Terotechnology 2017 Materials Research Forum LLC
Materials Research Proceedings **5** (2018) 206-209 doi: http://dx.doi.org/10.21741/9781945291814-36

Microstructure and Tribological Properties of ESD Coatings after Laser Processing

RADEK Norbert [1, a *], PIETRASZEK Jacek[2,b] and SZCZOTOK Agnieszka[3,c]

[1]Kielce University of Technology, Faculty of Mechatronics and Mechanical Engineering, Al. 1000-lecia P.P. 7, 25-314 Kielce, Poland

[2]Cracow University of Technology, Institute of Applied Informatics, Faculty of Mechanical Engineering, Al. Jana Pawła II 37, 31-864 Cracow, Poland

[3]Silesian University of Technology, Institute of Materials Science, str. Krasinskiego 8, 40-019 Katowice, Poland

[a]norrad@tu.kielce.pl, [b]pmpietra@gmail.com, [c]agnieszka.szczotok@polsl.pl

Keywords: Electro-Spark Deposition, Laser Processing, Coatings, Properties

Abstract. The paper is concerned with determining the influence of the laser treatment process on the properties of electro spark coatings. The properties were assessed after laser treatment by analysing the microstructure, measuring the microhardness and friction coefficient. The tests were carried out for Mo and Cu coatings (the anode) electro-spark deposited over the C45 steel substrate (the cathode) and molten with a laser beam. The coatings were deposited by means of an ELFA-541. The laser treatment was performed with an Nd:YAG, BLS 720 laser. The coatings are desirable in sliding friction pairs.

Introduction

The processes of coating formation on metal parts including electro-spark deposition involve mass and energy transport accompanied by chemical, electrochemical and electrothermal reactions [1]. Today, different electro-spark deposition techniques are used; they are suitable for coating formation and surface microgeometry formation [2-4].

Electro-spark alloying is becoming more and more popular as a surface processing technology. Electro-spark deposited coatings are frequently applied in industry, for example, to produce implants or cutting tool inserts. The coatings are deposited with manually operated equipment or robotized systems.

Coatings produced by electro-spark deposition are applied:

1. to protect new elements,
2. to recover the properties of worn elements.

As electro-spark coatings are reported to be resistant to wear and corrosion, they can be applied, for example, to the following:

- ship propeller components,
- casting moulds,
- fuel supply system components,
- exhaust system components.

Electro-spark deposited coatings are not free from disadvantages but these can be easily eliminated. One of the methods is laser processing; a laser beam is used for surface polishing, surface geometry formation, surface sealing or for homogenizing the chemical composition of the coatings deposited [5-8].

Materials Research Proceedings **5** (2018) 205-209 doi: http://dx.doi.org/10.21741/9781945291814-36

The work discusses the properties of electro-spark deposited Cu-Mo coatings subjected to laser treatment. The properties were established based on the results of a microstructure analysis, microhardness tests and tribological studies.

There are many alternative technologies for producing coatings and material properties improvements in relation to ESD technology [9-11].

Experimental

The tests were conducted for Cu-Mo coatings produced by electro-spark deposition, which involved applying Cu and Mo electrodes with a diameter of 1 mm (the anode) on the C45 steel substrate (the cathode). Here, copper constitutes the core coating material in the formation of low-friction surface layers; it also compensates for the occurrence of residual stresses. Molybdenum acts as the reinforcing constituents. The coating materials, i.e. molybdenum (99.8% Mo) and copper (99.2% Cu) in the form of a wire (ϕ = 1 mm) were purchased from BIBUS Metals Sp. z o.o. (certificate included).

The heterogeneous coatings were electro-spark deposited on the C45 steel substrate by means of the ELFA-541 made by a Bulgarian manufacturer. Based on the analyses of the current characteristics as well as the manufacturer's recommendations, it was assumed that the parameters of the ESD operation should be as follows: current intensity I = 16 A (for Cu I = 8A); table shift rate v = 0.5 mm/s; rotational speed of the head with electrode n = 4200 rev/min; number of coating passes L = 2; capacity of condenser system C = 0.47 μF; pulse duration T_i = 8 μs; interpulse period T_p = 32 μs; frequency f = 25 kHz.

The subsequent laser treatment was performed with the aid of a BLS 720 laser system employing the Nd:YAG type laser operating in the pulse mode. The following parameters were assumed for the laser treatment: laser spot diameter d = 0.7 mm; laser power P = 20 W; beam shift rate v = 250 mm/min; nozzle-sample distance h = 1 mm; pulse duration t_i = 0.4 ms; frequency f_l = 50 Hz.

