Morphological and structural features of electrospark coatings

Auchynnikau Yauheni¹, Pinchuk Tatiana², Eysymont Yauhenia³, Mihailov Valentin³, Kazak Natalia³ Bahanovich Ludmila⁴
Yanka Kupala State University of Grodno-Grodno, Republic of Belarus
State Scientific Institution “O.V. Roman Powder Metallurgy Institute” - Minsk, Republic of Belarus
Institute of Applied Physics - Chişinău, Moldova
State Scientific Institution “Physical-Technical Institute of the National Academy of Sciences of Belarus” - Minsk, Republic of Belarus

E-mail: ovchin@grsu.by, iscentr@tut.by, eysmont@grsu.by, valentin.mihailov@gmail.com, bakhanovich2@yandex.by

Abstract: The morphology of the coatings has a significant effect on the tribological characteristics of the contacting bodies. Depending on the relief of the surface layers of the coatings, the resistance of the modified substrates to corrosion is determined. It is known that the processes of friction and corrosion have a decisive influence on the performance of products. To reduce the influence of these processes, various protective coatings are used, including those formed by the method of electrospark alloying. The aim of this work was to study the morphology and structure of electrospark coatings formed by layer-by-layer electrospark alloying. In the course of the studies carried out, it was found that these coatings are morphologically heterogeneous, with a large number of cracks and splats.

KEYWORDS: MORPHOLOGY, COATING, ELECTRIC DISCHARGE, ALLOYING, PLASMA

1. Introduction.

The fundamental role in the failure of products and parts of mechanisms and machines is the processes of friction and corrosion. In this regard, it is necessary to use multifunctional protective coatings formed by various technological processes. The determining factor when using coatings is the economic aspect. So, at present, most of the protective coatings are formed using imported technologies and materials. When creating coatings, complex technologies are used that are expensive. In this regard, it becomes necessary to create new technological methods for the formation of multifunctional coatings based on domestic raw materials [1] - [3].

In the agro-industrial complex, multicomponent systems of organic and inorganic origin are widely used to restore and form the surfaces of friction parts and protect them from corrosion and mechanical wear. As a result of a synergistic combination of metallic and non-metallic components, high deformation-strength, tribotechnical, physicochemical characteristics are achieved [1] - [3].

One of the promising methods is electrospark alloying (ESA). The essence of the method lies in the process of deposition of molten material on the surface to be treated with an electric spark discharge. In some cases, melting of the material is achieved by the formation of plasma in a spark discharge, which significantly changes the properties of the layers being formed. The process of melting and deposition of the master alloy occurs in an air and inert gas environment [4]. The formation of coatings by the method of electrospark alloying is carried out on installations such as UR-121, IM101, SE-5.01, IMPULS-1A, SPARK-1000, etc. Low internal stress coatings can be obtained by preheating the part with a gas burner flame. The molten particles are deposited on a preliminarily prepared substrate, form strong adhesion or chemisorption bonds, and cool to form a hard coating [4].

Supercycling (106 Kc⁻¹) or high particle cooling rates can lead to the formation of unusual amorphous and metastable phases, which are unusual for materials obtained by other technologies. The method of electrospark alloying is characterized by a number of advantages: the possibility of applying coatings to products made of practically any conductive material.

The aim of this work is to study the morphology and structure of electrospark coatings formed by the layer-by-layer method.

