PROPERTIES OF TiN AND CrN CATHODIC ARC COATINGS ON Ti-6Al-4V ALLOY

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Tribological properties of TiN and CrN coatings deposited by cathodic arc method at three different bias potentials -50, -150 and -300V on Ti-6Al-4V alloy in pair with alumina have been investigated. The wear rate of the coatings is more than an order of magnitude lower than for the titanium alloy substrate. The friction coefficient is in the range of 0.4-0.8 for TiN coatings and 0.5 for CrN coatings. Coatings deposited at a potential of -50 V show optimal tribological properties.

Keywords: titanium alloy, coatings, cathodic arc deposition, wear resistance

Introduction. One of the main factors determining the energy efficiency of nuclear and thermal power plants is the reliability of the steam turbine unit (STU) [1]. Ion-plasma surface modification and the use of protective coatings with high wear resistance can improve the reliability and longevity of titanium alloy components and extend the time between turbine overhauls. The high protective properties of TiN coatings deposited at elevated nitrogen pressure of 1...3 Pa allowed the selection of conditions for the synthesis of the optimal coating for the strengthening of steam turbine blades made of Ti-6Al-4V alloy [2]. The tribological properties of TiN and CrN coatings deposited by cathodic arc deposition have been extensively studied [3, 4]. However, for specific technical applications of protective coatings, it is necessary to determine the influence of deposition process parameters on the wear resistance of the substrate-coating pair [5]. One of the most important parameters in the cathodic arc coating process is the bias potential, which determines the energy of the deposited ions. The ion energy determines the structure and properties of the coatings.

The aim of this work is to investigate the effect of deposition process parameters (bias potential) of protective nitride coatings TiN and CrN on the tribological properties of Ti–6Al–4V alloy.

Experimental. Using a Bulat-type apparatus, the schematic of which is shown in Fig. 1, and two metal plasma sources, coatings were deposited on titanium alloy samples at a distance of 300 mm from the cathode. The cathodes were made of pure titanium (99.9%) and chromium (99.9%). The current of the vacuum arc discharge was 85 A for each cathode. Negative bias potentials (U_b) of -50, -150 and -300 V were applied to the samples. The initial pressure in the vacuum chamber was 2×10^{-3} Pa. The nitrogen pressure during the deposition of TiN and CrN coatings was 2 Pa. The thickness of the deposited coatings was 13-15 μm.

The coatings were analysed by X-ray diffraction using a DRON-4-07 diffractometer with Cu-Kα radiation and a nickel selective absorption filter. The phase analysis of the samples and the determination of the crystal lattice parameters for the identified phases were performed using the Rietveld method. In addition, the size (d) of the crystallites in the coatings was calculated using the Scherrer formula.

Coatings microhardness was measured using a PMT-3 microhardness tester with a Vickers diamond pyramid at 1 N load.

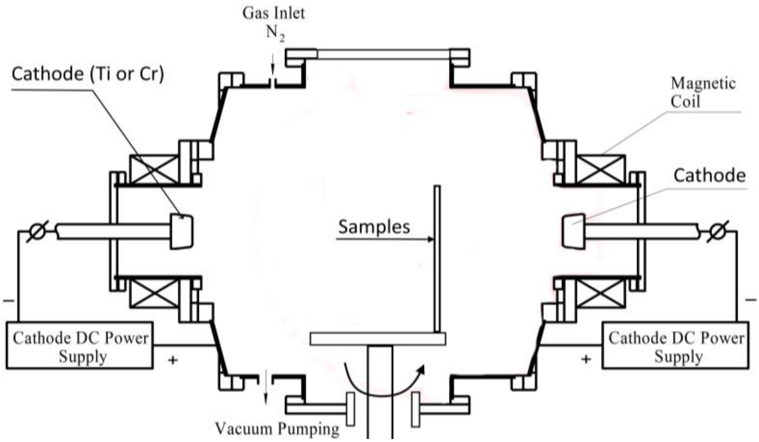

Fig. 1. Scheme of the Bulat 6 type apparatus.

The wear tests were carried out using a reciprocating device consisting of a pair of coated plates (dimensions 20 x 36 x 3 mm) and a 10 mm diameter ball of alumina with a hardness of 19 GPa. The friction coefficient was determined at a temperature of 20°C for 30 minutes using a force of 2 N to press the ball against the sample. The wear of the coatings was evaluated using the "Calibre C-265" profilograph-profilometer to measure the area S of the wear track profile.

