MICROSTRUCTURE OF ELECTRO-SPARK COATINGS FOR SLIDING FRICTION PAIRS

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Abstract

The paper presents the results of investigations into the microstructure of coatings made from bearing alloys on the bronze substrate. This option is used for slide bearing bushings to improve break-in parameters. The paper presents the method, a set of images taken at different magnifications and the analyses of composition at selected sites. The investigations made it possible to identify the basic components of the coating microstructure.

Keywords: electro-spark coatings, microstructure, bearing alloys, friction pairs

1. INTRODUCTION

Electro-erosion incremental machining, also known as electro-spark deposition, is categorised as one of methods based on the use of a concentrated energy flux. Currently, the method range includes the following: ESD (Electro Spark Deposition), ESA (Electro Spark Alloying), PES (Pulse Electrode Surfacing) and EDM (Electro Discharge Machining). The technologies mentioned above have the same principle of operation, based on the use of electrical discharge accompanied by mass processes and energy dissipation [1-4].
Analysis of properties of coatings obtained from ESD requires many methods [5-7].
The method of elecrtro-spark deposition is particularly useful for anti-wear coatings. Due to a wide range of the materials which can be used and the control of the environment of the electrodes, the method can be employed to alter, to a major extent, mechanical, thermal, electrical, thermoemissive, and other properties. In particular, the electro-spark deposition of the coating can be applied locally, yet strong adhesion to the substrate can be achieved and the materials are prevented from being heated in the process. Another distinguishing feature of the method is the possibility of using both pure metals and alloys, and also metal-ceramic composites and high-melting alloys. Finally, while using this method, it is possible to supplement the cathode (here the workpiece) with the anode components (the electrode) by means of diffusion, which can be achieved without altering the size of the workpiece. The method does not involve any special preparation of the workpiece, and the equipment needed to perform the operation does not have large dimensions, making it easily portable. The method drawbacks include the following: increase in surface roughness, tensile stress formation in the surface layer, and a decrease in fatigue resistance.
To limit the effect of the drawbacks mentioned above, different techniques can by employed, e.g. multilayer coatings, process optimisation, and the use of special electrodes. Very good results can also be obtained by combining electro-spark alloying with other technologies, e.g. burnishing. The machining of the surface with electro-spark coating must be approached in a special way. Due to a relatively low thickness of the coating, (approx 0.10 mm) it cannot be ground to reduce roughness. It is, however, possible to diminish roughness and to change the character of tensile stresses making them compressive stresses, by means of shot peening. Additionally, the values of the compressive stresses do not depend on burnishing parameters, which indicates that the state of plastic fluidity has been reached in the surface layer. In recent years, ultrasonic machining of materials has been widely used to reduce roughness. The machines for ultrasonic

finishing are designed for typical components that are cylindrical rings, conical/spherical, and others in shape. The advantages of the method of coating electro-spark deposition include the following:

- the possibility of depositing, on metal surfaces, any conductive materials which are tightly bound to the substrate,
- the possibility of performing the process locally, i.e. at a selected site of the workpiece,
- the lack of deformations and changes in the structure of the alloyed material.

The benefits offered by the method make it particularly suitable for enhancing the strength of sliding friction pairs.

2. PREPARATIONS OF SAMPLES FOR LIGHT MICROSCOPY OBSERVATIONS

Electro-spark deposited coatings have low thickness, therefore it is necessary to use a special technique to prepare metallographic micro-sections. Before grinding, a counter sample of copper or steel is pressed against the front face of the sample with the coating. The sample bound in this manner is then milled to the depth of 2 mm. This procedure is necessary because in the nearby area, the sample usually does not reach the pre-set thickness, which results from the pre-defined coating thickness and the method of deposition. The next operation involves grinding in accordance with the standard procedure. Such a manner of sample preparation prevents the coating from being ripped and the edges from being rounded. As a result, an appropriately prepared sample for microscopy observations is produced, and sharp image across the whole coating cross-section can be obtained. To reveal their structure, the metallographic micro-sections are subjected to chemical etching. For instance, for C45 steel coating, the agent used is nitric acid (3%) solution in ethyl alcohol (Nital) Ni1Fe. The quality of the prepared samples is initially assessed by light microscopy. On the samples prepared as above, microhardness distribution tests on the coating cross-section are also performed.