2. Materials and Procedures

Nanocomposite electrospark coatings based on nitrides, carbides, silicides of titanium and aluminum were applied by the method of electrospark alloying on Impuls-1A installations. Various grades of metals were used as substrates: BT 6; 40X13. The coatings were applied both to the metal as delivered, and the steel substrate was hardened to HRC 53-60 and polished to a purity not lower than grade 10. The studied objects were multicomponent coatings obtained from metal compounds, the compositions of which are shown in Table 1. The coatings were formed using the Impuls-1A installation (manufactured by the Institute of Applied Physics of the Academy of Sciences of Moldova). Modes of obtaining coatings are shown in Table 1. The morphology of coatings was investigated on a scanning electron microscope “MIRA3 TESCAN”. The microscope is equipped with detectors for secondary electrons SE and backscattered electrons BSE, which allow the study of samples in two modes. The study of the elemental composition was carried out using an INCA 350 micro X-ray spectrum analyzer (Oxford Instruments, England). Detectable elements from B to U. Minimum element detection limit - 0.5%

Table 1 - Modes of formation of coatings, compositions of electrodes

<table>
<thead>
<tr>
<th>Sample</th>
<th>Coating formation parameters</th>
<th>Electrode composition</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>coating formation mode, J</td>
<td>substrate</td>
</tr>
<tr>
<td>N01</td>
<td>0.9</td>
<td>40X13</td>
</tr>
<tr>
<td>N02</td>
<td>0.9</td>
<td>40X13</td>
</tr>
<tr>
<td>N03</td>
<td>0.9</td>
<td>40X13</td>
</tr>
<tr>
<td>N04</td>
<td>0.9</td>
<td>40X13</td>
</tr>
<tr>
<td>N05</td>
<td>0.9</td>
<td>40X13</td>
</tr>
</tbody>
</table>

3. Results and discussion.
During the formation of nanocomposite coatings by the methods of electrospark alloying, surface layers with a developed morphology are formed (Figures 1 - 4). According to the data of scanning electron microscopy, ESA coatings formed on a 40X13 steel substrate have a developed morphology. Thus, with an increase in resolution, the formation of the morphology of coatings of the “pebbled skin” type is observed. That is, the coalescence of molten cathode droplets occurs during deposition on the substrate surface with the formation of voids. The geometrical dimensions of these formations depend on the cathode material and the modes of coating formation. TiC coatings produce a smoother texture, which is reflected in its corrosion characteristics. A sufficient number of cracks are observed in the structure of the coatings, which affect the strength and adhesion characteristics of the coatings.

The obtained materials are in good agreement with the literature data [5]. The coatings formed by ESA on chromium-nickel stainless steel with titanium at a current of 2.0 - 2.5 A were distinguished by the presence of particles characteristic of electrospark coatings - plaits, which are melted particles of the transferred material (Figure 5, a). Similar plaits were observed in TiAlN coatings formed on a titanium substrate (Figure 3, b).

![Figure 1 - Morphology of the TiAlC electrospark coating formed on a 40X13 steel substrate (pulse energy 0.9 J)](image1)

![Figure 3 - Morphology of TiAlN electrospark coating formed on a HT6 substrate (pulse energy 0.9 J)](image3)

![Figure 4 - Morphology of an electrospark TiC coating formed on a VT6 substrate (pulse energy 0.9 J)](image4)

![Picture of morphology](image5)
a - surface image; b - distribution of the average linear size of structural elements

Figure 5 - Morphology of the coating formed by ESA at a current of 0.8 - 1.0 A [5]

Scanning electron microscopy data are in good agreement with the results of optical studies (Figure 6).

A chemical analysis of the surface layers of electrospark coatings showed the formation of structures in the form of drops, in which iron is the main component. Thus, during electrospark alloying, intensive mixing of the electrode and substrate material occurs, and the formation of surface structures with an increased iron content is possible (Figure 7).

a) b)

c) d)

e)


Figure 5 - Morphology of electrospark coatings formed on a steel substrate 40X13

Figure 6 - Distribution of chemical elements in the surface layers of the electrospark TiSiC coating formed on the VT6 substrate (pulse energy 0.9 J)

4. Conclusions

Thus, the investigated electrospark coatings are characterized by a developed morphology. A sufficiently large number of pores is observed in the coatings obtained by this method, which affects the physico-mechanical characteristics of these research objects. The most common defects are cracks and braids.

References.


