Proceedings of the Iowa Academy of Science

Volume 67 | Annual Issue Article 55

1960

# The Effect of Core Current on Magnetic Materials

John B. Dinklage
*Grinnell College*

# The Effect of Core Current on Magnetic Materials

JOHN B. DINKLAGE[1]

*Abstract.* The effect on the hysteresis of sending a direct current through the core of a ferromagnetic torroid is described. A model describing this effect is then related to the magnetostrictive properties of the material. An easy method for determining the "polarity" of the magnetostrictive properties of a material is presented.

Small torroids were constructed by winding magnetizing and pickup coils on a ferromagnetic wire. A nickel torroid was made of an 81.6 cm., .040″ Ni wire on which were wound a magnetizing coil of 3,400 turns and a secondary of 3,000 turns, insulated from each other and from the core by spaghetti. The wire was bent to form a torroid, and the ends butted together to form a closed magnetic circuit but insulated electrically by a thin film of polyethylene. The film assured electrical insulation at the joint so that a direct current could be run through the core but not across the junction. An adequate magnetic coupling was retained.

The hysteresis curves were displayed by conventional technique on a type 541 Tecktronix scope, using a type E plug-in unit. The integrator constants were 27k and 4 uf.

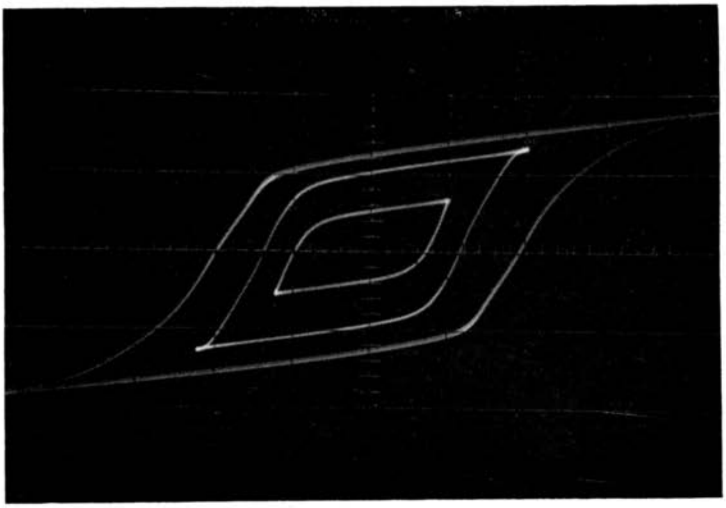

Figure 1. A family of hysteresis curves of a Ni torroid.
Calibration: 7.4 oersteds/division, horizontal
2,290 gauss/division, vertical

[1]Department of Physics, Grinnell College, Grinnell, Iowa.

A family of Ni hysteresis cures is shown in Figure 1. Figures 2*A* and 2*B* show the hysteresis of Ni taken while 8 amp DC was sent through the core. The direction of the core current in Figure 2*A* is opposite from that in Figure 2*B*. The unsymmetrical effect from the core current in Ni was not observed in Mumetal which is discussed later.

Sometimes loops appeared at the tips of the hysteresis curves. In these figures they are for the most part "integrated out", for they appear if a lower value for the capicator is used in the integrator. These loops seem to be related to the past magnetic history of the torroid's core, for they do not always appear, under the same conditions. They may merit further investigation.