3. SCANNING MICROSCOPY OBSERVATIONS

Three samples, namely N1, N2 and N3, made on the bronze substrate, were prepared for observations in accordance with the procedure described above. The photographs and analyses presented in the paper were obtained in the tests performed at the Scanning Microscopy Laboratory of the Kielce University of Technology. JEOL JSM-7100F Schottky Field Emission Scanning Electron Microscope was used.
The equipment used for electro-spark deposited was an EIL-8A model. Basing on the results of previous research as well as instructions given by the producer, the following parameters were assumed to be optimal for ESA: voltage U = 67 V, capacitor volume C = 150 μF, current intensity I = 0.9-1.0 A.
The coatings deposited had the following chemical compositions:

- N1- 80Cu13Pb7Sn bearing alloy
- N2- 78Pb15Cu7Sb bearing alloy
- N3 - 90Pb7Sb3Ag bearing alloy

As given in the literature on the subject [1, 4], the microstructure of electro-spark coatings shows three characteristic zones. The amorphous layer, called „white layer”, the proper layer, and transient layer having varied elemental concentrations, which is diffusive in character. In the samples, made of bearing alloys, subjected to analysis the „white layer” zone is marginal, whereas the transient zone is clearly noticeable, especially in samples N1 and N3. In the metallographic micro-sections presented in the paper, other objects typical of electro-spark coatings are also visible, namely pores, precipitations, and discontinuities. The N1 coating has the largest number of pores and precipitations. The analyses of the mean content of individual elements indicate that the results generally do not deviate from the data provided by the electrode manufacturer (Fig. 1).

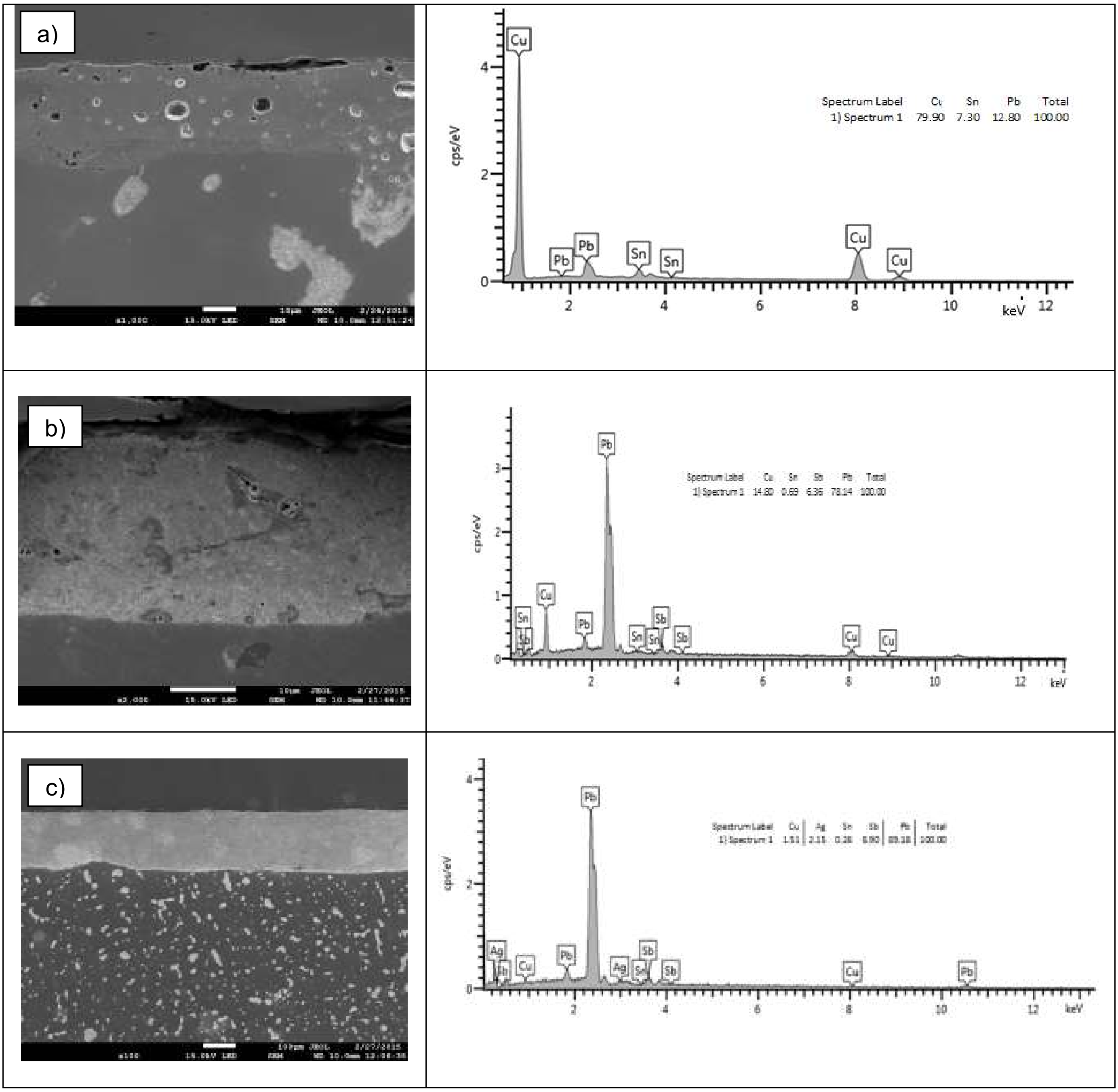

Fig. 1 Views of coating microstructures and the distribution of the average content of individual elements in the coating surface: a) N1, b) N2, c) N3

