ANISOTROPY OF THE MECHANICAL CHARACTERISTICS 
OF STEEL UNDER THE EFFECT OF ELECTRIC CURRENT 
PULSES AND CRYOGENIC TEMPERATURES*

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The article deals with the influence of high-density electric current pulses on the anisotropy of the mechanical characteristics and of the electrical resistance of the austenitic steel 07Kh13N4AG20 in the temperature range 293-4.2 K. It was established that electric current pulses have a strong influence on the anisotropy of the mechanical characteristics of the steel. The article shows that there exists a stable correlation between the degree of anisotropy of the mechanical characteristics and of the electrical resistance.

In the designing and stress analysis of power generating equipment with cryogenic cooling, and also in the devising of new technologies of the electromagnetic treatment of metals (in particular of embossing technologies) it is essential to take into account the anisotropy of the mechanical properties of metallic materials and the influence of electric current pulses (ECP) on them. The anisotropy therefore has to be investigated in a wide temperature range: from elevated to room temperature (the operating range of materials in technological processes of forming); from room temperature to the temperature of liquid helium (the range of their operation in power generating installations with cryogenic cooling).

It is known that the properties of substances depending on the direction include thermal, electrical, magnetic, strength, ductile, and other physical and mechanical properties. The anisotropy of mechanical properties is found in most structural materials, and as a rule it is deformational, i.e., it changes or originates anew during deformation. It manifests itself in the dependence of the mechanical characteristics on the orientation of the specimens relative to the direction of strain-hardening as a result of the crystallographic texture forming during deformation, on the geometric directivity of grains, subgrains, and inclusions, oriented microstresses, etc. [1]. Several researchers [2-4] believe that the main cause of the change in resistance to deformation under the effect of high-density electric current pulses is the interaction of the electron flux with imperfections of the structure. Therefore, even in materials with slight mechanical anisotropy the direction of strain-hardening may determine to a considerable extent the degree of change of their resistance to deformation and their mechanical characteristics brought about by ECP.

The anisotropy of the structure of a heterogeneous alloy can be qualitatively determined from the change of electrical resistance of specimens of this alloy made along and transversely to the direction of rolling because it is known that the electrical properties, especially electrical resistance, are determined by the phase and structural state of the material [5].

We investigated the economically alloyed steel 07Kh13N4AG20 which, in the state as supplied, has an austenitic structure which, according to the data of some researchers, is retained in cooling down to 20 K [6]. The cylindrical fivefold specimens (the initial diameter of the working part was 4 mm) were cut out of a sheet 12 mm thick, in the direction and transversely to the direction of rolling. There was no additional heat treatment of the steel. The specimens were subjected to uniaxial tensile tests with constant strain rate on a UTN-10 installation at 293 K (in air), 77 K (in liquid nitrogen), and 4.2 K (in liquid helium). During the loading process some specimens were exposed to ECP. The electric current pulses with amplitude 3 kA, width 10^{-2} sec were passed through the working part of the specimens in the direction of the acting force with specified levels of residual strain 0 (0.25\sigma_{0.2}; 0.5\sigma_{0.2}); 0.4; 0.8; 6.0%, and then in steps of 5% to destruction.

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During the loading we also measured discretely the electrical resistance of the specimens. Under equal conditions we tested five to seven specimens. The results of the measurements were averaged. We regarded changes as significant only when the difference between values of the characteristics, determined in each specimen, exceeded at points under comparison the sensitivity of the system of measurement in regard to the given parameter.