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APPLICATION OF COATING FOR REVITALIZATION COMPLEX THERMOENERGETIC FACILITIES

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Abstract

This research is focused in optimization production of electrical energy and possibilities of improving and extending of existing production capacities. In the total production of electrical energy in the world, the most represented energy is obtained by combustion. Main focus of this research is using multidisciplinary research in analyzing and improving work of thermopower plants. As know complex equipment in thermal power plants exposed to long-term effect of high temperatures and pressure, abrasion and load cycle counting. In these circumstances the exploitation of different causes can lead to damages, the individual components such as the wear and tear of working parts. The consequences of the reduction in production capacity and ventilation effect of the mill compared to the projected value, as well as frequent delays due to the replacement of parts, which significantly affects the productivity, profitability and energy efficiency of thermal power plants. Main idea of this research is to detect the critical elements and processes in thermoenergetic facilities and analyzing the process of damaging system which can lead to critical dysfunctions. This research will be focus in analysis working conditions and create procedures for the extension of the remaining work life parts of the ventilation mill and dust channel in thermal power plant Kostolac B. Focus will be on elements which are predominantly exposed to abrasive and erosive wear. One of most important tools which will be used in this process are the numerical simulation of multiphase flow for analysis of problems related to the occurrence of abrasion and erosion on system component. By analysis working condition, damages of elements, numerical simulation, thermography it will be selected the possible coating material for reducing wear in working elements. Beside coating process, it will be analyzed possibility of redesign some elements by changing the geometry and positions in systems. It will be present results of functional testing the redesign elements of ventilation mill in real exploitation conditions.

Keywords: Wear, abrasion, erosion, ventilation mill, coating

1. Introduction

Main demand for electrical energy is in constant growth because of the increasing population and the economy growth. Energy production must and should be part of the strategic plan for country and society in order to ensure the continuing development of society and industry [1-3]. Analyzing the total world production of electrical energy, it can be observed that the dominate way of production is by burning fossil fuels (coil, nature gas oil and etc.) [3,4]. Considering the data obtained from the International Agency for Energetic (IAE), the percentage of fossil fuel in production of electrical energy are more than 70% with potential growth in the next twenty years [4-6]. Efficient working of thermal power plants is based on the most economical production of electrical energy, obtained from combustion of lignite. Analyzing whole system for preparation and combustion of coil, one of the most critical parts of the system for electrical energy production is ventilation mill.

When the materials and construction in mining and energetic industries are analyzed, the most dominant damages are under the influence of numerous factors, such as: various mechanical stresses, elevated-low temperatures, compositions and atmospheric conditions, shapes and dimensions of a part or construction; structure and properties of material and quality of surface [5-8]. All those factors individually had effect on the remaining working life of materials and constructions but the biggest influence is in the mutual interaction of all this factors [8, 9].

This paper presents the usage of multidisciplinary research in identifying the problem in the system and the process of solving it. The main aim of this paper is to analyses the possibility of increasing the wear resistance of the parts of ventilation mill for coal grinding in the power plants. Optimal technology for coating of working parts which are exposed to damages and wear will be selected by this analysis. The approach of this paper is to unite multidisciplinary research of ventilation mills of thermal power plants including a variety of theoretical, numerical, empirical and experimental methods [9-13].

It is also done simulation of the process of ventilation mill working parts wearing, the sandblasting machines are used. Verification of analyzed results is done by experimental testing performed at the samples in sandblasting machines chamber. Medium for simulating wear is quartz sand and the samples are positioned at the angle of 75°.

