

DYNAMIC MAGNETIC HYSTERSIS OF AMORPHOUS FERROMAGNETS

J. Horvat, Ž. Marohnić* and K. Zadro**

Electrotehnical Institute "Rade Končar", Zagreb

*Institute of Physics of the University, Zagreb

**Department of Physics, Faculty of Science, Zagreb

ABSTRACT

Simple and accurate set-up for the measurements of dynamic magnetic properties of amorphous ferromagnetic ribbons is constructed. Measurements confirm their very good properties at frequencies 100kHz and reveal the origin of the loss in that range of frequencies. Conventional permalloy is also measured for the sake of comparison.

Because of their good soft magnetic properties (such as the low core losses high saturation magnetization and permeability) the amorphous ferromagnets are steadily replacing ferrites and other conventional materials in the high frequency applications. Since the properties of amorphous ferromagnets depend sensitively on composition, preparation conditions and on subsequent treatment(s), an accurate and simple technique for the measurements of magnetic properties at high frequencies is required in order to obtain the best material for a given application.

The experimental set-up described in this paper enables the accurate determination of the saturation magnetization, coercitive field, magnetic permeability, remanent magnetization, magnetic hysteresis curve and losses of magnetic ribbons (amorphous or crystalline) in the frequency range up to 100 kHz. The results of the measurements on the amorphous $\text{Fe}_{80}\text{B}_{18}\text{Si}_2$ and $\text{Co}_{70.2}\text{Fe}_{7.8}\text{B}_{12}\text{Si}_{10}$ alloys are compared to those for permalloy.

The set-up is designated for the measurements by the induction method on the samples with open shape (long straight ribbon). This geometry avoids the problems due to strains induced upon coiling the ribbons in closed shape and it also enables simple change of the sample. Furthermore the same coils are used for all samples which facilitates the comparison and diminishes the errors. The influence of the demagnetizing field is avoided by using long, narrow samples ($150 \times 2 \times 0.03 \text{ mm}^3$) in the homogenous magnetic field and a very short secondary coil (5 mm).

The arrangement (Fig.1) basically consist of two equal mutually perpendicular primary coils and of the interior secondary coils. In the center of one primary is placed secondary in which the sample, fixed to a fiber glass holder is introduced. The other secondary can be moved in the region of the lower field in the other primary and is connected in series with the first secondary. In this way

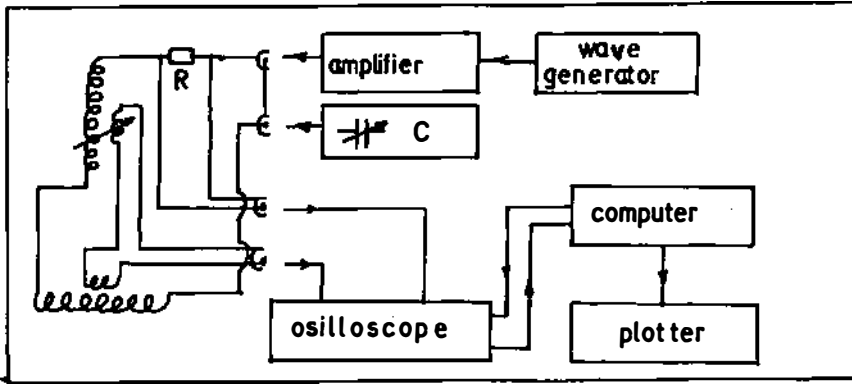


Fig. 1. Block diagram of the experimental set-up.

the effect of the magnetic field is eliminated and the output signal is proportional to time derivative of magnetization: $V = -N\mu_0 S dM/dt$, with N the number of turns in the secondary coil, S the crosssection of the sample and M magnetization. Primary coils are also connected in series and fed from the signal generator via an amplifier. A variable condenser is used to adjust the frequency of this circuit to that of the signal. Magnetic field is determined from the voltage (U) developed on the standard non-inductive resistor (R): $H = nU/R$ with n the number of turns per unit length of the primary. Sinusoidal field of constant amplitude (1600 A/m) is used at all frequencies. Both the output (V) and field (U) signals are fed to the digital oscilloscope connected with the personal computer for the data analysis. Obviously, the magnetization is obtained by the integration of V in time: $M = -\int V dt / N\mu_0 S$. For the calculation of hysteretic loss the same method of numerical integration (based on the third order parabola) was employed: $E = \int HV dt / NS$. The cross section S is determined from the mass, length and density of the sample.

