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Obtaining Functional Materials for Restoring and Strengthening Coverage Based on Complex Usage of Mineral Raw Materials

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Abstract

This article is devoted to the development of tungsten-free electrode materials for use in electrospark alloying (ESA), with boron-containing mineral raw material employed as an additive. Data are presented regarding the surface layers formed on AISI 1045 steel via the ESA method, using titanium carbide electrodes with a nickel molybdenum ligament and mineral raw material additive (datolite concentrate (DTC)). In addition, the alloy layer (AL) formation process on AISI 1045 steel via mechanized ESA using a tungsten-free hard alloy with 0.5–3 mass. % datolite concentrate additive is also studied. The most effective ESA mode in terms of the composition of the formed AL was: frequency 500 Hz and duration of spark discharge 20–80 μs for electrode D2 with 1% additive. The formation of nanostructures produced by TiC nanoparticles in the AL during the ESA process was determined via atomic force microscopy. The introduction of DTC increased both the productivity of the ESA process and the micro abrasive wear of the AL. Synthesized powder WC can be used for gas-thermal hardening surfaces of mobile materials and building structures.

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Keywords: electrospark alloy (ESA), hardness, titanium carbide, datolite concentrate (DTC), nanostructures

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1. Introduction

The electrospark alloying (ESA) method is commonly applied in industry to increase the service life of fast-wearing machine and cutting instrument parts. The advantages of this method include: the opportunity to place any flow-conducting material on metal surfaces; the high stick firmness of the applied layer with the base material; the low power-consumption of the process; the simplicity of introduction of the technological operations.

In ESA, the qualitative characteristics of the alloy layers (AL) depend considerably on the electrode material (EM). The most promising results have been achieved via the use of hard alloys, with the characteristics of titanium carbide such as its high hardness, wear resistance, refractoriness etc., proving beneficial for its employment as an EM in the production of ESA steels.

A number of well-known studies [1, 2] have examined EM creation from tungsten-free hard alloys of titanium carbide with Ni–Mo, Ni–Cr and Ni–Cr–Mo ligaments.

The most even and wear-resistant layer is typically produced when alloying using hard alloys containing 20–30% Ni–Mo ligament.

When creating EM it is necessary to take into account the influence of the inter-electrode environment and the potential formation of carbide and boride phases directly during the alloying process. To decrease the incidence of oxide films on the formed surface, materials are frequently added to the electrode's composition which carry out the role of fluxes (e.g. boron, silicon, calcium, manganese, alkaline elements). Such mineral assemblage fluxes often simultaneously play the role of microalloying additives in the surface layer, although boron is also employed for the purpose of decreasing the erosion resistance of alloying electrodes [3]. In this regard, of particular interest to the present study is the usage of datolite concentrate (DTC) additives in EM.

The purpose of this study was to further the development of tungsten-free EM in order to increase the effectiveness of the ESA process at the expense of decreasing the erosion resistance of the EM.

Improvement of the physical, chemical and operational characteristics of the AL was attempted by varying both the proportion of boron-containing mineral raw material additive, as well as the grain-size of EM produced via self-propagating high temperature synthesis (SHS). The parameters of electrospark discharge were also varied for the purpose of obtaining a nanostructured AL.

2. Equipment, techniques and materials

The charge for the TiC EM was produced from a reaction mixture containing titanium, nickel, molybdenum, DTC and soot powders by mixing the charge in a ball mill for 4 hours.

The prepared charge was then moulded into cylindrical billets in a press-form of pre-compression, while the electrodes were produced via SHS-extrusion.

During the ESA process, variation in both cathode AISI 1045 steel weight and anode erosion (TiC–Ni–Mo with the addition of datolite concentrate) with time of alloying and different electric parameters was determined. The compositions of the four different applied EM are displayed in Table 1.

Table 1. Composition variations of tested TiC–Ni–Mo EM with datolite concentrate additive.

Electrode designation	Composition (mass. %)
D0	70% TiC + 30 % (Ni + Mo)
D1	70% TiC + 29.5 % (Ni + Mo) + 0.5% DTC
D2	70% TiC + 29% (Ni + Mo) + 1.0% DTC
D5	70% TiC + 27% (Ni + Mo) + 3.0% DTC

Alloy layers were added using a typical Elitron-101 mechanized installation with a rotating front electrode. Processing was carried out using electric impulses produced from a specially developed IMES pulse generator; this generator could be controlled either via the built-in controller or by external computer [4]. The applied electric parameters are shown in Table 2.