Effect of annealing on the static properties of Ti-20Nb-10Ta alloy

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Abstract. The effect of heat treatment on the static mechanical properties of a Ti-20Nb-10Ta shape memory alloy in the form of thin wire is studied. After annealing at 600 °C for 20 minutes, a low modulus of elasticity was obtained. The best strength and ductility indicators were obtained after annealing at a temperature of 800 °C during 60 minutes.

1. Introduction
Endoprosthetics is a modern method of treating diseases and consequences of hip injuries [1].

Endoprosthetics surgery is difficult due to violations of the anatomical relationships and defects of the main and auxiliary elements of the hip joint. Most metal implants are made from Co-Cr-Mo and Ti-6Al-4V alloys. But there are problems associated with the effectiveness of these implants. One of them is a higher modulus of elasticity of alloys (more than 100 GPa) compared with human bone (about 4–30 GPa) [2-3].

Due to the different elastic moduli of the implant and the surrounding bone, there is a loss of bone density and mass (osteopenia), which leads to revision operations [4].

To solve this problem, recently developed new alloys with a lower modulus of elasticity and at the same time with the same strength [5-13].

The introduction of alloying elements (Nb and Ta) into titanium will improve the strength characteristics, lower the elastic modulus, and increase biocompatibility and corrosion resistance [14-15].

2. Materials and methods
The starting materials were high purity iodide titanium, tantalum and niobium.

By the method of five-time electric arc remelting with a non-consumable electrode in an argon atmosphere, ingots of these alloys weighing 60 grams were obtained. After smelting, the ingots were subjected to homogenizing annealing for 12 hours at a temperature of 900 °C in a vacuum of 10⁻⁵ millimeters of mercury.

After homogenizing annealing, the ingots were rolled in streams to sizes of 10 × 10 mm at temperatures up to 600 °C. Next, the workpiece was subjected to rotational forging to a diameter of 2-1.8 mm at temperatures up to 600 °C. Next, the workpiece was dragged to a diameter of 280 microns at a temperature of 150-200 °C. The dies were heated to 400 °C. Aquadag was used as a lubricant.
After receiving a wire of 280 μm, annealing was carried out at temperatures from 600-800 °C at temperatures from 20 to 60 minutes in a vacuum of $10^{-5}$ millimeters of mercury.

The study of static properties was carried out on a universal testing machine INSTRON 3382 with a tensile speed of 1 mm/min.

3. Results and discussion

Figure 1 shows the type of blanks at various stages of production. Figure 2 shows the microstructure of the alloy before and after annealing. The dendritic structure characteristic of cast alloys shows axes of the first and second orders.

![Figure 1. Plastic deformation of workpieces: (a) ingot after the first rolling in calibers, (b) workpiece after rolling in calibers, (c) bar after rotational forging, and (d) wire after drawing.](image)

![Figure 2. Microstructure of Ti-20Nb-10Ta alloy (a) after smelting and (b) after annealing at a temperature of 900 °C for 12 hours.](image)

As can be seen from the x-ray data (Figure 3), the peaks from the elements overlap each other, which makes their identification difficult. After annealing, there is a slight narrowing of the peaks,
which indicates stress relief. New phases are not allocated. The alloy is a substitution solution with a b-Ti lattice.

![X-ray data of Ti-20Nb-10Ta alloy before (upper) and after annealing (lower).](image)

The results of static tests of the investigated materials in the initial state and after various types of annealing are shown in Table 1. Figure 4 shows a typical view of the tensile curves of the studied materials.

| Type of processing                  | δ, %   | σ0.2, MPa | σв, MPa | E, GPa |
|------------------------------------|--------|-----------|---------|--------|
| Ti-20Nb-10Ta after drawing         | 4.12±0.01 | 494±5     | 684±4   | 46±2   |
| Ti-20Nb-10Ta (annealing at 600°C, 20 minutes vacuum) | 0.83±0.04 | 449±8     | 624±3   | 50±1   |
| Ti-20Nb-10Ta (annealing at 700°C, 20 minutes vacuum) | 0.67±0.02 | 422±7     | 621±9   | 41±2   |
| Ti-20Nb-10Ta (annealing at 800°C, 20 minutes vacuum) | 1.61±0.03 | 685±3     | 881±7   | 50±3   |
| Ti-20Nb-10Ta (annealing at 600°C, 60 minutes vacuum) | 3.56±0.08 | 506±4     | 718±5   | 49±1   |
| Ti-20Nb-10Ta (annealing at 800°C, 60 minutes vacuum) | 7.2±0.01  | 685±6     | 937±3   | 59±1   |
4. Conclusions
The methodology for producing homogeneous ingots of the selected composition was developed, including a fivefold electric arc remelting in an argon atmosphere and homogenizing annealing at a temperature of 900 °C for 12 h in vacuum.

The technology was developed and wires with a diameter of 280 microns from the selected alloys were obtained. The technology includes the rolling of smelted ingots, rotational forging of billets and drawing of bars at temperatures up to 600 °C in air.

The obtained wire was tensile tested after annealing at various temperatures and times. After annealing at 600 °C and 20 minutes, a low modulus of elasticity was obtained. The best strength and ductility indicators were obtained after annealing at a temperature of 800 °C and 60 minutes.

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