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MAGNETIC PROPERTIES OF FERRITE CORES UNDER DC-BIASED FIELD

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Ferrite cores are often magnetized under DC-biased field because they have been intensively used in electronic circuits such as an inverter circuit and a switching regulator circuit. Thus we investigated the effects of DC-biased field on magnetic properties in the frequency range of DC-100kHz for two kinds of ferrite cores, TDK PC38 and TDK H_3S, which have different shapes of B-H loop from each other. The magnetic loss per cycle, W/f, in the H_3S core decreased with increasing the strength of DC-biased field, although W/f in the PC38 core increased monotonically with DC-biased field. The observed decreasing tendency differs from the previous result for Si-Fe and ferrite cores, and can be attributed to decrease in eddy current loss as well as that in hysteresis loss.

Ⅰ. INTRODUCTION

Ferrite cores have been intensively used in electronic circuits such as an inverter circuit and a switching regulator circuit, in which the cores are often magnetized under DC-biased field. Consequently, DC-biased field affects their magnetic properties such as the permeability and the magnetic loss. In a Si-Fe core, it has been reported that the magnetic loss at a commercial frequency increases with increasing the strength of DC-biased field [1]. For a ferrite core, M. Murasato et al. have reported that the magnetic loss increased with increasing the strength of DC-biased field [2]. Thus it is important to clarify the effects of DC-biased field on magnetic properties in terms of designing circuits as well as physical interest in the magnetization process. However, details of effects of DC-biased field in ferrite cores, which are used at higher frequencies than Si-Fe cores, have been left unknown.

In this study, we investigated the effects of DC-biased field on magnetic properties of ferrite cores at the frequency range of DC-100kHz, and found that the effects of DC-biased field on the magnetic loss in TDK H_3S ferrite core extremely differs from that reported previously [1,2].

Ⅱ. EXPERIMENTAL PROCEDURE

Toroidal Mn-Zn-based ferrite cores, TDK H_3S and TDK PC38 were used for measurement in this study. The sizes and the electric resistivity of the measured cores are shown in Table. Ⅰ.

Table. Ⅰ The sizes and electric resistivity of [illegible] cores.

Sample	Magnetic Length (cm)	Cross Section (cm^2)	[illegible]
H_3S	7.85	0.45	[illegible]
PC38	7.78	0.402	~10

Hysteresis loops measured at 40kHz under a symmetrical excitation condition are shown Fig. 1. The loop of H_3S is wider than that of PC38 because of its low electric resistivity,

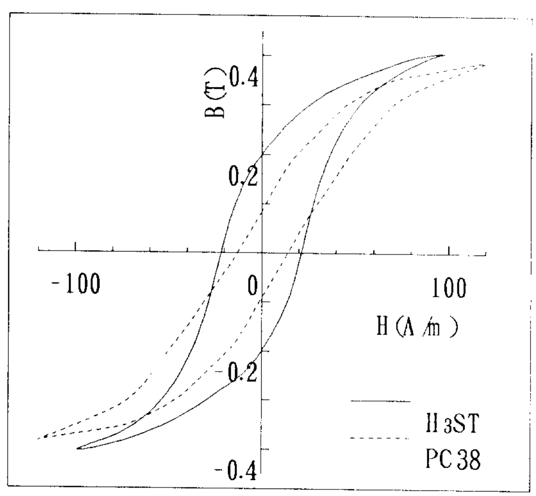


Fig. 1 B-H loops for H_3S and PC38 measured at 40kHz under a symmetrical excitation condition.

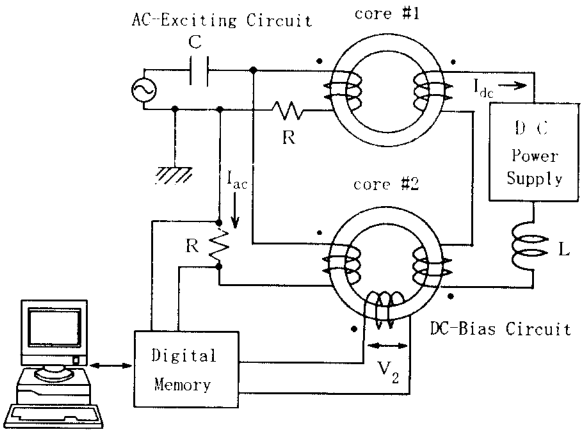


Fig. 2 System used for measuring AC magnetic properties under DC-biased field.

but its width becomes narrow at the region of $B_m \geq 0.1T$. On the other hand, the loop of PC38 looks like a parallelogram and the width of the loop is nearly constant up to B_m=0.3T.

The used system for measuring AC magnetic properties is shown in Fig. 2 schematically. DC-biased field was applied to the cores by a DC-bias circuit. In order to cancel the voltage induced in the DC-bias circuit, we used a couple of cores #1 and #2 whose windings for DC-current are connected in inverse series. Furthermore, a series inductor was used to suppress AC current in the circuit. AC flux density was determined by measuring V_2 induced in the secondary winding, and the magnetic loss was calculated from the exciting current I_{ac} and V_2.