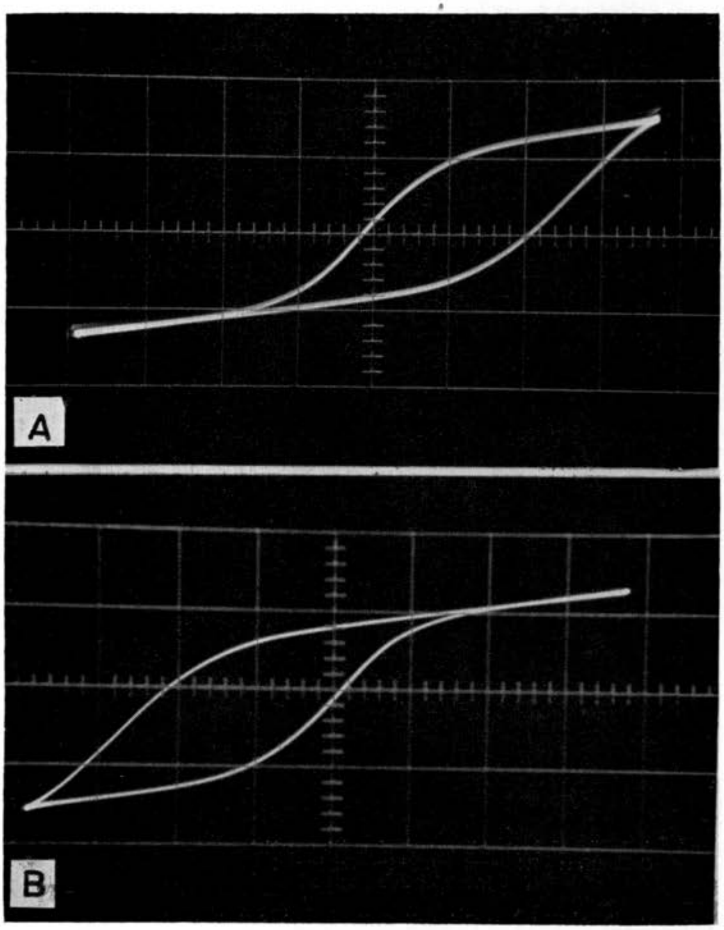


Figure 2. A. Hysteresis curve of a Ni torroid taken while 8 amp DC were sent through the core. B. The same, with direction of the core current reversed. Calibration is the same as in Figure 1.

The distortion of the hysteresis effect by core current is not a new phenomenon. Bozorth (1955, p. 502) refers to the work of Fenzi, who observed the same phenomenon in 1891. I ascribe this distortion of the hysteresis curves to domain rotation in the core and suggest that this rotational model is in agreement with a rotational model which relates to the magnetostrictive properties of the ferromagnetic core, to be described later.

The DC in the wire core of the torroid creates a biasing field in the wire which is concentric about the axis of the wire. This field tends to align the domains in a circular direction in a plane perpendicular to the axis of the wire (transverse direction). There was no stress or torsion on the core of the torroid, though it was noticed that the shape of the hysteresis is sensitive to changes in both, as the following comparison suggests.

The effect of biasing the domains in a transverse direction by core current, as shown in Figures 2*A* and 2*B*, is the same effect described by Bozorth (1955, p. 608) when he investigated the hysteresis of a Ni wire under tension. Thus, current in a Ni wire has the same qualitative effect on the domains as stress in the wire. This is in agreement with the negative magnetostriction attributed to Ni. Negative magnetostriction means that under stress the domains align themselves transversely.

Figure 3 shows a family of hysteresis curves on Mumetal. Core current in a Mumetal torroid affects its hysteresis in the same general manner as in a Ni torroid. Figure 4 shows a double exposure

