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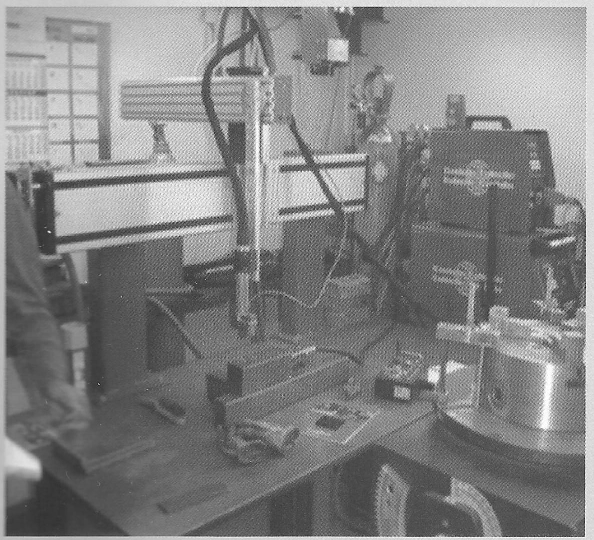

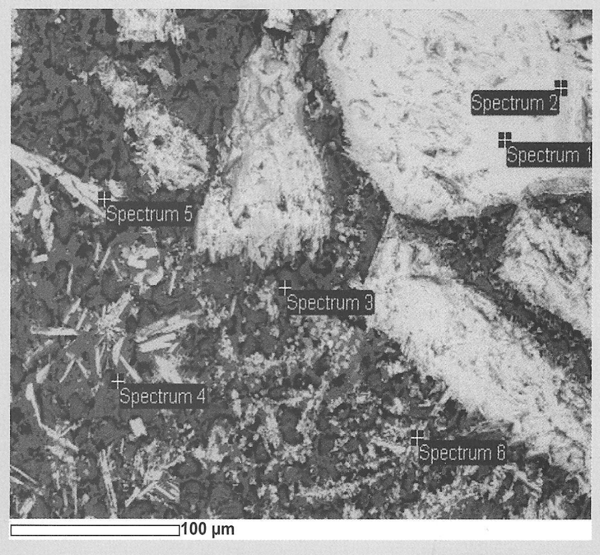

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CONTENTS	CUPRINS	

SCIENTIFIC BULLETIN OF
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BULETINUL ŞTIINŢIFIC AL
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USING THE NUMERICAL SIMULATIONS AND COMPARATIVE DIAGNOSTIC METHODS TO OPTIMIZE THE PRODUCT

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Abstract: Using the numerical simulation is an excellent tool, which can perform optimization of the structures and components, allowing a wide range of applications in order to reduce errors and therefore, reducing costs in production and providing great advantage in repairing and solving the construction issues. This paper presents some of the specific applications received by the application of software packages and CATIA results of other diagnostic methods: tensometric structural mechanical tests and testing by thermography stress state was measured in real time and load, while structural mechanical tests were conducted on parts of structures that have been analysed by using numerical simulations. Here is presented several approaches to optimization of product, the first optimization is for the proper selection of materials, simulation of crack propagation behaviour of the material and physical properties, the second optimization is done in program package ANSYS FLUENT simulation of multiphase flow in the ventilation mill and in the third part is shown the optimization of structures, using software package CATIA and parallel using of tenzometric and metallographic tests. Structural mechanical tests have shown a very pronounced effect of dynamic loads, that large shear stress shows also as a good agreement, where between the stresses, obtained by tensometric, thermography and numerical simulation. Analysing the results, obtained by numerical simulation, tensometric and structural mechanical testing were performed with the redistribution of critical stresses, and proposal for the structure optimization.

Keywords: Numerical simulation; optimization; tensometric, thermography, structural - mechanical tests, dynamic loads

1. Introduction

The numerical methods are the primary tool today in engineering analysis and simulation. These are used in all branches of science and technology for simulation of flow, in the field of various construction fluid mechanics, aerodynamics, hydrodynamics, and thermo-dynamics, and combustion, multiphase flow, in pharmacy, chemical industry, thermal power plants, and sports and so on. [1-3] Today in the world, there are a wide range of software for the numerical simulation. These uses are, especially, important in the case of complex testing on complex facilities.

Modern industry has a practical need to carry research and development activities out of current production, in the development laboratories in factories or laboratories at the universities and institutes. The activities in R & D processes outside of the production environment can be classified as modeling and simulation. Compared to the traditional design process, which based on experienced work of engineers, it brings a significant reduce of time and costs of developing the new products. [2-5] The advantage of this kind of design, is the possibility of project changes, in the geometry of product, and in process parameters, all at minimal cost. In these conditions, it is possible to optimize the design of products and processes, to predict failure and occurrence of defects in the product, to use optimally production equipment and tools, to increase their lifetime by reducing wear and prevent fracture. [1,2,4] Reducing the time of design and manufacturing the product, are achieved by using numerical simulations in the early design stage (before making tools for production and test production) because, all the potential problems can be observed and avoided. [3] With the numerical simulation can be defined the deformation force, material flow, temperature, stress on tools, properties and microstructure of the product, estimation of elastic correction and residual stress, monitoring of filling in the engraving tool, disclosure of defects origin in materials and tools failure etc... This way of planning can save time and avoid unnecessary costs. It, also allows numerical simulation and subsequent, easier modification of parts and constructions that are already in use and performing their optimization.

Flexible virtual models of the process allow examination of the effects of design changes, as the product geometry and process parameters on product quality and production costs. [1,2,3,5] In such conditions is the design optimization of products and processes, and predicting failure and occurrence of defects in the product, optimal use of production equipment and tools possible, with the increase of their lifetime, by reducing wear and prevention of fracture. The tools for numerical simulation of the manufacturing processes are not only support for product development and optimization of production process, but also the means to support the PLM system, for making the right management decision, at an early stage of design. [1,3,4]

The most widely applied and the most powerful "tool", for the numerical simulation of machining processes is, of course, the finite element method (FEM). In recent years, thanks to the rapid development of computer technology, a lot of commercial software has been developed, based on the finite element method for solving the problems in the metal processing. The options and prices of FEM programs are different, depending on how they adapted to the practical needs for the end user through the user interface, and how effective is the work considering the accuracy of analysis and computer time.

The numerical simulation process consists of the several phases: the first is generation and production of models, over which a numerical simulation will be done. It is best to create model faithful to the original design. Generating of network and model division on the large number of finite elements is done, after that. The number of elements depends primarily on the size of construction and possibilities of our hardware, to handle a certain number of elements. The last part is related to the choice model of simulation and defining the parameters, which depend on the input data and wish to get what we want with the simulation. Defining the boundary conditions causes having certain parameters fix. Therefore, it is necessary to introduce credible information to get the expected results that would be useful and realistic.

