex engineering activity that relies on disciplines such as designing, testing and many others, and that should respond in cases of specific system failures. Diagnosing specific systems requires an appropriate equipment, a list of specific measurements, as well as a selection of parameters. Regarding this, possible solutions have been proposed based on theoretical researches. The reliability analysis suggests parameter correlations for the optimization of the technical diagnostics procedure that will lead to decisions regarding system reliability.

The reliability analysis should use technical diagnostics as an auxiliary tool because it provides empirical data that can be used to determine the extreme operational values of specific systems in the power plant. Diagnostics helps determine system reliability with less costs for production. Diagnostics is used to roughly determine the operational conditions of the hydropower plant.

The technical diagnostics process means selecting the best parameters in determining the reliability of the system components.

Technical diagnostics, as a modern preventive maintenance technology, gains importance as a new and very useful method. This method entails procedures qualitatively related with the analysis of the reliability, mobility and technology impacts on the changes of specific system component parameters.

The research process for selection of a universal model connects the frequency of the examination of the operational parameters and the component delays in the hydropower plant. A parameters analysis can be used to develop a model to determine the optimal operational period of the components. The purpose of the model is to check the condition of the components, followed by a preventive maintenance procedure in order to avoid potential part failures and delays.

The analysis and development of an efficient technical diagnostics procedure model includes the introduction of the most important parameters and methods for failure and delay prediction and prevention. All preventive maintenance activities depend on the risk and the optimization of the system component maintenance process.

TECHNICAL DIAGNOSTICS IN HPP KOZJAK

When developing the model for HPP Kozjak, we considered the noted observed failure of the components of HPP Kozjak and analyzed their optimal parameters. The analysis comprised possible failures due to increased mechanical oscillations, increased operating temperature, the bearings fatigue etc.

The hydropower plant system components underwent a special technical diagnostics procedure focusing on specific parts of the system operating under the optimal parameters. This procedure included reliability in the event of increased mechanical oscillations, temperature, fatigue of certain bearings etc. The analysis provided an insight into the operational condition of the components, i.e. the period during which such components would operate. Recently, we need to perform technical diagnostics using more and more criteria. This is a complex process and it is difficult to find the solution. The technical diagnostics comprises several phases, as follows:

– Definition of the objectives, with the application of the components and the systems

– Definition of the method of operations and the impact of the system on the operations and the failure intensity

– Utilization of existing and new methods

– Adoption of final solutions and adoption of final decisions

– If a final solution is not adopted, then new parameters need to be defined and selected

The systems operation during a specific time (t) is monitored in order to maintain the quality and the availability of the hydropower plant components, as well as their exploitation, as the most important factor in determining the reliability.

– Availability or delay data for specific periods can be used to determine the reliability of the analyzed systems components. The making of the decision depends on how the parameters are selected in the optimization procedure. There are three approaches:

– The first approach involves using several component reliability functions which contain specific reliability criteria. In this case, there is a problem with detecting the failure, as well as with defining the optimal solution.

– The second approach involves a two stage optimization approach. The first stage resolves the reasons for the failure using the component reliability criterion. The second stage involves the selection of the criteria and the parameters and the adoption of the optimal solution.

The third approach is an optimization procedure, where the optimization involves a change. The problem with the decision making occurs at every change. The problem with the technical diagnostics optimization procedure occurs at different levels of the reliability determination depending on the application of appropriate parameters. The technical diagnostics depends on the parameters.

The determination of the actual state of the hydropower plant components is accompanied by a certain risk, as a result of the potential for unforeseen situations and the consequences from such situations. Therefore the following need to be determined

– Where does the risk come from

– How to assess the risk

– How to make an appropriate decision based on the risk.

One of the most complex tasks in the system utilization process is the determination of their operational state. The default state of each component of the power plant determines the operational state or functional reliability of the hydropower plant parts. The functional dependence of the model and the operational time interval until the failure represent a specific functional reliability of the system in an optimal functioning mode with the best reliability, i.e. optimal functioning with acceptable risk.A planned maintenance concept can be devised based on a universal functional reliability model.

The modern strategy of preventive maintenance of the power plan integral elements is based on the assessment of their actual state, which derives from continuous monitoring and analyzing of the optimization parameters. The testing program, implemented over a certain period of time, can provide data of the functional capability with a certain period of time.

The hydropower plant systems technical diagnostics optimization has the following core objectives

– Complete reduction of the shaft vibrations and damages to the leading bearings of the hydropower plant

– Ensuring optimal diagnostic operational parameters

– Maximal integration of the operation of the hydropower plant in the energy system

– Optimal use of the aggregates

In addition to the above issues the model also fulfills some additional requirements that can arise during operations, as follows

– Generation in accordance with a temporary technical diagnostics optimization strategy

– Changes to the constraints

– Changes to the requirements of a specific state at any given time

REASONS FOR FAILURE OF THE HYDROPOWER PLANT

Investigating the reasons for failure is one of the most important diagnostic tasks. It aims at indicating the locations and the reasons for failures of hydropower plant system components. The replacement of the integral components and the repair of installation errors represent a basis for finding the reasons for component failures. Investigating failures is the responsibility of the development department during operation and maintenance of the hydropower plant system components. The coordinated work of these departments throughout the lifecycle of the plant is a necessary prerequisite for extending the lifecycle of the hydropower plant system components.

All the states of proper functionality or failure of the plant components impact the availability of the components to the hydropower plant. When diagnosing the state of the hydropower plant components, the responsible officers frequently check the functionality, the operational capacity of the components and investigate the failures of the components.

Controlling component functionality or potential failure leads to delays in the work of the hydropower plant. The number of components to be tested depends on the state of the components and the degree of hydropower plant system fragmentation. This level of detail represents a deep diagnostics. Such diagnostics is implemented for hydropower plants and their integral components, in case of a breakdown or if the failure location cannot be immediately identified.

We can say that deep diagnostics usually serves to localize the failure within the framework of planned testing or in the case of a breakdown, as well as to determine the size and scope of the preventive maintenance within the framework of planned maintenance.

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Hydropower plant system component failures due to increased level of mechanical vibrations, temperatures, fatigue of the bearings can be identified during controls and data collection, i.e. when controlling the signal values measured and the preselected measurement locations. The hydropower plant system failure analysis comprises the application of the method and an analysis of the reasons for the failures that may have occurred due to increased level of mechanical oscillations, operational temperature and fatigue of the analyzed system components.

When investigating the failures of the components that disrupt the proper functioning of the hydropower plant, the diagnostics and the installation method of the systems in different conditions can be different. Depending on the results from the value measurements, decision will be made to undertake preventive maintenance procedures for the components. The control is based on the parameters of state of the components of the hydropower plant systems. The work of the components is monitored at all times. The analysis of the optimization parameters leads to delays in the operation of the hydropower plant system components, as follows:

– at the top generator bearing (N4),
– at the bottom generator bearing (N6)
– at the turbine bearing (N7)

When selecting the optimization parameters, the influence of the mechanical oscillations and the bearing fatigue reduces, and this, in turn, impacts the quality of the surface of the "crescent" element without changing the optimization parameters.

The parameter that reduces the impact of the operational temperature involves daily control of the viscosity of the oil and recycling (filtration and additives) every 6000 working hours of the hydropower plant.

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The observed delays do not include all the listed delays, but only those observed at the components N4, N6, N7, because that is where the measuring locations are located and those components receive the greatest load when the hydropower plant is working (Figure 1).

Figure 1 provides examples of delays on the individual components of HPP Kozjak due to mechanical oscillations, operating temperature and bearing fatigue. They can be used as a basis to predict the procedures for the application of the hydropower plant system component state parameters.

The results of the number of delays at the weak points, which have occurred during exploitation, can also be used in the functional reliability analysis of the work of the analyzed system components, as well as to determine their reliability characteristics.

From the point of view of functionality and constructive characteristics, the analyzed hydropower plant systems belong to the category of technically complex machine technology systems from a technology operations point of view, as well as for the application of the component state monitoring parameters. Constructively, the technical systems are constructed using high technology components (good surface processing, endurance, stability)

The delay analysis is presented using a reductive technique which lists all the adverse consequences that occur during the mechanical oscillations and the increased operating temperature, which, in turn, occur during the operation of the analyzed hydropower system components. The analysis should address the cause of the systems delay, as well as the way in which this cause leads to the component delay.

Once we know the values of all the relevant parameters, then we can calculate the period of hydropower plant system and component utilization. Only one piece of information about the expected values for the remaining utilization time period is not practical because of the possibility for unforeseen failures that can influence these data. In any case, we need to predict that no failures will occur during a specific time period

In practice, one analysis of the value of the remaining use time of the components with a given reliability is not sufficient. Several values for the remaining use time, with different reliabilities (for example 80% - 90%) need to be provided. The component and system user can then make a better decision about the future work of the power plant.

The explanation of the possibility to predict the remaining use time of the components shows the complications that can arise when predicting the remaining component duration. Practical applications require the use of simple methods, suitable for minimum information about operational irregularities, and easy to implement (Figure 1).

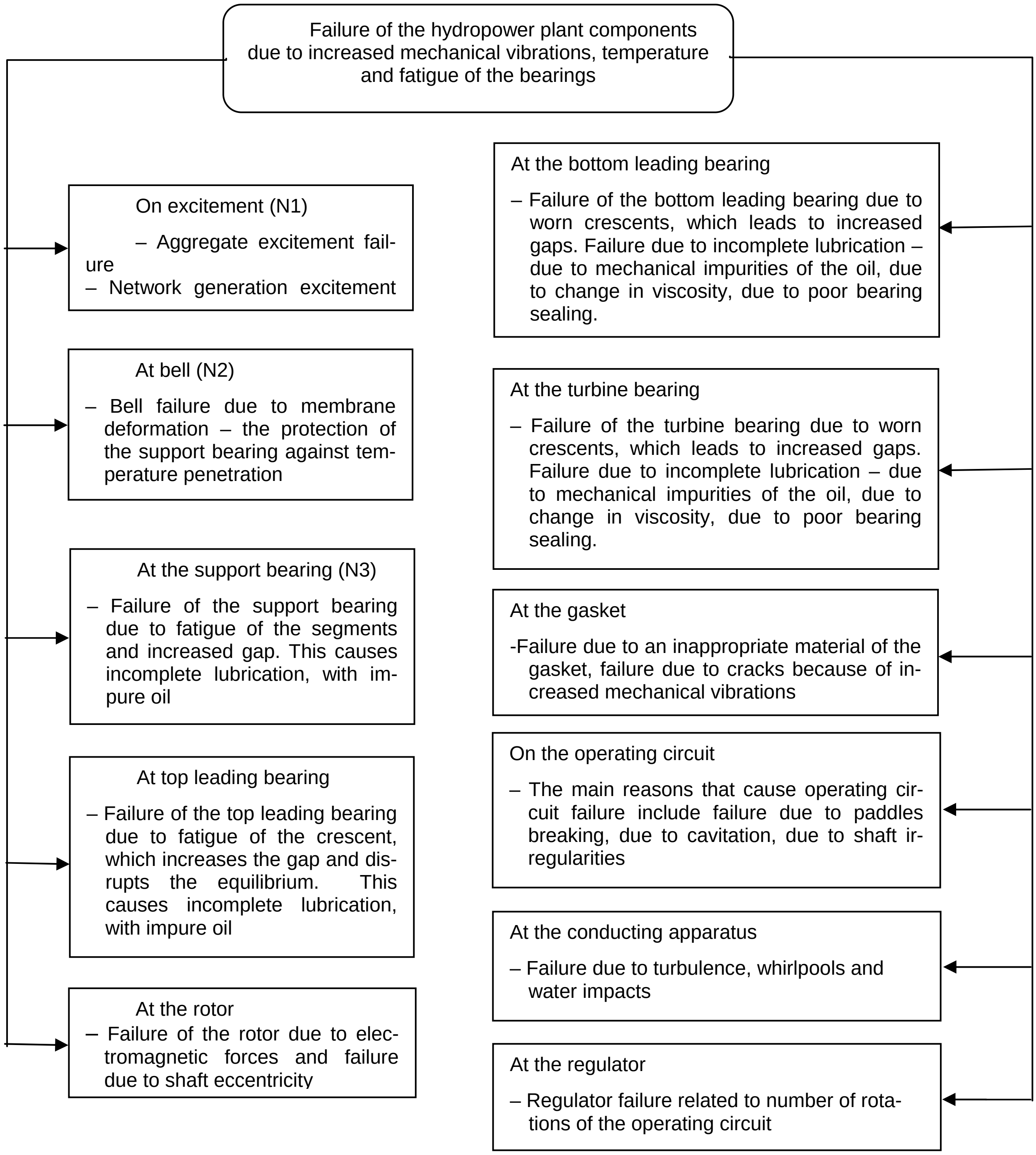

Fig. 1. System component tree

PREDICTING THE SITUATION AND HYDROPOWER PLAN DIAGNOSTIC ERRORS

The forecasts of the remaining duration of the component have to be simple and easily accessible, for example in table form. One relevant forecasting issue relates to the obtaining of data on system damages. Therefore one of the most important predictions is the prediction of the future wear and tear of the components. In this case, the most important form includes system diagnostics assessment and measurements.

In practice, the system duration prediction requires and accurate diagnostic procedure and knowledge of the level of damages, in addition to the application of a sufficiently precise method. The use of the components and the systems in the hydropower plant entails finding certain diagnostics measures for component duration (Figure 2).

