Effect of Previous History on Switching Rate in Ferrites*

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Existing theories of switching of square-loop ferrites indicate that the rate of switching is a function of the present state of magnetization and of the applied field. Experiments are described which show that the switching rate is also dependent on previous history.

Two cases have been studied. In the first case, the ferrite was partially switched to a predetermined extent by a pulse of variable amplitude and then the switching cycle was completed by a pulse of fixed amplitude. In the second, the ferrite was brought to the remanent state by a pulse of variable amplitude before the switching cycle. Changes as great as two to one in switching rate were produced by variations of previous treatment.

INTRODUCTION

THE theories of Haynes[1] and Gyorgi[2] both lead to equations which express the rate of change of magnetization of a square-loop ferrite as functions of the magnetization and the applied field. Haynes assumes motion of 180° domain walls from randomly scattered nucleating centers as the mechanism for low applied fields. At higher fields, incoherent rotation is postulated by Gyorgi. Both equations fit experimental switching curves for complete switching by constant applied fields, provided certain undertermined parameters are adjusted. To what extent these mechanisms overlap at intermediate fields is unknown.

Some effects are described in this paper which cannot be adequately explained by either theory. Considerable differences are found for the rate of change of magnetization with the same applied field for samples, which have been brought to a given state of magnetization in different ways. The same state of magnetization for a macroscopic sample may occur with quite different detailed arrangement of the domains. The differences between possible arrangements of domains apparently are of greater importance than has been previously thought.

Since the thickness of the walls of commercially available cores is such that the field changes appreciably with radius, affecting the results in some experiments, cores were prepared by grinding, which had thin walls. Those used in most of the experiments below had inside and outside diameters 0.060 in. and 0.050 in., respectively, and were prepared from General Ceramics S4 cores.

INTERRUPTED SWITCHING

Experiments on interrupted switching by Gyorgi and Rogers[3] in 1956 appeared to show that the rate of magnetization was dependent on previous treatment as well as on the present state of magnetization and the applied field. However, Haynes[1] states that a careful study of interrupted wave forms shows no serious discrepancies. We have carried out experiments on interrupted switching in an attempt to resolve this contradiction.

Cores in the remanent state were switched by two pulses of equal amplitude, the first of which was of insufficient duration to switch the core completely. The interrupted switching curve produced by these two pulses was compared with the complete switching curve produced by a longer pulse of the same amplitude.

The curves shown in Fig. 1A are for conditions such that 50% of the flux change was produced by the first pulse. As may be seen the response produced during the completion of the switching by the second pulse very nearly coincides with the corresponding part of the complete switching curve. Similar results were obtained when the interruption in switching occurred earlier or later, and for various amplitudes of the switching pulse. These results agree with the statement of Haynes.

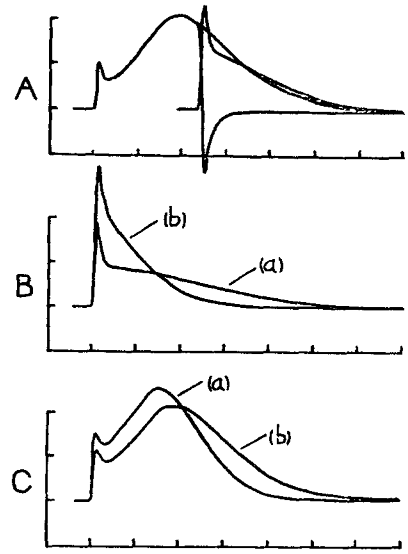

FIG. 1. Tracings of response curves. Vertical scale 0.1 v/division. Horizontal scale 0.2 μsec/division. Excitation 800 ma turns. A. Interrupted switching. B. Second half of curves when initial pulse was (a) 680 ma-t. (b) 1200 ma-t. C. Switching curves when core was previously reset by (a) 800 ma-t. (b) 1600 ma-t.

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[1] M. K. Haynes, J. Appl. Phys. **29**, 472 (1958).
[2] F. M. Gyorgi, J. Appl. Phys. **29**, 283 (1958).
[3] F. M. Gyorgi and R. Rogers, Conference on Magnetism, Boston (1956), p. 637.

SWITCHING BY TWO PULSES OF DIFFERENT AMPLITUDE

The main difference in conditions between this experiment and the one described in the previous section was that the two pulses used to switch the core were not of the same amplitude. A minor difference in technique used in this and succeeding experiments was the use of a series of three large pulses, of alternating polarity, in place of a single reset pulse. Some small effects due to previous treatment were removed by this procedure and the standard state of the core at the remanent point was made more reproducible.

In Fig. 1B an example is given showing the response produced by the second switching pulse of 800 ma turns. In both cases the duration of the first pulse had been adjusted to produce a flux change equal to 50% of that for complete switching. The difference in condition of the core at the beginning of the second pulse results from the difference in amplitude of the first pulse, 1200 ma-turn and 680 turns as indicated.

Many measurements have been made of curves such as the above. In all cases, significant dependence of switching rate on the value of the current which had been used to bring the core to the given state of partial magnetization was found. The greatest change in switching rate found due to this cause was approximately two to one.

EFFECT OF VARIATION OF RESET PULSE

A similar, although less marked, dependence of switching rate on previous history was found when the amplitude of the reset pulse preceding the switching cycle was varied. In Fig. 1C the two curves show the response for an 800 ma turn switching pulse when the core had been previously brought to the remanent state by 800 and 1600 ma turn pulses.

The greatest change in switching rate found due to this cause was approximately 50%.

A subsidiary experiment was performed to determine whether the difference in condition of the cores at the beginning of the switching cycle was due to the rate at which they had been reset, or to the maximum field in the reverse direction to which they had been exposed. The rectangular reset pulse was replaced by a triangular ramp with constant rate of rise of current but variable duration and maximum current. Resetting the core always occurred at a constant rate during the earlier part of this pulse. Comparatively little variation of the following cycle was found in this experiment. This appears to indicate that the effect shown in Fig. 1C was mainly caused by variation in the rate at which the core was reset.

EFFECT OF A TRANSVERSE FIELD

If a strong transverse field (i.e., a field perpendicular to the plane of the toroid) is applied and then removed the core is left in a state where the tangential magnetization is very small. The core can then be magnetized to saturation by a switching pulse in a winding through the core. The flux change during this operation has been found to be approximately 50% of that for complete switching, which is what might be expected. The form of the switching curve under these conditions has been compared with curves for completion of switching of half-switched cores as shown in Fig. 1B. It has been noted that the response after half-switching becomes more and more similar to the response after transverse field as the amplitude of the initial half-switching pulse is increased.

It has been previously shown[4] that the reversible or elastic component of magnetization varies approximately 3:1 between the remanent state and the demagnetized state. It is of interest to note that when the core is demagnetized by transverse field, the elastic response is approximately three times that at remanence also.

DISCUSSION

We are unable yet to give any theoretical explanation of the effects described. There is, however, some evidence that 180° domain wall motion is not the only mechanism even at low fields. The measurements of reversible magnetization appear to indicate that some domains are magnetized in a direction perpendicular to the toroid circumference in demagnetized samples. The resemblance between cores demagnetized by transverse field and cores demagnetized by partial switching strengthens this view.

[4] R. W. McKay, J. Appl. Phys. **30**, 565–575 (1959).