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WEARPROOF COMPOSITION COATINGS ON THE BASIS OF SiC-Al_2O_3 FOR RESTORATION AND REIFORCEMENT OF THE COMPONENTS OF AIRCRAFT GROUND SUPPORT EQUIPMENT

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The structure of coatings from composition material that contains the SiC-Al_2O_3 wearproof component and Ni-Al metallic binder, deposited by the method of high velocity air fuel deposition (HVAF) on medium-carbon steel steels has been researched. Tribotechnical descriptions of the deposited coatings under the conditions of friction without lubricating materials in the air environment have been studied and the features and regularities of their wear mechanisms have been determined.

Keywords: *high velocity air fuel spraying, wetting, wear resistance, ceramics, coating.*

Issue content.

The problem of the enhancement of the wear and corrosion resistance of machine parts is of current importance when machinery operates on high-speed loads. Ceramic materials having a high resistance to intensive wear and actions of aggressive media, e.g., ceramic composites based on silicon carbide and aluminum oxide, which not only exhibit high physico-mechanical characteristics, but are also inexpensive and not scarce materials, are promising for these applications. Lifetime of fuel transferring equipment, as we know, is restricted by wear and corrosion resistance of compaction elements. Therefore, these units are of the heaviest loadings. Their contact spot is of dry friction when the mode is dynamic. And when the working mode is steady the contact spot is soaked by the substance to be pumped – fuel and all its available additives and dissolved water.

Latest research and publications review.

Silicon–carbide composite materials may be used both as compact products [1] and as coatings on the surfaces of parts operating in triboconjugation units. The advantage of using ceramic materials as coatings is in the possibility of local application of them on interacting surfaces, which results in an essential saving of these materials. To deposit ceramic powdered composite materials onto steel surfaces by gas–thermal methods, one should add a powdered metal component to the mixture, which must ensure the adhesion bonding of ceramics and a steel substrate and cohesion bonding between the phases of a coating. The metal component should meet the following requirements: a good wetting between the metal and ceramic components (wetting angle ($\Theta \ll 90°$) and absence of the active chemical interaction.

At present the technology of the high–velocity air–fuel deposition (HVAF) of wear–resistant coatings has a wide application. This method differs from the detonation one in smoothness and continuity of the coating deposition process, and, hence, in an inessential dynamic action on the workpiece; and it differs from the plasma method by lower temperature influence on a workpiece and relatively low cost of the equipment [2]. The SiC–Al_2O_3 ceramics, which was previously tried as a compact ceramic material and exhibited high tribotechnical characteristics, was chosen as the wear-resistant component of the composite to deposit HVAF coatings [1]. A nickel-based alloy, which should afford the adhesion of the ceramic component to a steel substrate and high corrosion resistance, was chosen as a metal binder. Pure nickel does not wet ceramics of the $SiC–Al_2O_3$ system (Θ = 116°). To improve the wetting in the ($SiC–Al_2O_3$) system, aluminum, a surface-active element, was added to the nickel melt composition. Small (5–10 wt %) additions of aluminum to nickel contribute to a considerable decrease of wetting angles (to Θ = 67–53°). However, an active chemical interaction takes place between the liquid and solid phases. The optimal metal binder is a nickel melt, containing 15 wt % Al, as in the ($SiC–Al_2O_3$)–(Ni–15%Al) system wetting angles of 20° form and the active chemical interaction that brings about the formation of nickel silicides does not occur. Therefore, to deposit $SiC–Al_2O_3$ silicon–carbide ceramics onto a steel substrate by the HVAF method Ni–15%Al was chosen as the metal component [3].

Research aim.

The aim of the present study was to produce wear–resistant coatings from materials of the (SiC–Al2O3)–(Ni–15Al) system by the HVAF method to be used as interacting surfaces of end gaskets of centrifugal pumps and to test the coatings for wear resistance.

Results and discussion.