Here presented examples of numerical simulation software packages NASTRAN, which have undergone the optimization process of welding and propagation of crack, ANSYS FLUENT that underwent simulation of particle motion in the ventilation mill and power plant program for modeling and analysis of structures this is optimization of processes and influence of the processes on construction. CATIA, that performed optimization of a part of bus chassis construction. In this way, the whole process of numerical the simulations is circled, from simulation and optimization of material to the flow of fluids in some systems, as well as, the optimization and verification of the structure.

Beside the numerical simulation, there are other methods, by which you can do optimization, verification and redesign of construction. Thermography and tensometric are the methods which, together with the numerical simulation, can provide a complete picture of what is going on, in some part of the structure. A complete characterization of the system, in terms of the exploitation of properties, implies an understanding of their behavior, in the presence of errors, the valuation of their resistance to crack initialization and development one of the most dangerous types of errors.

An important direction of research is, how to discover a mistake before it reaches a critical size, in order to prevent the appearance of fracture. Thermography is a method that allows analysis thermoelastic stress, based on measuring the infrared radiation emitted from the surface, exposed or static of dynamic, linear elastic and plastic deformation and its converting into a visible image, thermogram. Based on the temperature distribution over the surface of the sample, during the action of force, determines the expansion of the plastic zone and the estimated direction of crack propagation. This is a new approach that can be used with the existing classical methods in the using for determination appropriate software to be of fracture mechanics parameters. [2-6]

Another method, finding the critical places and weaknesses of construction, is to use the tensometric and measuring tapes. The tensometry and experimental analysis of mechanical stresses allow the measuring of mechanical stresses and strains in the components and design of the product, what is the precondition for the optimal design and construction. Stresses, which can be measured, are: the stress due to external loading, thermal stress, and residual stress.

2. Case I

Analysis of welded specimen for simulation of process which can be used for further evaluation of structural life, fatigue, determination of critical areas of the structure . Experimental setup for testing of tensile features for specimens is illustrated on the Figure 1. Sample was joined by using standard TIG welding process. Tensile testing and thermography measurements were performed simultaneously. The extension was registered using double extensometer. Therma CAM SC640 Infrared camera, FLIR Systems, Figure 1. has been used for recording thermogram. It is capable of measuring temperature in the spot, on the line at the given surface of the various shape and dimensions, to show isotherms using gradation of grey or the palette of various colors and shades. On Figure 2. Is shown Diagram of load versus displacement. The camera is provided with the automatic correction of emissivity and atmospheric transmission.

To determine stress distributions of butt-welded joint specimen here is used finite element method. It is well known that butt weld is an important connection for the integrity of most types of welded structures such as bridges, ships, pressure vessels and offshore platforms. Higher utilization of structural materials leads to a need or accurate numerical tools for reliable prediction of structural response. It necessary to simulate the load and get a scenic view of results that can be used for further evaluation of structural life, fatigue, determination of critical areas of the structure and so on. Some of examples of NASTRAN application: [5-8] The finite element method (FEM) was use to obtain the local stress states at weld toes.

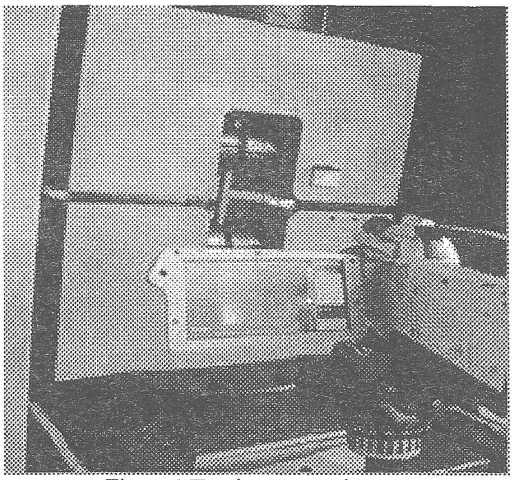


Figure 1 Tension test equipment

Butt-welded joint specimen is modeled using thin shell finite elements. Material of this sheet-metal is X10 CrNi 18 09, and welding process is TIG (141). When we have CAD model including geometry and surfaces then we define constraints and load on this model, material, property and create the 2D mesh in FE code. Next step in this work is to calculate stress in the plates and in the welding joint. For this purpose we used FE analyzing by MSC NASTRAN software.

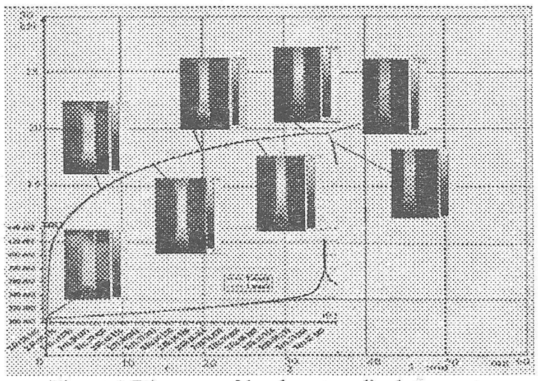


Figure 2 Diagram of load versus displacement

In this case critical area is weld joint of specimen. Figure 3 is illustrates FE results of stress distribution for the considered specimen with two butt welded plates under tension load. It can see critical area with respects strength of weld joint in this specimen. The places of maximal stresses, denoted as red color in Figure 3, are critical location. In this case, that is welding seam. Welding seam hear is area where ensue failure.

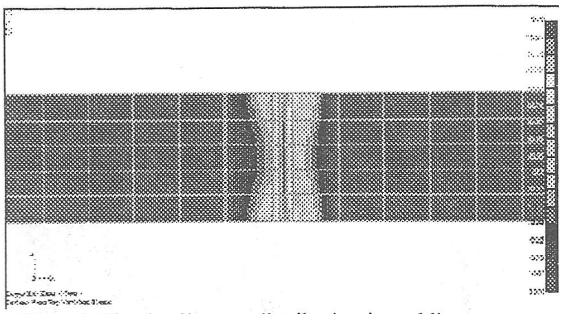


Figure 3 The detail stress distribution in welding area of specimen

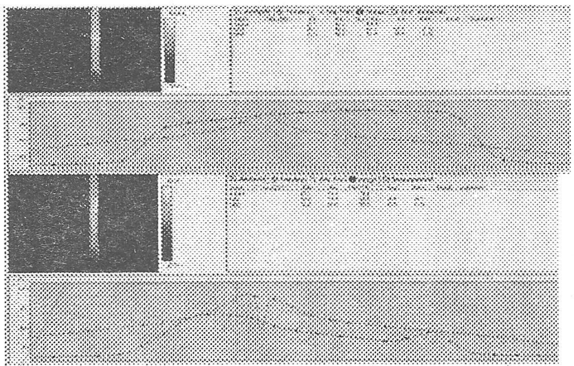


Figure 4 Thermograms and measured temperature values for specimen surface on lines L01 and L02.