2. Modal analyses of coated samples

Experimental modal analysis is done to select optimal coating technologies to increase working life of elements in ventilation mill. Speed and pressure is took from numerical simulation, analyzing the damages parts has and identify parts of mill which are the most exposed to wear, also speed and angle of mixture which act on surfaces of working parts. It is necessary to select an appropriate filler material which has optimal properties, great hardness and optimal resilience, which lead to reducing the wear. In previous research wide scale of filler materials resistance to wear is analyzed [12] and

for the purpose of this experiment, one group of filer material for model testing is selected and analyzed potential implementation in the functional testing.
Modal testing of macrostructure has been done, diagrams of distributions of hardness have been made, zone of the surface layer and Heat affected zone (HAZ). Microstructural analyses were obtained with scanning electron microscopy (SEM) and with EDS analysis.

2.1. Experimental procedure of modal testing

Modal testing is carried on the samples coated with adequate layer. Samples dimensions 250 × 250 × 15 mm, that are made of hot-rolled steel sheet S355J2G3 (ASTM 572), were prepared and used as substrates. In order to prevent the inclusion formation in the material deposits, prior to process of coating, the oxide layers were removed from the substrate surface by means of the grinding. Before coating, samples are preheated at T_p = 160 - 170 °C. Conventional process of coating (welding) was used: manual metal arc welding (MMA) and flux core wire welding (FCAW), plasma coating, and HVOF (High Velocity Oxy-Fuel) process. After process of deposition samples with coatings were air-cooled down to the room temperature.

Table 1. Materials and coating procedures

Coating material	Nominal chemical compositions / M*/C and M/Fe wt.% ratio	Process hardfacing
XUPER ABRATEC 5006	Ni-Cr-Bo-Si/ 60% WC	Plasma process
55586C	CoCrFeCW/ WC	HVOF
4010 EC	Fe-Cr-C-Si/Ti 0.18 (7.0 and 0.6)	MMA
4395N	Fe-C-Cr-Ni-Mo-W-B	FCAW

The most important condition of processes of deposition is that have low degree of mixing and the manufacturing cost of deposition consumables. Coating is carried out by technological lists with defined parameters (power, voltage, welding speed, line energy, preheating of materials and coatings, and application method of coatings).

2.2 Microstructuaral Analysis and Hardness Test

Samples for structure and hardness analyses were carried out by the water jet on the plane perpendicular to the coating surface. The obtained cross-sections are ground with SiC abrasive papers down to P-1200 and polished with alumina suspensions down to 1 μm. Microstructural tests were carried out on polished samples etched with a solution of 3% Nital. The microstructures of coated specimens were observed by scanning electron microscope (SEM) and their chemical compositions were examined by energy-dispersive spectroscopy (EDS). Also, the measurements of micro- hardness in the cross section of coated samples were made using a Vickers hardness tester HV 10.

2.3 Experimental testing

The microstructures with chemical analysis of the coated samples are analyzed; also hardness was evaluated. Structural tests were carried out on prepared and polished samples for purpose to scanning electron microscopy (SEM) with EDS. Also, the measurements of hardness in the cross section of coated samples were made by Vickers (HV10).

Table 2. Materials and coating g procedures

Coating material	Thickness of layer in mm	Degree of mixing / %	Hardness / HV10
XUPER ABRATEC 5006	≈ 4.5	11	750 - 1049
55586C	≈ 0.5 - 0.7	10	644 - 701
4010 EC	≈ 5.2	20	887 - 1028
4395N	≈ 5	10	918 - 1091

The low degree of mixing (11% and 10%) is achieved in coated samples with filler material XUPER ABRATEC 5006, 55586C and 4395. The maximum of hardness is achieved in samples coated with alloy 4395 (MMA) and 4010EC. Measurement of hardness distribution is done for all samples and range of values is presented in the Tab. 2. Values of hardness depend of point which is tested, coating layers is very tick and depend if the device possibilities. Process of measurement has been done in thru cross section of modal coated samples. The characteristic of coated layers and the variation in hardness can be explained by the distribution of the different phases along the depth of the coated deposit, as it was evident from microstructural investigation. Macrostructure and measurement of hardness distribution of the metalized sample cross section with a hard coating with filler material PG 6503 done with plasma metallization is presented in Fig. 1. Hardness vales of all samples are given in the Tab. 2. Diagram in Fig. 3 indicates that in near surface areas, points 7 and 13 has the highest values of hardens in the more than 1000 HV.