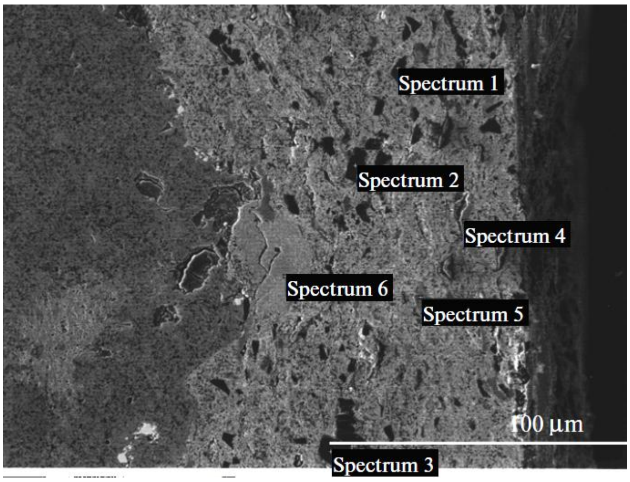
The microstructure of the coating (Fig. 1) is a composite material consisting of a matrix of nickel–aluminum alloy, in which particles of the $SiC–Al_2O_3$ ceramics and individual grains of silicon carbide and aluminum oxide are uniformly distributed (table 1). The presence of individual grains of SiC and Al_2O_3 may be attributed to the fact that in grinding compact ceramics it is likely that a partial separation of carbide and oxide phases takes place. The coating porosity does not exceed 5%, the size of ceramic inclusions changes from 3 to 10 µm.

The volume content of ceramic phases in a coating does not correspond to the initial one, which is explained by technological losses when coatings are deposited. The amount of ceramic components in a composite coating is 12–15% (Figs. 1.).

This was supported also by the X-ray diffraction analysis of the coating, which showed a presence of the SiC, Al_2O_3, and Ni–Al phases in it.

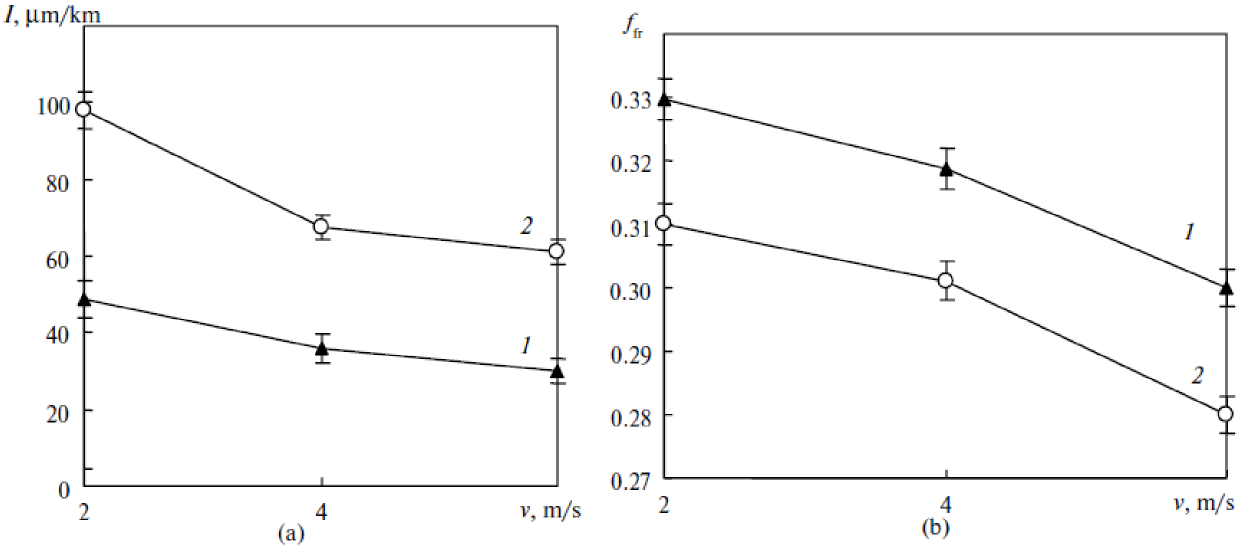
Since ceramic silicon–carbide HVAF coating are designed to be used as working surfaces of end gasket parts of centrifugal pumps, the conditions of tribotechnical tests were chosen in such a way as to simulate the operation conditions of the contact zone of low and medium velocity end gaskets. Tribotechnical tests were conducted according to two schemes: at a constant load of 6 MPa the effect of the gliding velocity was studied, and at the constant velocity of 7 m/s the effect of load on the wear intensity and coefficients of friction was analyzed. Tribotechnical tests of the HVAF composite coatings at a constant load show that as the gliding velocity increases, the wear intensity decreases from 48.9 µm/km at a velocity of 2 m/s to 30 µm/km at a velocity of 7 m/s. These values more than twice exceed the results of steel samples. (Fig. 2) Depending on the gliding velocity, the friction coefficients of coatings vary from 0,33 to 0,30. For steel samples without coatings, lower friction coefficients correspond to higher wear intensity as compared to the samples with a coating. This can b explained by the following: two different classes of materials have been tested, namely steels and composition coatings.

