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colour inside

Test methods for electrical and magnetic properties of magnetic powder cores

Méthodes d'essai des propriétés électriques et magnétiques des noyaux en poudre magnétique

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TEST METHODS FOR ELECTRICAL AND MAGNETIC PROPERTIES OF MAGNETIC POWDER CORES

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The text of this International Standard is based on the following documents:

Draft	Report on voting
51/1419/CDV	51/1436/RVC

Full information on the voting for its approval can be found in the report on voting indicated in the above table.

The language used for the development of this International Standard is English.

This document was drafted in accordance with ISO/IEC Directives, Part 2, and developed in accordance with ISO/IEC Directives, Part 1 and ISO/IEC Directives, IEC Supplement, available at www.iec.ch/members_experts/refdocs. The main document types developed by IEC are described in greater detail at www.iec.ch/standardsdev/publications.

The committee has decided that the contents of this document will remain unchanged until the stability date indicated on the IEC website under webstore.iec.ch in the data related to the specific document. At this date, the document will be

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- replaced by a revised edition, or
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INTRODUCTION

Magnetic powder cores have the characteristics of low relative permeability, high saturated flux density and low loss. Therefore, compared with ungapped ferrite, the equivalent impedance of a sample of magnetic powder core is much smaller, and the magnetizing current is very large, so the required excitation source will have both high frequency and high-power capacity, which is difficult to obtain in practice. Moreover, the impedance angle of a magnetic powder core under test is very close to 90°, and this results in great difficulties to obtain accurate measurements of power loss.

The IEC 62044 series provides measuring methods of magnetic properties at low and high excitation levels for magnetic cores made of magnetic oxides or metallic powders. However, the methods introduced in the IEC 62044 series cannot fully meet the measurement requirements for magnetic properties of magnetic powder cores. It is therefore useful to have a standard for suitable measuring methods for the magnetic properties of magnetic powder cores.

New test methods with pulse wave excitation and DC power method that account for the characteristics of magnetic power cores are introduced in this document, in addition to some modifications for the traditional test methods. Also, an air core inductor with single winding or dual windings is introduced in the document to verify or calibrate the accuracy of test methods for magnetic properties of magnetic powder cores, because of the linear properties of an air core inductor.

TEST METHODS FOR ELECTRICAL AND MAGNETIC PROPERTIES OF MAGNETIC POWDER CORES

1 Scope

This document provides the test methods for the electrical and magnetic properties of magnetic powder cores used for inductive components in electronics equipment, switch-mode power supplies and power conversion equipment, and introduces measuring principles, scope of application and matters of importance for each method.

The parameters used to characterize the magnetic powder cores include: inductance factor, effective permeability, complex relative permeability, temperature coefficient of permeability, frequency coefficient of permeability, DC bias characteristic, power loss, and quality factor. This document is the basis for determining the characteristic parameters of magnetic powder cores.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

IEC 63182-2, *Magnetic powder cores – Guidelines on dimensions and the limits of surface irregularities – Part 2: Ring-cores*

3 Terms, definitions, abbreviated terms and symbols

3.1 Terms and definitions

No terms and definitions are listed in this document.

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

- IEC Electropedia: available at https://www.electropedia.org/
- ISO Online browsing platform: available at https://www.iso.org/obp

3.2 Abbreviated terms

ARV	average rectification value
EPR	equivalent parallel resistance
ESR	equivalent series resistance
FFT	fast Fourier transform
MSE	modified Steinmetz equation
PWM	pulse width modulation
RMS	root mean square
SCR	silicon controlled rectifier
SRF	self-resonant frequency
ZVS	zero voltage switching

3.3 Symbols

All the formulae in this document use basic SI units. When multiples or sub-multiples are used, the appropriate power of 10 shall be introduced.

f	is the frequency, in hertz (Hz);
T_S	is the cycle, in seconds (s);
B_m	is the peak value of effective magnetic flux density, in teslas (T);
H_m	is the peak value of effective magnetic field strength, in amperes per meter (A/m);
P_c	is the power loss absorbed by the core, in watts (W);
P_w	is the winding loss, in watts (W);
P_{cv}	is the power density absorbed by the core, in watts per cubic meter (W/m^3);
A_e	is the effective cross-sectional area of the core, in square meters (m^2);
l_e	is the effective magnetic path length of the core, in meters (m);
V_e	is the effective volume of the core, in cubic meters (m^3);
φ	is the phase, in radians (rad);
$\Delta\varphi$	is the phase shift absolute error, in radians (rad);
N_2	is the number of turns of the voltage sensing winding;
ΔT	is the temperature rise, in degrees Celsius (°C);
N_1	is the number of turns of the exciting winding;
μ_0	is the magnetic constant (the permeability of vacuum), approximately $4 \times \pi \times 10^{-7}$ H/m;
μ_{ea}	is the effective amplitude permeability;
$\mu_{e\Delta}$	is the effective incremental permeability.

