Influence of Size and Geometry on Magnetic Core Losses

Álex Puyal-Ventura, Francisco José Perez-Cebolla, Lucas Herrero-Gracia, Carlos Bernal-Ruiz

Grupo de Electrónica de Potencia y Microelectrónica (GEPM)
Instituto de Investigación en Ingeniería de Aragón (I3A)
Universidad de Zaragoza, Mariano Esquillor s/n, 50018, Zaragoza, Spain.
Tel. +34-976762707, e-mail: 818519@unizar.es

Abstract

This paper analyzes the possible influence of the size and geometry of the magnetic core on the determination of volume losses under identical excitation conditions. Three types of cores made of the same material are evaluated over a wide range of frequencies using an experimental test bench built for this purpose.

Introduction

Magnetic components are essential elements in power electronics designs. They are commonly used for galvanic insulation, regulation tasks, resonant converters, etc. Making the proper design of these devices is necessary to achieve optimal performance and efficiency. However, designing a magnetic component is a complex task due to insufficient data provided by manufacturers.

Typically, much attention has been given to core excitation waveforms [1-3], thermal conditions [4] or material selection [5], but the influence of core geometry and size is often underestimated. This paper gives a reference to designers on how these parameters affect the behaviour of core losses by testing multiple sizes and geometries of the same material in different operation points.

Measurement Setup

The measurement setup consists of a H-bridge power stage, a Tektronix DPO7104 oscilloscope, two EA PS-2084 programmable power supplies, each providing up to 84 V and 10 A with a maximum power of 320 W and a Picolog TC-08 data logger for temperature measurements. An image of the complete setup is shown in Figure 1.

The H-bridge enables precise control over the desired control variables, which are: the bias magnetic field strength H_{DC}, the magnetic field density excursion ΔB, the frequency, and the duty cycle.

The excitation voltage is applied to the primary winding of the core under test (CUT). Voltage measurements are taken across a secondary winding while operating under no-load condition to ensure that parasitic resistances of the wire used do not affect the results. The waveforms of the voltage in each winding and the current in the primary winding are sampled by means of the oscilloscope and transferred to a PC, where they are processed in MATLAB to obtain the magnetic field density B and magnetic field strength H waveforms using modified versions of Faraday (1) and Ampère's (2) laws. An example of some waveforms can be seen in Figure 2.

$$V = N\frac{d\phi}{dt} = NA_e\frac{dB}{dt} \quad (1)$$

$$Ni = Hl_e \quad (2)$$

For this study, three N87 cores from TDK are tested. Two toroid cores with significantly different sizes (R50 and R102) are used to evaluate the influence of core size, while an EE 80/38/20 core was included to compare the influence of geometry.

Results

As an illustrative example, Figure 2 shows the voltage waveform in the secondary winding and the current waveform in the primary winding at a frequency of 200 kHz.

Based on the evaluation of waveforms similar to those in Figure 2, Figure 3 presents the B-H characteristics of the three cores for a maximum magnetic flux density of 50 mT at 200 kHz.

Volumetric losses associated with these B-H loops were evaluated over a frequency range of 20 to 200 kHz. The results are illustrated in Figure 4.

A priori, from a qualitative perspective, the relationship between core geometry and volumetric losses does not appear to be very significant, even at higher and lower frequencies, where greater differences can be observed.

However, given the small volume of cores typically used in power electronics topologies, evaluating losses in absolute terms (W) rather than per volume (kW/m^3) reveals how these differences become more significant.

Conclusions

This work has experimentally demonstrated that both size and geometry of magnetic cores can influence core lossess. Although material and winding conditions were kept constant, variations in physical dimensions led to measurable differences in energy dissipation.

REFERENCES

[1]. K. Venkatachalam, C. R. Sullivan, T. Abdallah and H. Tacca, "Accurate prediction of ferrite core loss with nonsinusoidal waveforms using only Steinmetz parameters," 2002 IEEE Workshop on Computers in Power Electronics, 2002.

[2]. J. Mühlethaler, J. Biela, J. W. Kolar, and A. Ecklebe. Core losses under dc bias condition based on steinmetz parameters. In The 2010 International Power Electronics Conference - ECCE ASIA -, pages 2430–2437, 2010.

[3]. Lifang Yi and Jinyeong Moon. Direct in-situ measurement of magnetic core loss under rectangular voltage excitation in power electronic circuits. In 2024 IEEE Applied Power Electronics Conference and Exposition (APEC), pages 378–383, 2024.