Tensile test was followed by thermografy, which shows, that there is an initial indication of residual stresses in the weld root, which, then spread on the entire weld and ends with crack propagation in HAZ specimen and break at that point. Numerical simulation shows thru the NASTRAN, a weak point that is placed in the middle of the weld, as can be seen in Figure 3. Crack initiation is associated with the stress concentration and errors in the weld. The main cause of the fracture is error in the welded joint, which is not detected by standard tests metods. It is very important, that numerical simulation shows where is a critical point in the middle of the tube and weld. Diagrams, done on specimens, show the correlations with numerical simulations. Monitoring the welded joint seciment, during the experiment in which acting the tightening load, it is noted that the major stresses in the middle of the weld are slightly left as in Figures 3 and 4

2. Case II

Analysis of ventilation mills work indicated, that it comes to the rapid cooling of transmission fluid during milling, which is caused by intensive drying, that takes place simultaneously with the process of milling. Thermovision temperature measurements, which represent the expanded program of research, within of this project, confirmed previous results. Medium temperature of the mixture, at the entrance of the mill is TSR. = 260 °C, and the output is TSR. = 185 °C. Mixture from the mill, through the regulation damper, introduced to the inertial separator, in which , due to inertia forces, come to segregation of larger, insufficiently milled particles, while turning/cornering power. [9-12] Along with the ungrounded particles, significant amount of cooled products of drying, are returned from the separator, which reduce the effect of the mill ventilation and increase energy consumption for grinding. In addition, recycled abrasive particles, enriched with minerals, which have a higher density than carbon mass, are significantly increasing the abrasion of working elements of the mill, what shorts their working life. These observations impose the need for detailed study of the flow phenomenon and considering possibilities of its optimization. In order to optimize the work of the mill, project provides recording the current situation, from which would the geometry and numerical simulation of multiphase flow domain be generated. The results of numerical simulations would indicate the critical points, which are mostly exposed to abrasive wear and tear. Based on the simulation it would be proposed some action for the reconstruction of mill and rehabilitation of working parts, exposed to wear and tear. Within this phase these were made some preparations, the numerical simulation and a study of multiphase flow of numerical simulation in the ventilation mill, with the channel of air mixture with blinds. [8-13] Geometry is generated, based on the project documentations. It is in the domain of numerical simulations and it includes the mill and the mixture channel, with blinds going up to the entrance of the burner. The geometric model, for the numerical simulation, was made on the basis of the current state of ventilation mill. In Figure 5 are shown geometric model of the ventilation mill with channels up to the entrance of the burner and hydro turbine with 12 shock plates. Within the limitations of hardware, an optimal network is generated in terms of adapting the density of network to the changes of geometry and variable sizes of the multiphase flow field (velocity, pressure, temperature, volume fraction of the components).

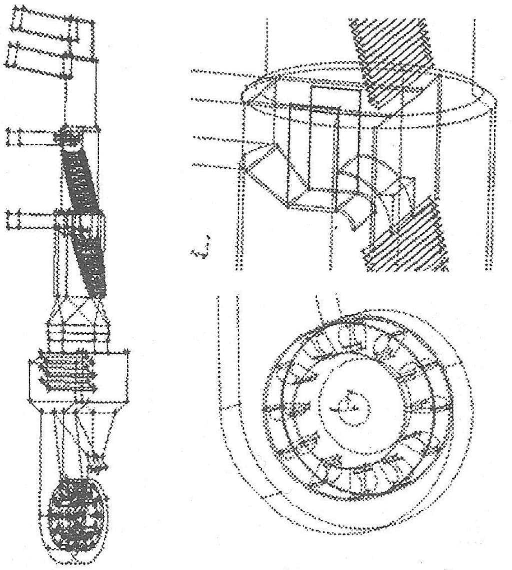
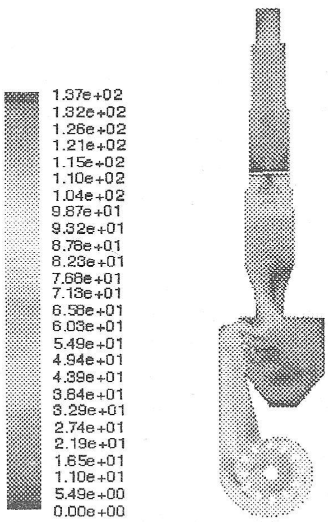
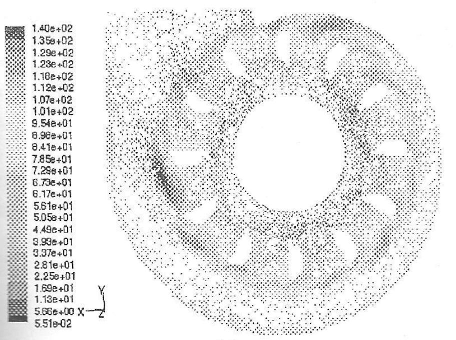


Figure 5 The geometric model of ventilation mill and air mixture channel, detail with the muffler air mixture to the lower burner and hydro turbine mill



(a)



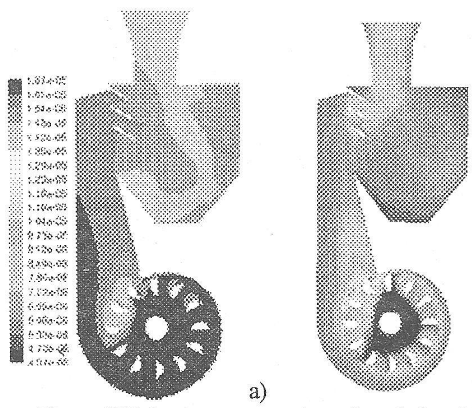
(b)

Figure 6 Field of absolute vectors' velocity mixture in a vertical plane passing through the axis of rotation (a) in the mill around the striking plates (b)

Model of multiphase flow in software ANSYS FLUENT 12, with a special focus on selected multiphase model presented, which was used to simulate the flow in the ventilation mill and the mixture channel with blinds. These are the mixture models, the Eulerian model and turbulence models. [14]

The results of numerical simulation, which are shown by the distribution of the velocity vectors, granular phase volume concentration, turbulence and fluid particles trajectories in the mill, are given in tables in the form of flow image. These results were compared with the measurement results Table 1. As an illustration of the flow complexity, in Figures 6 (a and 6 (b, are shown the vectors and velocity fields mixtures in the mill and the ventilation channels up to burner, in a vertical plane passing through the axis of the mill rotation. Velocity vectors of the mixture in the mill around striking plates, are given in Figure 6 (b, and the absolute velocity vectors of sand particles on the wall of the mill and on the suction plate.

