

International journal
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MACHINES
TECHNOLOGIES
MATERIALS

YEAR X **Issue 4 / 2016** **ISSN 1313-0226**



Published by
Scientific technical
Union of Mechanical Engineering



MACHINES. TECHNOLOGIES. MATERIALS

INTERNATIONAL SCIENTIFIC JOURNAL

PUBLISHER

SCIENTIFIC TECHNICAL UNION OF MECHANICAL ENGINEERING

108, Rakovski Str., 1000 Sofia, Bulgaria

tel. (+359 2) 987 72 90,

tel./fax (+359 2) 986 22 40,

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ISSN 1313-0226, YEAR X, ISSUE 4 / 2016

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ECONOMICAL ASPECT OF ASSESSMENT OF ELECTROCHEMICAL DRESSING OF SUPER HARD GRINDING WHEELS

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Abstract: Rational exploitation of super hard grinding wheels with metal bond requires estimation of constituent costs of grinding process and dressing of grinding wheels. In the article the method of electrochemical dressing of super hard grinding wheels and economical analysis of electrochemical dressing of these kind of grinding wheels consisted in assessment of selected costs of this process has been presented. Also analysis of costs of the grinding process has been depicted. Obtained relationships allowed us to estimate contribution of respective component of costs of grinding process using super hard grinding wheels and are basis for their optimization.

Keywords: SUPER HARD GRINDING WHEEL, ELECTROCHEMICAL DRESSING, COSTS OF GRINDING, DIAMOND, CBN

1. Introduction

Grinding wheels made of super hard abrasives (such as: natural diamond CD, synthetic diamond SD or cubic boron nitride CBN) bonded by means of metal bond are among the most modern abrasive tools. They are referred to below as super hard grinding wheels. These super hard grinding wheels have attractive operational properties, especially: a very good cutting abilities, long life, good tear strength, and high quality of grinding [1,2,6,7].

Super hard grinding wheels are generally used in the machining of hard – to – grind materials, e.g. cemented carbide, ceramics and glass, high – speed steel, tungsten carbide, titanium alloys. However, the range of use of super hard grinding wheels is limited by the difficulty in forming macro- and microgeometry of the cutting surface of a grinding wheel (CSGW) in the dressing process [1,2,4,7].

Both grinding wheels manufactures – during the original formation of the CSGW, and their users – during regeneration of grinding wheels face the problem of the dressing of grinding wheels. The difficulty in dressing of super hard grinding wheels largely resulted from their specific physical and mechanical properties, i.e. a high hardness of the abrasive and a good strength of the metal bond. Thus, the use of conventional dressing method (e.g. dressing with single – and multi – grain diamond dressers, rotating diamond dressers, grinding with Al_2O_3 or SiC grinding wheels, grinding ‘soft steel’, crush dressing with a hard rollers, etc.) is ineffective and uneconomical [2,4,6,10]. Neither can these difficulties be eliminated by means of unconventional dressing methods, such as jet sharpening or electro contact discharge dressing due to the disadvantages of these methods [2,3,4,10].

The analysis different dressing methods of super hard grinding wheels and the studies carried out at the Lodz University of Technology resulted in the development of electrochemical dressing technology with using alternating current (AC). This method is subsequently marked as the ECD-AC method [4,5]. Thus major advantages of this method are as follows; contactless supply of voltage to the grinding wheel being dressed, cathodic activation of the grinding wheel, lower cost of the power supply, and the possibility of using electrolytes of a low concentration of chemical compounds. These electrolyte solutions are characterized by insignificant noxiousness for the surroundings and the natural environment.

In the electrochemical dressing of superhard grinding wheels (ECD-AC) and the economical aspects of exploitation of super hard grinding wheels with metal bond have been presented. Also relationship which allows for determination of constituent costs of grinding operation using super hard grinding wheels and includes machine costs, grinding costs, dressing costs and wear of grinding wheel has been elaborated.

Basing on investigation results, the exemplary calculations of constituent costs of realized grinding operation of sintered carbides have been presented.

2. Method of electrochemical dressing

Dressing of super hard grinding wheels using ECD-AC method is a heterogeneous anodic process of digestion (solid substance/solution) of metal bond and gumming up products of CSGW. The scheme of dressing of super hard grinding wheels (cup grinding wheels) using ECD-AC method has been presented in Fig. 1, however a scheme a set-up constructed in order to carry out dressing is shown in Fig. 2. This is made up of a grinder, equipment with an additional electrochemical unit and a monitoring-measuring system.

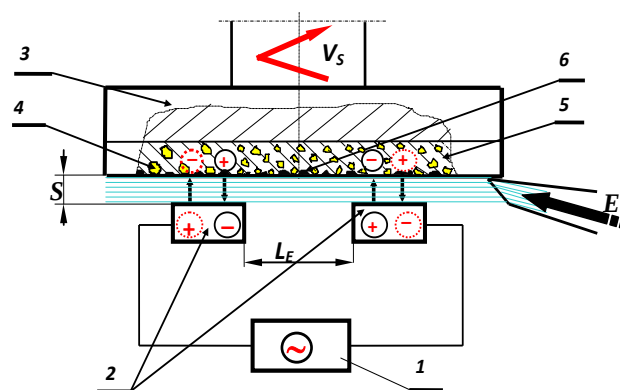


Fig. 1. The scheme of super hard cup grinding wheels dressing using the ECD-AC method: 1 – alternating current power pack, 2 – working electrode, 3 – grinding wheel body, 4 – abrasive, 5 – metal bond, 6 – products of loading in the CSGW.

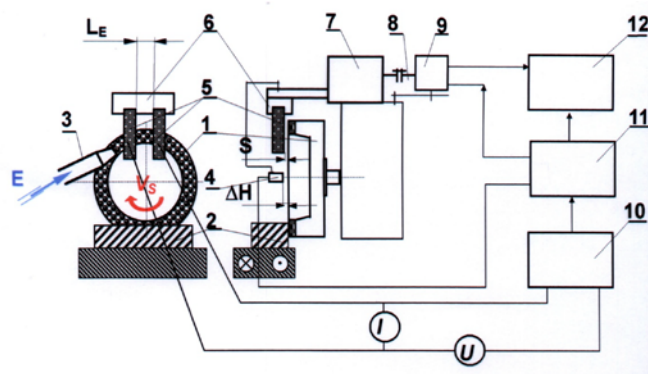


Fig. 2. The scheme of a stand for grinding wheels dressing using the ECD-AC method: 1 – grinding wheel, 2 – workpiece, 3 – electrolyte supplying nozzle, 4 – inductive sensor, 5 – tool-electrode, 6 – electrode holder, 7 – tool-electrode feed unit, 8 – guide-screw, 9 – stepping motor, 10 – AC power unit, 11 – LC generator, 12 – computer, L_E – spacing of electrodes, E – electrolyte solution, S – inter-electrode gap, ΔH – the linear grinding wheel decrement.

The dressing of a grinding wheel (3) consist in the anodic dissolution of a metal bond (5) and products loading the CSGW (6) in the inter – electrode gap (S), to which a electrolyte solution (E) of specially selected chemical compounds is supplied (containing up 5% sodium – potassium salts). An alternating current voltage is supplied to the grinding wheel by two carbon electrodes (2) connected with the power supply (1).

The dressing process consists in the cyclic dissolution of components of the grinding wheel, which alternately acts as anode or a cathode, corresponding to the frequency of changes in alternating current (Fig. 3).

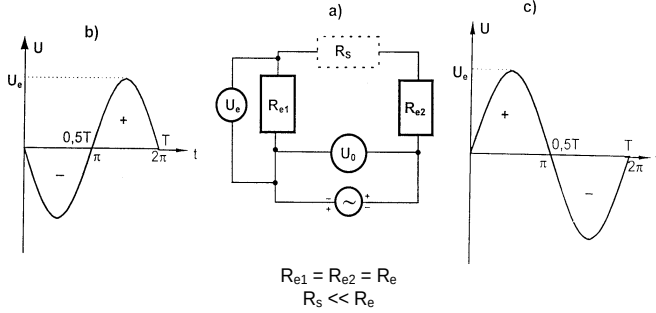


Fig. 3. A diagram of the equivalent electrical circuit of the ECD – AC method (a), and a course of voltage in the grinding wheel (b), and (c), R_e – electric resistance of inter-electrode gap, R_s – electric resistance of grinding wheel.

The anodic digestion of the grinding wheel compounds takes place in periodic of positive polarization of the grinding wheel (when it acts as an anode). In periods of negative polarization of the grinding wheel (when it is a cathode), the digestion of the passive layer (metal oxides and solid salts formed on the CSGW in the anodic process) mainly occurs. The removal of the passive layer from the CSGW is a favorable process, considering an increase in the digestion rate and the efficiency of the dressing process [4,5]. The application of two electrodes allowed an automatic change in the grinding wheel polarity and elimination of breaks in the dressing process in periods of negative polarization of the grinding wheel (Fig. 3b and 3c).

To investigate the process of dressing superhard grinding wheel by the ECD–AC method in the test send (Fig.2). Working voltage application to the grinding wheel (1) subjected to dressing, is executed with two carbon electrodes (5) fixed in an isolated casing (6), and connected to an alternating current supply power unit (10). In order to measure a grinding wheel linear decrement (ΔH), a contactless inductive sensor (4) cooperating with a LC generator (11) was applied. The stabilization of the inter electrode feed, is accomplished with a microcomputer (12), which by means of a stepping motors (9) and a guide screw (8), feed in the set of electrodes to the grinding wheel (1) subjected to dressing. To control the dressing process and to record its basic parameters, the special software.

3. Results and discussion

The investigations results presented concern the assessment of usefulness of the dressing method ECD–AC in shaping of macro- and micro geometry of the CSGW and regeneration of functional qualities of super hard grinding wheels [4,5].

Example investigation results confirming the possibility of the removed layer of the grinding wheel ΔH a face of a grinding wheel S3012 175x6x3x50 D125/100 M100 in the ECD–AC process is shown in Fig. 4. The investigations carried out have also showed the good conformity the theoretical calculations with the experimental investigations.

Economical usage of attractive operational properties of super hard grinding wheels points to necessity of analyze of all constituent costs of grinding operation. Significantly higher costs of super hard grinding wheels comparing to the wheels made of

conventional materials (i.e. with ceramic and resin bond) justify usage of aforementioned analysis.

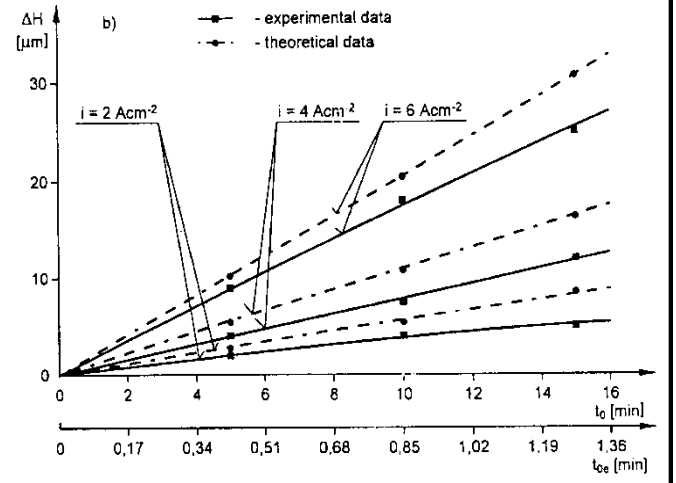


Fig. 4. A comparison of the theoretical calculations and the results of the experimental investigations of the grinding wheel (S3012 175x6x3x50 D 125/100 M100) layer ΔH removed in the ECD–AC dressing process.

Because of this in costs analysis of grinding operation it is necessary to consider: machine-hour cost of grinder – C_m , which amounts during grinding time – $C_{m gr}$ and during dressing time – $C_{m dr}$ and cost of wear of grinding wheel (super hard grinding layer) during grinding operation – $C_{gr m}$ and during electrochemical dressing time – $C_{gr dr}$. Taking into consideration all these costs components it is possible to evaluate total cost of grinding operation – C as the relationship (1):

$$C = C_{m gr} + C_{m dr} + C_{gr m} + C_{gr dr} \quad (1)$$

Entering a period of durability of grinding wheel (economical time) – T_e , time of grinding operation – t_m and time of dressing of grinding wheel – t_{dr} and cost of purchase of new grinding wheel – C_{gr} , respective costs components have been assessed as:

$$C_{m gr} = C_m t_m \quad (2)$$

$$C_{m dr} = C_m t_{dr} \quad (3)$$

$$C_{gr m} + C_{gr dr} = C_{gr} \frac{t_m}{T_e} \left(\frac{\Delta V_{gr} + \Delta V_{dr}}{\Delta V} \right) \quad (4)$$

where: ΔV_{gr} – wear volume of abrasive layer of grinding wheel during grinding process, ΔV_{dr} – wear volume of removed abrasive layer during ECD–AC dressing, which is calculated basing on dimension of abrasive layer.

Adding to formula (1) relationships (2-4) we obtain relationship (5):

$$C = C_m t_m + C_m \frac{t_m}{T_e} t_{dr} + C_{gr} \frac{t_m}{T_e} \frac{(\Delta V_{gr} + \Delta V_{dr})}{\Delta V} \quad (5)$$

Dividing both side of equation (5) by t_m we obtain relationships of unit cost grinding operation by super hard grinding wheel:

$$C' = C_m + \frac{C_m t_{dr}}{T_e} + C_{gr} \frac{\Delta V_{gr} + \Delta V_{dr}}{T_e \Delta V} \quad (6)$$

Basing on elaborated relationships the total calculations of cost of grinding operation and dressing and percentage share of components of constituent costs have been done. Calculation results concern grinding operation of sintered carbides using super hard grinding wheel: S3012 170x6x3x50 D125/100 M100 and dressing operation using ECD–AC method.

In calculations the values obtained in following investigation conditions: grinding time $t_m = T_e = 160 \text{ min}$, dressing time $t_{dr} = 12 \text{ min}$, wear volume of abrasive layer during grinding process $\Delta V_m = 401 \text{ mm}^3$, wear volume of removed abrasive layer during dressing process $\Delta V_{dr} = 50 \text{ mm}^3$, total volume of surface layer of the new grinding wheel $V = 9269 \text{ mm}^3$ and cost of the

new grinding wheel $C_{gr} = 422 \text{ Euro}$ and machine-hour cost of grinder $C_m = 20 \text{ Euro/h}$ have been considered.

Calculation results have been presented in Fig. 5-6. Analysis of obtained results points at significant share of unitary costs of dressing (about 5%) and costs of grinding wheel (25%) in total cost of grinding process using super hard grinding wheels

In grinding processes using grinding wheels with conventional abrasives, components of these costs do not exceed 3-5%, and are usually negligible. This fact justifies purpose of economical analysis of dressing of super hard grinding wheels and purpose of its optimization.

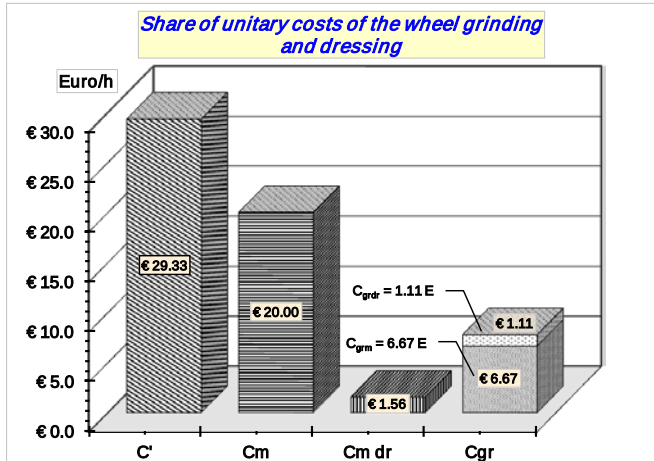


Fig. 5. Share of unitary costs of the grinding and dressing operation.

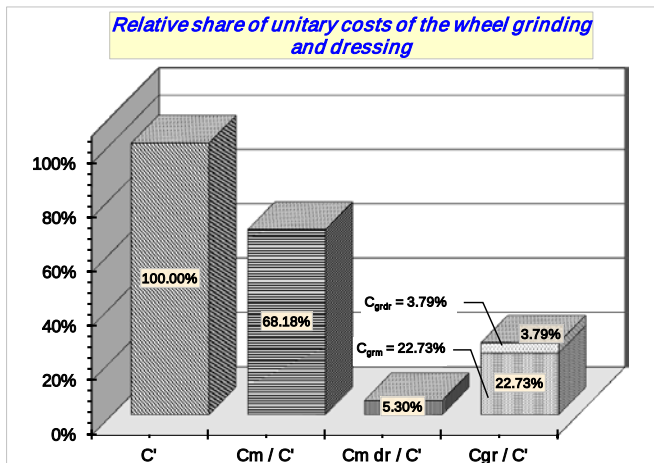


Fig. 6. Percentage share of unitary costs of grinding and dressing operation.

4. Conclusion

The effective method ECD-AC of dressing of super hard grinding wheels has been presented. This method consists of the anodic dissolution of the grinding wheel components (the metal bond and products loading on the CSGW), using alternating current in presence of low concentration of electrolytes.

The investigations carried out confirmed the usefulness of the ECD-AC method for forming the functional qualities of super hard grinding wheels. The investigations have confirmed that ECD-AC dressing method can be recommended for dressing of super hard grinding wheel. The implementation of ECD-AC method requires equipping the grinding machine with a cheap and a simple electrochemical unit.

Rational usage of operational properties of super hard grinding wheels with metal bond justifies purpose of performing economical analysis of costs of grinding and dressing.

Confirmation of this fact are obtained investigation results, which point at significant share of unitary ECD-AC dressing costs (about 5%) and cost of grinding wheel resulted from remove of

surface layer in this process (about 3%) in total unitary costs of grinding operation

It should be emphasized that in grinding processes using ceramic grinding wheels total cost of dressing and wear of grinding wheel do not exceed 3% and is usually negligible.

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KINETICS PRIMARY HYDROGENATION OF COAL TAR IN THE PRESENCE OF PSEUDO-HOMOGENEOUS IRON CATALYSTS

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Study of kinetic regularities destructive hydrogenation of primary coal tar (PKT) in the presence of pseudo-homogeneous iron catalysts (PHIC) is essential in the development of new, highly efficient hydrogenation processes, determine the optimal technical and economic conditions of the process, depending on the composition of the feedstock, the creation of new types of equipment and selection constructional materials [1-3].

The aim is to establish the kinetic parameters of the thermal degradation of the organic mass of primary coal tar (PKC) in the presence of pseudo-homogeneous iron catalysts (PGZHK).

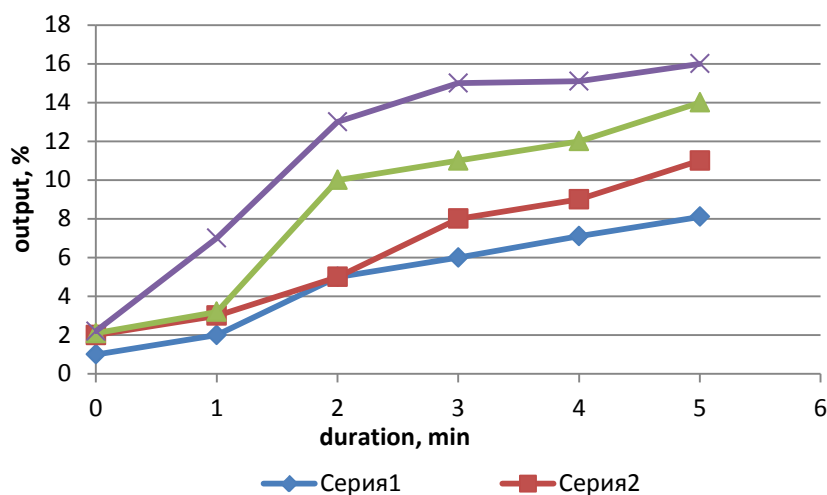
Experimental part

Kinetic parameters of the primary hydrogenation of coal tar was carried out under autoclave conditions. Volume 0.05 liter autoclave previously was purged with hydrogen to remove air from

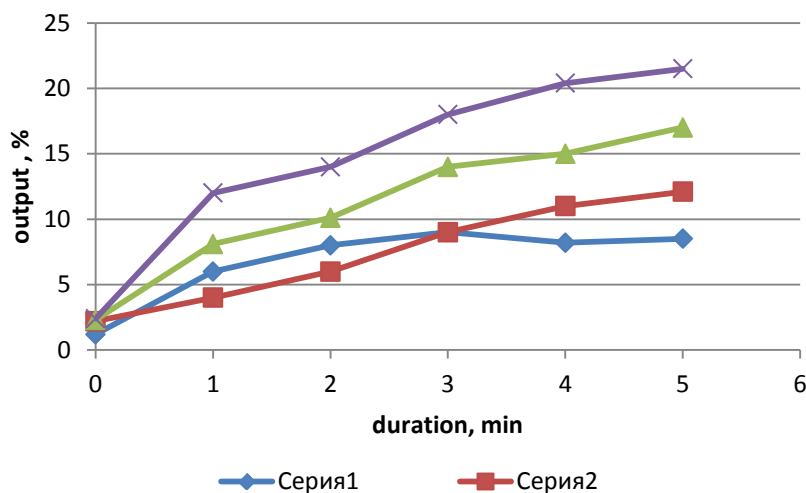
the autoclave, the initial hydrogen pressure was 2.0 MPa, the amount of added pseudo-homogeneous iron catalyst to organic primary weight coal tar was a 10% solution of ferrous sulfate and nickel.

Results and discussion

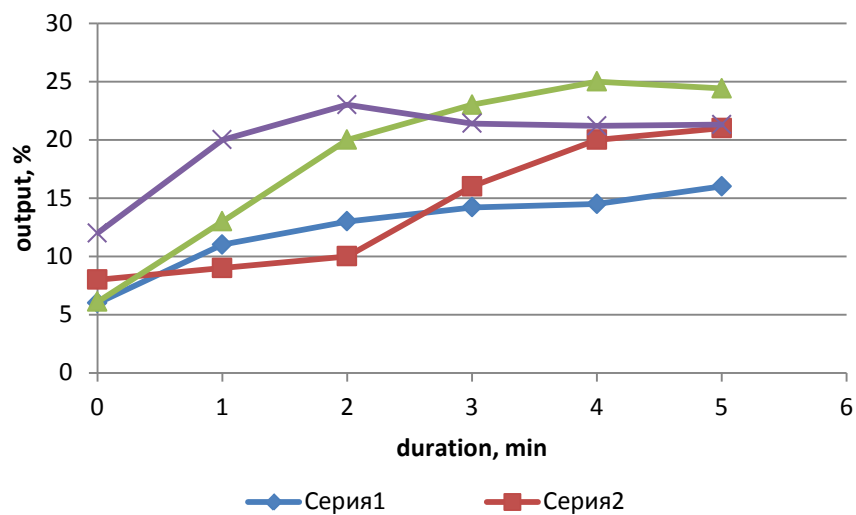
Figure 1 (a - d) shows the dependence of the output fractions hydrogenation process of PKT in the presence of PHIC, from which it follows that an increase in temperature and increase in contact time increases the output fraction to 453 K (Figure 1 a) in the temperature range 673 - 723 K 2 to 16%, as output fractions 453 - 503 K with 2 to 21% (Figure 1b). The maximum yield of the fraction 453 - 543 K is 25% (treatment time 4 min. at 707 K) (Figure 1). Output fractions 543 - 573 K with increasing duration of treatment time decreases monotonically.



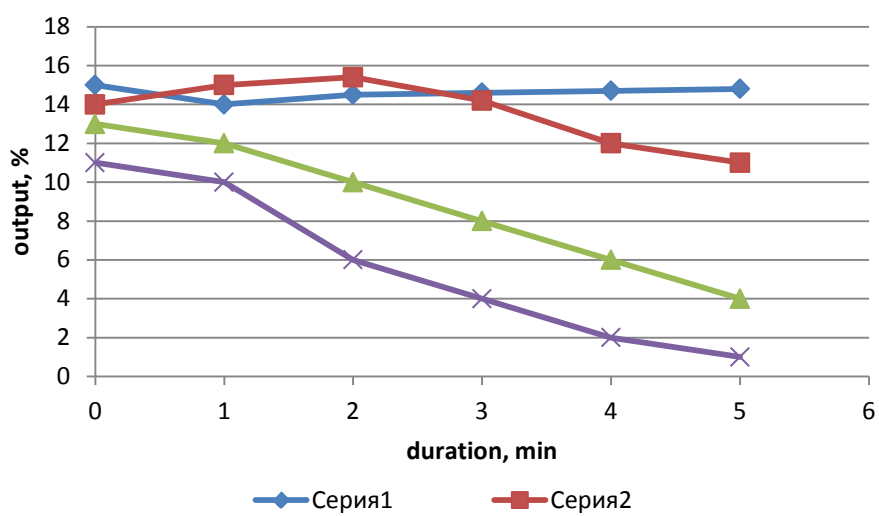
a)



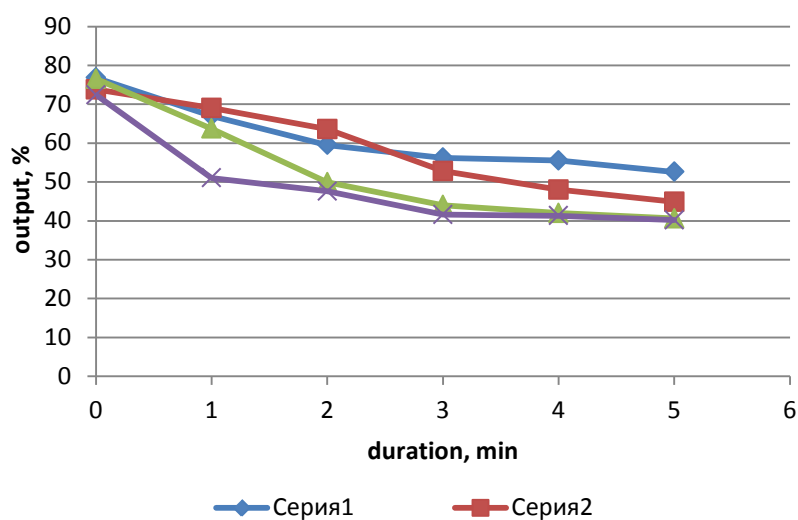
б)



в)



г)



д)

Figure 1. The dependence of the output fractions:

а) fraction to 453 K; б) 453 – 503 K; в) 453 – 543 K; г) 543 – 573 K;
 д) above 573 K of PKC on the duration and temperature of hydrogenation treatment in the presence PH IK

where

- series 1 – processing temperature 673 K ;
- series 2 – processing temperature 690 K;
- series 3 – processing temperature 707 K;
- series 4 – processing temperature 723 K.

Under conditions of catalytic hydrogenation PKT high degree converting is provided it into light and middle fractions by high activity PHIK, particle size of 0.01 - 0.1 microns. Moreover, from the References [4] that hydrocarbons (such as PKS) have conjugated bonds are complexing agents with respect to transition metals. In [5], the authors found that clusters of nickel and iron with naphthalene (one of the model compounds form the basis of the PKT) to form the intermediate π -complexes, it is possible that in our case takes the selective hydrogenation of the hydrogen atom of one

ring of naphthalene takes place. Subsequently, the resulting π -complex is decomposed and forms a hydrogen donor - tetralin which further participates in the hydrogenation reaction, a high molecular weight part of PKT, thereby increasing the conversion yield of PKT and output of middle and light fractions.

Given the literature data on the kinetics of the hydrogenation of coal, heavy oil residue and semicarbonization tar, the following scheme of the route PKC catalytic hydrogenation is offered. (Figure 2) [6]:

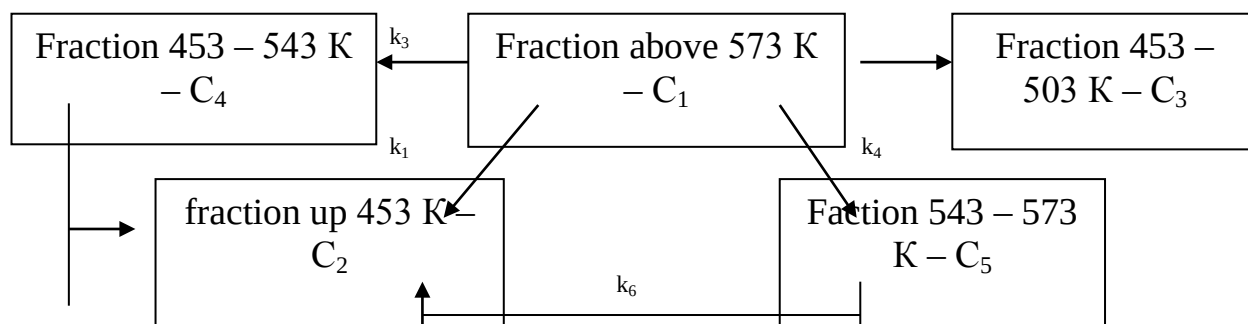


Figure 2. The kinetic scheme of transformation of the organic mass of the PKT in various fractions

Under the proposed scheme, the process can be described by the following system of differential equations (1):

$$\left. \begin{aligned} \frac{dC_1}{d\tau} &= -(k_1 + k_2 + k_3 + k_4) C_1 \\ \frac{dC_2}{d\tau} &= k_1 C_1 + k_5 C_4 + k_6 C_5 \\ \frac{dC_3}{d\tau} &= k_2 C_1 \\ \frac{dC_4}{d\tau} &= k_3 C_1 - k_5 C_4 \\ \frac{dC_5}{d\tau} &= k_4 C_1 - k_6 C_5 \end{aligned} \right\} \quad (1)$$

Where:

- $[C_i]$ – mass part of fractions at time τ ;
- $[C_1]$ fraction above 573 K; $[C_2]$ – fraction to 453 K,
- $[C_3]$ – fraction 453 – 503 K; $[C_4]$ – fraction 453 – 543 K;
- $[C_5]$ – fraction 543 – 573 K. $[C_i] = 1$;
- k_i – rate constant of hydrogenation, min^{-1} ;
- k_1 – the rate constant for the conversion of fractions до 453 K;
- k_2 – the rate constant for conversion 453 – 503 K;
- k_3 – the rate constant for the conversion of the fraction of PKT 453 – 543 K;
- k_4 – the rate constant for the conversion of the fraction of PKT 543 – 573 K;
- k_5 – the rate constant for the conversion of fractions 453 – 543 K in the fraction to 453 K;
- k_6 – the rate constant for the conversion of fractions 543 – 573 K in the fraction to 453 K.

The calculation of the system of equations (1) was carried out using a special program called "Search". The program developed for the calculation of the rate constants allows the calculation of the kinetic dependence for given initial conditions and to conduct automated selection of optimal gradient method of rate constants k_1 - k_6 . Optimization of the rate constants was carried out by minimizing the squared deviations between the experimental and calculated values of the mass fractions of hydrogenation products of PKT.

As a result of the calculation system of differential equations (1) a satisfactory agreement between the experimental data and the calculated values of these fractions is given. The calculated rate constants are shown in Table 1, which shows that the rate-limiting catalytic hydrogenation of PKT is the step of converting fractions above 573 K in the fraction of 543 - 573 K, and the fractions 543 - 573 K in the fraction to 453 K (k_4 and k_6).

Table 1. The calculated rate constant and the activation energy of catalytic hydrogenation of PKT in the presence of PHIK

T, K	$k_1 \cdot 10^{-3}, \text{min}^{-1}$	$k_2 \cdot 10^{-3}, \text{min}^{-1}$	$k_3 \cdot 10^{-3}, \text{min}^{-1}$	$k_4 \cdot 10^{-4}, \text{min}^{-1}$	$k_5 \cdot 10^{-4}, \text{min}^{-1}$	$k_6 \cdot 10^{-3}, \text{min}^{-1}$
673	0,36967	2,1333	1,3508	1,0783	2,7367	0,25017
690	1,2715	4,8733	2,5183	2,8950	7,2667	0,23568
707	7,9033	13,936	5,42	3,8067	15,005	2,1833
723	22,395	35,763	11,763	7,1917	33,350	5,965
E, kJ / mol	132,1	88,34	66,1	54,9	77,95	93,6
R	0,9952	0,9983	0,9976	0,9783	0,9988	0,9965

The values of activation energy were obtained by fitting the Arrhenius equation described by a linear function $\ln k = f(1/T)$ (Figure 2 a, b).

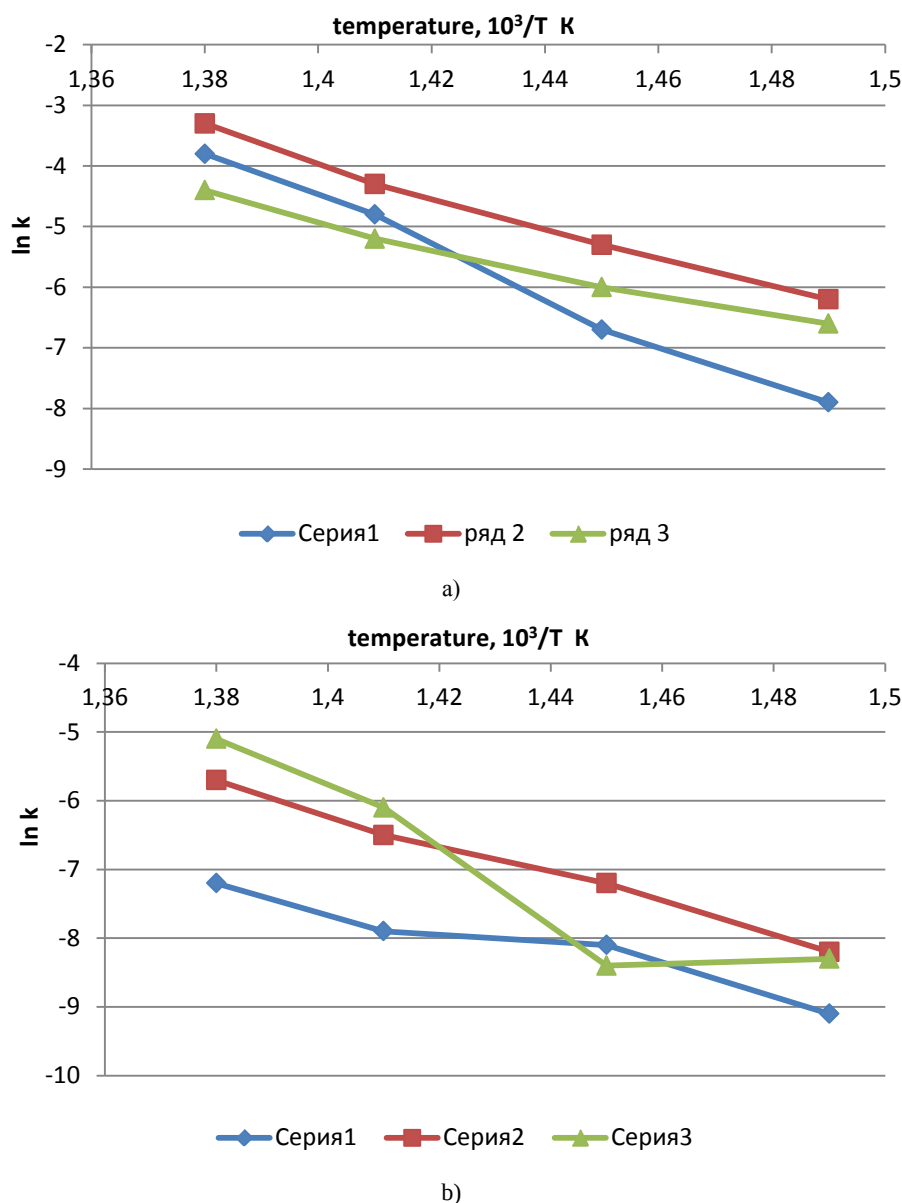


Figure 2. The dependence of the rate constant for the hydrogenation process of PKT from the return temperature : a) series 1 – rate k_1 ; series 2 – k_2 ; series 3 – k_3 ; б) series 1 – rate constant k_4 ; series 2 – k_5 ; series 3 – k_6

The apparent activation energy for the conversion process to the PCT in light and medium fraction is increased from 54.9 to 132.1 kJ / mol. The value of the apparent activation energy of the total transformation of the fraction above 573 K in the light and medium fraction is 54.9; 66.1; 77.95; 88.34 and 93.6 kJ / mol (see Table 1), which is characteristic of heterogeneous catalytic process, and the activation energy with the value of 132.1 kJ / mol - stage transformation fraction above 573 K to 453 K fraction corresponds to the diffusion region.