Figure 3 indicates the system used for the measurement of DC magnetic properties schematically. A core under measurement was excited by fairly low frequency (f=0.05Hz) and a hysteresis loop was traced with a B-H tracer. DC-biased field was applied with a DC current source.

Because the toroidal cores investigated in this study were excited under a DC-biased field, their flux density B includes the DC-biased component B_{dc} and the AC component B_{ac} which varies with time. As the eddy current loss depends on the wave form of B_{ac}, the wave form of B_{ac} was controlled into the sinusoidal form except the measurement at 0.05Hz. B_{dc} can not be determined directly, because B is calculated from dB/dt in our measuring system. Therefore we evaluated B_{dc} by comparing B-H loops measured under DC-biased fields with that measured under a symmetrical

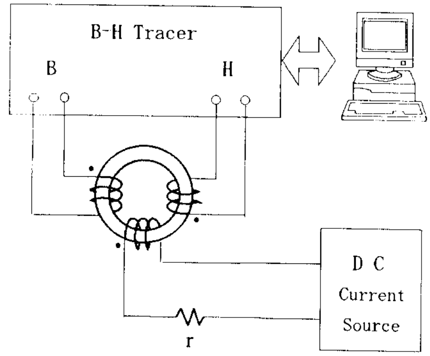


Fig. 3 System used for measurement of DC magnetic properties under DC-biased field.

excitation condition.

In this paper, the relative permeability μ_r and the magnitude of B_{ac} are defined as

$$\mu_r = \frac{B_{max} - B_{min}}{\mu_0 (H_{max} - H_{min})}, \quad (1)$$

$$\Delta B_m = \frac{B_{max} - B_{min}}{2}, \quad (2)$$

where B_{max}, B_{min}, H_{max}, and H_{min} are the maximum and minimum values of the flux density, and those of the applied field, respectively. Further, μ_0 is the permeability in vacuum.

Ⅲ. RESULT AND DISCUSSION

A. H_3ST

Typical B-H loops under DC-biased fields are shown in Fig. 4, together with that measured under a symmetrical excitation condition. With increasing the DC-biased field H_{dc}, B_{dc} increases gradually, and the core is magnetized up to nearly saturation at H_{dc}=40A/m. The estimated B_{dc} is shown in Fig. 5 as a function of H_{dc}.

The relative permeability μ_r decreases with increasing H_{dc} as clearly seen in Fig. 4. The calculated μ_r reaches one third of μ_r at H_{dc}=0 by applying H_{dc} of 40A/m, independently of the frequencies (Fig. 6).

Effect of DC-biased field on the magnetic loss per cycle, W/f, is shown in Figs. 7(a) and (b). The effect of DC-biased field on W/f is totally different from the results reported in

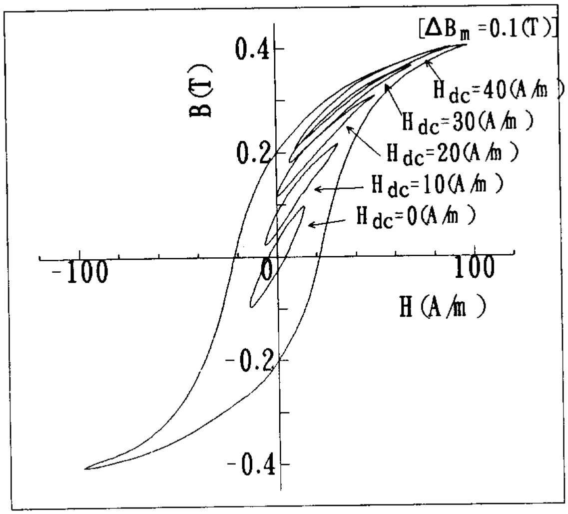


Fig. 4　Typical B-H loops measured at ΔB_m=0.1T and f=40kHz under DC-biased field H_{dc}, together with loop measured under symmetrical exciting condition.

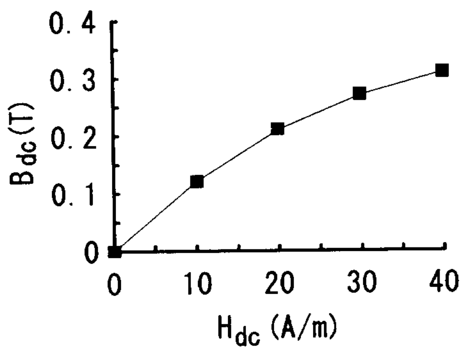


Fig. 5　Estimated DC-biased flux density B_{dc} at 40kHz as a function of DC-biased field H_{dc}.

the previous work [1,2]. In the H_3S core, with increasing H_{dc}, W/f decreases at first and then saturates (ΔB_m=0.2T) or increases gradually. The observed decrease in W/f is consistent with the shape of the B-H loop. As seen in Fig. 1, the width of the B-H loop becomes narrow at high induction level. This means that irreversible magnetization process decreases and reversible process plays important role at high induction level. This decrease in irreversible process at high induction level is possibly responsible for the observed

