$$\tau^- = 0,\ q_y^n = 1,\ q_y^v = 0,\ q_x^a = q_x^b = 0.$$

Figure 2 shows the results of the calculations. It is clear from the figure that the X dependence of the temperature is weaker for the experimental than for the calculated values. This "averaging" effect is apparently the result of longitudinal heat fluxes in the wall of the inner tube. This effect is particularly noticeable for small X, the region where the coolant enters the porous body, where the longitudinal heat fluxes reach a maximum. In addition, the slope of the experimental curve in the region of the coolant exit from the porous body indicates a definite outflow of heat from the hot end of the tube and the porous metal. The diagram of the experimental model shows that the coolant collector is located here. Taking all this into account, it should be noted that the calculated and experimental values agree rather well. In conclusion we note that calculations performed with the algorithm in [1] do not compare well with experiment, since, as stated previously, that algorithm cannot take account of the axial symmetry of the model.

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EFFECT OF IMPURITY ATOMS IN FERROMAGNETS ON MAGNETIC RELAXATION

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UDC 621.317.41:538.27

Results are presented from an experimental study of magnetic relaxation in iron specimens containing various amounts of carbon.

A number of studies have been dedicated to time effects in ferromagnets [1-9, et al.]. Study of magnetic relaxation processes in these materials is of great practical significance in connection with their wide use in machine construction, radioelectronics, computer technology, and other fields. The requirements for homogeneity and, especially, time stability of properties being demanded of these materials are increasing continually.

At the present time, according to standard 802-58 [10], in defining the magnetic characteristics of ferromagnetic materials it is necessary to consider the time required for relaxation processes.

One of the manifestations of time effects is a decrease in magnetic permeability of ferromagnets over time after demagnetization by an ac magnetic field of decreasing amplitude. This relaxation phenomenon has been termed magnetic permeability disaccommodation (MPD) and appears especially intensely in iron containing impurity atoms.

The present study is dedicated to an investigation of MPD in iron.

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Translated from Inzhenerno-Fizicheskii Zhurnal, Vol. 47, No. 6, pp. 991-995, December, 1984. Original article submitted August 5, 1983.

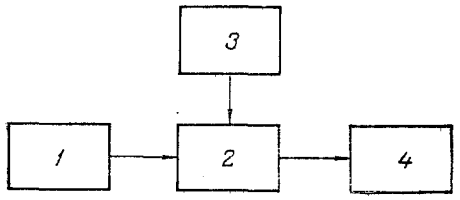

Fig. 1. Block diagram of system.

The specimens studied contained carbon in contents ranging from tenths of a percent to one percent, with a practically insignificant quantity of other impurities. The specimens were produced by induction smelting with varying amounts of carbon added. Before testing, all specimens were vacuum annealed at a temperature of 950°C. During the heating and cooling process the vacuum was maintained at a level such that surface oxidation was practically absent.

Measurements of the change over time of magnetic properties of the specimens produced by MPD were performed with a system whose block diagram is shown in Fig. 1. Module 1 is the demagnetizing circuit which produces a 50-Hz ac magnetic field which changes from $H_{max} = 4 \cdot 10^3$ A/m to a minimum $H_{min} \to 0$ ($H_{min} < 10^{-1}$-10^{-2} A/m) over the course of 5-7 sec. The magnetic field was practically constant over the length of the specimen being demagnetized. Following such a demagnetization regime to some degree ensured identical initial states for all specimens studied.

Module 2 is an LC-oscillator. The specimen being studied served as the core for the tank circuit coil, and changes in time of its magnetic properties led to changes in oscillation frequency. Module 3 is a current source, while module 4 is an instrument to record the change in oscillator frequency produced by MPD in the specimen. A frequency meter with resolution of 10^{-6} was used for this purpose.

The specimen under study was coupled to the tank circuit inductor and a frequency change occurred as a result of magnetic permeability disaccommodation. The relative change in magnetic permeability with time is

$$\frac{\Delta\mu(t_0, t)}{\mu(t)} = \frac{\mu(t_0) - \mu(t)}{\mu(t_0)} = \frac{\nu^2(t) - \nu^2(t_0)}{\nu^2(t)},$$

where $\mu(t)$ and $\nu(t)$ are the specimen magnetic permeability and frequency at a given time, and $\mu(t_0)$ and $\nu(t_0)$ are the permeability and frequency immediately after specimen demagnetization.

