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MnZn Ferrite Core MAF065 for Automotive Noise Filters

1. Introduction

MnZn ferrite cores are a type of magnetic material which is produced by mixing iron oxide as raw materials with manganese oxide and zinc oxide, followed by sintering the green cores at a high temperature. In the JFE Steel Group, MnZn ferrite cores are manufactured by JFE Ferrite Co., Ltd. (Kurashiki, Okayama Prefecture, Japan), JFE Ferrite (Thailand) Co., Ltd. (Rayong Province, Thailand) and JFE Jiangmen Ferrite Co., Ltd. (Jiangmen City, Guangdong Province, China), which are subsidiaries of JFE Chemical Corporation. The iron oxide as raw materials is obtained by JFE Chemical Corp. by spray roasting with hydrochloric acid used in cleaning (pickling) the surface of steel strips in the cold-rolling process at JFE Steel. Thus, as one feature of JFE's MnZn ferrite cores, these products are manufacturing by an integrated process entirely in the JFE Steel Group, from raw material with the world's highest level of purity to the final product cores.

Among MnZn ferrite cores, high permeability materials with initial permeability exceeding 4 000, are mainly used as noise filters. The high permeability MnZn ferrite commercialized by JFE Ferrite Co., Ltd. are produced as a product line called the MA Series[1]. High permeability materials are used as noise filters in power control units (PCUs) of hybrid electric vehicles and electric vehicles (HEV/EV), and demand is increasing accompanying the popularization of those automobiles. The properties required in automotive noise filters are high permeability, stability in high temperature operation and high frequency noise removal performance. This paper introduces the features of MAF065, which targets automotive noise filter applications, and has excellent performance in all these properties.

2. Features of MAF065

2.1 Positioning of Product

Figure 1 shows a comparison of the properties of the conventional JFE Ferrite high permeability materials and the newly-developed MAF065. In this figure, initial permeability increases from the left to the right, and the Curie temperature increases from the bottom to the top. Saturation flux density increases as the size of the plots become larger, and darker colors indicate a higher applicable frequency range.

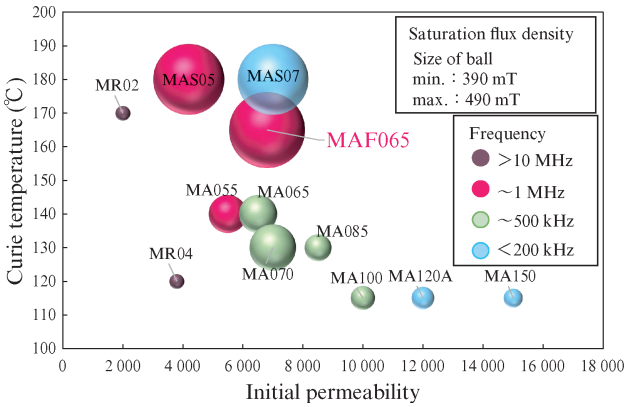

Fig. 1 Comparison of properties of conventional and developed JFE Ferrite high permeability materials

Among the MA Series products, the existing material MA055 is often used in the cores of noise filters for the high frequency region, as it has high impedance around 1 MHz. MAF065 was developed to have higher initial permeability, Curie temperature and saturation flux density than MA055, while maintaining the same high-frequency impedance characteristics as MA055.

2.2 Key Points of Material Design

When the grain size becomes large and uniform, the magnetic domain wall motion becomes easier, and initial permeability improves. Therefore, in MAF065, higher initial permeability than that of MA055 was achieved by optimizing the sintering conditions of the manufacturing kiln to control the crystal structure.

The Curie temperature was also increased by approximately 20% in comparison with MA055 by adjusting the ratio of the iron oxide, manganese oxide and zinc oxide raw materials, adding trace amounts of materials and optimizing the temperature and atmosphere during sintering.

The Curie temperature and impedance at high frequencies of 500 k to 1 MHz normally decrease as initial permeability increases. However, by adding trace

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amounts of proprietary components, impurities in the crystals easily segregate to the grain boundaries[2,3], which increases the resistivity of materials. As a result, MAF065 were able to achieve both low-frequency and high-frequency impedance characteristics.

2.3 Basic Magnetic Properties and Electrical Properties

2.3.1 Initial permeability

Table 1 shows the main properties of MA055 and MAF065. The initial permeability of MA055 is 5 500, while MAF065 has high permeability at 6 500. As initial permeability increases, the winding number of coils can be reduced and downsizing is possible, enabling weight reduction in automotive electrical parts.