Thus, in a hydrogenating treatment of PKC in the presence PGZHK in the temperature range 673 - 723 K constants of rate of formation of fractions up to 453 K, 453 - 503 K, 453 - 543 K and 543 - 573 K, activation energy is calculated, and it is found that PHIK accelerates the degradation reactions and hydrogenation.

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COMPARATIVE ANALYSIS OF MODELS DSAT-16 AND MOTP_VTU TO CALCULATE THE PROPERTIES OF THE LAYER IN THE WELDING AREA

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Abstract: The paper presents the characteristics of a modern software system for modeling and optimization of technological processes MOTP_VTU. It outlines the possibilities also to use the system at the design stage. A comparative analysis is performed of three characteristics to apply the new software system MOTP_VTU related to a similar existing one – DSAT-16. via similar systems it is possible to expand the basis of constructions and of functional materials in low technological level during exploration of the set of properties of these materials. This process of realization of scientific and technical ideas is a process to search via multi criteria support of decision making between the project task and the actual possibility, determined by the chemical composition and the processing-mode parameters.

Keywords: DSS, MCDM, MODELING, OPTIMIZATION, TECHNOLOGICAL PROCESSES

1. Introduction

The realization of technical solutions via *Informatics Science & Materials Science* is among prioritized scientific elaborations marked by the absence or a limitation of the possibilities of constructive and functional materials and also by an insufficient technological level in the research of the set of properties of these materials. This process of realization of scientific and technical ideas is a process to search a reasonable compromise between the required in the project and the possible reality; it is proved by the rapid development of these two branches of science and the adjacent industries after the convergence of *Informatics Science & Materials Science*. In this regard, modeling and optimization may be treated as methods of knowledge from the real life, forming the so called information society linked to the intelligent core of rapidly developing technologies [Samarsky, A. A., A. P. Mikhailov] [1].

Modern computer systems allow to create (to collect) huge data arrays to solve problems of processing, analysis and optimization algorithms of data related to materials. In this regard, the improvement of similar approaches, methods and software tools are directly connected to the improvement of the explored technologies via the obtained technological solutions with specific benefits for the materials for aerospace engineering up to biomaterials that save lives

2. Aim and Specifics of the Proposed research

The present research is goal-oriented at a comparative analysis between the already present computational system DSAT-16 and the new one MOTP_VTU created in the University of Transport “T. Kableshekov” [2] and on this basis to identify the possibilities provided to their users.

The stage of preparation of the numeric solution includes the elaboration of the algorithm and also of a software/system for the direct determination of the solutions. The solutions of models with increased numbers of parameters are always of a multivariate nature. The research of various numeric methods can significantly supplement the results from the analytical research; for lots of models this turns out to be the only realizable solution. The analysis of the numeric results and their usage are related to the adequacy of the models. The mathematical methods for testing/verification can determine if a model is built incorrectly and also they can determine the class of potentially robust models.

All this comprises elements of the system to support the decision making in the domain of analysis and multi criteria optimization of different selected indicators for control, and the optimization of quality parameters of metal-processing technologies.

A validated algorithm is applied. It is associated with the following two classes of problems:

- Informative with a predefined threshold;
- Operative – analytical.

The system (the software) allows work with a data base with full information for the decision maker about the analysis of the investigated multi parameter space and also the effective solutions for a series of quality indicators in this multidimensional research area. The data base itself is a set of tables that store the data grouped as rows and columns. Part of the data in the rows represent various combinations of the technological parameters that together with other data from the row determine the relation of this combination with the research quality parameters.

The main part for the final decision is quantitative information (as a level of detail and as a degree of reliability) formed at the stage of experimental testing and processing. There is a need to increase the accuracy of such calculations compared to already existing ones. They must provide a reasonable choice of alternatives at the initial stages of the design and the formulation of quantitative data of the criteria (mechanical properties or other indicators) for structural and parametric optimization.

3. The main idea of the proposed software in the field of metallurgy

At the design stage, the process of selection or synthesis of properties of compositions and processing materials gives the sense of the most important field of materials science. Solving problems regarding the relation “structure-properties” is always associated with resolving the contradictions that formulate the complex /set/ by certain characteristics. A good example in this regard is the production of alloys that overcome the contradiction between “strength and plasticity elongation”. Deciding such contradiction, as an innovation in the field of steels there have been created TRIP-steels, which in addition to high strength, possess higher plasticity, e.g. more than 6-10% and also more than the ones compared to Mart-steels. The traditional strategy for development of alloys consists of producing numerous samples of varying composition, and variations of elements and mode of treatment for a particular alloy with optimal properties. This approach leads to high costs for experimentation.

That is why within the group of methods for directed search, the “trial and error” method is the least preferred and it stands lowest in the hierarchy of methods.

An alternative and effective approach is to use data from previous experience, processed up to a statistical model, based on a

large amount of data related by composition, processing and properties.

The design of the alloy composition and the optimization of the technological-process parameters are directly related to the resolution of the compromise between the measured values related to certain selected indicators of the quality of a set of materials for a test group or a class [1]. The most characteristic for these approaches is that they do not use the principles of metallurgy and metal physics. It is relied mainly only on an a priori information about the relation "composition and processing and their influence on the properties". Compared with physical models, the advantage of statistical models is their ability to explore a complex of properties and to obtain information in a timely and effective manner, even when there are no well-established physical theories and models. These approaches are created for ease of the DM. After determining the composition such that they meet the formulated requirements, an expert and experimental verifications carried out.

Metallurgical design is not only the design on a base with alloying elements by type, number and amount of the elements, but it includes taking into account also their synergistic effect. It is necessary to select such a synergistic effect by the combination of elements in which the more expensive elements must be in lesser amounts.

Along with the execution of this task, the metallurgical design must meet also the sought compromise between the properties of the product, depending on the processing parameters. These several groups of parameters should form the general parameters of the metallurgical design. The complexity of the so defined problem consists in the large number of input parameters, and the fact that the chemical composition is involved implicitly by the synergistic effect in the system "composition-structure-processing-properties-price". Multicriteria genetic algorithms (MCGA) have proven to be effective in finding Pareto-optimal solutions of multicriteria optimization problems.

There are many MCGA capable of approximating Pareto - fronts with a set of points. One of the biggest difficulties in implementing MCGA to solve the described problem is the large amount of calculations of the computing functions of the criteria, because the order is several thousand. Reducing the number of these calculations is an important issue. Finding good approximation methods is particularly difficult due to the number of criteria and the possible interactions between them. The goal of this study is to propose an approach by which to determine optimal compositions corresponding to the precisely specified properties, a priori defined by the user, in accordance with the system "composition-structure-processing-properties-price."

The main goal of the research is to apply the approach to a specific task.

In this work a solution is proposed, based on the use of software model with applied techniques from the field of multi-criteria analysis and optimization, and the establishment of regressions between the mechanical properties of the alloy and its chemical composition based on neural models.[4]

4. Mathematical Model MOTP_VTU

General Characteristics of the Model

Data processing for an experiment begins with its formation into a table (matrix). The result from experiment "Y" we call output data (*data functions*). The values of "Y" depend on a series of other values "X" which we shall call input data (*factors*). These names are specified because the programs contain questions and guidelines for them. Every matrix is characterized by its number of rows and by its number of columns. It is accepted in the elaborated software that the number of factors cannot exceed 10 and that the output values cannot exceed 200, but there are no constraints like the ones for the number of factors. The matrix must be refined at messages for

shortage of memory ("out of memory") for the problem to find the model coefficients.

For example, the case with 5 numbers "X" and 3 numbers "Y" needs the following form of matrix formulation: $X_1, X_2, X_3, X_4, X_5, Y_1, Y_2, Y_3$. We begin with the factors and we end with the outputs.

We remember the meaning of every "X" and "Y". The so formed matrix is used for a further processing and search of solutions.

Data Input

Data input is the next stage of processing the results from the experiment. The input must be performed in rows, starting from the first and ending with the last line. There will be questions about the number of the rows, the number of the factors and the number of the outputs. The sum of the number of the factors and the number of the outputs determines the number of the columns in the matrix.

Programming language BASIC used for the realization of the algorithms operates with numbers with seven significant digits but it allows use also numbers with sixteen significant digits (*double precision*). There will be a question about this detail. This is particularly important for processing huge matrices. In our case of limitations this means a matrix with big number of rows. Numbers with up to seven significant digits (*single precision*) require half of the memory. The data input may be aborted at any time followed by an exit from the program for data input. At the end of the input there is a possibility to correct the detected errors. The matrix obtained in this way is saved as a .DAT file with a specific name.

After the end of the input a primary analysis is provided. At this stage, for every column there will be determined the estimates of the mathematical mean, the variance, the minimal and maximal values. These estimates are also saved and they are used later.

Processing and Internal Links

The further processing of entries may continue to search for linear and non-linear relationships between them. It allows each column of the matrix to be presented as a function of another column in the form:

$$(1) \quad Y = A_1 + A_2 \cdot X \text{ to } Y = A_1 + A_2 \cdot X + A_3 \cdot X^2 + \dots + A_{11} \cdot X^{10}$$

It is possible in this way to establish relations for every column, regardless of the "X" or "Y" with other columns and to draw respective conclusions for further processing.

To relieve the further work there have been elaborated two programs for interpolation: Newton interpolation with unequally spaced nodes, and Eitken interpolation with up to 6 nodes. They can be used to obtain missing table values.

Forming a Mathematical Model

As it has been already said, the number of factors is limited to 10. For every specific case from 2 to 10 factors, there have been elaborated separate programs, because in the case with 2 factors in the mathematical model there are 6 coefficients, in the case with 3 factors they are already 10 coefficients and for 10 factors they are 66 coefficients.

For example for the case with 4 factors the mathematical model has the form:

$$(2) \quad Y = A_1 + A_2 \cdot X_1 + A_3 \cdot X_2 + A_4 \cdot X_3 + A_5 \cdot X_4 + A_6 \cdot X_1 \cdot X_2 + A_7 \cdot X_1 \cdot X_3 + A_8 \cdot X_1 \cdot X_4 + A_9 \cdot X_2 \cdot X_3 + A_{10} \cdot X_2 \cdot X_4 + A_{11} \cdot X_3 \cdot X_4 + A_{12} \cdot X_1^2 + A_{13} \cdot X_2^2 + A_{14} \cdot X_3^2 + A_{15} \cdot X_4^2.$$

This is the complete and best operating model of mathematical form. After finding the coefficients, the program shows the results from the statistical estimate of the model and the estimate for its ability to predict.

Digital Optimization

In the case with a positive assessment of the adequacy of the mathematical model to predict, there can be sought a desired extremum – min or max.

This problem is solved with 3 programs for digital optimization:

1. Method of Hook and Dzhivs – the configuration method (for up to 10 factors);
2. Method of Nelver and Mid – the deformable-polyhedron method (for up to 6 factors);
3. The method of golden section to find an extremum of functions of a single variable.

The extremum is sought calculating the function value without using derivatives. The optimization is performed within the factor constraints. It is possible to find the extremum with these 3 programs for each case determined by the number of factors. Within the organization of the calculations every program “calls” internally the model coefficients, then it “asks” for min and max factor values and other necessary values.

Taguchi Assessments

The calculation of Taguchi assessments starts with calculating matrix (27.*) where “*” is the number of rows of the input matrix. This is done by the first program of the two programs. The calculated matrix is saved in a file. Though that the effect from Taguchi estimates is manifested for greater number of factors, this program is designed for versions from 2 up to 10 factors. The second program calculates Taguchi estimates from the already calculated (27.*) matrix.

Entering the Coefficients of a Model and Calculation of the Model

In cases with multi criteria problems, it is necessary to calculate a function based on the results from the extremum of another problem. This program makes it possible to enter the coefficients of the mathematical model and the values to calculate with. The program is elaborated in the version from 2 to 10 factors.

Sorting in Ascending Order

It is possible to sort a set of values with this program. Sorting is performed in ascending order: after the sorting is over, then the first value is the smallest, and the last value is the greatest one.

5. Analysis of the results obtained via the two software systems for a concrete example in the domain of welding

This analysis was necessary after the originally formulated problem to find the extremum of obtained mathematical models from DSAT for HRC, the “carbon equivalent and cost” for weld metal. The obtained mathematical models are of second degree with interactions on four factors: X_1 – carbon, X_2 – silicon, X_3 – chromium, X_4 – tungsten. The mathematical models can predict.

When the results were obtained then it was decided that this problem must be solved again with new mathematical models and programs developed in the University of Transport (see pt.4). The statistical analysis of the models shows the following properties:

DSAT Model

HRC	Carbon Equivalent	Cost
R = 0,6635	R = 0,9990	R = 0,9298
F = 2,3032	F = 1456,21	F = 18,6973

MOTP_VTU Model

HRC	Carbon Equivalent	Cost
R = 0,7828	R = 1.0	R = 0,9213
F = 4,6327	F = 14,771 E+11	F = 18,6973

In the cases with mathematical models for carbon equivalent and cost, both programs give approximately the same result, because they are analytically calculated values and there is no randomness.

The results from both models are very good: the coefficient of multiple correlation R is near to 1.

As noted, the mathematical models are able to predict, because the calculated value of Fisher criterion is greater than the value in the table for the case of F with (0,05, 14,41) = 1.9465.

This is not so for HRC. The VTU model has a greater coefficient of multiple correlation $R = 0,7828$ related to $R = 0,6635$ for the model DSAT. This difference is not small; it shows that the VTU model gives a better approximation to the experimental data.

The desired extrema of the mathematical models are: for HRC – maximum, for carbon equivalent and cost – minimum. The extrema are sought with the method of Hook and Dzhivs; in all cases the starting point is: $X_1 = 1$, $X_2 = 1$, $X_3 = 1$, $X_4 = 1$.

Results

HRC (max)

DSAT Models	MOTP_VTU Models
Ye = 11338,05	Ye = 11638,74
$X_1 = 3,5$	$X_1 = 2,0$
$X_2 = 4,0$	$X_2 = 4,0$
$X_3 = 0$	$X_3 = 6,15$
$X_4 = 8,1$	$X_4 = 9,5$

The MOTP_VTU model gives a little bit greater value for the obtained extremum.

Carbon equivalent (min)

DSAT Models	MOTP_VTU Models
Ye = 3,59	Ye = 8,00
$X_1 = 8,00$	$X_1 = 0,00$
$X_2 = 0,00$	$X_2 = 0,00$
$X_3 = 0,00$	$X_3 = 0,00$
$X_4 = 0,00$	$X_4 = 8,00$

In this case, the model DSAT gives a smaller value.

Cost (min)

DSAT Models	MOTP_VTU Models
Ye = - 42434,89	Ye = 5,71
$X_1 = 8,00$	$X_1 = 0,08$
$X_2 = 4,00$	$X_2 = 1,83$
$X_3 = 30,00$	$X_3 = 0,00$
$X_4 = 9,50$	$X_4 = 3,31$

In this case, DSAT gives as an extremum a negative number which is unacceptable as value whilst MOTP_VTU gives an acceptable value.

The second problem was to formulate HRC, the carbon equivalent and the cost as one-dimensional functions of the given X_1 , X_2 , X_3 , X_4 . This was achieved building mathematical models from 2nd to 10th degrees. Then a statistical analysis was performed and the best choice was related to R , the coefficient multiple correlation [3].

- Model HRC – the best performance is with variable X_3 with a polynomial of 8th degree, $R = 0,8406$.
- The carbon equivalent model – the best performance is with a variable X_1 with a polynomial of 4th degree, $R = 0,9847$.
- The cost model – the best performance is with a variable X_4 with a polynomial of 9th degree, $R = 0,8606$

The obtained results show that HRC, the carbon equivalent and the cost of weld metal may be represented as single-factor models; in them the better models are in the beginning, taking into account the simultaneous influence of 4 factors.

6. Conclusion

The realization of specific technical solutions with modern tools expands the possibilities at the design stage.

This was demonstrated by the comparative analysis of three characteristics during the application of the new software system MOTP_VTU.

It is possible to expand the basis of constructs and the functional materials for a low technological level of research for the set of properties of these materials.

This process of realization of scientific and technical ideas is a process to search a reasonable compromise between the design goal and the possible reality.

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CARBONACEOUS – SILICEOUS SHALES AS A RAW MATERIAL SOURCE FOR RECEIVING OF VANADIUM XEROGEL

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Abstract: The paper presents the results of the synthesis of the xerogel of vanadium in the interaction of vanadium pentoxide and ammonium. It is shown that as a source of vanadium pentoxide can be used successfully vanadium carbonaceous - siliceous shales. Using obtained vanadate ammonium in receiving technology of vanadium xerogel is more cost effective process than the use for this purpose the chemical reagent. Integrated use of this unique raw material is a critical component of modern waste-free and environmentally friendly technologies to highlight not only the connection of valuable components, but also the raw material for the production of vanadium xerogels. Synthesized by sol-gel method based on vanadium oxide xerogels with partially ordered highly layered structures already are widely used in various fields of science and technology due to their unique properties. Scope xerogels vanadium: production photocatalysts, composites, membranes and ion exchange materials.

Keywords: siliceous shales, vanadium pentoxide, sol-gel method, xerogel, nanomaterials.

1. Introduction

Vanadium compounds are of great interest in terms of their use in processes for the preparation of anisotropic morphologies. [1] So-precipitated vanadium pentoxide in the presence of the template in the synthesis of compounds with highly complex structure, on which is formed a xerogel metal.

In practiced technology, vanadium pentoxide and its compounds which is raw material basis for the synthesis of the xerogel is derived from ammonium vanadate by its drying and calcination.

The source of ammonium vanadate in the Republic of Kazakhstan can serve as a carbon-siliceous shales Big Karatau deposit with reserves of hundreds of millions of tons of [2-3].

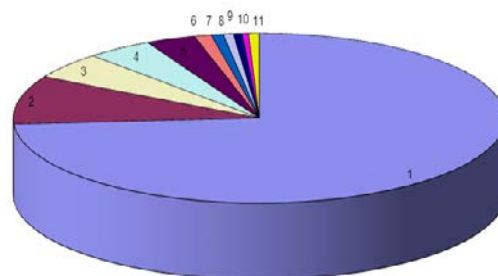
Organization of processing of uranium-bearing shale will not only comprehensively used in the mineral extraction along with uranium and vanadium, but also to solve environmental problems, as the vanadium compounds are relatively toxic reagents. Furthermore, the use of ammonium vanadate obtained xerogel vanadium technology will be more economical process than the use for this purpose the chemical reagent of the compound.

The elemental composition of the useful components shale besides uranium and vanadium are listed in Table 1.

Table 1: The elemental composition of carbon-siliceous shales Karatau

Components	Contents, %	mineralogical consist	Structure
Si	47,00	SiO ₂	Amorphous
C	10,06	carbon	Amorphous
O	35,00	—	—
V	0,60	VO ₂	Cubic
U	0,03	UO ₂	Cubic
Mo	0,02	CaMoO ₄	Orthorombic
REE	0,10	REE	Sphere

The ratio of the basic components of oil shale is shown in Figure 1.



1 – SiO₂; 2 – C; 3 – Fe₂O₃; 4 – Al₂O₃; 5 – CaO; 6 – V₂O₅; 7 – BaO; 8 – P₂O₅; 9 – MgO; 10 – MnO; 11 – other

Fig. 1 The ratio of the basic components of oil shale

Integrated use of this unique raw material is a critical component of modern waste-free and environmentally friendly technologies to highlight not only the connection of the components but also the raw material for the production of vanadium xerogel, which represents the prospect of using both scientific and practical interest.

In the development process for the synthesis of the xerogel vanadium as the starting vanadium compound, ammonium metavanadate was selected, resulting in the processing of oil shale Greater Tau. The source was ammonium metavanadate crystallization process. After the crystallization process X-ray analysis has shown [4] that it contains 99,6% NH₄VO₃.

Further, to obtain vanadium pentoxide as a raw material for the synthesis of the xerogel vanadium we used the ammonium metavanadate, highlighted earlier. X-ray analysis of the source of vanadium pentoxide, which is prepared from the vanadium solution has shown [5-6] that it comprises 98% V₂O₅ and 2% oxide of tetravalent vanadium VO₂.

It is found that the analyte vanadium compound substance has a pronounced crystalline structure.

It is known that most of the nanomaterials may be regarded as nanostructured materials having a hierarchical structure, and polyfunctional [7]. As noted above, the strategic direction of the preparation of such materials is the use of the principles of self-organization and self-assembly, allowing to achieve fast and efficient form of nanomaterials. The key to this approach is the use of different templates - intermediate controlling interaction at some level, and contributing to structural elements of a complex system in a certain way to self-organize.

2. Experimental procedure

In this paper, in order to synthesize a vanadium-containing gel as a template was used ammonia, which is participating in the formation of ammonia complex with vanadium-oxygen framework [8], contributes to the formation of developed structure of the nanomaterial.

Since the new generation of advanced structural morphology conducted under the entire contact surface of the components to occur at the atomic level, the addition of vanadium dissolved in the template should be carried out under intensive mechanical activation (at least 600 rev / min). 30% ammonia was added to the vanadium-containing solution according to 0.2-0.4 ml of a solution at a temperature of $\pm 22^\circ \text{C}$.

Every 10 minutes the pH was measured and an aliquot of the test solution to determine the concentration of vanadium. When calculating the concentration of vanadium into account the dilution of the solution when introduced into a template.

3. Results and discussion

The results of the experiments are given in Table 2.

Upon reaching pH 3.4 the solution slowly begins to thicken with the image-vanem sol vanadium compound with ammonia, rolling in the gel.

Cintezirovanny gel vanadium compounds should have the spatial development structure with a vanadium-oxygen framework [9].

Table 2: Results of experiments on the synthesis gel based ammonia complex of vanadium

τ , min	VNH_3 , ml	pH solution	Cv_2O_5 , g/l
10	0,2	2,13	25,4
20	0,2	2,42	23,1
30	0,2	2,79	21,9
40	0,3	2,96	20,3
50	0,3	3,08	19,99
60	0,4	3,28	19,43
70	0,4	3,4	19,32
80	0,4	3,92	19,29

Controlling the gelling process we carried out by visual observation of external changes in the vanadium-containing solution in stages (Figure 2).

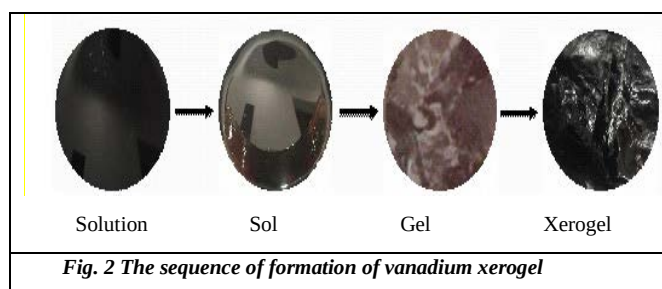


Fig. 2 The sequence of formation of vanadium xerogel

In order to study the composition and structure of the synthesized gel vanadium material was selected physical and chemical analysis of X-ray diffraction, electron microscopy, atomic force, infrared spectroscopy and thermogravimetric methods in comparison with the results of the analysis of raw materials [4].

On the basis of physical and chemical methods of investigation found that the use as a template ammonia involved because of the electron-donor properties of nitrogen atoms in the formation of ammonium vanadium complex $[(\text{VO}_2)_x(\text{OH})_y \cdot n\text{NH}_3]^{y-x}$ vanadiumoxygen frame vanadium compound, and to achieve pH ~ 3.5 resulting in the formation of the sol. Formation of the latter is due to the replacement of OH-groups in dekanavanadium ion $(\text{VO}_2)_{10}(\text{OH})_{16}^{6-}$ ammonia. With further increase in the pH (~ 4) appears coagulation contact between particles, leading to the structuring of the material. In the process of aging and drying of the gel is removed and partially hygroscopic crystalline hydrate water, there is a transition of crystal water connections for connections of OH groups. Crystallization water not completely removed, resulting in a high degree of order in the films associated with the location of each of the water molecules opposite short double bond $\text{V} = \text{O}$. Consequently, the growth of the chains occurs preferentially in the plane OH-equivalent groups. Most VO-H groups consist of vanadium-oxygen layers, the width of which amounts to about 12-18 nm. The layers have a morphology "whistle", in which the group VO-H characterized by significant structural flexibility. As a result of the transformation of the gel lost bond disappears and the template is formed xerogel having a porous mixed-layered, twisted, spatial development structure.

4. Conclusion

Thus, the creation of large-scale low-cost methods for the preparation of nanostructured materials - is one of the most difficult tasks facing science as its solution is necessary to use the results in technological processes.

Despite the rapid development of nanotechnology, information on nanomaterials based on vanadium oxide require further development. Research towards the synthesis of nanomaterials based on vanadium oxide and studying their properties is of great importance for the development of not only the scientific bases of nanotechnology and nanomaterials industrial applications due to their unique properties.

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VIBRATION ANALYSIS ON A CONVEYOR DRIVE UNIT IN CONVEYOR TRANSPORT SYSTEM FOR COAL

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Abstract: The subject of research in this paper is a conveyor drive unit from a conveyor coal transport system that is used by SM "Brod - Gneotino" to SM "Suvodol" (Power plant REK Bitola-Macedonia) because of its existing signs of increased vibrations. Vibration measurements of the drive transporter T5 was obtained to determine the vibration state of the drive unit. Each driveline (electric motor – hydro clutch - gear reducer) has ten measuring points - probes to monitor temperature and ten measuring points - probes for monitoring the vibration of the electric motor bearings and bearings of the gear reducer.

Through proper FFT analysis of the vibration signal that has been obtained by the probes we will determine further conclusions and recommendations regarding the state of the elements of the system and their dynamic stability.

KEYWORDS: CONVEYOR DRIVE, UNIT LIMITED CAPACITY, DYNAMIC STABILITY, VIBRATION, DETESCOPY

1. Introduction

The main transport system for coal from PK "Brod - Gneotino" to PK "Suvodol" consists five conveyors (different lengths, different height differences between the drive and return station ...) and are therefore equipped with a different number of identical drivelines (ten of them in total).



Fig1. Satellite map of the route for GTS T2-T6 and schematic



Fig.2 The image shows plant transporters of GTS

2. Material and methods

The main goal of the research in this paper is to define the dynamic stability of drive group – gearbox with FFT analysis of the measured vibration characteristic places.

In literature there are norms and standards that treat this issue in gear units, but each is based on models that depend on the direction in which we want to exercise our research.

Power plant REK Bitola-Macedonia adopted standard ISO-10816-3 as a criterion for assessing the condition of the bearings and the recommendations of the manufacturer of SKF bearings that are fitted to the drive groups and other appropriate places.

In addition to Table 1 is given a diagram of the ISO - 10816-3

Table 1.ISO-10816-3 - VELOCITY

								Velocity	
								11	0.44
								7.1	0.28
								4.5	0.18
								3.5	0.11
								2.8	0.07
								2.3	0.04
								1.4	0.03
								0.71	0.02
								mm/s rms	inch/s rms
rigid	flexible	rigid	flexible	rigid	flexible	rigid	flexible	Foundation	
pumps > 15 kW radial, axial, mixed flow				medium sized machines 15 kW < P < 300 kW		large machines 300 kW < P < 50 MW		Machine Type	
integrated driver		external driver		motors 160 mm ≤ H < 315 mm		motors 315 mm ≤ H		Group	
Group 4		Group 3		Group 2		Group 1			
A New machine condition B Unlimited long-term operation allowable C Short-term operation allowable D Vibration causes damage									

For defining the goal of this research we will make comparative measurements of the vibrations of the gearbox approximately in same operating conditions and compared the results to find the causes of the increased vibration of gearbox in drive groups. This approach and methodology for gathering results of comparative analysis should serve as a benchmark in further measurements of these and similar drive groups.

First, the measurement of the vibrations of the drive transporter T5 are taken in order to determine the vibration state of the drive.



Fig.3 Drive transporter T5

The gearbox which is the subject of analysis is running at speed 1500min⁻¹, which means working with 25 Hz own frequency. This is especially important when reviewing and analyzing vibrations.

For the measurement is used an on - line system for tracking the status of the reducer, meaning that we have fixed probes of individual measuring points which will be analyzed properly as they stand.

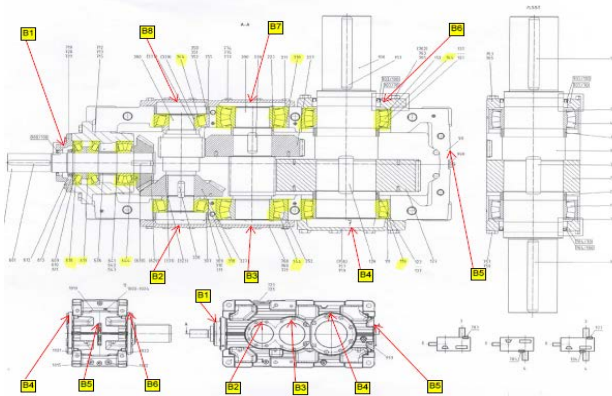


Fig. 4 Schematic representation of the measuring points of gearbox with a cross-section

With the intention to define the optimum frequency range, several measurements in the range of 0 to 1000 or 2000 Hz has been made. Because of the dynamic behavior of the transmitter that has not stationary character, the level of vibration is variable over time. Therefore three complete measurements are made and by each measurement eight averaging results are registered.

Each drive group (electric motor - hydro coupling - gearbox) has ten measuring points - probes to monitoring temperature and ten measuring points - probes for monitoring the vibration of the electric motor bearings and bearings of the gearbox. This system is fully automated. Management and monitoring of the operation of this system is performed from the control room.

In the control room via the SKF software we have visually monitoring the vibration of the electric motor bearings and gearboxes of all drive group transporters through probes.

Selected amplitude of vibration displacement (PEAK TO PEAK) to be the parameter that will be followed and obtained directly from the instrument, and it is registered in the corresponding software that is supplied with the instruments used for diagnosing and monitoring the condition of the drive group. Also acceleration vibration is a necessary parameter in separate calculation and need to be registered.

3. RESULTS AND DISCUSSION

The provided results of the measurements by the SKF software from the drive of the Transporter T5 are shown below.

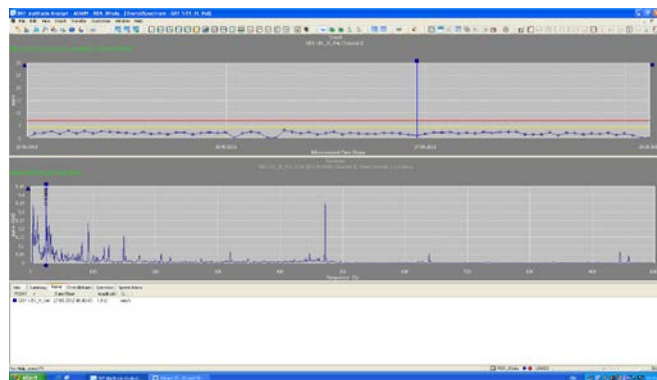


Fig.5 Measuring point V1H

Figure 5 present the measuring point V1H (horizontal), of the probe that is placed on the input shaft. This image is a table of SKF software showing the measuring point for V1H example: Date /

Time 28.06.2012 / 16:05:52 Summary FFT, Overall 0,046 mm / s Posit ... 91. Analyzing this vibration give us only a part of the real picture because it doesn't contain information of the bearings or the shaft situation at a given measuring point. Therefore, this figure below presents two graphs. The first graph represents a movement of vibration over time or changes in vibration in a given time interval called Trend.

On the lower graph is shown the frequency in Hz depending on the displacement (speed) expressed in mm / s. From this graph it can be analyzed the source of the vibrations. It can be concluded that the source of the problem is in the poor performance of the machine. This graph is called Spectrum.

In the present case we have amplitude of 0,43 mm / s at a frequency of 25Hz, and since the gearbox operates on the same frequency by the number of revolutions it means that the amplitude is the first harmonic.

In most cases this kind of a problem comes from not impaired centric or centric clutch electric motor - gear or loose foundation, ie, non-tight with the same strength bolts with nuts from the base.

A second characteristic of the amplitude 0,35mm / s is located about 470-480Hz, or 19th harmonic. This harmonic usually happens if there is a problem with a broken tooth ($f_{x1} = 25 \times 19 = 475$ Hz), but in the present case there might be a local bump on the side wall of the conical gear teeth and therefore this amplitude occurs.

Third characteristic amplitude of 0,34 mm / s to about 8Hz, presents us i.e. overlapping frequency sub-harmonic. This phenomenon usually occurs in the slack of the shaft relative to the bearing. In the present case this amplitude is negligible for further analysis.

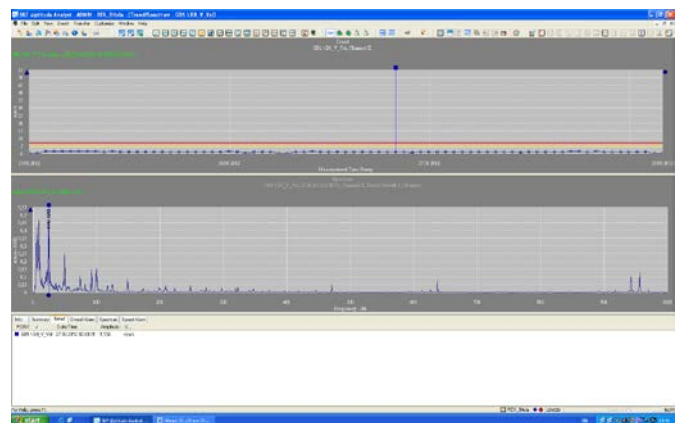


Fig.6. Measuring point B8V

Since the second shaft are two probes (measuring points) B2V and B8V they will be analyzed together.