The results of our investigation are shown in Figs. 2-5. Fig. 2 shows hysteresis curve for $Fe_{80}B_{18}Si_2$ alloy at different frequencies (f). Broadening of this curve with increasing f is apparent. The hysteresis of $Co_{70.2}Fe_{7.8}B_{12}Si_{10}$ and permalloy at 20 kHz are compared in Fig. 3. The increase in the width of hysteresis with f is the best monitored through the variation of the coercitive field (H_c) with f (Fig. 4). At the given frequency the width of hysteresis ($2H_c$) is the largest for $FeBSi$, intermediate for permalloy and smallest for nearly nonmagnetostrictive amorphous $CoFeBSi$ alloy. Fig. 4 shows that H_c 's of these alloys decrease in the same order at all frequencies. We note that for the samples with the same saturation magnetization variation of H_c with f would also represent the corresponding variation of losses.

Fig. 5 shows the frequency dependence of the loss per cycle and the unit volume (E) for all samples. It is seen that for amorphous alloys and $f > 20$ kHz $E = kf^n$.

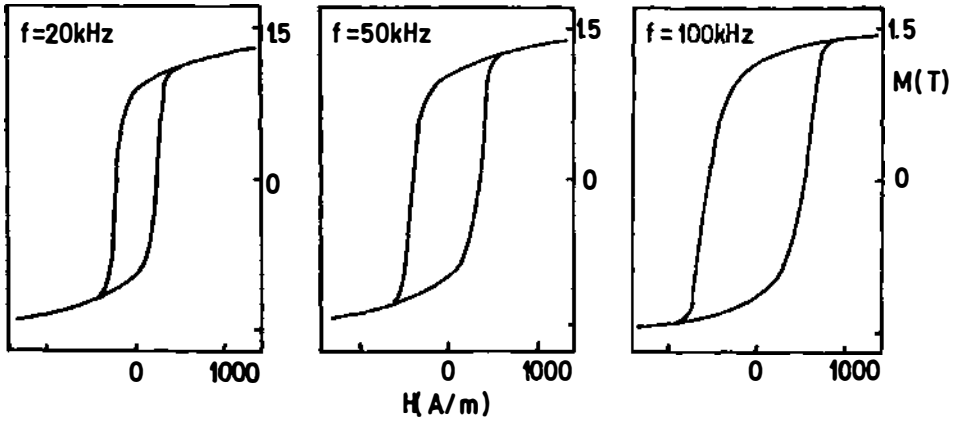


Fig. 2. Hysteresis curve of $\text{Fe}_{80}\text{B}_{18}\text{Si}_2$ sample at 20, 50 and 100 kHz

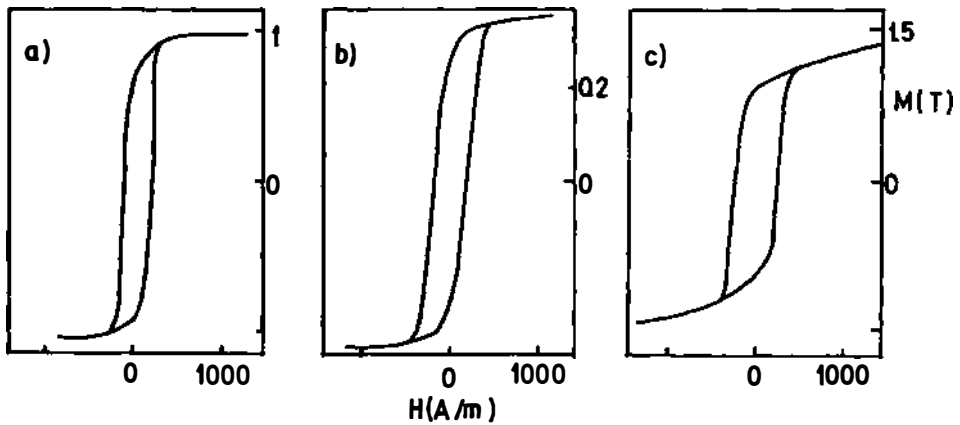


Fig. 3. Hysteresis curve of CoFeBSi (a), permalloy (b) and FeBSi (c) samples at 20 kHz

The identical value of $n = 0.58$ for both amorphous alloys indicates that the main source of the loss in that frequency range are the anomalous eddy currents [1]. Permalloy shows a more complicated variation which does not allow a simple explanation of his loss. We note that as obtained amorphous alloys were used in our measurements and hence their properties can be significantly improved by the further treatment.

