Influence of Low-Temperature Nitriding Parameters on Phase-Structure Composition of Modified Layers of Titanium Alloys

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Abstract – The influence of parameters of low-temperature nitriding in plasma of non-self-sustained low-pressure arc discharge on phase-structure of modified layers of titanium alloys VT6 (Ti–6Al–4V) and VT16 (Ti–3Al–4.5V–5Mo) was investigated. The dependence of wear rate of surfaces vs. structure of nitried layers was determined.

1. Introduction

Wide usage of titanium alloys is caused by their unique physical and chemical properties. The main disadvantage of titanium alloys is poor tribo-technical characteristics and high tendency to contact seizure at friction [1]. There are a lot of methods of improving of friction resistance of titanium alloys. One of the widely used is plasma-vapor deposition of functional coatings. But usage of this method takes to solve additional tasks one of them is problem of adhesion between coating and substrate. Thus, the usage of methods of surface hardening by diffusion saturation of surface and near-surface layers of materials seems to be perspective. As diffusing materials the following materials an oxygen, boron, carbon and nitrogen can be used.

Nitriding is a one of the most effective methods of treatment that improves hardness, wear- and corrosion resistance [2]. The performing the nitriding process in plasma of non-selfsustained low-pressure arc discharge allows to reduce time and temperature of process, to exclude deformation of parts, to save high clearance of surface.

In the current work results of investigations of dependence of nitriding time on changes of structure and properties of surface and near-surface layers of titanium alloys VT6 (Ti–6Al–4V) and VT16 (Ti–3Al–4.5V–5Mo) are presented.

2. Materials and methods

Nitriding process was done on ion-plasma installation (type of NNV-6.6-I1) in plasma of non-selfsustained low-pressure arc discharge [3]. Titanium alloys VT6 (Ti–6Al–4V) and VT16 (Ti–3Al–4.5V–5Mo) in coarse grain state were chosen as investigated materials. Nitriding was performing in gaseous mixture (40% Ar – 60% N2) at temperature 420 °C and different time of process (20, 40, and 120 min).

Surface microhardness was measured by automatic microhardness tester DM-8В (Affri) with load 0.1 N on GOST 9450-76 [4]. Surface morphology before and after nitriding was investigated with usage of scanning electron microscopy Quanta 600 FEG (zoom range from 1000× to 160 000×).

The surface roughness was controlled with usage of contact profilometer SURTRONIC before and after treatment [5]. Estimation of surface roughness was done on arithmetic mean deviation of the roughness profile. In addition measurements of cross section of wear track of samples after tribological tests were also performed with contact profilometer in five areas on three points. Using these data the average value of cross-section area was calculated.

Analysis of wear spot on static partner (ball) was done with usage of optical microscope Olympus GX 71.

Wear resistance test were performed on High-temperature Tribometer (CSM Instruments) on ball-on-disk scheme in conditions of dry friction. The load was 2 N and the velocity of sample rotation was 0.1 m/s. The static partner was ball of steel 100Cr6 with diameter 6 mm. Wear tests corresponds to international standards ASTM G99-959, DIN50324 [6]. During tests a friction coefficient and friction force of interacting surfaces were measured. After tests estimations of wear-rate of sample and static partner were done.

3. Experimental results and discussion

The investigations have shown that time of low-temperature nitriding considerably influences on changes of structure and properties of surface and near-surface layers of titanium alloys.

It was found that nitriding of titanium alloy VT6 during 20 min leads to increasing of surface microhardness in 2 times (Fig. 1).

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Fig. 1. Histogram of distribution of surface microhardness of titanium alloy VT6 after nitriding at different process times: 1 – initial state, 2 – 20, 3 – 40, and 4 – 120 min

Fig. 2. Surface morphology of titanium alloy VT6 after low-temperature nitriding during a – 20, b – 40, and c – 120 min. Scanning electron microscopy, ×80 000

Fig. 3. Histogram of changes of wear-factor of titanium alloy VT6 after nitriding at different process times: 1 – initial state, 2 – 20, 3 – 40, and 4 – 120 min

Insignificant increasing of surface microhardness of titanium alloy VT16 can be explained by the fact that the presence of alloying elements Al, V, Mo in alloy VT16 causes low velocity of nitrogen diffusion [8].

Investigations of surface morphology have shown that a layer of highly dispersed particles with globular shape forms on the surface (Fig. 2, a). Particles have size in range from 20 to 100 nm. Probably particles are nitrides of titanium.

Increasing time of nitriding up to 40 min don’t lead to further rise of surface microhardness. But the change of shape and character of nano-particles distribution is observed (Fig. 2, b).

After nitriding during 120 min the surface microhardness slightly decreases (Fig. 1) comparing with nitriding during 20 and 40 min.

Wear tests have shown following. After nitriding during 20 min the wear resistance of surface decreases comparing with a surface without treatment (Fig. 3).

Increasing of nitriding time leads to decreasing of wear-factor that indicates on decreasing of wear rate. This result can be explained by several factors. The nitried layer and layer of highly dispersed particles have formed at the beginning of treatment. So they have obstructed further diffusion of nitrogen into bulk of material. It has led to decreasing of thickness of diffusion layer.

At friction the thin nitried layer fails and products of wear play role of an abrasive material. Increasing time of nitriding leads to formation of more elongated layers. These layers are less exposed to failure so the decreasing of wear-factor occurs.

Investigations of surface morphology of titanium alloy VT16 also have detected formation of layer of highly dispersed particles on surface of samples (Fig. 4).

Similarly of character of distribution of nano-particles on the surface of titanium alloy VT6 the increasing of time of nitriding leads to changing of amount and shape of nano-particles on the surface of titanium alloy VT16. At the same time the surface microhardness practically had not changed with increasing of process time (Fig. 5).

Insignificant increasing of surface microhardness of titanium alloy VT16 can be explained by the fact that the presence of alloying elements Al, V, Mo in alloy VT16 causes low velocity of nitrogen diffusion [8].
Formation of layer of highly dispersed particles on surface in the aggregate with low temperature of nitriding is also constraining the velocity of nitrogen diffusion. As the result of these limitations under nitried layer the diffusion layer of small depth was formed. The small depth of the layer doesn’t allow possibility of measuring of changes of surface microhardness by method of microindentation. Nevertheless wear resistance of titanium alloy VT16 increases after nitriding (Fig. 6).

4. Conclusion
The performed experiments have shown the possibility of low-temperature nitriding (< 420 °C) of titanium alloys VT6 and VT16 in plasma of non-selfsustained low-pressure arc discharge.

It was found that low-temperature nitriding allows increasing surface microhardness of titanium alloy VT6 in 2 times. The surface microhardness of titanium alloy VT16 has changed insignificantly.

Formation on the surface of titanium alloys the layer of highly dispersed particles of titanium nitride has caused significant influence on character of surface wear in conditions of dry friction on ball-on-disk scheme.

References
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