Letters to the Editor

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Rotational Losses in 4-79 Molybdenum Permalloy at Low Frequencies

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(Received April 24, 1956)

IF a magnetic field larger than the maximum demagnetizing field expected ($4\pi M$) is applied to a ferromagnetic disk, then the material should be saturated and consist only of one domain. It has been shown[1,2] that when this magnetic field is rotated in the plane of the disk, the magnetization will rotate with the field in the plane of the disk and lag the field by an angle proportional to the field and the losses. The average torque on the sample multiplied by $2\pi f$ (f = rotational frequency in cps) is equal to the power dissipated in the sample by the rotating magnetic field. Since we are dealing with a single domain, the eddy current losses can be calculated and subtracted from the total loss observed to obtain the anomalous losses.

Previous work[2] over the frequency range from 15 kc/sec to 2 Mc/sec showed that the torque became field-independent above a certain value of field. These measurements, however, were made at low fields (10–20 oersteds) and it was not certain that domain wall motions were eliminated.

Subsequent measurements made at 60 cps showed that even at 600 oersteds the losses are still decreasing. Macroscopic eddy current losses were completely negligible for the $\frac{1}{8}$ mil thick 4–79 Mo-Perm sample used.

A rotating permanent magnet structure was used to obtain torque data on $\frac{1}{8}$ mil thick 4–79 Mo-Perm over the frequency range 5–30 cps. Over this range and for a magnetic field of 1700 oersteds, the eddy current torque is negligible. The anomalous torque obtained was found to be independent of frequency from 5–30 cps.

For both the 60-cps data and the 5–30 cps data a torsion arrangement was used to measure the sample torques. The time constant of the torsion suspension was approximately 5 sec, so that only the average or dc torque per cycle was measured.

The data shown in Figs. 1 and 2 were taken using a stationary magnetic field and a rotating sample. The sample, held by a bearing-supported rotor, was brought up to rotational velocities of the order of 200 cps by an air jet. The air jet drive was removed, and the time rate of change of angular velocity of the sample plus holder was measured as a function of angular velocity. Sample holder torques (bearing, windage, etc.) were measured by rotating the holder plus sample in the essentially field-free region of a three-coil Helmholtz arrangement and the holder alone in the magnetic field and then in the Helmholtz coil.

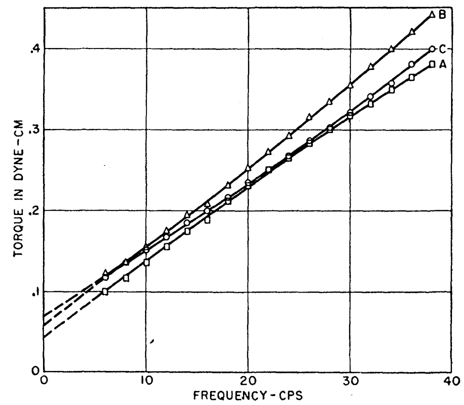

FIG. 1. The experimental eddy current plus anomalous torques on three 0.005-in.-thick, $\frac{1}{2}$-in.-diam disks of 4–79 molybdenum Permalloy plotted as a function of the rotational frequency of the magnetic field. The magnitude of the magnetic field was approximately 11 300 oersteds.

Figure 1 shows the torque data obtained on three supposedly identical samples A, B, and C (0.0051 in. thick, $\frac{1}{2}$ in. diam 4–79 Mo-Perm). Torque as a function of frequency was measured at five different field values on specimen disk C and the results are shown in Fig. 2. The torques plotted in Figs. 1 and 2 include only eddy current and anomalous torques on the sample and not bearing, windage, and sample holder torques which have been subtracted out.

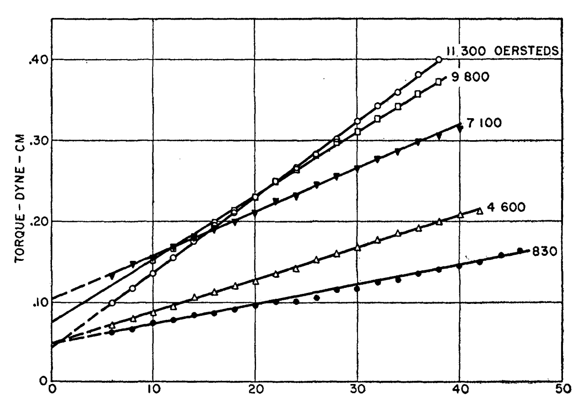

FIG. 2. The experimental eddy current plus anomalous torques on sample disk C of Fig. 1 plotted as a function of magnetic field rotational frequency for five values of magnetic field magnitude.

TABLE I. The experimental and calculated eddy current torques at 30 cps for various magnetic field amplitudes. The experimental eddy current torques were obtained from the data of Fig. 2 by subtraction of the extrapolated anomalous torques at 0 cps.