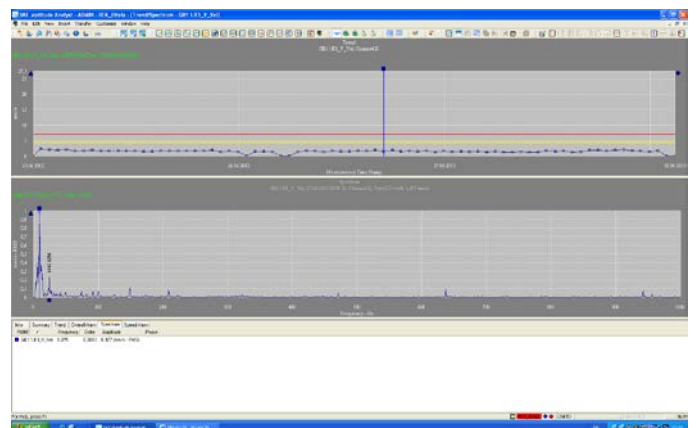


Fig.7 Measuring point B2V

Here we have a typical amplitude of 1,34 mm / s of 8,75Hz located in sub-harmonic analysis means applies third amplitude of measuring point B1N.

A second characteristic is the amplitude 0,75mm / s and is located approximately 80Hz, or third harmonic. In this case when we have a high suppressor harmonic and third harmonic in most cases the loose foundation. In this particular case where we have small values has not analyzed.

The first characteristic of this range measuring point is 0,52 mm / s of 25Hz, or the first harmonic. Feature first harmonic analyzed previously, and mainly occurs in non centric, unbalance or looseness.

A second characteristic amplitude is 0,46 mm / s of 12,5Hz, ie $\frac{1}{2}$ harmonic (sub-harmonic). Sub-harmonic commonly occur at some laxity whether the foundation or the shaft.

A third characteristic is the amplitude of 0,25 mm / s to 50Hz, a second harmonic. The second harmonic is expressed in non centric link electric motor - gearbox. But in this particular case when the power train is seen as a whole, it tells us that there is some laxity of the foundation. Given the small values of the vibration they are not taken for analysis.

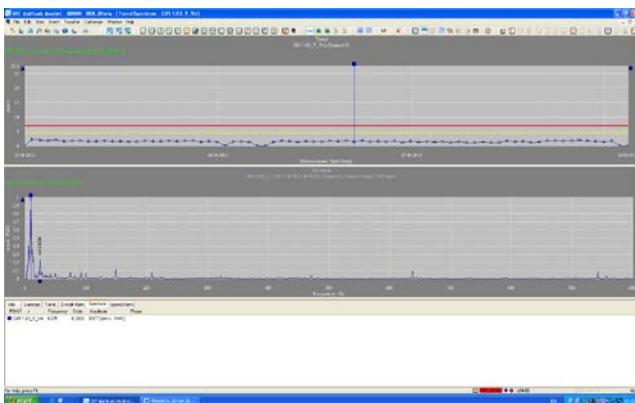


Fig.8 Measuring point B3V

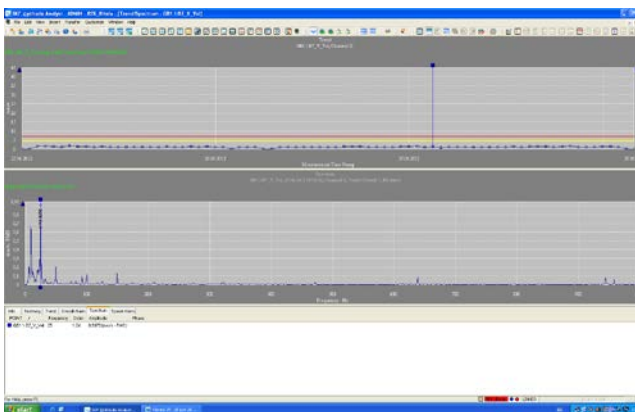


Fig.9 Measuring point B7V

Analogous to the second shaft analyzes the third shaft, ie together they considered the measuring points B3V and B7V.

The first characteristic is an amplitude 0,97 mm / s to 9,4Hz, i.e. 0.4 sub-harmonic. The occurrence of sub-harmonic is explained in the above measuring points (B1H, B2V, B8V).

The second characteristic is the amplitude 0,25mm/s of 25Hz, i.e. first harmonic. The occurrence of the first harmonic is the same as for measuring point's B1H, B8V.

First characteristic amplitude of 0,91 mm/s of 25Hz, i.e. the first harmonic. Second amplitude characteristic of 0,68 mm/s of 10Hz, i.e. 0.4 sub-harmonic. Here it is evident that have similar values as

the measuring point B3V substituted are the locations of the first and second characteristic frequency.

Analyzed as a whole measuring points B3V and B7V in this case occurs at slack foundation, but because we have small values they do not analyze them.

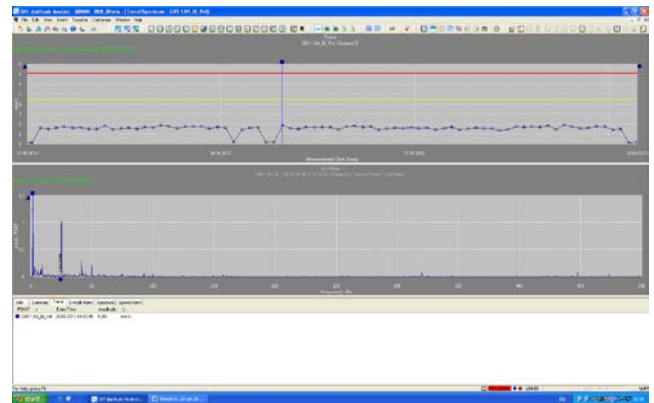


Fig.10 Measuring point B4H

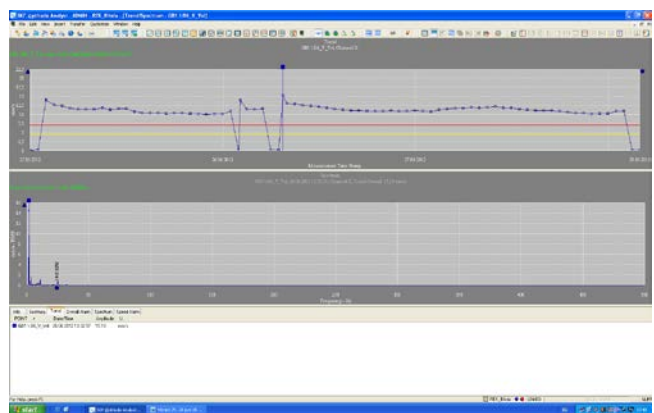


Fig.11 Measuring point B6V

Analogously third shaft analyze and fourth shaft. Characteristic of the fourth shaft is that the probes are placed in two different directions, vertically and horizontally as recommended in the analysis of vibration, compared with the second and third shaft where probes are placed in the same plane.

The first characteristic is an amplitude 1,21mm / s to 1,56Hz, i.e. 0.06 sub- harmonic. The second characteristic is the amplitude 1,00mm / s of 25Hz, i.e. the first harmonic. The analysis of this measuring point is the same as the measuring point B3V.

The first characteristic is an amplitude 14,4mm / s to 1,56Hz, i.e. 0.06 sub- harmonic. The second characteristic is the amplitude 1,00mm / s of 25Hz, i.e. the first harmonic. The analysis of this measuring point shows registered high vibration in the unauthorized area. Therefore together is analyzed the measuring point B5A (Figure 12) where it is proven that the first characteristic amplitude is 4,34mm / s, the 1,56Hz, i.e. 0.06 sub-harmonic. The second characteristic is the amplitude 1,00mm / s of 25Hz, i.e. the first harmonic

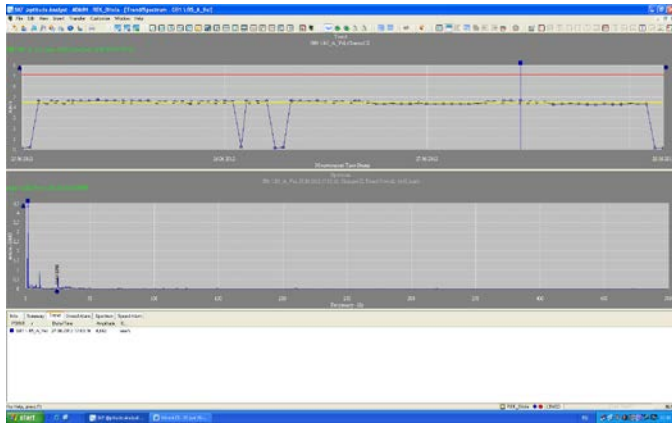


Fig.12 Measuring point B5A

4. CONCLUSION

The conclusion taken by the vibration analysis is the existing of the eccentric on the link gearbox-drum. The Drive groups: Electric motor - Hydraulic coupling – Gearbox are connected with rigid link to the drive drum. The output shaft of the gearbox with shaft of the drum through the rigid coupling should and must be centric to have dynamically stable operation against ISO standard

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THE SOLUTION OF THE PROBLEM OF ONE-PARAMETER PERTURBATION OF THE VISCOUS INCOMPRESSIBLE LIQUID MOTION THROUGH STRAIGHT ROUND PIPE

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РЕШЕНИЕ ЗАДАЧИ ОДНОПАРАМЕТРИЧЕСКОГО ВОЗМУЩЕНИЯ ДВИЖЕНИЯ ВЯЗКОЙ НЕСЖИМАЕМОЙ ЖИДКОСТИ ПО ПРЯМОЛИНЕЙНОЙ ТРУБЕ КРУГЛОГО СЕЧЕНИЯ

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Abstract: In this paper the analytical solution of the differential equation, describing viscous incompressible liquid motion through straight round pipe, with one perturbation parameter is given. The perturbation is introduced into the equation through the disturbed viscosity, depending on the temperature. The solution of the corresponding differential equation is sought in the form of a series in the small parameter. Thus the flow reaction to the internal disturbance is studied. The solution, presented in this article, gives an opportunity to further studying the temperature impact on a viscous weakly compressible liquid motion through a pipe. This research may be of interest to the problems of hydrocarbons control flow through main pipelines.

Keywords: NON-STATIONARY HYDRODYNAMICS, ONE-PARAMETER PERTURBATION, VARIABLE VISCOSITY, INCOMPRESSIBLE LIQUID, PIPELINE, MATH MODELING

1. Introduction

The hydrodynamic equations, describing a viscous liquid motion through a pipe, contain parameters, such as the liquid dynamic viscosity and its density. Previously the solution of the problem of the non-stationary viscous incompressible liquid motion through cylindrical round pipe was given by the author [1,2]. In those papers the viscosity and density were considered to be constant. However, these conditions are too strict for practical problems.

The dynamic viscosity generally is not constant: it depends on temperature. Moreover, real hydrocarbons are often weakly compressible media. In this article we solve the problem, which, in perspective, will allow to take into account the effect of the compressibility and variable viscosity during the real hydrocarbons motion through the pipelines.

The most common change in viscosity can be described by some small parameter. For example, when the temperature changes, the following formula may be considered [3]:

$$\mu = \mu_0(1 + \alpha(T - T_0)),$$

where μ_0 – the liquid dynamic viscosity at the temperature T_0 , α – some small parameter, depending on the substance. This relation holds for small temperature interval. In this work we will present a possible small change in viscosity in the form of

$$\mu = \mu_0(1 + \alpha), \quad |\alpha| \ll 1. \quad (1)$$

2. Formulation of the problem

The equation, which describes one-dimensional motion of the viscous liquid through a pipe with the circular cross-section of the radius R , has the form:

$$\frac{\partial v}{\partial t} = \frac{\mu}{\rho} \left(\frac{\partial^2 v}{\partial r^2} + \frac{1}{r} \frac{\partial v}{\partial r} \right). \quad (2)$$

The initial conditions are the initial velocity distribution over the pipe cross-section: $v(0, r) = \varphi(r)$; the boundary conditions, due to the “sticking” of the liquid to the pipe walls, are: $v(t, R) = 0$. In this paper we neglect the non-stationary conditions at the pipeline ends, and thus have a homogeneous differential equation.

Taking into account the expression (1), we write the equation (2) in dimensionless form:

$$\frac{\partial u}{\partial \tau} = (1 + \alpha) \left(\frac{\partial^2 u}{\partial \eta^2} + \frac{1}{\eta} \frac{\partial u}{\partial \eta} \right), \quad (3)$$

where $u(\tau, \eta)$ – dimensionless velocity, τ – dimensionless time, η – dimensionless radial coordinate. The initial and boundary conditions take the form $u(0, \eta) = \tilde{\varphi}(\eta)$ and $u(\tau, N) = 0$ respectively [1].

We construct a solution of the equation (3) and estimate the impact of the constant small parameter α on it. We will seek the function $u(\tau, \eta)$ in the form of the asymptotic expansion

$u(\tau, \eta, \alpha) \approx \sum_{n=0}^{\infty} u_n(\tau, \eta) \cdot \alpha^n$, limited to three terms and considering α small enough. [4,5]:

$$u(\tau, \eta, \alpha) = u_0(\tau, \eta) + u_1(\tau, \eta) \cdot \alpha + u_2(\tau, \eta) \cdot \alpha^2. \quad (4)$$

3. Results

3.1. The analytical solution

Instead of $u(\tau, \eta)$ we substitute its expansion in the parameter (4) into the equation (3). Then, to determine the expansion coefficients $u_0(\tau, \eta)$, $u_1(\tau, \eta)$ and $u_2(\tau, \eta)$, we obtain a system of differential equations:

$$\begin{cases} \frac{\partial u_0}{\partial \tau} = \frac{\partial^2 u_0}{\partial \eta^2} + \frac{1}{\eta} \frac{\partial u_0}{\partial \eta}, u_0(0, \eta) = \tilde{\varphi}(\eta), u_0(\tau, N) = 0, \\ \frac{\partial u_1}{\partial \tau} = \frac{\partial^2 u_1}{\partial \eta^2} + \frac{1}{\eta} \frac{\partial u_1}{\partial \eta} + \frac{\partial^2 u_0}{\partial \eta^2} + \frac{1}{\eta} \frac{\partial u_0}{\partial \eta}, u_1(0, \eta) = 0, u_1(\tau, N) = 0, \\ \frac{\partial u_2}{\partial \tau} = \frac{\partial^2 u_2}{\partial \eta^2} + \frac{1}{\eta} \frac{\partial u_2}{\partial \eta} + \frac{\partial^2 u_1}{\partial \eta^2} + \frac{1}{\eta} \frac{\partial u_1}{\partial \eta}, u_2(0, \eta) = 0, u_2(\tau, N) = 0, \\ \frac{\partial^2 u_2}{\partial \eta^2} + \frac{1}{\eta} \frac{\partial u_2}{\partial \eta} = 0, u_2(0, \eta) = 0, u_2(t, N) = 0. \end{cases}$$

Combining the third and the fourth equations of the system, we obtain:

$$\begin{cases} \frac{\partial u_0}{\partial \tau} = \frac{\partial^2 u_0}{\partial \eta^2} + \frac{1}{\eta} \frac{\partial u_0}{\partial \eta}, u_0(0, \eta) = \tilde{\varphi}(\eta), u_0(\tau, N) = 0, \\ \frac{\partial u_1}{\partial \tau} = \frac{\partial^2 u_1}{\partial \eta^2} + \frac{1}{\eta} \frac{\partial u_1}{\partial \eta} + \frac{\partial^2 u_0}{\partial \eta^2} + \frac{1}{\eta} \frac{\partial u_0}{\partial \eta}, u_1(0, \eta) = 0, u_1(\tau, N) = 0, \\ \frac{\partial u_2}{\partial \tau} = \frac{\partial^2 u_1}{\partial \eta^2} + \frac{1}{\eta} \frac{\partial u_1}{\partial \eta}, u_2(0, \eta) = 0, u_2(\tau, N) = 0. \end{cases} \quad (5)$$

Solving the differential equations, included in the system given, with the Fourier method, we obtain:

$$u_0(\tau, \eta) = \int_0^N G(\eta, \xi, \tau) \cdot \tilde{\varphi}(\xi) d\xi, \quad (6)$$

where

$$G(\eta, \xi, \tau) = \sum_{n=1}^{\infty} \frac{2\xi e^{-\frac{\mu_n^2}{N^2}\tau}}{N^2 (J_1(\mu_n))^2} J_0\left(\frac{\mu_n}{N}r\right) J_0\left(\frac{\mu_n}{N}\xi\right),$$

$$u_1(\tau, \eta) = \int_0^{\tau} \int_0^N G(\eta, \xi, \tau - \sigma) \cdot f(\tau, \xi) d\xi d\sigma, \quad (7)$$

$$u_2(\tau, \eta) = -\int_0^{\tau} \int_0^{\sigma} \int_0^N G(\eta, \xi, \sigma - s) \cdot f(s, \xi) d\xi ds d\sigma, \quad (8)$$

where

$$G(\eta, \xi, \tau - \sigma) = \sum_{n=1}^{\infty} \frac{2\xi e^{-\frac{\mu_n^2}{N^2}(\tau - \sigma)}}{N^2 (J_1(\mu_n))^2} J_0\left(\frac{\mu_n}{N}\eta\right) J_0\left(\frac{\mu_n}{N}\xi\right),$$

$$f(\tau, \xi) = -\int_0^N \sum_{n=1}^{\infty} \frac{2\xi e^{-\frac{\mu_n^2}{N^2}\tau}}{N^4 (J_1(\mu_n))^2} J_0\left(\frac{\mu_n}{N}\xi\right) J_0\left(\frac{\mu_n}{N}\zeta\right) \tilde{\varphi}(\zeta) d\zeta.$$

3.2. Numerical simulation

To convert $u(\tau, \eta, \alpha)$ into $v(t, r, \alpha)$ we need the liquid kinematic viscosity $\nu_0 = \frac{\mu_0}{\rho}$ and characteristic size of the pipeline – the diameter [1]. We choose the values of ν_0 and ρ corresponding to those of oil: $\nu_0 = 0.0003 \frac{\text{m}^2}{\text{s}}$, $\rho = 830 \frac{\text{kg}}{\text{m}^3}$; $d = 1 \text{ m}$. The Poiseuille distribution will be taken as the initial condition [3].

We rewrite the expression (4) for $v(t, r, \alpha)$

$$v(t, r, \alpha) = c_0(t, r) + c_1(t, r) \cdot \alpha + c_2(t, r) \cdot \alpha^2,$$

and plot its expansion coefficients (fig.1,2,3).

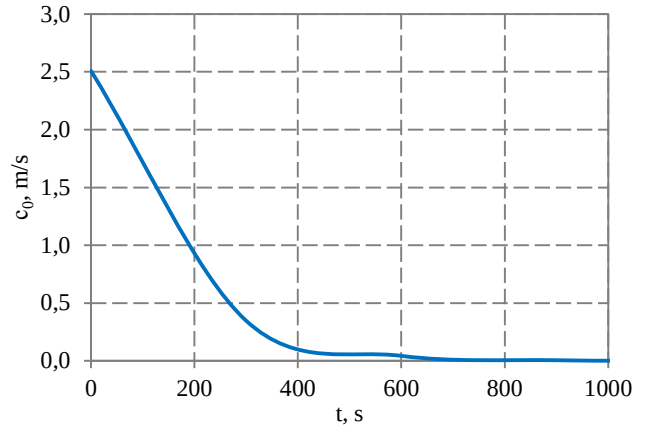


Fig. 1. The dependence of c_0 on time at $r=0$

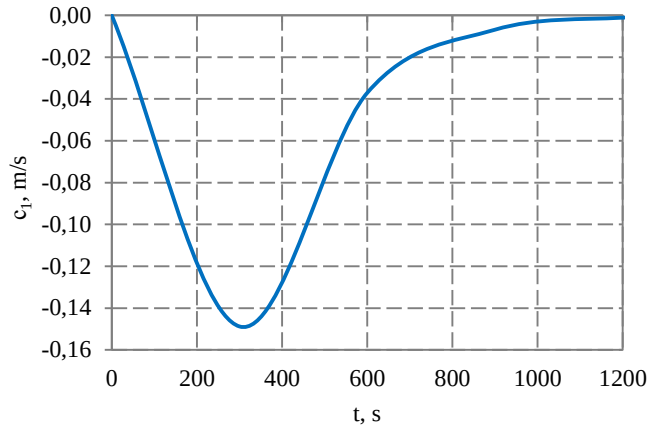


Fig. 2. The dependence of c_1 on time at $r=0$

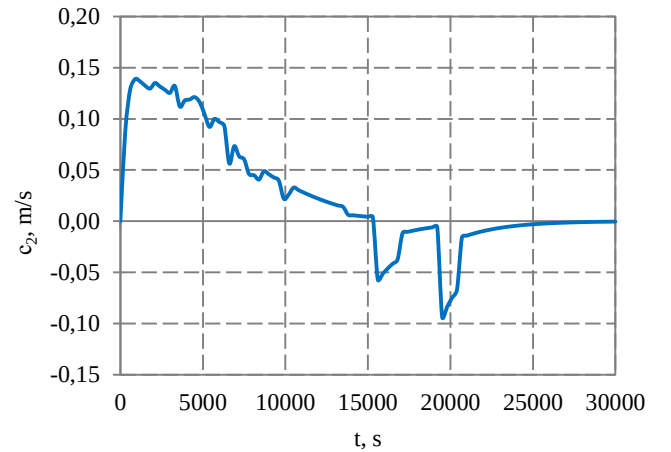


Fig. 3. The dependence of c_2 on time at $r=0$

As can be seen from the figures above, the main expansion coefficient – c_0 – is 10 times greater than c_1 and c_2 , that is why it can be concluded, that the second and third terms in the expansion of the function $v(t, r, \alpha)$ have little effect on its value.

Next we present the solution for the three variants of the parameter α value: 0.1, 0.01 and 0.001. Since the second expansion coefficient is of the order 0.1 – 0.01, it is permitted to take $\alpha = 0.1$.

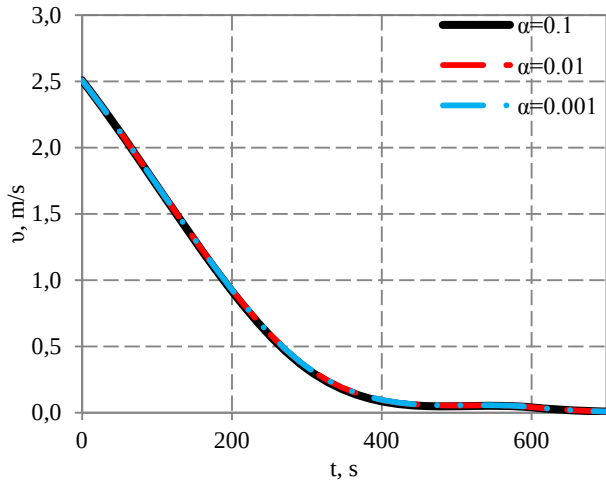


Fig. 4. The velocity dependence on time at $r=0$ for three different values of parameter α

On the figure below there are plots of the difference between $v_1 = v(t, r, 0.1)$, $v_2 = v(t, r, 0.01)$ and $v_3 = v(t, r, 0.001)$ (fig.5).

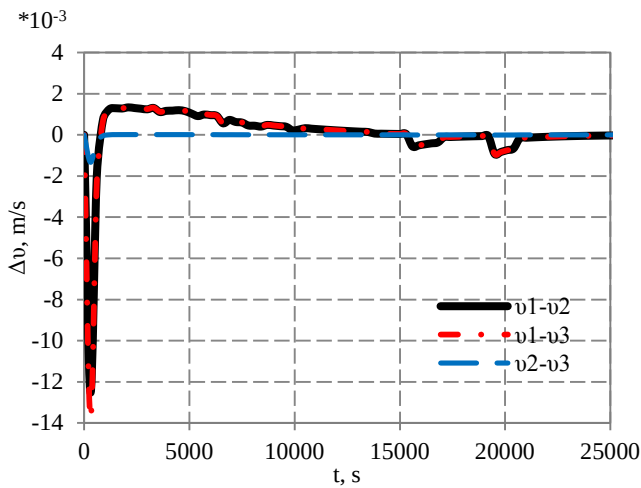


Fig. 5. The deviation between velocities on the pipe axis, calculated for different values of the parameter α , depending on time

Figure 4 clearly shows, that for three values of α , differing by an order, the velocity value on the pipe axis does not change significantly. The maximum value of the deviation between v_1 and v_2 , and between v_1 and v_3 is of the order of $c_1(t, r)$ and $c_2(t, r)$ (fig.5). The velocity values, obtained for $\alpha = 0.01$ and $\alpha = 0.001$, are practically the same.

4. Conclusion

In this paper the problem solution of the one-parameter perturbation of the viscous incompressible liquid motion through straight pipe with the circular cross-section is given. The obtained results allow saying, that one constant small parameter does not significantly effect on the behavior of the solution of the corresponding differential equation. In future it will help to investigate the variable viscosity impact on liquid flow at non-stationary conditions at the pipe ends.

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EXPERIMENTAL AND NUMERICAL DETERMINATION OF PRESS FRAME ELASTICITY

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Abstract: In this paper elastic deflections of press frame when symmetric load is applied have been investigated and press stiffness calculated. The commercial FEM package ABAQUS was used to estimate elastic stress and elastic deformation of press frame in case of 6.3 MN hydraulic press. For validation of FE results both axial and radial displacements of the press frame were measured by means of universal displacement transducers. Obtained results are compared and discussed.

Keywords: PRESS STIFFNESS, FEM, ABAQUS, DISPLACEMENT MEASURING

1. Introduction

Today, one of the goals of forming industry is production of complex components with high dimensional accuracy ready for directly assembling without any machining. It is very demanding task since great number of factors, individually or in combination, affect part's dimensions. In addition, the relationship between some parameters and part accuracy is not always known enough or it changes with changing process conditions. Therefore, for proper design of forming process identification of those factors and their effects on the (in)accuracy of the final part is of great importance. Results given in [1] indicate that forming machine (press) is one of the main causes of dimensional errors occurrence of formed components and that there is direct correlation between press related inaccuracies and part dimensional errors. If mechanisms generating press geometry deviation and the way in which it is transformed into components errors are known it may help not only prediction of part dimensional errors but also enables adjustment of the press-tool system as the press influence on forged components would be minimized or at least well controlled.

Forming machine may be considered as an elastically-deformable system composed of a number of movable and non-movable elements whose relative positions and geometry changes continuously during operation. According [2] geometry deviation of the press-tool system derives from the guideway clearance, the thermal distortion of press members, fluctuation of forming load, and, elastic deflections of press frame under load. The load comes from deformation resistance of workpiece material, the inertial forces due to successive press loading and unloading, press frame pre-stressing, and, the weight of elements attached to press frame. Fig.1 gives an overview of the interactions between press characteristics, deviations at press-tool system, and part errors.

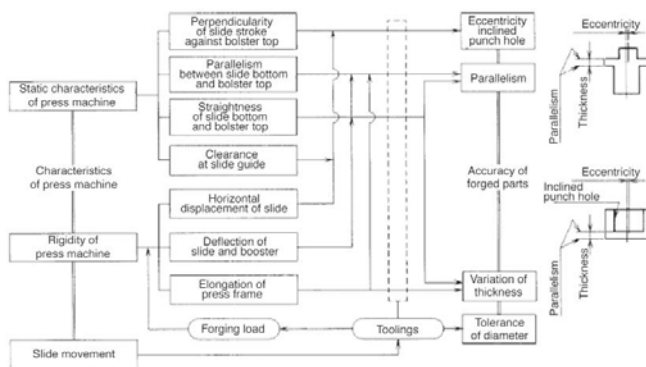


Fig. 1 Relation between some characteristics of press and accuracy of formed part [3]

The elastic deflection of press frame is the main source of inaccuracy at press system [4]. It causes tilting of both press ram and table, i.e. deviation of tool nominal position since it is firmly attached to these elements. Result of this are form and dimensional

errors of workpiece as it shown in Fig.1. Investigations [1] shown that press ram and frame contribute more than 90% of total press deflection, and that horizontal displacement and table tilt can be up to 5 mm. Furthermore, press nonlinear deflections, originated from guideway clearance and contact gap between press members (in case of mechanical press), superimpose tool deviations and additionally reduce accuracy. The size of press frame elastic deflections is influenced not only by load intensity, but also depends on of press type, frame design and its material properties, forming process, load character, guideway system, design of tool in terms of eccentric load occurrence etc. [5].

Basically, there are two ways to increase punctuality of forming machine. The first one is based on the reduction of press frame elastic deviation. This can be achieved by robust design i.e. by increasing press stiffness. Press stiffness is quantitative parameter of the load-deflection relationship. It can be calculated as the ratio of the elastic deflection and the corresponding force component.

$$C = \frac{F_{\max}}{\Delta l_{\max}} \quad (1)$$

where is:

- $F_{\max}$ – maximum force
- $\Delta l_{\max}$ – maximum deflection

Press stiffness is constant for certain machine. By knowing press stiffness one could approximately estimate the size of press geometry errors and elastic deviations, and accordingly that predict risk of part inaccuracy due to errors in machine system. This is why the correlation between the press stiffness and the nominal capacity has been often recommended as a guideline in selection of presses for different forming processes. The second way involves simultaneous procedure of the errors detection and correction in press-tool system. Due to improvement of sensors for the process monitoring and measuring equipment this approach is nowadays increasingly employed, but principally in case of machines with continual processing such are rolling, wire drawing, and, tube extrusion machines.

Doerge [6] was among the first investigated press load-deflection relationship and influence of press stiffness and press members on accuracy and quality of workpiece employing both numerical and experimental methods. More complex quantitative relationship between the press and die elastic deflections and the form errors in forging of an aerofoil blade is presented in paper [2]. The members of press and tool system were integrated into the Finite Element (FE) model as spring elements and general stiffness matrix with six degree of freedom which represent the linear press load-deflection relationships as well as an equivalent clearance vector to take into account the initial non-linearity due to guideway clearances were derived. Using similar theoretical approach for modeling components of the press-tool system and combining FE simulation with experimental results an efficient way to examine elastic

characteristic of the press-tool system was developed [7] based on the dependence of the workpiece dimensions on the actual punch stroke in case of a combined full-forward/backward can extrusion process. With other hand, paper [8] elaborates methods of modeling the press-tool system in order to improve the accuracy of FE simulations of metal forming processes in term of better prediction of forging errors caused by the elasticity of press and tool system. According the authors best results are obtained when coupling the process simulation with external simulation models of the press-tool system. The parameterization of the external models can be done by results from measurements or simulation.

In this paper both approaches (numerical simulation and experimental measurements) for characterization of elastic properties of a press-tool system were used. Except determining deflection of the press frame under different loads the aim of the research was to check accuracy of a simplified FE model of the press-tool system. Based on measured displacements press stiffness in axial direct is also determined.

2. FE simulation

The object of FE modeling was double action hydraulic press Sack&Kiesselbach, 6.3 MN (see Fig.2-left). The press frame ("O" type) is a monolith and robust construction made by casting. Moveable press table is in contact with two press columns of constant cross section used as a guideways. Due to very low velocity but very high nominal force, this press is mainly applied for cold extrusion and indenting operations.

The press geometry was modeled in SolidEdge CAD software, and then it was exported to ABAQUS program package using STL file format. Dimensions of the press elements were mainly imported from the press technical data sheet and completed by the measurement data of the real construction. In CAD modeling some simplification of the press geometry has been made by omitting technical holes, elements of guideway system, axillary components.

Program package ABAQUS used for the simulation is a general purpose FE software by which it is possible to solve both linear and non-linear problems of mechanics, heat transfer, electronic etc. FE model was created in accordance with the software procedure, and ABAQUS explicit mode was chosen for calculation. Here, only model of symmetrical loading of the press frame has been analyzed and load was set as static due to low velocity of the press ram (there is no an impact load). In FEM modeling only the cylinder load as the major force acting on the frame is taken into account, as the weight of the cylinder is omitted. A model of planar forces acting on the press frame was applied with the value equal to the press nominal force (6.3 MN). Discretization of the press frame was done using ABAQUS solid standard elements. It was composed of 112129 tetragonal elements and 25669 nodes (Fig.2-right). As material, cast iron with elastic modulus of 208MPa and Poisson's ratio 0.3 was selected. Post processing of obtained results was done in ABAQUS/Viewer module, which offers wide possibilities of the data displaying.

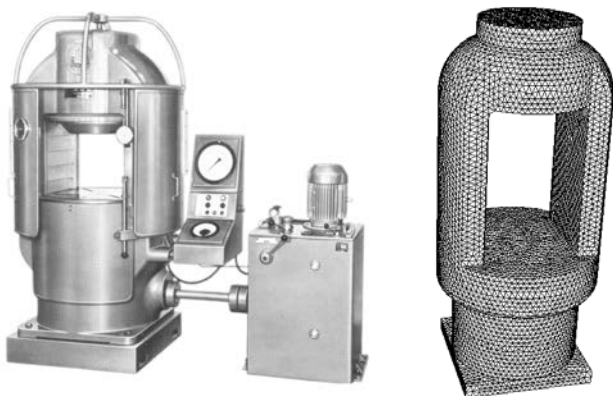


Fig. 2 Hydraulic press Sack&Kiesselbach (left) and FE model of the press frame (right)

3. Experiment

Experimental investigations of elasticity of the press (press-tool system) consist of measurement of both axial and radial deviation of the press frame under load. For that purpose inductive displacement transducers WI5 (HOTTINGER BALDWIN MESSTECHNIK GmbH – HBM) with a resolution of 1 μm were employed [9]. The sensors were placed on special supports (out of the press) in order to register absolute displacements of the press bed, press frame, and press columns. Axial displacement of the press bed was measured at few points as measuring point for radial displacement of the press frame was mid-point of the column height (Fig.3). The experiment (press loading) is performed using a tool consisting of two flat plates mounted to press ram and bed. The plates were in direct contact (there was no workpiece) as the load was continually increased up to max. value of 2 MN after that the press is gradually unloaded. Absolute pressure transducer P3M (HBM) is used to measure load-force. Signals from all sensors are processed by means of eight-channel amplifier SPIDER 8 (HBM) and recorded by CatMAN Easy 4.0 software package.



Fig. 3 Measuring points

4. Results

FE model of deformed and undeformed press frame under 6.3 MN load is shown in Fig.4-right, and distribution of von Misses effective stress in Fig.4-left. It can be seen that the press frame deforms symmetrically with respect to the vertical axis of the press. Similar, values of the effective stress are identical in the press columns. This result is expecting since model of load with no eccentric force is used in the simulation. Maximum effective stresses (about 180MPa) occur at regions where the press columns connect the press body as within the rest of column's volume they do not exceed 120MPa. Effective stresses in the press body (press bed and upper traverse) are significantly lower and it almost acts as rigid body. The values of both axial and radial displacements of the press frame are given in Fig.5.

