STUDY OF THE MAGNETIC PROPERTIES
OF THE ELECTROTECHNICAL STEELS
BY THE ZERO EXTERNAL FIELD μSR-METHOD

S.P. KRUGLOV, L.A. KUZMIN
Leningrad Nuclear Physics Institute, 188350 Gatchina, Leningrad district, USSR

and V.Yu. MILOSERDIN
Moscow Physics Engineering Institute, 115409 Kashirskoe shosse, 31, Moscow, USSR

Magnetic texture and magnetic inhomogeneity of anisotropic and isotropic electrotechnical steels have been investigated under different conditions of thermomechanical treatment and internal tensions estimated. The μSR-technique has also been used for investigations of magnetic circuits in electrical machines.

It is well known that the magnetic properties of any ferromagnetic material are determined by the magnetic domain alignment and macroscopic field distributions within the samples. The domain alignment may be described by the following parameters: (i) the magnetization vector $\langle M \rangle$ and (ii) the two-dimensional tensor components $n_{\alpha\beta} = \langle M_\alpha M_\beta/M^2 \rangle$ (here $\langle \ldots \rangle$ means the averaging throughout the sample, $M_\alpha$ is the domain magnetization component in $\alpha$ direction, with $\alpha = 1, 2, 3$). At the unmagnetized sample the value $\langle M \rangle$ is equal zero. The magnetic texture tensor $n_{\alpha\beta}$ is not equal zero and there are only five independent components in this tensor. Therefore only five independent measurements are necessary to determine all the tensor components.

The time dependence of muon polarization $P(t)$ can be used for determination of the texture tensor components. This dependence is given by the formula:

$$P_\alpha(t) = \left(n_{\alpha\beta} + (\delta_{\alpha\beta} - n_{\alpha\beta}) \cos \gamma \bar{b}t\right) P_\beta(0).$$

(1)

where $\gamma$ is the gyromagnetic ratio of the muon, $\bar{b}$ is the mean value of the local magnetic field on the muon and $\delta_{\alpha\beta}$ is the Kronecker symbol. It follows from formula (1) that it is enough to measure the non-precessing component or the initial value of the precessing component of the muon polarization at five independent orientations of the sample about the muon beam direction.

The experiments were carried out at the muon channel of the Leningrad Nuclear Physics Institute. The muon beam momentum was 110 MeV/c and the beam spot was 60 mm in diameter. All targets were prepared like packets from 20 steel plates with size $100 \times 100 \times 0.3$ mm. The plates in each packet were oriented
identically. The five orientations of the targets were as follows. The first orientation was that in which the normal to the plate plane was collinear to the beam axis and the rolling direction of the metal was oriented upwards. The next orientations were chosen with the angle between the beam axis and the plate normal equal to $\pi/4$; the rolling direction was then oriented with angles $0, \pi/4, \pi/2$ and $3\pi/4$ with respect to the initial orientation.

First of all the electrotechnical anisotropic steels submitted to different treatments were investigated. The results are given in table 1.

It is seen from these data that the samples with plane magnetic texture have the best magnetic properties. Also the samples with the most homogeneous field distribution have the smallest energy losses under remagnetization processes between the samples, provided that the texture tensor components are identical.

One of the mechanisms for changes of texture and inhomogeneity in a sample is thermomechanical treatment. The influence of different processes is shown in table 2.

Sample Nr. 6 was annealed with stretching tension, sample Nr. 7 was cooled together with its furnace and Nr. 8 was cooled rapidly (in air). It can be seen from this table that the unaxial magnetic texture is formed under annealing with stretching tension (the component $n_{33}$ is reduced by nearly a factor 2). This effect is connected perhaps with a partial compensation of the bending tensions which are responsible for this component. The other interesting effect is the change of the frequency of the muon spin precession under thermomechanical treatments.