The measurement of the electro-spark coating thickness is not a simple task. The coatings are relatively thin, and they have high roughness. The methods that are effective for other coatings, e.g. induction or magnetic methods do not work in this case. The most reliable measurement seems to be the one based on the observations of the metallographic micro-sections. The images (Fig. 2) indicate that the N3 coating is the thickest and has the thickness of 187.96 μm, the second coating is N1 having the thickness of 25.87 μm, and the N2 coating is the thinnest with the thickness of 23.16 μm. The thickness measurement methodology is presented in a detailed manner in Figure 2 for the N1 coating. The identified coating thicknesses show differences in the efficiency of the deposition process, in which electrodes made of different materials were used.

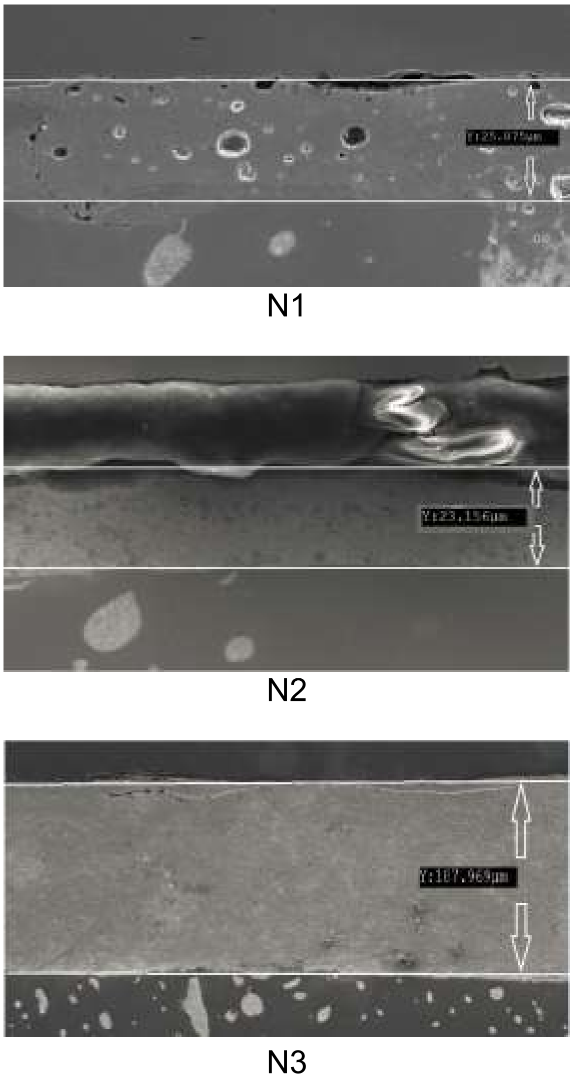

Fig. 2 Assessment of the thickness of the analysed coatings

The analysis of the linear elemental distribution makes it possible to asses the mutual penetration of the components, which indicates that the diffusion process has occurred. The profiles of the distribution curves, and precisely, their inclination at the site of coating-to substrate contact constitute a measure of the diffusion depth. Figures 3-5 present the profile of the distribution of the main components of the coating. Large diffusion area is found in N1 and N3 coatings. The depth of Cu and Pb diffusion, estimated on the basis of the plots, amounts to approx. 4 μm. Pb diffusion in the N2 coating shows much lower values, and amounts to approx. 1.5 μm.