The distribution of sand volume concentration, shown in Figure 6, in the ventilation mill and the mixture channel to blinds, indicate the plants zones that are most exposed to intense abrasion. Presents of the large concentration of sand and turbulence of mixture in the mill it's observed. Figure 6 Measured Volume concentration of sand and turbulence of mixture. Calculated medium velocity of gas mixture, at the intersection of the channel on the main burners and waste, is given in Table 1.



a) b)

Figure 7 Volume concentration of sand a) and turbulence of mixture b)

Table 1 - Measured and calculated medium velocity of gas mixture

	Speed (m/s)	
	Measuring	Numerical Simulation
Lower burner	30,3	30,7
Uper burner	27,0	21,3
Lower steam	17,3	22,4
Uper steam	22,8	22,0

Considering all the parameters and working conditions of the numerical simulations, can be confirmed where are the weak points, obtained by mechanical tests and explain the full picture creation of loading mechanism and is good starting point for the construction optimization. Optimization of ventilation mill includes optimization of process (grinding coal) and optimization of the structure.

2. Case II

Optimization of turntable of the bus here presented. It was done by using numerical simulations, structural and metallographic tests and experimental research into the using exploitation tensometry. The aim of this study is to determinate the cause of the fracture bolts on the front and back of the bus chassis turntable marks bolts and nuts that are Determining the cause of the fracture was carried out, according to the usual practice methodology, adapted to existing conditions and the type of test defects. The starting point of the tests is making the correct model bus chassis with a turntable up to little details. It was performed a preliminary numerical simulation, to determinate at which places will measuring tape be set up. Clamping force is defined by tightening moment whose value is preset bus turntable producer. Examination presents the results of measurements of the stress state, in the bolt connection area, between chassis and turntable of the bus. The measurements and results can serve as a basis for further analysis and establishing a correlation, between the measured stress state, using measuring tapes and stress, obtained by the calculations in the CATIA package software.

Measurement of stress is carried out by using the measuring tapes, which are placed close, as much as possible, while keeping their proper setting, above or below the bolt connections that connect the parts of the bus shown on Figure 8. It performed at the test site and while driving with empty and loaded bus. Having in mind, that the physical measuring tapes, placed relatively far from the place where the maximum stresses occur, in the bolts connection, and that the gradient of the stress drop in the zone is quite large. It can be concluded, that measured stresses are relatively high, indicating the occurrence of relatively high load elements of connection. The measurements have been made that bus loaded with sand bags to the total weight of 25,420 kg.

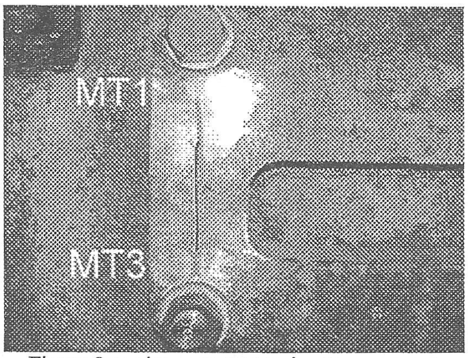


Figure 8 ponits were measuring tapes are put

Measuring the stress state while driving, was made by applying two cases of height reulation of buses, equipped with one or two active sensors, on the middle axis. The elected landslide sections with major damages of the road was as critical, where while driving, occures significant difference in height, between left and right wheel on one axis, and the difference in heights, between the axis, which are often not in the same phase, so these cause curling of the bus around the longitudinal axis. On the Figure 9, is shown the time record of stress changes, in the section with the highest measured stress. Regulating the bus height, in this case it is achieved by using two sensors. It may be noted, that the maximum value of the stress is on the measuring points, which are in the zone of bus turntable - back of the bus, on the left side of the bus conection much higher than the material can hold on.

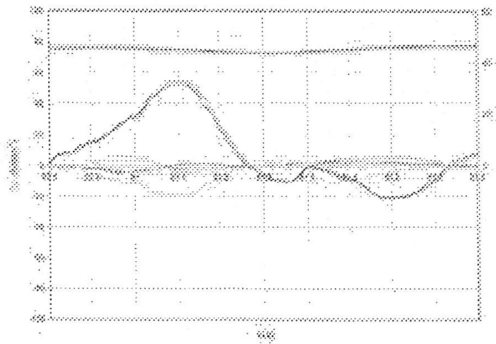


Figure 9 Time record from measuring's tapes during the drive on the section with bad roadway

After the verification of tightening torque effect on the stress condition in the area of bolts, measurements were carried out at the test site. Case of climbing or crossing the roadway, deformations with a height of approximately 150 mm was simulated. Presented in Figure 10.

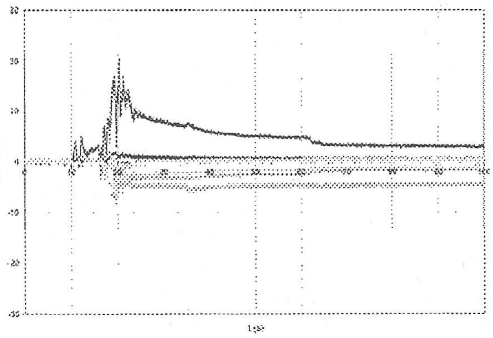


Figure 10 Stress state during crossing of the left bus wheel through barriers of 150mm

The general conclusion of measurements show that the measured stress on the road with major damage curves, depressions, elevations and holes, have stresses, several times higher than the highway. Bolts suffer variable dynamic loads during driving, which are in very short interval of time, several times higher than allowed.

The numerical simulation consists of making 3D FEM model for the calculation and analysis of the turntable assembly with bolts which is done connections to the front and back part of the chassis, using existing conditions it made 3D FEM model for the calculation and analysis of the turntable assembly with bolts connections to the front and back part of the bus chassis, under the modified state with wedges, making FEM calculation - static analysis, the stress and deformation state of the bus turntable assembly with bolts connections to the front and back part of the chassis. [15-17] The calculation includes both versions of links, with and without wedges. These show in some way the credibility of numerical simulation. Repeated numerical simulation of chassis with loads was done, and those were identical, during simulated load measurements, that were at the test site. At the same places where they placed the measuring tapes, now are set sensor devices in CATA program, which measure stress state during numerical simulation. The results were quite coinciding - the difference is about 8-10%, which is pretty good for these types of experiments. Such an overlap, says that the stress value at the very screws is reliable and give us a true picture of loadings.