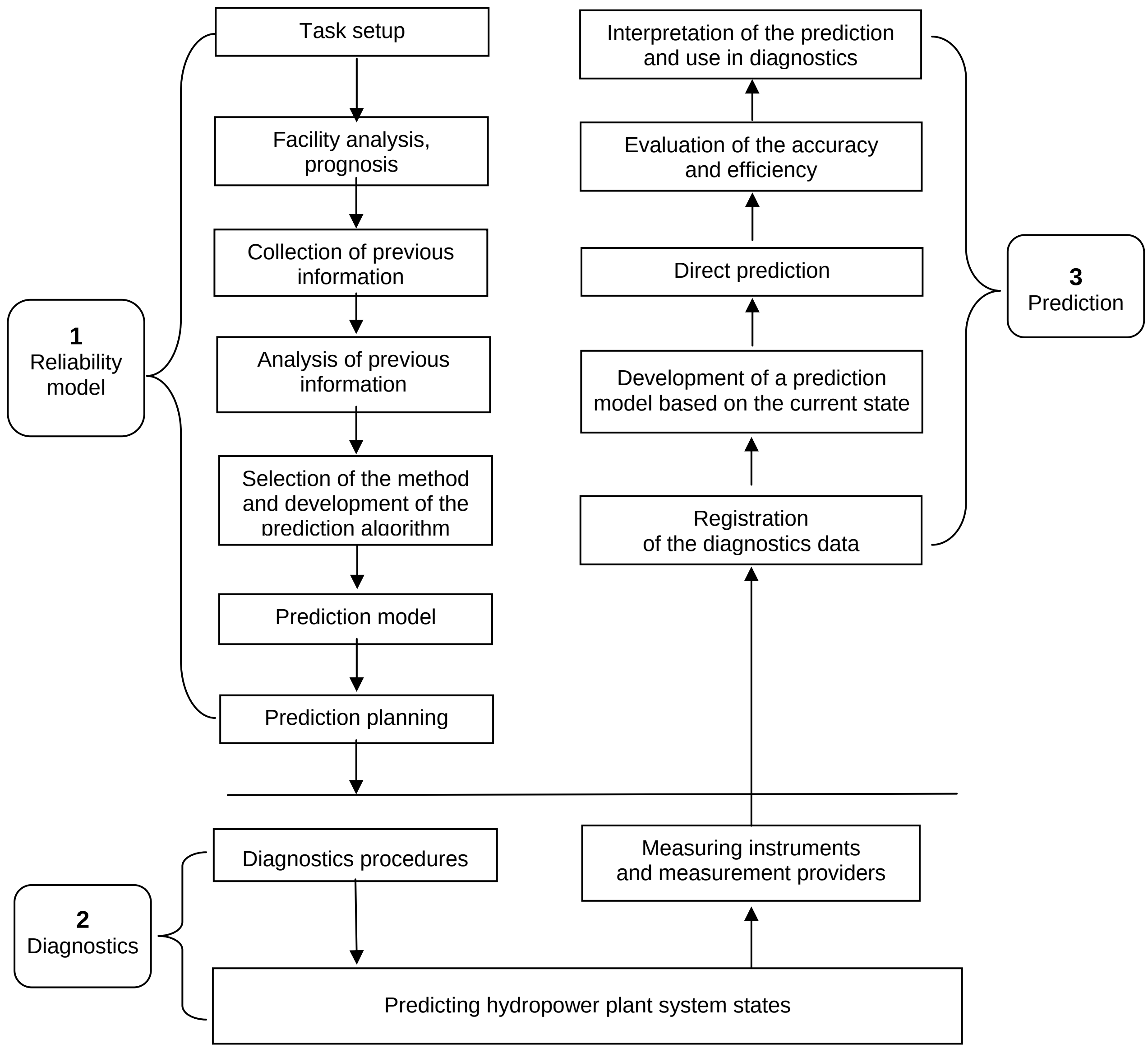

Fig. 2. Analysis of the process of predicting and planning regarding the technical state of the hydropower plant components

CONCLUSION

Optimal considerations require good knowledge of the statistical methods in various events and good ability for application and selection of the parameters of the components relevant for the optimization analysis. In addition, some parameter values may be adjusted depending on the obtained optimal values during the operational period of the hydropower plant.

The task of predicting the functional state of the components, in general, comprises the following:

– The results from the diagnostics of the components should be used to assess the ability of the component to work during the remaining functional period.

Determination is performed by means of a universal model within a specific period of time (t). The statistical classification depends on the working condition of the components and the parameters that provide a certain solution. The analysis of the parameter determination processes enables the elements of the power plant to work optimally.

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Original scientific paper

VIRTUAL OPTIMIZATION OF MACHINE TOOL STRUCTURE IN DESIGN PHASE

Saša Simonović[1], Zoran Pandilov[2]

[1]*Faber RDV, Brazda st. 10, No. 34, MK-1000 Skopje Republic of Macedonia*
[2]*Institute of Production Engineering and Management, Faculty of Mechanical Engineering,*
"Sts. Cyril and Methodius" University in Skopje,
P.O. Box 464, MK-1001, Skopje, Republic of Macedonia
simonovic12@gmail.com

A b s t r a c t: The main goal of this paper is to present the benefits from application of virtual technology in development of modern machine tools. The use of virtual technology in the industry becomes increasingly important regardless if it refers to small, medium or large companies which activity could be a development, design, construction or production. Faster development of innovative machine tools, shorter processing times, improved surface quality of workpieces and higher machine productivity are demands from machine tool builders and end-users. Approaches used to meet these requirements are virtual design, virtual prototypes and virtual optimization. This paper deals with dynamic modeling and optimization of machine tool structure using virtual software environment. The structural analysis of machine tools using Finite Element models and their experimental techniques are presented. The structure analysis and optimization of machine tool elements are discussed by using several examples. At the end of this paper the summary of the benefits and disadvantages of using virtual technology in design of machine tools is given.

Key words: virtual design; virtual prototype; virtual optimization; machine tool structure; Finite element analysis; simulation

ВИРТУЕЛНО ОПТИМИРАЊЕ НА СТРУКТУРА НА АЛАТНА МАШИНА ВО ФАЗАТА НА МОДЕЛИРАЊЕ

А п с т р а к т: Целта на овој труд е да се прикажат придобивките од примената на виртуелната технологија во развојот на модерни алатни машини. Денес се повеќе се зголемува интересот за употреба на виртуелната технологија во индустријата без разлика дали се работи за мали, средни или големи компании, чија главна дејност може да биде развој, проектирање или производство. Брз развој на иновативни алатни машини, покуси времиња на производство, подобрени површински карактеристики на работните парчиња и поголема продуктивност на машините, се барањата кои се поставуваат од страна на произведувачите на алатни машини, како и од крајните корисници. Пристапите кои се користат за да се постигнат овие барања и цели се виртуелното моделирање, виртуелните прототипови и виртуелното оптимирање. Во овој труд ќе биде прикажано динамичко моделирање и оптимирање на структура за алатна машина користејќи софтверска виртуелна околина. Прикажани се структурни анализи за алатна машина со користење на методот на конечни елементи. Структурните анализи и оптимирањето на алатната машина се анализирани преку неколку примери. На крајот на овој труд сумирани се придобивките и недостатоците од примената на виртуелната технологија во проектирањето на алатните машини.

Клучни зборови: виртуелно моделирање; виртуелни прототипови; виртуелно оптимирање; машинска структура; метод на конечни елементи; симулирање

INTRODUCTION

Intensive requirements and changes on the modern global market require faster development of new more advanced products. These new more advanced products are more complex. This is definitely the case with the machine tools. High performance fast machine tools are desired in order to reduce the machining time and to maintain or to improve machining accuracy [1]. Since the products complexity increases and the product life cycle times are reduced, the realisation and testing of physical prototypes become major bottlenecks for the successful and economically advantageous production of modern machine tools [2].

Machine tool builders and end-users demand faster development of innovative machine tools, shorter processing times, improved surface quality of workpieces and higher machine productivity. Time-to-market is decisive. In some industries, six months in order to appear on the market, could be too late and decisive in losing the race for market leadership. The machine tool builders can no longer afford time and cost-intensive manufacturing and testing of physical prototypes to detect weak spots and optimize the design. One of the keys of success for machine manufacturers lies in the extremely cost-effective virtual technology. In the last decade, machine tool builders started to use advanced software simulation packages which can accurately predict the dynamic behaviour of their prototype design variants without physically building any part, hence saving time. The design processes of modern machine tools use "virtual prototyping" technology in order to reduce the cost and time of hardware testing and iterative improvements of the physical prototype. The "virtual prototype of a machine tool is a computer simulation model of the physical product that can be presented, analysed and tested like a real machine" [3].

Traditional product development has been based on the iterative design process, large time consumption and expensive physical prototypes. Improvements of the capabilities and performances of the product were based and depended on trial and error method and experience from past product design, which leads to expensive and time consuming development process. Figure 1 shows a flow chart of traditional product development where all experiments are done on physical systems. The iterative process of modifying and improving physical prototypes and products is very expensive.

If prototyping and testing are done virtually, the resource consumption can be decreased. Figure 2 shows a flow chart of a product development process that uses virtual prototyping. In this case the resource-consuming actions are moved outside the iterative process.

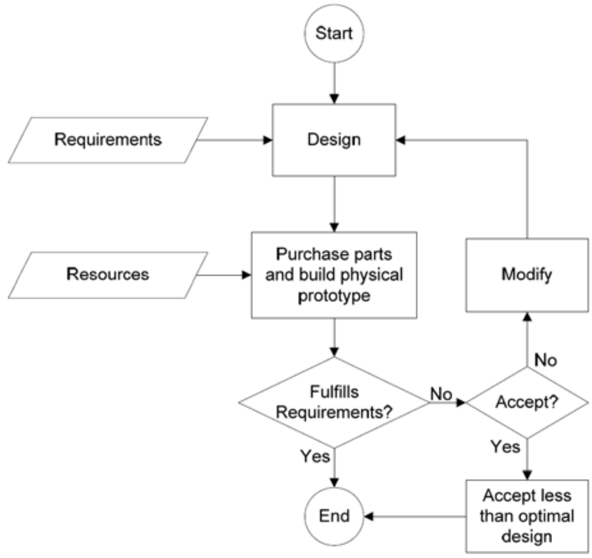


Fig. 1. Traditional product development process [5]

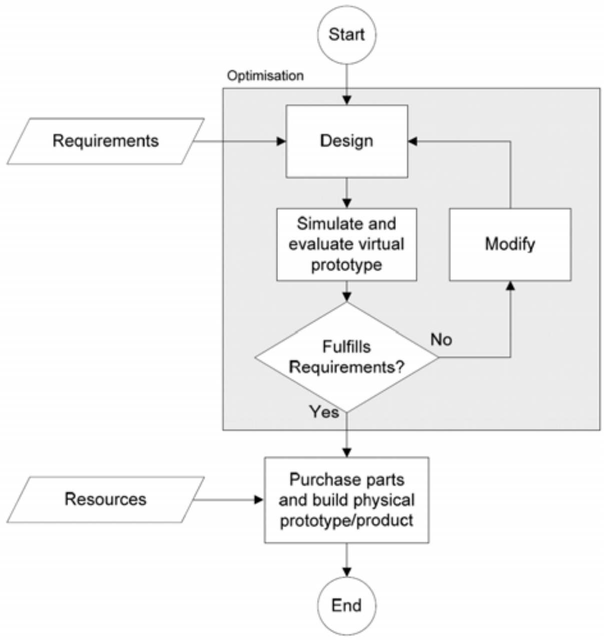


Fig. 2. Product development using virtual optimisation [5]

The iterative design process can be made with very low costs for the each iteration. This means that a large number of different designs can be evaluated automatically and therefore optimal design can be found.

The meaning of optimisation is to find the "best design". To do this, it is necessary to define what is "best design". First of all the objective should be defined. A quantitative measure of the performance, and some design variables that affect on the objective, should also be defined. The need for design variables restricts optimization as a tool in product development for an already established concept. It is not possible to perform optimisation studies before an overall description of the developed product exists. The early stages in conceptual design can use the simulation as a tool in the design work, hence reducing the need for physical prototypes. This is so-called simulation-driven design [4].

When you have to solve optimisation problem, it is also necessary to clarify what constraints the design variables. A large number of optimisation algorithms can be applied to solve the optimization problem. All of them are with different advantages and disadvantages, depending on the problems which have to be solved.

All tools which support products development and optimization represent assistance, but not replacement of engineering. The decision making process still needs to be done by humans. Research results given in reference [5] indicate that computer aided optimization mixed with classical engineering is the most efficient way to design products.

In the virtual prototype approach, engineers are able realistically to simulate the kinematic, static and dynamic behaviour of the whole machine tool system, including the cutting operations. Thus it is possible quickly to analyse multiple design variants until an optimized prototype which satisfies the machining requirements in the best possible manner is achieved.

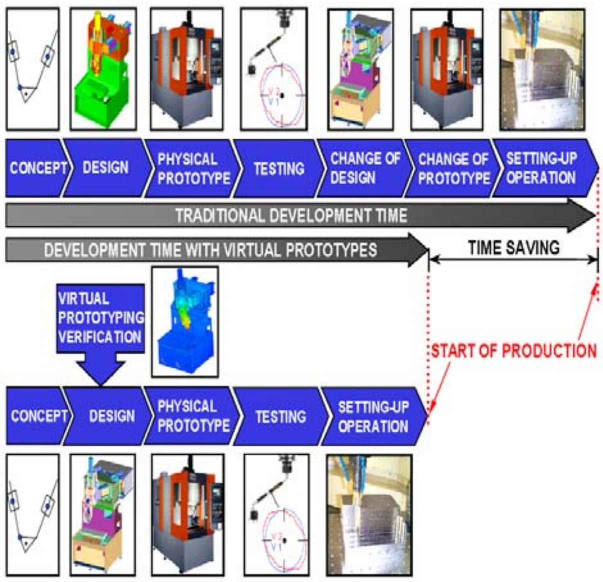


Fig. 3. Comparison of the traditional design process and the design process with virtual prototypes [3]

The virtual design engineering is enabled by the use of high performance computer technology and software engineering tools. Iterative changing of the virtual model of the machine tool during the design process and exercising with different design variants until the required performances are achieved significantly reduce the whole product development time and costs [3]. The advantages and the potentials of time savings by virtual prototypes are illustrated in Figure 3.

FINITE ELEMENT ANALYSIS OF MACHINE TOOLS

The importance of the Finite Element Method (FEM) for virtual analyses of machine tool structure constantly increasing over the last two decades. This method having the advantage of interface capabilities with the most CAD packages, Today the Finite Element Method (FEM) is the most common simulation approach among machine tool manufactures and research institutes. The Finite-Element-Analysis (FEA) is an established tool for evaluation of the structural behavior under static, dynamic and thermal loads. FEA provides an optimal machine design with respect to minimum structure mass and highest machining precision. It is applicable for 3D CAD models for single components, such as columns or spindle housings, as well as for assemblies for complete machine tools.

For structural problems the types of analysis can be divided into three groups: linear and nonlinear static analysis, the dynamic analysis and the thermal analysis [6].

A static analysis calculates the effects of steady load conditions on a structure, while ignoring inertia and damping effects caused by time-varying loads. A static analysis can, however, include steady inertia loads (such as gravity), and time-varying loads that can be approximated as static equivalent loads. Static analysis is used to determine the displacements, stresses, strains, and forces in structures or components caused by loads that do not induce significant inertia and damping effects. Steady load and response conditions are assumed in static analysis; i.e., the loads and the structure response are assumed to vary slowly in respect to the time.

On the other case, the dynamic analysis allows the examination of the structure with respect to time-varying effects. For machine tools the most important aspect is the analysis of normal mode dynamics in order to determine the vibration characteristics (natural frequencies and mode shapes) of a structure or a machine component in the frequency domain, as well as analysis of time domain response of the machine.

Apart from the mechanical aspects, the influence of heat sources on the machine structure is another relevant topic that can be examined by using the thermal Finite- Element-Analysis. In a thermal simulation three primary modes of heat transfer can be considered: conduction, convection and radiation.

A designer has to deal with all main issues of the behavior of a machine tool, with standard modules available in most commercial FEM software. For the effective use of simulations during the design process, Finite-Element programs are often integrated into CAD-systems or provide standard interfaces, such as IGES, STEP or Parasolid in order to transfer existing geometry models.

OPTIMIZATION OF A MACHINE TOOL STRUCTURE

The structure of a machine tool has two main functions: to hold the components and peripheral devices built in the machine and to withstand the forces which are produced by the process and from the machine motions [7]. The development of modern high speed machine tools requires lightweight design in combination with sufficient stiffness of the structural components.

