HARDENING OF THE SURFACE LAYERS BY TITANIUM WITH COMBINED TREATMENT

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Surface alloying of metals and alloys using concentrated energy flux (KPI) leads to a significant increase in functional properties: hardness, wear resistance, heat resistance and other benefits. This applies to hardening of titanium alloys, which have low wear resistance, high tendency to stick, and a large friction coefficient with virtually all materials [1, 2].

Among the methods of hardening treatment – laser, electron beam, and plasma alloying, in particular, electroexplosive alloying. Electroexplosive alloying (EEA) feature is that any conductive material – pure metal or an alloy, carbon fibers and others can be used as the explodable conductor. In addition, powders of various substances can be used as alloy additives with electroexplosive alloying. They are made into a multihase pulse to the plasma jet formed from the products of blast exposure tool and have an effect on the treated surface. In recent years, hardening through electron-beam treatment (EBT) using low-energy high-current electron beams is a technology that has seen an increase in use in industry which can be of cost-effective and of practical use.

Modification of the structure and properties of the surface layers of materials by (EEA) is made from products of electric explosion of conductors of the multiphase pulse plasma jet, melting of its surface and saturation components of the melt stream, followed by its crystallization conditions to form a self-hardening phases and new compounds. The result leads to the simultaneous increase in various mechanical and performance properties. Investigations show that the hardening is due primarily to finely divided second phase particles (carbides, boride, etc.) distributed in a viscous metal matrix. State of research in this area is characterized by the study of singularities of the types of (EEA) (eg, carburizing and karboboronizing, model of metals and alloys), which has already been successfully tested in a production environment using similar or traditional methods. Identification of patterns (EEA) contributes to the development of the general theory of surface alloying using KPIs.

The purpose of this paper is to identify the characteristics of the formation of structure-phase states after electroexplosive carburization, karboboronizing and subsequent electron-beam treatment surface doping of technically pure titanium VT1-0.

When choosing methods of hardening of metals and alloys, the methods should be based on the fact that the functional properties of the surface layers are identified by the primarily features of their structure and phase composition. The greatest hardening possible is achieved with surface alloying using a laser, electron beam and plasma heating of the surface. In this structure, phase composition and properties of modified fibers depend on specific technological methods of processing and parameter influence on there in forcing surface. Simultaneous use of EEA and EBT is explained by the fact that they have comparable values of absorbed power density, depth, and the diameter of the zone of influence, let you create new structural phase the state of the surface layers of metals and alloys, and widen the scope of their practical use. A unit called "SOLO" from the Institute of High Current Electronics SB RAS allows you to independently and continuously adjust main processing parameters (length of impulse, their number and density power) in any combination. The unit provides a heating rate of thin surface layers of materials to the melting point and the subsequent cooling in the order of 10^8–10^{10} K/s, a short time (10^{-6} to 10^{-3} s) to reach high temperatures, the formation of gradients in temperature to 10^7–10^8K/m with which surface cooling due to the heat sink in the bulk of samples occurs at a rate of10^4–10^9 K/s. Such processing parameters create conditions to form on the surface layers of thickness of the order of 10^{-7}– 10^{-}6 m with amorphous nano- and submicrocrystalline structure and in some cases lead to vastly improved physical, chemical and physicomechanical properties. Pulsed plasma multiphase jet used for EEA and low-energy high-current electron beams for EBT are well combined with each other. They share similar values of density absorbed power (about 10^5–10^6W/sm^2), affected surface area (3–5 sm^2) and hardening zone depth (approx. 10 μm).

The proposed combined treatment can significantly increase depth of the zone affected by alloying, to reduce the surface roughness, to reducegradient microhardness depth and internal stresses at the interface with the foundation, to increase the microhardness and wear resistance of the surface by more than 3–5 times, reduce the friction coefficient [3]. Such treatment provides the most complete implementation of all reinforcing mechanisms. By varying the process parameters depending on the specific goals and objectives of hardening, it is possible to obtain an optimal state structure that ensures maximum structural strength due tosolid solution strengthening by alloying elements, high density formation of dislocations and ultrafine structure obtained byhigh cooling rates, as well as the second phase particles.

