Technical Report

Effects of Ferrite Material PC90 and Application Products

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1. Introduction

Ferrite cores are widely used for power transformers, choke coils, deflection yokes of CRT, cores for noise filters, and the like. Among them, a MnZn ferrite core has low-loss and high saturation flux density characteristics when compared to other ferrite cores, and thus is often used for transformers, choke coils, and so on.

Along with demands for increasingly smaller size, thinner profiles, and lighter weights of recent electronic components, materials used for electronic components are required to have by far higher performances. Conventional low-loss materials have a scope for increase in temperature due to heat emission, but fall short for use in large excitation conditions because of not having a large saturation flux density (Bs). Meanwhile, conventional high Bs materials have a scope for use under excitation conditions but have a large core loss (Pcv), so increases in temperature are problematic, and this in turn prevents their high Bs characteristics from being used efficiently. For this reason, the problem remains that the distinctive features of the each material cannot be utilized.

TDK has developed and mass-produced the new material PC90 (see Table 1) which has both high Bs characteristics beyond the conventional high Bs material PC33, and low Pcv characteristics equal to the low Pcv material PC44. Therefore, it can be used without worrying about heat emission even under the large excitation condition and contribute to the miniaturization of electronic components. This article will introduce the material PC90. Further, this article will also introduce the effects in a case where PC90 is used for transformers and choke coils.

2. Control of MnZn ferrite characteristic

Generally, the Bs of a ferrite at a certain temperature T can be expressed by the following equation.

$$Bs(T) = Bs(0) \times (\rho/\rho t) \times (1 - T/Tc)a$$

Bs(0) : Saturation flux density at 0(K)
ρ, ρt : Density, theoretical density
Tc : Curie temperature (Ferromagnetism disappears at above Curie temperature.)
a : Constant

Parameters for heightening the Bs are Bs(0), Tc, and ρ. The Bs(0) of the ferrite, if it is a MnZn ferrite, is mainly affected by the ratio of the composition manganese ferrite ($MnFe_2O_4$), zinc ferrite ($ZnFe_2O_4$), magnetite ferrite ($FeFe_2O_4$). Thereby, for heightening the Bs, it is necessary to increase the proportion in the composition of $FeFe_2O_4$ or the like which has a large Bs(0). However, what is necessary is a high Bs in the operational temperature range of actual products.
For this reason, a great effect cannot be achieved if the Curie temperature is low even if the Bs(0) is high.
In order to solve this problem, TDK has controlled the composition by adding a fourth metal ion component to Fe, Mn, and Zn. In addition, in order to obtain a core with a higher density than a conventional core, the firing conditions (temperature, oxygen concentration) are finely controlled to realize a heightened Bs.

Meanwhile, a portion of the measures for heightening the Bs hinder the Pcv from being lowered.

Table 1 Material characteristics of material PC90

Material				PC90	PC44	PC33
Initial permeability	μi		25°C	2200±25%	2400±25%	1400±25%
Core loss [100kHz-200mT]	Pcv	kW/m³	25°C	680	600	1100
			60°C	470	400	800
			100°C	320	300	600
Saturation flux density	Bs	mT	25°C	540	510	520
			100°C	450	390	440
Curie temperature*	Tc	°C min.		250	215	290
Density	d_b	kg/m³		4.8×10³	4.8×10³	4.8×10³

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

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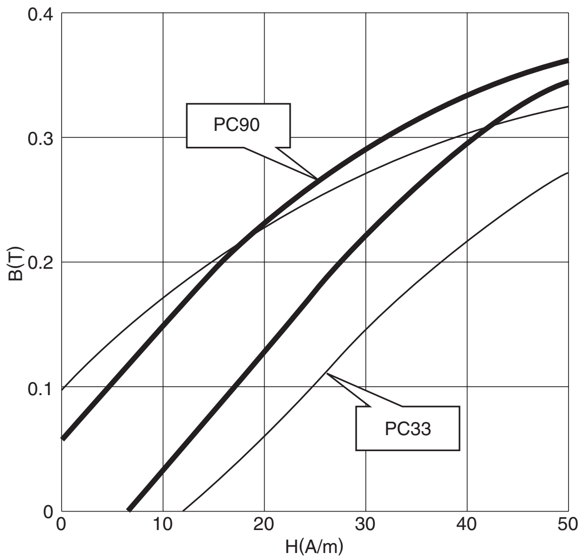
For example, in general, as the amount of $FeFe_2O_4$ is increased, the magnetic distortion becomes greater and the hysteresis loss, which is loss component, also increases.
Further, volume resistivity tends to be lowered, and the eddy current loss, which is also a loss component, increases. Under operation conditions at several hundreds of kHz, generally, each loss can be expressed by Pcv=Phv (hysteresis loss)+Pev (eddy current loss). The Phv increases in proportion to the driving frequency, and the Pev increases in proportion to the square of the driving frequency. In order to solve this problem, TDK has added extremely small amount of the elements and controlled with high accuracy the temperature and oxygen conditions when firing. As a result, a more precise and finer structure could be obtained and the hysteresis loss could be improved. In addition, the decrease in the volume resistivity could be suppressed to prevent the deterioration in the eddy current loss.

From the B-H loop in Figure 1, the effects thereof can be seen. The Phv is proportional to the area of the B-H loop. It can be seen that the material PC90 has a lower Br and Hc, which are used as references for loss, than the conventional high Bs material PC33, and the area of the B-H loop becomes smaller.

