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Surface Improvement by WC-Cu Electro-Spark Coatings with Laser Modification

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Abstract. The article presents the possibilities of using laser surface modification on the way ESD to better tribological properties. The question presented in the paper can be used to expand the knowledge in the field of application of electrospark deposition. Surface treatment by applying a coating by electro spark deposition has many advantages (eg. local interface or applying thin layers), and therefore this technology is used in the industry. A concentrated stream of laser beam can effectively modify the state of WC-Cu electrospark coatings and improve their performance. The aim of the study is to evaluate the influence of laser treatment on the properties of electrospark coatings. The evaluation of the properties of coatings after laser treatment was carried out by surface geometry analysis.

Introduction

High performance characteristics of modern equipment components are obtained, inter alia, by the use of new materials of construction and the application of protective layers, ensuring the best resistance to wear, erosion, or high fatigue strength [1-3]. Manufacturing new layers on machine parts is economically viable for use fragments or surface layer and where the surface layer must have different characteristics from the core. Electro-spark deposition (ESD) is a cheap and efficient way to improve performance properties of metal [4-6]. Developed in the post-war period, the technology has been frequently modified. The main advantages are related to the ability of a precise choice of the area to be modified and the ability of coating thickness selection. This method makes it possible to deposit ultra-thin and slightly thicker coatings made of different metal [7].

Analysis of properties of coatings requires many methods [8-10]. There are many alternative technologies for producing coatings and material properties improvements in relation to ESD technology [11, 12].

Materials

Based on literature and our own experiences, we developed 2 powder blends which have been produced by powder metallurgy methods for ESD coating electrodes. The tests were performed on the WC-Cu (50%-50%) and WC-Cu (25%-75%) coatings produced on the normalized C45 grade

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steel specimens by electrospark deposition. The coatings were deposited in the argon atmosphere with the use of an EIL-8A pulse generator for triggering spark gaps, with manual electrode displacement [13]. The following parameters were established in compliance with the manufacturer's guidelines and previous experience of the authors: voltage U = 230 V; capacitor volume C = 150 μF; current intensity I = 0.7 A; deposition time τ = 2min/cm^2. The coatings were subjected to laser treatment at the Centre for Laser Technology of Metals. A BLS 720 Nd:YAG laser capable of generating 150 W maximum average power, operating in the pulse mode and manufactured by Baasel Lasertechnik was used. The laser treatment was performed in the ambient air atmosphere. The tests used a focusing head. The TEM_{00} beam defined the radiation energy distribution. The parameters used were as follows: spot diameter d = 0.7mm; laser power P = 50W, 60W, 70W; specimen movement rate v = 250mm/min; nozzle-workpiece distance Δl = 1mm; pulse duration t_i = 0.4ms; pulse repetition frequency f = 50Hz; beam shift jump S = 0.4mm.

Methodology

Images of the microstructure of a selected sample were obtained by means of a JSM-5400 scanning electron microscope, which is owned by the Kielce University of Technology. It is a kind of electron microscope that allows observation of the topography of the material being examined. It is used for observation and characterization of organic and inorganic materials on a scale from nanometric to micrometric. The electron beam is the primary beam in this research method.

The geometric structure of the surface has a significant impact on many processes occurring in the surface layer. Measurements of the geometric structure of the surface were carried out in the Laboratory of Computer Measurements of Geometric Size of the Kielce University of Technology. The tests were carried out using a Talysurf CCI optical profilometer using the Taylor Hobson patented coherence correlation algorithm, enabling measurements with an axis resolution of less than 0.8 nm. The measurement result is recorded in a matrix 1024x1024 measuring points which, with the x10 lens used, gives a measured area of 1.65 mm x 1.65 mm and a horizontal resolution of 1.65 μm x 1.65 μm.

Results

From the microstructure images presented in Fig.1, it can be concluded that the laser modification significantly homogenized the state of the coating. As a result of applying a coating, the pores and microcracks are eliminated and the distribution of elements (Fig.2) is more uniform at a positive effect on the modified surface. The spectral analysis for selected points is given in Fig.3.

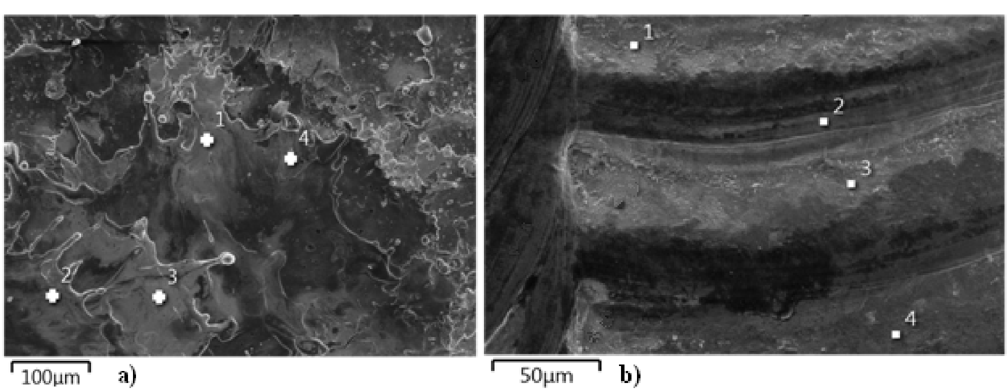

Fig. 1. Microstructure of coating WC 50% - Cu 50% before (a) and after (b) laser modification with the power of P=60W. Magnification x1000

Three-dimensional surfaces and their analysis using the TalyMap Platinium software allowed for a thorough understanding of the geometrical structure of the tested surfaces.