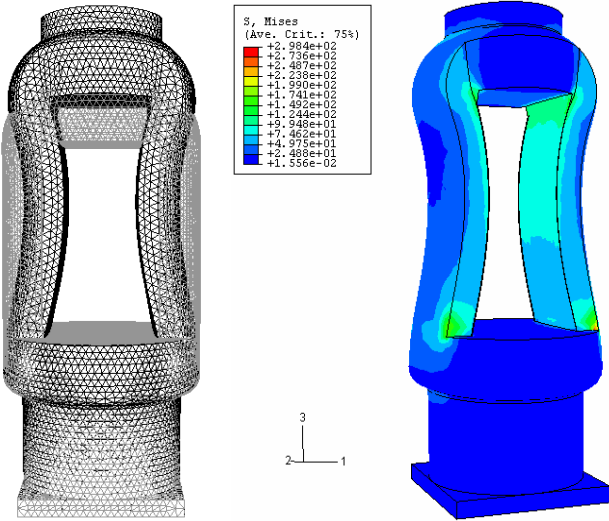


Fig. 4 Non-deformed and deformed press frame (right) and effective stresses (left) (load $F=6.3$ MN)

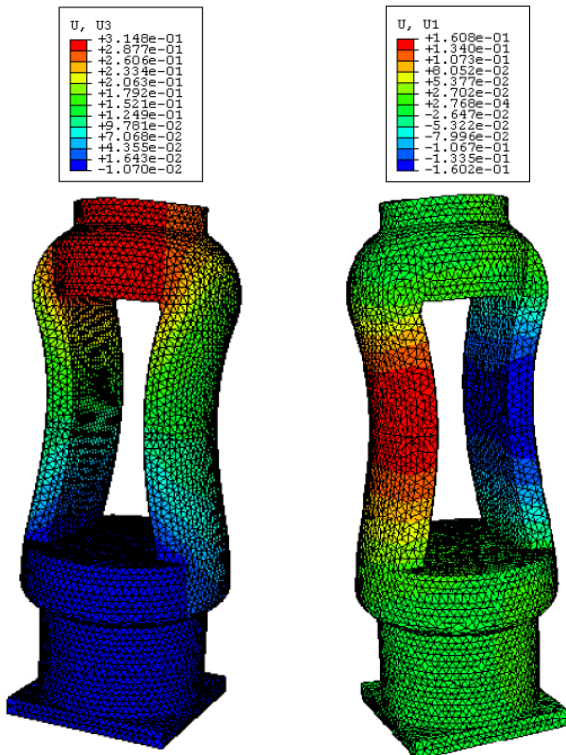


Fig. 4 Displacements of press frame in axial (right) and radial (right) direction (load $F=6.3$ MN)

For nominal press force of 6.3 MN, maximum displacement of upper part of the press (traverse) is +0,3148 mm (positive way of z-axis) as press bed moves down for -0,0107 mm (negative way of z-

axis). This means that the total change of the vertical (axial) distance between upper and lower part of the press is 0.3255 mm. Simulation shown that except elongation also bending of press columns occurs. Results of this is loss of parallelism and reduction of distance between the press columns. According to the simulation the maximum of bending amplitude is 0.16 mm, i.e. distance between left and right column is less for 0.32 mm. If compare the results of numerical simulations with experimental data it is evident that they are in good agreement (Fig.5 and Fig.6). Experimental values for both axial and radial displacements of the press frame are slightly higher with the maximum difference less then 10% for load of 2000 kN. It may comes from the measurement inaccuracy of due to lack of the FE model.

Elastic deformations of the press-tool system obtained by the experiment are given in Fig.7 (axial direction). In this case, measuring devise was in contact to the press table (movable part of the press – see middle photo in Fig.3).

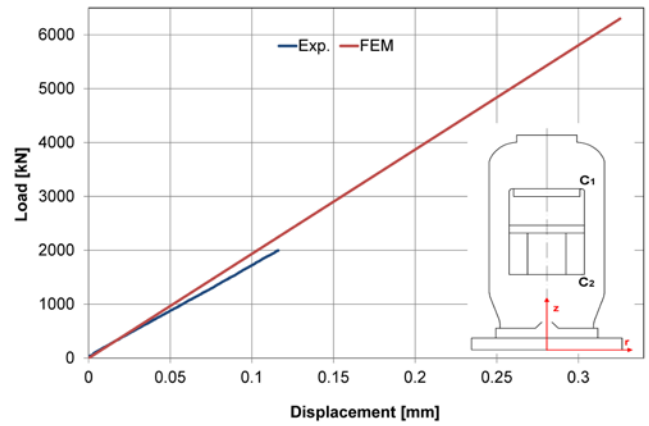


Fig 5 Axial displacement vs. load

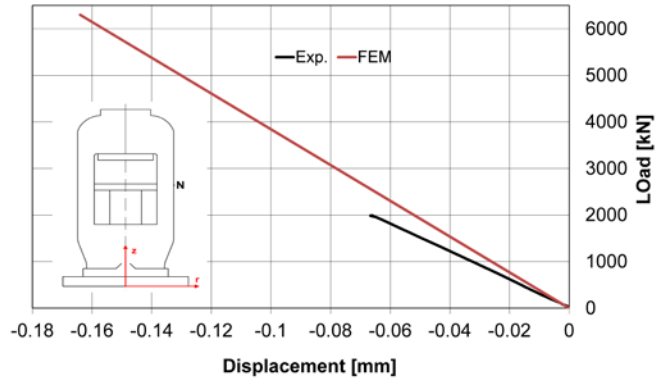


Fig 6 Radial displacement of the press column vs. load

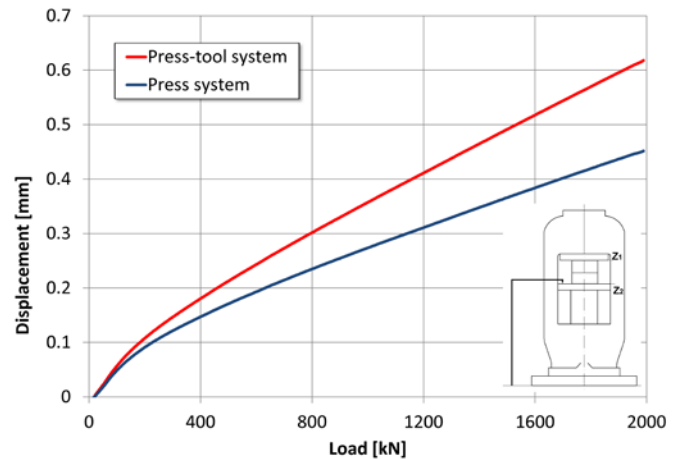


Fig 7 Elastic deformation of the press and the press-tool system

As it can be seen from Fig.7, elastic deformation of the press-tool system are much higher compared the press frame (Fig.5) since elastic deformation of the tool and the drive system are taken into account in this case. At very beginning of press loading deformations of this system are nonlinear as a result of clearance in the driving system and contact gap between both press and tool members.

If elastic deformation of the press-tool system (Δl_{p+t}) are known then elastic deformation of the press (press frame + drive system), can be obtained from the next expression:

$$\Delta l_p = \Delta l_{p+t} - \Delta l_t \quad 2$$

Due to simple configuration of the tool used in experiment, its elastic deformation can be calculated analytically. Using model of axially loaded bar, the change in length of the tool elements (flat cylindrical plates with constant cross section) is obtained from:

$$\Delta l_t = \sum \frac{Fl}{AE} = 2 \frac{Fl}{AE} \quad 3$$

where:

F – active force
 l – length of the plate
 A – cross-section of the plate
 E – modulus of elasticity

Elastic deformation of the press as a result of solving Eqs. 2 and 3 is also given in Fig.7. It can be seen that this deformation is almost four times higher than elastic deflection of the press frame (Fig.5), and reaches values of 0.452 mm for load of 2000 kN. This indicates that for the analyzed press condition and design of the drive system have dominant influence on the press elasticity in axial direction and consequently effect variation (errors) of workpiece dimension in direction of forming force.

Entering necessary data in Eq.1, following values for stiffness are obtained:

Press-tool system:	$C_{p+t} = 3890 \text{ kN/mm}$
Press	$C_p = 5763 \text{ kN/mm}$
Tool	$C_t = 12097 \text{ kN/mm}$
Press frame	$C_{pf} = 16129 \text{ kN/mm}$

5. Conclusion

Data about elastic characteristic of press and press-tool system are essential for proper design of forming process. In this paper two different approaches were employed for investigation of the press elasticity. The first one is based on FE analyses using ABAQUS software package. The aim was to develop simple but reliable FE model of press frame load. Accuracy of the FE model is checked experimentally. Displacement of relevant points of the press assembly is measured using transducers with high resolutions and obtained values fully confirmed results of the numerical simulation. Therefore, developed FE model can be utilized for quick estimation of the press elastic deflection under different load. It enables shortening of the time for forming process design and prevention of workpiece dimensional errors.

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FAILURE MODES AND EFFECTS ANALYSIS RESULTS USED IN PRODUCTS DESIGN PROCESS

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Abstract: Our paper's aim is to emphasize the useful combination between a functional decomposition approach met in literature as FAST Functional Analysis and System Technique - a technique used to decompose logically on levels of abstraction and ideally solution independent product's (system) functions and consistent with this decomposition to realize a Failure Modes and Effects Analysis analyze. In this way, for each function inventoried and organized on each detail level there will be associated their specific failure modes. This approach is applied next to a mandrel.

Keywords: FMEA, FAST, FUNCTIONAL DECOMPOSITION, MANDREL

1. Introduction

Regarding the development of similar products - existence of a structure capable to aggregate information - geometric technology information (precision, material of components, relationships between components), product's structure, assembly conditions, conditions / information from maintenance services all these should be a "guide" of good practice in terms of creating performing products that meet the requirements for the project and their achievement to a quality level suitable to these requirements.

This field of product design is very wide both in approaches/methods used in design as in particularities. Through methods used in this field some are present regardless the nature of domain, industrial or services.

Failure modes and Effects Analysis (FMEA) and FMECA are methods/tools largely used to assure safety conditions and are mandatory in different domains like automotive industry, logistics, manufacturing industry, and aerospace, military, medical etc. It is a very useful tool assuring early risks detection and focus on risks arisen from different potential failure modes. Early identifying risks conduct to avoid complicated correction processes regarding the project and entire development process thus contributing to reduce costs and time – nowadays key requirement regardless the project, activity or domain involved.

The Failure Mode and Effects Analysis (FMEA) documents single failures of a system, by identifying the failure modes, and the causes and effects of each potential failure mode on system service and defining appropriate detection procedures and corrective actions. When extended by Criticality Analysis procedure (CA) for failure modes classification, it is known as Failure Mode Effects and Criticality Analysis (FMECA) and it is a procedure by which each potential failure is ranked according to the combined influence of severity and probability of occurrence namely in calculating the RPN number (Denfense, 1980).

Many of literature existing papers deals with RPN number accuracy calculation, integrating FMEA with Quality Plans as an approach in Total Quality (Teng & Ho, 1996), automatic generation of a FMEA analyze using the unified modelling languages (Mhenni, 2014), fuzzy-logic-based method for FMEA to evaluate interdependencies among various failure modes with uncertain and imprecise information (Xu et al, 2002), how approximate failure rates for components can be used to select the most likely combinations of failures for automated investigation using simulation (Price et al. 2002).

FMEA is a method that can be applied at any detail level in design-component, function/sub-assemblies and assemblies and implies a very good understanding of systems functions and design and the guiding idea is that for a reliably product it has all its components reliable.

FAST- is a diagram that facilitates graphically and logic view of what functions are and how they work together. Thinking a product

in terms of functions does not hinder / constrain thinking related to the physical / processes features and characteristics and therefore can lead to a better problem definition and an easier way to solution. FAST describes the logic relations that must exist between the various functions that must be met in order to satisfy the main product's functionality (Borza, 2011).

Our paper's aim is to emphasize the useful combination between a functional decomposition approach met in literature as FAST (*) - a technique used to decompose logically on levels of abstraction and ideally solution independent product's (system) functions and consistent with this decomposition to realize a FMEA analyze. This approach is applied next to a mandrel.

The paper is structured as follows. Section two emphasis the FMEA and FAST approaches, in section three is the proposed approach and in section four are the conclusions and finally the references.

2. FAST and FMEA Approaches

FMEA can be applied to recognize probable failure modes, conclude their effect on the process of the product, and categorize actions to diminish the failures. A vital step is anticipating what might go incorrect with a product. It is a popular tool for reliability and failure-mode analysis. (Lipol & Haq, 2014).

To cover both design and production, FMEA should include the activities at both design and manufacturing stages. It is common and critical to conduct reliability analysis at the earliest stage of the product life cycle. (Mheni, 2014), (Teng & Ho, 1996).

Process FMEA is described as having the goal to identify failures associated with the fabrication, assembly processes, machine tools, fixtures and Production Methods. Design FMEA deals with possible components failure, consider the integration of components and their interactions effects on product functions, subassemblies functions. Component FMEA consider only the selecting materials and manufacturability of components. (Teng & Ho, 1996)

To realize a FMEA following activities are to be done: an inventory of failure modes, what effects they have on the product, process and corrective measures that are to be applied. If analyze of failure criticality is followed, the RPN are calculated using existent data, existent reliability informations and also external environment.

They are very important and should be inventoried, the potential safety implications in system failures, its performance indicators, in maintainability indicators extraction and not least in the generation of demands for maintenance service. It is essentially an evaluation technique that can be applied at any level of detail following an approach as well as bottom-up or top down up. It applies equally to functions, subsystems, parts and assemblies, as a basic requirement without which cannot be achieved a good functions understanding and system operation.

A FAST Diagram (Functional Analysis System Technique) (*) represents a translation of each working function into technical functions intern to products, establishing their relationships and involvement in satisfying the working functions and aggregating this in constructive solutions. This kind of diagram is built from left to right governed by the logic (see Fig. 1) [(Kaufman, 1965)]:

1. How is function accomplished? By B
2. Why is it necessary (the function)? So you can A
3. When function occurs what else happens? C or D

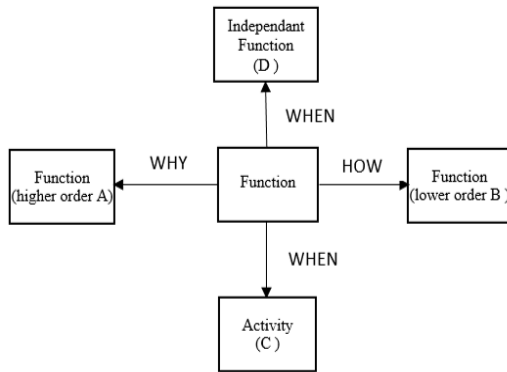


Fig. 1. FAST Diagram Logic (Kaufman, 1965)

In a FAST diagram, functions are represented by rectangular blocks and connected by lines and levels of detail, from the general to the basic function, are marked by indices corresponding to each level of detail. The indices indicate the position of the respective function in the diagram. In FAST diagrams appears the notion of simultaneity but it is rather a functional simultaneous notions then a temporal one, being interpreted as a logical simultaneity AND. (*).

Such a diagram suppose clearly define the limits of the study, namely to which part/product addresses. There are no correct diagrams but only valid ones depending on subject and scope. These diagrams are a team approach and helps team members in reaching consensus on their understanding of the project.

The product is expressed in terms of functions each function of a superior level being decomposed in positions of lower levels, from a high level of abstraction to lower levels. The last constituent element of the chart (last level) is materialized through the effective components of the product that alone or together with others components accomplish independent functions or subassembly functions (the functions from higher abstractization levels). Basically, such a breakdown conducts to a practical solution. Depending on the type of components and subassemblies and ways of aggregating those in different embodiment's different solutions can be achieved. Many alternative components may be capable of performing the identified functions.

Based on the relationship between components they are structured and combined and these relationships are materialized through links between the functions from FAST diagram. Such functional decomposition has the advantage of being accompanied by components that support / perform functions and it can be done both component as well as a functional FMEA in parallel.

3. Proposed approach

The paper aims to highlight the use of FAST approach for a product functional decomposition from general functions, technical functions and up to component level then applying FMEA analysis consistent with this in view to a do a combined approach of both functional as well as associated failure modes and their effects analysis FMEA.

FMEA is performed on data from design and components

drawings, each component is analyzed and using the relations connecting the components can be analyzed the failures of both the component itself and the "modules", sub-assemblies, in this respect following the logic of FAST approach.

Thus, in parallel, for each function inventoried and organized on each detail level there will be associated their specific failure modes. From the inventory the fails on functions level of detail and then the fails associated to components it can be extracted the failures and their effects the component / function itself as well as the respective subassembly set whole.

4. Applied approach

In section 2 were presented the process, design and component FMEA. In this regard, our approach being applied to a fixturing /work holding device is situated in process FMEA. Because there are not analyzed the relations with machine tool, cutting tool, its assembly but rather its functions and their associated components/ it fits in a design FMEA and component FMEA (figure 2)

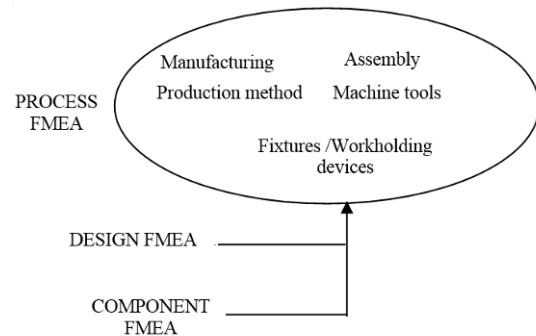


Fig.2.

When analyzing a product, namely its functionalities we have to have a deep understanding of all the composing elements of the product or subassemblies in contact relation, to identify external and internal contacts and also the relations between different product's elements because of its designing. They can be external links, which integrate the relations between some of the products components with one or more external environments, respectively internal links which take into account just the product's components.

Starting from an existent product, a mandrel, its functions are represented using an internal functional analysis decomposition, it can be developed a functional structure which in its turn conducts to the solution dependent functions all these following the FAST Diagram logic. In this way are achieved sschematic functions structures and this helps to the capturing of design rationale of a solution that was chosen or another (Aurisicchio et al. 2013).

In our approach, as regards its application to an existing product, components are known so their expression proceeded to function without a -verb -noun -standard formulation.

To realize this, we started to analyze the existent product, the mandrel (Grozav, 2006), (Rosculeț et al. 1983) (Fig.3) with a central wedge and plungers used for centering and fixing work pieces on their inner cylindrical surfaces.

This mandrel is a mandrel with mobile elements and is used in order to assure two reciprocating perpendicular symmetry planes for parts with inner cylindrical surfaces, fix forces being applied on these surfaces.

This mandrel can be used for centering on inner raw cylindrical surfaces and its components are: 1-central wedge, 2-Plungers (6 pieces) disposed at 60°, 3-central stem with screw, 4-springs, 5-mandrel body, 6 bushings. Part's centering and clamping is achieved through plungers synchronous movement obtained from the central wedge. When the stem with screw is manually actuated,

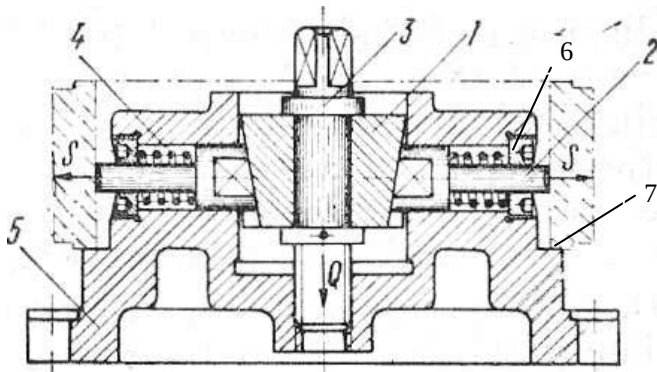


Fig.3. Self-centring mandrel with wedges and plungers
(Grozev, 2006)

the central wedge, centered in mandrel body, is driven by the stem and plungers guided on wedge surface are radially expanding until contacts the part's inner surface consuming the clearance and next transmitting the clamping force. The part is located through its contact with the mandrel body through pins 7.

The main functions (overall functions) and their corresponding technical functions are presented in following paragraph. The associated FAST diagram is in figure 4. With FP are principal functions and with FT are noted technical functions.

FP1 centering OL on inner cylindrical surface and prevent the piece movement

FT1 –use up clearance between work piece and elements that move radial, their contact with the work piece and work piece clamping needed for achieving the primary useful function FP1 is

achieved following the next functional chain between machine and piece:

- FT11- transmit movement from stem screw to the central wedge
- FT111- Wedge Centering in mandrel's body
- FT1111 Contact between wedge and mandrel body - auxiliary function
- FT1121 contact between wedge and stem with screw – auxiliary function
- FT12 – axial wedge movement
- FT13 - transmit the movement synchronous to plungers
- FT131 wedge-plungers contact
- FT1311 facilitate plunger movement-using wedge slots
- FT132 contact between plungers and bushings
- FT1321 contact between bushings and mandrel body
- FT14 – transmit the movement until plungers contact inner cylindrical surface and next transmit force to the piece
- FT141- wedge movement blocked - stem with screw retained as position
- FT1411 plungers blocked/retained as position and hold in contact with piece and wedge

FP1'- reverse movement – loosening the piece

CORRESPONDING COMPONENTS

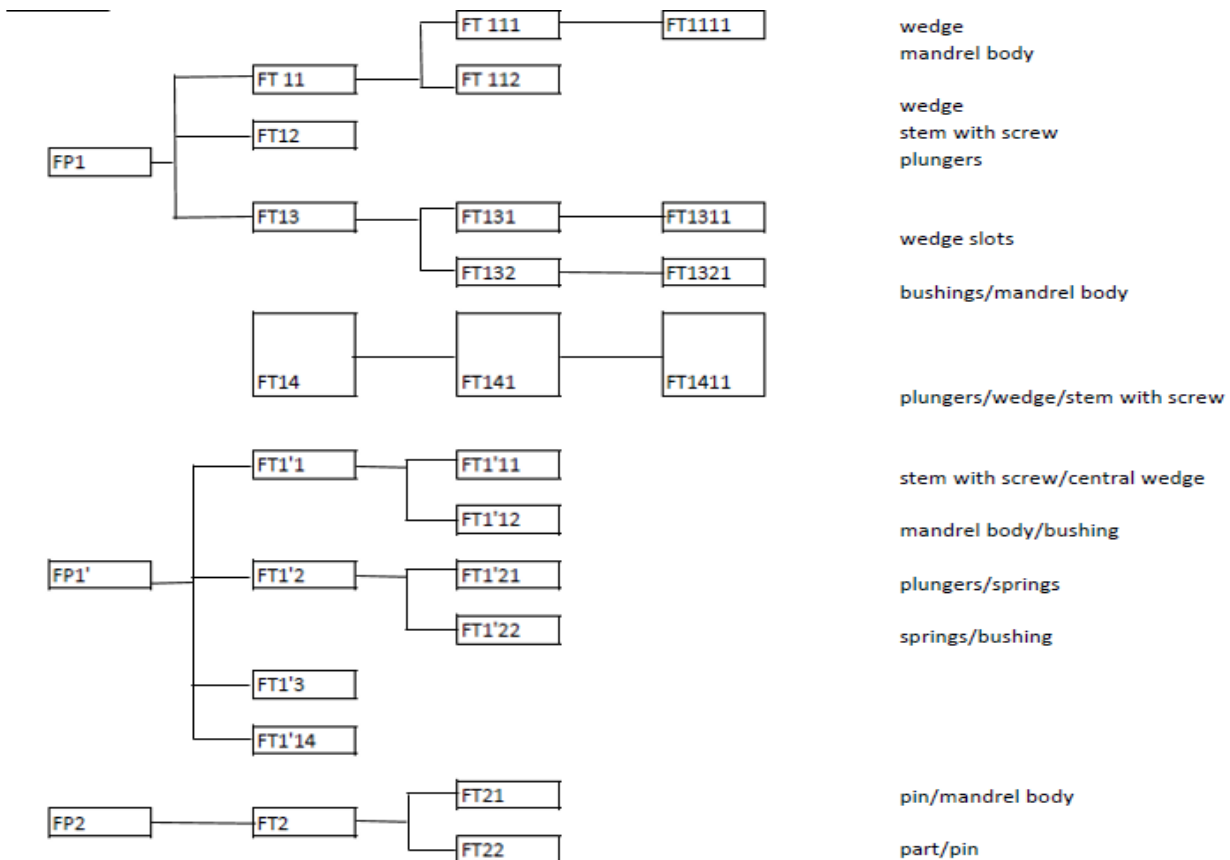


Fig.4.Functional decomposition of mandrel

FT1'1 transmit movement from stem screw to the central wedge
 FT1'11 contact between stem screw and wedge
 FT1'2 springs decompression
 FT1'21 contact between springs / plungers
 FT1'22 contact between springs/bushings
 FT1'3 plungers reverse movement
 FT1'4 loose contact between plungers and piece

FP 2 Hold the piece against locator is done through technical function FT2 that implies:

FT2 – Block part axial movement

FT21 - a contact between cover- locating pin
 FT22 - contact between piece and locating pin

For each function, its associated failures are:

FT11 screw failure
 FT111 - not set a proper clearance between mandrel body and wedge
 FT1111 wear
 FT1121 wear, unconformity shapes at connection between stem and wedge
 FT12 screw failure, plungers stack in mandrel body
 FT13 wedge slots and angle slopes
 FT131 wear
 FT1311 Wedge slots wear/damage
 FT132 Inadequate set up clearance between plungers and bushings
 FT1321 – set up adequate clearance between bushings and mandrel body
 FT14 –deformation of part's walls
 FT1411
 FT1'1 wedge screw failure
 FT1'11 Surfaces wear
 FT1'2 Springs failure
 FT1'21 inadequate contact surfaces
 FT1'22 inadequate contact surfaces
 FT1'3 wedge slots and angle slopes, spring force failure
 FT21 setting up an inadequate clearance
 FT22 locating pin wear

4. Results of discussions

In parallel, for each function inventoried and organized on each detail level there will be associated their specific failure modes. From the inventory of the fails on functions level of detail and then the fails associated to components it can be extracted the failures and their effects on the component / function itself as well as for subassemblies. For parts that are in contact each other it appears as mandatory to respect the adequate clearance and surface contact characteristics regarding reciprocate wear of surfaces. Regarding the synchronous plungers movement its fail is generated by either of components involved in this – stem with screw, wedge, springs, bushings and not at least the mandrel's body.

5. Conclusions

Even it seems to be very easy this analyze and the proposed approach are not because the products complexity because they are not single but in relation with another technical systems components. Presented failures are known but paper's aim was to emphasis a way to follow in finding onto levels of detail these

failures, associated with a functional model and rises some further questions and directions to follow - for example to inventory on types of work holding devices the potential failures and their causes using the presented approach and also how to take account of the results that come from a FMEA analysis for the current product and use it to achieve similar others but more reliable?

For similar products, the decomposition modules / assemblies and extraction of general conclusions about the types of defects, what should be avoided, what is improving if you try to avoid a failure which are the advantages and disadvantages using an combined approach may be useful. Such an approach can be applied to more complex systems for analyzing not a single product, but can be extended to related items, items that are part of the technological system: tool, part, machine tool. Depending on the system size / product application can be laboriously and very long. Because each method separately fit into a integrated engineering approach and their application involves team work, this approach is one that involves team work too and its application should be done through collaboration between team members.

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THERMOCHEMICAL CALCULATIONS AND EXPERIMENTAL INVESTIGATIONS ON Mo-Ni-B ALLOY SYSTEM PRODUCED BY COMBUSTION SYNTHESIS

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Abstract: In this study, Mo-Ni-B alloy system which can be a new hard alloy alternative to tungsten base cemented carbides, was investigated by means of thermochemical calculations and experimental trials. Thermochemical calculations were carried out to estimate the adiabatic temperatures and possible product compositions in the alloys by using FactSage 7.0 thermochemical software. The combustion synthesis process was performed under normal gravity and air in Cu copper crucibles by using metal oxides (MoO₃ and NiO), boron oxide (B₂O₃) as a boron source and aluminum (Al) as a metallic reductant. Alumina, (Al₂O₃) as a functional additive (diluent), were also added in order to reduce the adiabatic temperature of the reaction. Since the attained reaction temperatures for this system during the exothermic SHS process is so high (above 2000 °C), the reaction is self-sustaining and the melt consists of insoluble mixture of metallic compound and oxide phase which can be segregated under normal gravity force.

KEYWORDS: COMBUSTION SYNTHESIS, Mo-Ni-B, HARD ALLOY, THERMOCHEMICAL CALCULATIONS, FACTSAGE.

1. Introduction

Today, WC-Co MMCs are the mainstay of the manufacturing industry with a variety of applications including machining of many different metallic and nonmetallic materials [1]. According to the recent investigations, new hard alloys can be also successfully applied to wear resistance applications such as injection molding machine parts. For example, borides which have high corrosion resistance and strength can replace cemented carbides for some specific applications. A new hard alloy composite alternative contains a metal matrix of nickel as a binder and Mo₂NiB₂-type boride as a hard phase. However, due to the poor sintering behavior of borides and the formation of brittle phases with metals during sintering, reaction boronizing sintering technique are mostly used in previous studies which requires high power and consequently higher costs [2].

Combustion Synthesis (or Self Propagating High Temperature Synthesis) is one of the alternative production techniques that can be used to produce refractory metal compounds such as carbides, nitrides, silicides, borides as well as other intermetallics and metal matrix composites. The process has several advantages such as very short processing time, simple operation, low initiation energy requirement and low cost. In a SHS process, after ignition, the combustion front is formed and propagates throughout the reactant mixture yielding the desired product [3]. This work aims to establish a scientific background for high energy efficient, fast and low-cost production of Mo-Ni-B hard metal system starting from the cheap oxides by combustion synthesis method.

2. Experimental Studies

The raw materials of the SHS experiments are MoO₃ (99.5 wt. % pure, particle size < 60 µm), Al (99.6 wt. % pure and particle size <100 µm), NiO (99.0 wt. % pure and particle size <40 µm), Al₂O₃ (99.0 wt. % pure and particle size <50 µm). B₂O₃ was obtained by the calcination of 99.5 % pure boric acid (H₃BO₃, Eti Holding Inc.) in a nickel crucible at 800 °C for 2 hours followed by milling and sieving. After drying procedure of the powders in an oven at 110 °C for 2 hours, the mixture was prepared at different molar ratios. The SHS process was carried out in a copper crucible with the inner height of 200 mm and the inner diameter of 40 mm. The dried powder was mixed thoroughly in a Turbula mixer for 30 min. After the charge mixture was poured into the crucible and compacted thoroughly, a tungsten resistance wire was placed on the top of the compacted powder. The weights of the raw materials used in the experiments were shown in Table 1. The reaction was initiated by

passing electricity through the resistance wire. After initiation, electricity was cut off and the crucible was left to cool to room temperature. The characterization studies were performed by using atomic absorption spectroscopy (AAS), X-ray florescence (XRF), X-ray diffraction (XRD), scanning electron microscopy (SEM), energy dispersive spectrometers (WDS-EDS), and micro-hardness testing methods.

Table 1. Weights of initial raw materials for Mo-Ni-B systems

Initial Raw Materials	Exp. No	
	NI1	NI7
MoO ₃ , g	76,1	76,1
NiO, g	29,6	44,9
B ₂ O ₃ , g	18,4	18,4
Al, g	52,1	56,3
Al ₂ O ₃ , g	8,6	9,8

3. Results and Discussions

A thermochemical calculation was carried out to estimate the adiabatic temperature (T_{ad}) value and the possible product composition of the SHS reaction by using the advanced “Equilib” module of FactSage 7 developed by CRCT-ThermFact and GTT-Technologies²². In the calculations, FactPS, STGE2011, and FToxide were chosen as the most appropriate databases. In order to simulate the SHS reaction, 2 moles of MoO₃, 0.5 mole of NiO, 1 moles of B₂O₃ were equilibrated with different moles of Al. The reactions of the process were assumed as adiabatic ($\Delta H=0$) and the initial reaction temperature was selected as 25 °C.

The adiabatic temperature value (T_{ad}) is an important indicator to estimate whether a reaction is self propagating or not. The adiabatic temperature change versus Al addition in the combustion reaction is given in Figure 1. As can be seen, T_{ad} can reach over 2700 °C, when the Al addition is selected between 7-8 moles. Figure 2 shows that when the Al content in the raw materials increases, reduction and liquid Mo-Ni-B alloy formation also increases. However, in order to get higher boron content, Al dissolution in the alloy is unavoidable for the specific initial composition. The amount of gas also increases with Al addition due to the formations of AlBO_{2(g)}, BO_(g), Al₂O_(g), Ni_(g), B₂O_{3(g)}, and (BO)_{2(g)}.

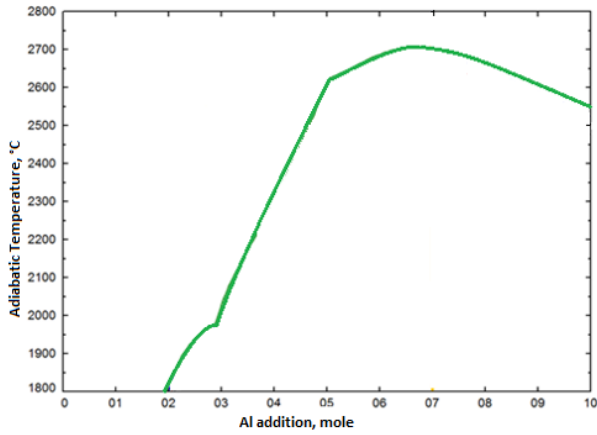


Figure 1. Thermochemical calculation for adiabatic temperature versus Al addition.

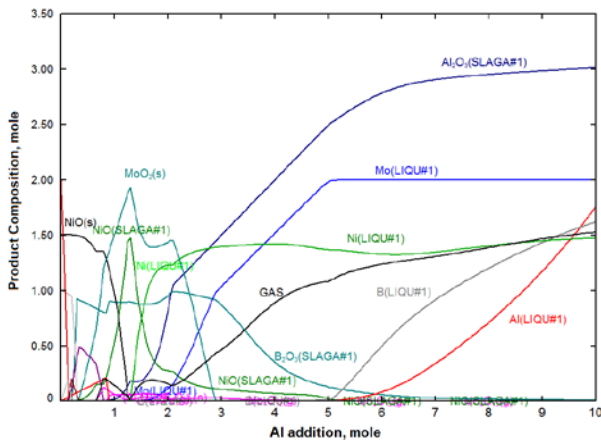


Figure 2. Thermochemical calculation for product composition versus Al addition.

The obtained SEM image of the specimen coded with NI1 is given in Figure 3. The EDS analysis shows that nickel reacted with excess aluminum to produce NiAl intermetallic which formed the matrix phase (1). The inner region of angular grains belong to MoB_2 phase (2) whereas the inner region are MoB (3). The mean hardness value of the specimen was found as 938,65 HV.

Figure 4 represents the obtained SEM image of the specimen coded with NI7. Since the initial NiO quantity is comparably higher than that of NI1, the excess Al reacted with high amount of Ni to form Ni_3Al phase. In the specimen, Mo_2NiB_2 region was also observed as gray angular form. The grains with white region represents MoB phase (3). The mean hardness value of the specimen was found as 943 HV.

