

The Wear Resistance of the Nanocomposite Coatings Obtained by the Cumulative- Detonation Device

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Nanocomposite coatings based on Ti, O, C and H were deposited on aluminium samples by using the cumulative-detonation equipment. The nanocomposite coatings were examined by scanning electron microscopy (SEM), transmission electron microscopy (TEM) with diffraction, X-ray phase analysis, hardness measurements and tribotests. It was established that the wear of nanocomposite coatings based on Ti, O, C and H less than to the wear of material of the substrate. For the nanocomposite coating which were formed from the hydrogenated titanium powder was recorded the lowest wear and coefficient of friction.

Keywords: Cumulative-detonation technology, Aluminium alloys, Nanostructured composite coatings, Wear resistance.

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1. INTRODUCTION

One of the priorities of science and technology is the creation of new materials, in particular, multi-, nano-composite coatings with a typical grain size of less than 100 nm [1,2].

One of the new technologies for applying protective coatings, composites and other functions is the cumulative-detonation technology of coatings [3]. For example, to protect from wear and corrosion of aluminum products have a fairly thin layer of composite coatings based on Ti, O, C and H, which does not affect significantly the weight of the structure [4].

Taking into account high physical-mechanical properties of titanium and titanium ability to form stable solid solutions and a series of compounds with different types of chemical bonds with the combustion products, which contain oxygen, nitrogen, hydrogen and carbon, is of interest to the creation and study of multicomponent composite materials based on titanium surface production of light alloys [5]. The combination of such diverse components leads to the formation of a new material whose properties are quantitatively and qualitatively different from the properties of each of its components, and superior to traditional materials for their mechanical properties [6].

The purpose of this study is to investigate of the wear resistance of nanocomposite coatings based on Ti, O, C and H obtained by the cumulative-detonation device.

2. EXPERIMENTAL PROCEDURE

The cumulative-detonation technology has of a pulse character. This makes it possible to form the composite coatings from a small distance (10-60 mm) in a shielding gas atmosphere. As a result, oxidation and losses of spraying materials are reduced.

In this work, coatings were deposited on the surface of samples by the cumulative-detonation device [4]. The

samples of aluminum alloy 1545K of the system Al-Mg-Sc were used as a substrate.

Composite coatings of titanium powder (the results of fragmentation of titanium sponge) were deposited in the environment of the combustion products, which contain oxygen, nitrogen, hydrogen and carbon. Titanium sponge was saturated with hydrogen before the dispersion. Obtained powder filter out and held in a vacuum oven at 900°C for 4 hours.

Four types of powder were used: 1 – titanium (Ti), 2 - hydrogenated titanium (Ti/H), 3 – a mechanical mixture of powders of titanium and boron amorphous (Ti/B), 4 - a hydrogenated mechanical mixture of powders of titanium and boron amorphous (Ti/B/H).

Composite coatings were deposited with a frequency of 20 Hz of the snake with a transverse displacement 4 mm and a three-time repetition. Speed of moving was 3000 mm/min, distance from the sample - 65-70 mm. The powders of Ti and Ti/H are sprayed by a two-chamber device with an output nozzle of 16 mm. Powders from a mechanical mixture of Ti/B and Ti/B/H were deposited on a single chamber device with an output nozzle of 20 mm.

Examinations of microstructure and elemental composition of the titanium powders and the nanocomposite coatings based on Ti, O, C, and H were carried out by using electron ion microscope Quanta equipped with integrated microanalysis system Pegasus 2000. Local phase and diffraction analysis of the titanium powder and the nanocomposite coatings was conducted by using transmission electron field emission microscope Tecnai G2 20F S-T (FEI) with microdiffraction and X-ray powder diffractometer ARL X'TRA. Measuring of microhardness of samples was done with automatic micro-hardness tester DM – 8B (Affri) by Vickers's test with load on indenter 0.05 N. Studies of wear resistance of composite coatings was carried out by tribometer methods using an automated machine friction (Tribometer, CSM Instruments, Switzerland) by a

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standard method of test "disk a ball" on the air at a load of 10 N, the linear velocity was 15 cm/sec, the radius of curvature of the wear - 6.7 mm, sliding distance - 1000 meters. As a result of the tests evaluated the wear factor of the sample and the statistical partner (Al_2O_3 ball with diameter 6 mm).