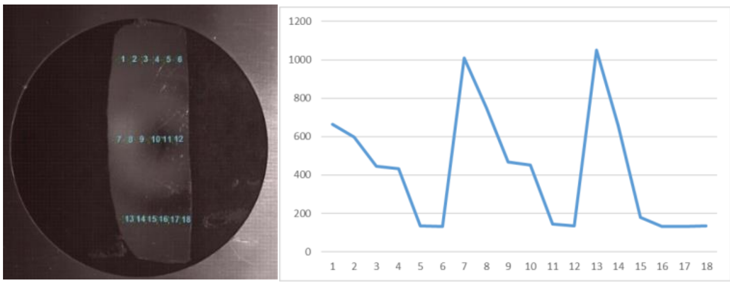
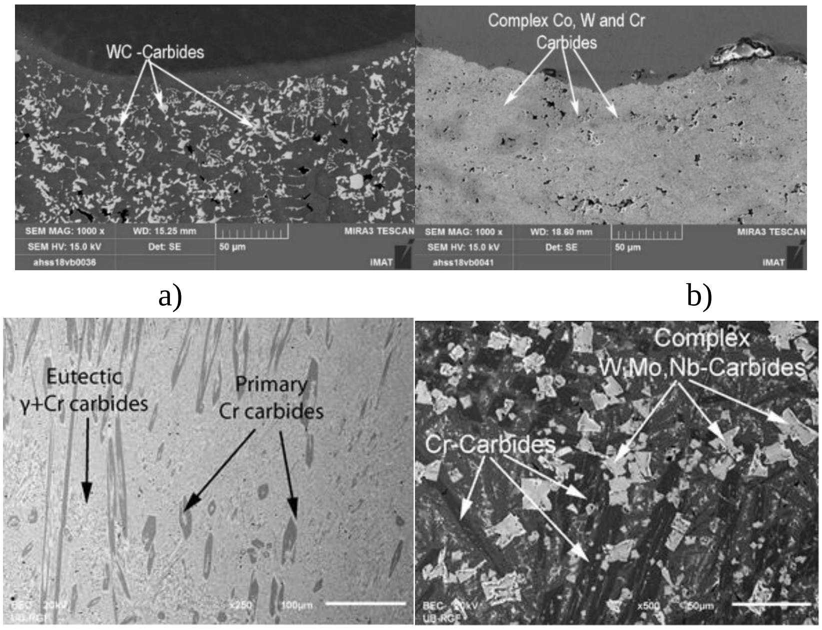


Figure 1. Macrostructure and hardness distribution on the sample cross section done with filler material PG 6503

Results show in the Tab. 2 indicates that a filler material 4010 EC and 4395 N, show relatively homogenous distribution of hardens and microstructure in the cross-section and much higher values of hardness relative to other two samples. Values of hardness in those two samples with filler materials 4010 EC and 4395 N are higher in 20 - 40%. Those two samples have much higher values of degree of mixing base material and filer material because are done by conventional process of coating (welding). Values of hardness are different in fact that some filler materials have similar chemical compound. This is consequences of different coating procedures and technologies of applying. SEM micrographs with EDS of different phases of coated samples with filler material XUPER ABRATEC 5006 are shown in Fig. 3. The EDS data, shown in Tab. 3, indicate on different matrix compositions and presence of carbides in coated layer. The near-surface structure of PG 6503 coating consisted of large WC grains point 2 (light phase, Fig. 3a) and EDS spectrum (Fig.. 3b and 3c) embedded in the Ni-based matrix and EDS spectrum (Fig. 4d) in which Fe was dissolved in a major amount, whereas Si and B were dissolved in minor amounts. In many locations, the small, worm-like, and random-oriented WC particles were also observed. The distribution of large WC particles (120 ± 31 μm) was non-uniform in coating's thickness direction but their presence was largest in the near-surface region of PG 6503 coating. During solidification achieves also complex carbides the near-eutectic structure and dominant presence of blade-like primary Cr-carbides, Cr-borides (Fig. 2a). In sample coated with PG 6503 is observed the presence of small chromium-based boride/carbide reinforcing particles and their short interparticle distance which strengthened more effectively the Ni-based matrix.