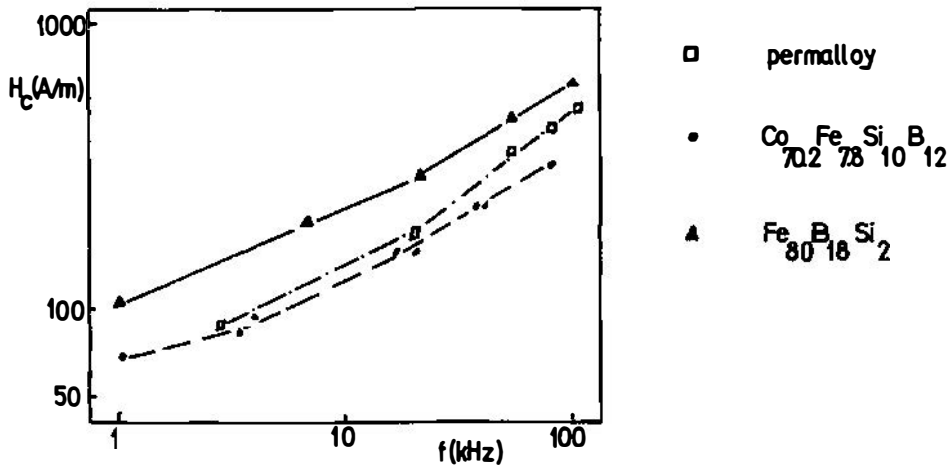


Fig. 4. Coercitive field vs. frequency for measured samples

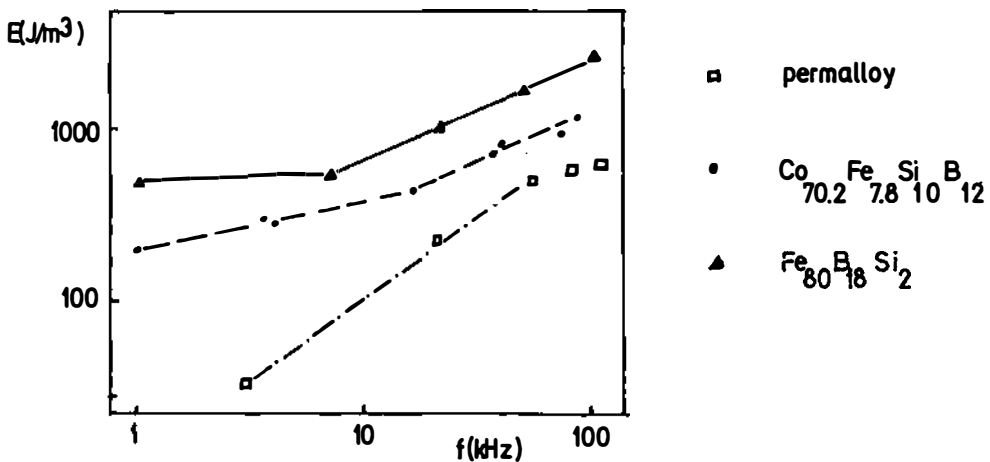


Fig. 5. Frequency dependence of the loss per cycle and the unit volume for the measured samples

In conclusion, a simple, accurate and reliable set-up for the measurements of the dynamic magnetic properties of ribbon shaped samples is constructed. Our measurements confirm very good characteristics of the amorphous alloys in the high frequency range ($f=100\text{kHz}$). Despite of higher saturation magnetization their losses compare favourably with that of permalloy. The main part of loss in these alloys appears to be due to anomalous eddy currents. Additional treatment of these alloys will further improve their properties.

REFERENCES:

/1/ F.E.Luborsky, in Amorphous Metallic Alloys, Butterworth, 1983, ed. F.E.Luborsky, p. 367