2.3.2 Curie temperature

The Curie temperature is the temperature at which a magnetic material loses its magnetic properties, which means the material will lose its function as a noise filter if the surrounding temperature exceeds that temperature. Since the Curie temperature of MAF065 is 165˚C, noise filters keep their function even in the area around the engine in HEVs, where the maximum temperature reaches as high as 150˚C.

2.3.3 Impedance characteristics

Figure 2 shows the frequency dependence of the normalized impedance of MAF065 and other existing products. Impedance is one of the key parameters of noise filters. MnZn ferrite cores are used as noise filters because they neutralize the common-mode noise generated by the difference in impedances mainly between electrical circuit boards and the ground. By using a coil with a MnZn ferrite core with sufficiently high impedance, it is possible to balance the impedance between the circuit board line and the ground, making it possible to suppress noise[4].

MAF065 has high-frequency impedance characteristics similar to those of MA055, which has excellent high-frequency impedance among the conventional products, as well as improved low- frequency impedance. With the increasing adoption of power semiconductors such as SiC and GaN, it is expected to be applied to filters to remove the higher frequency noise in switching mode power supplies.

2.3.4 Magnetic saturation characteristics

Although the saturation flux density of the existing high permeability products of JFE Ferrite is around 430 mT, MAF065 has the highest saturation flux density in the MA Series, at 490 mT. This has the advantage that magnetic saturation can be suppressed against large amplitude noise.

Figure 3 shows the temperature dependence of permeability when a large current is applied to the coil. The temperature at which permeability decreases is higher in MAF065 than in the other materials. This shows that MAF065 is difficult to reach magnetic saturation, even in power supplies that drive with a large current, such as EVs, and it can operate as a noise filter at high temperatures.

Table 1 Main properties of MA055 and MAF065

	MA055	MAF065
Initial permeability (10 kHz)	5 500	6 500
Curie temperature/°C	140	165
Impedance (1 MHz)/Ω·mm^{-1}	45	45
Satulation flux density/mT	434	490

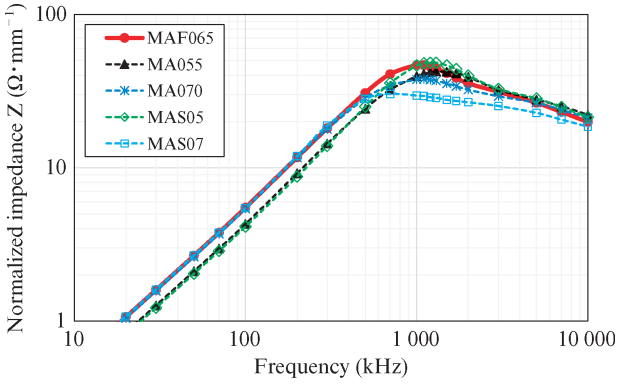

Fig. 2 Frequency dependence of impedance of MA series

3. Conclusion

This article introduced the MnZn ferrite core MAF065, which is applicable to automotive noise

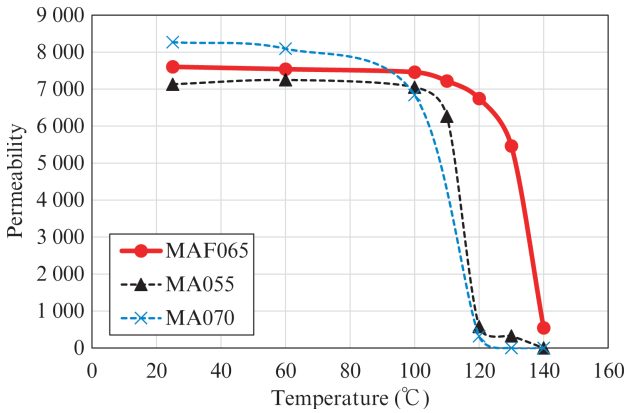

Fig. 3 Temperature dependence of permeability when large current (frequency 150 kHz, magnetic flux density 200 mT) is applied

filters.

In the future, we plan to develop a series of MAF materials as products with high Curie temperatures and excellent frequency characteristics, and will work to develop materials that respond to noise with even higher frequencies.

References

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4) Togawa, J. Coil/Transformer Design for Switching Power Supplies. 5th ed., CQ Publishing, 2019, 271p.

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