Investigations of the wear tracks on the surface of the coatings and spots of wear of surface balls were studied using an optical inverted microscope Olympus GX 51. Measurement of the average cross-sectional area and depth of the friction track was performed in four diametrically opposite and orthogonal to the areas of samples by an automated high-precision contact profilometer Surtronic 25. Quantitative evaluation of wear resistance of samples and counterbody was carried out by a wear factor [7], the method of calculation is given in the work [8].

3. RESULTS AND DISCUSSION

3.1 Characterization of nanocomposite coatings

The study of the microstructure and elemental composition of the transverse sections of samples with composite coatings showed that were obtained uniform coatings with thickness of 70 – 200 microns and good adhesion to the substrate, the bulk of the coating material is deformed and tightly packed (see. Fig. 1). Porosity of the coatings was determined by metallographic method was 2-5%.

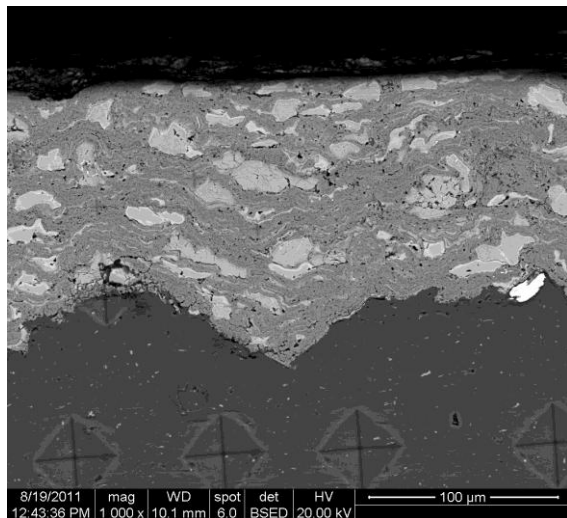


Fig. 1 – SEM image of cross section of the nanocomposite Ti/H coating layer and substrate

Table 1 – Tribological characteristics of nanocomposite coatings based on Ti, O, C and H

sample	The coefficient of friction (μ)		The wear factor, $\text{mm}^3 \cdot \text{N}^{-1} \cdot \text{m}^{-1}$	
	initial	test	counterbody ($\times 10^{-6}$)	sample ($\times 10^{-4}$)
Aluminium	0.126	0.480	0	14.445
Ti	0.226	0.855	5.937	2.305
Ti/B/H	0.127	0.808	3.95	1.201
Ti/H	0.174	0.868	1.486	0.364
Ti/B	0.149	0.846	5.254	1.239

Furthermore, it was established that the hardness of nanocomposite coatings is $1015 \pm 250 \text{ HV}_{0.05}$, which is 15 times higher than the hardness of the substrate material $85 \pm 5 \text{ HV}_{0.05}$.

Local phase and structure analysis of the composite coatings based on Ti, O, C and H showed that lamellas in the coatings consisted of the mixture of titanium nanocrystalline grains with face-centered close-packed lattice and amorphous phases, and nanoamorphous oxide of titanium. This structure could be caused by a high-temperature cycle in formation of composite coatings [9,10].

Carried out phase analysis showed that the main phase of the coating layer was Ti with a face-centered close-packed lattice. The calculated interplanar distances reflections suggest the presence in the coatings and the following phases: TiO, rutile TiO_2 , anatase TiO_2 , Ti_2O_3 . In the nanocomposite coatings formed from the hydrogenated powder, recorded the presence of $\delta\text{-TiH}$ phase and TiH_2 . The studies did not report the presence of boron in the coatings. Apparently this is due to the fact that micron particles of amorphous boron overheat and evaporate in the environment of the combustion products.

3.2 Study of the wear resistance of the nanocomposite coatings

Results of the study of wear resistance of the nanocomposite coatings are shown in Fig. 2 and Table 1.

It is known that the increased wear of alloys containing reactive titanium, associated with sticking of the wear products on the surface of the ball, which leads to a change in the geometry of the contact (the contact area decreases) and the properties of the counterbody (the formation of intermetallic compounds such as TiAl, having a high Young's modulus), which eventually leads to a sharp increase in contact stresses [11].