Authentication is done because the measurement of the stress state hasnt been done on the very screws, but above or below them. So a true picture of the loads could get in the tree of bolts only with the numerical simulation, what we can seen in the Figures 11 and 12, which show the analysis, done for the turntable assembly with screw connections to the front and back part of the bus chassis to the unmodified condition without wedges. Combined loads are visible and uneven distribution of stresses in the stem screw. The dominant loads are shearing and pulling, stretching, bolts. In Figure 13. is shown, the analysis done for the turntable assembly with bolts connections to the front and back part of the bus chassis, to the modified state with wedges, where is visible, that the shearing was reduced to the minimum, so that the load of screw tightening and pulling, or stretching, remains. [14,15,16]

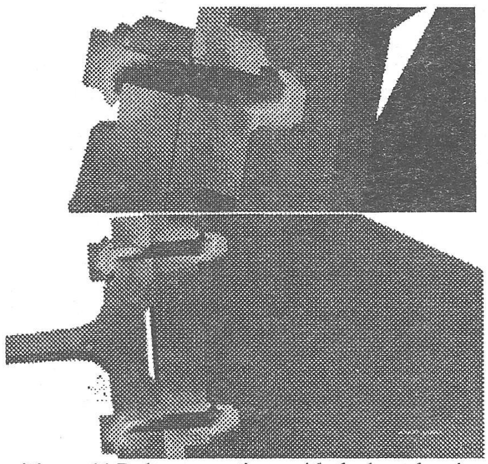


Figure 11 Bolts connections with the bus chassis turntable in unmodified condition where uneven load in the screws stem is visible

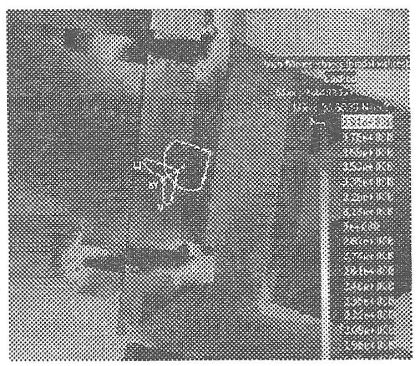


Figure 12 Chassis screws connection with the bus turntable in the unmodified state with a given value of stress

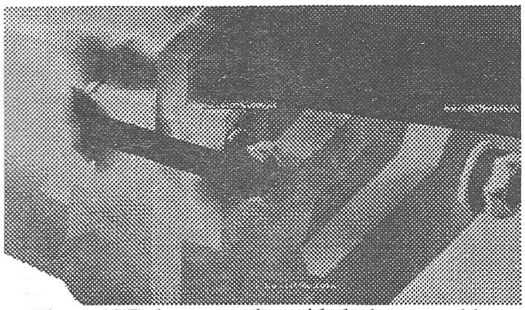


Figure 13 Bolts connection with the bus turntable chassis (with widgets modification).

In table 2 is shown comparative overview of the stress value in bolts, (when folding the back left and right wheel) with wedgets and without it shown in Figure 13. It can be seen, that the stress value decreased quite, for one order of magnitude, which tells, that the solution with the wedge is much better, because it reduces the screw load.

Table 2 Presents comparative overview of the stress value in bolts, (when folding of the back left and right wheel) with widgets and without it.

Nb.screws	Right sides down for 150mm	
	Without WEDGES	With WEDGES
	Screw body [N/m2]	Screw body [N/m2]
1	1,263e+009N_m2	1.814e+008N m2
2	1.07e+009N_m2	1.025e+009N m2
3	6.384e+008N_m2	6.222e+008N, m2
4	9.065e+008N_m2	8.497e+008N m2
5	8.405e+008N_m2	8,607e+008N_m2
6	8.746e+008N_m2	9,61e+008N_m2
7	8.28e+008N_m2	7.506e+008N m2
8	7.397e+008N_m2	7,666e+008N_m2

Mechanical and metallographic tests of screws, that were built into turntable (broken and unbroken) were done, too, so and as testing the new screws for comparison. It was performed, according to the following test methods and activities: Testing of non-destructive testing: Visual inspection, radiographic testing, chemical analysis of screws' sample materials, mechanical properties of screws' materials. Structure analysis of screws' materials: Testing macrostructure (light optical microscope, SEM-EDS) examination of the microstructure (light optical microscope, SEM-EDS) Fractographic examination.

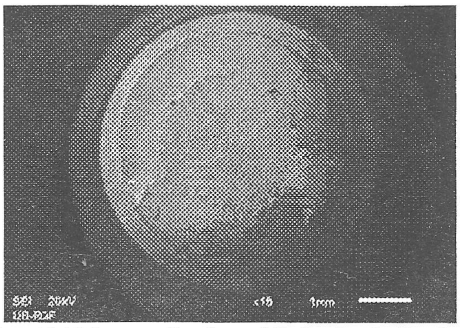


Figure 14 Macrografic view of the broken bolt, where can observed crack initialization zone, which characterizes predominantly ductile fracture

In the Figure 14 was observed crack initialization zone, which characterizes predominantly ductile. Fracture of the broken screws, appeared with the combined use of metallurgical instability of materials and conditions of exploitation. [16] Unfavourable structure of existing materials and mechanical damage, in the root zone of screw thread, influence the expansion of existing cracks to the final fracture.

Table 3 Mechanical properties of material samples bolts

Sample number	Yield stress, $R_{p0.2}$ [MPa]	Tensile strength, R_m [MPa]	Elongation, A [%]	Hardness HV5 in cross section
1	1112	1185	13	329-345
2	1095/	1173	18	/
3	1281	1302	17	/
4	1254	1283	15	362-386
6	/	/	/	381
7	1280	1303	12	/
8	1090	1126	17	296-362
9	1120	1131	15	303-345

In Table 3 are shown samples 1, 2, 3 and 4 built-of non crack bolts (strength class 12.9); 7 built-in - broken bolts (strength class 12.9); Samples no. 8 and 9 non-built - new bolts (strength class 10.9). The results of mechanical and structural analysis indicates the possible presence of excessive screws loads during exploitation. Appearance of screws fractures indicates the presence of material fatigue. On the screws is presented different degree of strain hardening of materials of used screws, that indicates their uneven dynamic load on the turntable connection of the front and back bus chassis during exploitation.

The measurements and results are the basis for further analysis, to establish the correlation between measured stress state, by using measuring tapes and stress state or load that are appearing and unadjusted screw connections with a turntable connection solutions on turnable bus chassis. Stress measurement is carried out by using strain gages, which are placed the close, as close as possible, while maintaining their proper setting, above or below the screw connections, that connect parts of the bus. The measurement was performed at the test site, during driving with empty and loaded bus. Having in mind that the measuring tapes are physicly placed relatively far from the place where the maximum stresses occur in the screw connection, and that the gradient of the stress drop in the zone is quite large, it can be concluded that the measured stresses are relatively high, indicating the occurrence of relatively high load of elements connection. Based on the conducted measurements can also be concluded that in terms of the load of screw connection of the turntable chassis it is better for the bus to have regulation of bus height with active sensor on the central axis. Measuring the stress caused by the bolt connections of torque of 400 Nm (specified by the manufacturer turntable) has been proven that the measured stresses corresponding simulated values of places in CATIA. FEM simulation of lifting and lowering right and left rear wheel of the bus simulation were testing when the whell came on prepared obstacles. FEM simulation of bolted connections with loads provided by the manufacturer as the maximum allowable turntable. Analysis without a wedge with simultaneous loading of a combination of forces in all three directions. This analysis is taken for comparison of the stress state in the threaded connections with wedges and without wedges. For simulations it was found that the stress at the measuring points 1 and 5 several times higher than in the treatment with no wedges. During the measurements is established that the stresses measured on the road which have extensive damage curves, depressions, elevations and gaps and conclusion is that stresses several times more biger value than it is allowed by the manufacturer of screws.