Tests of the samples with coatings at a constant velocity of 7 m/s showed that with increasing load the wear intensity increases from 20.4 µm/km at p = 2 MPa to 30 µm/km at p = 6 MPa



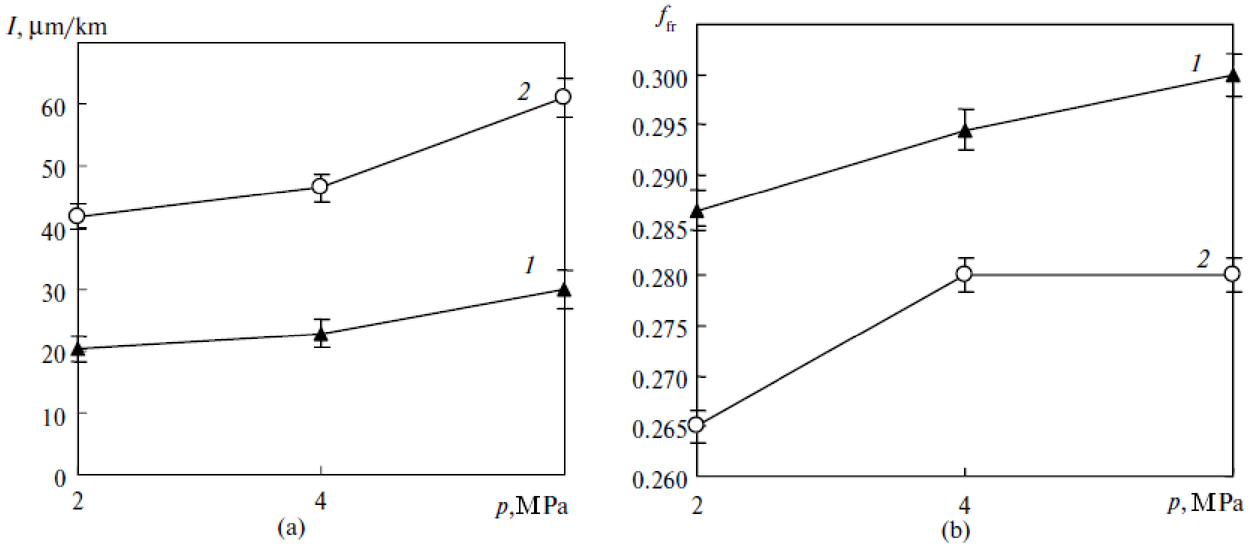
Spectra	C	O	Al	Si	Ni
Spectrum 1	47.53	-	-	52.47	-
Spectrum 2	21.11	23,44	22,45	32.89	
Spectrum 3	16.90	31,14	30,86	20.77	0.33
Spectrum 4	-	54.02	45.98	-	-
Spectrum 5	-	53.03	46,97	-	-
Spectrum 6	7.84	-	20.39	-	71.77
Max	47.53	54.02	46,97	52.47	71.77
Min	7.84	23,44	20.39	20.77	0.33

Fig. 1. Microstructures of HVAF coatings produced from materials of ($SiC–50Al_2O_3$)–50%(Ni–15%Al) system. Regions of X-ray spectrum microanalysis are indicated.



(a) (b)

Fig. 2. Dependence of the wear intensity (a) and friction coefficient (b) on the gliding velocity at a pressure 6 MPa: (*1*) HVAF coating (SiC–Al_2O_3)–(Ni–Al); (*2*) the grade 45 hardened steel.



(a) (b)

Fig. 3. Wear intensity (a) and friction coefficient (b) vs. load at a velocity of 7 m/s: (*1*) a (SiC–Al_2O_3)–(Ni–Al) HVAF coating,(*2*) grade 45 hardened steel.

(Fig. 3). The wear intensity of steel samples increases more sharply from 41.6 µm/km to 61 µm/km as the load increases. In testing at p = 6 MPa, and v = 7 m/s friction coefficients for steel samples are 0.28 and for samples with HVAF coatings 0.30. Thus, at severest testing conditions the wear intensity of samples with coating is half as high as the wear intensity of samples from the grade 45 hardened steel (Fig.3.). The wear intensity of the counterbody in testing does not exceed 10 µm/km.