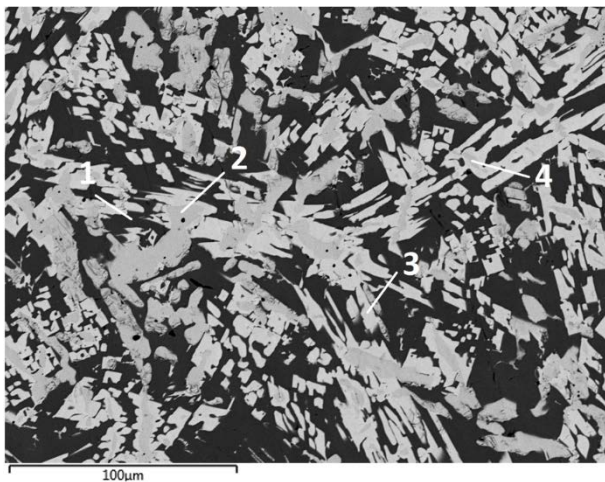


Figure 3. SEM analysis of the specimen NI1 (x500)

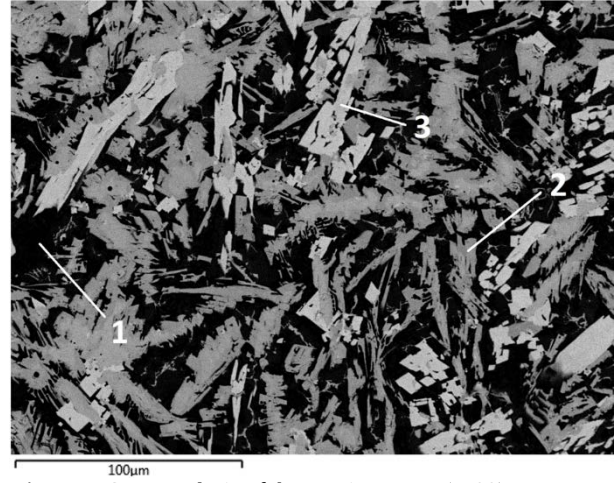


Figure 4. SEM analysis of the specimen NI3 (x500)

4. Conclusion

It is possible to produce a Mo-Ni-B containing metal matrix composites from oxides by aluminothermic reaction. The formation of ternary boride Mo_2NiB_2 in the product is possible with nickel oxide addition. Due to the high amount of excess Al in the alloy, NiAl or Ni_3Al phases form in the matrix. This study is an ongoing project and further experiments and analyses will be carried out in the near future.

5. Acknowledgement

The authors are pleased to acknowledge the financial support for this research from TUBITAK (The Scientific and Technological Research of Turkey - Project No: 213M555) and Russian Foundation for Basic Research (Project No:14-08-91374).

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SURFACE QUALITY OF WOOD PLASTIC COMPOSITES COATED WITH SOLVENT AND WATER BASED PAINTS

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Abstract: This study investigated surface hardness, roughness, and abrasion resistance of hot press molded wood plastic composite (WPCs) panels coated two types paints, water- or solvent-based paints. The WPC panels are produced from different amounts of pine wood flour (30 to 60 wt%), virgin polypropylene (37 to 67 wt%) and 3 wt% maleic anhydride polypropylene (MAPP). The surface abrasion resistance and hardness of the WPC panels painted with water or solvent based paints increased up to 50 wt% wood flour content, but further increment in the wood flour content decreased the abrasion resistance and hardness. The surface roughness of the painted WPCs increased with increasing wood flour content. The WPCs painted with solvent-based paints showed better surface quality as compared to the WPCs painted with water-based paints.

KEYWORDS: HYBRID COMPOSITES, MECHANICAL PROPERTIES, WOOD PLASTIC COMPOSITE, THERMOPLASTICS, WATER ABSORPTION, SURFACE HARDNESS,

1. Introduction

Coating Technology, a new process to coat wood plastic composites in virtually any color while enabling them to resist fading, heat retention, mold, mildew, stains and abrasion. The implementation of WPC with water-based paints could open up new application possibilities and markets in the construction sector, e.g. for façade and window sections. In the last few years, the WPC market in Europe has expanded rapidly and the outlook is viewed positively. In Germany, the current annual production volume is around 50,000 t, whilst Europe has an estimated capacity of around 120,000 t [1].

Among the reinforcing agents, natural fibers have significant advantages such as low cost, highly available and renewable, with low density and high specific properties as well as biodegradable and less abrasive to processing equipments. Among commodity thermoplastics, polypropylene (PP) possesses outstanding properties such as low density, good flex life, sterilizability, good surface hardness, very good abrasion resistance, and excellent electrical properties. However, the main drawback of PP is low modulus as compared to the wood. The purpose for the addition of cellulose-based fillers to thermoplastics is to reduce the cost per unit volume and to improve stiffness.

It is currently not possible to satisfactorily coat WPC surfaces with water-based paints. The reason for this is the low surface energy and the barely-existent functionality which result in bad wettability and lack of material anchorage for aqueous binders [1]. Solvent-based paints, sometimes referred to as "oil-based" or "alkyd" paints, contain a significantly higher level of organic solvents than water-based paints. These solvents are responsible for the strong odor noticeable in buildings that have been freshly painted. They are also potentially hazardous for both human health and for the environment which is why concerted efforts are being made to reduce or remove their presence in paints without negatively impacting on paint performance. water-based paints, often referred to as acrylic emulsions, are increasingly replacing organic solvents across a broad range of paint applications and surface areas [2].

Appropriate coatings can provide outstanding scratch resistance, as well as provide a surface that is easy to clean. Appropriate coatings can seal the WPC to prevent moisture absorption, mold growth, and physical property reduction. Using coating systems can also enable homeowners to repaint their WPC to match new decoration schemes, or repair scratches or mars over time of use [3]. There is limited information about the effect of raw material

formulation on the surface properties of WPCs painted with water or solvent based paints. In this study, the surface roughness, hardness, and abrasion resistance of painted WPCs produced with different amounts of wood and PP.

2. Materials and methods

2.1. Materials

PP granulates produced by Likom PP Co., Ukraine, was used as the polymer matrix (Fig. 1). Its density and melt flow rate (230°C /2.16 kg) were 0.90 g/cm³ and 6.5 g/10min, respectively. The compatibilizing agent, maleic anhydride modified homopolymer polypropylene (MAPP) (Optim-425, MFI/190°C; 2.16 kg = 110 g/10 min, density: 0.91 g/cm³), was supplied by Pluss Polymers Pvt. Ltd. in India.

Pine wood particles were obtained from the round woods by using a disc chipper with three knives, followed by grinding process in a laboratory type grinder. The average size of the wood flour without bark was 40 US-mesh (Fig. 2).



Fig. 1: Polypropylene and wood flour.



Fig. 2. Compound obtained from twin scriw co-rotating extruder.

The water based paint which was acrylic copolymer emulsion paint and solvent based paint which was long oil alkyd paint were supplied from a commercial paint manufacturer. The density and viscosity (DIN cup 4mm) of the water-based paint were 1.52 g/ml and 115 s, respectively. These properties were found to be 1.20 g/ml and 110 s for the alkyd paint, respectively.

2.2. Preparation of hot-press molded WPCs

The wood flour was dried overnight at 90 °C in a vacuum oven prior to melt blending. The pre-mixed wood flour, polypropylene, and coupling agent were fed into the main feed throat using a volumetric feed system. The pellets were then dried in an oven at 90 °C for 24 h after the extrusion process. The mat was prepared with the dried pellets by a hot compression molding process. The mixture was weighed and formed on an aluminum caul plate, using a 290 mm × 290 mm forming frame. A steel frame was used to prevent a lateral yielding of the dry-blend mixture during the hot pressing. Wax paper was used to avoid direct contact of the polypropylene flour with the metal platens of the hot-press. Subsequently, the pellets were compression molded in a hot press. The mats were hot pressed for 8 min under 5.5 MPa at 190 °C in a one-step process (Fig. 3). At the end of the hot pressing cycle, the panel was immediately moved from the hot press into a press at room temperature for cooling. 3 mm thick WPC panels were then trimmed to a final size of 100 mm × 100 mm.



Fig. 3: Production of hot pressed WPC boards.

A total of 16 experimental panels, 2 for each type of WPC panel, were manufactured. The air-dry density values of the specimens varied from 1.05 to 1.08 g/cm³. The raw material formulations used for the WPCs are presented in Table 1. The specimens were conditioned to constant mass at a temperature of 23 °C and a relative humidity of 50% according to ISO 291.

Table 1: The raw material formulations of the WPCs.

WPC code	Wood flour (%wt)	Polypropylene (PP) (wt%)	MAPP (wt%)
A	30	67	3
B	40	57	3
C	50	47	3
D	60	37	3
E	30	67	3
F	40	57	3
G	50	47	3
H	60	37	3

2.3. Paint application on the WPC panels

The solvent or water based paints were applied on the WPC boards by spray coating technique. The amount of the paint applied on the WPC surface was 200 g/m². The paint was uniformly applied on the surface of the WPC panels as shown in Figure 4.



Fig. 4: The application of the paint on the WPC board.

Curing of the paint was performed at room temperature for 24 h. The spray pressure and nozzle angle were 120-140 bar and 50°, respectively. The nozzle diameters for the water and solvent based paints were 0.48 and 0.33 mm, respectively. The 10 wt% water as thinner was added into the paint.

2.4. Measurement of surface roughness

Two samples with a size of 50 mm by 50 mm from each type of panel conditioned at 23 °C and 50% relative humidity were used for surface roughness evaluations. A total of ten measurements with a 15-mm tracing length, 5 along the sandmarks and 5 across the sandmarks, were taken from each face of the samples. The points of roughness measurements were randomly marked on the surface of test samples. A Mitutoyo SJ-301 surface roughness tester, stylus type profilometer, was employed for the surface roughness tests. Three roughness parameters characterized by ISO 4287 (1997) standard, respectively, average roughness (R_a), mean peak-to-valley height (R_z), and maximum peak-to-valley height (R_y), and root mean square roughness (R_q) were considered to evaluate the surface characteristics of the panels. Roughness values were measured with a sensitivity of 0.5 μm. Measurements were done at room temperature and pin was calibrated before the tests. The profilometer used for the measurements consisted of main unit and a pick-up which has a skid-type diamond stylus with 5 μm tip radius and 90° tip angle. The stylus traversed the surface at a constant speed of 10 mm/min and measuring force of the scanning arm on the samples was 4 mN (0.4 gf).

2.5. Abrasion resistance of the painted WPCs

The abrasion resistance of the painted WPCs was determined according to ASTM D4060 which was standard test method for abrasion resistance of organic coatings by the Taber abraser. The test specimen is mounted to the Taber Abraser turntable and rotated at a fixed speed under a weighted CS-10 abrading wheel. Initial and final abrasion levels were determined visually based on the initial indication of pattern fading and extremely worn out pattern on the paper, respectively. Rotations of the disks were consistently counted and corresponding values at abrasion levels were used to calculate average abrasion resistance. Four measurements, two for each specimen, were used for each WPC code.

2.6. Surface hardness of the painted WPCs

The surface hardness of the WPCs was determined according to ASTM D4366 – 14. The pendulum damping test has been found to have good sensitivity in detecting differences in coating hardness, where hardness is defined as resistance to deformation. A total of 10 measurements, 5 measurement for each specimen, were used for each WPC code.

3. Result and discussion

3.1. Surface roughness of the painted WPCs

The surface roughness values of the WPCs coated with solvent and water based paints are presented in Figures 5 and 6. As compared to the control WPC samples, the average surface

roughness (R_a) of the WPCs painted water-based paint slightly increased with increasing amount of wood flour while this was not observed for the WPCs painted with solvent-based paints. The average roughness of the WPCs painted with water-based paints increased from 2.36 to 2.75 μ as the wood flour content increased from 30 to 60 wt% in the WPC while this property was found to 3 to 2.5 μ for the WPCs coated with solvent-based paint. Previous studies reported that the increment in the filler content increased the surface roughness of the thermoplastic composites [4,5]. However in our study, it was observed that the surface roughness of the solvent-based paint coated WPCs decreased with increasing wood flour content.

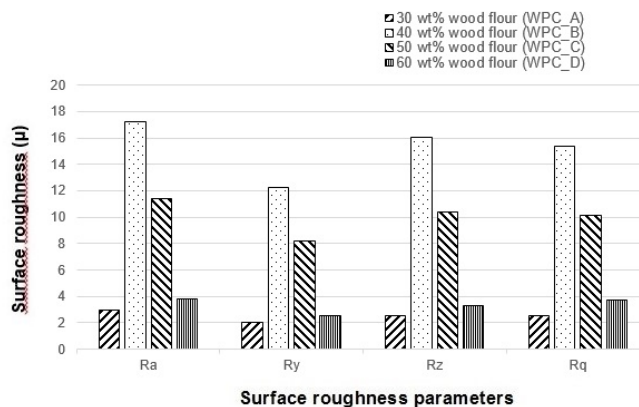


Fig. 5: The surface roughness parameters of WPCs coated with solvent-based paint.

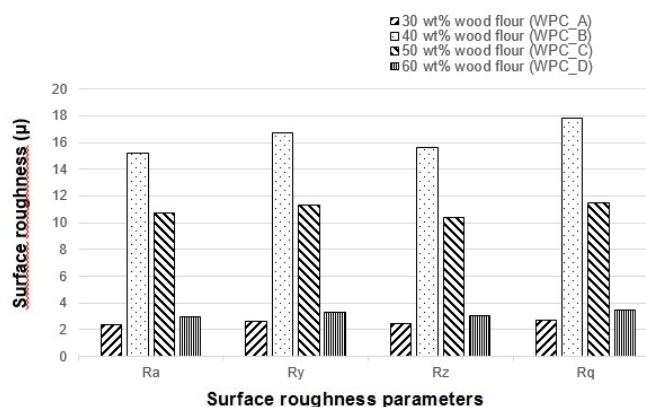


Fig. 6: The surface roughness parameters of WPCs coated with water-based paint.

3.2. Abrasion resistance

The results of abrasion resistance of the coated WPCs are presented in Table 2. In general, the abrasion resistance of the WPCs coated with water or solvent-based paints showed difference based on the wood flour content. The scratch resistance of the materials depends on the chemical composition, density and the hardness of the materials. The abrasion resistance of the materials is important when they are used as flooring material.

Table 2: The results of abrasion resistance of the painted WPCs

Paint type	WPC code	Initial abrasion (cycle)	Final abrasion (cycle)	Average abrasion (cycle)
Water-based paint	A	27	69	40
	B	42	154	98
	C	38	219	129
	D	36	95	65
Solvent-based paint	E	57	141	99
	F	42	180	111
	G	51	172	112
	H	28	78	53

3.3. Persoz pendulum

The results of persoz pendulum test are presented in Table 3. The number of oscillation of the WPCs coated with water-based paint increased up to 50 wt% wood flour content but further increment in the wood flour content decreased the number of oscillation. A similar results was found in the WPCs coated with solvent-based paint. However, the number of oscillation of the WPCs produced with 60 wt% was found to be higher than that of WPCs produced with 30 wt% wood flour. This was not observed for the WPCs coated with water-based paint.

Table 3: The results of persoz pendulum of the painted WPCs

Paint type	WPC code	Number of Oscillation	Duration (s)
Water-based paint	A	67	67
	B	70	70
	C	73	74
	D	55	55
Solvent-based paint	E	61	61
	F	69	69
	G	73	74
	H	70	71

4. Conclusions

The results of the research revealed that the surface properties of the WPCs coated with water or solvent based paints showed the differences based on the wood flour content. There was no significant difference in the average surface roughness values among the painted WPCs produced with the 30 wt% and 60 wt% wood flour. The highest abrasion strength and hardness were found in the coated WPC specimens produced with 50 wt% wood flour. Based on the findings obtained from the present study, it can be said that the WPCs prepared from the PP/wood flour/MAPP (47/50/3 wt%) had the optimum surface quality properties among the evaluated WPC codes.

5. Acknowledgement

This work was supported by Research Fund of the Istanbul University. Project number: BEK-20032. The authors wish to acknowledge Research Fund of the Istanbul University for financial support.

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THE EFFECT OF ADDING NIOBIUM ELEMENT (Nb) ON METALLURGICAL PROPERTIES OF Fe-Cr-C HARDFACING

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Abstract: in this study, the hard facing with Fe-Cr-C base welded wire and Fe-Cr-Nb-C cored welding wire by using submerged-arc welding method in single-pass, two-pass and three pass over the pieces of carbon steel (St37) was done. Cored welding wire Fe-Cr-Nb-C by an approximate ratio of 5.41 Cr to C ratio, was containing 5.6 to 7% of the niobium element. scanning electron microscopy, optical microscopy, X-ray diffraction and point analysis, indicates the presence of carbides (Fe, Cr) γ -C₃ and Nb₂C in hardened samples with Fe-Cr-Nb-C welding wire. The results showed that with increasing number of hardened passes, the percentage of carbon, chromium and niobium concentrations increased and as a result the dilution percent was decreased that cause to increasing hardness and better performance. test results indicate higher hardness of hardened samples with Fe-Cr-Nb-C welding wire compared to samples hardened with Fe-Cr-C welded base wire. With increasing number of of hard passes, hardness was increased, so that the highest and lowest hardness is related to three pass samples that was hardened with metal cored wire Fe-Cr-Nb-C. The reason of increased hardness in three-pass samples hardened with Fe-Cr-Nb-C metal cored wire was to with increasing in the number of hardened passes, dilution rate was reduced by the base metal and this cause to coarse and more uniform distribution of carbides.

KEYWORDS: COMPLEX CARBIDES, HARDFACING, SUBMERGED OPEN ARC WELDING, HARDNESS

1. Introduction

In this study, we tried to examine the effect of adding 5.6 to 7% niobium element to chromium alloy welding wire with an approximate ratio of 5.41 Cr to C ratio. here, adding complex carbide either chromium carbide and niobium carbide by morphology and different distribution was created in the microstructure that by the shape, phases distribution and review of complex carbides on wear properties of new welded wire and precise linking of microstructure by metallurgical and mechanical properties is the goal of this research.

Materials and methods

In this study, plain carbon steel (St37) was used as the base metal with dimensions of 10 × 100 × 150 mm. In Table 1 was shown the chemical analysis of welding base wire Fe-Cr-Nb-C and Fe-Cr-C. Samples numbers and pass numbers for each test was shown in Table 2.

Table 1 chemical composition of cored wires wt%

Flux Core d wire Nam es	Type of cored wires	Carbon	Silicon	Manganese	Chromium	Niobium
KJTU BO-455	Fe-Cr-C	4.3-4.8	1.3	0.3	26-29	-
KJTU BO-460	Fe-Cr-Nb-C	4.8-5.4	1-1.2	0.3-0.4	19-22	6.5-7

Table 2. Samples numbers and pass numbers of welding for each test

6	5	4	3	2	1	Sample Number
Fe-Cr-Nb-C	Fe-Cr-Nb-C	Fe-Cr-Nb-C	Fe-Cr-C	Fe-Cr-C	Fe-Cr-C	Type of cored wires
Three pass	Two pass	One pass	Three pass	Two pass	One pass	number of pass

Surface hardening by submerged arc welding method was performed according to presented parameter in Table 3.

Table 3. Welding parameters

Process	Voltage	Current (A)	Welding Speed (cm/min)	Polarity
Submerged-arc welding -Open arc	27-29	380-480	70-80	DCEP

Optical microscopy, Scanning electron microscope, XRD test, hardness and chemical composition analysis were carried out on welded samples.

The chemical composition and microstructure

The chemical composition of surface and percentage of dilution in layers was shown in Table 5. As can be seen by increasing the number of hardened layers, carbon, chromium and niobium were increase and the rate of dilution has decreased.

In Figure 1 corner diagram of iron with the ternary structure Fe-Cr-C was shown. Location of samples 1, 2 and 3 in Figure 1 was shown in Table 4.

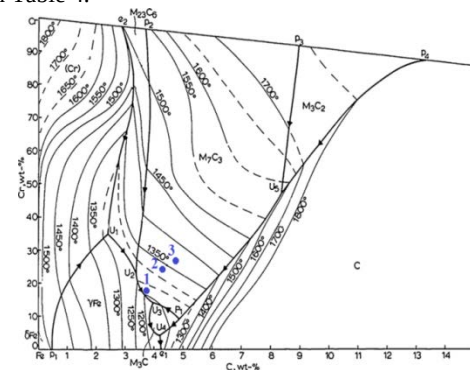


Fig 1. Corner diagram of iron with the ternary structure Fe-Cr-C [1]

According to the chart, hardened samples with Fe-Cr-C welding base metal have been included M₇C₃ phase. Nucleation and growth of M₇C₃ carbides at 1350 ° C was started and by over time from onset of freezing, melt carbon was reduced and eutectic transformation occurred. Also according to the percentage of carbon element, the resulting structure of the sample number 1 was hypo eutectic and examples 2 and 3 has been the hyper-eutectic.

In Figure 2 hyper-eutectic freezing diagrams from samples 4, 5 and 6 on the basis of chemical composition was indicated in Table 4. considering The percentage of chromium and carbon, the resulting structure in the samples 4, 5 and 6 was of the hyper-eutectic. According to Figure 2, at a temperature of 1500 ° C, M_2C carbide Table 3 Concentration of elements in different pass number of samples %wt and percent of dilution in each pass layer

was formed and then reaching to 1300 °, M_7C_3 carbide was formed. Then, reaching a temperature of about 1170 ° C, austenite was formed, and finally reducing the temperature to about 850 ° C and frozen, ferrite phase was formed.

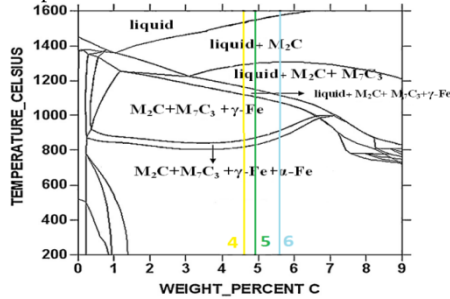


Fig 2. Hyper-eutectic freezing diagrams of system [2]

3.2. X-ray diffraction results

In Figure 3, X-ray diffraction results show that the phase Cr_7C_3 , Fe_3C , austenite-ferrite in three single-pass mode, two pass and three pass mode. Reason for the formation of Cr_7C_3 carbide, forming the chromium carbide element has been desire. In Figure 3 X-ray diffraction pattern of samples hardened with flux cored wire Fe-Cr-Nb-C was shown. X-ray diffraction results show that phases Nb_2C , $(Fe,Cr)_7C_3$, Cr_3C_2 , Cr_2Nb , Fe_3C , austenite-ferrite has been working on hard surfaces.

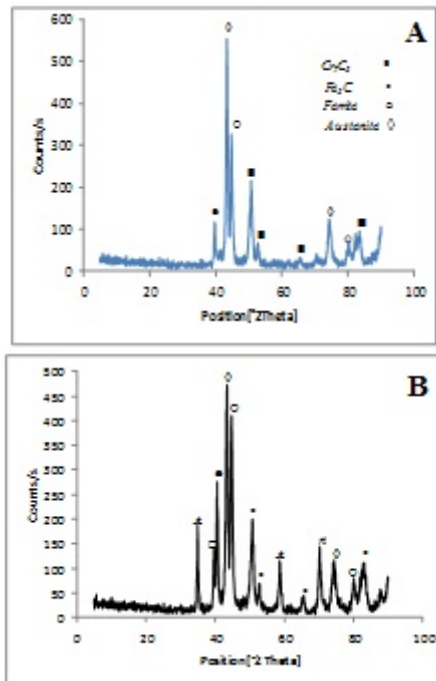


Fig 3. X-ray Diffraction patterns of A: Fe- Cr-C B: Fe- Cr- C -Nb deposits

With the addition of element niobium (Nb) to the wire base Fe-Cr-C, carbide was created on the cover due to the combination of lower free energy of formation of carbide NbC , as well as a greater willingness of niobium to iron in the carbide formation [3].

3.3. Grained microstructure

3.3.1. Optical microscopy (OM)

In Figure 4 images related to optical metallography of samples hardened with base welded wire Fe-Cr-C in single-pass mode, two pass and three pass was shown. As is shown, microstructure, consisting of tiny chrome carbide in the austenitic and ferritic field and distributed in accordance with the results of X-ray diffraction (Fig. 3). Increasing the number of hardened passes, due to reduced dilution of the base metal as it shown in Table 5, percent of chromium and carbon was increased and carbide size is larger, so that the sample 3 compared to the numbers 1 and 2 have been larger carbides. In Figure5 an optical microscope image of the hardened sample with flux cored wire Fe-Cr-Nb-C was shown. Comparing Pictures 4 and 5 show that by adding 5.6 to 7 of weight percent of the element niobium to wire welding base Fe-Cr-C, carbides containing niobium and iron and chromium was shaped, which are in accordance with the results of X-ray diffraction (Figure 3) and this carbide was uniformly distributed in austenitic and ferritic field. The reason for this is that the element niobium is stronger carbide former element than chromium. As can be seen, with increasing number hardened passes, the sample size of carbides become greater such that ,sample number 6 (sample three assists hardened welding with Fe-Cr-Nb-C) compared to the 4 and 5 with carbide has been greater.

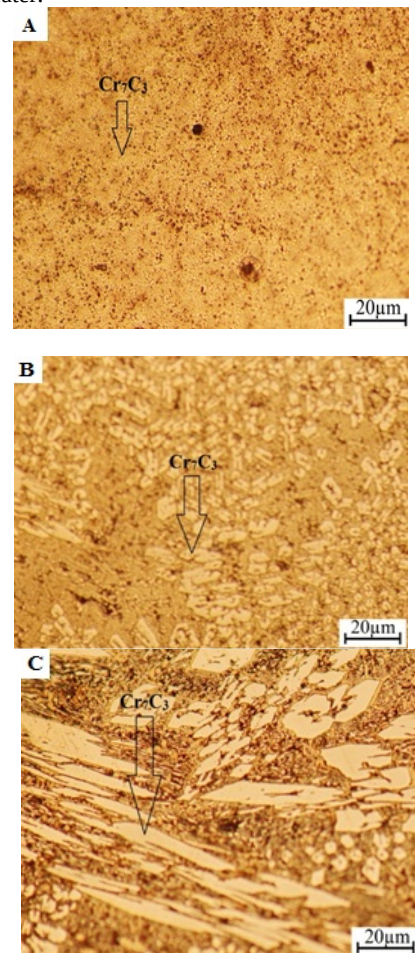


Fig 4. Optical microscopy of Fe -Cr -C layers A: one pass B: two pass C: three pass

Sample Number	Fe	C	Si	Mn	S	Cr	Nb	Percent of dilution
1	76.8	3.67	1.23	0.42	0.013	17.6	0.0018	40
2	68.2	4.25	1.42	0.41	0.027	21.5	0.0021	26
3	63.3	4.85	1.43	0.37	0.087	23.8	0.0034	18
4	73	4.65	2.26	0.38	0.031	16.1	6.35	27
5	71.3	4.97	2.71	0.36	0.045	18.7	6.6	15
6	69.3	5.65	2.78	0.33	0.048	19.6	6.8	11

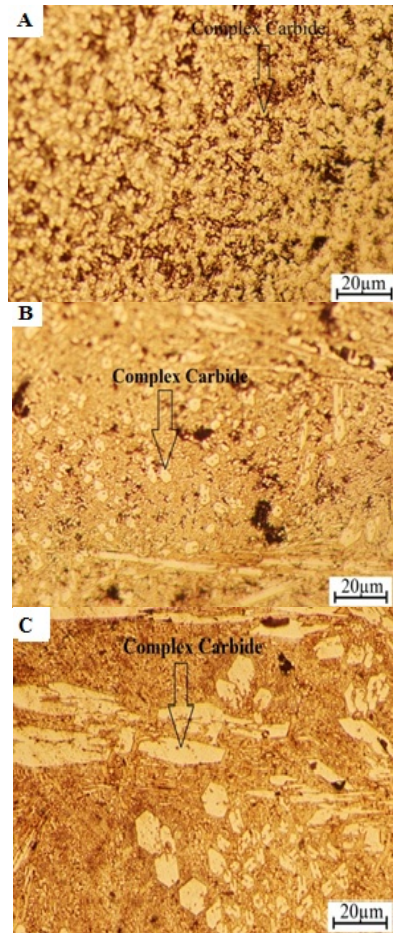


Fig 5. Optical microscopy of Fe-Cr-C-Nb layers A: one pass B: two pass C: three pass

Scanning Electron Microscope (SEM)

In Figure 6, Scanning electron microscope images of hardened samples with welded wire base Fe-Cr-C, was shown in three single-pass mode, two pass and three pass modes. According to Figure 6 (a), we can see that the structure of single pass mode composed of very fine carbides and whatever the number of hardened passes increased, carbides size gets bigger. The results of X-ray diffraction and optical microscopes images (Figures 3 and 4) the structure of hardened samples with Fe-Cr-C welding wire base was formed of chromium carbides in austenite and ferrite field. In Figure 7 SEM images of the samples 4, 5 and 6 have been hardened with flux cored wire Fe-Cr-Nb-C, was shown in three single-pass, two-pass and three-pass mode. As determined, and according to the results of X-ray diffraction and images of optical metallography (Figures 4 and 7) of the samples hardened with welded wire Fe-Cr-Nb-C, a microstructure with carbides containing niobium, iron and chromium in the austenitic and ferritic field was observed. By Comparing scanning electron microscopy (Figures 6 and 7) was shown that the number of hardened passes, the percentage of dilution is reduced, resulting in increased concentrations of niobium and carbide size become larger.

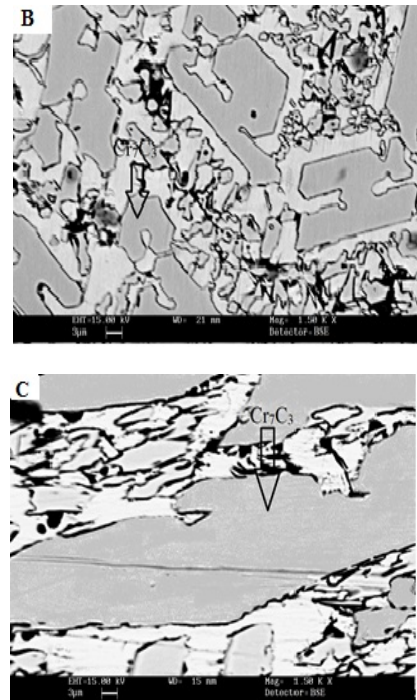
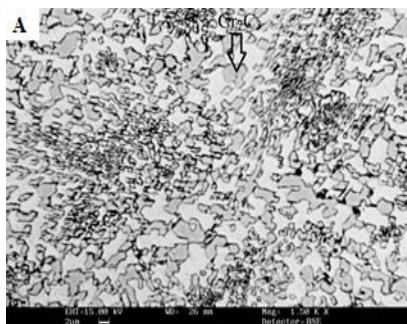


Fig 6. SEM images of Fe-Cr-C layers A: one pass B: two pass C: three pass

3.4. Element Analysis Test (EDS)

In Figure 8, the result of elemental analysis of the three-passes hardened by base welded wire Fe-Cr-C was shown. This analysis from the point A hardened sample with Fe-Cr-C Welding wire was shown in Figure 8. In this case, the maximum amount of iron, chromium and carbon is formed. By comparing the elemental analysis and X-ray diffraction results (Figure 3), determined that in the above example, chromium carbide is formed. In Figure 9 the results of the elemental analysis from point B on the hardened three-pass example by welding wire Fe-Cr-Nb-C was shown. Most of the elements in this carbide were niobium and carbon and so at point A, was formed carbide that containing (Nb₂C).

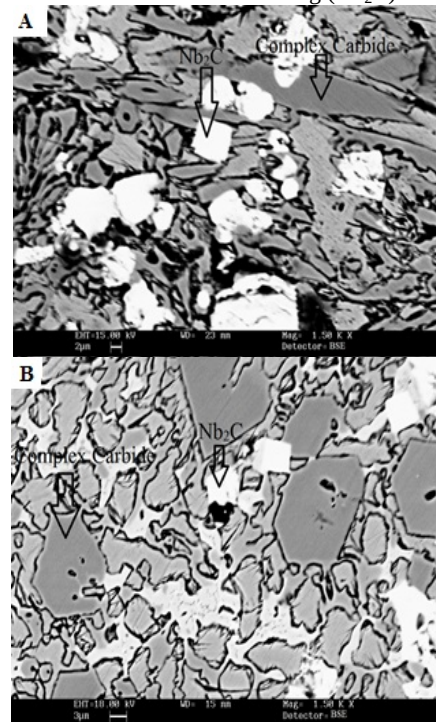


Fig 7. SEM images of Fe-Cr-C-Nb layers A: two pass B: three pass

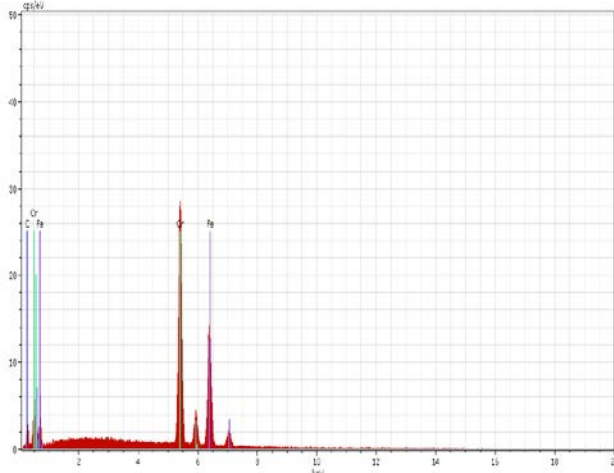
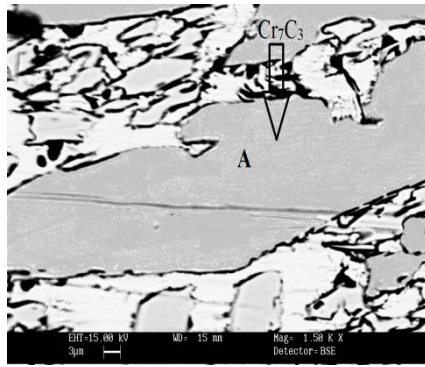


Fig 8. EDS analysis of Chromium carbide in Fe-Cr -C three pass layer

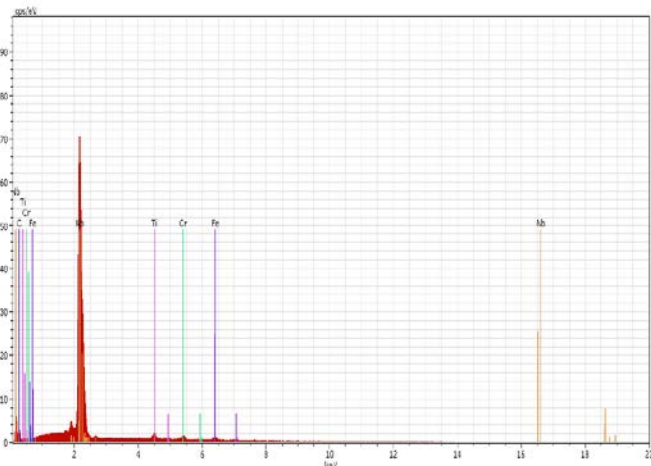
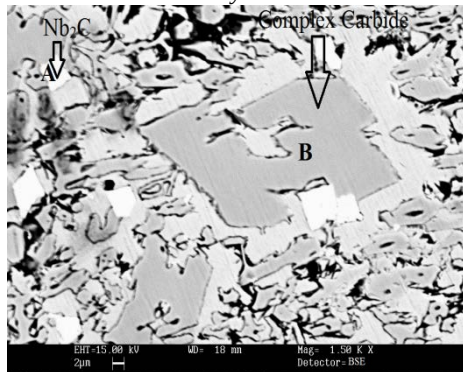


Fig 9. EDS Analysis of complex carbides in Fe -Cr -C- Nb three pass layer

4.4. Hardness results

In Table 6, test results of hardened layer were shown. Hardness of samples that hardened with metal cored wire Fe-Cr-Nb-C were higher than hardness of samples hardened with welded wire base Fe-Cr-C. The highest hardness is related to three-pass samples

hardened by wire Fe-Cr -Nb-C with 63.8 Rockwell hardness. As shown in Figures 4 to 7, with increasing the number of hardened passes, due to reduced dilution, increased value and hardness of the carbide elements.

