Influence of Air Gap Distribution in E-type Cores

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Abstract

This work analyzes the magnetic behavior of E-type cores by modifying the air gap configuration. Three different arrangements are compared, and their impact on flux distribution and losses is evaluated to improve design efficiency.

Introduction

Magnetic components are critical elements in power electronics. Their performance has a direct influence on the compactness of electronic systems, thermal behavior and overall.

Among the key design parameters, the arrangement of the air gap plays a crucial role in determining magnetic performance [1]. A proper implementation allows adjusting the inductance, avoiding material saturation, and reducing losses, thus contributing to a more efficient design. However, the air gap also alters the magnetic flux distribution within the core, which may undesirably affect its overall behavior.

There are multiple ways to arrange the air gap, with the most common being concentrated and distributed configurations. This study analyzes the behavior of three configurations for an E-type core: a single gap in the central limb, a gap distributed along that same limb, and a third configuration with the gap distributed across all three limbs. The objective is to assess their influence on magnetic field density and core losses [2-3], and to determine the most efficient compromise for high-performance applications.

Methodology

The behavior of a coil wound around an E80/38/20 magnetic core made of N95 material, subjected to the three air gap configurations are analized. These configurations are shown in Figure 1: (a) a concentrated gap in the central limb, (b) distributed along that same limb, and (c) shared among the three limbs. In all cases, the number of turns required to perform an inductance of 65 µH is used [4-5].

The magnetic excitation is achieved by applying a sinusoidal current through the coil, controlling both amplitude and frequency. Values of 10 A, 20 A, and 30 A at frequencies of 50 kHz, 70 kHz, and 100 kHz are used. These test points allow the analysis of the core's response under different operating conditions.

3D simulations are carried out using a finite element method (FEM)-based software tool, evaluating magnetic field distribution and core losses. Since sinusoidal signals are used, core losses are calculated using the modified Steinmetz equation applied to each i tetrahedron resulting from the meshed core volumen (1). The results make it possible to compare the behavior of each configuration.

$$P(W) = \sum_i v_i k f^{\alpha} B_i^{\beta} \qquad (1)$$

Results

Table 1 shows the core losses with a central limb air gap. Table 2 presents results for the configuration with gaps in all three columns, and Table 3 for the distributed gap along the central limb.

The losses in the first two cases are comparable, with slightly higher values in the single air gap core. However, the distributed air gap along the central limb significantly reduces the losses.

Figure 2 shows the magnetic magnetic field density in the central and one lateral column for the three configurations. In the concentrated gap case, a high flux concentration near the gap is observed. In the other configurations, the magentic field density near the air gap is lower, particularly in the distributed-gap case.

Conclusions

The results show that the air gap configuration significantly impacts core behavior. Specifically, the distributed gap along the central limb clearly reduces both losses and magnetic field concentration, making it a more efficient solution than the other configurations. This makes it especially suitable for applications where minimizing losses is a priority.

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FIGURES

Table 1. Core losses (W) with concentrated air gap in the central column.

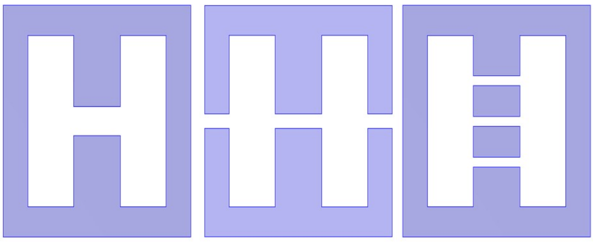
I(A) \ f(Khz)	50	70	100
10	0.352	0.658	1.277
20	3.2.555	4.778	9.276
30	8.148	15.237	29.581

Table 2. Core losses (W) with air gap distributed across the three columns.

I(A) \ f(Khz)	50	70	100
10	0.308	0.576	1.118
20	2.237	4.183	8.121
30	7.134	13.339	25.896

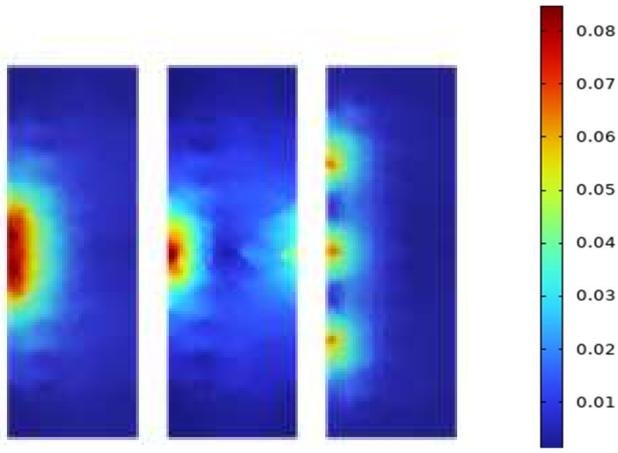
Table 3. Losses (W) in the core with distributed gap in the cental column.

I(A) \ f(Khz)	50	70	100
10	0.2049	0.383	0.744
20	1.487	2.781	5.401
30	4.744	8.870	17.222



(a) (b) (c)

Figure 1. Geometry of the different cores: (a) core with gap in the central limb, (b) core with gap in the three columns, (c) core with distributed gap.



(a) (b) (c)

Figure 2. Magnetic field density (in Teslas) operating at a current of 30 A and a frequency of 100 kHz: (a) core with air gap in the central column, (b) core with air gap in the three columns, (c) core with distributed air gap.