Results and discussion

A Joel JSM-5400 scanning microscope equipped with an Oxford Instruments ISIS-300 X-ray microanalyzer was used to test the coating microstructure. Figure 1 shows the microstructure of electro-spark deposited on two-layer Cu-Mo coatings. The layer thickness is approximately 8÷10 μm, and the range of the heat affected zone (HAZ) inside the (underlying) substrate material is about 10÷15 μm. In the photograph, the boundary line between the two-layer coating and the substrate is clear. The melting and solidifying processes during laser treatment resulted in the migration of elements across the coating-substrate interface. Laser radiation caused intensive convective flow of the liquid material in the pool and, in consequence, the homogenization of the chemical composition (Fig. 2). In the heat affected zone (HAZ), which was 20÷50 μm thick, there was an increase in the content of carbon.

The microhardness of the specimens with Cu-Mo coatings was analyzed by applying a load of 0.4 N and using the Vickers method. 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 microhardness of the substrate after electro-spark deposition equalled, on average, 280 HV0.4; the same value was reported for the substrate before the process. There was a considerable increase in microhardness after depositing the heterogeneous Cu-Mo coating. The microhardness of the Cu-Mo coating was approx. 587 HV0.4 - a rise of 110 %. The microhardness of the Cu-Mo coating in the heat affected zone (HAZ) after electro-spark treatment was 51 % higher than that of the substrate material. Laser treatment had a favorable effect on the changes in the microhardness of the electro-spark deposited on the Cu-Mo coating. There was an increase of 161 % in the microhardness of the Cu-Mo coating.

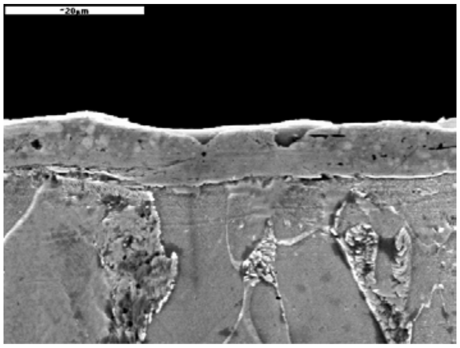

Fig. 1. Microstructure in the Cu-Mo coating

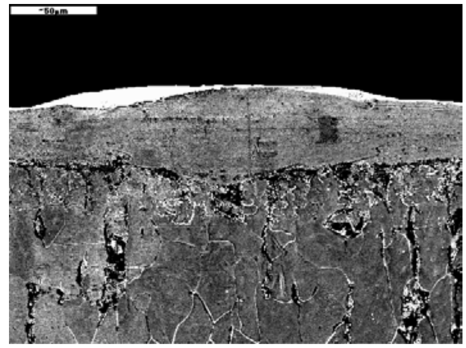

Fig. 2. Microstructure in the Cu-Mo coating after laser treatment

The coefficient of friction for the Cu-Mo coating before and after laser treatment was determined using a T-01- pin on disc type tribological tester, whose principle of operation is shown in Fig. 3. The tester enables continuous measurement of friction force at a set load. The pin of ϕ4 x 20 mm was made of medium-carbon steel with a hardness of 27 HRC. The testing was performed at the following parameters: load $Q = 10$ N, rotational speed $n = 382$ rpm, test duration $t = 500$ s.

Figure 4 shows the friction coefficient in the function of time at a load of 10N. This diagram illustrates the Cu-Mo coating before and after modification with a laser beam. Dry friction observed in the case of the coatings resulted in the transformation of the outer layer into a surface layer. This was mainly due to the sliding stresses and speed, and the interaction with the medium. The state stabilization of the anti-wear surface layer was observed.

In Fig. 4, one can see stabilization of the friction coefficient after 80 sec., its value fluctuating at 0.16÷0.18. In the case of the laser modified Cu-Mo coating, the friction coefficient stabilizes after 240 sec., and its value fluctuates at 0.35÷0.37. The average friction coefficient of the Cu-Mo coating is lower than that of the laser-modified Cu-Mo coating (at the moment of stabilization).