The use of virtual technology in development and optimisation of a machine tool structure for the mould and die industry is elaborated in the following text. The machine is gantry type and the starting concept is shown in Figure 4.

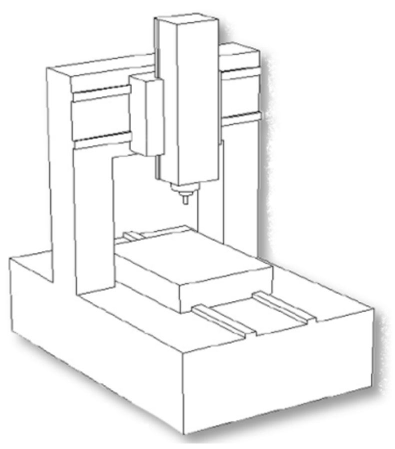


Fig. 4. Concept for high-speed gantry machine

This design locates the most of the machine mass in non-moving parts, which enables better stiffness and damping, allowing the moving axes supported by this structure to have minimum mass. On the other hand in closed-loop (gantry) structure, forces generated by the process and inertial forces are conducted to the ground trough two way bridge frame. That kind of structure enables a higher stiffness and accuracy at the tool center point (TCP) and symmetrical behavior from the influence of the thermal and mechanical loads.

The movable working table (X axis) is integrated in the machine bed, which is a solid base of the machine structure. So the most crucial part of the machine structure is the bridge frame, which is mounted on the bed, together with the movable outer slide for the Y axis and the vertical slide for the Z axis.

After the 3D modeling of the structural components in CAD system, the FEM analysis begins. The development of the machine structure and the optimization analysis is done on the standalone parts and on the assemblies. For the purposes of this paper, only the most important analysis for evolution models and the final version of the machine structure are presented.

The decision-making process in the optimization and the elimination of some model variants, is not done only from the analysis results, but also from the rising level of knowledge for the behavior of the analyzed structure. The use of the FEM analysis for obtaining the natural frequencies and mode shapes and the static analysis for the structure stiffness are very useful for the engineers in order to realize the machines structures behavior and making future decisions in the optimizing process.

As the lower position of the vertical slide for the Z axis and the middle position of the Y axis slide are the most critical, the values for the natural frequencies and the mode shapes for two evolutionary solutions are shown on the Figures 5, 6 and 7. The frequent analysis is performed on the assembly of the Y axis slide and the vertical slide for the Z axis.

In order to determine the displacements and stiffness at the tool center point (TCP), a static linear analysis is performed. A spatial resultant force of 1750 N (force of 1000N along each axis) that represents the reaction forces from the machining process is applied to the TCP. Considering that it is a linear analysis, the resulting stiffness is determined from the force/displacement ratio $\mathbf{C=F/\delta}$.

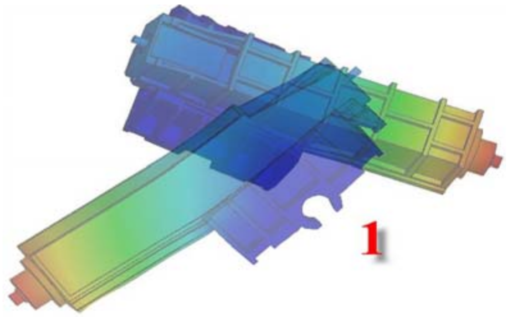


Fig. 5. First natural frequency and mode shape, model 1(right) 109.05 Hz, model 2(left) 113.72 Hz

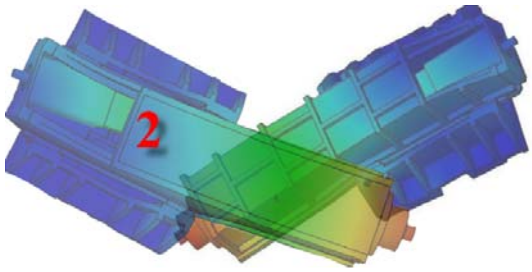


Fig. 6. Second natural frequency and mode shape, model 1(right) 136.44 Hz, model 2(left) 135.35 Hz

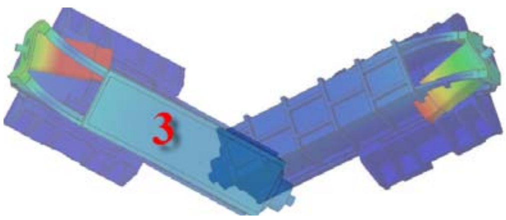


Fig. 7. Third natural frequency and mode shape, model 1(right) 182.95 Hz, model 2(left) 160.48 Hz

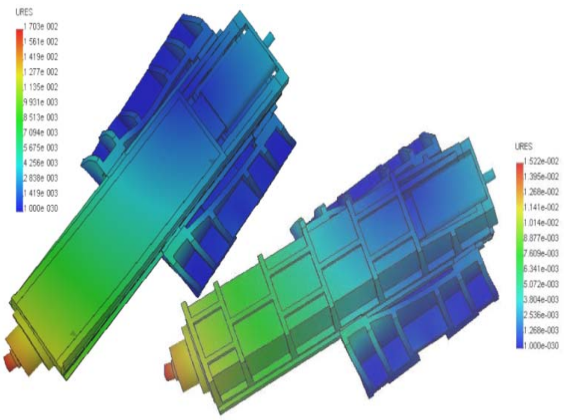


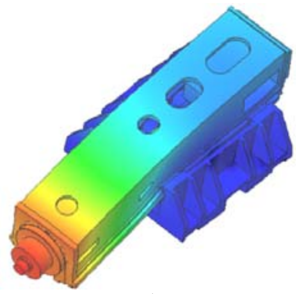
Fig. 8. Resulting displacements after applying of force

For the critical lower position of the vertical slide the stiffness for both models are:

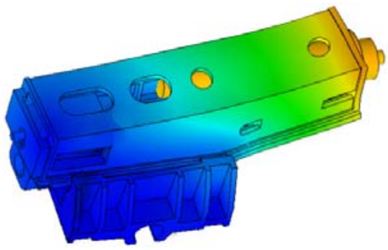
– Model solution 1 (right): C = 1750/15.22 = 115 N/μm (deformation δ = 0.01522 mm);

– Model solution 2 (left): C = 1750/17.03 = 103 N/μm (deformation δ = 0.01703 mm);

The overview of the analysis results and the knowledge obtained during the analysis give the basic directions for the optimization of the structure. The goal is to achieve bigger values for the natural frequencies and static stiffness with simultaneously reducing the amount of utilized material by using the casting technology. The upper part of the vertical slide on both models causes big deformation, so it is necessary to be removed. On the other hand the outer ribs on the model 2 are not appropriate when the casting technology is used. The final model for this assembly incorporates solutions in order to remove the above mentioned lacks. Hence, the upper part of the slide is removed, and few holes are applied on the vertical slide. Some of the holes are for technological purposes and some are for material reducing in order to increase the natural frequencies. But making this actions we must be sure that the stiffness is not decreased. Figure 9 shows the frequent analysis (natural frequencies and mode shapes) for the optimized version of the assembly.



1)



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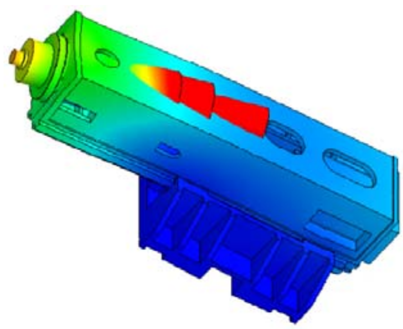

3)

Fig. 9. Mode shapes of the final design solution

The values for the natural frequencies are: first natural frequency 130.39 Hz, second natural frequency 148.79 Hz and third natural frequency 219.75 Hz. Comparison of the results show that the final solution have better values for the natural frequencies. But the static analysis will give the complete conclusion about the final solution of the assembly.

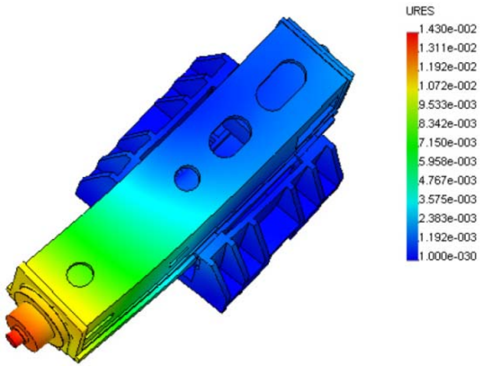

Fig. 10. Static analysis of the final solution

For the critical lower position of the vertical slide the stiffness is C=1750/14.3=122.4 N/μm (deformation δ = 0.01430 mm). The static analysis also confirms that the final solution has better characteristics in terms of static and dynamic behavior.

Another vital part of the machine structure is the bridge frame. For faster development and optimization in the design phase of the machine structure, the bridge is analyzed as standalone part. This saves time and enables at an early design stage realizing the lacks and avoiding development of bad constructive solutions. One of the models for the bridge, optimized in the early design phase is shown in Figure 11. The results for the natural frequencies are: first natural frequency 62.43 Hz, second natural frequency 71.26 Hz and third natural frequency 116.86 Hz.

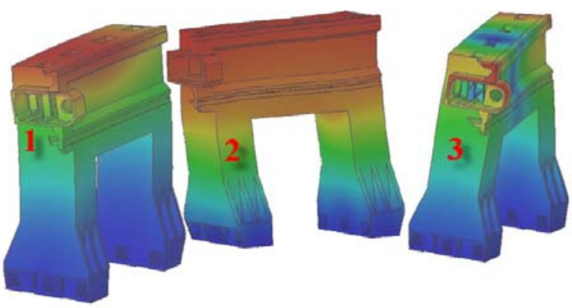

Fig. 11. Mode shapes for the bridge model

The following changes are made in the optimization process:

– Increased height of the base expansion of the bridge

– Increased thickness of the base ribs

– Increased height of the base ribs

The results for the natural frequencies after the changes are: first natural frequency 66.45 Hz, second natural frequency 74.22 Hz and third natural frequency 125.3 Hz.

It can be noticed that regardless of the model changes, the mode shapes are almost identical. The only difference is in the values for the natural frequencies. Considering these rules for changing the values for the natural frequencies some of the parameters in the modeling process are iteratively altered. These parameters are wall thickness, height and thickness of the ribs, base dimensions etc. To avoid the negative influence of vibration, center of mass of the bridge should be as low as possible. This is achieved with decreasing the wall thickness and ribs height in the upper region of the bridge and also with adding some technological holes. On the other hand the bridge base parts are increased for obtaining better stiffness and lowering the mass center. It is important to mention that with decreasing the wall thickness from 27 to 22 mm the natural frequency decrease minimally 1÷2 Hz, but it is accompanied with large material mass savings.

Natural frequencies and mode shapes of the optimized bridge model (Figure 12) after applying the above mentioned directions for optimization are: first natural frequency 74.12 Hz, second natural frequency 85.02 Hz and third natural frequency 135 Hz.

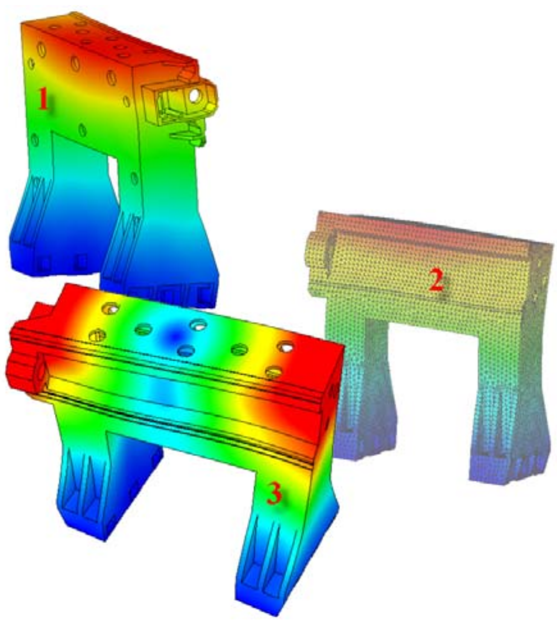

Fig. 12. Mode shapes of the optimized bridge model

These results show significant improvement obtained by virtual optimization which is done in the early stage of the design and development of the machine tool structure.

CONCLUSION

Virtual experiments are often more resource efficient than physical experiments, in terms of money, time and natural resources. Some conditions might not be measurable on a physical system, at least not with non-destructive methods. Virtual models are controllable and experiments performed on them are repeatable, something that cannot be guaranteed with physical models. Virtual experiments can be carried out in the time frame that suits the best to the observation method, something that cannot be done with physical experiments, where all testing needs to take place in real time. Virtual experiments do not break any moral rules as might be the case with questionable experiments on humans or on vulnerable natural systems. Some disadvantages shall also be mentioned. All virtual experiments need validated and verified models of the system. The performance of a simulation model is limited by the computer capacity available, something that is very clear when simulations need to be done in real-time.

An important factor of every simulation is the obtained knowledge during building the virtual models. This often is not fully recognised. Very often the finished model is seen only as outcome of modelling. When a virtual model is built, the designer learns a lot about the physical characteristics of the studied system, as well as how it can be optimised, simplified and described as clearly as possible.

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Original scientific paper

CONCEPT DESIGN FOR A MODERN MINER'S HELMET WITH INTEGRATION OF SAFETY NEEDS

Mihajlo Kocevski, Risto Taševski, Taško Rizov, Marjan Gavriloski

Institute of MKMMV and ZZK, Faculty of Mechanical Engineering,
"Ss. Cyril and Methodius" University in Skopje,
Karpoš II bb, P.O. box 464, 1001 Skopje, Republic of Macedonia
marijan.gavrilovski@mf.edu.mk

A b s t r a c t: This paper presents the design process of a modern helmet for miners that would be ideal for all workers who risk their lives every day in underground and surface mines to supply us the materials we need for our everyday life. The dangers that the miners face throughout their work time are chronologically explained, as well as the necessary preventive measures and the security measures needed for the achieved. Compared to the classic mining helmet only an impact protection and a lamp holding bracket is provided, the design of the helmet presented in this paper is based on the method of integrating the needs of the miner. Through the available technology today pretty much everything is possible, so it is truly sad because significant improvements have been made in the mining branch while the protection of the miners is still at a bare minimum. The exterior of the helmet is simple, with curved lines and is used to its maximum in order to integrate all the proper functions without ruining the esthetics. The interior of the helmet is designed to withstand an impact without allowing injury to happen. Besides the integrated functions such as the air filters and the option for attaching oxygen tanks, the helmet is still comfortable and it does not present a burden to be worn throughout the work.

