Technical Report

Ferrite Materials for Power Transformer PC95

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1. Introduction

With the rapid spread of small-sized, highly efficient, highly reliable switching power supplies in recent years, miniaturization and high-efficiency have increasingly been required for transformers used in parts such as DC to DC converters and inverters. As magnetic cores of transformers, there has been a need for materials with small magnetic loss (core loss). Core loss is part of the input energy of a magnetic field that is released as heat, resulting in decreased efficiency and an increased temperature. Accordingly, reducing core loss allows for a decrease in these losses and temperature increases, achieving miniaturization and high efficiency of transformers.

As a product lineup, TDK has been manufacturing low loss MnZn series ferrite materials that are suitable in power supply transformers for a variety of applications.

The material PC95, which has been developed and commercialized with a low core loss over a wide temperature range, will now be introduced.

2. MnZn series ferrite for power supply transformers

MnZn series ferrite has smaller crystal magnetic anisotropy and magnetostriction constants and a larger spontaneous magnetization than NiZn series ferrite. Therefore, since there is a small core loss and a large saturation flux density, it is most suitable for use in the main transformers of switching power sources.

TDK has been working to reduce loss in materials for power supply transformers by optimizing minor components and precisely controlling burning conditions.[1)]

It is general knowledge that the crystal magnetic anisotropy constant k_1 of MnZn series ferrite is dependent on temperature[2),3),4)] and that, near the temperature where k_1 becomes 0, the initial permeability μi has a local maximum. Strictly speaking, this is not exact; however, core loss represents similar temperature characteristics such as there being a local minimum near the temperature where k_1 becomes 0, like μi. Practically, by using transformers near local minimum temperatures at which core loss has a negative temperature coefficient,

Table 1 Material characteristics of ferrites for power transformers

Material					PC95	PC47	PC44
Initial permeability	μi			25°C	3300±25%	2500±25%	2400±25%
Core loss	Pcv [B=200mT]	kW/m³	100kHz Sine wave	25°C	350	600	600
				80°C	280	290	320
				100°C	290	250	300
				120°C	350	360	400
Saturation flux density	Bs [H=1194A/m]	mT		25°C	530	530	510
				60°C	480	480	450
				100°C	410	420	390
				120°C	380	390	350
Remanent flux density	Br	mT		25°C	85	180	110
				60°C	70	100	70
				100°C	60	60	60
				120°C	55	60	55
Coercive force	Hc	A/m		25°C	9.5	13.0	13.0
				60°C	7.5	9.0	9.0
				100°C	6.5	6.0	6.5
				120°C	6.0	7.0	6.0
Curie temperature*	Tc	°C min.			215	230	215
Electrical resistivity	ρ	Ω • m		25°C	6.0	4.0	6.5
Density	δ	kg/m³			4.9×10^3	4.9×10^3	4.9×10^3

* Unless otherwise specify the tolerance, the values are shown as a typical.

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it is possible to not only suppress temperature rises in transformers, but to also prevent abnormalities such as thermal runaway.[3] Due to this, by controlling the temperature at which the crystal magnetic anisotropy constant becomes 0 with factors such as the Fe2+ amount, ferrite materials having different local minimum temperatures for core loss have been made into a product series that corresponds with a variety of applications.

However, since newer electronic devices are used under varying temperature conditions, represented by car electronics, high efficiency must be achieved over a wide temperature range.

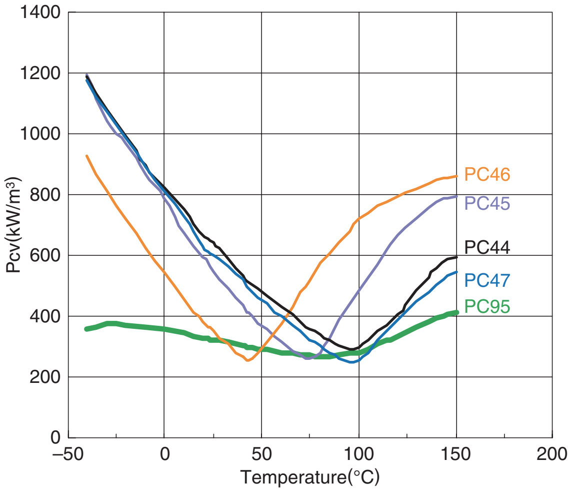
In order to meet such a requirement, TDK has simultaneously achieved a reduction in core loss and an exceptionally small temperature dependency, and has developed the material PC95, which has a small core loss over a wide temperature range.