[4]. Filip Grecki and Uwe Drofenik. Calorimetric medium frequency loss measurement of the foil inductor winding. In 2021 IEEE 19th International Power Electronics and Motion Control Conference (PEMC), pages 611–614, 2021.

[5]. M. S. Rylko, K. J. Hartnett, J. G. Hayes and M. G. Egan, "Magnetic Material Selection for High Power High Frequency Inductors in DC-DC Converters," 2009 Twenty-Fourth Annual IEEE Applied Power Electronics Conference and Exposition, Washington, DC, USA, 2009.

FIGURES

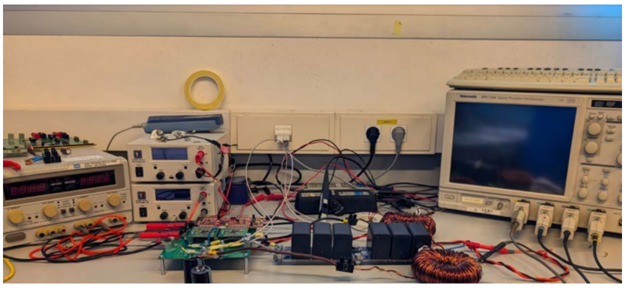

Figure 1. Measurement setup used for experimental tests.

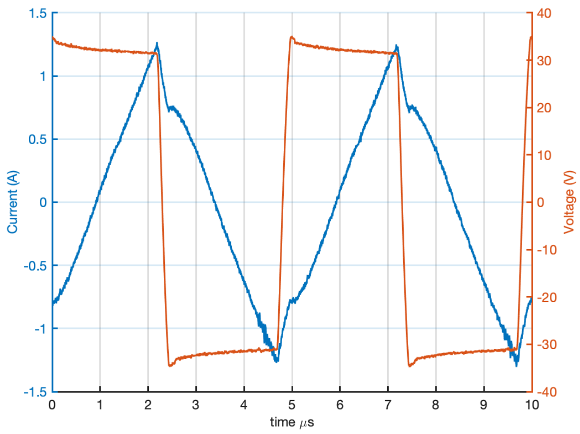

Figure 2. Voltage and current waveforms from the oscilloscope.

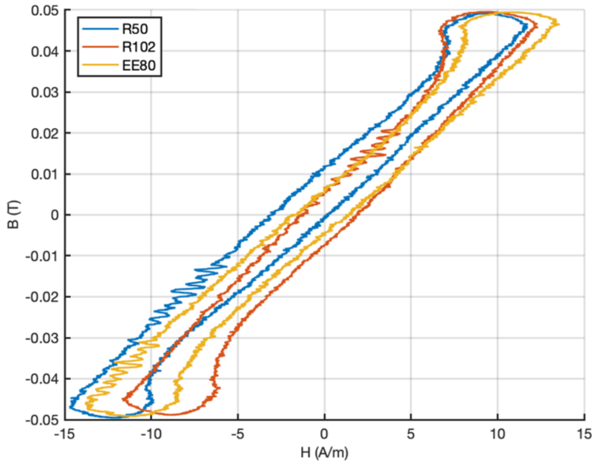

Figure 3. B-H loops for three different cores for a maximum magnetic flux density of 50 mT at 200 kHz and 25 ºC.

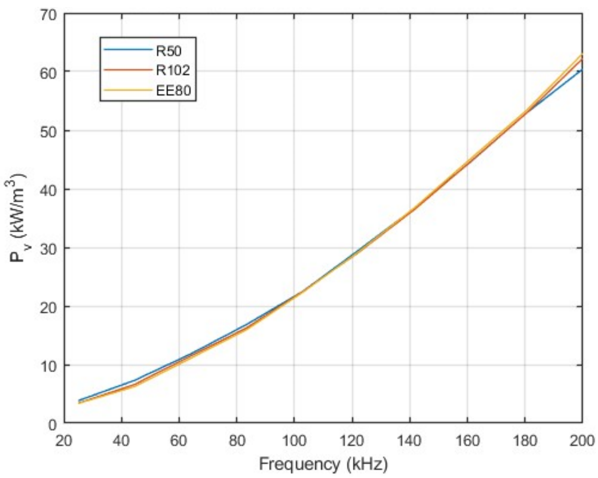

Figure 4. Losses **per volumen** as a function of frecuency **for a maximum magnetic flux density of 50 mT at 200 kHz and 25 ºC.**