Analysis of Power Loss in Mn-Zn Ferrites

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J. PHYS. IV FRANCE **7** (1997)
Colloque C1, Supplément au Journal de Physique III de mars 1997

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Abstract. By analyzing power loss in Mn-Zn ferrites at the secondary peak temperature of the initial permeability, we were able to obtain the first evidence that eddy current loss coincides with the equation derived from the classical theory of magnetism. By analyzing the dependence of power loss on the electrical resistivity, the power loss can be divided into the contributions of loss factors such as hysteresis loss, eddy current loss and residual loss. The residual loss obtained in this study stands for the loss factor independent of electrical resistivity.

1. INTRODUCTION

The reason why power loss analysis has been useless for developing low loss ferrite materials, is attributed to the difficulty for dividing the power loss into loss factors. For example, the power loss subtracted by the hysteresis loss (P_B-P_h) is thought to correspond to eddy current loss. As shown in Fig.1 [1], however, there is nearly one order difference between (P_B-P_h) and the eddy current loss estimated by equation(1), which is referred to an unknown loss factor as the residual loss. Furthermore, the validity of equation(1) has not been verified experimentally either.

$$Pe = (\pi^2/4)\, R^2 f^2\, Bm^2/\rho \qquad (1)$$

where Pe is the eddy current loss, **R** the length of eddy current circuit, Bm magnetic flux density and ρ the electrical resistivity.

At the last conference (ICF-6), one of the authors represented that the consistent relationship between (P_B-P_h) and ρ was obtained by analysing them at the temperature, T_{min} where the P_h shows a minimum [2].

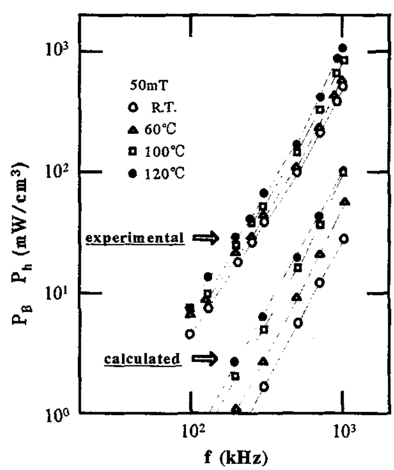

Fig.1 Frequency dependence of measured (P_B-P_h) and calculated eddy current loss.

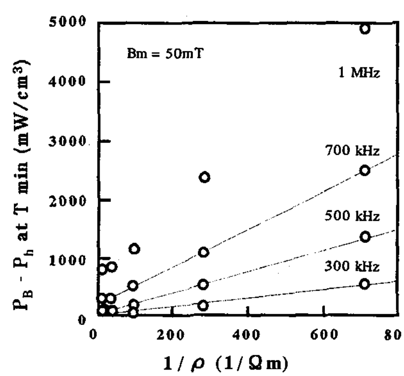

Fig.2 Relationship between (P_B-P_h) and 1/ρ at T_{min}.

2.EXPERIMENTAL

In order to investigate the effect of electrical resistivity on the loss factors, $Mn_{0.74}Zn_{0.18}Fe_{2.06}O_4$ samples with different contents of SiO_2-CaO were prepared by powder metallurgy. The secondary peak temperature of initial permeability T_{min} was around 373K for every sample. The measurements and analyses of the power loss and electrical resistivity were described in the previous paper [2].

3. RESULTS AND DISCUSSION

Figure 2 shows the plots of (P_B-P_h) versus 1/ρ at T_{min}. In this figure, (P_B-P_h) is found to be a linear function of 1/ρ. As seen in eq.(1), this could mean that the eddy current loss coincides with the gradient of the line **k**, so that the dependencies of **k** on frequency and Bm were

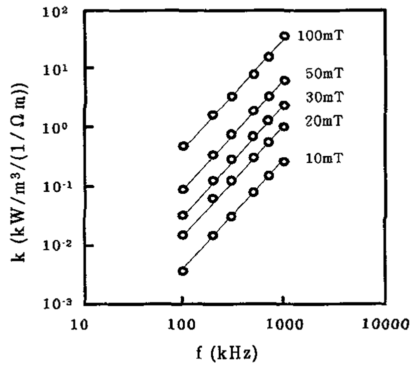

Fig.3 Frequency dependence of gradient **k** at 10mT~100mT.

