INFLUENCE OF A MECHANICAL STRESS ON FERRITE MATERIALS FOR BROADBAND APPLICATIONS

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ABSTRACT

The influence of mechanical pressure on the magnetic behavior of ferrite materials for broadband applications was investigated. The study of the pressure sensitivity of the initial permeability μ_i was performed by applying unidirectional and hydrostatic pressure. The pressure behavior of specific loss factor $\tan\delta/\mu_i$ and hysteresis loss coefficent η_B were measured by applying hydrostatic pressure.

Important differences in the sensitivity of initial permeability between applying hydrostatic or unidirectional pressure were observed. A dependency of the pressure sensitivity of initial permeability as function of initial permeability was found. Such a correlation does not exist for the pressure sensitivity of specific loss factor and hysteresis loss coefficient.

INTRODUCTION

New broadband access technologies (xDSL or LAN) require inductive components with ferrite cores in different high performance broad band ferrite materials. The production process of the inductive component, for example winding, clamping or potting, induces mechanical forces on the ferrite cores. This mechanical stress impacts the magnetic properties of the ferrite material and consequently the performance of the inductive component.

PRESSURE SENSITIVITY OF INITIAL PERMEABILITY

The pressure sensitivity of initial permeability μ_i was studied on ring cores of different broadband ferrite materials. The measurements were performed by applying both hydrostatic pressure, which simulates the effect of potting, and unidirectional pressure, resembling clamping forces. Fig. 1 shows the initial permeability as function of hydrostatic pressure for tree typical broad band materials with different initial permeabilities (see table 1).

A clear correlation between initial permeability and pressure sensitivity of the initial permeability was observed. The pressure sensitivity of the initial permeability is stronger for ferrite materials with higher initial permeability.

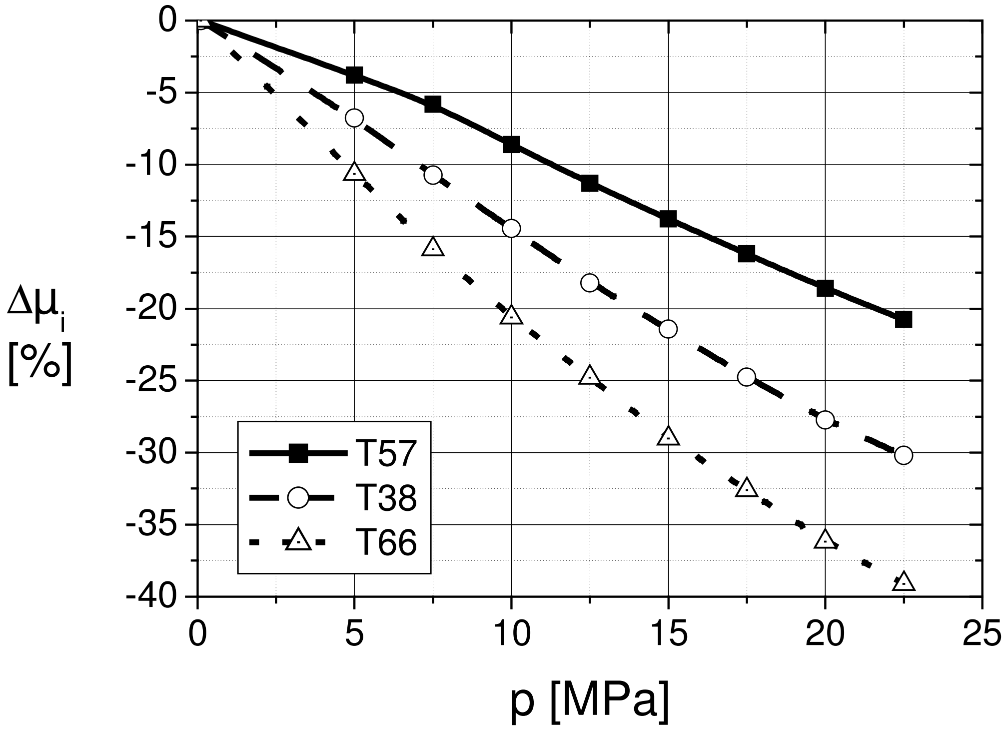

Fig. 1. Roll-off of initial permeability as function of hydrostatic pressure $\mu_i(p)$ at 25°C with frequency f=10kHz and flux density B=1mT

The pressure sensitivity of the initial permeability can be described by the following equation[1]:

$$\frac{\Delta\mu(\sigma)}{\mu_{i0}} = \frac{1}{1 + k \cdot \mu_{i0} \cdot \sigma} \tag{1}$$

μ_{i0} is the initial permeablility of the ferrite material without external pressure, σ is the pressure tension, and k is a material specific constant which is expected to depend on saturation flux density and magnetostriction[2]:

$$k = \frac{9\lambda_s \mu_o}{2B_s^{\,2}} \tag{2}$$

The constant k was determined by linear regression from the data given in Fig. 1 for different materials. The results for k and the corresponding correlation coefficients are shown in table 1.