3. Low loss ferrite PC95 over a wide temperature range

The material characteristics of ferrite for power source transformers are shown in Table 1. The temperature characteristics of core loss Pcv at 100kHz and 200mT are shown in Figure 1. Compared with conventional materials (PC44, PC45, PC46 and PC47 materials by TDK), for which the local minimum temperature for core loss is controlled in various ways, the core loss of the material PC95 is found to have a drastically small dependence on temperature.

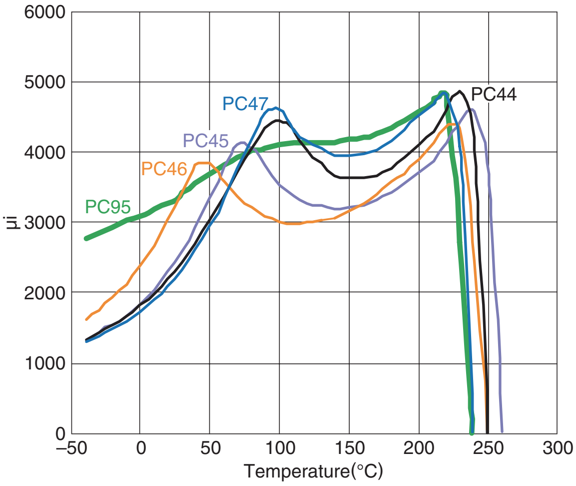
The material PC95 has a core loss that is equal to or less than 350kW/m³ (100kHz, 200mT) over a wide temperature range from 25 to 120°C (280kW/m³ at 80°C). The material PC95 is one of the best low-loss materials for power supplies over a wide temperature range, with its core loss being smaller than the material PC44 over all temperature ranges.

Figure 1 Temperature characteristics of core loss Pcv at 100kHz and 200mT



The temperature characteristics of the initial permeability μi are shown in Figure 2.

Figure 2 Temperature characteristics of initial permeability μi



The local maximum temperatures of the initial permeability of various ferrites correspond to the local minimum temperatures for core loss. The initial permeability of the material PC95 is found to have small temperature dependencies, such as core loss. This shows that nothing but that the crystal magnetic anisotropy constant of the material PC95 decreases over a wide temperature range, as was mentioned above. With the material PC95, the temperature characteristics of the crystal magnetic anisotropy constant are controlled by adding a fourth metal ion constituent in addition to Fe, Mn, and Zn, which are the main constituents. As a result, hysteresis loss can be reduced over a wide temperature range, which is one of the main components of core loss.

On the other hand, through the control of minor constituents and materials and firing process techniques, control of the crystal grain boundary structure and the high-density sintered object are obtained and hysteresis loss and eddy current loss are reduced. A comparison of the fine textures of the materials PC95 and PC44 is shown in Figure 3. While there is almost no difference in the crystal grain size between the materials PC95 and PC94, the material PC95 has fewer holes than PC94, with its high-density being apparent.

The dependency of core loss on frequency and drive flux density Bm is shown in Figure 4. In the frequency range of 100kHz or less, core loss is separated into hysteresis loss in proportion to the frequency and eddy current loss, in proportion to the square of the frequency.

It is apparent that the material PC95 has a smaller loss than the PC94 under all conditions and that both hysteresis loss and eddy current loss are reduced.