To explain the results obtained, the friction surfaces of the samples with coatings and samples of hardened steel without coatings were studied on a Camebax SX-50 electron microscopy. The structure of the friction zone of coatings is a rippled surface without essential damages (Fig. 4.). When studied at a high magnification, it is seen (magnification power is ×3000, see Fig. 5.) that the friction surface of coatings is a continuous oxide film of a complex composition containing iron, aluminum, and nickel oxides.

The presence of iron in the oxide film is explained by the fact that in testing the iron at the counterbody surface oxidizes due to the generation

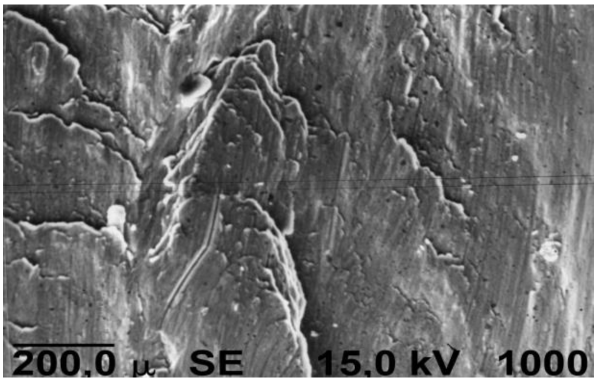


Fig. 4. Microstructure ×1000 of typical regions of the friction surfaces of samples with a HVAF coating.

of high temperatures in local regions of the friction zone and is transferred onto the surface of a composite coating.

This wear mechanism, which was described in Kostetskii work [4], belongs to the oxidizing type and is favorable in terms of wear resistance of the friction pair as the products of interaction act as a solid lubricant. The film formed on the coating surface during the friction contains iron, aluminum, and nickel oxides, exhibits no essential damages, and obviously has a high adhesion to the coating surface (see Fig. 4). The surface film, which consists of oxides with inclusions of ceramics components, increases the friction coefficient only slightly (by ~ 0.02) as compared with that of unoxidized surface of grade 45 hardened steel.

The role of ceramic inclusions of $SiC–Al_2O_3$ in the HVAF coating in the friction in a pair with a steel counterbody is also in a dispersion–hardening of the coating surface layers. The size of ceramic inclusions varies from 3 to 10 μm. On the one hand, they prevent the oxide film from being damaged, and on the other hand, obviously promote an increase of the film adhesion to the coating substrate due to the active interaction of the coating components with oxides.

Figure 6 shows a comparative diagram of tribothechnical characteristics of coatings from the $(SiC–Al_2O_3)–(Ni–Al)$ composition produced by HVAF and from WC–8%Co[2] produced by high_velocity oxygen–fuel (HVOF) spraying [5] and samples from grade 45 hardened steel without coatings.

A coating of a composite material of the $(SiC–Al_2O_3)–(Ni–Al)$ system ranks insignificantly below coatings from the WC–8%Co hard alloy in wear resistance, but it contains lower number of expensive components in its composition. This

