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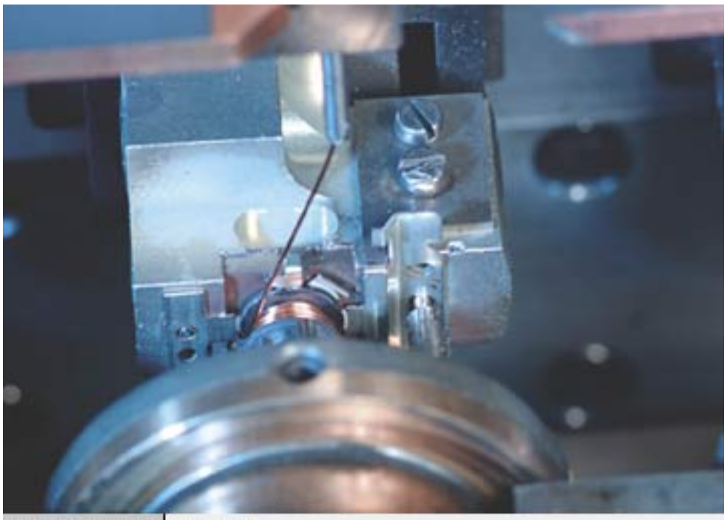
The impact of pressure on ferrites



BACKGROUND | FERRITES

The properties of ferrite materials change distinctly under mechanical pressure. This must be taken into consideration during testing or assembly to prevent distortion of test results or operating data.

Demand for high-performance, high-quality ferrite cores for broadband applications is steadily rising. EPCOS has teamed up with Munich University of Applied Sciences to examine the effects of mechanical pressure on the magnetic properties of ferrites for these products.

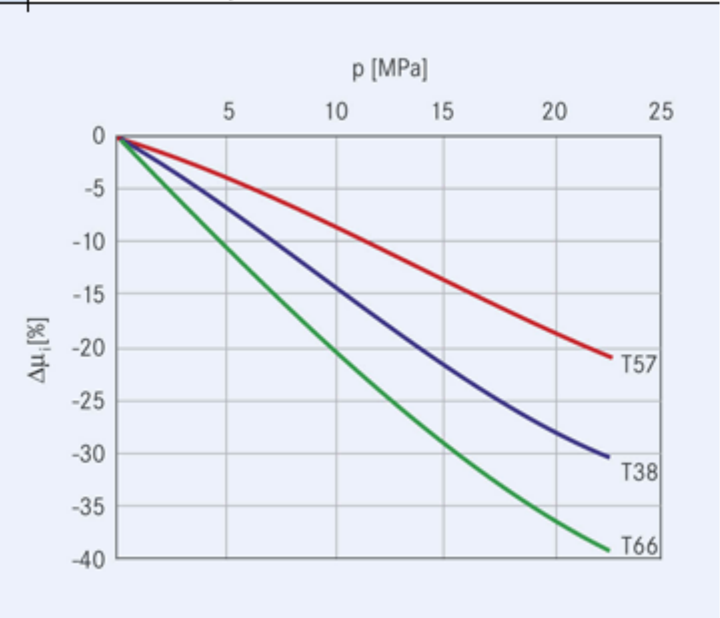
New technologies for high-speed Internet access such as DSL need inductive components with ferrite cores made of various high-performance materials. The winding, bonding and encapsulation processes involved in the manufacture of transformers generate mechanical forces that affect the ferrite cores. The resulting mechanical stress influences the magnetic properties of the ferrite material and consequently the performance of the inductive components.

The sensitivity of initial permeability μ_i to pressure was examined on toroidal cores made of different broadband ferrite materials. The tests were carried out by applying both hydrostatic and unidirectional pressure; the former simulates the effects of encapsulating the core while the latter represents bonding.

Tests with hydrostatic pressure

Permeability as a function of hydrostatic pressure is shown in ➔ 1 for three typical broadband materials with different initial permeabilities. The higher the initial permeability of the material, the more sensitive that property is to pressure.

1 Pressure sensitivity of various materials



1 Initial permeability as a function of hydrostatic pressure μi(p) at +25 °C, a frequency f of 10 kHz and a flux density B of 1 mT.