a) b)

c) d)

Figure 2. The structures of the samples, a) XUPER ABRATEC 5006, b) 55586C, c) 4010 and d) 4395 hardfaced coatings (back-scattering electron images)

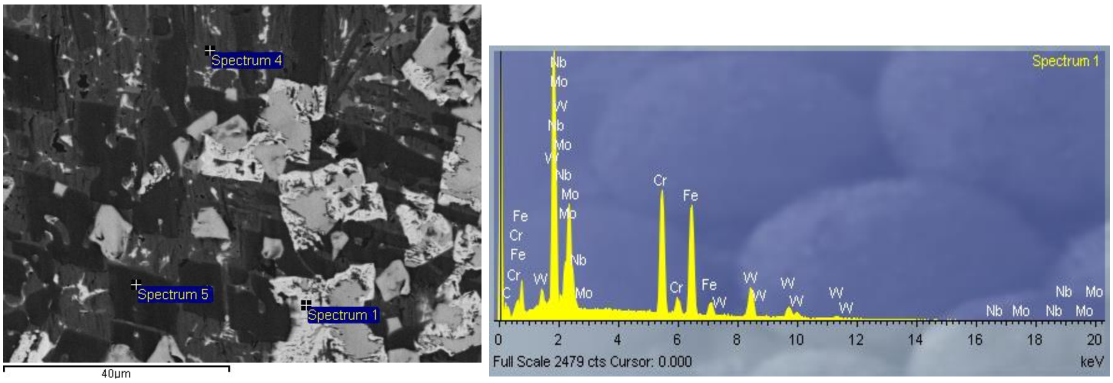
The Fig. 4b shows the structure of the material 55586C. Deposition of material shows homogenous structures with presence of porosity. Matrix of this coating is Fe base matrix with eutectic W carbides. Analyzing the filler material 55586C it can be see presence of complex Co and Cr carbides. Coated sample show a homogeneous distribution of carbides with polygonal and spherical shape. During the process of deposition its created very complex carbides, dominantly built with W but it crates various spectrum of complex structures.
The structure of the obtained 4010 coatings comprises a larger rod-like primary Cr-carbides with the total absence of the blade-like type of morphology (Fig. 2c). These results are in agreement with previous research findings [12, 17, 35] in which the addition of carbon facilitates transition from blade-like towards the rod-like morphology. The rod-like morphology is superior when wear applications are considered.

Table 3. EDS Chemical composition of the phases in alloys XUPER ABRATEC 5006, 55586C ,4010 and 4395 in mas %

Samples	Phases	C	Fe	Co	Ni	Cr	Nb	Mo	W
XUPER ABRATEC 5006 Ni-Cr-Bo-Si/ 60% WC	Matrix	2.62	64.29	/	24.74	0.35	/	/	7.28
	Carbides	4.33	40.15	/	12.91	0.42	/	/	42.20
55586C CoCrFeCW/ WC	Matrix	5.51	74.97	3.91	/	2.66	/	/	12.94
	Carbides	8.10	2.62	14.85	/	5.58	/	/	68.85
4010 EC Fe-Cr-C-Si/Ti 0.18 (7.0 and 0.6)	Matrix	3.84	81.94	0.50	0.21	9.99	/	/	/
	Carbides	10.11	37.02	0.52	0.25	52.25	/	/	/
4395N Fe-C-Cr-Ni-Mo-W-B	Matrix	5.90	64.08	/	/	13.15	0.67	7.56	8.20
	Carbides 1	4.35	22.88	/	/	18.25	7.55	16.26	30.55
	Carbides 2	3.31	58.11	/	/	34.04	/	1.04	3.50

