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MnZn Ferrites with Low Loss in Wide Temperature Range†

1. Introduction

In the JFE Group, JFE Ferrite and JFE Jiangmen Ferrite (Guandong, China), which are subsidiaries of JFE Chemical, manufacture soft magnetic MnZn ferrite suitable for the high frequency region of 10 kHz and higher. Main products include low loss material MB4[1)] and high permeability material MA055. With one manufacturing base for ferrite cores in Japan (Kurashiki City, Okayama Pref.) and two overseas bases (Rayong State, Thailand; Jiangmen City, China), the JFE Group has created a supply system which makes it possible to respond immediately to customers' demand.

Accompanying the progress of the information society in recent years, a variety of electronic devices are now used in applications which extend to general society. Switching power supplies are frequently used as the power source for these electronic devices. A low loss ferrite core is indispensable in the magnetic core of the transformer, which is the main part of this type of power supply, and various properties are required, depending on the purpose.

In 1998, the JFE Group was the first in the world to mass-produce "MBT1," which can maintain low loss under a particularly wide range of ambient temperatures. MBT1 is the optimum material for applications which are exposed to a wide temperature range from −40 to 150°C, for example, in power supplies for automotive equipment. In 2003, responding to the customers' requirements for lower loss, the JFE Group succeeded in developing and established a mass-production system for a soft ferrite, "MBT2," which features a 15% reduction of core loss in comparison with MBT1. Although still at the laboratory scale, JFE has also succeeded in developing "MBT3," which holds the industry record for low loss over a wide temperature range, displaying a minimum core loss value of 245 kW/m^3 (100 kHz, 200 mT) at 90°C and loss of 335 kW/m^3 at 140°C. This report introduces the properties of these products.

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2. Key Points in Development of MBT2 and MBT3

MBT1[2)] was the world's first mass-produced product which mitigated temperature-related changes in magneto-crystalline anisotropy[3)], thereby reducing the temperature dependence of core loss. This was achieved by partially substituting CoO for Fe_2O_3, which is the main component in MnZn ferrite. While employing this basic technology, lower loss was achieved in MBT2 based on the following viewpoints, resulting in successful mass production in a continuous sintering kiln.

(1) To reduce hysteresis loss, the compositions of the main component and additives are optimized.
(2) To realize the grain size and pore distribution which minimize core loss, the sintering temperature and oxygen concentration in the sintering atmosphere are precisely controlled.
(3) High purity iron oxide, JC-CPW, produced by JFE Chemical, is used[4)].

With MBT3, ultra-low loss has been realized by applying even more precise control, centering on the key points mentioned above.

3. Magnetic Properties of MBT2 and MBT3

The material properties of MBT1, MBT2, and a conventional low loss material, MB3[5)], are shown in **Table 1**. The temperature dependence of core loss, P_{cv}, of each material is shown in **Fig. 1**. MBT2 not only has small temperature dependence in comparison with MB3, but also realizes 15% lower loss in comparison with MBT1. The temperature dependence of core loss of MBT3, which has been developed in the laboratory study, is also shown in Fig. 1. MBT3 indicates 15% lower loss than MBT2, and also secures the industry's top level of performance over the temperature range from room temperature to 140°C.

Next, the loss factors in MBT2 and MBT3 are shown in **Fig. 2**. Here, total loss, P_c, was analyzed by dividing loss into hysteresis loss, P_h, and other factors (sum of eddy current loss, P_e, and residual loss, P_r). It was found that lower loss could be realized with MBT3 because the sum of eddy current loss and residual loss,

