Oksana Haponova[1, 2], Viacheslav Tarelnyk[3], Tomasz Mościcki[1], Gennadii Laponog[2], Joanna Sulej-Chojnacka[4]

[1]Institute of Fundamental Technological Research Polish Academy of Sciences, Warsaw, Poland
[2]Sumy State University, Sumy, Ukraine
[3]Sumy National Agrarian University, Sumy, Ukraine
[4]Łukasiewicz Research Network – Poznań Institute of Technology, Poznan, Poland

Electrospark Deposition by Using Nanoparticle-Containing Paste

Abstract

In the modern era of rapid scientific and technological development, there is an increasing demand for the creation of new materials with enhanced performance characteristics. Metal components of machines and equipment are subject to intensive wear, which is one of the main causes of their loss of functionality. Friction and wear lead to significant energy and material losses, making the improvement of wear resistance of working surfaces a highly relevant problem. One promising approach to address this challenge is the use of nanomaterials, which, due to their unique properties, allow for significant enhancement of the physicomechanical characteristics of coatings. Nanostructured layers provide high hardness, corrosion resistance, and extended service life of components. Traditional coating methods, such as CVD, PVD, or laser cladding, require complex and expensive equipment and have certain limitations. Therefore, methods that combine ease of implementation, energy efficiency, and environmental friendliness are attracting increasing attention. One such method is electrospark deposition (ESD), which enables the formation of coatings with high adhesion and the possibility of localized treatment of critical components. The use of nanoparticle-containing pastes in the ESD process opens new opportunities for obtaining nanostructured layers with improved properties. Investigating the structure formation processes of such coatings is a relevant task in contemporary materials science.

For the experiments, Armco iron was used as the substrate, while the alloying electrode was molybdenum obtained by the SPS technique from molybdenum powder. Coatings were formed on the "Elitron-22A" installation under various process conditions. The ESD process was conducted in the sequence: application of the carbon nanoparticle-containing paste to the treated surface followed by ESD using the molybdenum electrode. Multi-walled and single-walled carbon nanotubes dispersed in a polymer matrix via ultrasonic treatment were used as nanoparticles.

The results demonstrated that the use of nanoparticle-containing pastes during ESD promotes the formation of uniform and continuous coatings compared to those without nanoparticles. Optical and electron microscopy confirmed a uniform distribution of single-walled carbon nanotubes at a 0.01% concentration, while increasing the nanotube content (0.2–0.6%) led to agglomeration and reduced coating continuity. Microstructural analysis revealed three distinct zones in the coatings: an upper “white” layer, a diffusion zone, and the substrate. The addition

of nanotubes increased the thickness and continuity of the layer as well as microhardness. Specifically, the incorporation of 0.01% single-walled nanotubes increased hardness threefold (from 446 to 1438 HV). Further increasing the nanotube concentration did not yield additional improvements. Microstructural studies showed grain refinement and the formation of a homogeneous structure in the presence of nanotubes. Elemental analysis indicated that the molybdenum diffusion zone was 12–14 μm, while the carbon content in the coating remained essentially unchanged.

Thus, the use of nanoparticle-containing paste during ESD enables the formation of homogeneous and continuous coatings. The optimal effect is achieved with 0.01% single-walled carbon nanotubes, resulting in uniform filler distribution, increased thickness, and enhanced hardness (up to 1438 HV). Increasing the nanotube concentration beyond the optimal value leads to agglomeration and decreased coating quality. The addition of nanotubes contributes to grain refinement and the formation of a nanostructured layer, which can improve the operational properties of the surface.

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