Comparative characteristics of wear resistance of electroplated copper coating and composite electrolytic coating obtained with use of lead bronze electroerosive materials

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Abstract. This paper presents the results of a study of the elemental composition of dispersed particles obtained from Brs30 waste, as well as their morphology. Samples of metal products with applied copper composite coatings with the obtained particles were experimentally made and their physical and mechanical properties were studied. It is noted that samples with composite coatings based on copper obtained from an electrolyte suspension with the addition of dispersed particles of electroerosive lead bronze of the Brs30 brand have the best wear resistance.

1. Introduction
Currently, the urgent problem is the processing of waste lead bronze. Of greatest interest among the existing technologies for processing metal waste is the technology of obtaining powder materials based on the phenomenon of electrical erosion - electroerosive dispersion[1-5]. Its main advantages are environmental friendliness and minimal energy consumption. Among the prospects for the repeated use of materials obtained by this method, it should be noted that there is a possibility of their use as materials for metallization and galvanic coatings with improved physical and mechanical properties. Currently, in the modern scientific and technical literature there is no complete information on the use of dispersed particles obtained from waste lead bronzes by electrical erosion, in the formation of galvanic coatings and their effect on wear resistance [6-9].

The purpose of this work was to study the characteristics of wear resistance of galvanic copper coatings and composite coatings based on copper obtained from a suspension electrolyte with the addition of dispersed particles of electroerosive lead bronze grade BrS30.

2. Materials and methods
Waste of BrS30 alloy in the form of shavings was chosen as a starting material for obtaining dispersed particles. Distilled water was used as a working liquid [10, 11]. The deposition of coatings of two types was carried out on an L1 DIGIT galvanic installation. Nickles made of steel grade 30 HGSA
were used as a substrate for coating. To deposit a coating from a universal sulfuric acid electrolyte of copper plating, the following electrolyte composition was used: CuSO$_4$·5H$_2$O (200-250 g/l), H$_2$SO$_4$ (35-70 g/l), NaCl (0,01g/l), lemon acid (0,01 g/l) [5-6]. To prepare a suspension electrolyte suitable for obtaining a composite electrolytic coating, all these reagents must be introduced into a suspension of electroerosive lead bronze powder. The deposition of coatings was carried out with the following parameters: anode material - anode copper of the AMF brand; anode-cathode area ratio - 1: 1; bath material - chemical glass; working temperature – 18-25 °C; voltage – 2-5 V; current density range – 5-10 Aperdm2; deposition rate – from 1 μm /1 min. (at 5Aperdm2); stirring - obligatory.

The coefficient of friction and the rate of wear of the surface of the samples and counterbody were measured on an automated friction machine (Tribometer, CSM Instruments, Switzerland). The tests were carried out in air at a load of 2N and a linear velocity of 10 cm/s, with a radius of curvature of wear of 5-6 mm, the friction path was 200 meters.

3. The morphology and X-ray spectral microanalysis

Reasoning The results of the study of morphology and X-ray spectral microanalysis of the obtained dispersed particles are presented in Table 1 and Figure 1.

| Element | Massfraction, % | Atomicfraction, % |
|---------|----------------|-------------------|
| O       | 7.77           | 29.80             |
| Sn      | 1.77           | 0.92              |
| Fe      | 0.28           | 0.31              |
| Cu      | 55.59          | 53.71             |
| Zn      | 5.86           | 5.50              |
| Pb      | 28.10          | 8.33              |
| Al      | 0.63           | 1.44              |
| Total   | 100.00         | 100.00            |

Figure 1. Microstructure and morphology of dispersed particles

Based on the results of the presented data, it was established that the main elements in the powder obtained by the method of electroerosive dispersion of lead bronze waste in distilled water were oxygen, copper, zinc and lead. The rest of the elements are distributed relatively evenly in the powder [7]. It has been experimentally established that the shape of the resulting particles is mainly spherical.
or elliptical, the average particle size is 9.73 μm, the arithmetic value is 9.731 μm [8-10].

The results of the study of the microstructure and morphology of the obtained standard and composite galvanic coatings are presented in Figure 2 and Table 2.

Table 2. Results of X-ray spectral microanalysis of the obtained coatings

| Coating          | Element, % |
|------------------|------------|
|                  | Al | Si | Fe | Ni | Cu | Pb |
| Standard         | 0,84 | 0,67 | 1,59 | 1,68 | 95,23 | - |
| Composite        | 0,72 | 0,92 | 1,32 | 0,40 | 89,52 | 7,12 |

Figure 2. Microstructure and morphology of the obtained coatings: a) standard; b) composite

The study of the microstructure of the transverse section of the samples showed that coatings with a thickness of 2-2.7 μm were obtained without visible defects at the "coating/substrate" interface. The coatings have a mixed structure with well-melted powder particles.

The small thickness of the coatings is due to the choice of the deposition time in accordance with the recommended thickness of the copper coatings.

The results of the study of the wear resistance of the experimental samples are shown in Table 3. It should be noted that the pores of the substrate are more uniformly filled with a composite coating with the addition of electroerosive lead bronze.

Table 3. Tribological characteristics of electroplated coatings

| Sample         | Statistical partner wear factor (ball of Al₂O₃ Ø6 mm), mm³.N⁻¹.m⁻¹ | Sample wear factor, mm³.N⁻¹.m⁻¹ |
|----------------|------------------------------------------------------------------------|---------------------------------|
| Standard coating | 3,753                                                               | 407,9                           |
| Composite coating | 0,107                                                              | 50,94                           |

4. Research findings
It has been experimentally established that the wear factor of the statistical partner when testing a sample with a standard electroplated copper coating is higher than the wear factor of a statistical partner when testing a sample with a composite electrolytic coating based on copper obtained from a suspension electrolyte with the addition of electroerosive lead bronze particles. It is noted that the
wear factor of a specimen when testing a specimen with a standard electroplated copper coating is higher than that of a specimen when testing a specimen with a composite electrolytic coating based on copper obtained from a suspension electrolyte with the addition of electro erosive lead bronze particles. This is also confirmed by the study of the wear track on the surface of the coatings after testing on a Quanta200 3D scanning electron microscope (Figure 3).

![Figure 3. Wear tracks on the surface of coatings after testing: a) standard coating; b) composite coating](image)

5. Conclusion
It was found that the main elements in the powder obtained by the method of electro erosive dispersion of lead bronze waste in distilled water were oxygen, copper, zinc and lead. The rest of the elements are distributed relatively evenly in the powder. The particle shape of the resulting conglomerates is spherical and elliptical, the average size is 9.73 μm.

Samples of metal products with standard and composite copper-based galvanic coatings applied to them were made, their physical and mechanical properties were investigated:
- coatings with a thickness of 2-2.7 μm were obtained without visible defects at the "coating-substrate" interface;
- the main elements in the coatings are Cu and Pb;
- composite electrolytic coatings obtained from an electrolyte suspension with the addition of particles of electro erosive lead bronze have the best wear resistance.

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