Influence of Heat Treatment on Magnetic and Mechanical Properties of Steel 10HSND

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Abstract. The effect of heat treatment on the mechanical and magnetic properties of steel 10HSND and morphology of carbides transforming under heat treatment, on mechanical and magnetic properties was studied. Method of determining the structural changes during the rapid testing on changing of the magnetoelastic part of the magnetic field of scattering was proposed.

1. Introduction
During steel operation, there happens their natural aging. Aging of metals causes changes in their mechanical, physical and chemical properties [1]. Carbon steels loading process is accompanied by changes of mechanical stresses over a large range, and hence, under the circumstances the elastic stresses and thermal heating may change the structure of material due to carbon reallocation and defects, which leads to artificial aging [2]. In a study [3], a concept of structural carbide construction of steels on the micro level, which allows the formation of a number of visco-strong steel properties. Traditional methods of determining the mechanical properties do not provide reliable results on the material state. Therefore, it is necessary to develop methods that allow determining the state of carbon steels. In this paper the artificial aging process was achieved by steel heat treatment.

The objective of the study: research of the heat treatment effect on the magnetic and mechanical properties of steel 10HSND and development of practical recommendations for non-destructive testing of these properties on changing the magnetic parameters of the material.

2. The methodology of the study
For studies, samples in shape of plates of 10 mm thickness and 75 × 75 in size mm were prepared. All samples were quenched from 950 °C and tempered at 600, 640, 680 and 720 °C with following cooling in water. After the heat treatment, magneto-mechanical tests were conducted: coercive force, a tangential component of the magnetic field intensity before and after the shock loading, hardness specific resistance and magnetostriction were measured. Dependence of ultimate tensile strength and yield point on tempering temperature was taken from the steels grade guide. To monitor the change in carbide-ferrite phase, photomicrographs at the optical microscope with an increase in 1000 were obtained.

3. Results and discussion
Figure 1 shows the austenitic structure of steel, quenched from 950 °C.
Figure 1. Structure of secondary sorbite in steel 10HSND after quenching from 950 °C and tempering to a) 600°C; b) 640°C; c) 680°C; d) 720°C.

The data in Figure 1 shows that the structure of steel after high temperature tempering changes forming secondary sorbite. At higher tempering temperatures, structure - martensite breaks up into ferrite-carbide homogeneous mixture containing carbide inclusions. The evolution of the size of carbide inclusions is clearly seen in Figure 1, and in Figures 1a - 1d improving of structural reallocation of carbides can be seen, i.e. carbides areas become more distributed and decrease in size. Secondary sorbite structure is the most homogenous in Fig. 1d, with further increase of tempering temperature, coalescence process is observed - minor carbide monocrystals "disappear" being absorbed by larger ones, and structural restructuring of carbides become more considerable in size again.

Figure 2 shows the dependence of the coercive force on tempering temperature. It can be seen that up to temperatures 600 °C takes place almost monotonic decrease of a parameter up to tempering temperature 720 °C, and with further increase in temperature, there is an abrupt jump.
Such a parameter as specific resistivity behaves in a similar way (Fig. 3).

Resistivity contrast jump at high tempering temperatures indicates the role of thermal defects. One can assume that the carbon atoms are involved in this process. This conclusion is in agreement with a decrease in the magnetostriction at increase in tempering temperature (Figure 4). The mechanism of these phenomena in steels underexplored.
Normally, at heat treatment, the control parameter is the hardness, however, as shown by the data in Figure 5a, hardness, with an increase in tempering temperature, decreases almost monotonously and does not "feel" the reallocation carbides and their sizes, as well as ultimate tensile strength and yield strength, changes of which with the tempering temperature are shown in Figure 5 B.

![Figure 5](image)

**Figure 5.** Dependence of hardness (fig. a); ultimate tensile strength $\sigma_\text{p}$ and yield strength $\sigma_\text{y}$ of steel 10HSND quenched from 900 °C (fig. b) from the tempering temperature.

In the graph (Figure 6), the dependence of the changes of the tangential component of the magnetic field intensity on the tempering temperature is shown. On the curve, a maximum at tempering temperature of 640 °C is clearly visible, then a sharp decline in a parameter with an increase in tempering temperature can be seen, therefore, one can judge on the restructuring involving carbon and thermal defects by changing the tangential component of the stray magnetic field.

![Figure 6](image)

**Figure 6.** Dependence of magnetoelastic changes in the tangential component of the stray magnetic field tension on the tempering temperature for steel 10HSND.

4. **Conclusions**

The paper shows that, along with the known mechanisms of the material structure changes with increase in tempering temperature, there are other mechanisms in which the role of thermal defects is significant. Identifying the role of the latter in structural transformations requires additional studies. Such magnetic parameter as a change in the tangential component of the stray magnetic field monitors the change in the structure due to the carbon reallocation and can be used in the rapid analysis as an indicator of non-destructive testing of mechanical properties of steel.

**References**

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