FURTHER EXPERIMENTS ON THE PROPAGATION OF LARGE BARKHAUSEN DISCONTINUITIES

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The formula[1] for the time of penetration for a large travelling Barkhausen discontinuity has been recalculated on the assumption that at each point on the discontinuity in the wire the resultant of the impressed field H and the eddy current field is the critical field H_0. This results in doubling the numerical coefficient so that the formula now reads

$$\delta t = 3.94 \times 10^{-8}\ a^2 \Delta I/\rho(H - H_0) \tag{8A}$$

where a is the radius of the wire, ΔI the change in induction, and ρ the specific resistance. This alteration halves the ratio of $\delta t_{\text{exp}}/\delta t_{\text{calc.}}$ as given in Table I[1] to the value 2. The corresponding formula for a strip of thickness $2a$ has the coefficient 7.88×10^{-8}. Oscillograms taken, however

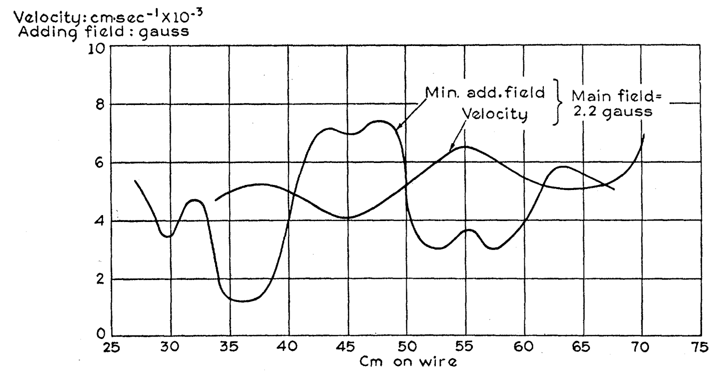

Fig. 1.

to check the validity of these formulas for different size wire fail to verify them, in that t was proportional to a rather than to a^2. Empirical substitution in the formula of $0.031a$ for a^2 reproduce the experimental values reasonably well. Probably the assumption regarding the magnetic field balance at the discontinuity in the wire needs revision. Perhaps the existence of a field arising from the distribution of magnetic pole strength along the wire should be taken into consideration.

Introduction into the formula of either the velocity of propagation v, or the spatial length λ of the discontinuity naturally involves the other of these two quantities through the relationship $\delta t = \lambda/v$. Thus the slope A of the $v-H$ characteristic can be expressed by the formula

$$A = \frac{v}{H - H_0} = 0.26 \times \frac{10^8 \rho\lambda}{0.031 a \Delta I}\cdot$$

This shows that over the considerable ranges of magnetic field, tension and wire radius where ΔI and A change only slightly, λ/a should also be constant to the same degree. This has been verified experimentally.

In the propagation of large discontinuities, two parameters were found to be of particular significance, H_0, the critical field below which no propagation could be obtained, and the constant A, giving the slope of the velocity-field curve. In the wires investigated the change in H_0 with tension, heat treatment, etching, etc., is very similar to the change in coercive force in ferromagnetic wires which have small discontinuities. The slope, however, varied in ways not at all suggestive of other known properties of the material.

[1] K. J. Sixtus and L. Tonks, Phys. Rev. **37**, 930 (1931), Eq. (8).

The first series of experiments bearing on slope variation were conducted with etched wires. Since the front edge of the discontinuity lies on the surface of the wire, it was of interest to observe what effect changes in the surface, such as caused by etching, would have. For wires which were etched from 15 mil down to anywhere between 14.8 and 5 mil, the slope A increased about 50 to 100 percent. It could be shown that neither the reduction in diameter itself, nor absorption of hydrogen was the cause. It may be that the cracks which developed in the surface during the etching were responsible for this effect.

In other experiments a circular field was applied by sending a current through the wire which was under tension and torsion or under torsion alone. In this case also variations in slope of 60 percent were observed.

A plausible explanation for this behavior in the last experiments was finally found as a result of investigating the possible connection between critical adding field and $v-H$ slope at different places along the wire. In places where only a small adding field was necessary to start the discontinuity with a given main field, the velocity and also the $v-H$ slope were higher than in places where a higher adding field was needed. (Fig. 1.) A small critical adding field evidently indicates that the alignment of the magnetic axis of the elementary regions is imperfect, and we may conclude that in regions with imperfect alignment the velocity and slope is high and vice versa.

Thus we arrive at the view, that in the experiments with etched wires the applied tension cannot produce a perfect alignment in the surface of the wire on account of the irregular cracks present. In the other set of experiments, too, the circular field presumably produces a deviation from perfect alignment resulting in an increase in slope.

EFFECT OF IMPURITIES ON FERROMAGNETISM*

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ELEMENTS present in, or added to iron may generally be divided into two classes depending on the position they occupy in the iron space lattice. The first class includes the elements that take the place of the iron atoms and for this reason are called *substitution elements*. Even in large percentages they remain as a part of the iron lattice. Some of them, like Ni and Co, are soluble in all proportions. Others, like Si and Al, have an unlimited solubility in the liquid state and a limited solubility in the solid state due to their tendency to form compounds with iron that are precipitated and can be identified as distinct phases under the microscope. The other class of elements are sufficiently different from iron to prevent their atoms from falling into the ranks of the iron atoms, and yet there are definite indications that to a small extent they become entangled in the iron lattice. Such elements are sometimes called *interstitial elements*, because the only way in which the experimental results can be accounted for is by assuming that their atoms, within the slight solubility range, occupy the position *between* the iron atoms. To this class belong C, O, N and S. If the solubility range (less than 0.01 percent) is exceeded, they are precipitated from solution as compounds of iron, Fe_3C, FeS, FeO, etc. as the temperature drops towards room temperature.

The term "impurities" will be applied to the elements of the second class, because they are usually found in the iron whether they are wanted or not and are very difficult to remove quantitatively. What applies to iron in this respect applies in general to nickel and cobalt and to alloys of these three elements with each other and with other substitution elements.

The effect of impurities on the magnetic properties of iron has been studied very extensively in an attempt to determine the magnetic properties of actually pure iron. While the effect of small amounts of impurities on the saturation value is very small, their effect on the initia- and maximum permeabilities and on the coercive force and hysteresis loss is very great. An

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