Table 4. Hardness in HRC for different tests

Sample Number	1	2	3	4	5	6
Hardness	± 0.4 56.5	$0.8 \pm$ 59.5	60.1 ± 0.4	± 0.5 58.5	± 0.5 62.5	63.8 ± 0.4

4. Conclusion

In this study, the effects of adding the element niobium on metallurgical properties hard weld base Fe-Cr-C were studied, the most important findings of the research include:

1. Hardening the surface with welded wire base Fe-Cr-C on plain carbon steel result in the formation of chromium carbide in austenitic and ferritic field .
2. By adding the element niobium to alloy system Fe-Cr-C, alloy of niobium carbides and carbide complex is formed in austenitic and ferritic.
3. With a reduction in dilution effect of increasing the number of hardened layers, the percentage of alloying element such as carbon, chromium and niobium which causes coarse carbides is increased.
4. The highest hardness is related to three-pass samples with flux cored wire Fe-Cr-Nb-C with a Rockwell C hardness of 8/63, but also the lowest hardness is related samples harden with to single pass welding with base Fe-Cr-C with hardness 56.5 Rockwell .

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HEAT TREATMENT, MICROSTRUCTURE AND PROPERTIES OF 75CR1 STEEL, FOR USE IN HEAVY LOADED ELEMENTS

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Abstract: This study aims to optimize the heat treatment of tool steel 75Cr1 which is used for heavy loaded elements in transmissions. A salt bath was used to quench and temper the steel at different temperatures. Mechanical tests and microstructural characterization were done to define the heat treatment parameters corresponding to the optimal performance of the elements. Optical microscopy, electron back scatter diffraction and x-ray diffraction were used to characterize the microstructure, while tensile tests and toughness tests were employed to determine the mechanical properties after different heat treatments. It was found that the yield strength decreases with increasing annealing temperature and that the toughness decreases with increasing annealing time and temperature. The changes of the mechanical properties are discussed in relation with the thermal treatment and the corresponding microstructures.

Keywords: HEAT TREATMENT, TOOL STEEL, MICROSTRUCTURE

1. Introduction

Important factors affecting competition in the automotive market are product quality, innovation and development time, price, reliability, safety, fuel economy and emission control [1]. The Continuously Variable Transmission (CVT) is a very efficient system with a high potential for future application in new generation vehicles. This type of automatic transmission provides low fuel consumption, no torque interruption during gear change and optimum power range of the engine [2]. Instead of using fixed gears, the CVT uses two pulleys connected by a pushbelt to transmit torque. The pushbelt is built up of hundreds of steel elements and two maraging steel ring packs. The elements are subjected to high cyclic loads and they should possess a high yield stress and wear resistance. Therefore a tool steel 75Cr1 is used for the production of the elements.

The steel is annealed at varying temperatures and soaking times and subsequently oil quenched and tempered. The steel contains chromium, which participates in the cementite formation. According to [3] the alloying elements partition between the austenitic matrix and the retained (undissolved) carbides during austenitizing. This partitioning fixes the chemistry and volume fraction of the carbides as well as the composition of the austenite. Finer carbides and a larger volume fraction of carbides will control the austenitic grain growth and can influence significantly the mechanical properties. Hence, the goal of the work is to understand better the influence of the heat treatment parameters on the strength, elongation and toughness of the elements made of 75Cr1 steel.

2. Experimental procedures

The nominal composition of the steel is given in Table 1. This high carbon low alloyed steel is classified as tool steel. The as received material has a thickness of 1.8 mm and is in the so called soft annealed (or spheroidization annealed) condition. In this condition the steel microstructure is ferrite with (Fe,Cr)₃C carbides. The steel was subjected to 40 different heat treatments in a salt bath with varying annealing temperatures and times and subsequently oil quenched to form martensite. The different temperatures were 800, 820, 860 and 900 °C, and at each temperature the samples were soaked for 2, 4, 6, 8, 10, 12, 15, 20, 25 or 30 minutes before oil quenching. Afterwards all samples were tempered at 190 °C for 45 min. For every set of heat treatment parameters, 3 tensile samples, 30 samples for the toughness test and several extra samples for the microscopy tests were prepared.

Table 1: Nominal composition of 75Cr1.

Element	C	Si	Mn	P	S	Cr	Fe
wt. %	0.74-0.80	0.25-0.40	0.65-0.80	max. 0.025	max. 0.010	0.30-0.45	bal.

XRD analyses were performed with a Siemens Diffractometer D5000 with a molybdenum X-ray tube. The angular range of 25°-40° was scanned with a step size of 0.05° and 5 s/step. Using the formula of Cullity [4], the fraction of retained austenite was calculated for different heat treatments. The electron backscatter diffraction (EBSD) data were acquired in a FEI Nova 600 Nanolab at 20 kV and beam current 2.2 nA. The sample preparation consisted of mechanical and electrolytic polishing with A2 Struers electrolyte, followed by 40 min OP-U polishing with pressure less than 5 N. Tensile specimens were prepared according to the ASTM standard E8M-04 (gage length 50 mm). Tensile tests were carried out on a Zwick Z250 testing machine with a speed of 20 MPa/s until the yield point, and 0.0067 mm/s cross head speed for strain controlled plastic deformation until fracture. The Izod impact tests were executed on a Zwick/Roell HT55P machine.

3. Results

Equilibrium calculations of the Fe-C-Mn-Cr-Si system were performed using the Thermo-Calc software. From the Fe-C isopleth in Fig. 1 one can derive that for 0.75% C the A_{e1} and A_{cm} temperatures are 722 and 770 °C respectively and that ferrite, cementite and austenite are in equilibrium in the temperature range between 722 and 734 °C.

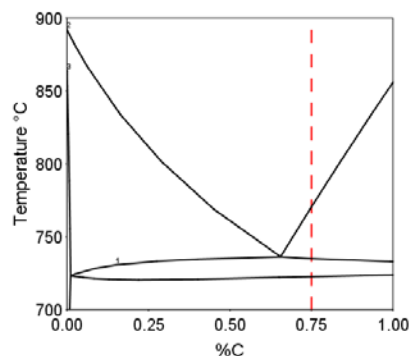


Fig. 1 Fe-C isopleth of the alloy, the carbon content of the 75Cr1 steel is indicated with a red dashed line.

Fig. 2 displays the variations in the equilibrium phase fractions for the 75Cr1 steel grade as a function of temperature. According to Thermo-Calc calculations cementite is the stable carbide among the other complex carbides. When the annealing temperature is above 734 °C, the maximum equilibrium cementite fraction is 1.6%.

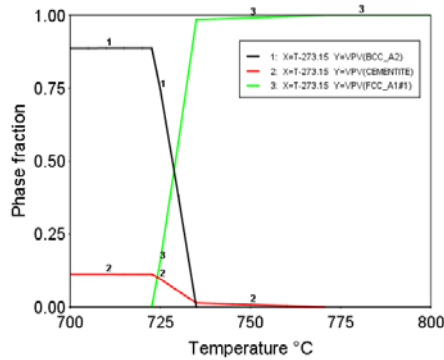


Fig. 2 Relationship between phase fraction and temperature in 75Cr1.

The microstructure of the as received material in the soft annealed condition is visualized in Fig. 3. Etching with 4% HNO₃ in ethanol (4% Nital) for 8-11 s reveals clearly the grain boundaries and the spherical carbides (Fig. 3a). The volume fraction of carbides measured by quantitative metallography on multiple samples was about 12-13%. The EBSD maps (Fig. 3b, c) show that around 8% spherical iron carbides are present in the ferritic matrix. This underestimation of the carbide fraction measured with EBSD in comparison to the optical microscopy data is most probably due to the smaller area of the EBSD scan and the incorrectly indexing of some carbide orientations.

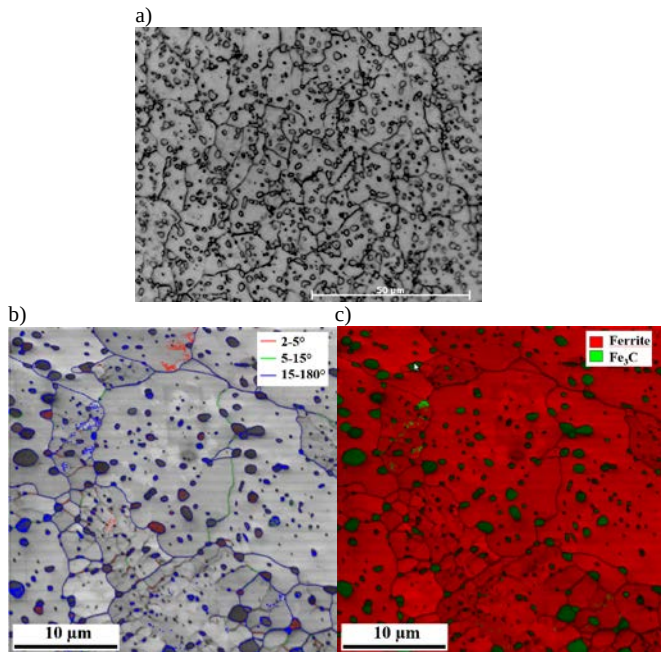


Fig. 3 Microstructure of the as received material; a) optical microscopy after Nital etching, b) EBSD image quality and grain boundary map, c) EBSD image quality and phase map superimposed.

Fig. 4 shows the image quality and inverse pole figure maps of a sample annealed at 860 °C for 15 minutes which is oil quenched and afterwards tempered. The martensitic structure typical for high carbon steel is visible. In comparison with the starting material, less and smaller carbides can be observed. Some small regions of austenite in between martensite could be distinguished in Fig. 4c.

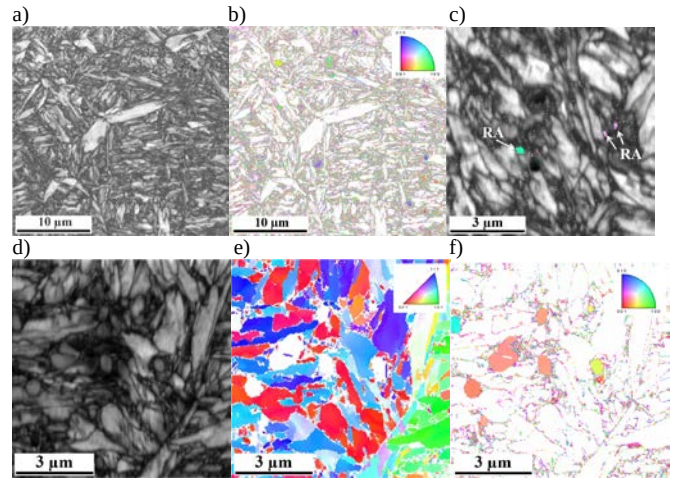


Fig. 4 Microstructure of 75Cr1 annealed at 860 °C for 15 min, quenched and tempered; a) image quality map, b) same area as in 'a', inverse pole figure map of the carbides, c) image quality map with retained austenite (RA), d) image quality map, e) inverse pole figure map of the ferrite, same area as in 'd', f) inverse pole figure map of the carbides, same area as in 'd'.

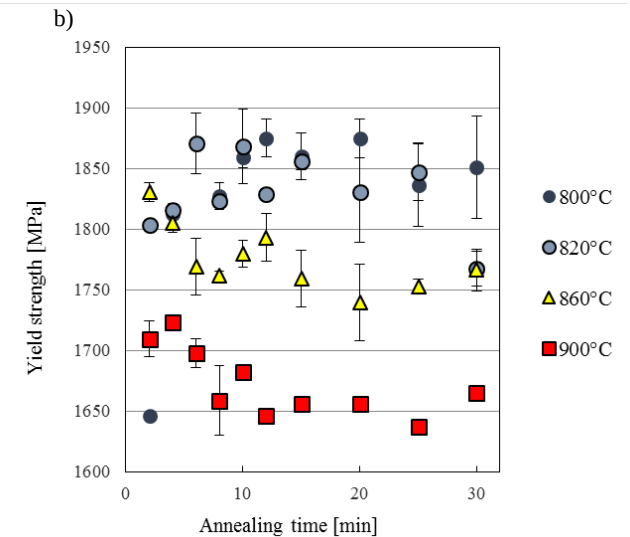
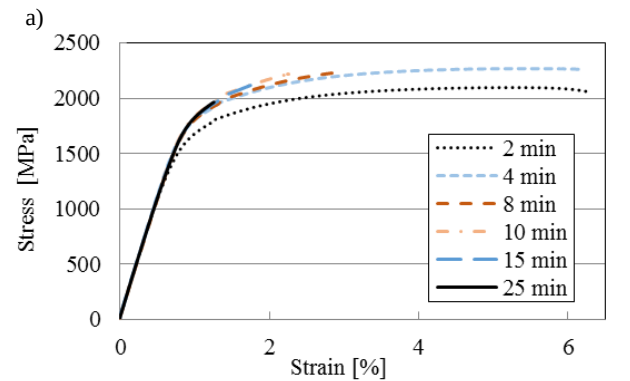


Fig. 5 a) Tensile stress-strain curve of 75Cr1 annealed at 860 °C for various times, quenched and tempered b) Yield strength versus annealing time for different annealing temperatures and times (also quenched and tempered).

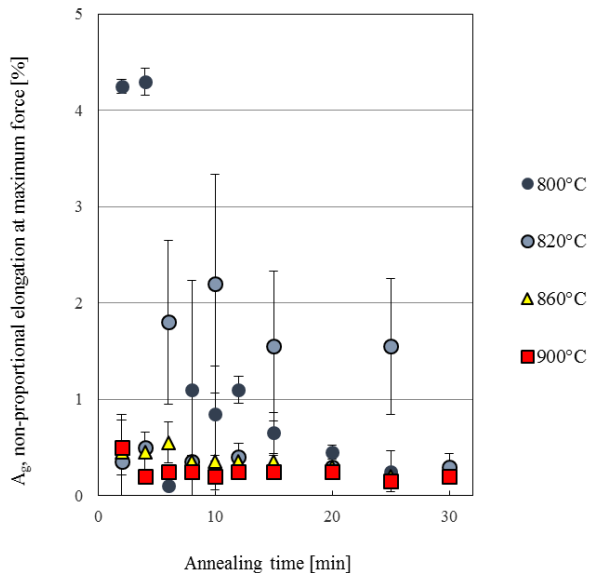


Fig. 6 Non-proportional elongation at maximum force versus annealing time deviated from tensile stress-strain curves of 75Cr1.

The effect of the annealing time on the tensile properties of the tool steel for 800°C is shown in Fig. 5a. The longer the austenitizing process, the larger is the loss of ductility. This effect is less clearly visible at higher annealing temperatures (Fig. 6). A summary of the values for the yield strength for all heat treatments is plotted in Fig. 5b. The increase of the annealing temperatures causes a decrease in the yield strength. On the other hand, if the annealing temperature is 860 °C or 900 °C, the yield strength increases at shorter annealing times. Correspondingly the elongation at fracture decreases with increasing temperature and increasing holding time, as can be seen in Fig. 6. The Izod impact test (Fig. 7) shows clearly that higher austenitizing temperatures and longer soaking times lead to a decrease in toughness.

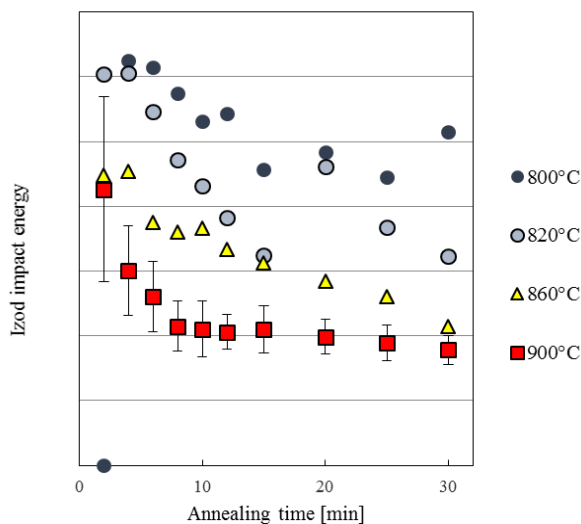


Fig. 7 Izod impact test for the different austenitizing conditions.

Fig. 8 shows that the amount of retained austenite, as measured with XRD and calculated with the formula of Cullity, increases clearly with temperature and also with time. The carbide fraction which was determined with ImageJ on Picral 4%-etched samples, reveals clearly a decrease in carbides with increasing annealing time and temperature.

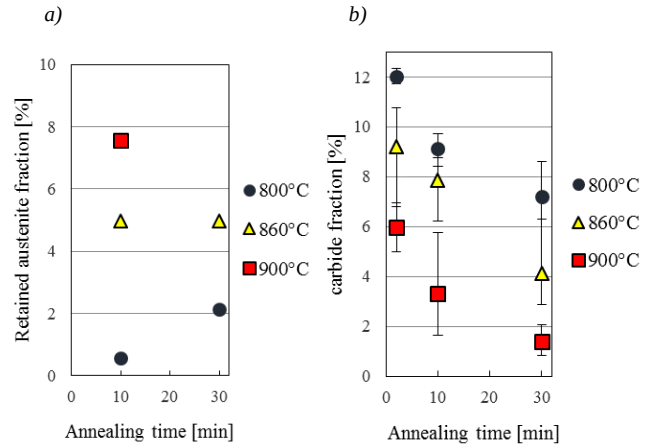


Fig. 8 a) Retained austenite fraction after different heat treatments, determined with XRD- Cullity's formula, b) Carbide fraction using Image J software on samples etched with Picral 4%.

4. Discussion

Higher annealing temperatures and times lead to a decrease in the impact toughness, and to a decrease in the yield strength. Analyses of selected samples show that the retained austenite fractions are higher and the carbide fractions are lower when the annealing temperatures and soaking times increase. With increasing austenitizing temperatures and times, more cementite can dissolve in the austenite and correspondingly more carbon and alloying elements can go into solution. Austenite grain growth can be expected at elevated temperatures especially when a critical amount of cementite is dissolved. Liu *et al.* [5] studied an Fe-2.03Cr-3.91C (at%) alloy and found that the undissolved cementite was enriched in Cr during austenizing. They suggest that the main part of the reaction for the studied alloy is controlled by Cr diffusion. Hillert *et al.* [6] concluded that the dissolution rate of cementite is controlled by the rate of diffusion of carbon in the very early stages and of the alloying element in the later stages.

The enrichment of the austenite matrix with carbon and alloying elements will lead to a decrease of the Ms temperature and as a consequence more untransformed austenite will retain at room temperature [4]. Retained austenite, depending on its carbon content and distribution in the microstructure, may contribute differently to the strength and ductility. A lower tensile strength can be observed after quenching and tempering in cases where the fraction of retained austenite is high. This austenite fraction can transform under strain during loading –this is the so called transformation induced plasticity (TRIP) effect. Additionally the very thin film-like morphology of the retained austenite situated between the martensite laths can contribute to the ductile fraction and correspondingly to an increase of the toughness [8,9]. On the other hand formation of the high carbon martensitic structures formed after short soaking times and low temperatures leads to an increase in strength (Fig.5b) and toughness (Fig. 7).

Hence the combination of high strength and high ductility could be obtained via quenching from low temperatures after short soaking times. High temperatures and high soaking times lead to lower strength and lower ductility.

5. Conclusions

The changes in the microstructure and mechanical properties of a tool steel 75Cr1 were studied as a function of the austenitizing temperature and time. It was found that:

- Lowering the annealing temperature and time leads to a higher strength and ductility due to less retained austenite. A lower annealing temperature also leads to less carbon saturation of the austenite and a more ductile material.

- High austenitizing temperatures and high soaking times will lead to a decrease in ductility.

Acknowledgements

The authors acknowledge the financial support of the Dutch Materials Innovation Institute (M2i) under the contract M21.10.11442 .

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ANALYSIS OF THE DEEP DRAWING PROCESS OF BOX-SHAPED PARTS

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Abstract: *The analysis of stress-strain state of the bisector of the corner of the blank at a drawing of box-shaped parts. Analytical dependences for the meridional and circumferential stress on the bisector of the angle. It is shown that an increase in the limit drawing ratio compared with an extract of the cylindrical part is a consequence of the growth in absolute value of district compressive stresses. It was found that the maximum value of the coefficient of drawing of box-shaped parts cannot exceed the value of $K = \exp(1 + 1/\sqrt{3}) \approx 4,84$.*

KEYWORDS: DRAWING; BISECTOR; STRESS; STRAIN.

1. Introduction.

One of the difficult problems in the theory of forming sheet metal drawing process is the analysis of box-shaped parts. In this case, the difficulties characteristic in the analysis of drawing process of cylindrical parts, added further difficulties related to the need to consider the variability of the strain distribution along the perimeter of products, due to the absence of axial symmetry in the plastic region [1]. When developing of technological processes drawing box-shaped parts for easy implementation of practical calculations we introduce the concept of conditional drawing coefficient, which is similar to the drawing ratio of cylindrical parts, is determined by the expression $K = R/r$, where r – a radius of curvature in the plane mates of box-shaped parts wall, R – distance from the center to the edge of the corner rounding of blank the bisector of angle [2].

Many experimental studies have established that at multistage low draw box-shaped parts with a relatively large radius of corner rounding, the limiting ratio of drawing of corner region is 1.5-2 times higher than the drawing of cylindrical parts [1,2].

In order to explain of this experimental fact and clarify the mechanism of forming of the sheet metal in a non-axe symmetric drawing Popov E.A. developed an approximate theory analysis of stress-strain state in the absence of axial symmetry of deformation [1]. In this theory, the following main assumptions: the analysis carried out without changing the thickness and deformation hardening, introduced a priori given expression for the shear stress is linearly dependent on the circumferential coordinates. Under that conditions the use of assumptions plasticity hypothesis on the constancy of maximum shear stress (a condition Tresca-Saint Venant), allowed reduce the problem to a statically determinate and obtain analytical dependence for distribution of stresses along the meridional contour holes of the matrix. From this solution it follows that the greatest value of the specified stress on the front edge of the matrix along the bisector of the corner region of the blank different from the analogous values for the ax symmetric drawing some factor less than one, depending on the circumferential extension of the plastic zone.

By equating established in such a way that the greatest value of the meridional stress with yield strength of the material ($\sigma_{\rho \max} / \sigma_s = (1 - a/2\alpha) \cdot \ln(R/r) = 1$; $a = 0,5$; $\alpha = \pi/4$), it is theoretically possible determine the drawing ratio $K = R/r = \exp(1/0,682) \approx 4,3$ [1]. Other similar analytical solutions [3 and etc.] differ from slightly above and only specify the value of a factor in the expression for the maximum meridian stress.

In [1,2] the increase in the limiting factor in the drawing box-shaped parts based on the fact that, "... on the boundaries of the corner region of the shear stresses are applied, oriented towards the center of curvature and create strength, pulling corner portion of the hole matrix and unloading dangerous in this section, and it also decreases the meridional tensile stresses".

Such a justification to increase the limiting ratio in the drawing of box-shaped parts causes a certain confusion for the following reasons: it is well known that shear stresses can not create power. In this problem the shear stresses in the corner region of the blank produce moments about the axis perpendicular to the plane of the sheet. The direction of the bisector of the corner portion of the blank

on the condition of symmetry is the main focus, so in this respect can not occur shear stresses, therefore, does not exist shear stresses can not decrease the meridional tensile stresses and unload the dangerous section.

In [3] an increase in the drawing ratio and increasing the height of the corner of the box-shaped parts is justified on the basis of even more unbelievable assumptions "... the difference between the velocities of the material in the walls of the straight and corner sections. Therefore, the condition of the continuity of blank to be that fast moving items seized slowly moving adjacent elements and have them pushed into the matrix and unloaded stress impact". Obviously, such statements need no comment.

It follows that in the present time in the scientific technical literature there are no reasonable analytical solutions to determine the limiting ratio in the drawing box-shaped parts. It therefore seems appropriate mathematically correct statement of problem of forming of sheet metal in the absence of axial symmetry of the plastic region, on the basis of which it will become possible to determine the ultimate value of the drawing ratio and study of the mechanism of forming, set free from contradictions.

2. Problem statement and analysis of the stress state.

Consider forming in the corner region of the blank in the drawing box-shaped parts, considering that forming the sheet metal occurs in plane stress conditions [1,2]. It is assumed that the plate thickness S is small compared with the transverse dimensions of the parts, whereby it is considered that the stress components acting on the middle surface, little change in thickness. For this reason, these stress values are averaged over the thickness of the respective stress components. From the condition of symmetry of the plastic zone at the corner of blank should be that the direction of the bisector is the main focus, so that the meridional and circumferential stresses acting in this direction are the main normal stresses. Therefore, for analysis of stress-strain state of the bisector is permissible to use the results of the analytical solutions obtained for axis symmetric drawing.

In [4-7] demonstrated and justified that the main directions of stress-strain state is appropriate and convenient to consider the deviatory plane of Mises plasticity cylinder in oblique two-dimensional coordinate system. In these works, the original equations of the theory of plastic flow in the plane stress, namely, the equilibrium equation for the changes in the thickness of the material plasticity condition Mises condition of constant volume constraint equation stress and increment (speed) strains are reduced to a single structure in the form of a differential relationship between meridional stress increments and equivalent deformation (strain intensity)

$$d\sigma_{\rho} = \sigma_s d\varepsilon_i. \quad (1)$$

Received of (1) the following according to the meridional and circumferential stress

$$\sigma_{\rho} = \sigma_s \frac{2}{\sqrt{3}} \cos\left(\varphi + \frac{\pi}{6}\right); \quad \sigma_{\theta} = -\sigma_s \frac{2}{\sqrt{3}} \sin\varphi, \quad (2)$$

obtained from the combined solution of the equations of stress and relationship increments (speeds) strains based on the constancy of the volume and satisfying plasticity at plane stress [1]

$$\sigma_\rho^2 - \sigma_\rho \sigma_\theta + \sigma_\theta^2 = \sigma_s^2. \quad (3)$$

The receipt of power-law of strain hardening $\sigma_s = A\varepsilon_i^n$ ($A = \sigma_b e^n n^{-n}$, $n = \ln(1 + \delta)$ - parameters receipted law of strain hardening, σ_b - tensile strength, and δ - relatively uniform deformation of the material when tested in uniaxial tension) under the assumption of proportional changes in the components of linear strains ($\varepsilon_\rho / \varepsilon_\theta = \text{const}$), allowed to integrate a predetermined differential equation and obtain analytical dependence for the equivalent strains

$$|\vec{\varepsilon}|_i = \varepsilon_i = (1 + n) \frac{2}{\sqrt{3}} \cos\left(\varphi + \frac{\pi}{6}\right), \quad (4)$$

where φ - the polar angle between the radial deformation and vector of equivalent strain in the deviator plane. Distribution of principal strains for the initial stage of the drawing, and a geometric interpretation of the nature and physical parameter φ considered in detail in [5].

One possible and theoretically founded explanations for this increase in the limiting drawing ratio of box-shaped parts is the assumption about the growth of the district compressive stresses along the bisector on the peripheral region of the blank.

In (3) that the circumferential stresses the absolute value may increase, while the growth of the absolute value of the meridional of stress. In order to substantiate the proposal will consider the initial stage of axe symmetric drawing ($\sigma_s = \sigma_{0.2}$; $\varepsilon_i = 0,2\%$; $n = 0$) in the direction of the bisector. In [5], in this case the relationship between the parameter set in the deviator plane and the relative coordinates ρ/r of the element in a material medium deformable blank in the form of relation

$$\frac{\rho}{r} = \exp\left[1 - \frac{2}{\sqrt{3}} \cos\left(\varphi + \frac{\pi}{6}\right)\right]. \quad (5)$$

From (2) and (5) it follows that, $\varphi = \pi/3$; $\sigma_\rho = 0$; $\sigma_\theta = -\sigma_s$, $\rho/r_0 \Rightarrow e(2,72)$. Therefore, a further increase in the relations ρ/r is only possible in the transition of opposite ($\sigma_\rho \sigma_\theta \leq 0$; $\sigma_\rho \geq 0$; $\sigma_\theta \leq 0$) biaxial stress state of same name in the biaxial ($\sigma_\rho \sigma_\theta \geq 0$; $\sigma_\rho \leq 0$; $\sigma_\theta \leq 0$). According to (2) in $\varphi > \pi/3$ the meridional stress changes sign and the main stress in absolute value reach the maximum possible, in a plane stress, values $-|2/\sqrt{3}|\sigma_s$ and $|1/\sqrt{3}|\sigma_s$. Comparing (5), and the like according to [1,2], you can see their formal external similarity. If the parameter φ in (5), characterized in the direction of the bisector (in the main direction) angular extent of stress-strain state in the deviator plane, then θ in [1,2] is a circumferential coordinate of the element in a material medium blank. Assuming in (5), we find

$$K = \frac{R}{r} \Rightarrow \exp\left(1 + \frac{1}{\sqrt{3}}\right) \approx 4,84. \quad (6)$$

Thus theoretically possible the drawing ratio of box-shaped parts can not exceed 4.84.

If we assume that were not included in the analysis of factors (bending and straightening of curved edges on the deforming tools, friction, etc.) have the same effect on the decrease the theoretically possible factor in the drawing of cylindrical parts and box-shaped parts ($2,72 \Rightarrow 2,0 \div 2,1$), practically achievable values in the second case it is sufficient close agreement with the experimental results ($4,84 \Rightarrow 3,5 \div 3,7$) [1,2].

3. Results of the analysis and discussion. From the analysis it follows that the parameter φ of the bisector of the corner region of the blank at the box-shaped drawn on the details of the deviator

plane can vary $0 \leq \varphi \leq \pi/2$ and be engaged in the sector with a central angle equal $\pi/2$. In this range of the parameter φ vector of equivalent strain is either parallel or perpendicular to the oblique coordinate axes, whereby the main strains in the meridional and circumferential directions vary from 0 to 1. With large size of the plastic zone in the deviator plane are realized following the scheme of the stress-strain states:

when $\varphi = 0$, ε_ρ positive, but ε_θ and ε_z - are negative and equal to $\varepsilon_\rho/2$, i.e., linear stretching deformation is realized;

when $\varphi = \pi/6$, $\varepsilon_z = 0$ but ε_ρ and ε_θ , are equal in value and opposite in sign, i.e., realized a net shift (plane strain) in the plane ($\rho; \theta$);

when $\varphi = \pi/3$, ε_θ negative and positive, but ε_ρ and ε_z numerically equal $\varepsilon_\theta/2$, i.e., linear compressive strain is realized;

when $\varphi = \pi/2$, $\varepsilon_\rho = 0$ but ε_θ and ε_z are equal in value and opposite in sign, i.e., is realized a net shift (plane strain) in the plane ($\theta; z$).

Therefore, in general, on the bisector of the corner of the blank at a drawing box-shaped parts, plastic region is displayed on the deviator plane strains in three specific sectors with the central angles equal $\varphi = \pi/6$, on the borders of which are changing the scheme of the stress-strain states.

The results of the analysis of the relationship between the value and character of the distribution of shear stresses and the growth of the district compressive stresses will be presented in our future publications.

3. Conclusions

1. The analysis of the stress-strain state in the drawing of box-shaped parts based on an interdependent changing the thickness of the material and strain hardening.
2. On the basis of the established distribution of the meridional and circumferential stresses in the direction of the bisector of the angle defined theoretically possible ratio of drawing box-shaped parts $K = \exp(1 + 1/\sqrt{3}) \approx 4,84$.
3. The mechanism of forming non axially symmetric drawing, allows to justify an increase in the limiting ratio compared to the drawing of cylindrical parts.

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ANALYSIS OF THE TRAFFIC MANAGEMENT SYSTEM IN URBAN NETWORKS

АНАЛИЗ СИСТЕМЫ УПРАВЛЕНИЯ ТРАНСПОРТНЫМИ ПОТОКАМИ В ГОРОДСКИХ СЕТЯХ

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Abstract: *In the article is considered traffic management system in urban networks. Presented analysis of the criteria in the transport network management techniques. Showed results achieved in the implementation and management of traffic flows in the cities, their advantages and benefits. Development of mathematical dynamic models for calculating working parameters of the transport unit allows to create a well-functioning traffic management system. These systems allow to solve optimization problems, to regulate traffic flows in populated areas, thereby allowing the full potential of the existing route network, as well as it will ensure an adequate level of safety, convenience and efficiency of transportation with the least environmental impact.*

KEYWORDS: TRAFFIC MANAGEMENT SYSTEM, URBAN NETWORKS, TRANSPORT CONTROL DEVICES, OPTIMIZATION

1. Introduction

Starting from the second half of the eighties a number of dynamic systems that calculate the parameters of a transport node (a cycle or composition of phases of traffic lights based on actual changing traffic conditions) is developed. However, the quality of dynamic management, as we know, determined by the quality of the model traffic flow. There are also limitations, due to the fact that the developed model is usually not prepared for extreme changes of the condition of a traffic flow. Nevertheless, the issue of dynamic control of the node or node group is not simple considering that on a simple crossroads may be 12 directions of movement of vehicles, i.e. for a simple network formed by ten nodes, we are talking about 120 directions. The output of the regulatory process should be to minimize delay to 120 destinations, and the traffic intensity varies in time and space [1], [3].

Development of mathematical dynamic models of calculation of parameters of a transport hub will create well-functioning of traffic control system. These systems will allow to adjust traffic flows in built-up areas and in undeveloped suburban areas, thereby will allow to use the full potential of the existing route network, as well as significantly reducing the influence of the number and consequences of road accidents on the functioning of the transport system of the city.

2. Analysis of publications

Traffic control device used to manage the transport network in the city. Usually it is equipped with sensors to monitor the presence of vehicles or pedestrians. The executive elements are the signal lights (traffic lights), CCTV cameras, GPS sensors, which provide information to the driver or pedestrians. The control device can work in isolation without communication with other control devices or with a central station that can be installed in a coordinated line or may be managed by the control center. From the management point of view, there are two basic states: managing the transport node and the transport network (area) [2].

3. The aim and task

The aim of this publication is the analysis of the traffic management systems. Modern systems of traffic management can be divided into static and dynamic (traffic-dependent). For control systems of the traffic flows the big interest has transport-dependent control device. In case of transport-dependent control available detectors before the stop lines that capture the instantaneous presence of vehicles, and control device thus responds to the instantaneous conditions in the node, for example, increasing the duration of the green signal. These changes are transmitted to the Central management node, which makes subsequent adjustments to the device nodes of the road.

Therefore, we are talking about traffic management in the transport nodes in the used grid time (which is line management), and also all traffic.

Consequently, the biggest interest have the systems which are working in real traffic conditions.

4. The main section

Consider existing systems of traffic control [1], [2].

The modern system of traffic control management is equipped with a control device characterized by control devices (nodes). They are controlled: 1 - on a fixed schedule; 2 - on a state of a transport stream (transport-dependent).

Traffic management in transport nodes is divided in the following categories:

- time-dependent control – transport status is determined on the basis of statistical analysis of historical values of the characteristics of traffic flow (traffic intensity) and on the basis determined by the output values of the regulatory process;
- transport-dependent control (in real time) – management, the intervention of which is calculated on instantaneous traffic situation. Methods of real time (online) provide work in real-time, every second make changes and optimize the control parameters, i.e. duration of the green signal in the corresponding direction.

Traffic light control in real time is well known and is used as a standard under the name transport-dependent control or dynamic control. Its principle is that the node is usually equipped with two types of sensors: sensors intervals and call that are in most cases inductive loop. The transport device control program that continuously tests the state of the traffic flow over separate sensors and on the basis of pre-defined algorithms increases the duration of signals, modifies the phase sequence or phase invests on call. These changes are usually carried out within a predetermined time cycle and predetermined maximum values, the duration of green signals.