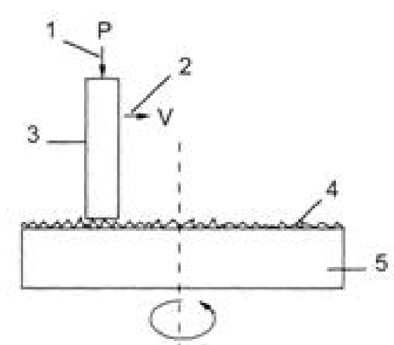

Fig. 3. Principle of operation of the pin on disc type tester: 1-applied force, 2-linear movement, 3-substrate,4-abrasive surface, 5-rotating disc

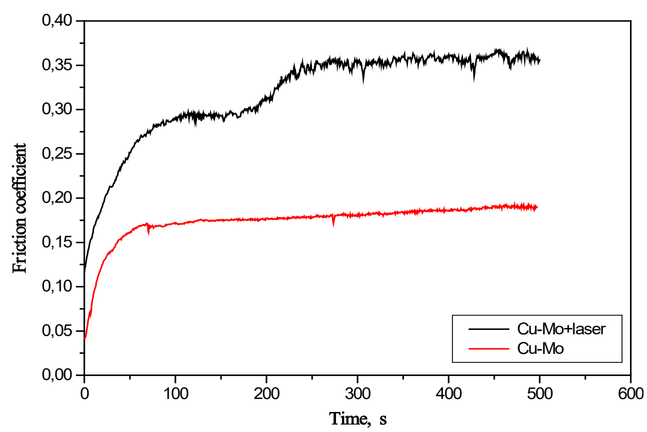

Fig. 4. Relationship between friction coefficient and time

Summary

1. There is no change in the chemical composition of electro-spark deposited coatings after laser treatment in spite of their melting and solidification. The results of laser radiation are the

homogenization of the chemical composition, structure refinement and the healing of microcracks and pores.
2. The average value of the friction coefficient (at the moment of stabilization) obtained during the tribological tests for the Cu-Mo coating is approximately 54% lower than that obtained for the same coating after laser modification.
3. Laser treatment caused a 20% increase in the microhardness of the electrospark deposited Cu-Mo coatings.

References

[1] I.V. Galinov, R.B. Luban, Mass transfer trends during electrospark alloying, Surface & Coatings Technology 79 (1996) 9-18. https://doi.org/10.1016/0257-8972(95)02434-4

[2] T. Chang-bin, L. Dao-xin, W. Zhan, G. Yang, Electro-spark alloying using graphite electrode on titanium alloy surface for biomedical applications, Applied Surface Science 257 (2011) 6364-6371. https://doi.org/10.1016/j.apsusc.2011.01.120

[3] B. Antoszewski, E. Evin, J. Audy, Study of the effect of electro-spark coatings on friction in pin-on-disc testing, Journal of Tribology-Transactions of the ASME 3 (2008) 253-262.

[4] N. Radek, A. Sladek, J. Broncek, I. Bilska, A. Szczotok, Electrospark alloying of carbon steel with WC-Co-Al_2O_3: deposition technique and coating properties, Advanced Materials Research 874 (2014) 101-106.

[5] N. Radek, E. Wajs, M. Luchka, The WC-Co electrospark alloying coatings modified by laser treatment, Powder Metallurgy and Metal Ceramics 47 (2008)197-201. https://doi.org/10.1007/s11106-008-9005-7

[6] N. Radek, J. Konstanty, Cermet ESD coatings modified by laser treatment. Archives of Metallurgy and Materials 57 (2012) 665-670. https://doi.org/10.2478/v10172-012-0071-y

[7] J. Pietraszek, N. Radek, K. Bartkowiak, Advanced statistical refinement of surface layer's discretization in the case of electro-spark deposited carbide-ceramic coatings modified by a laser beam, Solid State Phenom. 197 (2013) 198-202. https://doi.org/10.4028/www.scientific.net/SSP.197.198

[8] N. Radek, J. Pietraszek, B. Antoszewski, The average friction coefficient of laser textured surfaces of silicon carbide identified by RSM methodology, Advanced Materials Research 874 (2014) 29-34. https://doi.org/10.4028/www.scientific.net/AMR.874.29

[9] R. Ulewicz, Hardening of steel X155CrVMo12-1 surface layer, Journal of the Balkan Tribological Association 21 (2015) 166-172.

[10] A. Dudek, L. Adamczyk, Properties of hydroxyapatite layers used for implant coatings, Optica Applicata 43 (2013) 143-151.

[11] A. Dudek, A. Wronska, L. Adamczyk, Surface remelting of 316 L+434 L sintered steel: microstructure and corrosion resistance, Journal Of Solid State Electrochemistry 18 (2014) 2973-2981. https://doi.org/10.1007/s10008-014-2483-2