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PRODUCTION OF HETEROGENEOUS SURFACES BY HIGH ENERGY TECHNIQUES

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1. Introduction

During tribological investigations was found that employed heterogeneous surfaces models into boundary interaction of solid surfaces make significant improvement [1]. Surfaces described as heterogeneous consist of areas, which are different one from another in geometrical, physicomechanical or physicochemical properties. The heterogeneity of surfaces is frequently due to the application of more than one technology, and can be constituted by:

- shaped surface features such as grooves, pits or channels resulting from milling, eroding, etching, laser-beam forming, etc.;
- areas with different physicochemical and physicomechanical properties, e.g. areas with diversified hardness and mechanical strength accomplished by

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local surfacing or selective surface hardening (e.g. electron-beam machining, laser-beam forming or thermochemical treatment);

- areas with diversified surface microgeometry, e.g. areas eroded at the points of focus (laser treatment or electro-spark deposition), or areas with formed surface microgeometry, for instance, in terms of desired microroughness directivity or load capacity (laser and ESD technologies).

Heterogeneous surfaces can be obtained by different methods [2-3]. The laser treatment of electro-spark deposited coatings being one of them [4-5]. Electro-Spark Deposition (ESD) is one of the methods that requires concentrated energy flux. The method was first used in the USSR in the 1940s almost simultaneously with the destructive electro-erosion treatment. The ESD technique was worked on intensively in the 60s and commonly applied to deposit hard-melting materials on selected metals and their alloys, mainly steel, in the 70s. Polish scientists became interested in electro-spark deposition of coatings as early as in the 80s. The method developed into a number of varieties permits us not only to produce coatings but also modify their surface microgeometry [6-7]. The electro-spark deposition coating is characterized by non etching structure. It is stay white after etching.

The surface layer is constituted in environment of local high temperature and high pressure. The fundamental value parameters of electromachining are as following [8]:

- shock wave pressure comes from electric spark is $(2\text{-}7)10^3$ GPa,
- temperature rich $(5\text{-}40)10^3$ Celsius degree value.

Nowadays various electro-spark deposition methods are applied in technological processes. The surface layer constituted by them are characterized by complex features of internal and geometrical structure.

How the surface layer was generating by electro-spark deposition process is depicted in details in Figure 1. To understand this scheme below is necessary to list accurate descriptions, i.e.:

1 - material of base (cathode), 2 - working electrode (anode), 3 - created coating with established operational features, 4 - plasma, 5 - diffusive or reactive-diffusive zone, 6 - nearer surrounding (shielding gas), 7 - further surrounding (air),

8 - electrode holder with channels supplying gas, IR - infrared radiation, UV – ultraviolet radiation. The surface layer can be conscious modified by adding selected elements to created complex structure [1, 4, 6]. This modification improving tribological surface properties of friction pairs. During mating parts synergistic and catalytic effect scan be noticed. The first one is generated under lubricant influence. The second one has significant wear impact for surface layer. However the wear cycle is dependent from both of them.

