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Letters to the Editor

ON THE MATTEUCCI EFFECT IN THIN PERMALLOY WIRES

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The Matteucci effect (M.e.) consists in the induction of an electromotive force E_M at the ends of a torsionally stressed cylindrical ferromagnetic sample magnetized in a longitudinal cyclic magnetic field [1]. The connection of the M.e. with the elementary magnetization processes, accompanied by the Barkhausen jumps, has been established in the study of the M.e. [2–5]. Papers [6, 7] deal with the electric impulse forms in the M. e. in greater detail.

In this paper we want to report briefly the results obtained by an experimental study of the M.e. in cylindrical permalloy samples of various compositions and diameters, and to indicate a possibility of a practical use of the M.e.

For the study of the M.e., we have designed a measuring device that enables to stress samples simultaneously in torsion and tension in the cyclic magnetic field of a farmonic course with amplitudes ranging from 0 to 300 Oe, and with frequencies ranging from 20 Hz to 22 kHz. In a 20 cm long sample of PY 58, we have reached the maximum value of the electric impulse amplitude $E_M = 5.5$ V.

Samples of the required composition have been made by vacuum casting of technically pure iron and nickel, and by cold drawing to the required diameters after a preliminary mechanical treatment. The samples have been annealed in a pure hydrogen atmosphere for four hours at a temperature of 700 °C.

We have investigated the dependence of the electric impulse amplitude E_M upon the torsion twist value φ in thin cylindrical samples of PY-58. As seen from the course of the dependence shown in Fig. 1, the electric impulse amplitude E_M increases with the increase of the twist angle φ only up to certain value; it reaches a state of „saturation“. The twist angle, from which on the amplitude of impulses E_M practically does not change, is called the „saturation“ angle φ_s.

The electric impulse amplitude E_M also depends on the crossdimension of the samples. The impulse amplitude E_M decreases with the increase of the diameter of the samples. This corresponds to the decrease of the magnetization speed with an increase of the permalloy sample diameter [8]. The initial slope $\mathrm{d}E_M/\mathrm{d}\varphi$, as well as the „saturation angle φ_s, conspicuously depend on the heat treatment of the samples. In both the annealed and unannealed samples twisted up to „saturation“, the amplitudes of the impulses E_M reach the same values.

In the unannealed NiFe (15 % Ni) samples, a decrease of the impulse amplitude E_M

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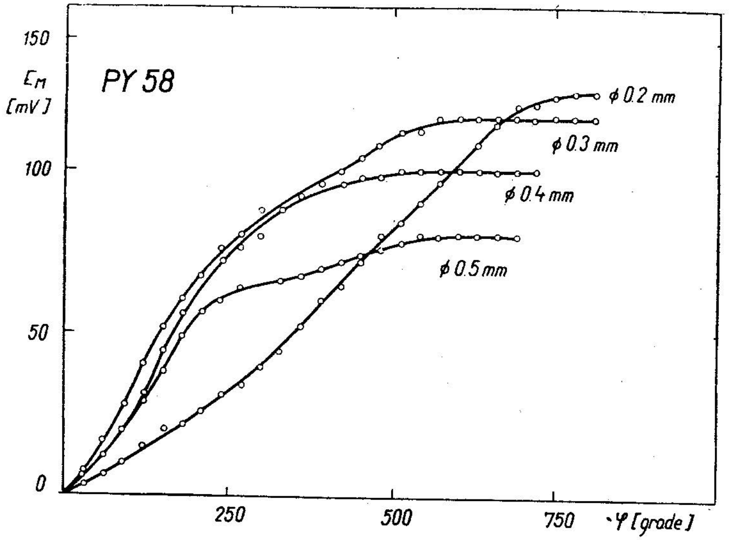

Fig. 1. The dependence of the amplitude of electric impulses E_M upon the twist angle φ for various diameters of unannealed PY 58 samples.

