Study of the coefficient of heat expansion of TiNbTaZr alloy

K V Sergienko1, D D Titov1, S V Konushkin1, A S Baikin1, E O Nasakina1, M I Baskakova1, A Bespamiatnova1, E E Baranov1, L A Shatova2, A G Kolmakov1 and M A Sevostyanov1

1A.A.Baikov Institute of Metallurgy and Materials Science, Russian Academy of Sciences, Moscow, Russia
2Voronezh State Technical University, st. 20-letiya Oktyabrya, 84/4, Voronezh, Russia

E-mail: ksergienko@imet.ac.ru

Abstract. This article describes the study of the thermal expansion coefficient of a TiNbTaZr alloy by a dilatometric differential method used to determine phase transformation temperatures. The object of the study was samples of an alloy of TiNbTaZr with a variable composition, which underwent homogenizing annealing and rotary forging. According to the obtained results, all the studied alloys have three temperature regions, which are distinguished in the graphs of uniform elongation with increasing temperature.

1. Introduction
Dilatometry, as a method of studying substances, is based on the effect of changing the linear dimensions of samples with a change in temperature. Initially, dilatometry was used only to determine the coefficient of thermal expansion of mainly solids. However, this method is able to determine the presence of phase transitions, which are characterized by the influence on the sizes of samples of materials, in particular alloys, thereby violating the linear growth of the sizes of samples with increasing temperature. This research method usually determines not the absolute value of the expansion coefficient, but the difference between the expansion of the sample under study and the standard devoid of phase transitions in the temperature range under study. Thus, comparing the mutual change in the size of the sample and the standard, with a change in temperature, various extensions of the sample are revealed, meaning any transformations in the latter. As well as differential scanning calorimetry (DSC), this method cannot give an unambiguous answer because of what process the expansion linearity is disturbed with increasing temperature, however, the temperature at which the phase composition studies, heat treatment, and much more is appropriate.

2. The object of study and used equipment
The object of the study was samples of alloys of the TiNbTaZr system with niobium content from 20 to 30%, tantalum from 10 to 15%, zirconium 5% and titanium by the residual principle. Obtaining samples consisted of melting ingots on a vacuum arc furnace with a non-consumable tungsten electrode, conducting homogenizing annealing, rolling ingots to a cross section of 10x10 mm2, rotary forging to a circular cross section with a diameter of 4 mm, cutting a bar to obtain samples in the form of cylinders 4 mm in diameter and 10 long mm, the ends are polished. Studies were conducted on a high-temperature dilatometer DIL 402 C7G from Netzsch. This equipment allows continuous measurement of linear dimensions, under conditions of programmable exposure to temperature in the range from 20 to 1800 °C. Studies are conducted in argon or nitrogen. The maximum heating rate can be 25 °C per minute. The following research conditions were used in the work: temperature from 50 to 1000 °C, medium — argon, heating rate 10 °C per minute. The following are graphs of research (Fig. 4-9).
3. Experimental

When preparing the samples, the structure of Ti20Nb13Ta5Zr ingots after melting (Figure 1), homogenizing annealing at 800°C (Figure 2), and rotary forging (Figure 3) was investigated. The various compositions of the TiNbTaZr system have the same structure at each stage of the study between themselves.

![Structure of the Ti20Nb13Ta5Zr ingot after smelting](image)

**Figure 1.** Structure of the Ti20Nb13Ta5Zr ingot after smelting

After smelting, the structure of the ingots (Figure 1.) has a clearly defined dendritic structure, which indicates non-uniformity of the chemical composition and requires homogenizing annealing to level the composition at 800 °C for 12 hours. After the homogenization annealing (Figure 2) was carried out, the dendritic structure was destroyed with the formation of grains, which were stretched in the direction of the rod during rotational forging (Figure 3).

In the figures (Figure 4-9.) Shows the dilatometric curves of various compositions. Internal transformations in metals and alloys are characterized by changes in volume, linear dimensions and coefficient of expansion. The dilatometric method is based on the study of these changes.

When heated, due to an increase in the interatomic distance in the lattice, there is a uniform reversible increase in the length (volume) of the body - thermal expansion. Phase transformations, on the other hand, lead to an abrupt change in the parameters, which results in a change in the nature of the dilatometric curve.
Figure 2. The structure of the ingot Ti20Nb13Ta5Zr after homogenizing annealing

Figure 3. The structure of the ingot Ti20Nb13Ta5Zr after drawing
Figure 4. The results of the study of the alloy Ti20Nb15Ta5Zr

Figure 5. The results of the study of the alloy Ti30Nb13Ta5Zr
Figure 6. The results of the study of the alloy Ti20Nb10Ta5Zr

Figure 7. The results of the study of the alloy Ti25Nb10Ta5Zr

Figure 8. The results of the study of the alloy Ti25Nb13Ta5Zr
Figure 9. The results of the study alloy Ti30Nb10Ta5Zr

In metals that do not undergo structural transformations, the change in length during heating and cooling occurs monotonously, and the dilatometric curve does not change with a change in the rate of heating and cooling.

When cooled, on the contrary - the reduction of the metal is interrupted by its elongation in the temperature range of structural transformation.

An initial visual analysis of the dilatometric curve is performed. In the general case, there should be no abrupt multiple abrupt anomalies on the curve indicating either that the specimen was not prepared for measurements properly (not the lower and upper planes of the specimen are uneven or not parallel to each other, the specimen surface is not sufficiently clean) or breaks in the process of heating and cooling. If such are present, measurements are usually repeated with newly made samples.

Temperature curves of softening and (or) temperature expansion of samples are separately distinguished on the curve. The temperatures of anomalies corresponding to phase transitions (water evaporation, structural transition, vitrification, melting, and other transitions associated with changes in the mechanical state of the object of study) are noted. In these areas, the magnitude of the change in thickness and the coefficient of thermal expansion of the sample under study are determined.

Phase transitions or other thermal processes associated with changes in the mechanical properties of the sample under investigation on dilatometric curves manifest themselves in the form of kinks or steps. For a clearer determination of the temperatures of the processes, the curve of the first derivative of the TMA signal is also plotted, on which anomalies appear in the form of peaks (Figure 4-9).

4. Results and conclusions

According to the data obtained, it can be concluded that in each composition there are three phase transitions in the temperature range under study: the first starts at a temperature of 440 °C, the second - 690 - 750 °C and the third - above 890 - 970 °C. The phase transition temperatures differ slightly for each alloy. Thus, it is advisable to conduct research by X-ray phase analysis of ingots at temperatures of 400, 600, 800 and 1000 °C to determine the phase composition.

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