The influence of process effects of argon plasma on the elements distribution in the surface layer of VT16 titanium alloy during vacuum ion-plasma treatment

To cite this article: L M Petrov et al 2018 J. Phys.: Conf. Ser. 1121 012023

View the article online for updates and enhancements.
The influence of process effects of argon plasma on the elements distribution in the surface layer of VT16 titanium alloy during vacuum ion-plasma treatment

L M Petrov¹, K V Grigorovich², G S Sprygin², S B Ivanchuk¹, A N Smirnova¹ and V D Semionov¹

¹ Joint Stock Company “National Institute of Aviation Technologies”, 24 Petrovka, Moscow, Russia
² Federal State Budgetary Scientific Institution “Institute of Metallurgy and Materials Science named after A. A. Baykov”, Russian Academy of Sciences, 49 Leninskiy Prospect, Moscow, Russia

E-mail: info@niat.ru, grigorovichkv@gmail.com

Abstract. The influence of process effects of electron and ion streams of argon plasma on the elements distribution in the surface layer of VT16 alloy has been investigated. It has been shown that the interaction of plasma stream elements with the surface under treatment serves to generate processes of back diffusion of the substrate elements to the surface thus changing the distribution of elements in the surface layer.

1. Introduction
The surface of parts manufactured from structural metal materials share a series of structural features residing in the fact that atoms of the surface have free physical interconnections, which form structural instability, chemical superactivity and adsorption capability of the surface to atoms of the environment elements with the resulting change in physical and chemical properties not only in the surface, but also in the surface layer of parts during their manufacture. The surface layer of structural metal materials differs from the basic material primarily by conditions of the previous treatment (metallurgical, heat treatment, machining, chemical, etc.) that determines formation of its physical and chemical and mechanical properties, defectiveness and residual surface stresses [1].

Manufacturing parts of structural metal materials including those made of titanium alloys, as a rule, is associated with the use of process effects implemented by different methods of surface treatment. The tooling interaction with the surface under treatment has a complex nature, which affects formation of the changed surface and subsurface structures having different defects and lattice disturbances of the initial structure of metal. Such structural changes in the surface layer condition require its thorough cleaning and surface activation to eliminate defects and lattice disturbances.

Depending on the type of surface treatment various structural changes occur in the surface and the surface layer, namely, change in the energy state evaluated by the value of the reduced surface potential, variation in the surface layer hardness as well as change of the chemical composition in depth of the surface being treated.
The greatest changes in the chemical composition of the surface layer are observed during edge cutting machining. The implemented tool/processing effects generate surface strain-and-shear processes promoting elimination of the initial surface and formation of a new surface layer with a new level of structures and properties. In this case the process effects may be repeated, which causes further changes in properties and chemical composition of the surface layer [2]. The range of values for surface energy properties may vary according to intensity of surface treatment processes that are due to structure heterogeneity of the surface layer.

Processing effects of the Ar plasma on the surface under treatment are related to the processes of heating and etching of the surface layer. During vacuum ion-plasma treatment surface cleaning and activation are performed employing modes of electron heating (processing with Ar plasma electron stream) and non-self-maintained gas discharge (processing with Ar plasma ion stream). Here we observe an insignificant surface layer hardening depending on the action mode of gas plasma stream.

Investigation of the layer-to-layer chemical composition by depth of the generated layer allowed us to establish its variations both at the surface itself and in the undersurface layer (figures 1–2).

![Mass, %](image1)

Figure 1. The influence of the process effect of Ar plasma on the element composition distribution of VT16 titanium alloy in the subsurface layer, depth = 0.5 μm (Al×10, Si×5, Mo×5) formed during edge cutting machining: (a) – electron stream (U_{ref} = +65V, 30 min, T = 400–450 °C); (b) – ion stream (U_{ref} = –500V, 30 min, T = 400–450 °C).

The interaction processes of gas plasma elements with the surface accomplished in the surface layers serve to activate adsorption-diffusion processes. In this case layers with depth to 0.5 μm are enriched with carbon, silicon and nitrogen, and concentration of titanium in the surface layer is reduced and that is likely associated with the presence of defects in this layer, which favours forming specific distribution and concentration relation in the chemical composition of the alloy within the given micro-area.

In the macro-area to a layer depth of 8 μm we observed equalization of the element chemical composition and its further stabilization to values corresponding to standard values for the given alloy [3].

The study of the influence of process effects of Ar plasma stream on the elements distribution in the VT16 alloy chemical composition in the generated surface layer made it possible to establish the influence of the operation modes on elements distribution in the produced surface, figure 1–2.

Processing with the argon plasma electron stream served to increase C and N concentration in the surface layer at a depth of 1 μm and to reduce concentration of Ti in the narrow range at a depth to 0.25 μm, figure 1. The ion stream of argon plasma served to raise C and N concentration to a depth of 2 μm and to lower Ti concentration to a depth of 0.15 μm, figure 2.
Figure 2. The influence of the process effect of Ar plasma on the element composition distribution of VT16 titanium alloy in the subsurface layer, depth – 0.5 μm (Al×10, Si×5, Mo×5) formed during edge cutting machining and vibro abrasive strengthening: (a) – electron stream (Uref = +65V, 30 min, T = 400–450 °C); (b) – ion stream (Uref = −500V, 30 min, T = 400–450 °C).

Processing with the electron stream within 5 minutes results in heating of the processed part to 400 °C; here we see an increase in the value of the reduced surface potential (Vp) to the positive side. Such variation in the value of the reduced surface potential points to removal of the oxide with adsorption substances from the surface, and it characterizes effectiveness of the electron stream action. As a result of this processing, heating of the surface layer causes a significant increase of the surface hardness in the load range from 0.1H to 0.5H and its stabilization in the load area from 0.5H to 10H.

The ion plasma processing mode also provides heating of the surface to 400 °C, however, the increase in hardness and its change is observed in the load area to 3H, which shows considerable changes in the surface layer. The process effect of tools during edge cutting machining of the surface layer of VT16 titanium alloy does not virtually lead to the change in its hardness. There is no surface strengthening zone, but in the area of loads to 3H we observe a slight decline of hardness that is likely to be associated with the formed structural defectiveness being the result of strain-and-shear surface processes. The load area from 2H to 10H is characterized by stability of hardness values typical of the three-dimensional initial structure of material under investigation.

Thus the distribution of interstitial elements in depth of the surface layer according to the modes of gas plasma stream effect results in formation of interstitial solid solutions with different depth and concentration as well as a change in the nature of hardness growth in the micro-area.

Acknowledgement
The study has been conducted under the program of Presidium of the Russian Academy of Sciences No.55 “The Arctic Region – Scientific Basis of New Technologies for Exploration, Maintenance and Development” for 2018 (Government task number 007-00129-18-00).

References
[1] Sulima A I, Shulov V A and Yagodkin Yu D 1988 The Surface Layer and Operational Properties of Machine Parts (Moscow: Machinostroenie) 240 p
[2] Iliyin A A, Plikhunov V V, Petrov L M, Ivanchuk S B, Karpov V N and Fyodorova T V 2006 Aviation Industry 4 23–6
[3] Plikhunov V V, Petrov L M, Ivanchuk S B, Spektor V S, Sarychev S M and Smirnova A N 2009 International Conference “Titanium-2009 in CIS” (Odessa, May 17–20) pp 348–52