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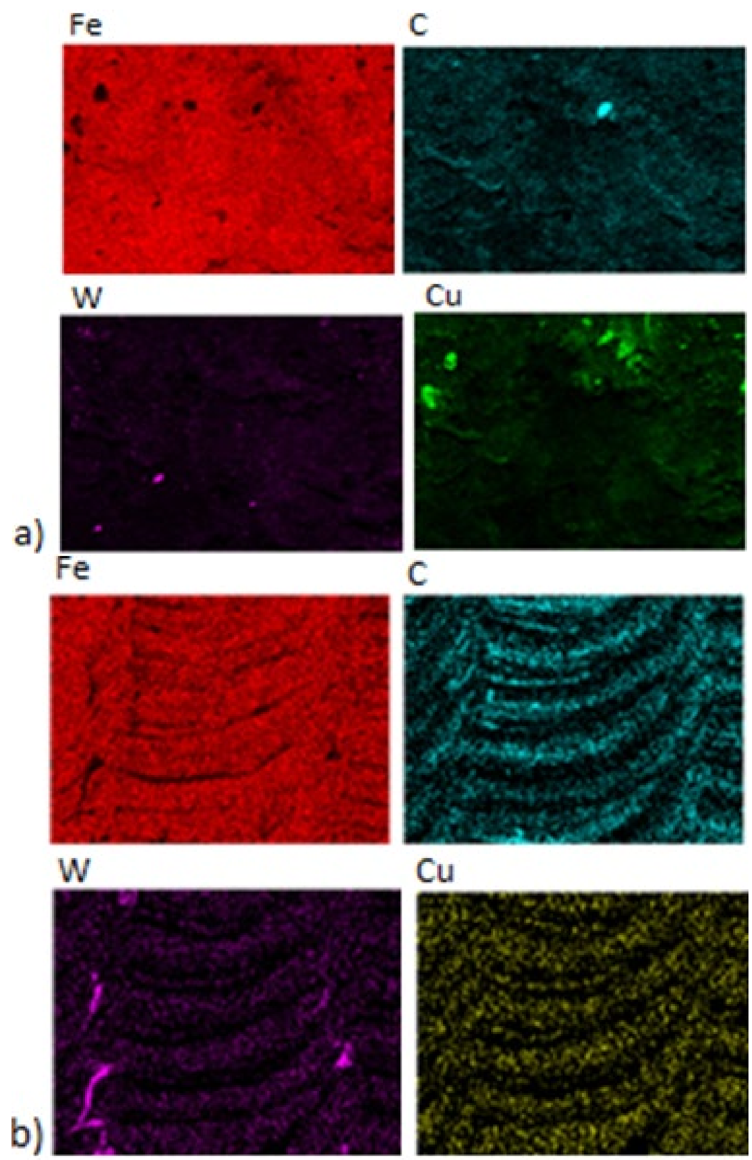

Fig. 2. Surface distribution of elements a) before laser modification b) after modification with the laser beam of P=60W

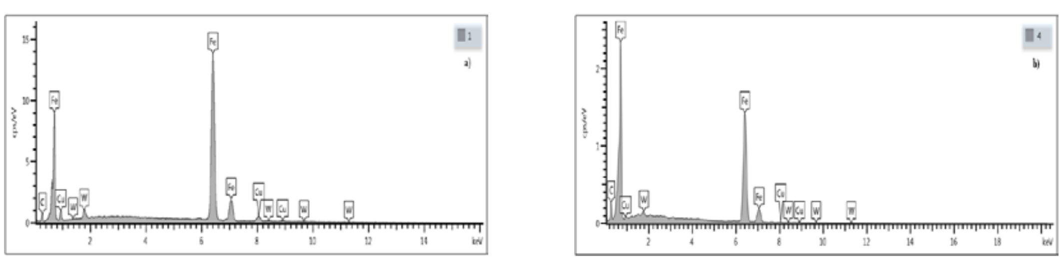

Fig. 3. Spectrum of EDS coating WC50%-Cu50% :a) before laser treatment in point 1, b) after laser treatment P=60W in point 4

The analysis of the results contained in Table 1 and the image of the surface topography of the samples indicates that, depending on the coating applied, different laser power used to modify the substrate improved the parameters of the geometrical structure.