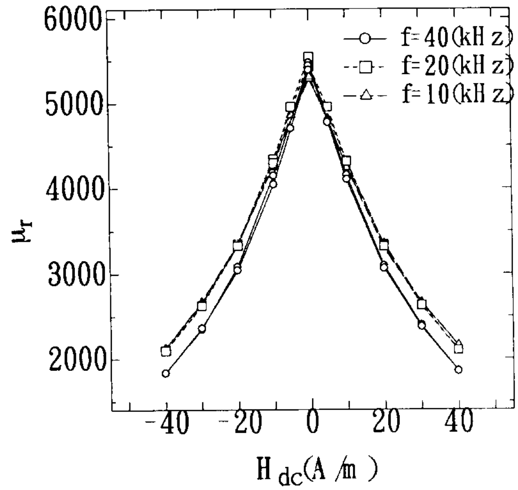
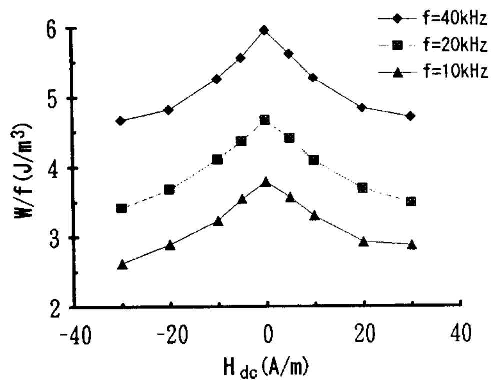
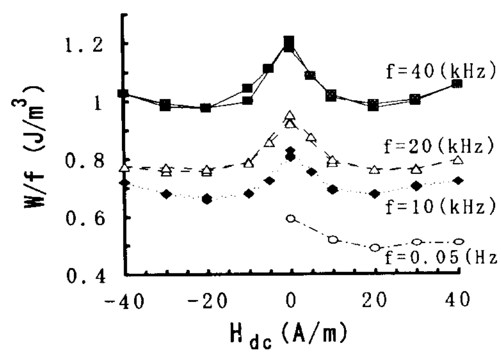


Fig. 6　Effect of DC-biased field on the relative permeability μ_r of H_3S core at ΔB_m=0.1T.



(a) ΔB_m=0.2T



(b) ΔB_m=0.1T

Fig. 7　Effect of DC-biased field on core loss per cycle, W/f, in H_3S core.

decrease in W/f by DC-biased field.

The decreasing tendency of W/f is remarkable at higher frequencies and larger ΔB_m. This results suggest that the observed decrease in W/f can be attributed to a decrease in eddy current loss as well as hysteresis loss. The decrease in eddy current loss may be related to the change in the magnetization process: the change from the domain displacement mode to the rotation mode of magnetization. However, the definitive origin have not been clarified at the present.

B. PC38

Effect of H_{dc} on W/f in the PC38 core is shown in Fig. 8. In the PC38 core, W/f increases with increasing H_{dc} similarly to the case of the previous works. It is also noted that the amount of increase in W/f does not depend on frequency so much. This behavior can be attributed to the fact that the contribution of eddy current loss to W/f is small

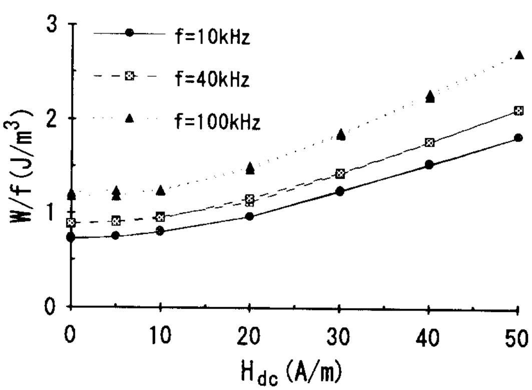


Fig. 8 Effect of DC-biased field H_{dc} on core loss per cycle, W/f, in PC38 core.

in the PC38 core because of its large electric resistivity (Table. I).

The shape of the B-H loop of the PC38 core shown in Fig. 1 differs from that of the H_3S core, and looks like a parallelogram. Thus a decrease in the irreversible process is not expected even at high induction level. This difference may be responsible to the difference between the W/f vs. H_{dc} curves in the H_3S and PC38 cores.

V. CONCLUSION

We investigated the effect of DC-biased field on magnetic properties of two kind of ferrite cores, PC38 and H_3S, which have different shapes of B-H loop from each other. In the PC38 core, the magnetic loss increased with increasing DC-biased field similarly to previous result. On the other hand, the totally different result was obtained for the H_3S core. The magnetic loss in the H_3S core decreased in small DC-biased field region, and then increased gradually with increasing DC-biased field. The decrease in eddy current loss as well as hysteresis loss are responsible for the decrease in the magnetic loss observed in the H_3S core. The difference in the magnetization process reflected in the shape of the B-H loop is possibly responsible for the different behaviors of the H_3S core from that of the PC38 core.

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