4. Conclusions

The Numerical simulations are now presented required tools to optimize product and process. Used software packages are highly respected in product development and in science. To make the numerical simulations, to give more precise results, need a lot of attention, choosing the input data; conditions of working and exploitation, measurements in real working time, data on emergency states and testing their creation what apply to all three cases, especially in the CASE II. Selection of diagnostic techniques and product status and working conditions are closely related to the precision of the numerical simulation results.

CASE I. Numerical simulation and thermography show a correlation to the critical point, in the middle of the tube and weld. Diagrams that are done on specimens show correlations with numerical simulation, and here is done optimization of the welding process and materials.

CASE II confirmed considering all the parameters and operating conditions of ventilation mill, numerical simulations have confirmed indications of weak points, that we have obtained through mechanical testing and clarify the picture of the formation mechanism of load. Here is done the combined optimization a coal grinding process and design optimization of ventilation mill.

CASE III extensive testing by numerical simulation is using CATIA software, shown that bolts which link bus chassis with a turntable in the case of turntable with a wedge and without wedge, showing way of loading and unloading bolts, so indicate structural and mechanical tests. Confirmation of numerical simulations was done, using the measurements tenzometric. Here is done optimization of the construction turntable bus

This proved to be a very safe methodology in debugging designs with large precision and safety. The results of the numerical simulation can be taken as a relevant process in redesigning products. The main goal of the numerical simulation and the comparative method are the identification and removal of errors in processes and construction. All of these methods are an advanced technology that allows making better decisions and maintain control of the process of product development, modification and its development. The numerical simulation is achieved by reducing the time required for product development, as it can see the possible errors and defects, which may be removed to little cost. All this lead to the optimization of products and tools, to improving quality and increase competitiveness in the market.

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UTILIZAREA SIMULĂRILOR NUMERICE ŞI A METODELOR COMPARATIVE DE DIAGNOSTICARE PENTRU A OPTIMIZA PRODUSUL

Rezumat

Using the numerical simulation is an excellent tool, which can perform optimization of the structures and components, allowing a wide range of applications in order to reduce errors and therefore, reducing costs in production and providing great advantage in repairing and solving the construction issues. Here presents some of the specific applications received by the application of software packages and CATIA results of other diagnostic methods: tensometric structural mechanical tests and testing by thermography stress state was measured in real time and load. Several approaches to optimization of product: Case I is for the proper selection of process, simulation of crack propagation behaviour of the material and physical properties, Case II is done in program package ANSYS FLUENT simulation of multiphase flow in the ventilation mill and in the third part is shown the optimization of structures, Case III is done using software package CATIA and parallel using of tensometric and metallographic tests.

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STUDIES OF THE PROPERTIES OF DIFFERENT HARD COATINGS RESISTANT TO WEAR

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Abstract: Metallization coatings, to improve the properties of the surface coating of material (wear resistance, corrosion etc.) are methods, which more and more, take precedence over other procedures, particularly in economic terms. The benefits of these actions are reflected in the simple preparation of the base material, the possibility of performing procedures in the field, and relatively low operating temperature of the base metal surface. In this way, there is no structural transformation of the materials that are applied coatings. The aim of this paper is, in solving the problem of increasing the wear resistance of the parts for transport and coal grinding in power plants, to investigate the optimum application of technology in hard coatings by different procedures, and filler materials. Application of hard coatings was carried out with cold (plasma and arc treatment) and hot metallization (with concurrent and subsequent drowning). It has been used the filler materials of diferent chemical composition and properties based on Ni (Ni-Cr-B-Si-C; Ni-Cr-B-Si-Fe; Ni-Cr-B-Si / WC, NiWCrFeCSi, NiWCCrTi, NiWCrCoCSi) and Fe (Fe-Cr-C-Si-Mo; Fe-Cr-C-B-Si-Ti; Fe-Cr-C-B-Ni-Si). Cut pieces for mechanical and structural investigations were carried out with water spray jet. These were investigation of its structure, measurement and distribution of hardness in the samples, with hard coatings. Based on the results of these tests, there were selected the filler materials and procedures applying hard coatings, which would be apply in the revitalization of parts in transport and coal grinding.

Keywords: metallization; model-surfacing; resistance to wear; structure; hardness

1. Introduction

Metallization is a common name for mutual related coating processes where filler material warms quickly in the hot gases, and at the same time at high speed deposited to the base material, which results coating with desired characteristics [1, 2, 3, 4]. Many examples of metallization materials tend to be alloys containing hard carbides [5]. Metallization represents one of the modern methods, which takes the lead, thanks to advantages against to other procedures, particularly in economic terms, the range of materials that can be applied and the various scopes of applications. This surface treatment enables relatively quick application of high-performance materials to parts of different sizes and geometries in thickness from a few millimeters to parts of about 25 mm. The advantages of this process are lies in the fact that using of metallization requires a minimum of preparation of the base material. Also, the performance can be in the field, and the process favors the relatively low working temperatures of the base metal surface (compared with techniques such as welding), thanks to which there is no structural transformation of the elements which coatings are applied. Application of metallization, in the economic point of view, is very acceptable, because it allows application of high-quality coatings on lower-quality materials.

Metallization procedures basically can be divided into cold and hot processes. Devices for cold processes, depending on the design, use filler material in the form of wire or powder, and hot process equipment use filler material only in powder form. In choosing process, it is necessary to take into account the following criteria: the impact of the test section (equipment and tools, working part form, dimensions, purpose), the type of wear (corrosion, crack formation), base material (type, quality, melting point, and hardness), filler material (type, purpose, and quality), workability (surface quality) and occupational health and safety. Based on the required characteristics and the chosen procedure, the filler material is selected. It has more than 200 filler materials for metallization, which differ in terms of chemical composition and physical-mechanical properties.

Cold metallization can perform with gas, plasma, supersonic and gas-detonation process and can be applied to all metal materials other than pure copper, glass and non-metals [2, 4]. Core temperature does not exceed 250°C, so that the basic material retains mechanical properties occupied prior to metallization.

Hot metallization can be carried out by applying a powder on the relatively cool surface and subsequent heating and melting of the powder or the simultaneous heating surface, causing the melting of powder. Using heat process it can be metallized only materials that have a melting point above 1150°C. During hot metallization, the materials are heat-treated (improvement, tempering, hardening) and they lose some of its properties, depending on the thickness of the coating, and filler material that is used in powder form [5, 6].

In practice, the metallization is applied for the revitalization of homogeneous components in order to protect them and extend their life. It is a unique process, so in practice there are no standard procedures for defining and applying the most optimal technology or the assessment of remaining life of repaired components. A special problem is a complex procedure of checking the quality of metallized samples. Beside the procedures, the new filler materials are being engaged to provide longer lifetime of parts exposed to wear. The final goal of modern technologies for revitalization is that the life of a component, or appropriate material from which it is made, is at least equal to or longer than predicted, or that is really possible to define periods of regular control.