Key words: miner helmet; futuristic design; protection at work; *safety* design

КОНЦЕПТ ДИЗАЈН НА МОДЕРЕН РУДАРСКИ ШЛЕМ СО ИНТЕГРИРАЊЕ НА ПОТРЕБИТЕ ЗА ЗАШТИТА

А п с т р а к т: Во трудот е претставен дизајн на модерен рударски шлем, кој би бил идеален за сите работници кои секојдневно го ризикуваат животот во подземните и површинските рудници со цел да обезбедат суровини кои ни го олеснуваат секојдневието. Низ хронолошки редослед се опишани опасностите на кои рударите се изложени со текот на работното време, како и превентивните мерки и заштита од истите. За разлика од класичните шлемови кои освен за заштита од удари и држач за ламба немаат друга намена, употребен е метод на интегрирање на потребите на еден рудар. Сето тоа се разбира е достапно со денешната технологија и е стварно жално бидејќи и покрај огромниот напредок во рударството, мерките за заштита се останати на минимално ниво. Надворешноста на шлемот е едноставна, со заоблени линии и е максимално искористена за интегрирање на сите потребни функции без притоа да се наруши естетскиот изглед. Внатрешноста на шлемот е дизајнирана да може да претрпи удар без да нанесе повреда на рударот. Покрај интегрираните функции како што се филтрите за воздух, можност за приклучок на кислород, шлемот има доволна удобност и не претставува тешкотија да се носи во текот на работата.

Клучни зборови: рударски шлем; футуристички дизајн; заштита при работа; проектирање за сигурност.

DANGERS IN MINING

Miners are constantly exposed to dangers during their everyday work. The dangers are various and they differ according to the fact is the miner working in a underground or in a surface mine, the region in which the miner operates as well as the available technology (machines and tools) used in the process. Unfortunately, besides the significant improvement in the available technology, human health and security has remained on a basic level. For their protection miners are still using basic helmets, sometimes with build-in masks, and not a thing more for their further protection has been accepted.

Dangerous air particles

The most abundant compound in the Earth's core is the free crystal silica which presents the most often air dust with which miners are in contact. The most probable form of the silica is quartz and it can be found as cristobalite and tridymite. The contents of silica in different types of ores vary, but even that is not a real indicator of the level of free silica that can be present in the air. It is not unusual to have presence of 30% of free silica dioxide in the ore and 10% in the air, or vice versa. Sand can contain up to 100% silica dioxide and granite can contain up to 40%.

After a longer exposure of a human organism to silica, silicosis might occur, which is a typical pneumoconiosis which is developed in years and without trace. Exposure to silica is often connected with increased risk of tuberculosis, lung cancer as well as some auto immune illnesses like sclerodermas, systematic lupus erythematosus and rheumatic arthritis.

Dust from coal presents a significant danger in the underground and surface mines. The composition of the dust varies depending on the type of coal that is excavated. The dust is created during explosions, drilling, cutting and transportation of the coal. The dust from coal can result in pneumoconiosis and it contributes to development of chronic illnesses like bronchitis and lung emphysema [1].

DANGEROUS GASES AND FUMES

Most common toxic gasses that are present in the mines are methane and sulfurous dioxide (Table 1). The presence of these gasses results in deficit of oxygen. Methane is highly flammable. Most explosions in coal mines are result of ignited methane and are followed by even stronger explosions of the coal dust. Throughout the history of coal mining, fires and explosions have been the main cause for death of thousands of miners.

Table 1.

Most common toxic gases and their impact on health

Gs	Used name	aImpact on health
Methane (CH_4)	Explosive gas	Suffocation
Carbon monoxide (CO)	White suffocate	Chemical suffocation
Hydrogen sulfate (H_2S)	Lazy suffocate	Nose irritation, eyes and throat; obstruction of the respiratory system
Lack of oxygen	Black suffocate	Anoxia
Explosion of product	Consistent suffocate	Irritation of the respiratory system
Exhaust from engines	Exhaust gas	Irritation of the respiratory system; lung cancer

Phyzical dangers

Noise is very much present in mining. It is created by the operation of the powerful machines, air-conditioning systems, explosions and transportation of ore. Exposure to noise in underground mines is significantly higher compared to surface mines. Noise can be reduced by using conventional means for noise control of the mining machines and with use of hearing protection equipment [1].

Ionizing radiation is dangerous in mining as well as in other industries. A free radon might be released from the ore by detonation or it might enter a mine through underground streams. A radon and decomposing products emit non-ionizing radiation, some of them having enough energy to cause cancer cells to lungs.

Heat presents danger in mines as well. In underground mines, main source of heat is the ore itself. The temperature of the ore is increased by 1°C for every 100 m depth. Other sources of heat stress are the physical activity of the miners, circulation of air, surrounding temperature and moisture of air, as well as the heat generated by the mining equipment. The temperature can reach around 40°C in the deep mines (deeper than 1.000 m). Mains sources of heat in surface mines are the physical activity, proximity to hot engines, air temperature, moisture and sunlight. Reduction the heat stress can be achieved by introducing cooling devices, limiting the physical activity and providing adequate quantities of drinking water, protection from the sunlight and appropriate ventilation.

Drills can cause significant **vibrations** that can result in damage to the nerves in miner's hands – vibration white finger. This symptom is noticed for the first time in mines in Japan, India and Canada.

PREVENTIVE MEASURES FOR PROTECTION

Head protection of the miner is necessary due to the potential for head injuries caused by mechanical or electrical nature, low temperature, heat radiation, dirt radioactive radiation, wet and other. For protecting the miner's head from mechanical injuries a helmet is used. Protective helmets must comply with the following requirements: to be durable on deformation and penetration, to be able to absorb impact and to be easy for maintenance. Depending on the use, they are produced from leather, phenol epoxy, polyamide, polyethylene, polyester etc. Helmets can be in form of a hat or a cap.

Plastic helmets are not suitable for high temperatures, but on the other hand are very light. Helmets from aluminum are more durable, easy for maintenance, deflect heat, but are permanently deformed on impact. Negative side of the aluminum helmets is the fact that they are conducting electricity.

For head protection from electrical current helmets made from materials that have the appropriate resilience are made.

For head protection only from heat radiation hoods from asbestos are used, or a combination of asbestos and aluminum foil. These hoods are often combined with a face protector and protection for neck and shoulders. For protecting the eyes of the miner cobalt glass is used. If in the mines beside the mechanical injures, danger from high temperature is present, than the protective helmets are made from thermo resistant material.

In a case where beside the mechanical injuries, the miner's work is followed by low temperatures, the protective helmets should have additional parts that can be placed underneath the helmet. These parts are made out of cotton or wool fabrics, or leather with fur. If in the working conditions the protection from cold is primary, and there is no present possibility for mechanical injuries, than caps lined with fur are used.

In wet working conditions, where beside the danger of mechanical injuries, there are possibilities for wetting the miner's head, than helmets made from water resilient materials are used. In working conditions where rotating parts of machines can tangle upon the worker's hair, protective caps, hoods, nets and scarfs are used

Fig. 1. Standard protection equipment for miners (Source: Environmental Protection Agency).

Comment [B1]: Каде е цитирана слика 1 во текстот

Dirt and dust in the working environment can cause various skin conditions to the head of the miner. In order to prevent this, appropriate caps made from thick cotton fabric are used. They have to be easy to maintain. In working conditions where radioactive radiation is present, the whole body of the miner is exposed to it, so specific protection equipment only for the head is not available. The protection comes in a form of an overall suit composed of protection for the body, head and face [3].

For **protecting the eyes**, in general various types of protective glasses are used. If danger to the **face** is present, the eyes protection equipment is always made in such a way that it covers the whole face.

Depending on the factors for eyes damage, different types of eye googles are produced, like: protective glasses with transparent glass – used in operations where danger of injuries to the eyes are possible from flying small particles, for example when filing, grinding, stirring etc.

When there is a danger to the eyes present from flying particles from the front and from the side, glasses with side protection are used. This is the case in operations like grinding, milling, wood grating or similar activities.

For protecting the eyes from eroding materials (ammonia, formaldehyde etc.) transparent triplex glasses with leak-proof frames are used.

For workers that operate with welding machines, in order to protect their head, neck and eyes of the direct and indirect effect of the ultraviolet and heat radiation, as well as from the flying particles special shields are used. They can be hand held or head mounted.

The **protection of the hearing** organs of miners is necessary due to the fact that the damage from noise is significant to the hearing organs and through them to the complete nerve system. Noise is defined as any non-desired sound with high intensity that causes uncomfortable hearing reaction. Noise today is produced as a result of the fast technological development of the industrial production, motor transportation and noise producing activities [5].

If the noise is constant during the working period, the working capability of the miner is decreased, the hearing organs are getting damaged and in certain level the nerve system is ruined. Due to that, the protection of the hearing is essential.

For those workplaces where noise that cannot be reduced with technical means below the allowed limit is present, workers must use appropriate protection equipment, like:

– cotton for protection from noise level up to 75 dB

– ear plugs for protection for noise level up to 85 dB

– ear protection equipment for noise level up to 105 dB

Ear plugs cannot reduce the average value of the audibility for more than 15 dB. Also, the protection equipment should not irritate the ears and must provide that the noise will not surpass the allowed limit [1].

Beside the regular conditions that apply to all protective equipment (not to irritate skin, not to transfer paint and to be easy to maintain), the noise protective equipment should:

– to damp noise efficiently

– to be comfortable

– their use should not result in physiologic or pathologic changes to the ear canal

– to only allow to pass sounds with low frequency

The ear plug is usually made in a form of an unformed or formed plug. The unformed plug is made out of material (bee wax, cotton or similar plastic material), formed according the ear canal of the user. The formed plug is made out of material that is not irritating for the skin, not easily fumbles and is bad in transmitting the sound oscillations. These plugs have pre-defined shape [6].

The ear protective equipment is consistent of two shells with elastic semi-circle holder. The shell is consisted of cushion and body of the shell, and the elastic semi-circle holder is consisted of two elastic strips formed according the shape of the head. The force with which the ear protective equipment is pushing upon the head should not be bigger than 10 N (approx. 1 kp) and the weight of the equipment should not be bigger than 0.4 kg [4].

Protection of the respiratory system

By breathing an exchange of gases is done between the organism and the environment. The goal of the respiratory system is to supply the necessary level of oxygen and to throw out carbon dioxide (CO_2) which if present in increased level can cause suffocation and death.

Workers that work in polluted environment where fog, smoke, dust or anything similar is present (when concentration level is above allowed), appropriate equipment for protection of the worker breathing organs must be used.

For protection of the respiratory system from rough and inert dust, i.e. fine industrial dust that consist silica dioxide (SiO_2), suitable protective equipment foresee respirators with appropriate design and protective capability [7].

For protection of the organs from dangerous gases, fog, smoke or dust in high concentration i.e. when in the environment the level of oxygen is less than 16% the use of masks in various shapes and design and isolation equipment with oxygen are used [5].

Fig. 2. Modern protection equipment for miners
(Source: http://inside.mines.edu/Mining-Edgar-Mine)

Comment [B2]: Каде е цитирана слика 2 во текстот

A gas mask is used for protection of the respiratory system, the face and eyes of those workers that operate in working conditions where the level of oxygen is at least 16%.

The protective equipment for the respiratory system should not obstruct normal breathing during use and it must be adjusted for quick and easy installation. The selection of the equipment is done based on the type and time of containment of the workers in the room.

The respiratory system protective equipment might be divided according the type of pollutants and the type of operation.

According the type of the pollutant the equipment is divided in respirators for purification of the air from aerosols, protective masks for protection from gasses and fumes with filters for purification of air and isolation materials that are used in case of lack of oxygen.

According the operation the equipment is divided in: equipment based on filtration and protective equipment based on isolation.

The protective equipment based on filtration purifies the air of the environment (for example protective mask, respirator for purification). These protective devices include:

Equipment for protection from aerosols (mechanical filters) which include respirators for aerosols

Equipment for protection from gases and fumes which include protective masks, cartridges with active filling and self-saver for carbon monoxide (CO)

Equipment for combined protection from gases and aerosols which include protective mask with active filling and filters for aerosols.

The equipment based on isolation is used in case of decreased concentration of oxygen under the allowed level.

This includes:

– Tube mask with pot or without pot for supply with clean air from a distant environment

– Tube mask with attachment for compressed air used only if central line for compressed air supply is available (from a central compressor or a tank).

– Isolation devices with open or closed system that supply the user with clean air from a tank, where the exhaled air is released in the atmosphere (in open system) or released in to a chemical cartridge where certain amount of oxygen is missing (closed system). The recirculated air is again brought to the respiratory system [6].

DELOPMENT OF CONCEPT DESIGN

After conducting thorough research and analysis of the danger with which are miners faced daily, two concept designs that fulfill all demands have been developed.

The first concept design (Fig. 3) has integrated protection for eyes, protective mask with air filter and a complete protection of the head and the neck. Also, on the front upper part of the helmet two LED lights are fitted powered by lithium batteries fitted in the middle part of the helmet's layers.

Fig. 3. Side, front, back and perspective view of the first concept design

On the back of the helmet an opening is positioned for supplying fresh air for breathing, filtered through the air filter fitted on this side of the helmet. The elegant design resembles the design of military fighter jet helmets. Organic forms have been used in this concept design enabling complete integration of the functions in the available space without deranging the look or to result in difficulties in use of the helmet.

Figure 4 presents a real-look render of the helmet where the Head-Up Display is presented at the eyes mask where the miner can receive important information about the temperature, air pollution, gas leakage or other information. All this is made available by the sensor located in the helmet's sides. The central processing unit processes the sensor's data and sends the information to the OLED display positioned between the layers of protective glass. This display as well as the CPU, are powered by the same lithium batteries integrated in the helmet [2].

Fig. 4. Real-look render of the concept design 1 of a miner's helmet

The face mask can be adjusted by a simple push of a button which releases the mechanism and allows the mask to be translated to the front and rotated upwards above the helmet (Fig. 4.) This function provides the helmet with the ability to be used in underground mines as well as in surface mines where most of the time a face protection is not necessary. When positioned above the helmet, the display and sensors are not in function.

In Figure 5 both sides of the mask are presented where the sensors are located which measure specific parameters in real time. The sensors and the display are powered by 2 batteries located in the back end of the helmet with total nominal power of 12.000 mAh. The battery capacity is sufficient to provide constant operation of the helmet with all its features for 72 hours. The helmet has sensors for:

– Temperature
– Altitude and pressure
– Air humidity
– Detection of poisonous gases in the air
– GPS chip
– Radio transmission for communication.

Fig. 5. Face mask with included sensors attached on the sides

In the helmet 2 LED lights are fitted with total power of 12 W powered by a separate lithium battery positioned behind behind them. The capacity of this battery is 3.000 mAh, which is sufficient for constant operation of the lights for more than 140 h. The lights are turned on by a simple switch positioned on their front. By rotating this switch 15 degrees clockwise the lights are turned on.

The face mask can be adjusted by a simple click to the undoing button allowing for the mask to be moved forward and rotated above the helmet (Fig. 6). This provides the helmet to be used underground as well as in surface mines or other areas where the face mask is not necessary. When the mask is released, the sensors and display are not in function.

Fig. 6. The face mask is adjustable depending the needs of the miner (for underground or surface mines)

In the helmet 2 LED lights are fitted with total power of 12 W powered by a separate lithium battery positioned behind behind them. The capacity of this battery is 3.000 mAh, which is sufficient for constant operation of the lights for more than 140 h the lights are turned on by a simple switch positioned on their front. By rotating this switch 15 degrees clockwise the lights are turned on.