The increase of the Cr-carbides volume fraction is probably the result of the carbon and chromium addition [17, 18, 26, 35]. It has been point out that large primary carbides, which are identified to be (Cr, Fe)7 C3 (Tab. 3), are formed from the melt of the coating (hardfaced) electrodes and exhibit columnar growth with a hexagonal cross section. However, the samples coated with filler materials 4395 show a homogeneous distribution of carbides with polygonal and spherical shape (Fig. 16). The EDS date shown in Tab. 3 indicate that coated layer is phase with high content of W, Cr, Nb, Mo and C. Present carbides are the primary, special carbides type WC, MoC, NbC, complex carbides Fe3 (W, Mo) 3C i Cr-carbides [3, 12, 26].

SEM micrographs with EDS of different phases of coated samples XUPER ABRATEC 5006 are shown in Fig. 3. The EDS data, shown in Tab. 3, indicate on different matrix compositions and presence of carbides in coated layer.



a) b)

Figure 3. a) SEM micrograph and EDS structure of the coated sample XUPER ABRATEC 5006

3. Experimental testing of modal samples

Wear of working parts in ventilation mill has been indicated by lost the material from the surface. Experimental testing which is set in this research has opportunity to simulate the working condition in ventilation mill in order to analyses behavior filler material in exploitation condition. Analysis of the angles under which coal particles, together with mixture transport fluid and mineral particles leave the working wheel, and on the basis of which the angle of setting the obstacles elements is determined in order to increase the grinding efficiency. The grinding efficiency behind the impact wheel will be greatest if the obstacles elements are placed administratively on the direction of movement of larger particles of coal dust. For the friction coefficient of 0.6, the angle at which the carbon powder leaves the impeller is 29.5°, while for the coefficient of friction 0.8 this angle has a value of 25.7°. The angle at which the transport gas leaves the working wheel would be smaller than the angle under which coal particles are made, but this only applies if coal dust particles are of such a size that, due to inertia, they cannot fully follow the gases of the gaseous fluid. When the coil particles are small enough, as is the case are analyzed, the mixture of the gas and solid phase acts as a whole and the angle α under which the impeller is greater than the angle for the conveyor fluid and smaller than the angle for the charcoal powder. The term for the angle under which the obstacles elements should be placed so that they are governed on the path of the largest particles of coal dust is given in [1] as:

$$\beta = arcsin\left(\frac{D_1}{D_0}\cos\alpha_u\right) \quad (1)$$

Where α_u is the angle at which coal particles leave the working wheel, D_o to the middle diameter of the position of obstacles elements on house ventilation mill, and D_1 is the diameter of the working wheel. By modifying the above term, provided that the mixture as a whole hits the barriers obstacles elements at a right angle and taking into account that $D_1/D_o = 0.92$, for the angle $\alpha = 25°$, the angle of setting the slaughtering obstacles $\beta = 54.3°$ is obtained, while for $\alpha = 20°$ it gets $\beta = 58.7°$. Such specific angular values β do not differ much from the value in which the numerical simulation gives the lowest value of the static pressure at the entrance to the dust channel.
For the purpose of this experiment are done the analyses of coating materials are done for two different angles 20° for 75°. Those two defined angles are in coincidence with angles which are obstacles in house of ventilation mill are exposed to mixture flow. Those two angels are representing most critical wear expose of working parts on flow of mixture of coil, sand and other mineral mater.

