REFRACTORY AND CERAMICS MATERIALS

ELECTRIC-SPARK ALLOYING OF STRUCTURAL ALLOYS WITH A COMPOSITE BASED ON TiCN – AlN


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The mass-transfer kinetics, the mechanism of formation, the tribotechnical characteristics, and the resistance to high-temperature oxidation of a coating formed on the hard alloy WC – 6% Co and on the titanium alloy VT6 by electric-spark alloying with electrode material based on TiCN – AlN with an Fe - Cr binder have been investigated. The phase distribution of the components in the coating was shown to be the same for both alloys. Electric-spark alloying of WC – Co and VT6 was found to reduce their wear by 33 and 60%, respectively. Moreover, the working temperature of the coated WC – Co alloy increased by 160 deg compared to the original surface.

Keywords: electric-spark alloying, high-performance alloys, resistance to high-temperature oxidation, tribotechnical characteristics, hard alloy.

Since the beginning of the 1980s ceramic coatings obtained by vapor-phase deposition (PCVD, i.e., plasmachemical vapor deposition, vacuum-arc deposition, magnetron sputtering, etc.) have been used extensively in many branches of industry. At present four types of such coatings are used principally — TiN, Ti(C, N), (Ti, Al)N, and CrN [1], primarily for making machining tools, drawing plates, corrosion-resistant components, ball bearings, etc. The best results have been obtained for (Ti, Al)N coatings, whose microhardness is greater than that of TiN coatings and increases with the aluminum content [2]. Tools with such a coating are used primarily for high-speed cutting and for hobbing without a cutting fluid. A (Ti, Al)N coating ensures superior corrosion resistance and high viscosity, which reduces the danger of it shearing off the cutting tool when machining discontinuous surfaces [3, 4].

Another way of obtaining protective coatings on large parts, especially for local deposition, is by means of electric-spark alloying (ESA), which is distinguished by a low deposition temperature (<70°C), simple technological operation (the process takes place in air, does not require complicated equipment, and is completed in one stage), and a low power consumption (0.2-0.7 kW). The ESA method consists in forming a composite coating on the basis of refractory compounds and a ceramics by electric erosion of the electrode (anode) material, the interaction of the electric erosion products in liquid-vapor and solid phases with the material of the part (cathode) being machined and elements of the ambient medium in a microbath of melt on the working surface. In vapor phase deposition a coating is formed as a result of the successive deposition of thin layers (1-3 μm) in various combinations: MeC, MeN, MeCN, etc. In ESA a gradient structure of the coating forms as a result of convective mass transfer and thermal diffusion of alloying elements in the pool of melt under high-temperature oxidation.

Various classes of electrode materials are used for ESA: metal alloys as well as hard alloys such as tungsten alloys and tungsten-free alloys based on refractory compounds. Use of tungsten-free hard alloys ensures that the electric-spark coatings have better service characteristics than do WC – Co alloys because of the high wear resistance, corrosion resistance, and high material transfer coefficient [5].

The aim of the work reported here was to study the mechanism of formation as well as the tribotechnical and corrosion properties of coatings obtained by ESA of structural alloys with an electrode material based on TiCN – AlN.
Fig. 1. Microstructure of the material of a TiCN – AlN electrode with FeCr binder. Magnification: 140 (a) and 3140 (b).

Fig. 2. Distribution of Ti and Al (a), Fe (b), and Cr (c) in the structure of the electrode material TiCN – AlN.

Electric-spark alloying was carried out on an Élitron-21 high-frequency apparatus operating in the regime: short-circuit current 0.9 A, current pulse frequency 1240 Hz, and pulse energy 0.08 J. The alloying electrode material used was a hard alloy based on TiCN – AlN with an Fe(Ni) – Cr (30%) binder, which was obtained in the form of 3 × 4 × 35-mm rods by powder metallurgy methods. The electrode material had the following mechanical characteristics: bending strength σb = 780-850 MPa, cracking resistance KIC = 8-9 MPa·m1/2, hardness HRA 87-89, friction coefficient f = 0.22-0.24, porosity <2%, and oxidation temperature ≤1300°C. For the substrate we used VK6 hard alloy (WC – 6% Co) and VT6 titanium alloy (6% Al, 4% V) in the form of 5 × 5 × 2-mm specimens cut by the electric erosion method.

A quantitative analysis of the microstructure of the electrode material was made with an SIAMS hard-and-software complex for materials science analysis of structure images. This system feeds image with a general magnification of more than 3000 into a computer, where they are processed and analyzed.

Tribotechnical tests were carried out in a shaft – bushing setup under dry friction conditions in a pair with heat-treated 65G steel with a specific load of 2 MPa and sliding at speeds of 4 to 16 m/sec. The resistance to high-temperature oxidation in air was studied by differential thermal analysis on a Seteram instrument with the temperature changing to 1200°C at the rate of 20 deg/min. Metallographic analysis, x-ray phase analysis, and electron probe microanalysis were performed on PMT-3, DRON-3 (in CuKα radiation), and Camebax SX-50 instruments, respectively.