With the use of this concept design of the helmet it is foreseen to be used racks where after use of the helmets the miners will place them and connect them to chargers for their next use (Fig. 7).

Fig. 7. LED lights fitted in the front part of the helmet

All functions and sensors in the helmet are powered by lithium batteries placed in the back side of the helmet. The batteries are rechargeable and a standard 12 V socket for the charger is positioned on the back side (Fig. 8). The batteries can be sully charged in less than 3 hours.

Fig. 8. Socket for battery charger build-in the helmet

Fig. 9. Racks for helmets with integrated chargers and pedestals.

Comment [B3]: Каде е цитирана слика 9 во текстот

At the section view presented in Figure 10 the interior of the helmet is presented together with the protective basket for the head of the miner. The protective basket is attached with elastic bolts which have the function to absorb the impact. The basket is made of plastic, and the lower part is lined with polyurethane in order to increase the absorption capability from impacts, but also to make it more comfortable for wearing.

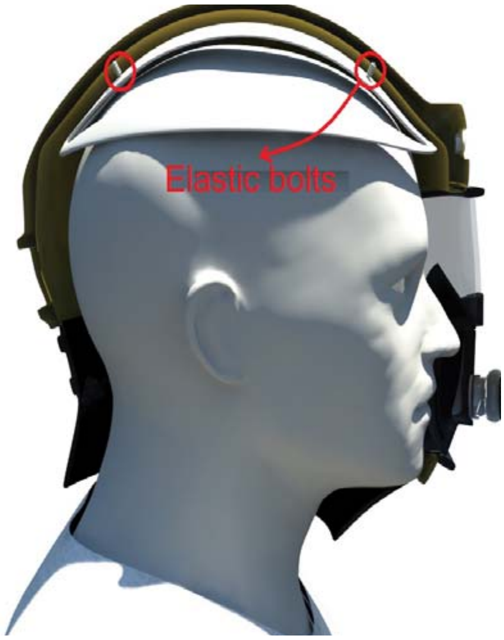

Fig. 10. Section view of the helmet

The second concept design has more futuristic look with moreover the same functions as the first concept design (Fig. 11). With this concept design the focus is placed on the functions for air-conditioning and air filtration.

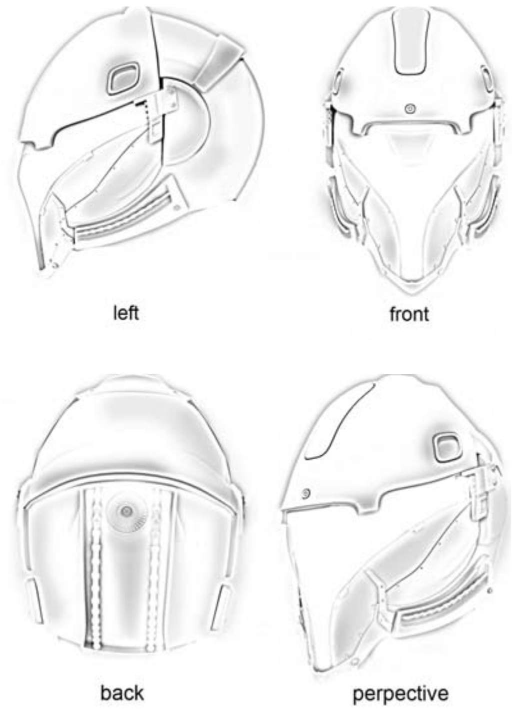

Fig. 11. Side, front, back and perspective view of the second concept design

At the front part of the helmet a fixed mask made of three-layered protective glass with integrated display is placed.

This concept has a non-detachable mask. In order for the mask to be removed, it has to be completely undone from the helmet and removed in such a way. Also, this concept has an integrated camera at the front of the helmet connected wirelessly to the headquarters of the mine where a real time video feed can be monitored in order to follow the movement and operation of the miner.

Figure 12 presents the helmet of the miner while wearing. Also, the Head-Up Display can be seen at the front mask for protection of the eyes and face where the miner can receive information about the temperature around him/her, information for any leaks of poisonous gasses and other relevant information which will further facilitate the miner's operation.

On Figure 13 the sensors placed on the both sides of the helmet are shown. These sensors collect data that is processed by the CPU and display information in real time to the protective glass and the integrated display. The sensors are powered by two batteries placed on the back of the helmet with total capacity of 12.000 mAh. With this capacity the helmet can operate constantly for 72 hours with all functions activated.

Fig. 12. Photorealistic render of the second concept design of the helmet

Fig. 13. Sensors on the side of the helmet

The helmet has the following sensors integrated:

– Sensor for temperature

– Sensor for altitude and pressure

– Sensor for humidity

– Sensor for detection of poisonous gasses in the air

– Integrated GPS sensor

– Integrated radio frequency sensor

The OLED display integrated in this concept design is a bit different from the one in the previous concept because it is occupying bigger area in the user's field of view. In order to be safe, the display is integrated in a three-layered protective glass resistant to impact and breaking, scratches and heat.

The camera placed in the front part of the helmet enables to monitor the worker's operation with the ability to get further intructions from the headquarters that is monitoring the process. The connection is made avilabe through a wireless protocol.

The second concept design has an engineering design that does not allow an easy detachment of the face mask. Nevertheless, this option is still made available by unclamping the pads placed on the lower and upper part of the face mask and with that it is completely removed from the helmet (Fig. 14). By detaching the face mask the functions of the sensors and the display are suspended until it is again mounted to the helmet.

Fig. 14. Clamps for detaching the face mask from the helmet

Figure 15 presents the six LED lights placed on both sides of the helmet. These lights are with total power of 36W (6W each LED) powered by two lithium batteries placed behind them. The capacity of the batteries is 6.000 mAh (2 x 3.000 mAh) which enables the lights to be used for more than 120 hours. The lights are turned on with a switch in a form of buttons placed on the side of the lights (Fig. 15). This design enables the lights to be turned on separately on each side.

Fig. 15. LED lights placed on both sides

All functions and sensors are powered by lithium batteries integrated in the sides and in the back of the helmet. The batteries after certain period of use are charged through the socket placed on the back of the helmet. Batteries are fully charged in six hours.

For storing and charging of the helmets the same rack is used as presented in the first concept design.

Fig. 16. Active carbon filter integrated in the fornt part of the helmet

Comment [B4]: Каде е цитирана слика 16 во текстот

Compared to the first concept design, here a special filter is used (Fig. 14) that is an active carbon filtration process. That means that the breathing air is filtered through a several layers carbon material. This material does not allow tiny particles to pass through and thus protecting the miner from breathing in particles with size smaller than 10 nano meters.

With the integrated system for air circulation, the helmet is constantly supplied with fresh air and a stable temperature level is maintained. As show in Figure 17, the system is placed in the back side of the helmet and it is consisted of an electric fan with metal hoses integrated in the helmet supplying the air.

Fig. 17. Air circulation system for fresh air supply

On the section view presented in Figure 18 the head inlay with polyurethane is displayed. This inlay also does not hold on the moisture. Compared to the first concept design, in the concept the protection used in this engineering design is similar to the helmets for motorcycle drivers. With the polyurethane inlay instead of protective basket an additional protection and absorption from strong impacts is provided without causing significant injures.

The only negative side is that air circulation through the helmet inlay is not possible. This system for protection in combination with the system for air circulation will not result in difficulties while use.

Fig. 18. Head inlay with polyurethane

CONCLUSION

The conducted research shows that the regular miner's helmet is simply not enough for maximum protection of the user. Aa result of that the miner is forced to use additional equipment such as light, radio transmitter, batteries, air filter, protective mask for eyes and other body parts that only make the operation more difficult.

The safety of the miners is neglected regardless the development in technology and in the mining industry.

Concept designs have been developed for modern miner's helmet using the method of integrating the needs of the users. A concept of a helmet is created that will satisfy all protection measures necessary for protecting the miners. During the design process of the helmets, the anthropological measures and ergonomic methods defined for the potential group of users have been used.

The production costs and the selling price of the concept helmets is higher than the regular miner's helmet but as concluded in the description of the concept designs they are completely integrated with all necessary protective equipment for miners.

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*Reprint**

A NUMERICAL METOD FOR THE DETERMINATION OF COMPLEX CURVES OF CROSS SECTIONS OF THE BUSES' SUPERSTRUCTURES BY APPLICATION OF THE SUFFICATION METOD

Živančo Panovski

IEV-Ltd, Industrial Engineering of Vehicles Ltd– Skopje, Republic of Macedonia
Prostration, Designing and production, Project Analysis and Advisory for Industry Investment,
Nikola Rusinski Str., No. 3B/1-25 Skopje
iiv-panovski@t-home.mk

A b s t r a c t: The superstructure's shape's variability's dynamics in bus production depends of the continuous demand for technological improvements, the types of buses, as well as their aesthetic design aspect. The success of the entire project depends on the time required to prepare a developing task, manufacture and examine a prototype vehicle and launch the same into a serial production

Key words: basic curves; LO-1; LO-2; LO-3; design; application of the suffocation method

НУМЕРИЧКА МЕТОДА ЗА ОПРЕДЕЛУВАЊЕ НА СЛОЖЕНИ КРИВИ ОД ПРЕСЕЦИ НА АВТОБУСКИ НАДГРАДБИ СО ПРИМЕНА НА МЕТОДИ НА ПРИГУШУВАЊЕ (СУФИКАТИЈА

А п с т р а к т: Динамиката на променливост на обликот на надградбата при автобуското производство е условена од континуираните побарувања за потребни техничко-технолошки подобрувања на типови и категории на автобуси, како и естетско-дизајнерски аспект. Битен фактор за успех на целиот проект претавува времето во смисла на подготовка на развојната задача, изработка на прототипното возило, неговото испитување и конечно до лансирање на автобусот во сериско производство.

Клучни зборови: основни базни криви; LO-1; LO-2; LO-3; дизајнирање; примена на методи за пригушување – суфикатија

1, INTRODUCTION

In case of complete variability of the bus' superstructure's shape, the reliability of the fabrication period, as well as both the project design and the technological documentation, is required. The necessity for punctuality demands the application of modern methods in the design and finalization of the bus. This doesn't only contribute to the timely realization, but also provides possibilities for versatile performances during constant commencing conditions.

2. CONIC SECTIONS IN THE DESIGN OF BUS' SUPERSTRUCTURES

A conic (LO) is a curve obtained by intersecting a circular conical surface with a plane. These can be ellipses, circles, parabolas, straight lines, etc. The basic curves are lines of transversed, longitudinal and horizontal sections of the bus' superstructure: LO-1 (Pic. 2); LO-2 (Pic. 3); LO-3 (Pic. 4).

To further define the basic curves LO, generally two coordinate systems, independent from one another, are chosen. Due to the symmetry of the

*Reprint of the "*Savremeni premer*", Year 5 No 1 and 2, p-p. 334–337 (1983), Cr6atia vehicle, in this particular case their coordinate origins are plotted on the vehicle's longitudinal axis, which height has been conditionally defined, the coordinate origins O1 and O2 here, plotted on the z-axis, are intercepted by two axes characteristic to the vehicle, both perpendicular to the first one. The application of two coordinate origins allows for the simplification of the project's program and opens up the possibility for independent separate work on the two builds, both front and back.

Due to the technical conditions of the bus and coach factory SANOS, MCII, BUSCAR, NOGE, and act. Technological Park, complex curves, consisting of mild curves with a continuous change of the bending, is taken into consideration. Generally the equations of the basic curves, applied in the construction of the front part, with a coordinate origin in the point O1 in vehicle types such as, coach factory assume the following forms:

2.1. Basic vertical curve of the front part LO-1 (Pic. 2) comprising of 4 conics n=4

$$F_1(y,z)=(y_1-y_{0_n})^2+(z_1-z_{0_n})^2-R^2{}_{0_n}=0$$

$$Z_1=f_1(y_1) \text{ for } \forall y_1\in(A_1-E_1)$$

where

$n=1...4$

$y_1(y_{\min}^{LO-1}+y_{\max}^{LO-1})$

2.2. Basic horizontal curve of the front part LO-2 comprising of 3 conics n=3

$$F_2(X,Z)=(X_k-X_{0_n})^2+(Z_k-Z_{0_n})^2-R^2{}_{0_n}=0$$

$$Z_k=f_2(X_k) \text{ for } \forall X_k\in(A_2-D_2)$$

where

$n=1...3$

$X_k(0-X_{\max}^{LO-2})$

2.3. Basic curve of the side and top LO-3 (Pic.4) comprising of 4 conics n=4

$$F_3(X,Y)=(X_1-X_{0_n})^2+(Y_1-Y_{0_n})^2-R^2{}_{0_n}=0$$

$$X_1=f_3(y_1) \text{ For } \forall y_1\in(A_3-E_3)$$

where

$n=1...4$

$Y_1(Y_{\max}^{LO-3}+Y_{\max}^{LO-3})$

From 2.1, 2.2 and 2.3 it is one can deduct that the previous are a sum of segment cross-sections, i.e. circles predefined in an interval where:

n – Is the number of conic intersection;

$X_{0_n}, Y_{0_n}, Z_{0_n}$ – are the coordinates of the circle's centers;

R_{0_n} – represent the circle's radiuses.

While defining the basic curves LO and their intervals for the front part construction the following requirements need to be satisfied:

2.4

$$y_{\min}^{LO-1}=y_{\max}^{LO-1} \quad \left|y_{\min}^{LO-1}\right|\le\left|y_{\min}^{LO-3}\right|$$

2.5. Generally

$$Z_{\max}^{LO-2}\le Z_{\max}^{LO-1} \quad X_{\max}^{LO-2}\le X_{\max}^{LO-3}$$

2.6

a) The curves can be perpendicular to one another, i.e. they are either plotted in or parallel to the defined planes of the coordinate system, or

b) the basic curves can not be perpendicular to one another, in which case, due to the symmetry of the vehicle LO-1 must be perpendicular to LO-2, and LO-3 must be positioned at a certain angle to LO-2. This is a prerequisite to modern bus construction, as a result of the wide open front view as a result of the improvement of the aerodynamic vehicle features.

3. A NUMERICAL METHOD FOR THE DETERMINATION OF CROSS-SECTIONS OF COMPLEX FORMS OF THE BUS' SUPERSTRUCTURE BY APPLICATION OF THE SUFFOCATION METHOD

3.1. Application of the suffocation method:

– Method of the triangle
– Method of the trapezium
– Inscription of the surface

By applying the construction type of the vehicle that satisfies the requirements from 2.4, 2.5, 2.6-a, and the equations of the basic curves LO-1, LO-2 and LO-3, the cross-sections can be determined by: applying an arbitrarily horizontal plane h_1 (Pic. 5) with coordinates $h_1[\infty:y_1:\infty]$ and intersecting it with the curves LO-1 and LO-3 in the points M_{11} and M_{31} plotted on them, (which are a function of y_1's coordinates themselves), resulting in the intersecting points' coordinates being:

$$M_n[0;Y_{M_{11}};Z_{M_{11}}]$$

and

$$M_{31}[X_{M_{31}};Y_{M_{31}};0],$$

where $Y_{M_{31}} = Y_{M_{11}} = Y_1$.

