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Microstructure of laser-modified electro-sparking coatings

Mikrostruktura powłok elektroiskrowych modyfikowanych

Abstract

The article summarizes research on a method used to improve tribological properties. The paper presents possibilities of using laser surface modification by means of EDM. The performed research confirmed that the concentrated laser beam stream can effectively modify the state of the ESD coating layer, WC-Cu and improve their usability. The work aims to assess the properties of coatings after laser treatment, based on the observation of the newly created structure of the material, the measurement of adhesion and microhardness measurement.

Keywords: WC-Cu coating, laser treatment, electrospark deposition, surface

Streszczenie

W artykule podsumowano badania nad metodą poprawy właściwości tribologicznych. Przedstawiono możliwości zastosowania modyfikacji laserowej powierzchni na drodze obróbki elektroiskrowej. Wykonane badania potwierdziły, iż skoncentrowanym strumieniem wiązki laserowej można skutecznie modyfikować stan warstwy powłok elektroiskrowych, WC-Cu i wpływać na poprawę ich właściwości użytkowych. Artykuł ma na celu ocenę właściwości powłok po obróbce laserowej przeprowadzonych na podstawie obserwacji nowo powstałej struktury materiału, pomiaru przyczepności oraz pomiaru mikrotwardosci.

Słowa kluczowe: powłoki WC-Cu, modyfikacja laserowa, obróbka elektroiskrowa, powierzchnia

1. Introduction

Due to new market demands, it is advisable to create new protective layers for machine parts if their fragments or surface layer are worn, and if the surface layer requires other features than the core. Currently, there is a growing role of machining using a concentrated energy stream, which is used primarily in the machining of components from difficult-to-machine construction plastics, as well as for parts with very complex shapes, which would be too labor-intensive and time-consuming to use as traditional methods. In this group of treatments, those that use broadly understood erosion, often supported by electrical energy, such as electro-erosion machining, can be mentioned.

The electrospark deposition (ESD) process is a surface treatment technique used to produce hard and wear resistant coatings on various metallic materials. It uses high current/low voltage electrical pulses of short duration to coat electrode material (anode) with a substrate (cathode) [1]. During the process, energy stored from high voltage capacitors is discharged through an electrode of the material to be deposited. Thus, a small molten part of the material is removed from the electrode and coated to the substrate in the form of a sudden spark [1, 2].

Electrospark deposition is a cheap and efficient way to improve the usable properties of metal. The use of a laser beam to smoothen the coatings applied by the spark erosion method should ensure a reduction of surface roughness and change in the shape of the unevenness profile. The purpose of laser compaction is to reduce the porosity of the coating and to eliminate cracks, delaminations and cracks in the surface of the coating, which results in a significant improvement in the integrity of the coating [1-4].

2. Materials

Based on literature and our own experiences, we have developed a powder blend, which has been produced by powder metallurgy methods for coating electrodes ESD. The tests were performed on the WC-Cu (50–50%) coating produced on the normalized C45 grade 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 [5–7].

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 $\tau = 2$ min/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 was used, operating in the pulse mode, manufactured by Baasel Lasertechnik. 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 $d = 0.7$ mm;
- laser power $P = 60$ W;
- specimen movement rate $v = 250$ mm/min;
- nozzle-workpiece distance $\Delta l = 1$ mm;
- pulse duration $t_i = 0.4$ ms;
- pulse repetition frequency $f = 50$ Hz;
- beam shift jump $S = 0.4$ mm.

2.1. Adhesion and microhardness tests

Measurements of the adhesion of WC-Cu coatings (50% WC and 50% Cu) before and after laser treatment were made using the scratch test method. A REVETEST device from the Swiss company CSEM was used for the measurements. The measurements were carried out with the following scratch test parameters: load growth rate – 103.2 N/min; speed of table advance with the sample – 9.77 mm/min; crack length – 9.5 mm; Diamond Rockwell cone with rounding radius – 200 μm.

The scratch test consisted in making the scratches with a properly selected penetrator (in this case a diamond cone – Rockwell) with a gradual increase in normal force (loading the penetrator) with simultaneous measurement of the resistance force of the material (tangential force) and recording of acoustic emission signals which informed about the formation damage to the layer in the form of cracks or peeling of the layer. The lowest normal force causing a loss of adhesion of the coating with the substrate is called the critical force and is taken as a measure of this adhesion.

To assess the value of the critical force, the change of acoustic emission and tangential force signals as well as microscopic observations (optical microscope built into the REVETEST apparatus) is used. In the tests that were carried out, values of critical forces were evaluated on the basis of microscopic observations of the resulting scratches after passing of the penetrator, which were referred to the course of acoustic emission signals. The sample results are presented in Table 1, which contains the values of critical forces from three measurements of a given sample and their average values calculated.