Sensor intervals, located approximately 30-50 m before the stop line, got its name due to the fact that it continuously measures the time intervals between vehicles and if they are less than a given value (usually 3-5 seconds), it increases the duration of green signals up to a predetermined maximum. Such a measurement method called "Management by measurement of time interval". In addition, the duration of green signals may also be increased on the basis of the measurement conditions of the sensor, which essentially represents the relative time during which the sensor is located above the vehicle, and based on this value, expressed as a percentage, extends or shortens the duration of the green signal. Sensor call is located before the stop line or in more remote locations, where can irregularly be formed congestion. In both cases, depending on the control algorithms embedded phase, is identified if the employment of a sensor of the vehicle.

Certainly, it is possible multiple grouping controls in a line and method of management in the system, also called "green wave". Methods of calculation are well known and come from the calculation of the coordination parameter, which is the time shift.

The latter on the basis of the distance between the intersections and depending on the velocity of the vehicle determines the time delay of the signal "travel allowed" at the next intersection for vehicles traveling from the previous node.

The second possibility of traffic management is that individual nodes are connected to the traffic management center traffic flows, which coordinates and manages the nodes at the district level. There are following modes to control the scope:

- time-dependent control – information about the characteristics of traffic flow conditions in the area are obtained by statistical analysis of data on the characteristics of traffic flows. Based on this, is determined the mode of operation of the transport control device, after which they are introduced into the control device, depending on the time of day or day of the year. In the calculations, optimized the duration of the green signal, the cycle duration and the time shift;

- transport-dependent control – characterized by the fact that for the different states of traffic flows in the network system pre-calculated signal plans stored in the control devices or in the centre of traffic management of traffic flows.

If the network is not classified traffic flow conditions, only one parameter is used for describing, which is the intensity of the movement. Transport-dependent control is used in the real time scale and every second receives the signals of the selected sensors. However, the switching signal of the programmes is carried out with a certain hysteresis to ensure stability in the transport network. In practice, this means changing the program of the control device in the grid several tens of minutes.

The instant response to the situation based on the creation of the state of traffic flow in a node or in a network based on the measured transport parameters. Therefore, this system is always equipped with sensors and is more expensive. The measured data are included in the model of traffic flow, which performs optimization.

Optimization in autonomous mode gives the possibility to calculate the basic adjustable parameters: cycle time, phase sequence, the time shift and the duration of green signals for the historical data. These data are obtained by long term measurements by means of transport detectors or, not very well, replaced by local tracking and account. On the basis of long-term recorded data is usually developed statistical model for the intensity of the movement, usually gives the opportunity of determining on typical weekdays and weekends, resulting in severely restricted change of variables.

The implementation of these control devices have been applied in developed and presented models of traffic management.

Improving the efficiency of road usage is the main objective, the implementation of which will ensure adequate levels of safety, convenience and efficiency of transportation with the least impact on the environment. Implementation is possible only with widespread usage in transport devices of a dynamic and modern systems of traffic management - intelligent systems that evolve in many branches of economy of the leading countries in the world. The use of such systems for transportation can significantly increase the efficiency and safety of transport, provide the service to users of transport on a higher level.

The main tasks of such systems are:

- increasing capacity of the transport network;
- improving the safety of traffic participants.

In the modern understanding, the transport management system of cities is not only a system of traffic control at intersections with traffic lights. These systems are equipped with other systems and devices. For example, information displays along with communication give drivers the opportunity to choose alternative routes of movement, with special attention paid to the elimination of the consequences of traffic accidents, congestion, etc.

One of the biggest implemented European projects for traffic control of a large urban area was the Munich COMFORT project [4]. It was the first project that coordinated management of traffic flows in the downtown, and took into account planning the motorway network in the suburban area. Control algorithms evaluated the condition of traffic flow, optimized the traffic light predicted the development of the transport load and directed vehicles out of the field, which often had traffic jams.

This system achieved the following:

- the investment paid off within 2 years;
- decreased raids by 35%;
- reduction of traffic accidents by 30%;
- decreased the amount of congestion by 31%.

Depending on the implementation of the complex of the main works and purpose of traffic management distinguish the following subsystems (Fig. 1):

1. Analysis of transport networks.
2. Automatic identification of road traffic accidents.
3. Information and navigation.
4. Management depending on traffic loading

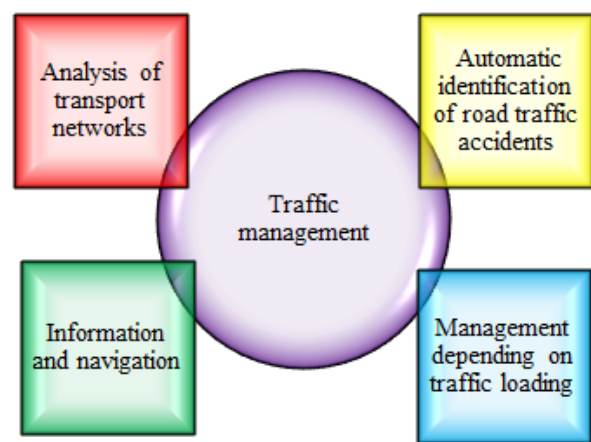


Fig. 1. Traffic management subsystems

1. Systems of analysis of transport networks.

Transport data from the sensors installed in transport hubs can be used for the primary traffic management. However, integrated system of traffic management in urban networks requires more detailed information about the situation of the network, as demonstrated in projects such as QUARTET PLUS and EUROSCOPE. In the context of the widely adopted concept of "mobility management" and the close linkages between the monitoring and management of traffic flows, these projects have experienced in practice new system based on videodetective (use as sensors, stationary cameras). In these projects, for the first time in practice, were tested new algorithms to determine time of movement, speed on the lanes and in the network and algorithms to determine the points of origin and destinations. Especially important for transport information system is data of points of origin and destination. Projects also were tested forecasting algorithms that could be used for short-term (1-20 minutes), intermediate term (11-12 hours) until long-term forecasts (1-2 days). Both projects helped to identify inaccuracies and limitations that characterize the forecasts of parameters of functioning of the transport network, and identified areas for further development, one of which is the use of data from propel labs, live traffic flow (floating car) – project CAPITALS.

Private, but very important area of using the results of data analysis is the region of establishment (detect or detection) of the traffic accidents occurrence.

Timely detection of incidents can begin the process of taking the necessary measures, which include the strategy of traffic management in this situation, informing drivers of the situation and a rapid response of the rescue services. The project IN-RESPONSE, in addition to detecting incidents, have been developed that model to predict road traffic accidents.

2. Automatic identification systems of road traffic accidents.

The subject of several European projects have been addressing the issues of management of the liquidation of consequences of road accidents. Traffic management system in the cities of UTC (Urban Traffic Control), are using special modules ensure the detection of incidents and their impact on traffic flows. Projects, such as IN-RESPONSE and IN-EMERGENCY, demonstrated the variety of equipment, including high-speed warning system designed for rescue services, and tools that support decision making by operators of the rescue service.

3. Information systems and navigation.

Systems for informing drivers using on-Board units or controlled road signs and displays that are located along roads, have ever-increasing importance for traffic flows management on road networks. Information about possible problems greatly reduces the congestion due to the fact that the driver is informed and can choose other options to the path of motion or the suitable parking lot or just parking.

At the time, such systems, as TFIS (Traffic Flow Information System information system impacts on traffic flow), were often used in different European projects.

The use of information and navigation systems in the framework of the European projects are presented in such systems of following cities:

- Bristol (CONCEPT) – TFIS for the best use of Park and Ride system;

- Brussels (CAPITALS) – TFIS as part of a master control system of traffic in tunnels on the inner ring of the city;

- London (CLEOPATRA) – determination of the influence of TFIS, when identifying locations of traffic accidents, the choice of drivers on the road to the road network and the efficiency of the transport network;

- Lyon (CLEOPATRA) – information strategy for TFIS in the automatic mode using data derived from measurements conducted on road network;

- Munich (TABASCO) – TFIS for the best use of Park and Ride system;

- Piraeus (COSMOS) - a strategy for changing the movement direction of vehicles in the area of the seaport;

- Southampton (EUROSCOPE) – integrating the impact of road traffic accidents and control sites;

- Toulouse (CLEOPATRA) – strategy of changing the direction of movement of transport streams;

- Turin (CLEOPATRA) – TFIS strategy with the strategy of traffic management in the city.

Information before the trip and information on the stops of urban public passenger transport have a significant impact on the behavior of most passengers, so it turned out that they, ultimately, caused a small but significant increase in the number of passengers. Integration of transport management in the city, urban passenger public transport and information systems in Turin has reduced travel times on urban passenger transport by 14%, in passenger cars – 17%, which, in turn, led to the growth of urban public passenger transport by 3% and overall improvement of traffic in the city. Investments in the subsystem identify the locations of road accidents in the transport management system in Southampton have paid off within one year, however, payback significantly depends on the method and speed of identification of road traffic accidents.

4. Management systems depending on traffic loading (intelligent systems).

In the city, management depending on the traffic load, as a type of control, has a growing importance for maintaining satisfactory mobility, as it uses different subsystems for traffic management. The application of this program contains, for example, the office at the entrance to the Central area of the city

(CAPITALS project) and techniques of artificial intelligence, by combining control on entry and management using the traffic lights system of providing information and assistance to drivers and subsystems with the provision of transport information.

Practical results of the use of traffic control systems in the United States and Canada [5], [6] are the following:

- Toronto (Canada): all 75 objects managed by the system SCOOT (Split, Cycle and Offset Optimization Technique system of movement control), using this system allowed to reduce the number of stopped vehicles by 22%, delays of transport vehicles – by 17%, the average fuel consumption by 5.7%, which had a positive impact on the environment.

- Los Angeles, CA: new management and tracking system has more than 1150 traffic lights and 4600 detectors used to optimize the management process. The result was reduced consumption of fuel by 13%, by 41% decrease in the number of stopping vehicles and by 16% decreased loss of time.

- Chicago, Illinois: project of optimization of urban public passenger transport based on coherent benefits to buses at intersections, resulting in the speed of buses increased by 25-50%. As a result, significantly increased the attractiveness of urban public passenger transport and at the same time, decrease of environmental load (through reducing the number of buses while maintaining intervals).

Positive effect of introduction of transport flows management systems in urban networks is determined by the fact that in their information environment, transport and heads of administrative bodies have the opportunity to get the most rapid and objective data about the passenger and other transport modes, and the ability to quickly monitor and therefore manage the safety of transport systems.

Analysis of the use of the traffic management system in the cities shows that there have been positive results in the areas of:

- increasing the capacity of the transport network by 25-35%;
- reducing traffic delays by 30-40%;
- reducing the number of road accidents by 20-25%;
- reducing the number of vehicles stopped by 20-35%;
- reduction of time travel on urban passenger public transport and passenger cars by 15-20%;
- reduction of the environmental load (reduction of pollution and noise).

5. Conclusions

Model traffic flow, which carries out the optimization should be able to manage the macroscopic offline. It is based on a deterministic simulation of algorithms and optimization, as calculated by the signal plans for the space-time vector of the intensity data for previous periods. Their advantage is that they are based on well-known mathematical models and can be implemented deterministic process control. Developed algorithms on data nodes and management models allow to create transportation management systems. These systems significantly improve the efficiency and safety of transport, help to ensure service users transport at a higher level.

For Odessa, with its level of development of the transport network, the problem of automated traffic management is highly relevant. A superficial assessment of the situation in the transportation network of Odessa, leads to the conclusion that the implementation of the management system will enable flexible management of traffic flows depending on their intensity. Based on the above, we can conclude that for using foreign experience of working with management systems must be performed a complex of works on increasing the efficiency of use of the transport network of the city, which, in turn, will pave the way for use of intelligent transport systems in Ukraine.

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REDUCTION OF EMISSIONS FROM OFF-ROAD HEAVY-DUTY DIESEL ENGINES USING CATALYZED DIESEL PARTICULATE FILTER

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Abstract: Several different techniques and methodologies have been applied to reduce emissions from diesel engines. The main by-products of diesel engine combustion are carbon monoxide, carbon dioxide, total hydrocarbons, oxides of nitrogen, and particulate matter. Diesel particulate matter and oxides of nitrogen are two of the most potentially harmful components of the diesel engine exhaust. Since 1990, the US Environmental Protection Agency (EPA) has been regulating off-road diesel emissions and imposing rules and standards on manufacturers and operators. The objectives of this study was to determine the mechanical durability of Diesel Particulate Filters (DPF) that are retrofitted on off-road heavy duty diesel engines, over prolonged periods of in-field operation and to assess the emission benefits of particulate catalyzed filter. The specific task was to evaluate the exhaust emissions from a Caterpillar 3408 engine on an engine dynamometer. Since the ability of the DPFs in reducing particulate matter (PM) emissions was of a prime concern, it was concluded that the DPFs are very effective in achieving up to 98% reduction.

Keywords: PARTICULATE MATTER REDUCTION, CATALYZED FILTER, HEAVY-DUTY DIESEL ENGINE EMISSIONS

1. Introduction

Diesel engines are highly robust and reliable machines and can be used for a number of years. Their usual life span is around 10-15 years but can be substantially increased by rebuilding the engines, which takes the life span up to 30 years. Though off-road engines generally operate in large open spaces, improper operation and irregular maintenance cause an increase in the pollution in the surrounding areas. One of the major problems in assessing the damage done by diesel exhaust alone is the difficulty in quantifying the amount of diesel matter in the atmosphere. Like any other internal combustion engine, diesel engines convert the chemical energy contained in the fuels to mechanical power, through combustion. The main by-products of combustion are carbon monoxide (CO), carbon dioxide (CO₂), total hydrocarbons (THC), oxides of nitrogen (NO_x), and particulate matter (PM). Diesel particulate matter (DPM) and NO_x are two of the most potentially harmful components of the diesel engine exhaust.

Extensive research has been conducted over the years, to reduce the risk of air pollution due to diesel engines. There have been significant developments in fuel injection systems, engine combustion chamber designs, injection timing studies, and alternate fuel formulations. The efforts have gone further in trying to control the post-combustion stage, by using after-treatment devices, and reaction catalysts to convert incomplete combustion products into much safer compounds.

2. After-Treatment Solution for Diesel Emissions

Exhaust after-treatment technology has been used since the start of 2000. Devices such as Diesel Particulate Filter (DPF), also known as particulate traps, control emissions by physically capturing particulate matter and by using catalysts to convert the chemical compositions of exhaust matter.

An after-treatment device is a component used to reduce engine exhaust emissions downstream of the combustion chamber. Catalytic converters and particulate traps are examples of after-treatment devices. These devices are currently being used to reduce PM emissions extensively. The filtration devices along with reformulated fuels form an excellent combination in filtering out the particulate matter from the exhaust stream. The three primary types of after-treatment devices are the oxidation catalysts, particulate traps and the continuously regenerating traps. They have also been used to reduce NO_x, by using systems such as Selective Catalytic Reduction (SCR) and Exhaust Gas Recirculation (EGR). In SCR systems, urea solution is added to a catalyst, which reacts with the exhaust to reduce NO_x. In EGR, the exhaust gas is fed back to the intake, which in turn contributes to reduction of the combustion

temperatures, therefore reducing NO_x formation. Reformulated fuels have been researched as an option for reducing emissions. Fuels with high cetane number, low aromatic content, and low sulfur content have known to be beneficial. After-treatment devices require low sulfur fuels for their proper operation and hence some so called synthetic diesel fuels look promising.

The two DPFs used in the current study were the continuously regenerating trap (CRTTM) from Johnson-Matthey and the catalyzed diesel particulate filter (DPXTM) from Engelhard. The CRTTM is a two-stage, passive, catalytic, ceramic wall-flow filter. The DPXTM from Engelhard uses a patented catalytic technology to change the chemical structure of diesel exhaust.

Lean NO_x catalysts provide a catalytic reduction of NO_x through a lean fuel approach. The system uses hydrocarbons (HC) in the exhaust to reduce the high temperatures, hence reducing NO_x formation. Nevertheless, since the system is susceptible to sulfur poisoning and requires a high amount of HC to be generated, it has not gained enough popularity with diesel manufacturers. To supplement the additional HC required either an excess quantity of fuel can be injected directly in the exhaust stream or urea can be used. Ammonia in the form of urea forces catalytic reactions to convert NO_x to N₂ and water. Khair and McKinnon, have reported that DOCs along with DPFs reduce NO_x and PM substantially. 1.1 g/bhp-hr and 0.01 b/bhp-hr emission values, for NO_x and PM, respectively, were obtained with 368 parts per million (ppm) sulfur fuel [1].

Diesel Particulate Filters (DPF) were first researched in the late 1970s, when they were characterized by wall flow systems that forced exhaust gases through porous walls of the filter element. The systems had problems with regeneration and performance. The temperatures required to burn soot were too high. The introduction of catalysts in the filters brought the temperatures down to manageable limits [2]. A particulate filter is an after-treatment device with open-pore, wall-flow systems. They are usually designed as foams or loosely sintered structures made of materials such as, ceramic and porous metal. These materials are highly thermal-shock resistant but have a brittle nature. The trapping of particles occurs due to impaction on the filter material, or due to interception and diffusion. The particulate trap affects the tailpipe emissions from a diesel engine due to the presence of catalysts in its filter medium or due to the effect of backpressure created on the engine. Catalytic material is coated on to the walls of the filter medium to aid in the oxidation of hydrocarbons, CO, and in the regeneration process of the DPF. Exhaust gases may react with the catalysts having either a positive or a negative influence on the emissions. Excessively high backpressure is known to reduce the

NO_x formation through internal exhaust gas recirculation but increases CO emissions and adversely affects fuel economy.

Commonly used regeneration methods include: passive and active systems, onboard and replaceable filters, and permanent and snap-on filters [3]. Passive systems do not rely on external devices to heat-up the filter and/or direct exhaust flow between two DPFs. They fully rely on self-controlled catalytic mechanisms. Thus, these systems must attain regeneration conditions during normal operation without any additional control systems. Passive regeneration strategies include catalyst-based regeneration using either a catalyst applied to the surfaces of the filter or an upstream oxidation catalyst; fuel-borne catalysts, and NO₂ traps, Fig. 1. Active systems include air- intake throttling, post top-dead-center fuel injection, catalyst injection systems, and on-board or off-board fuel burners or electrical heaters.

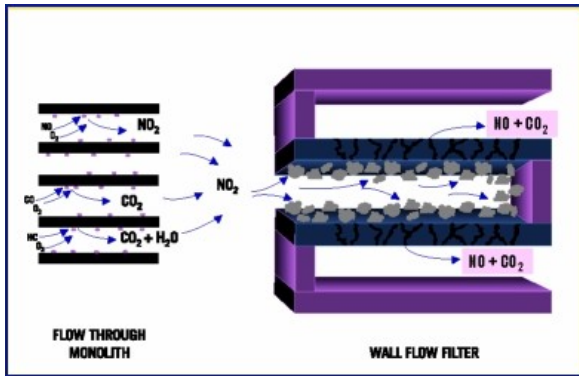


Fig. 1 NO₂ reaction in a CRTTM filter [3]

CRT particulate filters usually contain a combination of an oxidation catalyst and an uncatalyzed filter, which requires ultra-low sulfur fuel, Fig. 2. The device is made up of two chambers where the oxidation step is separate from the soot collection/combustion process. The first chamber contains a substrate coated with a proprietary highly active platinum oxidation catalyst, which is designed to oxidize a portion of the NO in the exhaust to NO₂, which is the key to the elimination of soot collected by the CRT filter. The catalyst also oxidizes CO and HC into CO₂ and H₂O. In the second chamber, the exhaust flows through a particulate filter, where gaseous components pass through but soot is trapped on the walls of the filter, where it is destroyed by the NO₂ produced by the catalyst in the first chamber. The fuel sulfur level must not exceed 50ppm, but less than 30 ppm is preferable for reliable regeneration (burning of soot). In order to achieve very low levels of PM emissions, the CRT requires fuel with a sulfur level of < 15ppm sulfur [3].

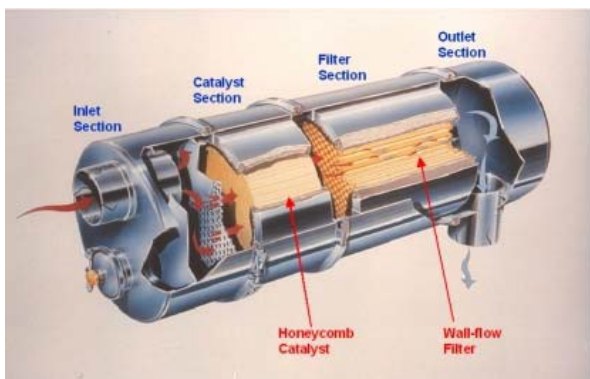


Fig. 2 Cut-away view of the patented Johnson-Matthey CRT DPF [3]

3. Diesel Engine Testing Process

University Laboratory conditions for tested engine used a steady state cycle and also employed a transient cycle that was developed using in-field operational data. The temperature readings for intake and exhaust systems are acquired using thermocouples. Torque may be measured through torque sensing devices placed in

the driveline of the drive shaft. Modern engines control the fuel rate through an Electronic Control Unit (ECU) that is integral to the engine. The ECU broadcasts speed and percent load (or torque) in addition to information on other engine operating parameters. An ECU protocol adapter was used in this study to obtain speed and torque information. The two objectives of DPF/trap study was to determine the mechanical durability of DPFs that were retrofitted on off-road equipment, over prolonged periods of in-field operation, and to assess the emission benefits of particulate trap retrofit on the same equipment.

The specific objective of this study was to evaluate the exhaust emissions from a Caterpillar 3408 engine on an engine dynamometer. The engine was exercised over ISO 8178 steady state schedule and a transient cycle that was representative of the in-field duty cycle [5]. The engine was operated on a California Air Resources Board (CARB) specification diesel fuel, followed by ultra-low sulfur fuel, named Engine Control Diesel (ECD) without any DPF, and then with a Johnson-Matthey CRTTM and an Engelhard DPXTM, Fig. 3. Emissions were evaluated at the beginning of the test, and once again after 1400 hours of engine's DPF operation. The test engine was a rebuilt, mechanically controlled, 8-cylinder, Caterpillar 3408, a rear engine taken out of a 657E Scraper. The in-field data was collected from a 657E Scraper with a Caterpillar 3408E electronically controlled rear engine. The engine speed and torque were logged using the Electronic Technician software to record the ECU generated data, using a communication adapter, both supplied by Caterpillar Manufacturer.



Fig. 3 Picture of the Engelhard DPX used in laboratory testing

3.1 Test Equipment

The engine dynamometer tests were conducted at University of Wyoming, Department of Engineering Laboratory. All the test equipment and procedures were in compliance with the requirements of US EPA Code of Federal Regulations, CFR 40 Part 86, Subpart D and ISO 8178 [5, 6].

The Caterpillar 3408 (CAT 3408), chosen for this study was 18 liter, V-8 cylinder, mechanically controlled, direct-injection, turbo-charged, after-cooled engine a parallel manifold design, with two intake and exhaust valves per cylinder. It has two full-flow oil filters and a fuel filter. The camshaft is in the center of the "v" with conventional valve lifters, push rods and rocker arms. The in-field data was collected on an electronically controlled rear engine. However, the laboratory testing was performed using a similar mechanically controlled engine, Fig. 4 and Fig. 5. Caterpillar Inc. provided data on both the electronically controlled and mechanical engine that showed that the speed and load values were well within 6% of each other.

The required load is applied on an engine using dynamometers in a laboratory environment Fig. 6. Depending upon the load rating required, the size of the engine, and the application three types of dynamometers were used: the water-brake, eddy-current, and the electric dynamometers.



Fig. 4 Engine setup with, instrumentation rack, and dynamometer controllers



Fig. 5 Gaseous emissions analyzer bench and PM sampling cart



Fig. 6 Test engine coupled with GE DC dynamometer

3.2 Test Fuels

Two fuels were used during testing; CARB Off road diesel, ultra-low sulfur Emission Control Diesel-1 (ECD1). Fuels were analyzed according to the ASTM methods specified in the US EPA CFR 40, Part 86, Subpart D [4]. It has been shown that ultra-low sulfur ECD1 reduces all regulated emissions when compared to CARB Off road diesel [7].

Emission Control Diesel (ECD) fuels are produced from crude oil using a conventional refining process [7]. The original ECD contained less than 15 ppm sulfur, less than 12% aromatics by volume, and a cetane number of greater than 60. The production of

ECD required extensive hydro treating which added to the costs. It was shown that the high cetane number and low aromatic levels have a negligible effect on DPF regeneration and conversion efficiency [4]. Hence, a second generation ECD fuel named ECD-1 was formulated, identifying the low sulfur content as the major property required for catalyzed DPF operation. ECD-1 has a maximum sulfur content of 15 ppm but has aromatic and cetane levels that are more typical of currently used diesel fuels. CARB diesel is a blend of one-third volumes from three different fuels, made by companies located in southern California [7].

3.3 Test Conditions

The task of the current study was to generate a transient cycle representative for off-road engine, and evaluate the emissions characteristics of the CAT 3408, by operating it on fuels with different sulfur content. The engine was tested with two different types of DPFs. No modifications were made to the physical or performance characteristics of the engine nor the DPFs. PM was of prime importance and its reduction was kept as the basis for the retrofit evaluation. Also back pressure values on DPF equipped runs were of particular interest. A high backpressure value was considered to be highly significant to the study.

All engine-retrofit configurations were run on both the steady state and transient cycles. The torque and speed set points of the ISO-8178 8-mode cycle and specific weighting factors for each mode, were used to calculate the total weighted emissions [5]. Engine speed and torque remain constant throughout the defined period of each mode. A transient cycle is a test period in which the engine speed and torque are continuously varying according to a predetermined set of values. Engine speed and torque set points were individually determined by mapping the engine on all the test fuels.

3.4 Transient Cycle Characteristics

Before creating a representative duty cycle of actual in-use operation, a few questions needed to be answered on the requirement for transient, in-use emission measurement. Typically, diesel engines are calibrated, by the manufacturer, to meet a certain level of emission standards based upon engine operation at a discrete number of steady state points. However, running an engine on any one particular transient cycle also defeats the purpose. To get a true depiction of in-use, real-time emissions, every engine or piece of equipment must be exercised through engine application driven duty cycle. This duty cycle should be created from the engine's actual in-field data points, representing the whole range of speeds, loads and activities that the vehicle goes through. Measuring emissions while a vehicle or equipment is in operation gives a picture of the level of emissions control that can be achieved. The alternative to this is laboratory testing. Different advanced technologies have been developed which enable real-time, on-board emissions measurements. This would allow measurement of speed and load conditions on the engine while it is in operation. Such activity would need adherence to newer standards, measurement, and calibration and test procedures.

3.4.1 The need to test under steady state operation

Steady state cycles cover the range of intermediate speeds and loads that may not even be included in a typical transient cycle. Steady state cycles have always been used as bench-marks for emission testing, hence, provide an excellent means of comparison. They provide a high level of consistency in test procedures.

The goal of generating a representative transient duty cycle is to cover the range of all the typical, repeatable activities undergone by a vehicle, engine or equipment and to record their corresponding speed-load data in real-time operation. Under transient operation, it is difficult to optimize the engine parameters for low emissions. Particulates may be formed due to excess fuel injected into the cylinder during speed and load changes and a whole host of engine parameters ranging from turbocharger, in-cylinder temperatures,

injection timing, to exhaust system dynamics and after-treatment systems.

The cycle that was developed in this study met the above criteria; hence, it could be used as a common means of measuring emissions from non-road engines. Measurement of emissions was also performed in accordance with the ISO 8178 standards [5]. Emissions were measured at eight combinations of speed and torque settings. The results were then weighed to a single value. As expected, the transient cycle results were not in agreement with the ISO 8178 cycles [5]. Steady state 8-mode cycles were originally developed for certification purposes. There are differences in emissions for different applications and driving patterns, which load the engine in a transient manner.

3.5. Analyzed Test Results

DPFs need high temperatures for regeneration. The first mode of the 8-mode cycle is the R100 mode, which raises the exhaust temperatures to approximately 1000 °F. At high temperatures the DPF enters the regeneration mode. The first retrofit configuration was ECD1 diesel with the CRT trap. It should be noted that sampling times were lengthened for retrofitted engine tests to allow collection of sufficient PM sample.

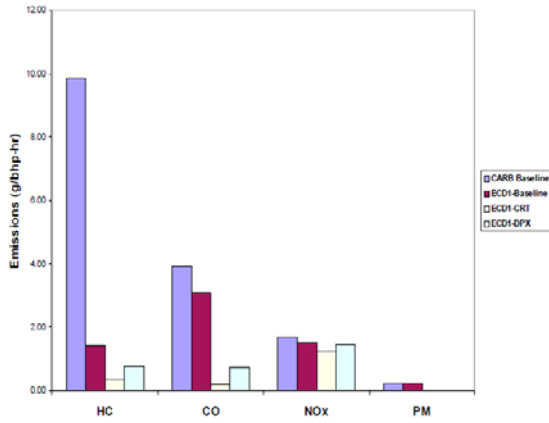


Fig. 7 Comparison of CARB baseline with ECD1, with and without trap, under 8- mode steady state operation

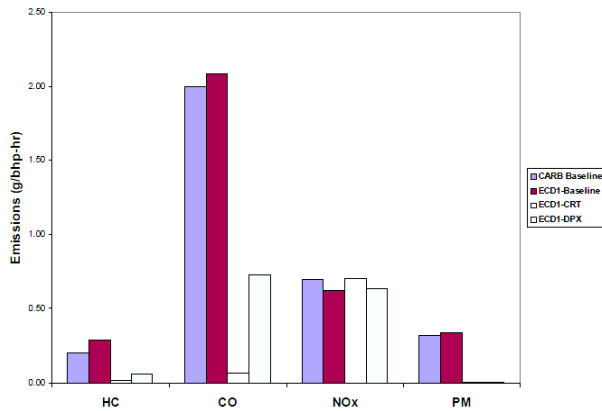


Fig. 8 Comparison of CARB baseline with ECD1, with and without trap, under transient operation

Table 1, Fig.7 and Fig. 8 presents the total weighted average emissions for HC, CO, NOx, and PM under steady state operation, in grams per brake-horse power (g/bhp-hr). It also presents the total continuous sampling emissions under transient operation, in g/bhp-hr.

The general formula for calculating percentage difference was:

$$\% \text{ Difference} = (\text{Reference Value} - \text{Actual Value}) / (\text{Reference Value}) \quad (1)$$

In Equation (1), the steady state values were taken as reference and the transient values are taken as actual values because they represent “real-world” emissions. There exist large differences in emissions for every configuration tested except for CO. This suggests that the steady state cannot be used as a means of determining “real-world” emissions. CO and PM seem to be reasonable in their percent differences. HC and NOx values are very different between steady state and transient. Except for PM emission, the baseline percentage differences using CARB diesel are more than 50% for HC, CO, and NOx. Similarly, while using ECD1 diesel, the percentage difference was more than 40% for HC, NOx and PM.

Table 1: Overall weighted emissions for steady state and average continuous emissions for transient cycle.

Configu- ration	8-mode Weigh- ted Ave- rage (g/bhp- hr)	Tran- sient Cycle (g/bhp- hr)	Percent % Diffe- rence	8-mode Weigh- ted Ave- rage (g/bhp- hr)	Tran- sient Cycle (g/bhp- hr)	Percent % Diffe- rence
HC			CO			
CARB- Baseline	9.86	0.21	97.91	3.90	1.99	48.88
ECD1 Baseline	1.44	0.29	79.90	3.09	2.08	32.66
ECD1 +CRT	0.35	0.02	94.11	0.19	0.06	65.41
ECD1 +DPX	0.78	0.06	92.15	0.73	0.73	0.75
NO _x			PM			
CARB- Baseline	1.70	0.70	59.03	0.25	0.32	25.50
ECD1 Baseline	1.52	0.62	58.83	0.24	0.34	40.74
ECD1 +CRT	1.24	0.70	43.69	0.004	0.006	51.71
ECD1 +DPX	1.46	0.63	56.54	0.006	0.005	13.78

It should be noted that since only one engine was tested during this study, any inferences about average emission factors representing the performance of a particular fuel or other after-treatment device would be inappropriate. Nevertheless, this study gives some idea about the effect of fuel and diesel particulate filter/trap used for reduction of exhaust emissions from heavy-duty off-road diesel engine.

4. Diesel Particular Filter/Trap Durability

The following common issues, but not all of them, were observed during in-field operation on off-road engines equipped with DPF: CRT and DPX filters had structural failures due to vibrations; CRT and DPX filters experienced high backpressure. Burning of carbon soot had caused significant burn-through of the ceramic trap element; Engelhard filter elements were broken, Fig. 9. The substrate inside the canning had shifted and was partially broken up so that loose chunks were present. Visual inspection revealed that the substrate had become dislodged from the center-body and allowed to “beat” itself against the outlet cross-members and the housing, resulting in substrate attrition and fracture. The major demise was due to mechanical stress. No sign was evident that the substrate experienced excessive temperatures, local hotspots and/or chemical attack. The trap had not experienced burn through as no soot was observed on the outlet channels. The preliminary finding was that the ceramic contacted the restraining crossbars which first scored, and then cracked the ceramic. The excessive

contact between the ceramic and the crossbars may have been due to backpressure or due to vehicle vibration.



Fig. 9 Filter damage on Engelhard DPX™

5. Conclusion

- The diesel engine retrofits fulfill the US EPA off-road emission standard requirements
- Results from the steady state and transient cycles showed significant differences. PM emissions were 14% lower for transient than steady state cycles, and the HC emissions for transient operation were 97% lower than for steady state cycle.
- In most of the test configurations, the 8-mode weighted average emissions were greater than the transient average emissions, though the results were within the standards.
- There was a remarkable reduction in particulate matter, hydrocarbons and carbon monoxide in all the combinations of fuel with filters tested under transient loading. This amounted to a 98% reduction of PM emissions for the low-sulfur fuels+DPF configurations. Brake specific CO emissions were reduced by 96% with the ECD1+CRT setup.
- The duty cycles of off- road construction equipment provide greater shocks and heavier vibrations than are found in on-road vehicles. Advanced manufacturing techniques will be needed to produce a durable commercial product for off-road applications that meets the diesel emission reduction standards same time.

Acknowledgements

The study was possible and conducted using the equipment of the Mechanical Engineering Laboratory, Department of Engineering at University of Wyoming, USA, and test equipment provided by Oasis Emission Consultants, Inc., Rock Springs, WY. The authors thank for the extended support and help from UW ME Lab team and the enormous assistants from technicians of Oasis Consultants in helping with conducting the testing, taking measurements, and providing Software program to perform the calculations.