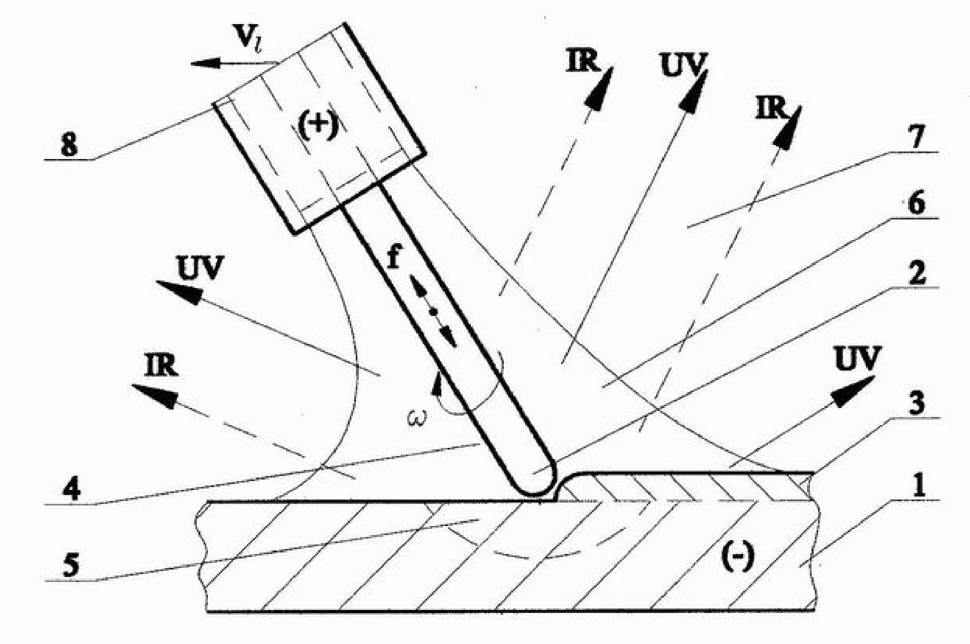

Fig. 1 Scheme of surface layer forming by electro-spark deposition method

It has been suggested that ESD coating quality can be improved by applying laser technologies. A laser beam used for surface smoothing, surface geometry formation, and surface sealing is able to reduce surface roughness and change the profile form of the irregularities. For smoothing purposes, it is recommended that power density should be small and the laser beam diameters big so that the melting process affects the coating at a small depth. The aim of laser concentration is to reduce the coating porosity and dispose of scratches, cracks, and delaminating, and, in consequence, to improve the coating density. The predicted advantages of laser treatment of ESD coatings include:

- better smoothness,
- smaller porosity,
- better adhesion to the substrate material,
- better resistance to wear and seizure,
- more compressive stresses resulting in better resistance to fatigue,
- better resistance to corrosion,
- shaping of surface.

2. Experimental

The two stages investigation was carried out. First of all Cu-Mo coatings were electro-spark deposited on C45 steel coupons and after that they were modified by Nd:YAG laser beam. The copper inside coatings is being fundamental material to created of low-friction surface layers. It is itself also internal stresses compensator. This material is characterized by good thermal conductivity, which can be very helpful in high loaded contacts – heat can be taken away into material core from friction zone. The other selected element was molybdenum as an important strengthen surface content. Mo is also helpful into creation of hard phase compounds, e.g.: MoC. In practical meanings this compound will improve durability of tools kinematics pairs. The electro-spark deposition of Cu and Mo wires with a diameter of 1 mm was performed by means of an ELFA-541, a modernized device made by a Bulgarian manufacturer. 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 chemical composition of the steel is presented in Table 1.

Table 1. Chemical composition of C45 steel

Elements	**C**	**Mn**	**Si**	**P**	**S**
Content %	**0.42 to 0.50**	**0.50 to 0.80**	**0.10 to 0.40**	**0.04**	**0.04**

The parameters of the electro-spark deposition established during the experiment include: current intensity I = 16A (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 (for Cu L = 1); capacity of the condenser system C = 0.47 μF; pulse duration Ti = 8 μs; interpulse period Tp = 32 μs; frequency f = 25 kHz.

The main aim of carried out investigations was:

- observing the surface state by means of a stereoscopic microscope,
- analyzing the surface macrogeometry,
- measuring the microhardness with the Vickers method.

3. Results and Discussion

The heterogeneous Cu-Mo coatings structure after electro-spark deposition on steel coupons and eroded by laser beam were investigated. The observation was done by OLYMPUS SZ-STU2 stereoscopic microscope. The erosion was performed with the point pulsed-laser technique using the Nd:YAG type of laser under the following conditions:

- laser spot diameter, d = 0.7 mm,
- laser power, P = 10; 20; 30; 40; 50; 100 and 150 W,
- beam shift rate, V = 1200 mm/min,
- nozzle-sample distance, h = 1 mm,
- pulse duration, t_i = 0.8; 1.2; 1.48; 1.8; 5.5 and 8 ms,
- frequency, f = 8 Hz.

As can be seen from Figures 2 and 3, the effect of the laser erosion action is in the form of crates. The first one is showing lower laser power (P = 20 W) interaction effect on the treated surface (Fig. 2). The second one is illustrating phenomenon (Fig. 3), where 5 times laser power was increased (P = 100 W). The cavity depth depends mainly on the laser power density and the pulse duration. Coatings with such geometry have various tribological applications. By rubbing the surface selectively, it is possible to produce cavities inside which hydrodynamic forces can be generated during fluid film lubrication. Moreover, the hard areas around the cavities are capable of bearing normal loads.

Fig. 2. Stereoscopic photograph of a Cu-Mo coating laser-eroded at 100 W (x57 magnification)

Fig. 3. Stereoscopic photograph of a Cu-Mo coating laser-eroded at 20 W (x57 magnification)

The investigations of the effects of the laser erosion involved measuring the diameters and depths of the cavities obtained at different laser powers. The results of the measurement performed with a PG-2/200 form surfer are presented in the form of graphs in Figures 4 and 5. Studying the graphs, one notices that the higher the power of the laser beam, the greater the diameter and depth of the cavities. An exception is the cavity depth produced at 150 W. The value is smaller than that obtained at 100 W (Fig. 4). This might have been due to a considerable pulse duration (t_i = 8ms), the laser power being 150 W. However, if P = 100 W, the pulse duration t_i was 5.5 ms. In the case of lasers operating in the pulse mode, the power is averaged in time; thus, if the pulse durations are long, the laser beam is less effective.