Electro discharge coatings had comparable adhesion. The average value (from three measurements) of the WC-Cu coating's critical force was 7.70 N. The laser treatment improved the adhesion of the WC-Cu coating to 24% without this treatment. Higher adhesion of laser treated coatings may be caused by limiting their porosity and thus improving their tightness. However, detailed arrangements regarding this problem will be implemented in the next stages of the research.

The microhardness was determined using the Vickers method. The measurements were performed under a load of 0.4 N. The indentations were made in perpendicular microsections in three zones: the white homogeneous difficult-to-etch coating, the heat affected zone (HAZ) and the substrate. The test results for the ESD WC50-Cu50 coating before and after laser treatment are shown in Table 2. The laser treatment of the ESD coating caused a slight decrease in the microhardness of both the coating and heat affected zone.

Table 1. Results of adhesion measurements

Coating	Critical power [N]			Average value [N]
	Number of the measurement			
	1	2	3	
WC-Cu	8.19	8.56	6.34	7.70
WC-Cu+laser (P = 60 W)	9.56	10.17	8.86	9.53

Table 2. Results of microohardness tests

Coating	Microhardness HV0.4		
	Coating	HAZ	Substrate
WC-Cu	643 ± 54	438 ± 23	278 ± 18
WC-Cu+laser (P = 60 W)	617 ± 21	407 ± 22	279 ± 7

2.2. Microstructure testing

Microscopic examinations were carried out on samples made in a plane perpendicular to the applied surface, which gives the possibility of observing the characteristic areas of the material to be tested, its structure and enables measurements of the thickness of applied coatings. The photo (Fig. 1) presents an example of the microstructure of the WC-Cu coating (50% WC and 50% Cu) applied by electro-discharge treatment on steel C45.

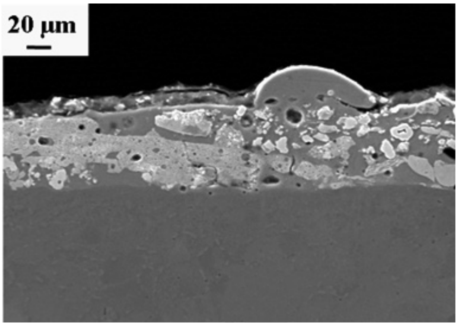

Fig. 1. Microstructure of the WC50%-Cu50% coating

The photo shows an example of a microstructure of the WC-Cu coatings coated electro-spark deposition. Based on the obtained results, it was found that the thickness of the obtained layers was from 36 μm to 60 μm, while the range of the heat affected zone (SWC) into the ground material was from about 20 μm to 30 μm. In the photo of the microstructure shown, there is a clear boundary between the coating and the substrate, and pores and microcracks can be observed.

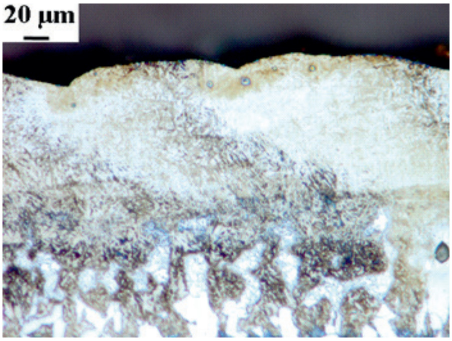

Fig. 2. Microstructure of WC50%-Cu50% coating after laser treatment with P-60W

As a result of the laser beam modification of the WC-Cu coatings applied with electro eroding and the subsequent coagulation, their chemical composition has changed. Laser treatment has homogenized the chemical composition of the coating (Fig. 2). There was also fragmentation of the structure and crystallization of highly supersaturated phases due to the occurrence of significant temperature gradients and obtaining high cooling rates. The TWP produced as a result of laser treatment did not have microcracks and pores and discontinuities at the boundary layer – substrate. The thickness of laser-treated WC-Cu coatings ranged from 40µm to74 µm. The SWC, created as a result of laser irradiation, had a range of 30–45µm and this is related to the higher density of laser processing power in relation to EDM.

3. Conclusions

Based on the research carried out so far and after analyzing their results, we can conclude that:

- A concentrated beam of laser beam can effectively modify the state of a material layer and thus improve the performance.
- The use of WC-Cu coatings imposed on electro-sparking increased the operating properties, in particular, increased their usability
- Laser irradiation of coatings assists in healing of micro-cracks and pores.
- The laser treatment of the ESD coating caused a slight decrease in microhardness of both the coating and heat affected zone.

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