TRIBOLOGICAL PROPERTIES OF DETONATION COATINGS BASED ON TITANIUM ALUMINIDES AND ALUMINUM TITANATE


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Operation of coatings based on tialite, $\gamma$-TiAl, titanium aluminides with discrete inclusions of TiN and also alloys based on cobalt, nickel, and titanium in friction pairs with polyethylene grade “Chirulen” and stainless steel 12Kh18N10T is studied. It is established that tialite coatings formed from nanostructure powders of Ti – Al by detonation deposition are the best for operation under dry friction conditions in a pair with stainless steel 12Kh18N10T (minimum friction coefficient and minimum wear of the contact surfaces). It is shown that in the sliding rate range selected effective operation of material in friction pairs with polymer is provided due to transfer it to the contact surface and formation between rubbing surfaces of a thin film fulfilling the function of a solid lubricant. It is established that stable operation with the minimum wear in a friction pair with polyethylene grade “Chirulen” is provided by a coating of $\gamma$-TiAl and Al$_2$TiO$_5$, and also coatings based on titanium aluminide with fine TiN inclusions.

Keywords: tribological properties, wear-resistant coating, tialite, gamma-aluminum-titanium alloy, structure.

INTRODUCTION

It is well known that titanium and its alloys during operation in friction pairs with metals are inclined towards marked adhesive interaction accompanied by seizure of the friction surface. One of the most effective means of protecting articles made from titanium and its alloys from wear during sliding friction without a lubricant and under limited lubrication conditions is deposition of wear-resistant coatings. As is well known the affinity of the chemical composition of the base and the coating in many cases creates good conditions for strong adhesion between them, i.e. one of the most important conditions for high operating efficiency of articles. In this connection development of titanium-containing wear-resistant coatings for articles of aerospace technology prepared from titanium alloys is important and promising for the future. Favorable results are also possible with the use of coatings in medicine. Titanium alloys are biocompatible and corrosion-resistant materials [1]. However, their use for medical objects, in particular for hip or knee joint prostheses is not sufficiently effective due to low wear resistance.

It has been shown previously [2] that use of different types of powder of the same chemical composition (Ti – 50 at.% Al) and variation of their interaction with a working gas medium during detonation deposition makes it possible to form coatings fundamentally different in phase composition and structure. It has been established that from mechanically alloyed nano-composite powder Ti – 50 at.% Al with oxidation reaction with the working gas atmosphere it is possible to form a coating based on Al$_2$TiO$_5$ on atomized powder, and with a nitriding reaction it is possible to form a coating based on titanium aluminides with fine TiN inclusions. With use of cast microstructural powder $\gamma$-TiAl its phase composition is inherited by the coating [2, 3].
The aim of this work is to accomplish comparative evaluation of the tribological properties of coatings deposited by the detonation-gas method from powders of Ti – 50 at.% Al of different types with different regimes. Among the advantages of the detonation method one should note the possibility of forming coatings with the minimum porosity that in many cases (for example in corrosive atmospheres) is a required condition for their successful operation.

**EXPERIMENTAL PART**

Coatings were deposited on a substrate of titanium alloy VT16 (1.6-3.8% Al, 4.0-4.5 V, 4.5-5.0% Mo) by means of a detonation-gas device “Dnepr-5MA” developed at the Institute for Problems of Materials Science, National Academy of Sciences of Ukraine (IPM NANU). The following coatings were deposited: A) with a structure of gamma-titanium aluminide; T) with a structure mainly aluminum titanate (tialite) Al$_2$TiO$_5$; N) with a structure in the form of a matrix of titanium aluminides with fine TiN inclusions. Coating formation conditions have been described in [2].

We have studied the tribological properties of both the coatings A, T, and N obtained, and also alloys “Ceradent” based on cobalt (25% Cr, 7-9% Ni, 6% Mo, balance Co) and “Wiron99” based on nickel (20% Cr, 6% Mo, balance Ni), and also titanium alloy VT6. The data obtained for the alloys were compared with the results of the coatings studied. We note that alloys based on cobalt and titanium similar to those in question are used both in medicine (for implants [4]) and also in aeroengine construction [5].

Alloys based on cobalt and nickel have undergone all the required technical and clinical tests, and they are used successfully in preparing dental prostheses faced with ceramics, composites and plastics, and also in other constructions for medical purposes. The wear resistance of alloy “Ceradent” has been studied in a friction pair with ultrahigh molecular polyethylene grade “Chirulen” from the firm “Hoechst” AG (Germany) with a sliding rate of 0.1 m/sec in physiological solution. It has been established [6] that the wear resistance of “Ceradent” is comparable with the wear resistance of aluminum oxide ceramics. Nonetheless, over an extensive range of rates and loads the tribological properties of these alloys have not been studied sufficiently. In our work apart from polyethylene “Chirulen” as the counterbody in friction pairs we used stainless steel 12Kh18N10T applied in engineering [5, 7].

Tribological tests were carried with end friction of a cylindrical specimen ($h = 20$ mm, $d = 10$ mm) over a circular counterbody. The sliding rate was varied from 0.18 to 0.76 m/sec for the polymer counterbody and from 0.27 to 1.12 m/sec for the steel counterbody. In all cases tests were performed without a lubricant with load $P = 3.12$ MPa for 10 min. Optical microscopy was carried out in a “Jenaphot-2000” (Germany) instrument.

**RESULTS AND DISCUSSION**

A study of the structure for the coating – base interface by optical microscopy points to the high quality of coatings applied on all substrates (Fig. 1). Absence of discontinuities at the boundary between the metal base and coatings, coarse pores, and cavities in the coating structure point to the high quality of deposition. These structures are favorable for providing the required level of coating mechanical properties, including tribological properties. However, we note even with this high general evaluation coating T appears to be the most uniform having a structure with uniformly distributed very fine pores. These coating structural features are a consequence of use for its deposition of mechanically alloyed conglomerated nano-structural powders of the system Ti – Al [2, 8]. Coating A was deposited...