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Table 1. Parameters of the surface geometry of coatings before and after laser treatment

Parameters of the surface geometry	Laser power			
	ESD	P=50 [W]	P=60 [W]	P=70 [W]
WC50%-Cu50%				
Sa [µm]	3.98	4.08	3.80	5.36
Sq [µm]	5.25	5.11	4.69	6.75
Ssk	-0.22	-0.08	-0.28	0.01
Sku	3.87	2.98	2.70	2.93
Sp [µm]	18.20	22.37	12.89	24.97
Sv [µm]	21.52	19.44	18.96	25.05
Sz [µm]	39.73	41.08	31.86	59.03
WC25%-Cu75%				
Sa [µm]	4.22	4.06	4.35	4.53
Sq [µm]	5.35	5.12	5.44	5.66
Ssk	0.44	0.07	-0.28	-0.52
Sku	3.36	2.98	3.09	3.09
Sp [µm]	28.12	16.51	17.49	17.74
Sv [µm]	17.24	25.64	23.02	24.26
Sz [µm]	45.35	42.16	40.51	41.99

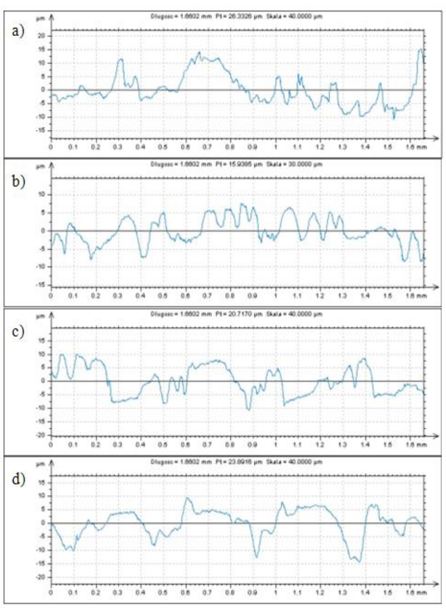

Fig. 4. Results of microscopy measurements of WC25%-Cu75%: a) without laser treatment b) laser-modified P=50W; c) laser modified P=60W; d) laser-modified P=70W

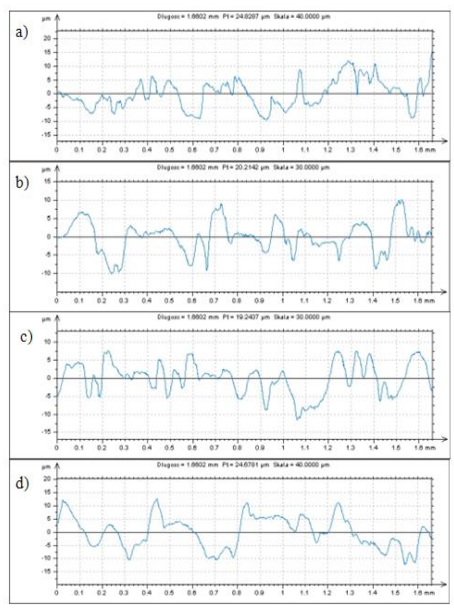

Fig. 5. Results of microscopy measurements of WC50%-Cu50%:a) without laser treatment b) laser-modified P=50W; c) laser-modified P=60W; d) laser-modified P=70W

For the WC50%-Cu50% coating, the best parameters are obtained when modifying the laser with P = 60W. For each analyzed parameter of the geometrical structure, the value has been improved. However, for the WC25%-Cu75% coating, the best parameters are obtained when modifying the laser with P =50W. Unfortunately, in this case one parameter, i.e. Sv, the maximum depth of the valley, has not been improved. In the discussed cases, laser treatment caused a decrease in the main values of geometrical parameters of the surface of the electroless coatings in relation to the SGP parameters of the coatings before the laser treatment. The same relationship can be seen in the description of the roughness profile amplitude parameters (Figs. 4 and 5). For the WC50%-Cu50% coating at the P-60W laser power, the Ra parameter, the arithmetic mean profile deviation, equalled 3.85 μm, while after laser treatment with the P = 60W power it decreased to 3.01 μm Rz. The maximum height of the profile was also reduced by 3.14 μm in relation to the value before modification of the laser beam. Only the Rv parameter had a worse value, the maximum valley depth of the roughness profile from 8.02 μm to 8.8 μm. The WC25%-Cu75% coating, when modified with the P-50W laser, also improved its performance. The mean of the arithmetic deviation changed its value from the initial Ra = 3.57 μm to Ra = 2.78 μm.

Summary

On the basis of the conducted tests, it can be stated that the surface of carbon steel can be modified by the ESD method using WC-Cu electrodes with different percentage of both components. The concentrated laser beam stream can be used to effectively modify the state of the ESD coating layer, WC-Cu and to improve their performance. The use of laser treatment for the modification of WC-Cu coatings applied with electro-discharge coating improved in some cases the geometrical structure of these coatings. Possible further research, with deeper investigation on the impact of particular factors, should include statistical multivariate analyzes [14, 15], including RSM (the response surface methodology) [16] and a factorial modeling [17], CA (the cluster analysis) [18, 19] and modified adjustment calculus [20]. It may also be interesting to compare subjective (by human) and objective (by software) – by means of image analysis methods [21-24] – visual assessments of observed surfaces.

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