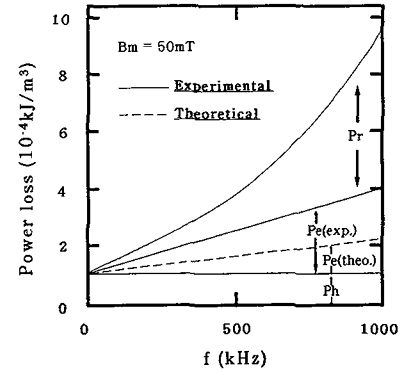

Fig.4 Frequency dependence of total power loss and loss factors a cycle.

examined. As shown in Fig.3, the gradient of the plot of **k** vs. **f** is about **2**. A similar relationship holds true for Bm as well. Consequently, the eddy current loss is found to be obtained experimentally from the gradient of P_B-P_h) vs. $1/\rho$ plots at T_{min}.

The T_{min} corresponds to the secondary peak temperature of the permeability [2], at which anisotropy constant is null and domain size is almost equal for every sample with different compositions. Therefore, assuming that **R** in eq.(1) depends on the domain size, the analysis at T_{min} is to keep **R** constant for every sample, which results in the consistent relationship between $(P_B$-$P_h)$ and $1/\rho$.

The intersection on the ordinate in Fig.2 is the residual loss, because this remains when Ph and Pe are subtracted from the total power loss. But this is not an unknown loss component in our opinion. That is to say, the intersection on the ordinate in Fig.2 means the loss factor independent of the electrical resistivity, in analogy with the gradient as ρ-dependent loss factor, eddy current loss.

Figure 4 shows the frequency dependence of the loss factors per cycle for the commercial grade sample. It can be seen from this figure that the eddy current loss obtained experimentally is roughly double the one estimated using equation(1) and the residual loss becomes predominant around 1MHz. As shown in Fig. 5, the residual loss increases with an increase in both Bm and frequency while the gradient of the lines increases as Bm decreases. The gradient **n** (residual loss $\sim f^{n}$) is plotted against Bm in Fig. 6. The value of **n** is about 4.5 till **n** decreases gradually with an increase in Bm from 20mT. The variation of **n** with Bm can be attributed to a change of the contribution of loss mechanisms such as the dimensional and domain wall resonances.

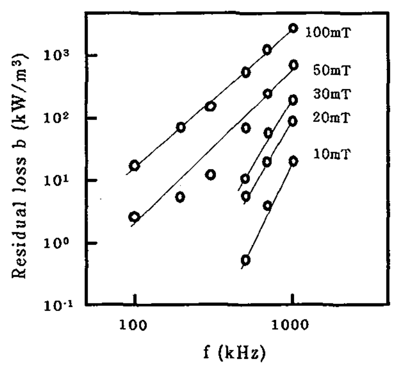

Fig.5 Frequency dependence of resistivity independent loss at 10mT~100mT.

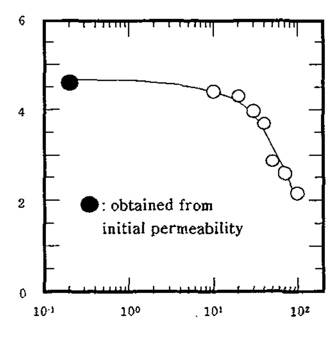

Fig.6 Exponent **n** in residual $\propto f^{n}$ v.s Bm.

4. CONCLUSIONS

By analyzing the power loss in Mn-Zn ferrites at T_{min}, the power loss could be divided into loss factors. Equation(1) can express the dependence of the eddy current loss on electrical resistivity, while the experimental value is double the estimated one using equation(1).

5. REFERENCES

[1] S. Yamada and E.Otsuki; IEICE Trans. Commun. vol.E75-B,(11),(1992),1192.

[2] E. Otsuki; Proc. of ICF-6,(1992),317.