Table 1. Material constant k with correlation coefficent and initial permeability for different broad band ferrite materials for hydrostatic pressure.

Material	$\mu_i(\sigma = 0$ MPa) measured	k $[\frac{1}{MPa}]$	**correlation coefficient *r***
T57	3937	$3{,}12 \cdot 10^{-6}$	0,9950
T38	9174	$2{,}20 \cdot 10^{-6}$	0,9980
T66	11778	$2{,}51 \cdot 10^{-6}$	0,9988

For measurements with unidirectional pressure the pressure was applied in the direction of the z-axis of the ferrite ring core. The measurement results with unidirectional pressure yield a different pressure sensitivity of the initial permeability with k = 30 1/Mpa being a factor of 10 higher. Following equation (2) the magnetostriction constant amounts to ~10^{-7} under hydrostatic and ~10^{-6} under isostatic pressure conditions. Both values compare well with reported values of <10^{-6} [3].

PRESSURE SENSITIVITY OF SPECIFIC LOSS FACTOR

The measurements of the pressure dependence of the specific loss factor was only performed by applying hydrostatic pressure. The results are given in Fig. 2.

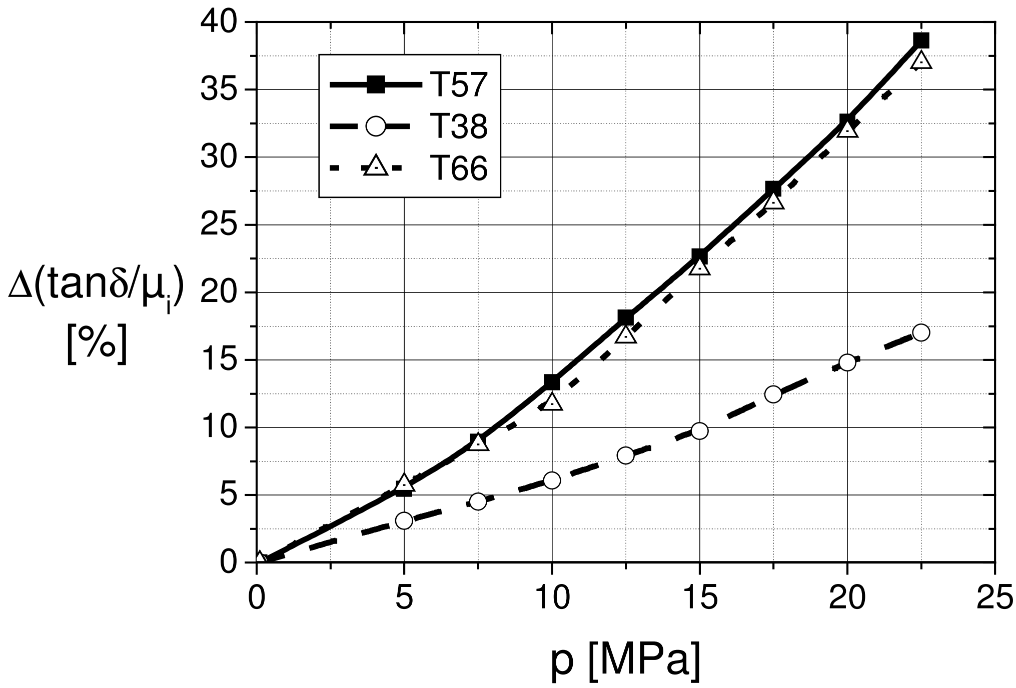

Fig. 2. Percentage change of specific loss factor as function of hydrostatic pressure $\mu_i(p)$ at 25°C with frequency f=10kHz and flux density B=1mT.

A correlation between the pressure sensitivity of the specific loss factor and the value of the initial permeability of the material could not be observed. There is also no correlation between the pressure sensitivity of the specific loss factor and the value of the specific loss factor without applying pressure.