This can be described by the following equation:

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

Here, μ_{i0} stands for the initial permeability of the ferrite material without application of external pressure. σ stands for mechanical stress, and k for a material-specific constant that is expected to be a function of the saturation flux density (B_s) and magnetostriction (λ_s), i.e. elastic deformation due to magnetization:

$$k = \frac{9\lambda_s\mu_0}{2B_s^2} \qquad (2)$$

The constant k was determined for various materials by linear regression from the data in → 1. The results for k and the corresponding correlation coefficients will be noted from → 2.

Applications & Cases

2 | Material constants of ferrites

Material	μ_i (σ = 0 MPa)	k $\left[\frac{1}{MPa}\right]$	Correlation coefficient
T57	3 937	3.12×10^{-6}	0.9950
T38	9 174	2.20×10^{-6}	0.9980
T66	11 778	2.51×10^{-6}	0.9988

2 The material constant k, the correlation coefficient and the initial permeability for various broadband ferrite materials under the effect of hydrostatic pressure.

Tests with unidirectional pressure

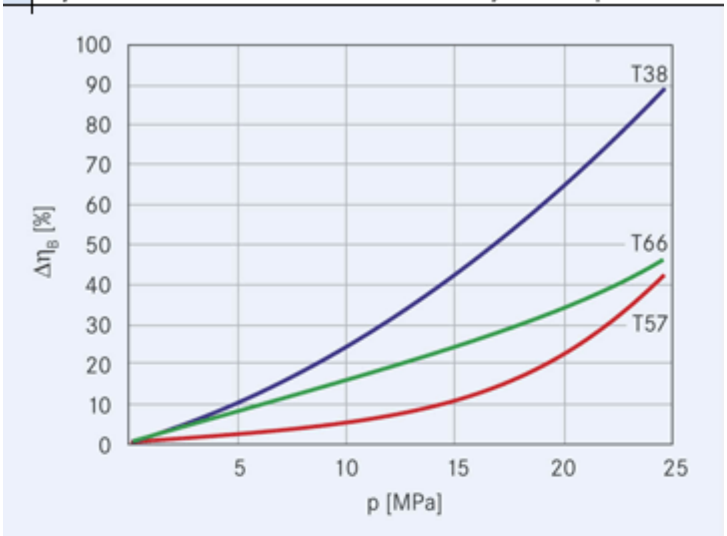
When unidirectional pressure was applied, the forces acted along the *z* axis of the ferrite toroidal core. The results showed a different pressure sensitivity of initial permeability in this case, the value of k being ten times higher at 30/MPa. According to equation (2), a magnetostriction constant of about 10^{-7} is obtained under hydrostatic pressure conditions and about
10^{-6} under unidirectional ones.

Specific loss factor

The effect of pressure on the specific loss factor was determined only by applying hydrostatic pressure; the results can be seen from → 3. No correlation was observed between the pressure sensitivity of the specific loss factor and the initial permeability of the material. Nor was there any correlation between the pressure sensitivity of the specific loss factor and the latter's value without the effect of pressure.

The hysteresis loss coefficient correlates with the third harmonic that dominates the entire harmonic component in the case of symmetrical excitation. This parameter is of crucial importance to broadband transformers used for DSL applications. The relative change in the hysteresis loss coefficient as a function of hydrostatic pressure is shown in → 4.

4 | Hysteresis loss coefficient as a function of hydrostatic pressure



4 Results at +25 °C, a frequency f of 10 kHz and a flux density B of 1.5 mT.

Differentiated results

The pressure sensitivity of three parameters of ferrite materials used for small-signal transmission was examined on toroidal cores made of different broadband materials. The parameters measured were initial permeability μ_i, hysteresis loss coefficient η_B and specific loss factor tan δ/μ_i. The tests were carried out by applying both unidirectional pressure to resemble bonding during assembly and hydrostatic pressure to simulate the effects of encapsulation.

In general, initial permeability μ_i drops and the hysteresis loss coefficient η_B rises when both types of pressure are applied. However, the results show an identical discrepancy of about one degree of magnitude for $\mu_i(p)$ between unidirectional and hydrostatic pressure for the same quantity. The higher the initial permeability of the material, the more sensitive it is to pressure. However, such a correlation does not exist for the pressure sensitivity of the hysteresis loss coefficient η_B, which appears to depend more closely on microstructural properties.

Especially when ferrite cores or pot core halves are glued or encapsulated, high forces and thus high pressure can be generated after curing. Whether and to what extent this changes the permeability of cores must be determined empirically.