Choosing the type of EEA is made by considering how each one can increase microhardness of the surface. As anexplodable conductor in this work, a carbon ribbon (brand LU-P/0.1-50, weight of 140 mg) was used. In the karboboronizing processing, a sample of amorphous powder of Boron marked “B” with mass of 50, 100 and 150 mg was injected in the region of explosion. Electroexplosive processing was carried out when the absorbed power density 5,5 GW/m^2 and timed impulse of 100 ms. This processing mode allows for melting and alloying of surfaces without splash melt caused by in homogeneous pressure of the plasma jet on the irradiated surface. Subsequent EBT surface alloying was performed with the following parameters: absorbed power density was 2,0, 2,25 и 3,0 GW/m^2. Duration of impulses was 100 and 200 ms; with a rate 0,3 Hz; the number of impulses was 5 and 10. The treatment was carried out in argon at a pressure of 0.02 Pa. For each carburizing mode determines the distribution of microhardness depth modified layers. The result which provided the maximum values of microhardness and hardening zone depth was considered most optimal.

In the present study microhardness was measured and microscopic study of surface topography was conducted. Structural-phase states of surface titanium layers BT1-0 after EBT surface electroexplosive carburizing was also conducted. After carburizing microhardness has a maximum value 800 HV on the machining surface and decreases monotonically to 180 HV at a depth of about 50 μm. Its increase can be linked primarily with formation of titanium carbide reinforcing particles in the alloying zone. After a maximum of EBT, microhardness is observed not at the surface but at depth of about 20 μm. With this, the value reaches 2500–3000 HV, thus increasing microhardness up to 14 times compared with a microhardness of the foundation of the material. Increasing the pulse duration from 100 to 200 ms results in a slight increase in the microhardness near the surface exposure and forming a second maximum at a depth of 70–80 μm. Such distribution microhardness indicates the intensity of the process of interaction of titanium carbon not only in EBT remelting zone, but also in the deeper layers, and the effect of mechanical stress by formed layers.

Scanning electron microscopy showed that the carburizing of titanium is accompanied by the formation of an irradiated surface with a discontinuous coating with a developed layer and high roughness. Three components of the characteristic morphological structure of the surface are highlighted: Conglomerates of particles of graphite, titanium carbide and titanium globular morphology(75% surface area); particles of carbon fibers (15%); regions of hard titanium carbide based solution, with nanoscale titanium carbide inclusions (10%).

On the cross-sections of the samples, zone of alloying was revealed at a depth of about 50 μm, which contained particles of carbon fibers distributed over the entire depthup to the boundary with the substrate. With chemical etching, light particles of globular shape are detected; apparently titanium carbide.

After the EBT, the sample surface is shiny and blends in with the area of alloying. On transverse sections, a two-layer structure hardening zone was revealed. Near the surface is a layer thickness about 20 μm, which can be considered a zone of re-melting with EBT. Particles of carbon fibers with the SEM analysis cannot be detected. Below that isa layer containing a large amount of titanium carbide of globular morphology and particles not fully reacted with titanium carbon fibers. Its thickness is 60 μm. The total thickness of the zone of hardening is about 80 μm; an increase relative to the zone of carburizing zone with EEA by a factor of 1.6. It should be noted that the position of the maxima of the microhardness correlateswith the position of the interface of the top layer remelted with EBT, with the underlying area of alloying and alloying zone with the base alloy.

On transverse sections, a multilayer structure was revealed. On the processed surface, a thin layer is formed. It is this layer that has the maximum level of microhardness. This layer is characterized by the heterogeneity of the structure and the presence therein of carbon particles of quasi-amorphous state with nanoscale(5–50 nm) amounts of the titanium boride TiB and β-titanium. Under the surface is the zone of alloying, the structure of which is characterized by cells of high crystallization; deeper– dendrites crystallization with the axes of the first and second order; grain structure and plate type. EBT then leads to the unification of the coating layer and areas of alloying and leads to the union of the surface area and alloying zone and adjusting phase composition to a depth of 20–25 μm. Hardening is achieved due to the formation of highly dispersed structure, hardened carbide particles and titanium borides.

It was found that when electroexplosive carburization microhardness surface reaches 800 HV. When EBT increases in surface microhardness up to 2500–3000 HV, two peaks microhardness at 20 and 70–80 μm from the surface area are formed and the depth of hardening from 50 to 90–100 μm is increased. After electroexplosive alloying process, microhardness near the surface raises up to 2500–3000 HV. The thickness of the reinforced surface layer is 120 μm. Carburizing titanium leads to the formation of an uneven coating on the surface. Three specific characteristics are identified on the surface. Subsequent EBT evens out the treated surface, and merging of the surface area with the area of alloying occurs. It was established that hardening is achieved due to carbide formation, and borides of titanium and forming of submicron and nanoscale structures.

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