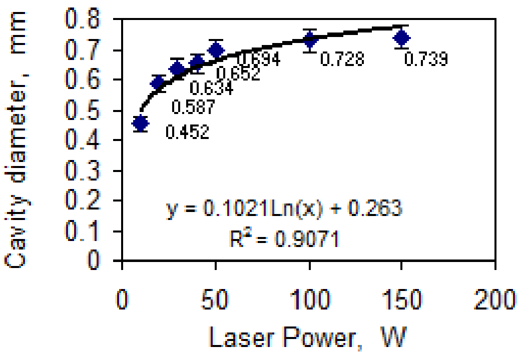

Fig. 4. Interdependence of cavity diameter and laser power

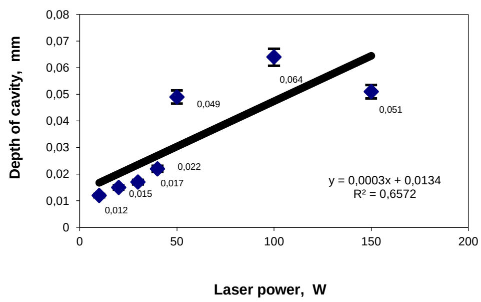

Fig. 5. Interdependence of cavity depth and laser power

At the next stage, the Vickers microhardness test was conducted using a load of 0.98 N. The measurements was carried out on Cu-Mo coatings laser-eroded at 20 W. The distribution of microhardness is shown in Figure 6.

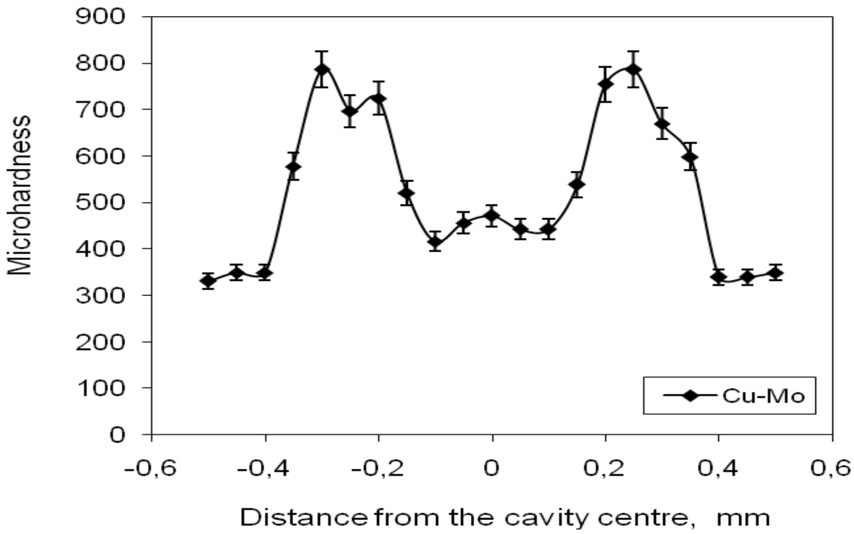

Fig. 6. Distribution of microhardness on the surface of a laser-treated Cu-Mo coating

It was established that there was an increase in microhardness at the points of laser machining, the increase being strictly related to the changes in the coating structure, and therefore, to the method of laser treatment. The surface hardening at the points of laser interaction and in the heat-affected zone (HAZ) follows the phase changes occurring in the material first heated and then immediately cooled. The average microhardness of the C45 steel substrate was 300 HV. That of the ESD coatings amounted to about 430 HV. The laser treatment of the ESD coatings caused an increase in microhardness to approximately 850-880 HV. In the heat-affected zone, the microhardness fluctuated around 580-630 HV. The laser beam surface forming resulted in changes in the microhardness of electro-spark deposited Cu-Mo coatings.

Conclusion

- It is possible to diversify the surface of electro-spark deposited coatings, i.e. to obtain heterogeneous surfaces. The laser-affected areas are characterized by the occurrence of regular cavities, hardened areas and varied roughness.
- The surface heterogeneity (i.e. the cavities) are desirable in sliding friction pairs. They may be used as reservoirs of lubricants as well as sources of hydrodynamic forces increasing the capacity of a sliding pair.
- The future investigations will be continued in direction for development better heterogonous surface for tribological applications by using ESD technique.

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THE DIFERENCE OF WALL ELEMENTS STATE INCLUDING THE FRF FUNCTION

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Abstract

The recommendation of the PN - B-03002 norm shows a need of quality control of wall elements production, and classified them as elements of category