Does Nickel Show a Positive Elongation in the Joule Magnetostrictive Effect?

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The question as to whether there is a positive Joule magnetostrictive effect in nickel has once more arisen. The following note points out that there is no positive elongation unless remanent magnetism or an extraneous field is present to give the sample of nickel a preliminary magnetization before the main field is applied. Even then, there is no positive elongation unless the preliminary magnetization is opposed to that of the main field.

THE above question seems to have cycles of recurrence. Not always does it take the form of the caption. In 1893–1904, Honda and Shimizu[1] carried on an extensive discussion with Heydweiler[2] concerning the presence or absence of a Villari reversal effect in nickel. If the Villari reversal effect occurs in nickel, then a positive elongation of nickel should also be found in the Joule magnetostrictive effect. This relation between the Villari and Joule effect seems to be very definitely established.[3]

Recently two papers[4] have appeared purporting to show a positive elongation for the Joule magnetostrictive effect in nickel and saying that it is an effect to be expected.

It is desired to point out that this may be misleading as these two papers state definitely that in the regular Joule magnetostrictive effect they did not find a positive elongation. They found a positive elongation only when the magnetizing force was reversed in observing a hysteresis curve for the Joule magnetostrictive effect. A positive elongation in nickel occurs only when there is remanent magnetism present in the specimen or an extraneous field is imposed, and then *only when the magnetizing field is opposed in direction to the remanent magnetization or the extraneous field.*

In Fig. 1 are shown continuous records of the changes in length of a nickel rod as the magnetizing force is increased from zero up to 71.2 gausses. The vertical lines in the photographs denote certain currents' strengths in the magnetizing coil. All of the photographs in Fig. 1 show six vertical lines and represent field strengths of 0, 14.2, 28.5, 42.7, 56.9, and 71.2 gausses respec-

[1] Honda and Shimizu, Ann. d. Physik **14,** 791 (1904); Phys. Zeits. **5,** 254 (1904); Ann. d. Physik **15,** 855 (1904); Phys. Zeits. **5,** 631 (1904).

[2] Heydweiler, Sitzungsber. d. Wurzb. phys. med. Ges. **11** Marz (1893); Phil. Mag. **35,** 469 (1893); Beibl. **17,** 1095 (1893); Ann. d. Physik **52,** 462 (1894); **15,** 415 (1904); Phys. Zeits. **5,** 255 (1904).

[3] Thomson, Applications of Dynamics to Physics and Chemistry, pp. 48–63, 1888. Williams, Proc. A.S.T.M. **19,** Pt. 2 (1919); School Science, and Math. **22,** 859 (1922); Phys. Rev. **10,** 129 (1917); Jour. Franklin Institute **203,** 843 (1927).

[4] Dietsch, Zeits. f. techn. Physik **12,** 380 (1931). Kersten, Zeits. f. Physik **72,** 500 (1931).

tively. In Fig. 2 the maximum field strength was carried up to 413 gausses. The constant of the magnetizing coil was 142.4 gausses per ampere.

The magnetizing coil in these experiments stood in a vertical position. In *a* the vertical rod was demagnetized by a decreasing a.c. in the presence of the vertical component of the earth's magnetic field. This shakes the rod

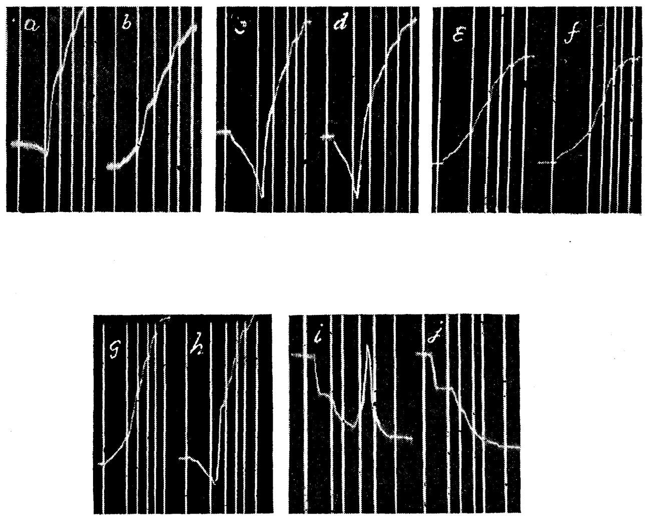

Fig. 1.

