Calculation of the Reversible Permeability of Gapped Cores from Measured Ring Core Data

D. Lange

► To cite this version:

D. Lange. Calculation of the Reversible Permeability of Gapped Cores from Measured Ring Core Data. Journal de Physique IV Proceedings, 1997, 07 (C1), pp.C1-137-C1-138. 10.1051/jp4:1997146 . jpa-00255093

HAL Id: jpa-00255093

<https://hal.science/jpa-00255093>

Submitted on 1 Jan 1997

HAL is a multi-disciplinary open access archive for the deposit and dissemination of scientific research documents, whether they are published or not. The documents may come from teaching and research institutions in France or abroad, or from public or private research centers.

L'archive ouverte pluridisciplinaire **HAL**, est destinée au dépôt et à la diffusion de documents scientifiques de niveau recherche, publiés ou non, émanant des établissements d'enseignement et de recherche français ou étrangers, des laboratoires publics ou privés.

Calculation of the Reversible Permeability of Gapped Cores from Measured Ring Core Data

D. Lange

Siemens Matsushita Components GmbH & Co KG, S+M FER MPD, P.O. Box 801709, 81617 Munich, Germany

Abstract. In ferrite data books the reversible permeability for small excitation levels is usually given vs. external dc magnetic field for different values of the effective permeability. To determine these curves the incremental permeability has to be measured on cores with different air gaps. Due to the grinding of different air gaps the determination of those curves is very costly. Also a judgement of the incremental permeability from ring cores, which are used in the material development, is not possible.

In this paper the calculation of the incremental permeability for cores with homogeneous cross section from measured data of ring cores is presented. The reversible permeability vs. dc magnetic field and the amplitude permeability vs. flux density has to be measured. With those data the reversible permeability vs. flux density for the ring core can be calculated. Gans made the assumption that the reversible permeability vs. flux density is a material property. By calculating the drop of the flux density due to an air gap the incremental permeability for a gapped core with homogeneous cross section can be calculated as a function of the external dc magnetic field.

Calculated and measured data for E-cores made of the S+M material N87 are in excellent accordance.

1. INTRODUCTION

For the design of chokes the incremental permeability for small excitation levels, also called reversible permeability μ_{rev} , is an important property. In ferrite data books μ_{rev} is given as a function of the applied dc magnetic field H_{dc} for only several values of the effective permeability. To get intermediate values those curves has to be graphically interpolated, which is difficult due to the logarithmic scale of the plots. The calculation of H_{dc} , at which μ_{rev} is decreased about 10% against the effective permeability was given in [1]. Based on Gans assumption that μ_{rev} as a function of flux density B is a material property [2], μ_{rev} can be calculated as a function of H_{dc} for cores with any air gap. $\mu_{rev}(B)$ has to be determined from measured ring core data. For the calculation of μ_{rev} vs. H_{dc} the influence of the air gap on μ_{rev} and on the relationship between the applied dc magnetic field and the flux density has to be determined.

2. DETERMINATION OF $\mu_{rev}(B)$ FROM RING CORE DATA

With common measurement techniques μ_{rev} vs. H_{dc} can be measured on ring cores. To get μ_{rev} vs. B the flux density has to be calculated. The relationship between H_{dc} and B gives the fundamental equation

$$H_{dc} = \frac{B}{\mu_a(B) \cdot \mu_0} \quad (1)$$

For ring cores H_{dc} is identical with the magnetic field in the material H_{int} . $\mu_a(B)$ can be measured on the commutation curve [4] if assumed that the commutation curve is identical to the initial magnetization curve [4].

3. INFLUENCE OF AIR GAP

The influence of an air gap applied into a magnetic circuit can be described with the demagnetization factor β [5].

$$\beta \approx \frac{1}{\mu_e} - \frac{1}{\mu_i}$$

μ_e is the effective permeability of the magnetic circuit with air gap and μ_i is the initial permeability of the material. If the flux density is constant over the magnetic path the same equation is valid for the relationship between the effective reversible permeability μ_{erev} of the magnetic circuit with air gap and $\mu_{rev}(B)$ of the material. This is valid for cores with constant cross section over the magnetic path. Hence μ_{erev} can be described as a function of B .

$$\mu_{erev}(B) = \left(\frac{1}{\mu_{rev}(B)} + \beta \right)^{-1}$$

Due to an air gap the magnetic field H_{int} in the material is lower than the applied magnetic field H_{dc} .

$$H_{int} = H_{dc} - \frac{\beta}{\mu_0} \cdot B$$

With equation (1) the applied magnetic field can be described as a function of flux density.

$$H_{dc}(B) = \frac{B}{\mu_a(B) \cdot \mu_0} + \frac{\beta}{\mu_0} \cdot B$$

With the ring core data $\mu_{rev}(B)$ and $\mu_a(B)$ both μ_{erev} and H_{dc} are given as a function of flux density and hence the function $\mu_{erev}(H_{dc})$ is given.

4. RESULTS

$\mu_{erev}(H_{dc})$ was measured on ETD44 cores in the material N87 at $T = 25^\circ\text{C}$. The initial permeability of N87 is 2200. The N87 material data $\mu_{rev}(H_{dc})$ and $\mu_a(B)$ for the calculation of $\mu_{erev}(H_{dc})$ were measured on R29 cores at $T = 25^\circ\text{C}$. The demagnetization factor β was calculated with measured values of the effective permeability of the ETD44 cores and with the nominal initial permeability of N87.

Figure 1 shows a comparison of measured and calculated data.

Figure 1: Comparison of measured and calculated data for an ETD44 core in the S+M Material N87 at $T = 25^\circ\text{C}$

References

- [1] Lange D, "Berechnung von Grenzdaten bei der Gleichstromvormagnetisierung", Conference on electronica, Munich November 1992
- [2] Gans R., "Die Gleichung der Kurve der reversiblen Suszeptibilität", *Phys. Z.* **12** (1911), pp 1053 - 1054
- [3] Bozorth, R., "Ferromagnetism", (Van Nostrand Company, Inc., 1951), p 6
- [4] Kampczyk W, Röß E., "Ferritkerne", (Siemens AG, 1978), pp 170 - 172
- [5] Kampczyk W, Röß E., "Ferritkerne", (Siemens AG, 1978), pp 250 ff