Results and discussion. The TiN and CrN coatings deposited on the titanium alloy had a golden and gray color, typical of the cathodic arc deposition method. According to X-ray diffraction analysis of the Ti-6Al-4V alloy sample, the lines of two titanium polymorphic modifications, α-Ti and β-Ti, are observed. The diffractograms of Ti-6Al-4V samples with TiN coatings deposited on their surface have two very strong, rather narrow coating lines: reflections (111) and (222) of cubic TiN nitride (NaCl structural type). The other lines of this phase are absent, which is explained by the formation of a strong axial-type texture in the coating with the axis [111] normal directed to the surface. In chromium nitride coatings, only cubic chromium nitride CrN with a strong (111) orientation texture was detected, regardless of the bias potential.

The mechanical properties (microhardness, friction coefficient and wear rate) of initial alloy and coatings are presented in Table 1.

Table 1. Mechanical properties of the samples

Materials and coatings	U_b, V	H, GPa	Friction coefficient, μ	Wear rate, mm^3/Nm
Ti6Al4V	-	3.5	0.55	6.32×10^{-4}
TiN	-50	30	0.5-0.8	8.61×10^{-6}
	-150	26	0.4-0.8	2.73×10^{-5}
	-300	33	0.4-0.7	2.83×10^{-5}
CrN	-50	21.4	0.5	1.43×10^{-5}
	-150	26.5	0.3-0.5	1.85×10^{-5}
	-300	26.6	0.4-0.5	1.58×10^{-5}

The initial titanium alloy's microhardness is 3.5 GPa, and the friction coefficient remains constant at 0.55 throughout the entire test period. This value is very close to the literature values μ = 0.55-0.6 for the Ti-6Al-4V alloy – aluminum oxide pair at a load of 2 N [6]. The wear rate for the alloy in the initial state is 6.32×10^{-4} mm^3/Nm and the depth of the friction track reaches a maximum of 10 μm.

TiN coatings have a high microhardness of 26-33 GPa. Titanium alloy with TiN coatings exhibits coefficients μ in the range of 0.4-0.8. Depending on the bias potential, a slight decrease in the coefficient μ for the TiN coatings is observed: at a potential of -50 V it is 0.5-0.8 and at a potential of -300 V it is 0.4-0.7. The wear rate of the TiN coatings is more than an order of magnitude lower than for the initial alloy (Table 1). The minimum wear rate 8.61×10^{-6} mm^3/Nm is observed for coatings deposited at a bias potential of -50 V. Increasing the bias potential (-150 and -300 V) leads to an increase in the wear rate, which is 2.73-2.83×10^{-5} mm^3/Nm.

Titanium alloy with CrN coatings shows a similar trend of change in mechanical and tribological properties as a function of bias potential (Table 1). The microhardness of CrN coatings increases with increasing bias potential from 21.4 to 26.6 GPa. The friction coefficient is 0.3-0.5 and is slightly dependent on the bias potential. The CrN coatings deposited at a bias potential of -50 V exhibit the lowest wear rate (1.43×10^{-5} mm^3/Nm). Increasing the bias potential (-300 V) results in a slight increase in the wear rate to 1.58×10^{-5} mm^3/Nm.

Conclusions. Titanium nitride and chromium nitride coatings have been deposited on Ti-6Al-4V alloy by cathodic arc method at three different bias potentials -50, -150 and -300V.

X-ray structural analysis shows that single-phase textured cubic nitrides TiN and CrN are formed in these coatings at bias potentials of -50 to -300 V. TiN and CrN coatings have high microhardnesses of 26-33 and 21.4-26.6 GPa, respectively. As the bias potential increases, the microhardness of the coatings increases. Studies of the tribological properties of the substrate and coatings at room temperature in pair with alumina ball have shown that:

- for Ti-6Al-4V alloy, the friction coefficient is 0.55 and the wear rate is 6.32×10^{-4} mm^3/Nm;
- TiN and CrN coatings deposited at a bias potential of -50 V show the lowest wear rate of 8.61×10^{-6} mm^3/Nm and 1.43×10^{-5} mm^3/Nm, respectively. The friction coefficient is in the range of 0.4…0.8 for TiN coatings and 0.5 for CrN coatings.

The results obtained indicate the promising use of TiN and CrN coatings to increase the wear resistance of Ti-6Al-4V alloy.

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