PRESSURE SENSITIVITY OF HYSTERESIS LOSS COEFFICENT

The hysteresis loss coefficent correlates with the third harmonic distortion, which for symmetric excitations dominates total harmonic distortion. This parameter is crucial for broadband transformers used in DSL systems. The relative change of the hysteresis loss coefficent as function of hydrostatic pressure is shown in Fig. 3.

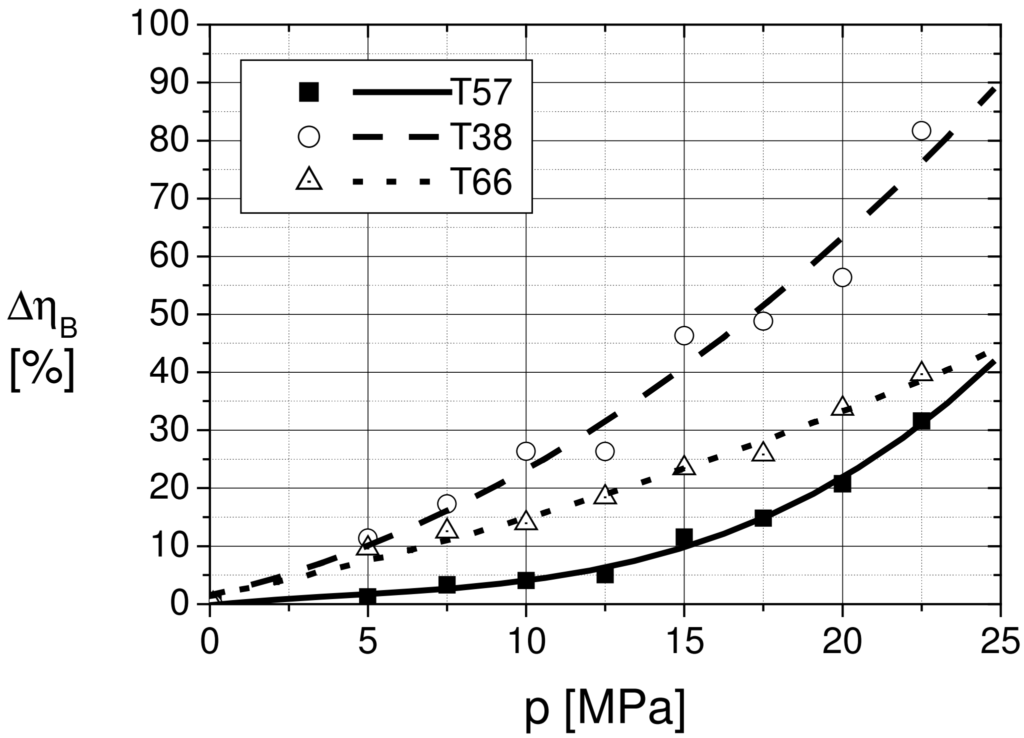

Fig. 3. Percentage change of hysteresis loss coefficient as function of hydrostatic pressure $\mu_i(p)$ at 25°C with frequency f=10kHz and flux density B_1=1.5mT and B_2=3mT

The hysteresis loss coefficient for all measured material is comparable. No correlation between the pressure sensitivity of the hysteresis loss coefficient and the initial permeability could be observed.

CONCLUSIONS

The pressure sensitivity of small signal ferrite material parameters like initial permeability μ_i, hysteresis loss coefficient η_B and specific loss factor $\tan\delta/\mu_i$ was studied on ring cores of different broadband ferrite materials. The measurements were performed by applying both unidirectional pressure, resembling the clamping assembly process and hydrostatic which simulates the effect of potting. In general the initial permeability μ_i decreases and the hysteresis loss coefficient η_B increases by applying both types of pressure but the results show a discrepancy in the $\mu_i(p)$ of an order of magnitude between unidirectional and hydrostatic pressure with the same nominal value. The pressure sensitivity of the initial permeability is stronger for materials with higher permeability materials as with an lower initial permeability. Such a correlation does not exists for the pressure sensitivity of hysteresis loss coefficient η_B, which seems to be more related to microstructural features.

OUTLOOK

First studies of the pressure sensitivity of the saturation flux density and the dc-bias behavior were performed. A clear influence of mechanical pressure was observed. The saturation flux density and the dc bias behavior are the important magnetic parameters for ferrites used in LAN applications. These kind of measurements will be continued.

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