down and leaves it permanently magnetized in a direction with the north pole down. When the magnetizing field in the solenoid was applied to the rod, with the field of the solenoid directed upwards, a positive elongation occurred. In *b* the rod was again demagnetized, in the presence of the earth's magnetic field, but this time the magnetizing force in the solenoid had its

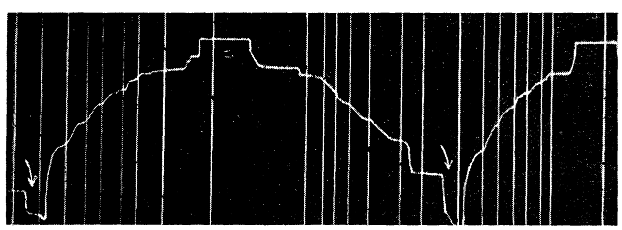

Fig. 2.

direction downwards. This time there is absolutely no positive extension of the rod.

In *c* and *d* no demagnetization occurs, but in both curves the magnetizing force is reversed to what it was in the preceding magnetization. The magnetizing force in both cases is opposed to the remanent magnetism of the nickel rod. This is the effect observed by Dietsch and theoretically discussed by Kerstens. If no demagnetization occurs and the magnetizing force is applied each time in the same direction as the remanent magnetism of the nickel rods, then no positive elongation occurs. This is illustrated by the curves *e* and *f*, Fig. 1.

By means of a second coil surrounding the main magnetizing coil, one may apply an extraneous field and leave it on while the rod is being magnetized by the main coil. *g* and *h* show what occurs when the rod is demagnetized in the presence of this field and then the main magnetizing force is applied. This extraneous field had a value about three times as great as the vertical component of the earth's magnetic field. In *g* it will be observed that no positive elongation occurs since the main magnetizing force is in the same direction as the extraneous field. A positive elongation in the presence of this extra field occurs only when the main magnetizing force is opposed to the added field. This is shown in *h*, Fig. 1. It will be noted that the positive elongation in *h* is greater than in *a*.

One may apply any magnitude of extraneous field he chooses, and introduce it at any value of the main field desired and so get any form of curve one may select for the Joule magnetostrictive effect in nickel. In *i* and *j* are shown the queer changes in length which can be obtained for iron if one applies extraneous fields. In *i* there is an elongation then a shortening followed by a second elongation, while in *j* the change in length is wholly an elongation.

In Fig. 2 is shown a hysteresis curve of the Joule magnetostrictive effect in nickel. It is one continuous run in which the two points of positive elongation are indicated by arrows. These are the so-called positive elongations found by Dietsch and are of the same type of elongation as shown in *c* and *d*, Fig. 1. In the true sense of the word they are not positive elongations. Thus far we have no positive indications to show that either the Villari reversal effect or the Joule positive elongation occurs in nickel.

Particular attention is called to Fig. 2 to show how well the temperature changes are controlled. If temperature were affecting the length then the horizontal portions of the curve would not be parallel to the edge of the photographic film, but would be tilted up or down as the film progressed past the slit in the camera.

The inference has been made in a number of papers that the capacity-beat method is the only method by which these positive elongations may be detected. This inference is to be challenged. The mechanical-optical device with which the curves in Figs. 1 and 2 were made fifteen years ago did not begin to approach the limit to which it could have been pushed and yet it shows this positive elongation very plainly. Furthermore, since these photographs were made, a greatly improved extensometer has been constructed and will be described in a subsequent paper. The ability to secure a continuous record of the changes in length is a very desirable feature of any extensometer.