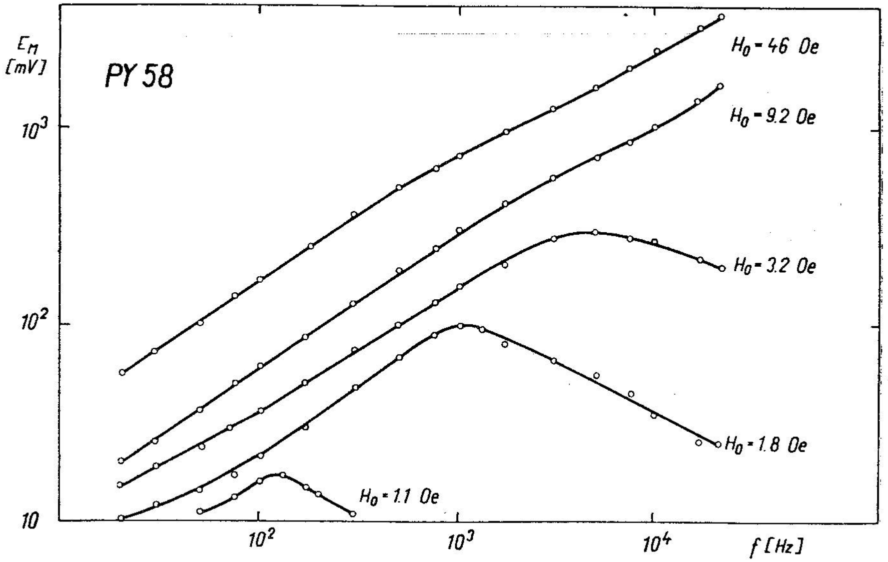

Fig. 2. The electric impulse amplitude E_M measured in annealed PY 58 samples as a function of the magnetic field frequency f for varios magnetic field amplitudes H_0.

with an increase in the tension stress was observed, similarly as in paper [9]. We have found by our measurements, however, that the effect of the tension changes at greater twist angles. Thus, e.g., at the „saturated“ sample twist, the electric impulse amplitude E_M at a tension of 39.8 kp/mm is 20 percent larger than at the zero tension stress.

The amplitude of electric impulses E_M in PY 58 samples increases with the increase of the longitudinal magnetic field amplitude H_0 in accordance with the exponential function $E_M \sim H_0^x$, where $x \approx 0.6$. The amplitude E_M similarly depends on the magnetic field frequency f. We have found by our measurements that this dependence does not generally hold in the whole frequency range. According to Fig. 2, at small field amplitudes H_0, the impulse amplitude E_M increases up to the so-called „critical“ frequency f_0, from which on the amplitude E_M gradually decreases. Thus, e.g., at the field amplitude $H_0 = 1.1$ Oe, E_M increases up to $f_0 = 125$ Hz only, at $H_0 = 1.8$ Oe up to $f_0 = 1$ kHz and at $H_0 = 3.2$ Oe up to $f_0 = 5$ kHz.

It seems that the M.e. can be used for the location of failures in ferromagnetic samples. For local magnetization a small coil easily movable along the sample, was used in our experiments. Fig. 3 shows the dependence of the electric impulse amplitude E_M upon the magnetization coil position l. Both the position and the magnitude of the E_M amplitude decrease correspond to the positions and the magnitudes of the mechanically caused defects 1 and 2. The course of the dependence $E_M = E_M(l)$ before the defects have been brought about is marked by the dashed line.

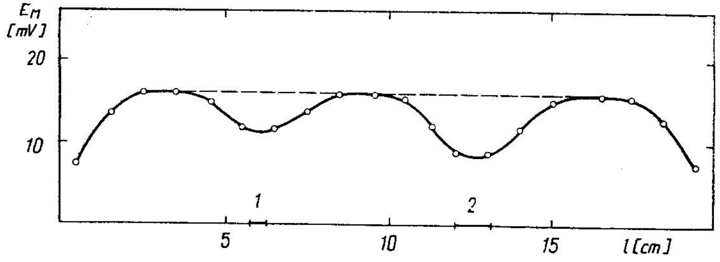

Fig. 3. Axial location of failures in a ferromagnetic sample by means of the Matteucci effect.

The authors of papers [10, 11] have shown that the torsional stress affects the magnitude of the Barkhausen jumps as well as the cyclic magnetization wave speed. On the basis of our experimental study of the M.e., we have come to the conclusion that the Matteucci effect at the „saturation“ twist of permalloy samples is an accompanying phenomenon of the great Barkhausen effect, which occurs at the cyclic magnetization of the circular magnetization component appearing at the torsional stress of ferromagnetic materials. At the same time, the amplitude of the electric impulses E_M in the M.e. corresponds to the propagation velocity of the magnetization wave.

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