Experimental studies of magnetic relaxation curves $\Delta\mu/\mu = f(t)$ characterizing disaccommodation of magnetic permeability of specimens with various carbon contents are shown in Fig. 2. These curves were obtained at room temperature immediately after specimen demagnetization. During the experiments the relative change in frequency was recorded, and the relative change in magnetic permeability of the specimen produced by magnetic relaxation was then calculated. The relative uncertainty of frequency measurements ranged from tenths to one percent.

It follows from examination of the curves $\Delta\mu/\mu = f(t)$ (Fig. 2) that the change over time of magnetic properties of all specimens studied occurs more intensely in the initial stage, after which the process slows and at a certain point is practically stabilized. The character of these curves was the same for all specimens with the same carbon content. The curves merely shift upward when the amount of carbon atoms is increased. In the first 15-20 sec the change over time in specimen magnetic properties is maximal, comprising more than 80% of the steady-state value of the relaxation parameter. In subsequent time intervals the relaxation rate continually decreases, tending to some limiting value.

This type of development of the relaxation process upon transition of the ferromagnet from the nonequilibrium to the equilibrium state can be explained by the fact that the rate of domain boundary displacement varies, and thus all such boundaries do not immediately occupy their steady-state positions, but "get stuck" in "fresh" positions on each occasion. Moreover, in view of inhomogeneity of magnetization in the boundary layer, gradients develop in magnetostriction stresses, which intensify diffusion of impurity atoms in the crystalline lattice. This in turn leads to redistribution of stresses in a given region, which affects the character of energetic potential barrier distribution, creating different obstacles to motion of domain boundaries.

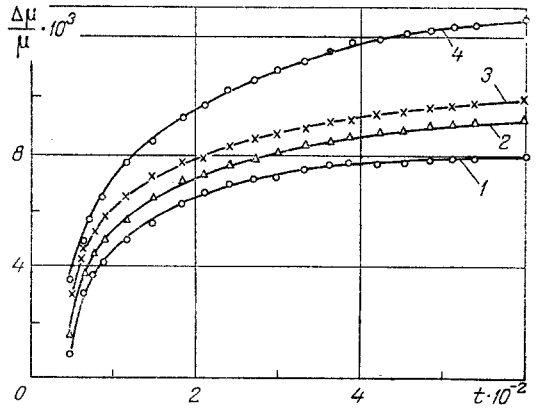

Fig. 2

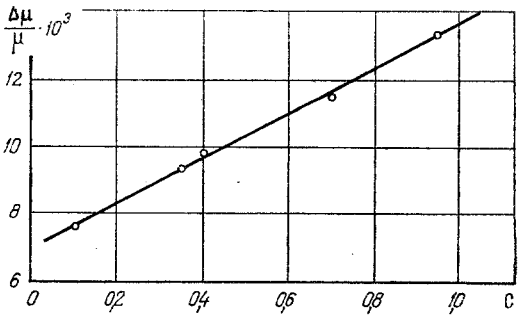

Fig. 3

Fig. 2. Magnetic relaxation curves of MPD in specimens with various carbon contents: 1) 0.1%; 2) 0.36; 3) 0.45; 4) 0.95% C. t, sec.

Fig. 3. Steady-state relaxation parameter (at $t = 6 \cdot 10^2$ sec) vs content of carbon atoms C in specimen, %.

Thus, it can be proposed that one of the important factors influencing the time change of magnetic properties in ferromagnets is an elastic aftereffect, produced by redistribution of internal stresses in the volume of interdomain boundary layers.

The experimental curves of Fig. 2 show that with increase in the quantity of carbon impurity in the alloy magnetic relaxation intensifies. Impurity solution of carbon atoms in the bcc lattice leads to deviations from cubic symmetry, causing nonaxial elastic deformation which intensifies the aftereffect, generating in turn an increase in the steady-state relaxation parameters.