The intersecting points M_{11} and M_{31} typifies the suffocation ΔX_1 and ΔZ_1 on the complex curve LO-2, plotted on the h_1 plane.

3.2. Determining the suffocation

From Picture 5 it can be concluded that:

$$|\Delta X_1| = |X_{\max}^{LO-2} - X_{M_{31}}|$$

for

$$\forall X_{M_{31}} \neq X_{\max}^{LO-2},$$

i.e.

$$|\Delta Z_1| = |Z_{\max}^{LO-2} - Z_{M_{11}}|$$

for

$$\forall Z_{M_{11}} \neq Z_{\max}^{LO-2},$$

where:

– ΔX_1 is the suffocation of the complex curve (LO-2) relative to LO-2 along the X-axis depending on its function of y_1:

$$X_{M_{31}} = f_3(y_1) = X_1;$$

– ΔZ_1 is the suffocation of the complex curve (LO-2) relative to LO-2 along the Z-axis depending on its function of y_1:

$$Z_{M_{31}} = f_1(y_1) = Z_1.$$

By replacing $X_{M_{31}}$ in a general condition the result is the following:

$$\Delta X_1 = X_{\max}^{LO-2} - \sqrt{R_{0_n}{}^2 - (y_1 - y_{0_n})^2} + X_{0_n}$$

Ranging in the definition interval of $F_3(x, y)$ for

$$\forall Y_1 \in (A_3 - F_3).$$

Analogously by replacing $Z_{M_{31}}$ it is determined that:

$$\Delta Z_1 = Z_{\max}^{LO-2} - \sqrt{R_{0_n}{}^2 - (y_1 - y_{0_n})^2} + Z_{0_n},$$

Ranging in the definition interval of $F_1(y, z)$ for

$$\forall y_1 \in (A_1 - F_1).$$

3.2. Determining the coordinates of points on the complex curve (LO-2), depending on the suffocation

After having determined the suffocation ΔX_1 and ΔZ_1 (explained in 3.1), an advancement is made towards determining the complex curve (LO-2) itself, which is derived as a sum of points plotted on intersections of three auxiliary planes that are perpendicular to one another h_1, f_1, p_1, f_k, p_k. The method of determining the intersecting points as elements of the complex curve is the following:

Two arbitrary points G and H are chosen on the intersection of the planes of the basic curves LO-2 and LO-3, or LO-1 and LO-2, respectively. Four planes (T, T_1, S, S_1, the first two comprising the first pair and the following two-the latter one), are plotted in such a manner that the intersection between the first, and the second pair, lies in the plane of the basic curve, LO-3, or LO-1, respectively. The first intersection marks the G-axis, whereas the latter one marks the H-axis. For easily acquiring the coordinate points, the problem is derived to a planar scale, where every longitudinal intersection gained by an intersection with the h_1 plane defines LO-2.

In general conditions, every arbitrary point M_{2_k} (Pic. 5-a), determined by its coordinates X_{2_k} and Z_{2_k}, that comprises the basic curve LO-2, is corresponded by a point M_{21} with coordinates X_{2_1} and Z_{2_1}, plotted in the h_1 plane. By solving the system of intersections, we derive the coordinates of the point M_{21}, where:

$$M_{21}[X_{21}, Z_{21}];$$

$$X_{21} = Xl_{21}; Z_{21} = Zl_{21};$$

$$M_{21}\left\{\begin{array}{l} \dfrac{(X_{\max}^{LO-2} - \Delta X_1)\left[\chi_2 - \dfrac{\chi_2\left(X_{\max}^{LO-2}\right) - X_{2k}}{X_{\max}^{LO-2}}\right]}{\chi_2} \\ ;\dfrac{\left(X_{\max}^{LO-2} - \Delta Z_1\right)\left[\chi_1 - \dfrac{\chi_1\left(Z_{\max}^{LO-2}\right) - f_2\left(X_{2h}\right)}{Z_{\max}^{LO-2}}\right]}{\chi_1} \end{array}\right\}$$

$\chi_1 = X_G = const.$;

$\chi_2 = Z_H = const.$

By replacing ΔX_1 and ΔZ_1, the point gets the following coordinates:

$$M_{21}\left\{\frac{f_3(y_1)X_{2k}}{X_{\max}^{LO-2}};\frac{f_1(y_1)f_2(X_{2k})}{Z_{\max}^{LO-2}}\right\}$$

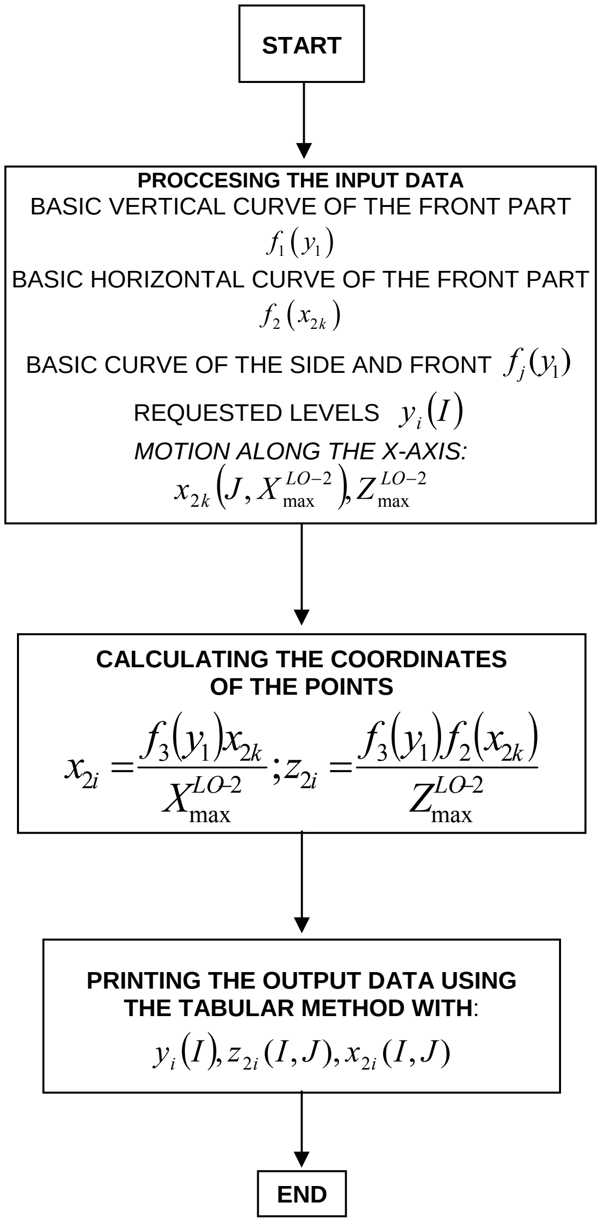
where the following for $f_3(y_1)$ apply:

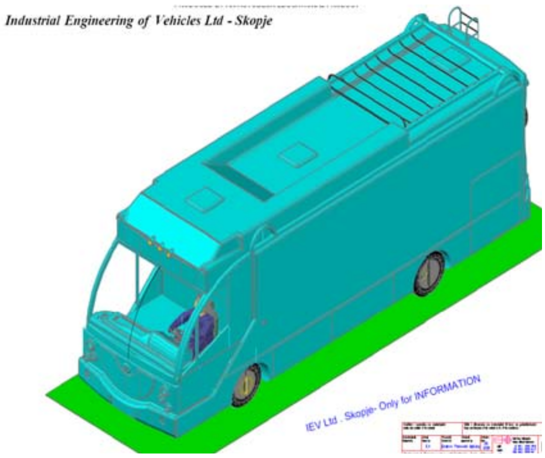
– For $\forall y_1 \in$ in the interval from the equation of the basic curve LO-3 defined in $F_3, F_3(X,Y)$, (which can be deduced from 2.3);

– For $\forall X_k \in$ in the interval from the equation of the basic curve LO-2 defined in F_2, (F_2 (*X*, *Z*), (from 2.2);

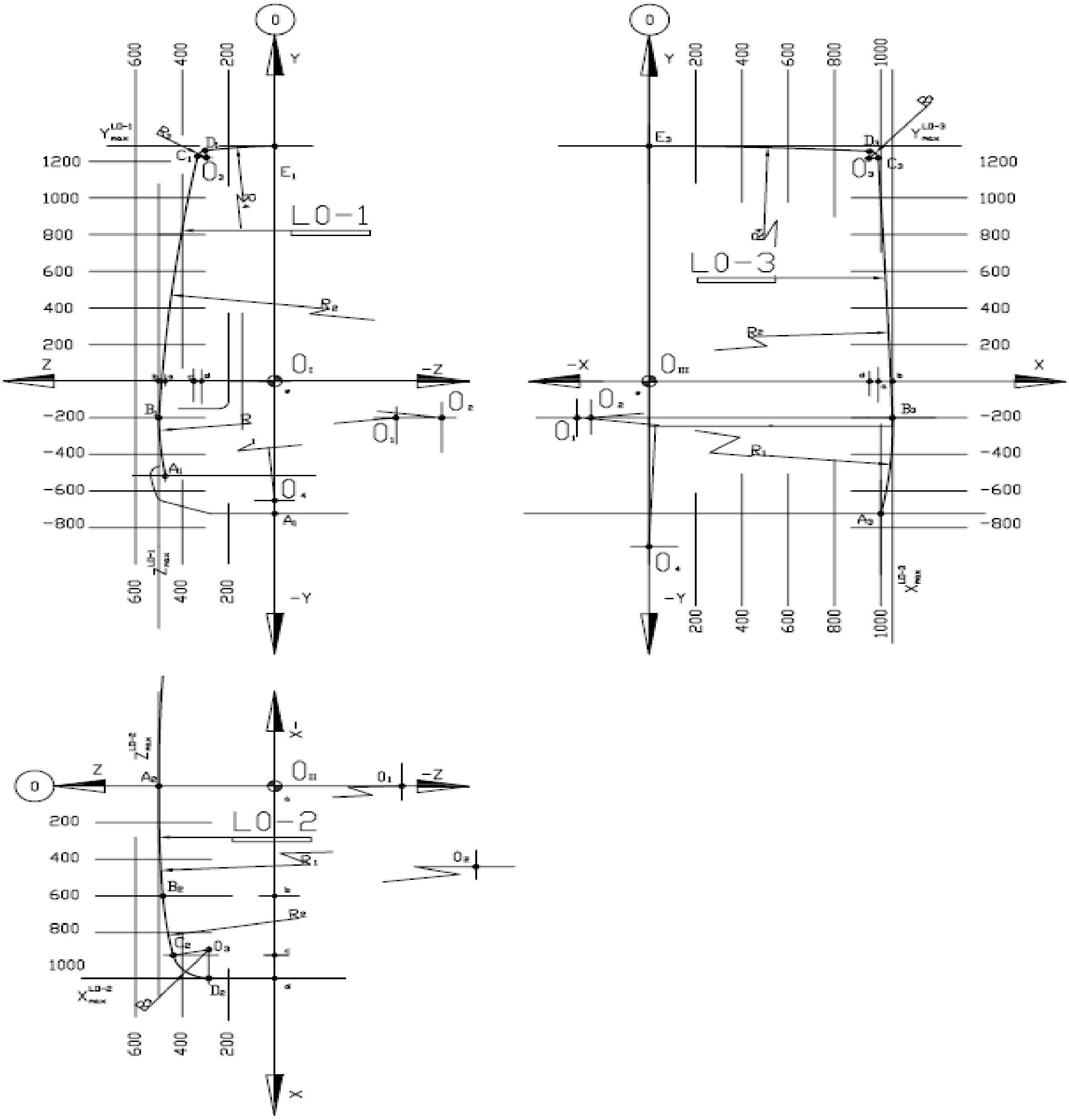
– For $\forall y_1 \in$ in the interval from the equation of the basic curve LO-1 defined in $F_1, F_1(Y,Z)$, (from 2.1).

BLOCK DIAGRAM

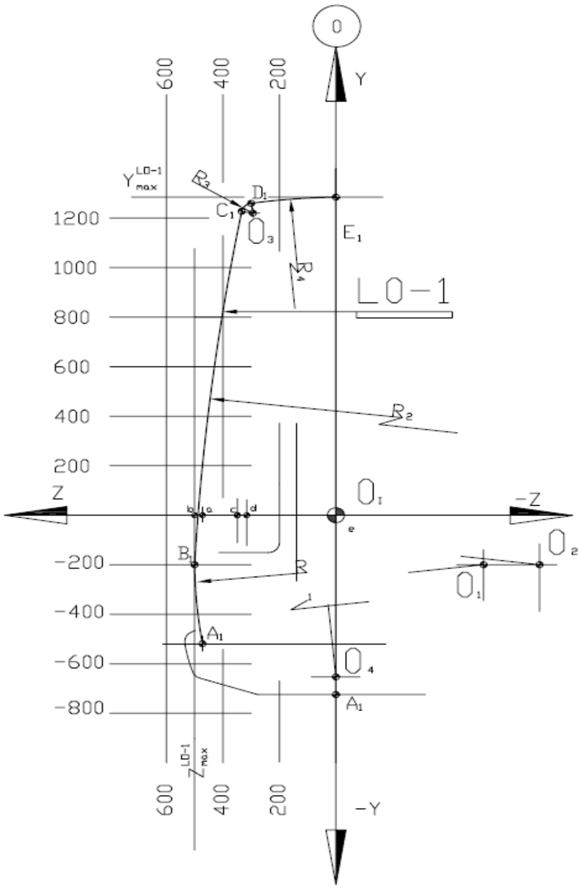




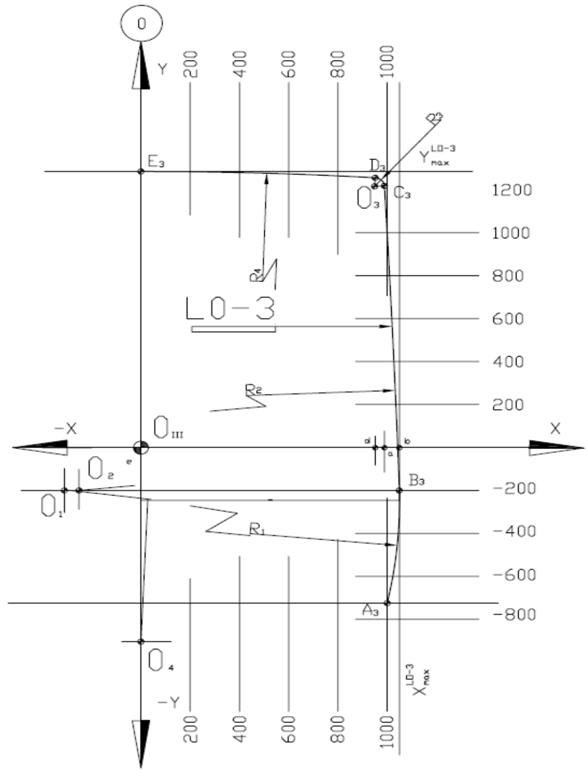
Pic. 1: A coordinate system of a bus' superstructure.