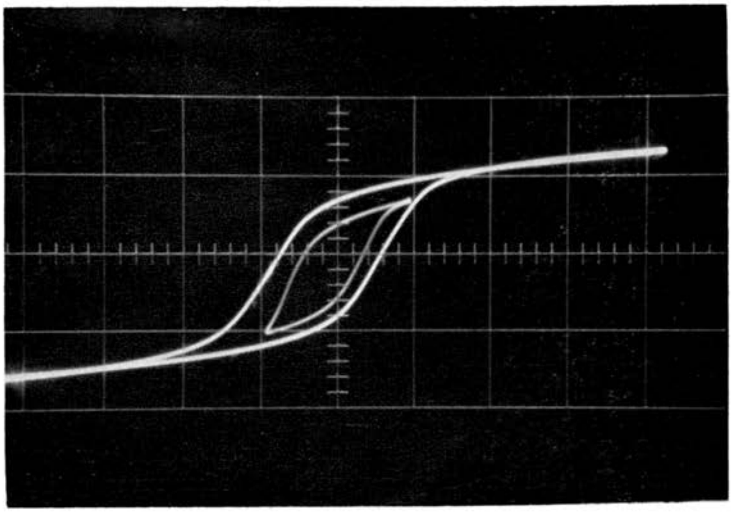

Figure 3. A family of hysteresis curves of a Mumetal torroid.
Calibration: 0.52 oersteds/division, horizontal
1,830 gauss/division, vertical

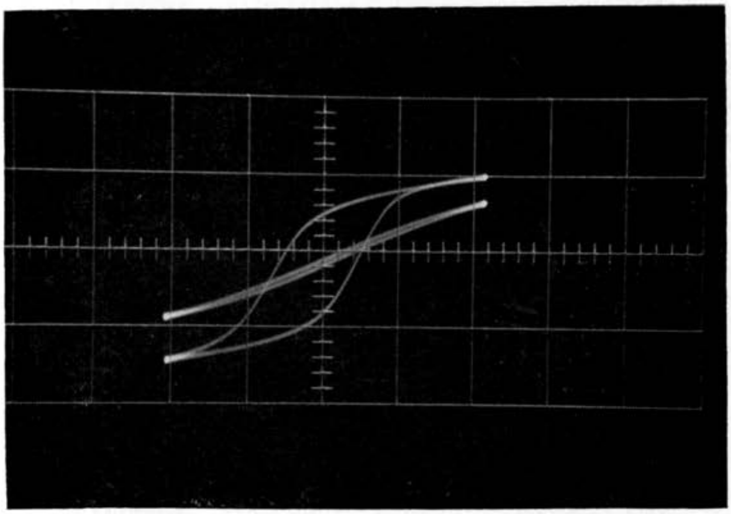

Figure 4. A double exposure of two hysteresis curves on a Mumetal torroid. The fat curve is normal; the thin curve shows the effect of 2 amp DC through the core. The direction of the core current did not change the shape of the thin curve. Calibration is the same as in Figure 3.

of a normal Mumetal hysteresis curve and the resulting curve when 2 amp DC is sent through the core. This effect is to be expected, assuming the rotational model. The Mumetal hysteresis was symmetrical with respect to the direction of core current, whereas Ni was not.

Mumetal is positively magnetostrictive, however, which means that stress aligns its domains longitudinally. This suggests an area for further investigation. If stress could be applied to a positively magnetostrictive wire to nullify the simultaneous effect of core current on its hysteresis, the biasing torque on a domain from the stress would then oppose the biasing torque from the core current-field, possibly leading to a quantitative study of the forces on the domain.

The Mumetal torroid consisted of a magnetizing coil of 100 turns and a pickup coil of 1,500 turns wound on a 60 cm., .031″ Mumetal wire. The torroid was constructed in the same manner as the Ni torroid.

## A Quick Method to Determine the Magnetostrictive "Polarity" of a Material

Grant O. Gale (1954, 1957) has earlier reported on other aspects of current effects in ferromagnetic wires. Further investigation of this effect has been done using the following experimental setup.