In many applications, where excellent wear resistance and sufficient impact resistance are required, filler materials modified with the composite particles, as the presence of composite powders in the microstructure may improve their wear resistance without greatly sacrificing toughness [5, 7]. Parameters, which affect the hardness wear resistance, are the structure, shape, size and distribution of micro constituents in the metallizes coatings. Based on previous research, it can be concluded for the intensity of abrasive wearing affect the following factors: the nature and characteristics of the abrasive, aggressive working environment, the operating speed and load, and material properties of working parts, or their contact surfaces [2, 3, 4]. In recent years, in the area of resistance to abrasion and erosion, the technologies of surfacing have been developed or are developing, which use more complex materials alloyed with Cr, Mo, Nb, W, V, Ti, B, Co and other elements [1, 2, 3, 4, 5]. However, before applying these materials in the exploitation conditions, it is necessary to test model metallization samples in order to test the recommendations. The aim of this paper is, in solving the problem of increasing the wear resistance of the parts for transport and coal grinding in power plants, to investigate the optimum application of technology in hard coatings by different procedures, and filler materials.

2. Experimental part

Application of hard coatings was carried out with cold (plasma) and hot metallization (with subsequent drowning). The device which is used in the experiments and method of applying the coating to the test are shown in Figure 1. Cut pieces for mechanical and structural investigations were carried out with water spray jet. The table 1 presents the metallization procedures, signs and nominal chemical composition of filler materials, which are used in model testing. Metallization was carried out on samples which were hot-rolled steel sheet S355J2G3, in one and two layers.

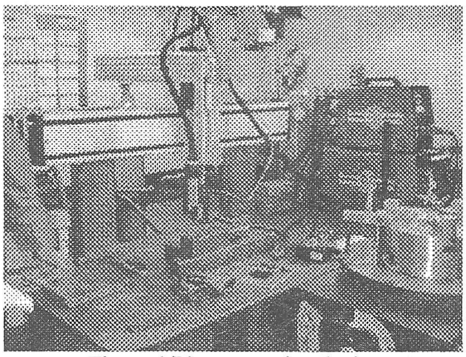


Figure 1 Plasma coating device

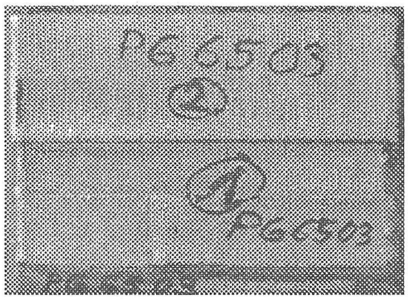


Figure1 Metallized sample with one and two layers (PG 6503)

Table 1: Filler materials and metallization procedures

Additional material	Nominal chemical compositions	Process
APG6503	NiCrBSi/WC	plasma
APG16659	FeCrCMo	plasma
B12496	NiCrBSiC	Hot metallization
10112	NiWCrFeCSi	Hot metallization
DARC599	NiWCCrTi	Cold metallization
DARC502	FeCrCSiTi	Cold metallization
E06361N	FeCrCBNiSi	Hot metallization
EX	FeCrNiBCSi	Hot metallization
10009	NiCrBFeSi	Hot metallization
12112	NiWCrCoCSi	Hot metallization

In this paper, the results of model tests carried out with plasma process of metallization and hot metallization wuth subsequent drowning with 3 filler materials (APG6503, APG16659 and B12496) in one and two layers were shown. Dimensions of the base material prepared for the plasma process were 250x200x15 mm. Filler material APG 6503 with nominal chemical composition Ni-Cr-Si-Bo/60%WC was used in powder form. Metallization parameters were: U=24-25 V, I= 85 A (after the establishment of stability), and the deposition rate of filler material was 70 g/min. The first layer was done with four passages and the second with one passage. In Fig.1 the appearance of metallized sample is shown. Filler material APG 16659 with nominal chemical composition FeCrCNiMo was also used in powder form. Metallization parameters were: U=22-26 V, I=87-96 A (after the establishment of stability) with the same deposition rate of filler material.

Hot metallization with subsequent drowning was used for filler materials B 12496 (warm-powder alloy). Dimensions of base material were 100x100x15 mm. Preparation of probes for metallization consist of grinding, blasting and preheating (80-100°C). Metallization is performed by entering the powder of filler material in the oxy-acetylene flame and depositing to the base material. Layer is applied in three passes at temperatures up to 300^{0}C. Drowning is performed at a temperature of T=1020-1050°C for 4min.

3. Microstructual Analysis and Hardness Test

The microstructures of the metallized samples were analyzed, and their hardness was evaluated. Cutting the samples to analyze the structure and hardness was carried out on the plane perpendicular to the surface of metallized layer. Structural tests were carried out on polished samples etched with a solution of 3pct Nital (structure) with standard optical microscopy (OM) and scanning electron microscopy (SEM) with EDS. Also, the measurements of hardness in the cross section of metallized samples were made by Vickers (HV5).

4. Results and discussion

Figures 2a and 3a show the measurements of the macrostructure of samples metallized with additional material APG 16659 with plasma process, and B 12496 with hot metallization with subsequent drowning, and the Fig. 2b and 3b show the measurements of the hardness distribution in a layer and the base metal.

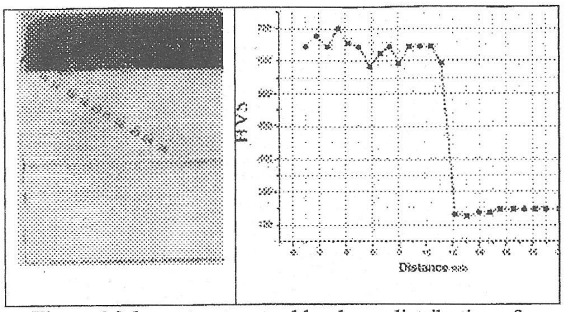


Figure 2 Macrostructure and hardness distribution of the sample cross section with a hard coating is applied in two layers, with additional material APG 16559

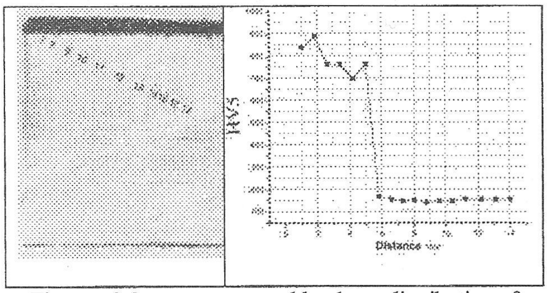


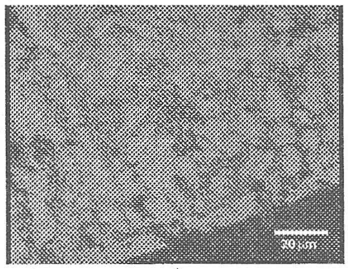
Figure 3 Macrostructure and hardness distribution of the sample cross section with a hard coating is applied in one layer, with additional material B 12496

The variation in hardness (Table 2) can be explained by the distribution of the different phases along the depth of the metallized deposit, as was evident from microstructural investigation (Fig. 4, 5, 6).

