INTRODUCTION

To date, in many countries around the world, a large number of titanium alloys have been elaborated that are intended for wide range of applications [1–3]. However, selecting the best alloy (for a given purpose) from the whole range of titanium alloys is complicated due to the lack of a science-based system for comparing their composition, structure, and properties.

For achieving the best mechanical properties of the titanium alloy, one needs to obtain a desired morphology of the metal structure, which depends on the regime of a thermomechanical treatment (temperature, speed, and degree of deformation). Currently, when producing titanium blanks, foreign and domestic manufacturers made wide use of special programs [4] for forecasting the structure of the deformed metal. These programs allow one to determine parameters of intermediate and finishing thermal treatments of the metal. However, the use of models for predicting the structure of titanium alloys is hampered by the absence of sufficient input data on the physicochemical and thermophysical properties of materials. Even the key thermophysical parameters, such as the temperature dependences of thermal conductivity and heat capacity, are poorly represented in the literature and in the existing databases. As a rule, the available data do not cover areas of hot deformation and phase transitions above 1000°C.

This work was aimed at conducting an experimental study of thermophysical properties of the titanium alloy Ti–5Al–5V–5Mo–3Cr–1Zr (VST55531) in a wide range of temperatures by the methods of differential scanning calorimetry (DSC), laser flash, and dilatometry. The obtained data on heat capacity, thermal diffusivity, and thermal expansion have been used for calculating coefficient of thermal conductivity. The sequence and temperatures of structural transformations during heating of the alloy have been established. It has been shown that the studied alloy possesses a coefficient of thermal conductivity that is 3.5–4 times smaller than that of pure titanium.

EXPERIMENTAL

The samples for analyzing the thermophysical properties were prepared from a rod 70 mm in diameter produced on an SRVP-130 radial-shear-rolling mill [6]. The chemical composition of the rod was as follows (wt %): 5.3 Al, 5 V, 5 Mo, 2.8 Cr, 1.0 Zr, 0.3 Fe, 0.006 C, 0.1 O, and 0.01 N. The finishing deformation upon the rod rolling was performed after heating it to a temperature $T_{\text{pt}} + 60$°C, which corresponds to the single-phase $\beta$ field. After deformation, the samples were cooled in air. A large quantity of $\beta$-stabilizing elements (Mo, V, Cr, Fe) allowed us to obtain the $\beta$ phase.
at the given cooling rate. The rod microstructure (Fig. 1) is represented by equiaxed grains of the \( \beta \) phase with almost straight boundaries, which testifies the occurred recrystallization process. No signs of the decomposition of the \( \beta \) phase are present in the microstructure. Thus, the sample for testing heat conductivity was in the single-phase \( \beta \) condition.

The thermal diffusivity \( \alpha(T) \) was measured by the laser flash method on an LFA 457 automated experimental equipment of the NETZSCH company in the atmosphere of pure helium. The samples had a cylindrical shape 10 mm in diameter and 2.5 mm thick. The sample to be measured was fastened in a special holder and placed in a silicon-carbide electric furnace in an inert atmosphere. The heating of the lower part of the sample was performed by a 0.5-ms laser pulse, and a change in the temperature of its upper part was detected by an InSb infrared detector.

The thermal expansion of the VST55531 titanium alloy was studied on a DIL 402C NETZSCH dilatometer using a highly sensitive transducer of linear displacement. The experiments were carried out at a constant heating rate of 2 K/min in the atmosphere of high-purity helium.

The thermal analysis of the VST55531 sample was carried out using an STA 449 F3 NETZSCH instrument for synchronous thermoanalysis in a flow of argon. The temperature regime included heating from room temperature to 1000°C at a rate of 10 K/min. There were used Pt crucibles and \( \text{Al}_2\text{O}_3 \) inserts. The heat-capacity measurements were carried out by the standard technique, and a sapphire sample close in weight to the tested sample was used as the reference material.

### RESULTS AND DISCUSSION

The results of high-temperature measurements of the thermal diffusivity of the VST55531 sample are shown in Fig. 2. Each point in Fig. 2 is represented by the mean value averaged over five measurements in the regime of heating. The temperature dependence of the thermal diffusivity \( \alpha(T) \) for the VST55531 sample contains bends at 325, 550, and 820°C, which are accompanied by a change in the slope of the thermal diffusivity curve at higher temperatures. This behavior of \( \alpha(T) \) indicates the occurrence of phase transformations in the tested temperature interval. To describe the behavior of the thermal diffusivity in the temperature range from 20 to 1000°C, four ranges have been chosen in accordance with the observed features in the thermal-diffusivity curve. The approximation of the experimental data yields the following equations:

\[
\alpha_1(T) = 2.14 + 0.005\Delta T_1, \\
(\Delta T_1 \text{ for the interval } 25-325°C),
\]

\[
\alpha_2(T) = 2.77 + 0.0035\Delta T_2, \\
(\Delta T_2 \text{ for the interval } 325-550°C),
\]

\[
\alpha_3(T) = 2.07 + 0.0046\Delta T_3, \\
(\Delta T_3 \text{ for the interval } 550-820°C),
\]

\[
\alpha_4(T) = 3.46 + 0.003\Delta T_4, \\
(\Delta T_4 \text{ for the interval } 820-1000°C),
\]