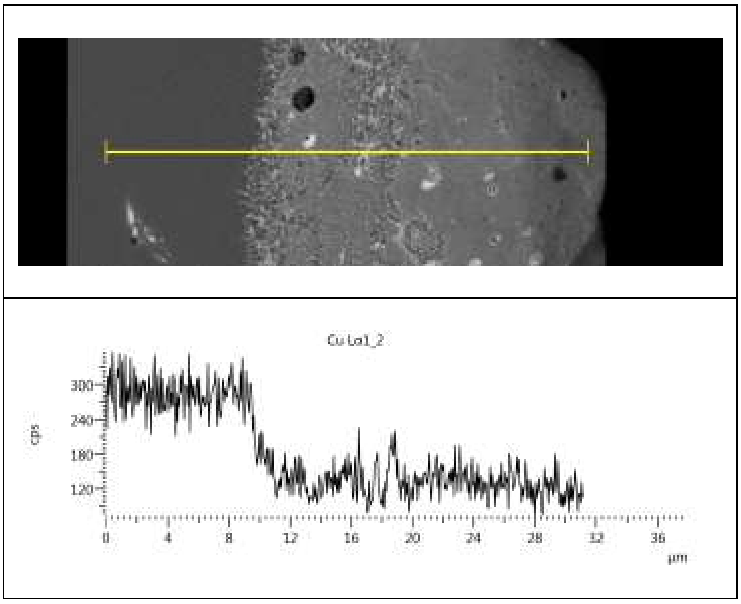

Fig. 3 Microstructure and Cu linear distribution in the N1 coating

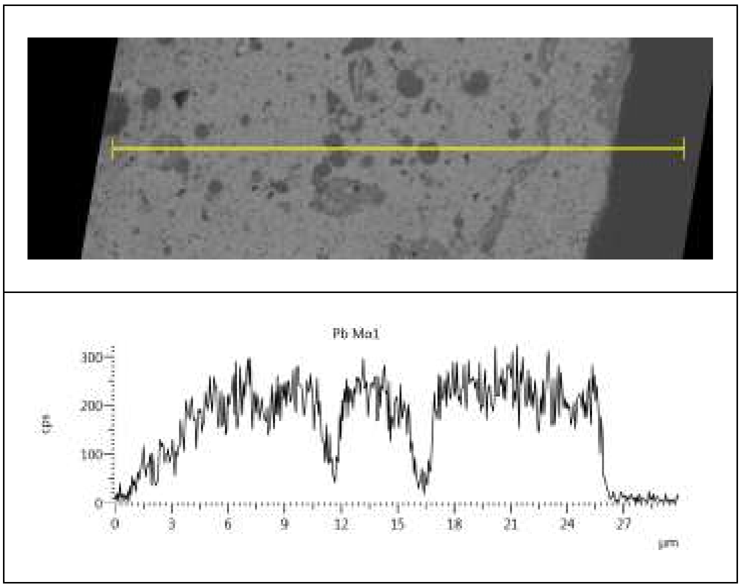

Fig. 4 Microstructure and Pb linear distribution in the N2 coating

Analyzing the percentage content of individual elements in the characteristic zones of the coating, it is possible to refer to the most important components of the coating structure. On the basis of the analysis of the coating microstructures, bright fields, dark fields, and also pores and precipitations can be differentiated. Table 1 presents the percentage content of Pb and Cu for the bright and dark fields of the structure. The analysis of the results in Table 1 indicates that dark fields are found for the elevated Cu content and diminished content of Pb. The bright fields, however, are formed when the Cu content is reduced and the Pb content is increased.

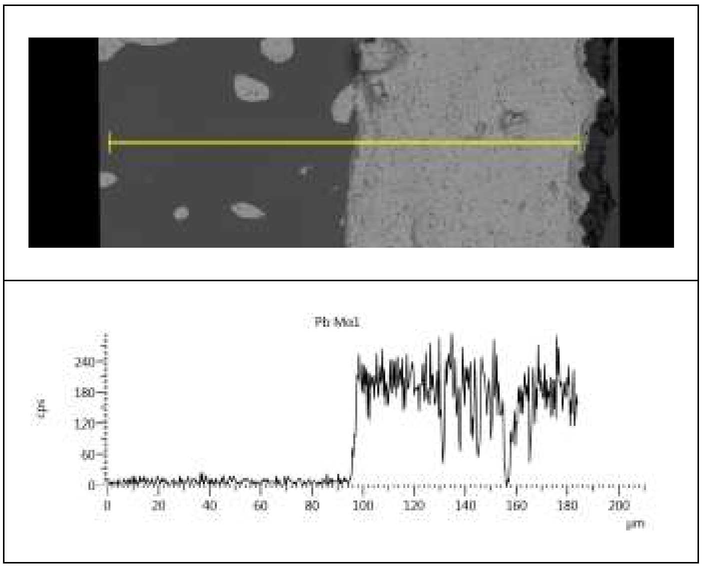

Fig. 5 Microstructure and Pb linear distribution in the N3 coating

Table 1 Pb and Cu contents in the characteristic coating zones

Coating No.	Bright fields		Dark fields	
	Cu	Pb	Cu	Pb
N1	14.95	35.17	59.42	10.21
N2	57.47	18.35	64.19	11.52
N3	1.6	98.48	2.38	76.57

CONCLUSIONS

Microscopic observations and the composition analysis performed with the X-ray probe make it possible to identify the basic components of the coating. As a result, the course of the process and the correctness of the selection of the machining parameters can be evaluated. The analyses of the pattern of elemental distribution make it possible to asses the character of the coating-to-substrate bond, and also provide the basis for the assessment of the diffusion depth. Microscopy observations offer the possibility of detecting coating defects, such as microcracks, porosity or the precipitation of other elements that constitute the substrate components.

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