A ferromagnetic wire about a foot long was placed inside of a

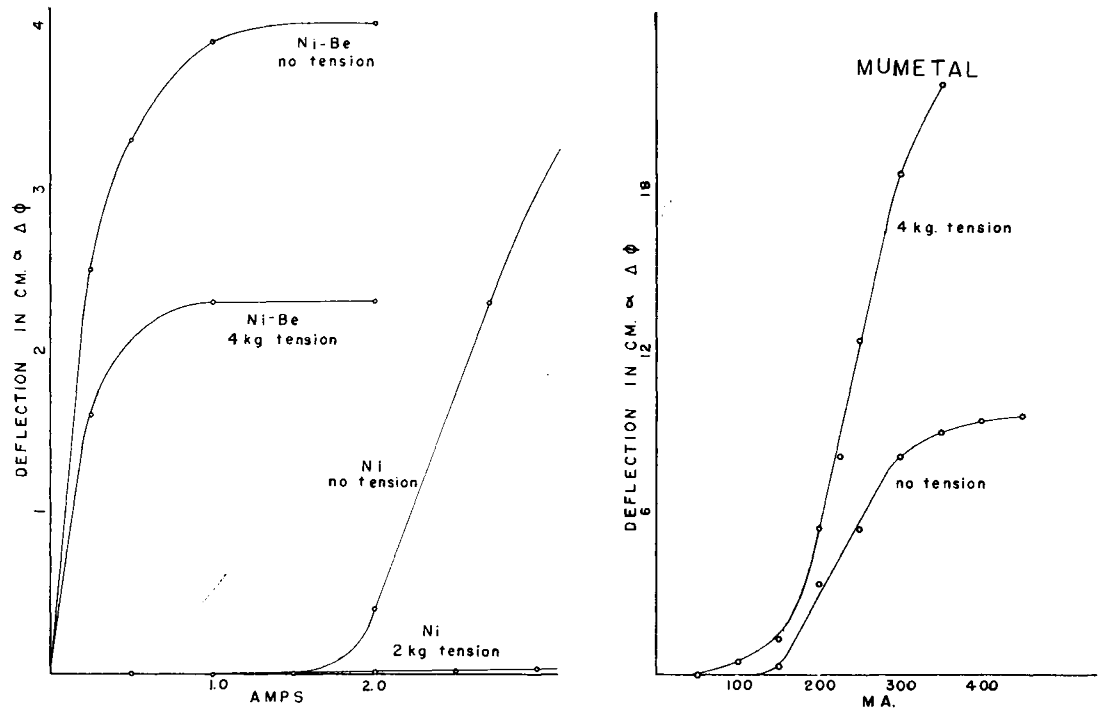


Figure 5. The magnitude of a DC started in different wires is plotted horizontally. Starting the DC in the wire produces a signal in a search coil surrounding the wire. The magnitude of the signal is plotted vertically.

pickup coil of about 22,000 turns. The output signal from the pickup coil was fed to a critically damped galvanometer. Means for sending a direct current through the wire were provided.

In Figure 5 the magnitude of the signal induced in the pickup coil by starting a direct current in the wires is plotted against the magnitude of the DC started.

These results are explained by the rotational model. Stress on Ni tends to align the domains transversely, as does the DC in the wire. It is the rotation of the domains, considered here as bar magnets, which causes flux to cut the secondary and produce the signal. Under tension, the domains in Ni have a smaller angle through which they may rotate until they become completely oriented in the transverse direction. Hence tension in Ni squelches the effect. In positively magnetostrictive materials (Mumetal) the domains are aligned longitudinally under stress, allowing the core current-field to rotate them through a greater angle and produce a greater signal in the secondary.

This effect can be used for a quick test to determine the magnetostrictive "sign" of a material, as was done on the NiBe sample. A direct current is started in the wire and the voltage produced across the pickup is read. If tension increases the voltage produced by starting the same current again, the material is positively magnetistrictive, and vice versa. There is great demand for a method as simple as this if it can be refined to give some quantitative magnetostrictive information about the sample.

This report verifies some of Mr. Gale's previously reported data (1954, Figure 2). This was done, qualitatively, by using a ballistic galvanometer in place of the DC amplifier and recording potentiometer which he used.

## Literature Cited

Bozorth, R. M. 1955. Ferromagnetism. D. Van Nostrand Company, Inc., New York.

Gale, Grant O. 1954. An electromagnetic effect. Proc. Iowa Acad. Sci. 61: 330-333.

——— and Sullivan, George. 1957. Current effects in ferromagnetic wires. Proc. Iowa Acad. Sci. 64: 457-460.