As was noted above, change in magnetic properties upon MPD occurs more intensely at the initial moment, then slows, and at some point in time ($t \geqslant 10$ min), the process practically stabilizes (Fig. 2). Analysis of experimental data for the specimens with different carbon contents shows the presence of a near-linear relationship between steady-state relaxation parameters for $t \geqslant 10$ min and carbon concentration C. The dependence of steady-state relaxation parameters on carbon concentration C in the specimens is shown in Fig. 3. It is evident from the figure that the experimental points practically fit a straight line.

The results of the experimental study provide a basis for the statement that the carbon impurity atoms are responsible for the increase in intensity of relaxation processes. The intruding carbon impurity atoms act like relaxation centers and intensify the elastic aftereffect due to distortion of the crystalline lattice. The studies also indicate that magnetic relaxation methods may be applicable in developing methods for nondestructive monitoring of impurity atoms in ferromagnets.

NOTATION

t, time; L, inductance; C, capacitance; μ, magnetic permeability; ν, frequency; H, magnetic field intensity; J, magnetization.

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THIN-LAYER FLOW OF A TWO-PHASE MEDIUM OVER THE SURFACE OF A CENTRIFUGAL MIXER, TAKING ACCOUNT OF RHEOLOGICAL FACTORS

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UDC 532.529.5:621.929.9

On the basis of a hydrodynamic model of multivelocity interpenetrating continua, the flow of miscible materials over the working surface of centrifugal mixers is investigated.

The mixing of highly disperse materials with viscous liquids is widely used in various branches of industry. Success in the development and commercial introduction of mixers that ensure a high quality of distribution of disperse materials in viscous liquids with sufficient productivity in continuous operation and allow the difficulties associated with the specific properties and treatment conditions of these materials to be overcome is only possible in the presence of a mathematical description of the processes occurring in them on mixing. One apparatus satisfying these requirements is the multicascade centrifugal mixer. A possible form of this type of mixer is shown in Fig. 1. In the present work, the flow of miscible materials over the working surface of the mixer is described, allowing the optimal constructional elements of the apparatus to be determined.

In the operation of a rotational mixer, highly disperse liquid and solid components are fed to the center of the rotating element of the first stage of the rotor and, in layers, pure liquid, the mixture forming, and the solid component flow over the surface of the conical ring. As a result of their combined motion under the action of the centrifugal force $\bar{F}$, collective deposition of the solid material in the liquid occurs, and then all this mass is dispersed by the edge of the rotating element (Fig. 1). The processes occurring in the subsequent stages of the rotor, which are analogous in construction, are flow of the two-phase medium and dispersion, as a result of which the final redistribution of the components is accomplished.

The motion of each layer of material over the surface of the rotating rotor is described by the equations of continuum mechanics; each layer corresponds to a particular rheological equation of state. The flow of pure liquid is described by the Navier–Stokes equation, and the mixture constitutes a two-phase medium, the flow of which may be described using the results of [1, 2]. The motion of the highly disperse material may be regarded as motion of some continuous medium according to its rheological equation of state. In this case, however, the general problem is greatly complicated; therefore, it is assumed that the solid material moves in the longitudinal direction at some mean velocity $V_l[\delta_1(l)]$, and that there is no relative motion at the interface between the mixture and the solid phase. These assumptions are completely justified for the given case of flow.

Let $\delta_0(l)$, $\delta_1(l)$, $\delta_2(l)$ be the thickness of the pure liquid layer, the pure liquid layer and the layer of mixture forming, taken together, and the thickness of the whole layer, respectively. Consider the flow of miscible materials in the orthogonal coordinate system x^1, x^2, x^3 fixed with respect to the rotor (Fig. 1), under the following assumptions, which are valid for the given type of flow: the flow is axisymmetric and steady; the film thickness is considerably less than the corresponding radius of the conical rotor ring, i.e., $\delta_2/R = \varepsilon \ll 1$;

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Translated from Inzhenerno-Fizicheskii Zhurnal, Vol. 47, No. 6, pp. 995-1000, December, 1984. Original article submitted October 17, 1983.

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