The analysis of wear tracks uncoated samples shows that they are intensively wear, and thus the transfer of recorded material on the counterbody (see. Fig 2).

Microphotographs the friction surface of samples (see. Fig. 2) shows that wear of the nanocomposite coatings is characterized by wear of directional plastic deformation without any visible signs of seizure. It was found that friction surfaces are longitudinal contact sites oriented in the direction of sliding and do not experience significant damage and changes.

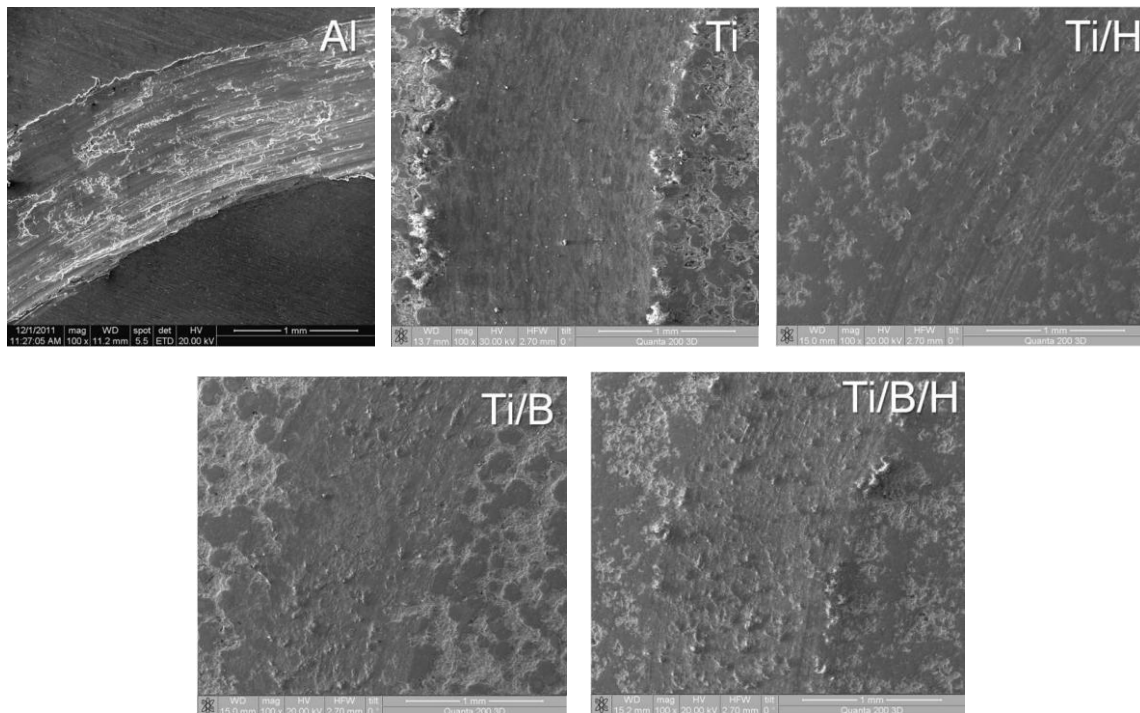


Fig. 2 – Wear tracks on the surface of the samples after tribotests

4. CONCLUSIONS

Cumulative-detonation technology provides formation of dense composite coatings based on Ti, O, C, H thickness of 70-200 microns with hardness of $1015 \pm 250 \text{ HV}_{0.05}$. The porosity of coatings was $\sim 2\text{-}5\%$, which correlates with the technological requirements of industrial coatings. The apparent limit of adhesion of the coating to the substrate is free of defects. It was established that the wear of nanocomposite coatings based on Ti, O, C and H less than to the wear of material of the substrate - aluminum alloy 1545K and titanium alloy mark Rematitan (Ti 99.5% by mass) [11]. For the nanocomposite coating which were formed from the hydro-

genated titanium powder was recorded the lowest wear and coefficient of friction.

Based on the results of the study could be offered energy-saving technology for deposition of wear resistance nanocomposite coatings based on Ti, O, C, H on substrates of aluminum alloy.

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