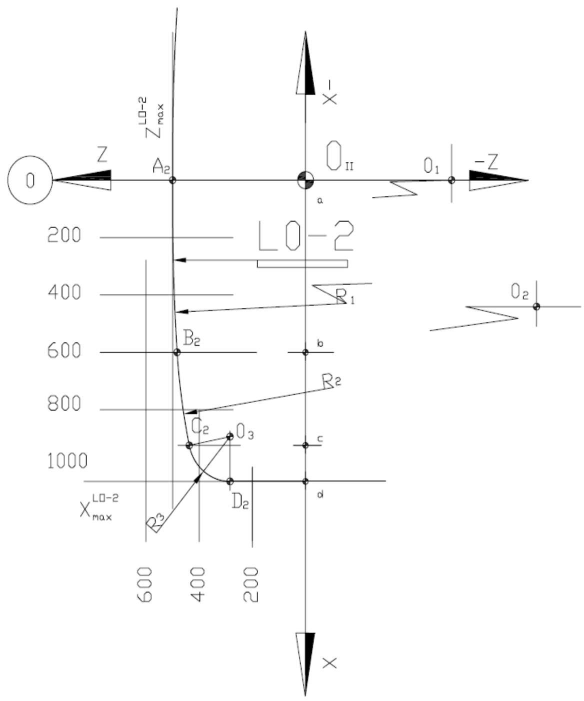
Pic. 2: Basic vertical curve of the front part LO-1 comprised of 4 conics.



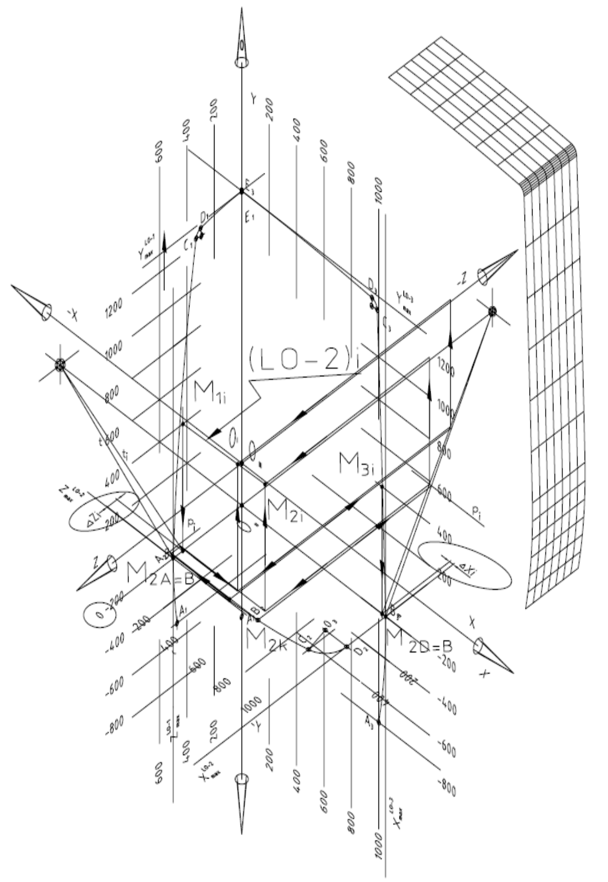
Pic. 3: Basic horizontal curve of the front part LO-2 comprised of 3 conics.



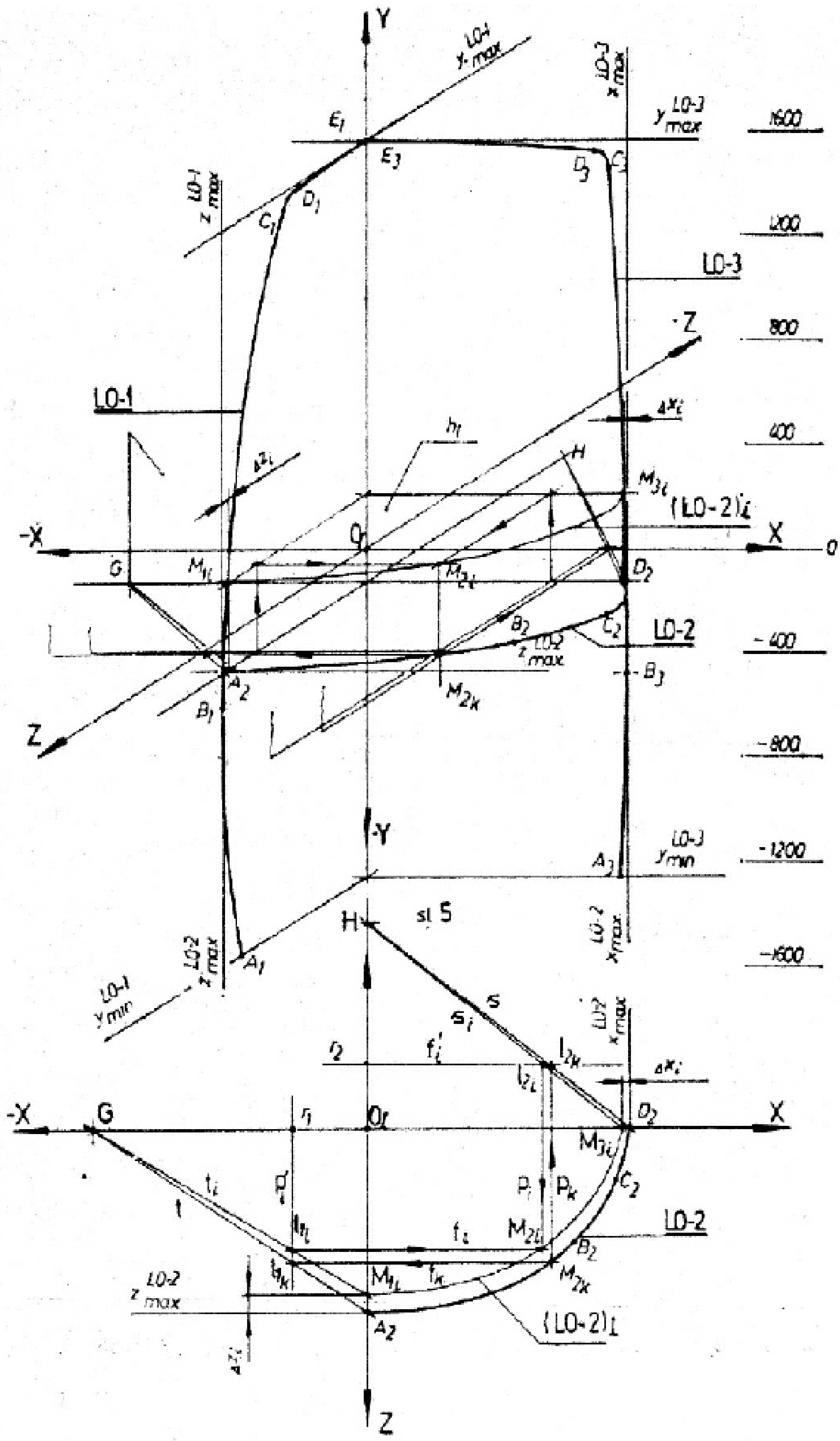
Pic.5-a: Curve LO-2i



Pic.4: Basic curve of the side and roof LO-3 comprised of 4 conics.



Pic. 5b.: Basic curve LO-1, LO-2 and LO-3.


Y
-X
X
O
-Y
Z
-Z
LO-1
LO-2
LO-3
(LO-2)'i
(LO-2)i
1600
1200
800
400
0
-400
-800
-1200
-1600
H
G
O1
D2
M3i
C2
B2
A2
M2k
M2i
M1i
E1
E3
D1
C1
D3
C3
B1
B3
A1
A3
s
si
S
t
ti
fi
f'i
fk
Pi
Pk
P'i
h1
Δxi
Δzi

Pic. 6.

CONCLUSION

The coordinates of the points that comprise the complex curve (LO-2) are defined by the equations of the basic curves LO-1, LO-2, LO-3, as well as the maximum values of the basic curve LO-2 along the X and Z axes, i.e. the coordinates of the point $M_{2i}\left(X_{2i}, Z_{2i}\right)$ proportionally prevent the suffocation along the X and Z axes. The determination of the coordinates of the complex curve LO-2 completely defines the complex form of the segment of the bus' superstructure, which can be further detailed itself.

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Original scientific paper

UNIFICATION OF DESIGN FOR THE "FAMILY" OF THE VEHICLE CATEGORY M3, CLASS II AND CLASS III WITH "THREE SECTION"

Živančo Panovski

IEV – Ltd , Industrial Engineering of Vehicles Ltd
Procuration, Designing and production, Project Analysis and Advisory for Industry Investment
Nikola Rusinski Str., No. 3B/1-25 Skopje, Republic of Macedonia
BUSCAR Ltd-Skopje /2004-2009/
iiv-panovski@t-home.mk

A b s t r a c t: Design of the chassis and body, with stainless steel, components, aggregates and elements from company's NOGE – Bus and Coach Factory from Spain, MAN and ZF, designing with "three section."

Key words: the basic curves; LO-1; LO-2; LO-3; design; stainless steel; designing with "three section"

УНИФИКАЦИЈА НА ДИЗАЈНИРАЊЕ ЗА "ФАМИЛИЈА" НА ВОЗИЛА КАТЕГОРИЈА М3, КЛАСА II И КЛАСА III СО "ТРИ СЕКЦИИ"

А п с т р а к т: Овој труд се занимава со, точката 5 и точката 6 од постулатите на ПРИРАЧНИКОТ ЗА КВАЛИТЕТ, односно, примена на дизајнот на возилата. Примената на оптимизација во дизајн и производство, според принципот на: изработка на шасија и надградба на возилото со примена на три секции е претставен како пример во кооперација. Резултат дава фамилија на возила од Категорија М3 , класа II и класа III и опции кои: вкупната маса и вкупната должина се променлив, односно, кои се ограначени од страна на тип на материјалот и конструкцијата.

Клучни зборови: основни базни криви LO-1, LO-2, LO-3; дизајнирање со материјали со висок степен на квалитет на корозивност (stainless steel); примена на концеп со три секции

INTRODUCTION

Design of the chassis and body, with stainless steel, components, aggregates and elements from company's NOGE – Bus and Coach Factory from Spain, MAN and ZF, designing with tree section.

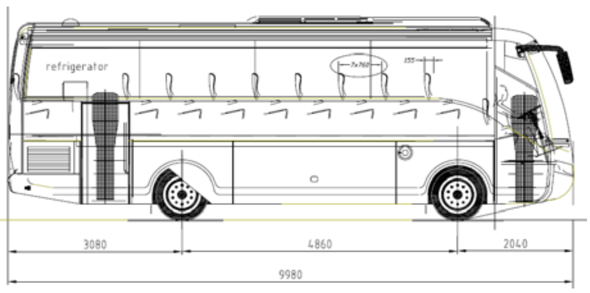
The superstructure's shape's variability's dynamics in bus production depends of the continuous demand for technological improvements, the types of buses, as well as their technical and aesthetic design aspect. The success of the entire project depends on the time required to prepare a developing task, manufacture and examine a prototype,

Vehicle and launch the same into a serial production.

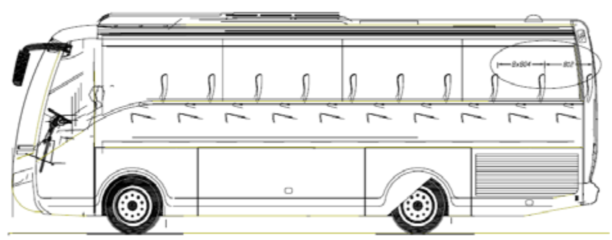
In case of complete variability of the bus' superstructure's shape, the reliability of the fabrication period, as well as both the project design and the technological documentation, is required. The necessity for punctuality demands the application of methods – QUALITY MANUAL in the design and finalization of the bus. This doesn't only contribute to the timely realization, but also provides possibilities for versatile performances during constant commencing conditions.

MATERIALS AND METHODS

On the Figures 1a and b are presented NOGE – PROTOTYPE Bus & Coach. where new technologies and technicues where implemented.



a)



b)

Fig. 1. NOGE – PROTOTYPE Bus & Coach. BUS SHOW 2008, Madrid, Spain

Aim

Expanding the sales on new markets identifies the need for satisfying certain criteria regarding the quality. Following the rising trend in vehicle development globally, implementing new techniques and technologies, BUSCAR Ltd decided to accept these criteria.

This and the other documents from the quality system are created to fulfil that aim. This is the top document in reference to the quality and all the activities that are relevant to the quality of our products are presented inside it. Among the other, one of its aims is satisfying the requirements of the standard ISO 9001/2000.

The quality manual is based on the process concept, which means that its realization is based upon the management of the processes in the company.

Definitions

Quality manual – documents that defines the quality policy and describes the organizational quality system.

Quality policy – common targets and company's orientation towards the quality, which are officially created by the company's top management.

In BUSCAR Ltd quality system, other definitions are placed, in order as they are mentioned in the respective documents that are subject of the standard ISO 8402. In cases where different definitions for certain term appear, the definitions presented in the standard ISO 8402 take precedence.

Responsibilities and authorities

Development manager

Development manager is responsible to the General Manager for the following:

– Ensuring that all legal norms and international rules and directives regarding the construction of the vehicle are applied.

– Control of the new development projects for new types of vehicles as declared of the standard ISO 9001/2000.

– Participates in preparation and maintaining the necessary documents for certification of the vehicles.

Other employees in the departments

All employees are responsible for monitoring the product, the process they directly participate in, and the quality system. Every located problem must be identified. Every employee may suggest solution for a certain problem.

Resources

The company identifies and provides necessary resources for product verification, as for trained personnel, also for materials, various tools, components and everything other, necessary for satisfying the defined specifications.

Design

In BUSCAR Ltd, while working on a concrete project, special attention is paid. Every Project goes trough fundamental analysis from different point of view:technical, technological, economic etc. All of this is dictated from the nature of the product itself – the bus.

The organization of the project is under authority of the project leader, who is appointed by the development manager. His duty is to prepare plan for the project, to appoint qualified personnel, who is adequately equipped with resources for carrying the project out, and also to coordinate other involved organizational groups.Every project must comply with legal norms and international regulations with no exemption. Also, other inputs in the project are determined:

– Standards
– Terms defined in the contracts
– Technical requirements
– Results from tests and inspections
– Spare parts
– Safety requirements
– Environment protection requirements

Ambiguous, confusing or incomplete requirements are located and solved before start of the project

Project outputs are documented, as various on technical documentation. Key factors for proper functioning and safety of the vehicles especially are marked in the documentation.

Project verification is made with manufacture of the prototype and completing the following documentation. Verification can be also done with:

– Project review
– Comparison with similar successful project

The changes in the project are controlled, reviewed and verified by development manager.