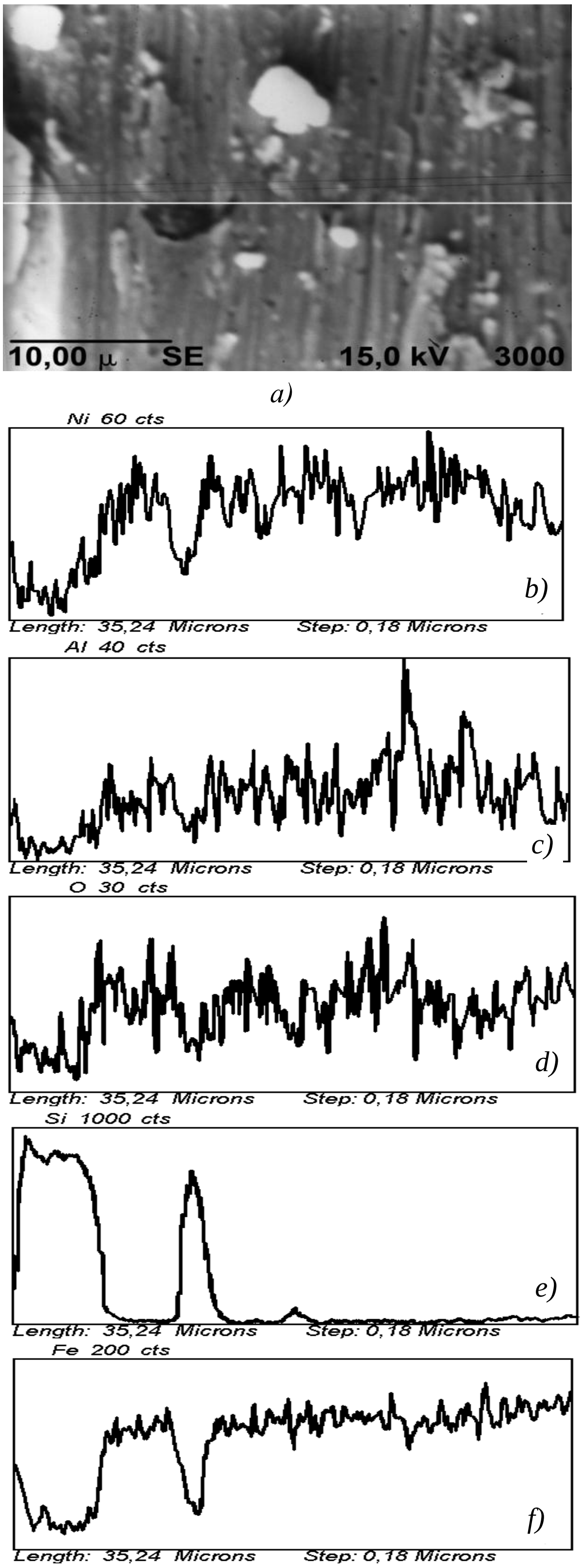


Fig. 5. Microstructure of a friction track region of the HVAF coating (a, ×3000) and a distribution of nickel (b), aluminum (c), oxygen (d), silicon (e) and iron (f) in it.

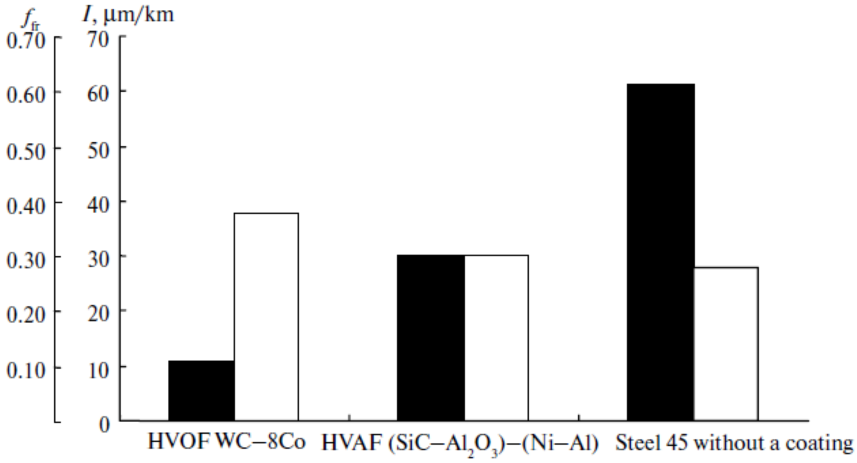


Fig. 6. Wear intensity (□) and friction coefficients (■) of HVOF coatings from WC–8Co hard alloy, HVAF coatings of the (SiC–Al_2O_3)–(Ni–Al) system, and the grade 45 hardened steel without a coating at a gliding velocity of 7 m/s and a pressure of 6 MPa.

composite may be recommended for using as HVAF coatings of working surfaces of end gaskets of centrifugal pumps.

Conclusions.

1. New composite metal–ceramic HVAF coatings of the (SiC–Al_2O_3)–(Ni–Al) system have been produced on steel 100–150 µm in thickness. The structure of these coatings is a metal–ceramic matrix, in which 12–15% SiC–Al_2O_3 refractory compounds are uniformly distributed.

2. The tribothechnical characteristics of the HVAF coatings have been studied in a wide range of the load–velocity parameters. It has been found that under the heaviest testing conditions (p = 6 MPa and v = 7 m/s) the coating wear intensity is 30µm/km, which is twice as much as the wear resistance of steel.

3. The wear mechanisms of HVAF coatings and steel have been established in dry friction in pair with a steel counterbody. It has been shown that high tribothechnical characteristics of HVAF coatings are attributed to the formation of complex films based on iron, nickel, and aluminum oxides during friction, i.e. an oxidizing wear mechanism is realized.

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