Figure 1 B-H loop comparison of PC90 and PC33 (1)

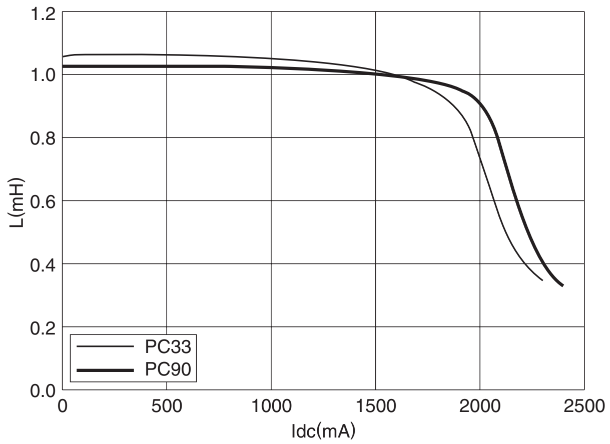


3. Effects of a product using the PC90

In a choke coil using the ferrite core, its important characteristic is how stably the L value is obtained when a high DC current is applied, in comparison with the L value when the DC current (Idc) is 0. Generally, for improvement of DC superposition characteristics, the importance of obtaining a high Bs as a material characteristic is known.

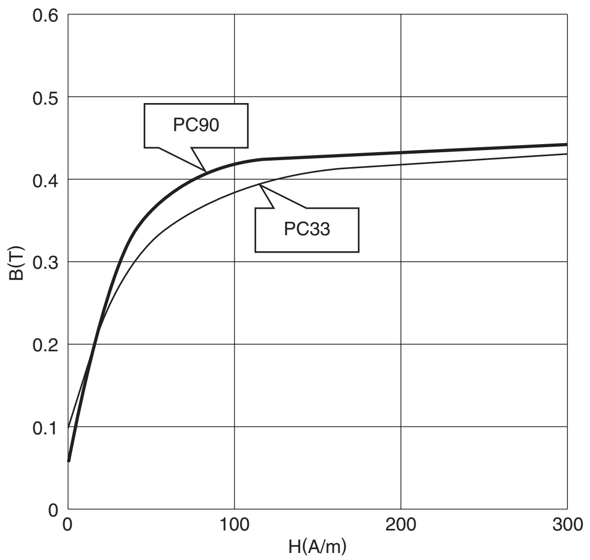
Figure 2 shows the DC superposition characteristics of the conventional high Bs material PC33 and the PC90 compared as the same shape. The Bs is 440mT for the PC33 and 450mT for the PC90, which is a difference of about 2%. However, it is confirmed that the DC superposition characteristic is increased by about 8% (here, the comparison was made using a value of Idc having an L value of 80% relative to the L value when Idc=0). If driven under the same condition, the choke coil can be miniaturized beyond the Bs difference. This can be explained by using the B-H loop shown in Figure 3.

Figure 2 DC superposition characteristic comparison of PC90 and PC33



(at 100°C, AL-value: 100(nH/N^2) where N is the number of coil turns)

Figure 3 B-H loop comparison of PC90 and PC33 (2)



The Bs for the PC90 is steeply saturated as the effect of the lowered Pcv as compared with that of the conventional high Bs material PC33. In addition to the heightened Bs, the improvement of the B-H loop due to the lowered Pcv realizes an improvement of the DC superposition characteristics beyond the Bs difference.

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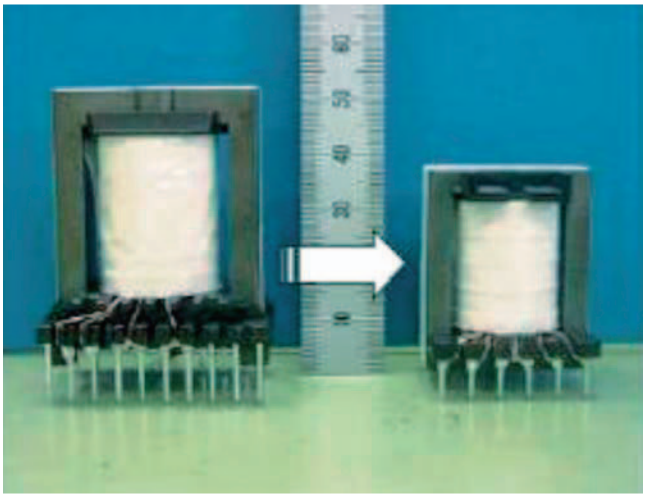
Transformers are also required to have a small size, thinner profile, and lighter weight. PC90 has a Bs which is about 15% higher than the conventional low Pcv material PC44. Thereby, if driven under the same flux density, a transformer using PC90 can be designed with a cross-sectional area less than one using PC44. As an effect thereof, in terms of the weight of a transformer core, PC90 can realize a weight reduction of about 20% in comparison with the PC44. Further, when designing the transformer, it is possible to further miniaturize the transformer by making the loss ratio of iron loss (core loss) to copper loss (coil loss) approach the ideal of 1:1 and by making the most of the high Bs characteristics of PC90. In the case of a comparison with the conventional material PC40 (Bs=390mT, Pcv=410kW/m^3), as shown in Figure 4, PC90 can realize a volume reduction of about 36% in the volume to weight ratio without worrying about the heat emission. As such, by using the PC90 material having a high Bs characteristic exceeding the conventional PC33 material and a low Pcv characteristic equal to the conventional material PC44, electronic components or cores can be made smaller in size, with thinner profile, and lighter in weight.

TDK will develop and mass-produce materials with high Bs and low Pcv characteristics under various usage conditions to keep pace with trends in diversified electronic components.

Figure 4 Miniaturization of transformer using PC90 core (comparison with PC40)

PC40 SRW35EC PC95 SRW28LEC



• Please note that the articles from the November 4, 2004 Edition of the Dempa Shimbun contained in this chapter have been edited by our company.