Purchasing

After receipt of the order for a specific vehicle (or few vehicles) starts the process of purchasing specific materials, necessary for realization of the production. Every vehicle has its number (Vehicle Identification Number - VIN), which appears in every purchasing document. Materials and components that have long delivery term are planned previously, or in time. If there were no stock of these materials, purchasing covers some stock also, which would allow normal work without stops of the production.

All orders contain exact specifications for the concrete material or component. Before they are confirmed, they are also reviewed.

Based on a previous experience in purchasing, or the terms under which it has been done (quality, price, terms), each purchasing officer prepares list with suppliers. Thereat the following is considered:

– Whether the supplier has an implemented and certified quality system

– Whether the supplier's quality system is positive evaluated from BUSCAR Ltd.

– Whether the supplier has some certificate or homologation for the product etc.

In the list each supplier is evaluated. If the supplier is of such nature that it can possibly endanger the production continuity, the chief purchasing officer determines its rank on this list. Updating of this list is continuous process, and the old lists are saved with purpose to track the supplier's performances.

The evaluation of the suppliers that are appointed as suitable does not erase the company's obligation to control their products.

All materials and components that are purchased are controlled according to their specifications. If there is no possibility of their control at the company, services from external institutions can be accepted. The control can be done at supplier's premises by need, before the delivery of the products. Materials and components can be purchased for a specified vehicle or for some stock. When they enter the company, input control is informed. If they are aimed for stock, they are marked and stored.

Document management

All documents and data that are creating BUSCAR Ltd quality system are being systematically controlled and maintained by the quality department.

The subjects of the control are also the other documents: various orders, plans, results of audits and tests etc.

Quality system documents are reviewed and approved by authorized persons before they become official. Validity of these documents is from the date of their latest revision.

All changes and supplements as a result of the revision are documented and recorded in special lists for such purposes. These lists are kept with purpose to provide overview in the changes, supplements and the status of the documents, which is basic for traceability of the development of concrete processes.

The status of the quality system documents can be "in preparation", "in use" or "information". The ones in use are subjects of revision, and the informative ones are not. The owners of the documents in use are to be supplied with reviewed documents automatically.

The originals of all valid and invalid quality system documents are kept in the quality management department. The invalid copies are destroyed by their owner right after their validity stops.

Design – Unification of the ”family” Design for the vehicle Category M3, Class II and Class III with “three section”. Bus Coach, INTERCITY buses, are shown on Figures 2 to 12..

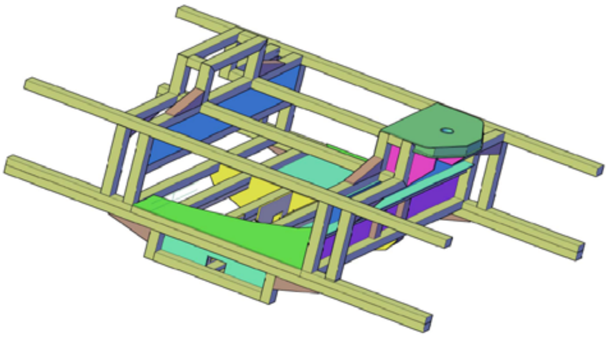


Fig. 2. Front section from the chassis

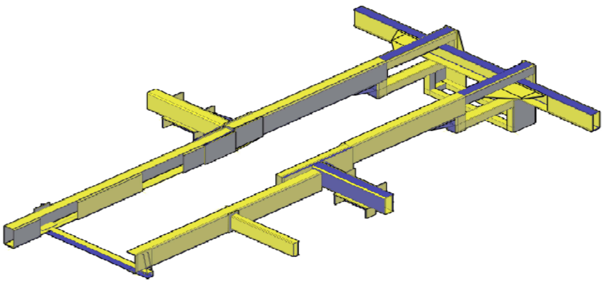


Fig. 3: Rear section from the chassis. The section from the cassis (Fig 3 and Fig. 4), design with constriction standards steels

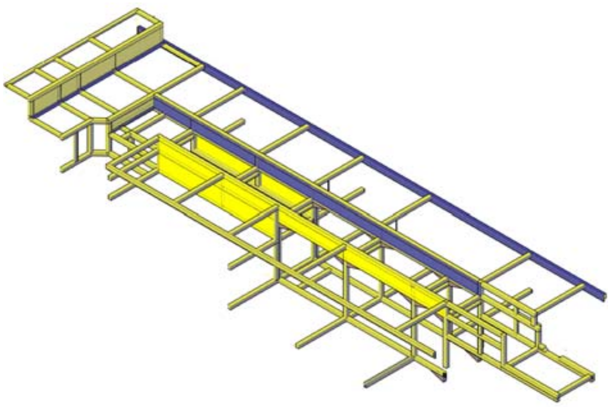


Fig. 4: Middle section from the chassis.

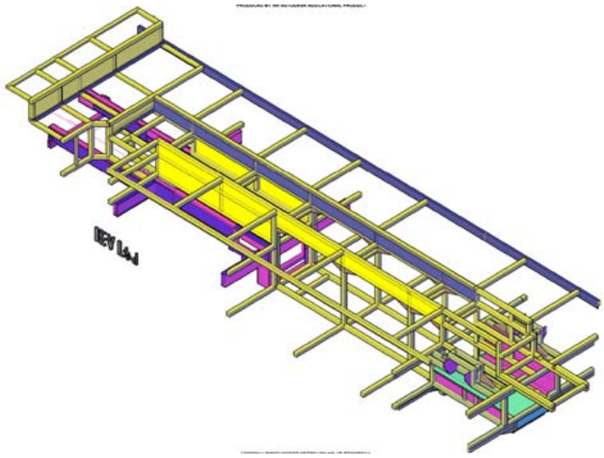


Fig. 5. Assembly the chassis:Design of the chassis with “three section”.

Assembly: the front section of the chassis and elements with the ZF front independent axle.

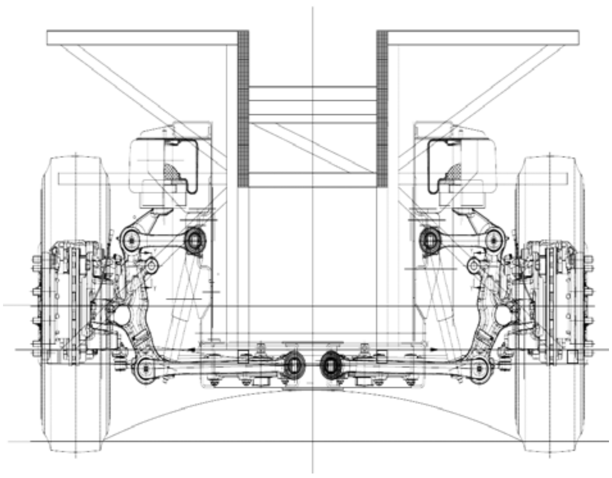


Fig. 6. Connection between the front part (Fig.3) and ZF RL 75 E, independent front axle. (Fig.8) .

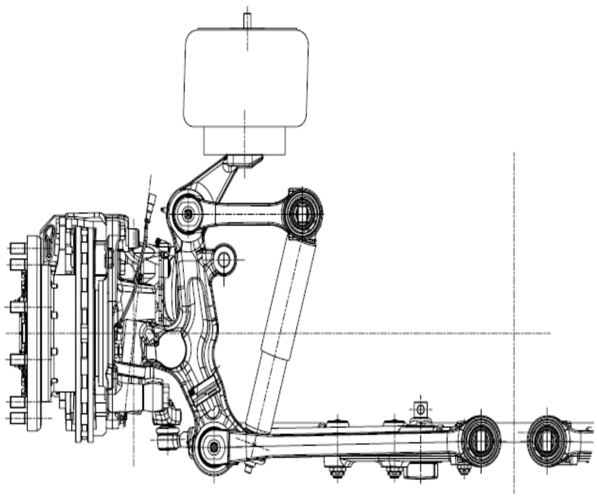


Fig. 7. ZF RL 75 E, independent front axle.

Assembly: the rear section of the chassis, with elements of the ZF rear axle and rear sway bar from PROLETER-Arilje – Serbia.

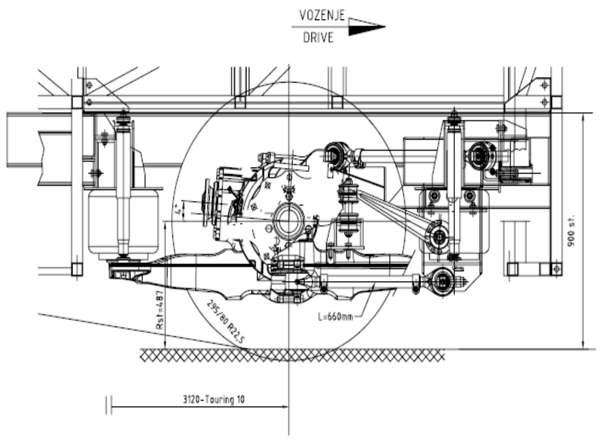


Fig. 8. Connection between the rear part (Fig. 4 and Fig. 10). ZF A 132 ABS/ASR rear axle

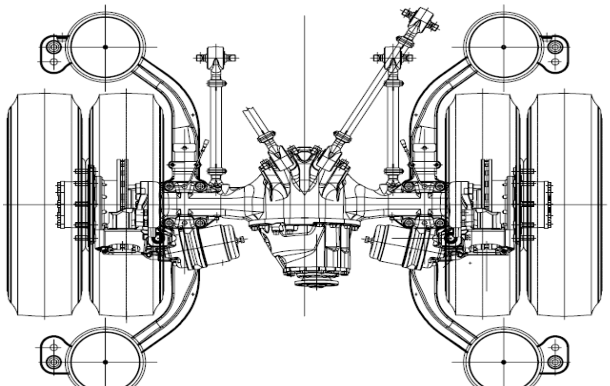


Fig. 9. ZF A 132 ABS/ASR rear axle

Assembly: Between the front section of the chassis and elements of the ZF steering systems.

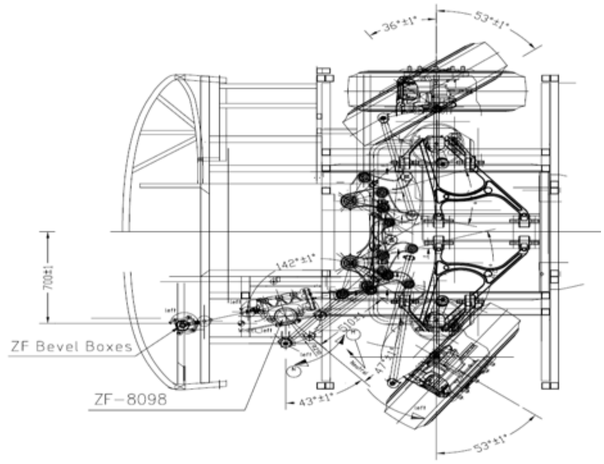


Fig. 10. Unification: Cinematic schema of the steering system (ZF), for type of busis: TOURING 10 and INTERCITY-semi Low floor and Low floor.

Assembly: Between the rear section of the chassis and elements from MAN engine and ZF gearbox with Intarder.

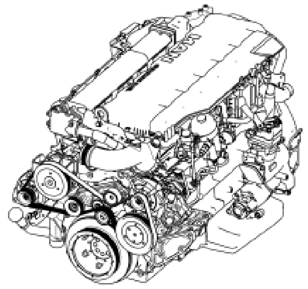


Fig. 11. Engine type: MAN D 2066 LOH with power from, 225 [kW] to 294[kW].

Fig. 12. ZF-S-Transmission Integrated retarder system: for ZF bus transmissions. Type:ZF S 1701 BO – ZF S 1901 BO

Assembly: Between the rear section of the chassis and elements from MAN – engine, ZF gearbox and ZF rear axle (Figure 13).

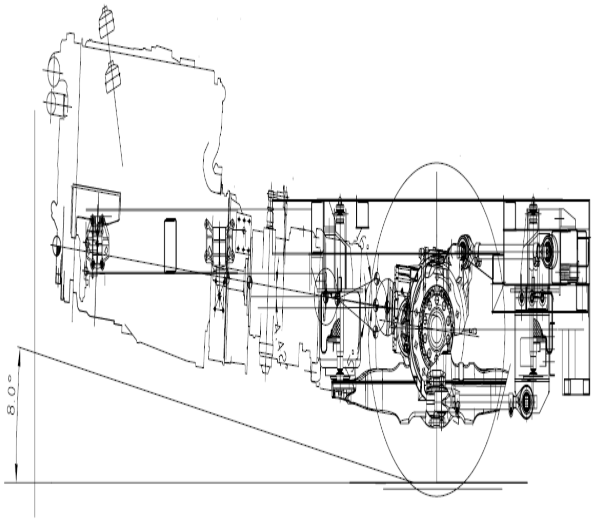


Fig. 13. Assembly between the rear section of the chassis and elements

Assembly: Uniting the chassis design, with concept - three sections for the "family" of the bus superstructure of the vehicle, for Class II and Class

III. Type of the buses, Coach, with a length btw. 10 m to 13 m (Figure 14).

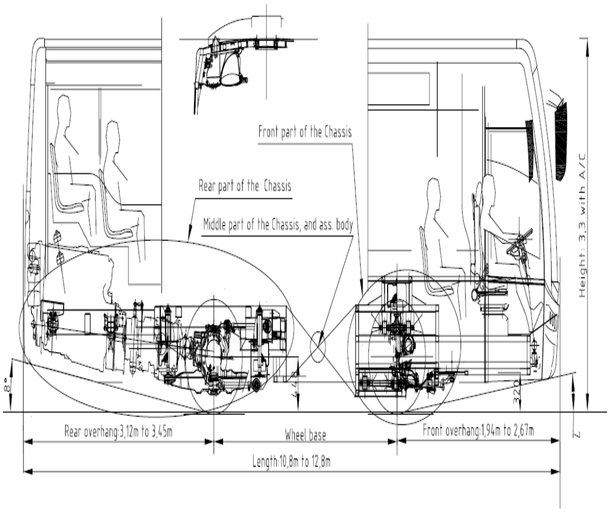


Fig. 14. Uniting the chassis design, with concept - three sections for the "family" of the bus superstructure of the vehicle

CONCLUSION

This paper has deals with, points 5 and 6 of the postulates of the QUALITY MANUAL, ie, application the design of the vehicles..Application of optimization in design and manufacturing, under the principle of: making the chassis and superstructure of the vehicle by applying the three sections is presented as an example which is realized in cooperation. The result gives a family of vehicles of Category M3, Class II and Class III and options in which: total weight and total lengths are variables, i.e., which are limited by the type of material and construction of the vehicles.

SUMMARY

Introducing the concept of the base vehicle in the production program of companies that are producers of vehicles and they are users of aggregates and components from suppliers based and priority is: the successful optimization of design and production. It resulted in a successful sale of vehicles, which basic importance is the quality of the product, which is determined by standards, ie, the application of international technical documents / EEC, ECE / and Directives from EU.

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