Increasing the Wear Resistance of Light Alloys

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Electric spark alloying is an effective method of increasing the wear resistance and changing the physicochemical, mechanical, and operating characteristics of materials in the thin working layers of machine parts [1-3]. The practical applications of this method have been extended considerably due to the development of new highly wear-resistant materials—refractory compounds and cermets based on them [4-5].

However, increasing the wear resistance by using electric spark alloying has so far been limited to machine parts made of iron-carbon alloys and special steels. It is of interest to determine the applicability of this method to increase the wear resistance of light alloys based on aluminum, magnesium, and titanium. In many cases it has proved to be necessary to improve the wearability of machine parts manufactured from these alloys. It has been assumed that because of the high chemical activity of these light alloys electric spark alloying would differ from that observed in coating iron-carbon alloys.

Here we give the results of electric spark alloying of titanium alloys with refractory compounds. The substrates were samples of titanium alloys VT-14 and VT-1. The alloying was conducted in the ÉFI-ELEKTROM apparatus with electrodes of the hard alloy VK2, titanium carbide, tungsten carbide, and boron carbide, as well as titanium boride and zirconium boride. On the basis of preliminary tests, alloying was conducted as a finishing operation; protective coatings up to 30-40 μ thick were obtained.

Figure 1 shows photomicrographs of the cross sections of the substrate coated from electrodes of the hard alloy VK2, tungsten carbide, boron carbide, titanium carbide, titanium boride, and zirconium boride. It can be seen that all the electrode materials studied coat the titanium alloys quite well; the most satisfactory bonds between the substrate and the coating were those produced from titanium boride and the VK2 cermet. It can also be seen that the coatings produced by boron carbide and zirconium boride are less dense and more porous than those from TiB₂ and, especially, VK2.

It was found that the coating applied with the VK2 electrode consists of carbides WC (with a microhardness of 17,000 MN/m²) and W₂C (32,000 MN/m²) and a phase of lower hardness (10,000-15,000 MN/m²) based on both carbide phases. These data are confirmed by the results from other investigations [6, 7].

The coating produced by the boron carbide electrode consisted of two phases—boron carbide (48,500 MN/m²) and a phase based on boron carbide (H₀ = 26,000-29,000 MN/m²).

The coating produced by the zirconium carbide electrode consisted of a hard phase (22,800 MN/m², which corresponds to the hardness of zirconium carbide) and a softer phase (14,600 MN/m²).

The coating produced by the titanium boride electrode consisted of a single refractory compound with a hardness of 33,000 MN/m², while that resulting from the titanium carbide electrode was a phase based on TiC with a hardness of 18,000 MN/m².

Metallographic analysis showed that the coatings on the samples result from the deposition of the electrode material on the substrate and its interaction with the substrate, forming a phase with a lower hardness than that of the original refractory compound.

To determine the wear resistance of the titanium alloys coated with the various refractory compounds we used the well-known method of abrasive wear in the Kh4-B testing apparatus. The abrasive surface was EB-320 abrasive cloth. All tests were made under a specific pressure of 0.955 MN/m² and a friction length of 15 m. The effectiveness of the coatings was determined by the ratio of weight losses from wear of the coated and uncoated titanium alloys. The tests were repeated several times. The results are given in Table 1.

*Deceased.

Fig. 1. Microstructure of titanium alloys coated with different materials (×400). a) VK2; b) WC; c) B₄C; d) TiC; e) TiB₂; f) ZrB₂.

Except for tungsten carbide and the hard alloy VK2, no corrections for the different densities of the materials were made, since the densities of the compounds and the titanium alloys were practically the same.

During the tests we observed extremely high values of relative wear resistance for some samples. For example, these values reached 22 and 44, respectively for coatings produced from titanium and zirconium diborides. This results from the multiphase and special structure of the coatings. It can be seen from the table that the relative wear resistance of the coating is independent of its hardness, which again confirms the assumption that a correlation between relative wear resistance and hardness is observed only in the case of pure metals [4, 9].

The lack of any correlation between hardness and wear resistance is due to many factors, the most important being the dual nature of the abrasive wear resistance of refractory compounds: the resistance to microcutting but breaking off of microvolumes. Carbides of refractory metals, which are highly brittle