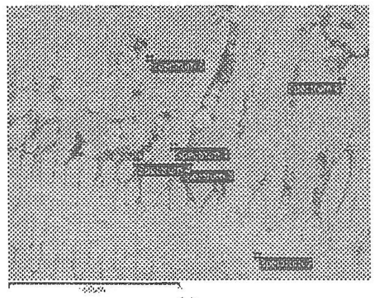
Table 2: Characteristics of metallized layers

Filler material	Nominal chemical composition	Number of layers	Hardnes,HV5
APG 6503	NiCrBSi/WC	1	532-739
		2	502-713
APG 16659	FeCrCMo	1	575-701
		2	593-701
B 12496	NiCrBSiC	1	701-891
		2	701-770

An optical micrograph of sample metallized with one layer with filler material APG 16659 is given on Figure 4a, while on 4b SEM detail of dendrites is shown. In Dendrites which are normal to the sample surface are present. That is most probably due to high-speed cooling that is achieved during the plasma process. Secondary dendritic branches are short and poorly expressed [4].



a)



b)

Figure 4 a) Optical micrograph (OM) b) SEM detail of sample metallized with one layer with filler material APG 16659

Figure 5 is SEM micrograph of the metallized sample with one layer with filler material B 12496. The structure of the sample after hot metallization with subsequent drowning with filler material B 12496 is shown, and there is a distinct porosity in the layer and at the interface. In the initial stage of dust was deposited behind the flame, which caused a partial meltdown of the powder porosity and surface coatings pronounced topography [3]. After the change of depositing powder (powder is deposited on the sample before firing) surface shows no porosity and pronounced topography. In addition to increasing the volume of gas flow and stretch marks, it was observed the presence of small transverse cracks [3, 6].

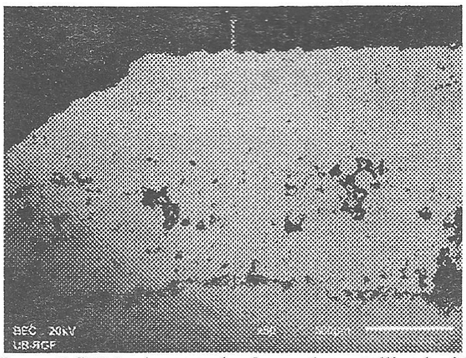
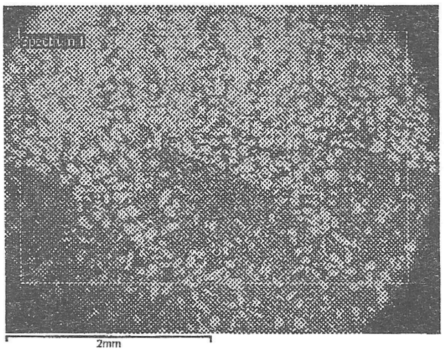
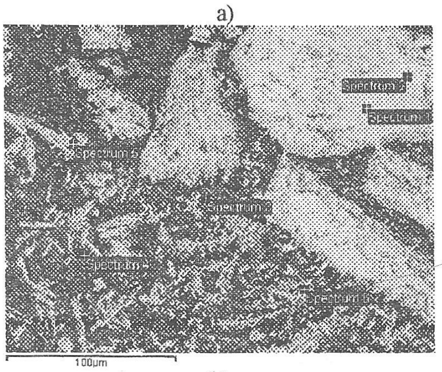


Figure 5 SEM micrograph of sample metallized with one layer with filler material B 12496

In Figure 6 SEM micrographs of sample metallized with two layers with filler material APG 6503 are shown. The sample metallized with plasma process show carbides with rod-type, polygonal and spherical shape [3, 5, 6, 7]. As the complex carbide fraction increases, hardness and wear resistance improve [1, 2, 3].



a)



b)

Figure 6 SEM micrograph of sample metallized with two layers with additional material APG 6503:
a) interface of 2 layers, b) carbides

The microstructures of metallized specimens were observed by a scanning electron microscope (SEM) and their chemical compositions were examined by energy-dispersive spectroscopy (EDS).

Figure 7 is SEM micrograph of the metallized layer with additional material APG 6503 with plasma process, and in table 3 the EDS data of chemical composition of micro constituents are shown. Deposit contains a high density of tungsten carbide (WC) in a ferrous based matrix (M).

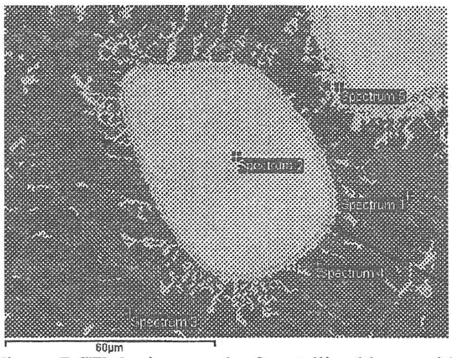


Figure 7 SEM micrograph of metallized layer with filler material 6503 with plasma process

Table 3: Chemical composition of the phases obtained from EDS analyze from Figure 7

weight%	C	Cr	Mn	Fe	Ni	W
Spect. 1	8.28	0.4	0.98	61.4	15.1	13.78
Spect. 2	9.21	0.0	0.00	0.30	0.17	90.33
Spect. 3	5.07	0.1	0.92	70.8	14.4	8.62
Spect. 4	4.94	0.0	0.76	69.4	14.3	10.47
Spect. 5	5.77	0.0	0.20	19.8	4.79	69.34

5. Conclusion

Test of the structure and hardness metallized samples done by different procedures and filler materials indicated that increase in thickness or number of layers of metallization reduces hardness. In the microstructure of metallized carbides were noticed with different shape, size and composition depending on the chemical composition of filler material. In processes with filler materials alloyed with Ti, W, Nb, B, Mo, etc. there are complex of rod-type, polygonal carbides and spherical sizes. Metallized layer hardness increases with a greater presence of complex carbides of polygonal and spherical sizes. The polygonal carbides are the most significant microstructural factor in determination the hardness and wear resistance of the metallized layer. It can be assumed that in this way the resistance to wear will increase, too.

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STUDIEREA PROPRIETĂȚILOR DIFERITELOR ACOPERIRI DURE REZISTENTE LA UZURĂ

Rezumat

Metallization coatings, to improve the properties of the surface coating of material (wear resistance, corrosion etc.) are methods, which more and more, take precedence over other procedures, particularly in economic terms. The aim of this paper is, in solving the problem of increasing the wear resistance of the parts for transport and coal grinding in power plants, to investigate the optimum application of technology in hard coatings by different procedures, and additional materials. These were investigation of its structure, measurement and distribution of hardness in the samples, with hard coatings. Based on the results of these tests there were selected the additional materials and procedures applying hard coatings, which would be apply in the revitalization of parts in transportat and coal grinding.

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