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INTERNATIONAL FORUM “A NEW SILK ROAD” AND PROSPECTS FOR DEVELOPMENT OF EURO-ASIAN TRANSPORT CORRIDOR

МЕЖДУНАРОДНЫЙ ФОРУМ «НОВЫЙ ШЕЛКОВЫЙ ПУТЬ» И ВОЗМОЖНОСТИ РАЗВИТИЯ ЕВРАЗИЙСКОГО ТРАНСПОРТНОГО КОРИДОРА

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Abstract: *In view of the new realities created by signing the Association Agreement between Georgia and the European Union, Georgia for the first time was given the opportunity to be properly involved in the processes of global economic integration. This problem can be successfully resolved through safeguarding the Euro-Asian transport-communication space – “A New Silk Road”, and in the conditions of harmonizing the country's geo-economic interests.*

It should be noted that the first test train has passed already through the Georgian section of a new Baku-Tbilisi-Kars railway line. This section is what should become a component part of “A New Silk Road”. The construction of 180 kilometers of this railway line has been already completed, and now everything is being done for completing all works by the end of 2015. This railway line is considered as the most significant project in the South Caucasus region of the Euro-Asian transport corridor.

KEY WORDS: NEW SILK ROAD, RAILWAY FREIGHT ACTIVITY, RAILWAY LINE, SOUTH CAUCASUS REGION.

1. Introduction

Passing of the overland section of the project “A New Silk Road – Economic Belt”, initiated by Chinese President in 2011, through Georgian territory will provide our country with serious geo-economic benefits. However, at this stage, this project faces certain challenges, which on the International Forum “A New Silk Road” held in Tbilisi in October 2015.

Over 1000 representatives of about 30 countries took part in this Forum, including Chinese government officials and representatives of about 300 Chinese larger companies. This event was held in 2015 for the first time, but there are plans to hold it annually.

Georgia is a country linking West with East, and North with South. Holding of such Forum in Tbilisi is an important step, which helps Georgia to become a regional hub and a center for cooperation in South Caucasus, since Georgia is a favorable gate for Europe to link with Asia.

Silk road is an oldest trade route. For centuries, it has been linking China with Europe passing through Central Asia. But a new silk road is aimed at linking China with European countries, and strengthening cooperation of Central Asia with North African countries [2].

The highly interesting projects have submitted to this Forum, including putting into operation a main railway line linking China with Europe. In addition, there were drawn up several very interesting proposals for giving opportunities to different countries for cargo exchange through Georgian territory. These countries are both European and Asian ones. It is essential to reassure the world that Georgia is an attractive country for investments. Georgia will surely be that serious transit country and that transport-logistics hub, which will link East with Europe in the view of freight traffic activities.

2. Preconditions and means for resolving the problem

Georgia's overland, air and maritime transport infrastructure will be able to serve freight traffic from China to Europe. The government of Georgia considers the Anaklia Port as a main sea-gate of Georgia, and as one of the main logistic center in South Caucasus region. The mentioned Port shall serve freight traffic from China to Europe. The Anaklia Port is to be a largest berth not only in Georgia, but on the north-eastern Black Sea coast

as well, and, this being the most important, the transportation route from China to Europe passing through Georgian territory is a shortest one. Georgia shall execute function of a regional transport, infrastructural and industrial hub, and shall become a significant link in the Europe-Asia Transport Corridor.

A new railway line linking Chinese port Liaoning, located on the Yellow sea coast near Shanghai, with Almaty in Kazakhstan, is called “A New Silk Road”. Already several projects related to “A New Silk Road” have been considered for many a year. China holds negotiations for building a main railway line across Asia. According to one of these projects, the route should be lengthened from Almaty to the Caspian Sea, and after the carriage by sea, it will be lengthened to Turkey passing through Azerbaijan and Georgia. A new railway line should also pass through Turkey's territory. Last year, there was put into operation the tunnel under the Bosphorus strait, which connects the Euro-Asian transport systems. When “A New Silk Road” is put into operation, China links with the European Union circumventing Russia.

The railway and maritime administrations of Georgia, Azerbaijan and Kazakhstan set up a Coordination Committee for the Trans-Caspian Corridor development. The Committee is aimed at the attraction of intransit shipment, adopting a coordinating policy for establishing tariffs for carriage (transparent tariffs), infrastructure development and creation of a joint integrated logistics product. Implementation of “A New Silk Road” allows these three countries, as well as Turkey, Iran and Balkans, for strengthening transportation and economic relations between them. The capability of this Transport Corridor, which passes through the mentioned countries, will be increased significantly, if we take into account the project for construction of a new Zhezkazgan-Beyneu railway line, expansion of Aktau Port, completion of works for construction of Kars-Akhalkalaki Railway line and putting into operation a new tunnel under the Bosphorus strait [1].

According to the estimate made by specialists, by the year of 2023, the trading volume between China and Turkey will be increased from \$24 billion to \$100 billion, and therefore, the Kazakhstan-South Caucasus Transit Corridor will be of special value.

A 254-km section of Baku-Tbilisi-Kars railway Line passes through Georgian territory. As a result of project implementation, the important railway corridor from Asia to Europe will be open. A new railway will have capability of carriage of 1 million passengers annually and 5 million tons cargo at the first

stage. Finally, it is planned to increase the actual carrying capacity of railway until 15 million tons.

The Baku-Tbilisi-Kars Railway has been named the most important project in South Caucasus region. Implementation of the main railway line project was started in 2007, but its construction – in 2008. It envisages rehabilitation-reconstruction of Marabda-Akhalkalaki railway line on the country's territory, and construction of a new railway line from Akhalkalaki to the border with Turkey. It should be also noted that the railroad passing through the Georgian section is the highest railway in Europe.

The first test train has passed already through the Georgian section of a new Baku-Tbilisi-Kars railway line. This section is what should become a component part of "A New Silk Road". The construction of 180 kilometers of this railway line has been already completed, and now everything is being done for completing all works by the end of 2015.



Pic. 1. Baku-Tbilisi-Kars railroad section

On December 13, 2015, the first train from Chinese port Liaoning pulled in Tbilisi. By incoming of this train, "A New Silk Railway" has been officially opened. The train moved through China, Kazakhstan, Azerbaijan, and passing through Georgia, it will arrive in Turkey. This is the first intransit shipment and the really implemented "Silk Road" Project. For the future, the transit train is to link Asia and Europe in the shortest possible time. Cargo dispatched from port Liaoning, the most easterly part of China, will arrive in Istanbul within 14-15 days, at the latest that can be considered the best result under conditions, when ship needs 40-45 days for the same operation. The mentioned project envisages to transport several thousand containers additionally since the year of 2016 that will increase significantly the country's transit capacity.

Thus and so, from a strategic standpoint, this New Silk Road is no less important than the Baku-Tbilisi-Ceyhan (BTC) and Baku-Supsa pipelines, or the so-called South Caucasus Pipeline, the Baku-Tbilisi-Erzurum (BTE): oil and natural gas may be exhausted within the 40 or 50-year period, but the global Silk Road will have a global impact for a long time in the future. Passing through tunnel existing at the Bosphorus strait bottom and the Kars-Akhalkalaki-Tbilisi-Baku Railway Line, this Road links to each other the European and Asian transport systems. In view of the above, in to attract shipments from Central and Eastern Asia, this Silk Road needs more government support, which includes the following measures [3]:

- For keeping the TRACECA competitive ability, it is expedient to provide continuous coordination of work with Caucasus and Central Asia countries, and provide the coordinated tariff policy. It is also necessary to carry out comprehensive analysis of production and

transportation fields, and through this to determine potential cargos to be attracted;

- It is necessary to study the Central Asian freight (6-8 million tons, i.e. the potentially attracted volume that is possible in the conditions of attracting additional cargos and adopting the so-called "transparent tariffs", and opening ferry traffic lines). Presumably, about 8-10 million tons of cargo are transported from Asia to Europe annually through the alternative corridors passing through Russia. In case of implementing tariff policy coordinated with neighboring countries, it will be possible to attract these flows;
- Georgian ports have to diversify cargo turnover in order to become able to compensate in the future the expected losses caused by possible reduction of oil and oil products transportations by adopting "transparent tariffs" and increasing container services;
- The overall capacity of Georgian ports (Poti, Batumi, Kulevi) is 40-45 million tons annually. Currently, the volume of intransit cargo traffic is 20-25 million tons (railway + motor vehicle transport), in other words, only about half of the potential capacity of Georgian sea port terminals is used at the moment. In addition, it should be taken into account that after putting into operation the Kars-Akhalkalaki Railway by the end of 2016, Georgian sea port terminals will lose part of intransit cargo traffic. Besides, the global economic indices of cargo turnover over the last 10 years are not distinguished by high rates of growth, and, at the same time, there is also the growing competition from other transport corridors. Thus, the construction of a new port in Anaklia with annual capacity of 100 million tons could be justified by focusing on those special cargos (wheat, cotton, liquefied gas, etc.), processing of which in other competitive port terminals (in Turkey, Ukraine and Russia) is limited or not carried out at all.

3. Conclusion

In view of the new realities created by signing the Association Agreement between Georgia and the European Union, Georgia for the first time was given the opportunity to be properly involved in the processes of global economic integration. This problem can be successfully resolved through safeguarding the Euro-Asian transport-communication space, and in the conditions of harmonizing the country's geo-economic interests. The program "A New Silk Road – Economic Belt" allows for strengthening economic relations in the fields such as: transport, communications, trade, energy and tourism.

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DETERMINING THE INFLUENCE OF VIBRO-ENERGY OF INTERNAL COMBUSTION ENGINE ON CAR SUPPORTS AND FRAME

ОПРЕДЕЛЕНИЕ ВЛИЯНИЯ ВИБРОЭНЕРГИИ ДВС НА ОПОРЫ И РАМУ АВТОМОБИЛЯ

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Abstract: When the internal combustion engine operates there are arising forces acting on the supporting elements, and by both value and sign they represent variable forces. They vary depending on time, depend significantly on load conditions of engine and are characterized by different vibro-frequency energies. These energies are unevenly distributed due to fact that the engine design comprises the elements having inertial, flexural and dissipative properties, frequency characteristics of which often vary within a wide range.. The paper describes the method for determining frequency characteristic of vibro-energy transferred to the frame by introducing the vibro-energy transfer coefficient, which allows for determining frequency characteristics of vibro-energy transferred to the frame, on the basis of which, in turn, it becomes possible to determine efficiency of bearing shoes.

KEY WORDS: INTERNAL COMBUSTION ENGINE, VIBRO-ENERGY, FREQUENSY CHARACTERISTIC, NOISE LEVEL, VIBRO-ENERGY TRANSFER COEFFICIENT

The vehicle's reciprocating internal combustion engines, their details and mounts are of complex design, thus the engine weight distribution law in horizontal, vertical and any other direction is of a very complex nature. The flexural properties and energy dissipation are also unevenly distributed. Such design properties lead to considerable propagation of vibro-pulses caused by impact and operation processes during the motion of the engine details and mounts. The mentioned forces act on the supporting elements, and by both value and sign they represent variable forces. The value of their variation depends on both the engine rotational frequency and load conditions, the frequency characteristics of which often vary within a wide range. On the basis of oscillatory motion caused by forces arisen in a system, there are determined frequency characteristics of vibro-energy of the engine external surface influencing on a car frame by passing through the bearing shoes that in turn causes vibration of frame and increases the noise level as well as puts the engine bearing shoes and car frame out of order.

For describing and studying the frequency characteristics of the engine bearing shoes, it is possible to use the vibro-energy transfer function, which represents the ratio between the car frame vibro-energy and the engine vibro-energy. In this case, there is examined the influence of one system on another one by means of intermediate member (bearing shoes). If we name the pulse and energy of force acting on a system an external or entry action, which we denote by $y(t)$ function, then the pattern of a system's studying parameters variation is considered with its output reaction, which we denote by $x(t)$ function. So, the action of a system's input parameter $y(t)$ and output reaction will be functionally linked by means of the appropriate operator W_φ . The mentioned operator determines the nature of transformation of input reaction action when moving through the system, and simultaneously, this operator can be both linear and nonlinear. The operative form of vibro-energy transformation in a system can be displayed as shown below:

$$(1) \quad x(t) \rightarrow W_\varphi y(t)$$

In order to better analyze the vibration transfer coefficient, there has been examined a linear system, in other words, the system, which is described by the linear differential equations with constant coefficients and linear homogeneous operators, which has the following properties:

$$(2) \quad \left. \begin{aligned} W_\varphi[\sum_{i=1}^n y_i(t)] &= \sum_{i=1}^n W_\varphi[y_i(t)] \\ W_\varphi[C y(t)] &= C W_\varphi[y(t)] \end{aligned} \right\}$$

First of all, such a linear system is characterized by the impact of the external forces on the object under study. In general, the linear system can be described by differential indices of the n -th degree and constant coefficients

$$(3) \quad \sum_{k=0}^n A_k \frac{d^k x}{dt^k} = \sum_{e=0}^m B_e \frac{d^e y}{dt^e},$$

where, $n > m$ and it is assumed that $\frac{d^0}{dt^0} = 1$. When studying the linear system, the initial conditions are studied in the usual way, and the rest state is taken as an initial state of system, but the external impact is represented by a unit function or unit impulse. In this case, the system's output reaction takes the form of a unit function or a unit impulse function, accordingly. Let us consider passing of a simple harmonic motion through the linear system

$$(4) \quad y(t) = B e^{j(\omega t + \varphi_1)} = B e^{j\omega t} \cdot e^{j\varphi_1} = \dot{B} e^{j\omega t}$$

where, complex amplitude $\dot{B} = B e^{j\varphi_1}$.

During steady-state operating conditions, the system's output reaction is of a harmonic nature as well

$$(5) \quad x(t) = A e^{j(\omega t + \varphi_2)} = A e^{j\omega t} \cdot e^{j\varphi_2} = \dot{A} e^{j\omega t}$$

This equation represents a particular solution of the 3rd equation, and by inserting (3) and (5) equations, we obtain in the 3rd equation

$$(6) \quad \dot{A} \sum_{k=0}^n A_k(j\omega)^k = \dot{B} \sum_{e=0}^m B_e(j\omega)^e$$

In the conditions of a simple harmonic motion of system, the ratio of the system's output and input complex amplitudes represents complex transfer coefficient of a linear system

$$(7) \quad W_\varphi(j\omega) = \frac{\dot{A}}{\dot{B}} = \frac{A}{B} e^{j(\varphi_2 - \varphi_1)} = \frac{\sum_{e=0}^m B_e(j\omega)^e}{\sum_{k=0}^n A_k(j\omega)^k} = \frac{Q(j\omega)}{P(j\omega)}$$

If $(\varphi_2 - \varphi_1) = \varphi$, then finally we obtain

$$(8) \quad W_\varphi(j\omega) = \frac{A}{B} e^{j\varphi}$$

By (7) and (8) equations, we obtain

$$(9) \quad \left. \begin{aligned} \frac{A}{B} &= W_{\varphi}(j\omega) = \left| \frac{Q(j\omega)}{P(j\omega)} \right| \\ \varphi &= \arg W_{\varphi}(j\omega) = \arg \frac{Q(j\omega)}{P(j\omega)} \end{aligned} \right\}$$

Consequently, it should be noted that the transfer coefficient module represents the ratio of harmonic amplitude of the system's output reaction (A) and input reaction of harmonic amplitude (B). This ratio depends on the frequency (ω) and is a system's amplitude characteristic $k(\omega)$. φ is a phase change of input and output harmonic process, thus the dependence $\varphi(\omega)$ represents a phase-frequency characteristic. Therefore, the linear system's complex transfer coefficient can be written down in the following form

$$W_{\varphi}(j\omega) = k(\omega)e^{j\varphi(\omega)}$$

As could be seen from these equations, coefficient $W_{\varphi}(j\omega)$ represents sufficient characteristic of linear system.

If during the study of system, the external perturbation action is nonperiodic, then the output reaction will have several forms of nonperiodic process. But if both parts of motion equation takes integral transformation of one-sided basis for the initial zero conditions, then the complex spectrum is easily obtained for the appropriate processes like in case with the equation (9), and we obtain

$$\frac{F_x(j\omega)}{F_y(j\omega)} = \frac{Q(j\omega)}{P(j\omega)} = W_{\varphi}(j\omega)$$

Consequently, the energy transfer coefficient can be determined not only by the external harmonic impact, but as a ratio of complex spectra of nonperiodic processes between the input and output parameters. On that basis, we can conclude that in order to determine the energy transfer coefficient, it is necessary to determine first the frequency characteristic of interacted bodies, in this case - of the engine and car frame vibroenergy that, according to above stated yields a function characteristic of intermediate member (the engine's supporting shoe), in other words, in such case it is described by a transfer function.

When the engine operates, the oscillatory energy of the external surface for this case is written down in the following form

$$(10) \quad y(t) = \frac{M_g}{2} \tilde{V}_{gj}^2$$

The oscillatory energy transferred to a car frame is determined as follows

$$(11) \quad x(t) = \frac{M_e}{2} \tilde{V}_{ej}^2$$

where, M_g – engine gross weight, kg; $\tilde{V}_{gj}^2$ – vibro-speed of the engine's external surface, m.sec⁻¹; M_e – car frame weight, kg, which is subjected to the action of engine; $\tilde{V}_{ej}^2$ – vibro-speed of a car frame surface, m.sec⁻¹. Based on the acoustics theory, and with high enough accuracy, we may assume that the engine's sound radiation coefficient is equal to the surface radiation coefficient, which comprises the maximum sound power, in other words, radiation coefficient σ_g and the surface's maximum sound radiation energy σ_{max} are equal to each other, and then the engine's sound power is

$$(12) \quad W_{gj} = \sigma_g \cdot \rho c S_g \cdot \tilde{V}_{gj}^2,$$

Also, if we assume that radiation coefficient of a car frame is equal to σ_c , then sound power of car is

$$(13) \quad W_{cj} = \sigma_c \cdot \rho c S_c \cdot \tilde{V}_{cj}^2,$$

where, $\rho c = 400$ kg/m²sec – is a specific acoustic impedance of the environment;

S – (m²) – is a radiation surface area.

If by using the 12th and 13th formulas, we determine the effective speed of the engine and car frame and insert in the 10th and 11th equations, we obtain

$$y(t) = \frac{W_{gj}}{\sigma_g \cdot \rho c \cdot S_g}, \quad x(t) = \frac{W_{cj}}{\sigma_c \cdot \rho c \cdot S_c}$$

but

$$(14) \quad W_{\varphi(t)} = \frac{x(t)}{y(t)} = \frac{M_e}{M_g} \cdot \frac{\sigma_g}{\sigma_c} \cdot \frac{S_g}{S_c} \cdot \frac{W_{cj}}{W_{gj}}$$

If we denote that $m_e = \frac{M_e}{S_e}$ kg/m² and $m_g = \frac{M_g}{S_g}$ kg/m²,

then

$$W_{\varphi j} = \frac{m_e}{m_g} \cdot \frac{\sigma_g}{\sigma_c} \cdot \frac{W_{cj}}{W_{gj}}$$

Consequently, the transfer function of vibro-energy $W_{\varphi j}$ represents a frequency characteristic expressed in accordance with a sound power.

On the other hand, the surface's vibro-speed is expressed in the following form

$$V_j^2 = V_0^2 10^{0.1 L_{Vj}}$$

where, $V_0^2 = 5 \cdot 10^{-8}$ m²·sec⁻¹ – vibro-speed limit value;

$W_{Vj}(db)$ – vibro-speed logarithmic level.

With regard for the 15th formula $V_{gj}^2 = V_0^2 10^{0.1 L_{goj}}$ and $V_{cj}^2 = V_0^2 10^{0.1 L_{cvj}}$

With provision for the latter one, the 14th formula has the following form

$$W_{\varphi j} = \frac{M_e}{M_g} \cdot 10^{0.1(L_{coj} - L_{goj})}$$

The obtained expression represents a frequency characteristic of vibro-energy transfer coefficient, and it predetermines the values of logarithmic level of the engine and car frame vibro-energy at the mounting locations of supporting shoes. The latter formula also allows for describing the efficiency of supporting shoes in various frequency ranges.

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MONITORING PROGRAM FOR NON-MOTORIZED TRANSPORT IN THE CITY OF SKOPJE

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Abstract: Information about non-motorized transport, i.e., cycling and walking, are needed for planning and management support of urban transport systems. However, in the city of Skopje, monitoring programs still aren't established by transport officials on regular basis. Hence, transport planners and researchers lack bicycle and pedestrian counts for managing traffic demand. Having in mind principles for comprehensive monitoring as a framework for assessment, this paper summarizes approaches and recommendations for initiating monitoring program in the city of Skopje. Also, describes steps in establishing monitoring program and identifies possible application of the analyzed monitored data for non-motorized transport.

KEYWORDS: CYCLING, WALKING, MONITORING

1. Introduction

The benefits of non-motorized transport (cycling and walking) as sustainable transport modes are widely recognized [1]. They're environmentally friendly, have health benefits associated with physical activity and take up less road space per user.

Creating communities that support cycling and walking is an important strategy for promoting health, reducing air pollution, and lessening our dependency on an auto-centric transport system. Yet the design of our cities, neighborhoods and transport systems often discourages people from walking or bicycling to places where they work, learn, play, or shop. Urban planners, transport engineers, and other public health professionals need accurate counts of bicyclists and pedestrians to help inform transport planning and investing that support these transport modes [2].

Therefore, there is a need to launch initiatives to count bicyclists and pedestrians in the city of Skopje. These initiatives are based on a growing body of research that documents practical approaches to counting and ways that counts can be used in modeling, as well as in other aspects of transport planning [2].

Traffic volumes are a basic input for transport planning and engineering; hence a modern and comprehensive monitoring program need to be established to produce estimates of non-motorized transport [3]. Not having this program in the city of Skopje and not having data for the trends in the levels of bicycle and pedestrian activity, transport planners and engineers lack basic information about bicycle and pedestrian volumes needed to plan for these modes. In addition, the lack of routine counts for bicycling and walking means these modes of travel have not been assessed adequately in long-range transport plans.

Therefore, emphasizing the need for counting and implementing monitoring program in the city of Skopje, this paper describes the steps needed to develop a consistent and comprehensive monitoring program. It also explores how counted data for bicycle and pedestrian transport can be analyzed and used in order to support transport planning and attain wide public promotion.

2. Non-motorized transport in the city of Skopje

2.1. The Basic plan for bicycle use

The Basic plan for bicycle use in the city of Skopje was completed in 2004, in the framework of the project “Capacity building of Ministry of environment and spatial planning”, coordinated by European agency for reconstruction [4]. The purpose of this plane was to improve the environmental quality and health condition of the citizens, through the use of bicycle.

This plan for bicycle use has been a starting point for activities aimed to popularize and promote bicycle as a transport mean. Its vision was a creation of a safe, comfortable and friendly

environment for bicycle use in the city of Skopje, which will encourage citizens of all ages to use bicycle for transport and recreation in everyday life [4].

The current state of the cycling network in the city is presented in fig. 1, in which current and planned cycling paths are marked in red and blue.



Fig. 1: Current and planned cycling network in the city of Skopje
Source: [4]

Cycling surfaces in the city of Skopje are categorized in several categories (fig. 2 – a, b, c).



Fig. 2:
a) cycling paths
b) cycling lanes
c) recreational cycling paths along Vardar river

Source: [4]

Compared with the situation a few decades ago, the improvements in the development of cycling infrastructure are obvious. Still, additional effort is required to create a well-connected and modern cycling network, in order to encourage the use of this sustainable mode of transport.

2.2. Further development of cycling

Development of cycling in the city of Skopje is a vital part of the sustainable urban transport plane for the city. Results of the so far made progress in the creation of safe, comfortable and friendly environment for the use of bicycle are optimistic and have justified all the efforts for its achievement [4].

Lately, many successful efforts for development of cycling in the city of Skopje have been done, in order to promote and popularize cycling and to attract more bicycle users on urban streets. For realization of this aim, changes in urban network for development of safe, modern and continuous cycling network in the city of Skopje have been made. Also, several years ago a system for bicycle renting was introduced, which is still in function, widely accepted between citizens.

“Skopje - cycling city 2017” is new capital project for advancement of cycling infrastructure in Skopje and for improvement of safety in cycling. In the frame of the project, four main cycling routes will be defined, along city’s boulevards; also, 51 km long cycling paths will be reconstructed. The goal is to alleviate the movement of cyclist, to increase safety and to achieve an effective cycling network. This will be companied with public campaigns and strengthening of the public responsibility. These activities are aimed towards building the perception that cycling and walking are attractive modes of transport and towards increasing their usage by providing appropriate environments and infrastructure.

Presented achievements have contributed for successful development of cycling in the city of Skopje, and for building of sustainability of urban transport. The future progress in cycling will depend of the efforts directed to the development of continuous, safe and modern cycling network.

2.3. Walking

Having in mind that the city of Skopje is approaching to 600.000 inhabitants, it’s clear that walking is not a first option for everyday urban journeys (work, school, shopping, recreation...). Compared with other transport modes in the city, so far walking has got the least attention. That is the reason why aren’t prepared any plans and programs schemes for development and progress of walking infrastructure, and why aren’t available data or statistics of any kind.

3. Development of monitoring program

3.1. Need for counting

Traffic counts are one of the basic building blocks of transport planning and engineering [3]. Transport planners and engineers need information about volumes of bicyclists and pedestrians on streets, sidewalks, multiuse paths, and other facilities to design safe and efficient urban transport systems.



Fig. 3: Urban cycling and walking; Source: [5]

For example, if transport managers do not know traffic volumes and do not observe seasonal variations, they cannot determine exposure and accident rates, and they cannot assess the effectiveness of programs to reduce bicyclist and pedestrian fatalities. Similarly, if transport managers do not know volumes of bicyclists and pedestrians on particular facilities, they cannot determine efficient maintenance programs that maximize benefits of resources devoted to system operations [3].

Counting initiatives will show whether the levels of bicycle and pedestrian activity are increasing and also their variations due to differences in infrastructure or season, neighborhood socio-demographics, urban design, land use, and other characteristics of the built environment [2].

Monitoring data are key requirement for transport plans, providing accurate figures such as scheme assessment and evaluation. Hence, cycle and pedestrian monitoring provides valuable information for decision-making [5].

By monitoring pathways and cycle ways, local authorities gain the data they require to evaluate the access to safe and convenient walking and cycling facilities, to justify the investments and to adapt the layout to real needs and demands [5].

3.2. Counting non-motorized traffic for transport planning

Data of bicycling and walking patterns, such as peak hour traffic and average daily bicycle traffic, are commonly used in transport planning and management to estimate daily or annual traffic, compare mode share, or design facilities [2].

Counts of bicyclists and pedestrians can be used to estimate demand for facilities, the potential benefits of investments, and the need for traffic control modifications. Planners can use counts and models to estimate traffic on proposed new cycling and walking facilities, to quantify their attraction and to understand visitor circulation. Counts can also be used to encourage state and local officials to institutionalize commitments to counting and planning for infrastructure that supports bicycling and walking [2]. As monitoring programs are initiated, public health professionals and policy-makers will be more empowered to make stronger arguments for investments in bicycling and walking facilities, as well as other interventions to increase active travel [2].

The lack of pedestrian and bicycle volume data is a barrier to transport officials efforts to plan more effective facilities and to improve safety for pedestrians and bicyclists. The lack of system-wide pedestrian and bicycle volume data limits the ability of transport officials to provide or improve pedestrian and bicycle facilities where the need is greatest and is an impediment to developing better predictive methods for pedestrian and bicycle crashes [6].

The most common ways for use of pedestrian and bicycle count data are [6]:

- tracking changes in pedestrian and bicycle activity over time;
- measuring the usage of a bicycle or pedestrian facility;
- evaluating before-and-after volumes after a new facility is opened/improved;
- identifying high-priority locations for pedestrian and bicycle facility improvements;
- prioritizing pedestrian and bicycle projects;
- conducting risk or exposure analyses;
- quantifying exposure and develop crash rates and identifying the before-and-after safety effects of upgrading a facility;
- monitoring travel patterns at automated count sites, for use in developing factors to expand short-term bicycle and pedestrian counts at other locations;
- modeling transport networks and estimating annual volumes;
- developing and calibrating multimodal travel demand models.

Once started, non-motorized count data will likely continue to grow in importance as cities integrate non-motorized performance measures into their performance management programs [6].

3.3. Approaching to counting

Monitoring and evaluation program should be developed for any intervention and the costs of this should be factored in when evaluating the cost of the proposed infrastructure. The program would typically be some variant on a logic map or logic framework – a systematic and visual presentation of the key steps required to develop a monitoring program based on the scheme objectives [7]. This requires the identification of aims, objectives, inputs, outputs, outcomes and impacts. A simple example is given in fig 4.

Objective	Input	Output	Outcome	Impact
Improve cycling safety	Infrastructure improvement resources	Physical route, signage etc	Increased usage, improved perceptions of safety etc	Reduction in incidence of accidents, congestion reduction etc

Fig. 4: Data gathering; Source: [7]

The approach to counting must consider the characteristics of the route or network. There are no quick fix ‘counts required per kilometre’ or ‘survey this many users’. Rather, the data to be collected should directly address the intended outcomes and impacts, and should relate to what is on the ground [7]. Is there a suitable location for an automatic counter on the route/network? Are there schools/workplaces that are served by the route/network where data can be gathered? Are there ‘braids’ in the route/network that dictate cyclist and pedestrian flows?

The other key constraint is cost. The investment in monitoring programs needs to be proportionate and address the outcomes and impacts cost-effectively. Scaling of costs is not a simple matter [7]. If a more detailed data set is required, costs are inevitably higher. A low cost scheme may not necessarily correspond to a scheme with a minimal data requirement.

3.4. Planning the monitoring program

The following steps are involved when starting to plan a non-motorized count program [6]:

- **Specification of the data collection purpose.** It is important to define at the start *why* data will be collected and *how* the data will be used, as this information drives subsequent decisions about where, when, and how to collect data. Both current and potential future uses of data should be considered.
- **Identification of data collection resources.** Available resources will help define the initial scale of the program. Many successful programs have started with a small number of count sites and later expanded after the value of performing counts had been demonstrated.
- **Selection of general count locations and determination of the count timeframe.** Pedestrian and bicycle data collection programs can benefit from combining two approaches (table 1): (1) gathering short-duration counts (typically less than one day to several days, but potentially up to several months) at many locations; and (2) gathering continuous counts over multiple years at a small sample of locations. Count sites can be selected in a number of ways, but the data collection purpose should always be a consideration when selecting sites. In addition to identifying the geographic scope of count program, previously should be thought about *how long* and *how often* counts will occur.

Table 1: Key steps in institutionalizing non-motorized transport monitoring; Source: [8]

Permanent Data Management Program	Short-term Data Program
1. Review the existing permanent count program	1. Select count locations (random and/or non-random)
2. Develop an inventory of available permanent count locations and equipment	2. Select type of count (segment and/or intersection)
3. Determine the traffic patterns to be monitored	3. Determine duration of counts
4. Establish seasonal pattern groups	4. Determine method of counting (automated and/or manual)
5. Determine the appropriate number of permanent automated traffic recorder (ATR) locations	5. Determine number of short-term counts
6. Select specific count locations	6. Evaluate counts (accuracy characteristics, variability)
7. Compute monthly factors	7. Apply factors (occlusion, time of day, day of week, monthly, seasonal)
8. Develop seasonal factors	

- **Consideration of available counting methods and technologies.** There are a number of available technologies for counting pedestrians and bicycles, and many count programs use several of these.

Implementation of the monitoring program should be performed after planning, and here different set of steps are involved (table 2).

Table 2: Planning and implementing the monitoring program

Source: [6]

Planning the monitoring program	Implementing the monitoring program
– specify the data collection purpose – identify data collection resources – select count locations and determine the count timeframe – consider available counting methods and technologies	– obtain necessary permissions – procure counting devices – inventory and prepare devices – train staff – install and validate devices – calibrate devices – maintain devices – manage count data – clean and correct count data – apply count data

3.5. Analysing the monitoring data

The analysis should be planned at the stage of designing the data collection approach and should respond directly to the requirements of the monitoring program [7]. For instance, there would be no requirement to report on trips to school if the primary outcome measure is tourism-derived revenue.

The complexity of assembling an expression of impact depends on the reporting needs and the data sources used. It is relatively easy to report on the usage of a short stretch of route if a counter is available and user intercept survey data available [7].

However, this approach can risk significantly underestimating usage on a more complex network due to the failure to account for sections of the route not covered by data collection activity [7].

The output from the analysis is required to communicate the usage and input and should be clearly expressed in the monitoring program. Options might reasonably be expected to include [7]:

- measures of levels of walking and cycling
- measures of/change in:
 - levels of walking and cycling
 - levels of walking and cycling among particular user groups
 - levels of walking and cycling by particular trip type category
- perceptions of safety
- perceptions of other facets of a route
- revenue generation performance of a route
- health benefits associated with a route
- economic benefits associated with a route
- benefit to cost ratio of a route.

Presentation of these results must have regard to the target audiences and be accessible to them [7]. Whilst a detailed analysis may be appropriate for a more technically minded audience, a strong emphasis on more visual representation of key results will be more suited to others.

Today's technology provides a range of solutions for monitoring and analysis of the data. No matter of the level of sophistication, the flow of data should be similar (fig. 5)

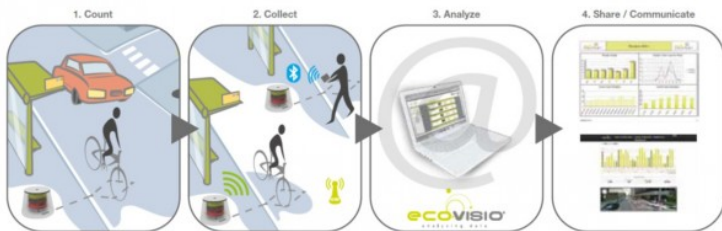


Fig. 5: Processes in monitoring program;
Source: [5]

Meeting government cycling targets and showing that count collecting data is important is one thing, but sharing the data with the public is a great way to share the success of cycling policy.

Example is a creation of the public web page, as an easy way to share the data with the public and other stakeholders. The counted data can be published on a dedicated web page for easy access by website users.



Fig 6: Example of public web page;
Source: [5]

Today's technology can offer a range of technology based solutions that can promote cycling and walking infrastructure and highlight active routes to both pedestrians and cyclists, encouraging increased usage. Based on counted data, technology can give support from custom design and product supply, through to delivery and on-going support [5].

4. Conclusion

Strengthening the share of non-motorized transport, i.e., cycling and walking, and increasing the number of journeys made by bicycle or on foot represent a real objective in the building of a less congested, less polluted, and less noisy city that makes better use of space and energy.

Information about use of streets, bike lanes and sidewalks by bicyclists and pedestrians is needed to support planning and improve management of transport systems. For a variety of reasons, including the absence of regulations and because most bicycle and pedestrian transport occurs on local streets, so far aren't established monitoring programs in the city of Skopje.

Monitoring data are important for the support of transport planning - therefore, it's vital that authorities establish a monitoring program of non-motorized transport, which will set a baseline and changes will be measured from that. This will indicate priorities in cycling and walking, help make the case for continued investment, show where further investment is needed and provide data for the planning and design of continuous and safe cycling and pedestrian networks and facilities [7]. Data relating to a given route or network can be used to examine the efficacy of the development, to report

back to funders, to generate public support, or to make the case for continued improvement. If monitoring program is established and counted data are used for these purposes, their contribution for the effectiveness in the realization of the project "Skopje – cycling city 2017" without any deny, will be indispensable.

Once developed and implemented in the city of Skopje, as suggested in the paper, the possibilities of monitoring program will be limitless. Policy-makers, transport system managers and researchers can use monitored data for non-motorized transport in a wide variety of applications, including facility and system planning, allocation of resources for infrastructure investment, evaluation of project and program alternatives, and assessment of transport safety and management interventions [2].

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