Ti-(15-25)Nb-5Ta ALLOY PLATE HARDNESS RESEARCH FOR MEDICAL APPLICATIONS

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Abstract. This work is devoted to the study of the hardness of various compositions of TiNbTa alloys for medical applications in the hip joints. This TiNbTa alloy system has a shape memory effect and superelasticity. The paper describes the technology for producing plates 1 mm thick of TiNbTa alloys. Carrying out thermal and mechanical treatments of these alloys. The effect of Nb doping on the structure and hardness of TiNbTa alloys is shown.

1. Introduction
The desire to improve the quality of life of patients after injuries and extensive operations is the most important task facing physicians and materials scientists in connection with this, recent studies on the development of new nickel-free metallic medical alloys for the manufacture of implants and their parts [1-2], are widely used by research teams from many countries. Existing materials for restoration and replacement, in particular, fragments of bone tissue and joints have a number of significant drawbacks and require refinement, both in terms of corrosion resistance and biomechanical compliance with body tissues. At the moment, alloys such as stainless steel, Co-Cr-Mo, and Ti-6Al-4V alloys [3-4], which can withstand heavy loads and, unlike ceramic materials, are not brittle, are mainly used for the manufacture of an endoprosthesis [5]. However, there are several problems associated with the effectiveness of these implants, which lead to revision operations in 10-15 years [6-8]. It is known that the use of the alloys used is not optimal due to the high Young's modulus, which causes a discrepancy with the required mechanics for replacing bone tissue. Taking over most of the load on itself, the implant causes a decrease in the load on the bone, which in turn leads to a decrease in the density and strength of the bone, followed by the loss of strong adhesion of the bone and the implant, as well as a possible fracture of the bone. It is also known that Ti-6Al-4V alloy has a low tibiological resistance caused by low adhesion of the surface oxide layer, which is prone to continuous fragmentation. One of the promising materials for the manufacture of bone implant parts and having the best range of properties in medical applications is the Ti-Nb-Ta alloy. The aim of the work was to study the hardness and microhardness of the surface of Ti-Nb-Ta alloys after rolling the alloy into sheets.

2. Materials and methods
Melting was carried out in a vacuum electric arc furnace with a copper water-cooled tray. As charge materials, iodide titanium, technically pure niobium and tantalum were used. The palletizing was carried out according to the principle of the gradient of the melting temperatures of the starting materials. Vacuum was carried out to a residual pressure of 10^-2 mm RT. century, then the furnace chamber was filled with high purity argon to a pressure of 0.4 atm. To absorb impurities, at the first stage, a zirconium getter was melted in one of the holes of a copper water-cooled tray. Then, melt was made in other wells of the starting materials until a single ingot was formed. For uniform mixing of metals, at least 5 remelts were performed with ingots turning over after each remelting. The weight of the ingots is 20 g. Next, the ingots are remelted into one ingot weighing 180 grams with two remelts. For the final homogenization and elimination of the dendritic structure, homogenizing annealing in vacuum was carried out at a pressure of 10^-5 mm. Hg. Art., within 12 hours at a temperature of 850 °C.

The primary deformation of cast billets with a thickness of 10 mm was carried out on a two-roll mill DUO-300 to a final billet thickness of 1 mm. The preforms were heated to a temperature of 600 °C before deformation in a muffle furnace for 25 minutes.

As objects of study, we used 1 mm thick plates of the following compositions: Ti-15Nb-5Ta, Ti-20Nb-5Ta, Ti-25Nb-5Ta at.

Plates for further research were cut on an EDM machine. Samples for metallographic examination and hardness were prepared by sequential grinding after pressing on a Piatto diamond disk with a grain size of P120 for 5 minutes, P220 for 10 minutes, P600 for 15 minutes, on an Aka-Allegran-3 fine grinding diamond disk with DiaMaxx suspension Poly with a diamond particle size of 6 μm, on Akasel NAPAL velvet with a suspension of DiaMaxx Poly with a diamond particle size of 3 and 1 μm. The microstructure was detected by etching in a solution of hydrofluoric and nitric acids with distilled water in the ratio HF:2H2SO4:7H2O.

The investigations were carried out using a light microscope, which makes it possible to conduct observations using the bright and dark field methods, as well as in polarized light. A set of lenses allows you to get magnifications up to 2000.

Hardness measurements were carried out on an Instron Wolpert Wilson Instruments 930N universal hardness tester. In the work, the Vickers method was used according to GOST 2999-75, the essence of which is expressed in the indentation of a tetrahedral diamond pyramid with an angle of 136 ° between opposite faces into the prepared polished surface of the test sample, while the indentation force is 30 kgf and the load time is 10-15 seconds. After the indentation, the Vickers hardness is calculated from the size of the fingerprint after the indentation. For each sample, there were 5 measurement points.

3. Results
Images of the microstructure of the compositions Ti-15Nb-5Ta (Figure 1), Ti-20Nb-5Ta (Figure 2) and Ti-25Nb-5Ta (Figure 3) were obtained.
The images show individual grains having a stretched shape in the rolling direction, while the aspect ratio of the grains is less than the degree of compression during rolling, which indicates partial recrystallization during heating before rolling. There are point inclusions of the alpha phase.

Figure 1. Ti-15Nb-5Ta.

The images show individual grains having a very elongated shape in the direction of rolling, possibly a high voltage. There is also the formation of grains directed perpendicular to the rolling direction. There are point inclusions of the alpha phase.

Figure 2. Ti-20Nb-5Ta.
Figure 3. Ti-25Nb-5Ta.

The images show individual beta-phase grains representing the matrix, having a very elongated shape in the direction of rolling and dark bands of the alpha phase.

The hardness study was carried out on specimens prepared by polishing to a mirror shine, the temperature at which the studies were carried out was room temperature (23 °C), humidity 50%. Samples were not subjected to additional heat treatment except for those used for rolling. The obtained values for hardness are presented in table 1 and graph 1.

Table 1. The results of hardness of the alloy according to the method of Vickers with a load of 30 kg.

| Alloy composition | Greatness   |
|-------------------|-------------|
| Ti-15Nb-5Ta       | 173±2 HV    |
| Ti-20Nb-5Ta       | 205±2 HV    |
| Ti-25Nb-5Ta       | 175±2 HV    |
4. Conclusions
According to the data obtained, it can be noted that the hardness of the alloy is higher than the hardness of each initial component, so the hardness of titanium is 99 HV, niobium 135 HV and tantalum 85 HV. The highest hardness is possessed by samples of plates with the composition Ti-20Nb-5Ta, while the compositions Ti-15Nb-5Ta and Ti-25Nb-5Ta are comparable in hardness.

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