EVALUATION OF THE SIMULTANEOUS EFFECT OF STATIC TENSION AND TEMPERATURE ON THE DISSIPATIVE PROPERTIES OF TURBINE BLADE STEEL 1Kh12N2VMF

V. V. Matveev, B. S. Chaikovskii, and D. E. Shpak

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Steel 1Kh12N2VMF (EI961) [1], which is widely used as a material for turbine blades, is characterized by a relatively high level of energy dissipation. The level of energy losses in this steel depends largely on its operating conditions, in particular on the effect of the field of centrifugal forces and temperature [2-4]. It was shown that the damping properties of this steel are greatly impaired both by static loading and by temperature. However, the effect of static tensile stresses and of the temperature on the level of energy losses in the material was studied with these factors acting separately.

Under real operating conditions the material of turbine blades is exposed to the simultaneous effect of static tensile stresses and temperature. The task of the present investigation is therefore to evaluate the joint effect of these factors on the damping ability of the examined steel in one and the same state.

The principal mechanism of energy dissipation of steel EI961 in dependence on the conditions of heat treatment may be either magnetomechanical hysteresis ensuring a sufficiently high damping level ($\delta > 1\%$) or microplastic deformations [5].

Specimens were made of material which had previously been hardened in oil at 1020°C and then tempered at 680°C for 2 h. These conditions ensured the best combination of damping and fatigue characteristics [6]. To eliminate the effect of work hardening of the surface layer as a result of machining on the dissipative properties of the material [7], the specimens were heated to 600°C before the tests, held at that temperature for 2 h, and then furnace cooled.

The damping properties of the material were studied by a known method [8] on a specimen whose end was constrained, whose working part was prismatic (5 x 20 x 150 mm), and which was subjected to flexural vibrations on a KD-1M installation.

To obtain the most uniform temperature distribution over the length of the working part of the specimen, we used a detachable three-section electric furnace with separate control of each section. The temperature was measured with Chromel-Alumel thermocouples connected to an EFF-2-11A potentiometer. The oscillations were registered by resistance strain gauges made of wire Kh20N80 with 0.03 mm diameter. The highest temperature to which the specimens were heated (600°C) was given by the operating conditions of compressor blades made of this material.
Fig. 1. Dependence of the bending vibration decrement of the specimen on the intensity of the magnetic field in the case $\sigma_t = 0$ with different amplitudes of the maximum cyclic stress: 1) $\sigma = 21$ MPa; 2) $\sigma = 84$ MPa; 3) $\sigma = 168$ MPa.

Fig. 2. Amplitude dependences of the bending vibration decrement of the specimen for different static tensile stresses $\sigma_t$ at 20°C (a) and at 600°C (b): 1) $\sigma_t = 0$; 2) $\sigma_t = 25$ MPa; 3) $\sigma_t = 50$ MPa; 4) $\sigma_t = 100$ MPa; 5) $\sigma_t = 150$ MPa.

To evaluate the effect of the high-temperature sensors and of the outlet wires on the damping ability of the specimens, we carried out an experiment: specimens with very low energy dissipation ($\delta = 0.03-0.04\%$) were first tested with high-temperature sensors glued to them, and then with strain gauges on paper base (PKB-10-200) at room temperature. The difference between the obtained results ($\Delta \alpha = 0.02-0.03\%$) characterizes the energy losses due to the high-temperature strain gauges.

To isolate the basic mechanism of energy dissipation in the investigated steel, we tested its damping properties in a magnetic field with different intensity up to saturation (Fig. 1). The magnetic field suppresses processes of displacing the boundaries of the domains, and thereby it greatly reduces energy dissipation, although in the regions of weak magnetic fields some increase of the damping may occur [9, 10]. It can be seen from Fig. 1 that for the given state of the examined steel the vibration decrement in the absence of a magnetic field is almost one order larger than the vibration decrement in a saturation field ($H > 400$ Oe); this testifies to the fact that the prevailing contribution to damping is made by magnetomechanical hysteresis.