Table 1 Magnetic characteristics of MB3, MBT1, and MBT2

	Temperature (°C)	MB3	MBT1	MBT2
Initial Permeability, μ_{iac}/μ_0	23	2 500 ±25%	3 400 ±25%	3 300 ±25%
Saturation flux density at 1 200 A/m, B_{ms} (mT)	23 60 100	510 450 390	510 460 390	530 470 400
Remanence, B_{rms} (mT)	23 60 100	130 90 55	90 70 60	70 50 40
Coercivity, H_{cms} (A/m)	23 60 100	14.3 10.3 8.8	9.0 7.0 6.0	7.5 5.5 4.3
Core loss at 100 kHz and 200 mT, P_{cv} (kW/m^3)	23 60 100 120	700 500 410 500	390 330 340 400	370 310 300 370
Curie temperature, T_c (°C)		≧215	≧230	≧215
Resistivity, ρ (Ω • m)		≧6	≧4	≧4
Density, d (kg/m^3)		4.9×10^3	4.8×10^3	4.8×10^3

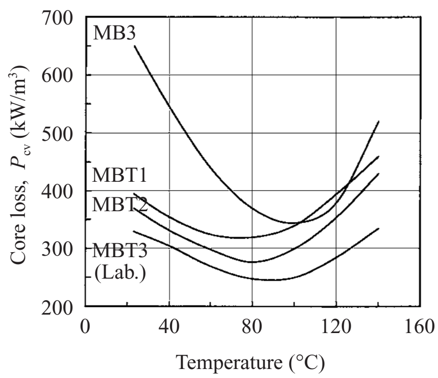

Fig. 1 Temperature dependence of core loss at 100 kHz and 200 mT (MB3 is the conventional low loss material. MBT1, MBT2, and MBT3 indicate the smaller temperature coefficient of core loss than that of MB3.)

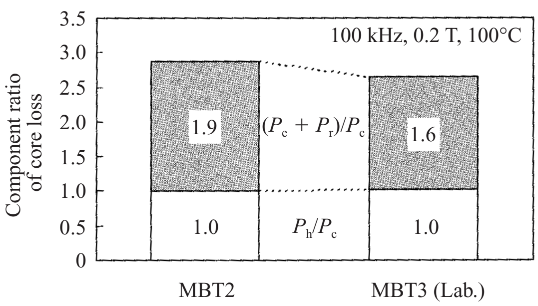

Fig. 2 Component ratio of core loss in MBT2 and MBT3 (P_c, P_h, P_e, and P_r corresponds to total loss, hysteresis loss, eddy current loss and residual loss respectively. P_h/P_c of MBT2 is defined as 1.0.)

which accounts for approximately 65% of total loss, was reduced by 15%, while at the same time avoiding an increase in the hysteresis loss of MBT2.

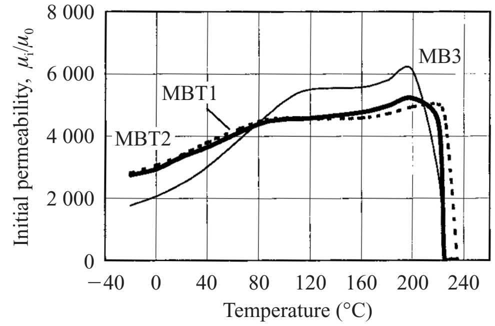

Fig. 3 Temperature dependence of initial permeability in MB3, MBT1, and MBT2

Finally, the temperature dependence of relative initial permeability, μ_i/μ_0 (μ_0 is permeability in a vacuum) of MB3, MBT1, and MBT2 is shown in **Fig. 3**. The temperature-related change in μ_i/μ_0 is small in MBT1 and MBT2 compared with MB3. Therefore, the former materials are effective in reducing temperature-related changes in inductance of coils wound on ferrite cores. Taking advantage of these characteristics, these materials are being used in practical applications as cores for automobile antennas.

4. Conclusion

The JFE Group succeeded in mass-producing MBT2, which indicates low core loss over wide temperature range. Although still at the laboratory scale, the JFE Group also succeeded in developing MBT3, which features lower loss than MBT2. In the future, JFE plans to develop material and production technology with the aim of realizing mass production of MBT3.

References

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