3.1. Experimental testing modal plates are 75°

Mass reducing of modal test plates during the experimental test is shown in Tab. 4. Modal test plate are exposed to angle of sand flow 75°. Time of exposure to sand flow is similar for every group of filler material with small differences.
After test performance minimum material lost has sample with filler material 4395 N for 0.020 kg. Samples coated with filler materials 4010 EC have 0.052 kg, XUPER ABRATEC 5006 has 0.066 kg and 5586C has 0.81 kg which shown on Fig. 7. Samples coated with filler material 55586C have material lost 2.79% of total volume deposited material on sample which is 0.09 - 0.1 kg. Generally, filler material 4395 show best wear resistance for this simulate wear, where is analyzed mass lost and percentages of mass lost relative of volume deposit layers. But generally all filler materials except 55586C has god wear resistance on sand flow to angle of 75°. Percentages of material lost has some different values, in the Tab. 5 is present all results of material lost relative to volume of coated material.

Table 4. Materials and coating g procedures for exposure angle 75°

Coating material	Time of exposure / s	material lost / kg	material lost / %
XUPER ABRATEC 5006	373	0.066	1.5
55586C	371	0.081	2.79
4010 EC	363	0.052	1.24
4395N	352	0.020	0.5

Filler material PG 6503 has material lost 0.066 kg which is shown in Tab. 4, mass of coated layer is ~1.660 kg per sample and total material lost is 1.5 %. Filler material 4010EC has material lost 0.052 kg which is shown in Tab. 4 mass of coated layer is ~1.450 kg per sample and total material lost is 1.2%. On Fig. 7 are shown all coated samples after testing in sandblastings machinery. On several samples is observed the damages of surface layers. The biggest damage is present in sample coated with filler material 55586C, Fig. 7 it can see big hole from sand flow. Sample coated with filler material 4395N has small surface damages, but this material has minimum material lost. Other two samples coated with filler materials 4010EC and XUPER ABRATEC 5006 show the minimum surface damages relative to other two samples. Those two samples have the bigger material lost then sample coated with filler material 4395N.

Figure 5. Appearance of modal testing plate after experiment

4. Conclusion

There is no doubt that energetic was and will be area of special importance for the entire economy and society. If the supply and production of energy is made a stable, modern and well-organized sector, it is certain that this will mean good for the entire economy of the country.

The previous research and analyses indicate locations, which is most exposed to wear, due to sand and other mineral particles movement.

On the basis of the experimental tests of the modal testing, the selection of critical area, optimal coating technologies and filler materials for apply on working parts of ventilation mill will carried out. The following criteria were applied in the selection: working conditions, abrasion resistance, required finishing quality, permissible thickness, porosity of the layer and cohesion strength of the base and applied layer, characteristics of the basic material, shape and size of the work piece and costs of whole process. After the applying alloys on modal samples, it's done the simulation of wear conditions which occur on ventilation mill which is close as similar to working conditions. For the purpose of this experiment is done the analyses of coating materials are done for angle for 75°. Selected angle are representing most critical wear expose of working parts on flow of mixture of coil, sand and other mineral mater.

Comparative, quantitative and visual, analyses have indicated that samples goes from 2.79% with filler materials 55586C to 0.5% of weight loss with filler materials 4395, and greater resistance to wear compared to the original plates with 3.9% weight loss. The experimental test s has pointed to the possibility using this filler materials and coating procedures can lead to wear reducing of working parts ventilation mill compared to the existing ones. Other two materials coated with filler materials 4010EC and XUPER ABRATEC 5006 has weight lost from 1.21 to 1.5, but is very important to check weigh of deposited layers where 4395 N has smallest one. When is analysed the total weight has filler material 4395 N has in kg the lowest one.

The application of this approach can reduce the number of possible repairs and extends the period between them and give significant economic effects. The experimental functional tests of revitalized mill wearing parts in real exploitation conditions show that the proposed modification, coating technologies and filer materials can give good results. The application of appropriate reconstructions, supported by additional research, in other coal preparation system, can expect good results in terms of reducing the wear of the working elements of the ventilation mill and extending their lifetime, and thus facilitating coil exploitation with a smaller number of stops in exploitation.

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