Figure 3 Comparison of fine texture of PC95 and PC44 materials

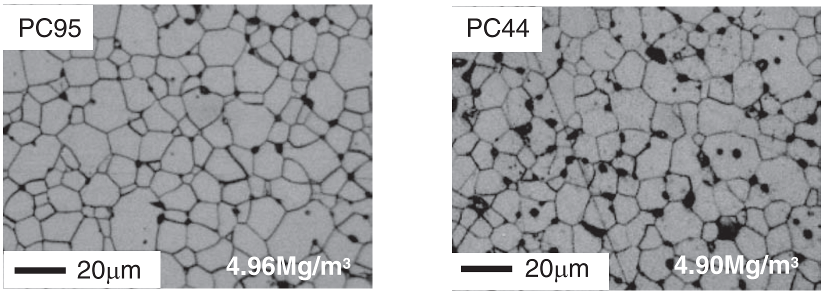
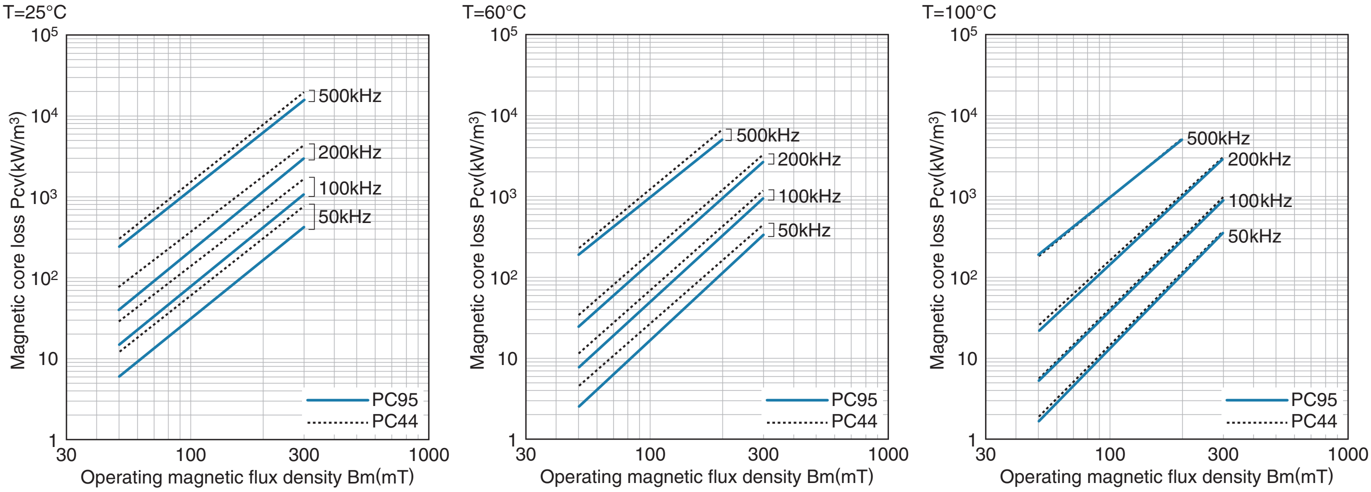


Figure 4 Dependence of core loss of PC95 and PC44 on frequency and drive flux density Bm



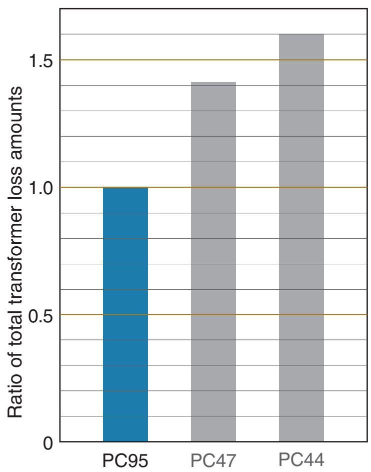
4. Applications of the material PC95

The material PC95 is expected to be used not only in ordinary switching power supplies but also in a variety of applications, due to its advantage of being usable under nearly optimal conditions over a wide temperature range. For example, in the case of DC to DC converters for electric cars such as HEVs or FCEVs, in addition to the environmental temperature conditions at the time of driving, the operating temperature range depends significantly on the workload. Such usage of the material PC95 will help promote of miniaturization and high efficiency of power supplies, the reduction of car weight, and the improvement of fuel efficiency.

The simulation results of total loss of a transformer, considering the operating temperature when using the material PC95 as the main transformer in a DC to DC converter for an electric car, are shown in Figure 5 (the total loss of the transformer in the graph is denoted by a loss ratio of the conventional material with the material PC95 being 1). When using the material PC95, the total loss of transformers is estimated to be reduced by approximately 30 to 40%. In an inverter transformer for the backlight of an LCD, since multiple transformers are used in the apparatus, the temperature variations are large in various locations in the apparatus. Therefore, by using the material PC95, which has low core loss over a wide temperature range, the heat generation and power dissipation of the entire apparatus can be effectively reduced.

TDK will continue to progress low loss and a high saturation flux density under various usage conditions in the future, in order to promote the miniaturization, high efficiency, and high reliability of various electronic devices.

Figure 5 Total transformer loss amount



Derived from simulation of change in operating temperature of the DC to DC converter's main transformer compatible with vehicle's driving environment change (driving period: one year).

References

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2) TDK Corporation: with Ferrite, 1986
3) Teitaro Hiraga, Katsunobu Okutani, Teruhiko Ojima. Ferrite: MARUZEN CO., LTD. (1986)
4) Keizo Ohta: Basics of Magnetic Engineering, KYORITSU SHUPPAN CO., LTD. (1973)

• Please note that the articles from the July 3, 2003 Edition of the Dempa Shimbun contained in this chapter have been edited by our company.