H (oersteds)	T_{exp}	T_{calc}
11 300	0.280	0.278
9800	0.235	0.239
7100	0.164	0.171
4600	0.120	0.119
830	0.073	0.078

A consideration of the experimental errors and the error in calculating the eddy current contribution to the torques suggests that the anomalous loss in 0.005 in. thick 4–79 Mo-Perm is frequency-independent over the frequency range from 6–38 cps. Table I illustrates the agreement between the experimental and calculated eddy current torques.

The results quoted here plus the previous work done from 15 kc/sec to 2 Mc/sec indicate that the anomalous losses in 4–79 molybdenum Permalloy are essentially frequency-independent from 6 cps to 1 Mc/sec. The field dependence and the frequency spectrum from 0 to 6 cps are being investigated at the present time.

[1] R. Kikuchi, J. Appl. Phys. (to be published).
[2] T. L. Gilbert and J. M. Kelly, Conference on Magnetics and Magnetic Materials, Pittsburgh, Pennsylvania, June 14–16, 1955 (unpublished).

Method of Polarizing Nuclei in Paramagnetic Substances

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(Received May 31, 1956)

OVERHAUSER[1] has shown that a saturation of the electron spin resonance leads to a large enhancement of the nuclear polarization. A necessary condition for this enhancement is that the nuclei relax via the electrons whose resonance is being saturated. A scheme which is applicable to substances which exhibit resolved hyperfine lines was proposed by Bardeen, Slichter, and Pines.[2] It requires that the predominant relaxation process for the nuclei results from a modulation of the $a(\mathbf{I}\cdot\mathbf{S})$ hyperfine interaction.

The scheme proposed in this paper, applicable to substances which show a resolved hyperfine structure, places no requirements on the detailed relaxation mechanism of either the electron or the nucleus. It requires, however, that one sweep through a certain fraction of the external magnetic field in a time short compared to either relaxation time. The method is illustrated in Fig. 1, which shows the energy levels of a system with $I=\frac{1}{2}$, $J=\frac{1}{2}$ *vs* applied magnetic field as given by the Breit-Rabi[3] formula. This system is placed

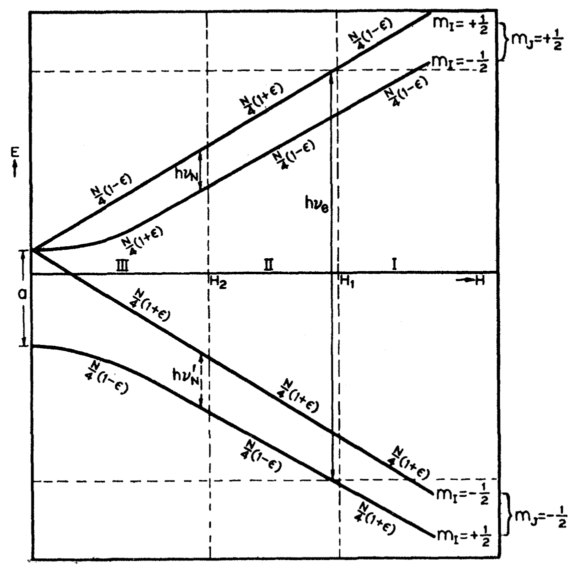

FIG. 1. Energy levels and their populations for a system with $I=\frac{1}{2}$, $J=\frac{1}{2}$.

in a microwave magnetic field of frequency ν_e and radio-frequency field ν_N, both being perpendicular to the external magnetic field H. For $H>H_1$ (see Fig. 1, region I), the population of both upper levels is given by $\frac{1}{4}N(1-\epsilon)$, where N is the total number of electrons and $2\epsilon\simeq g_e\mu_0H/kT$ is the electronic Boltzmann factor. (We are neglecting the nuclear Boltzmann factor $g_n\mu_0H/kT$ which is approximately 10^3 times smaller.) If we sweep through H_1, we will induce electronic transitions between the $m_I=+\frac{1}{2}$ levels. If we do this under adiabatic fast passage conditions,[4] the net magnetization of the electrons responsible for this transition will be turned through 180°. This reversal of the magnetization results in a reversal of the Boltzmann factor as indicated in region II of Fig. 1. At this stage, each set of levels corresponding to the same m_J exhibits a nuclear polarization and we could perform a nuclear resonance experiment in which the signal would be proportional to the electronic rather than the nuclear Boltzmann factor. However, the total population of both $m_I=+\frac{1}{2}$ levels equals that of the $m_I=-\frac{1}{2}$ levels, so that the sample as a whole does not exhibit a net polarization as yet. In order to obtain a net polarization we have to turn over the population of *only* one set of levels. This may be accomplished either by having a fixed radio-frequency and sweeping the magnetic field through H_2 in an adiabatic fast passage or keeping a fixed magnetic field and sweeping the radio-frequency. This is made possible by the fact that the spacing of the upper set of levels is different from the lower set ($\nu_N'>\nu_N$) as may be seen from the Breit-Rabi formula.[3] In order for only one transition to occur, the difference in level spacings has to be at least equal to the nuclear line width. The degree of nuclear polariza-