4 Instruments and equipment

4.1 General provisions

A suitable circuit (as specified in Annex A to Annex F and Annex H) and instruments shall be chosen for measuring.

4.2 Excitation source

4.2.1 General provisions

The properties of magnetic powder cores provided by manufacturers are generally based on a sinusoidal wave excitation source, because that is the most repeatable and easily replicated measurement. Applications include many diverse non-sinusoidal conditions, and therefore methods for testing with other waveshapes are necessary for specific cases. Sine wave basic data is most useful as a common point of reference for characterizing materials, comparing materials, correlating testing between labs, and setting clear specification limits. Excitation sources in this document include sinusoidal wave and square wave sources. Note that the waveform of a voltage source (setting the magnetic flux density) does not necessarily match the waveform of the associated current (since the magnetic field strength follows in accordance with the inductive properties of the device under test). Likewise, the waveform of a current source (setting the magnetic field strength) does not necessarily match the waveform of the associated voltage (from the induced flux density). The excitation source shall have low internal impedance, with frequency and amplitude stable to within ±0,1 % during measurement.

4.2.2 Sinusoidal wave excitation source

When sinusoidal wave excitation is specified, the total harmonic content of the excitation source shall be less than 1 %. When the excitation voltage is sinusoidal, the magnetic flux density is calculated as in Formula (1).

$$B_\mathrm{m} = \frac{\sqrt{2} \times U_\mathrm{1rms}}{2 \times \pi \times f \times A_e \times N_1} \tag{1}$$

where

U_1rms is the root mean square (RMS) of the excitation voltage, in volts (V).

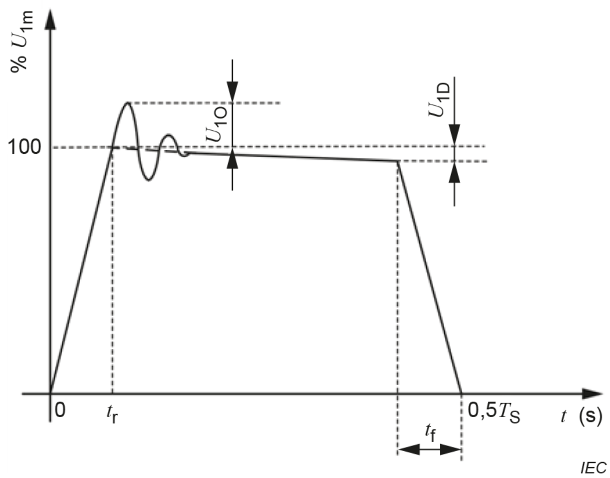
4.2.3 Square wave excitation source

When square wave (the pulse width modulation (PWM) waveform with 0,5 duty cycle) excitation is specified, as shown in Figure 1 (the negative half wave is the same as the positive half wave in shape), the overshoot U_1O shall be less than 5 % of the peak pulse amplitude U_1m, the droop U_1D shall be less than 2 % of the peak pulse amplitude U_1m, and the pulse rise time t_r and pulse fall time t_f shall be less than 1 % of the cycle of the square wave.

NOTE Clause I.2 describes the rationale of “less than 1 %”.

When the excitation voltage is square, the magnetic flux density is calculated as in Formula (2).

$$B_\mathrm{m} = \frac{U_\mathrm{1m}}{4 \times f \times A_e \times N_1} \tag{2}$$



Key

U_{1m}	peak pulse amplitude is the maximum value of an extrapolated smooth curve through the top of the pulse, excluding any initial "spike" or "overshoot", the duration of which is less than 10 % of the pulse duration, in volt (V) (see IEC 61007:2020, 3.3)
t_r	pulse rise time
t_f	pulse fall time
U_{1D}	droop
U_{1O}	overshoot

Figure 1 – Figure of square waveform

4.2.4 Calculation of magnetic flux density

In general, the magnetic flux density with an arbitrary AC waveform exciting voltage can be calculated as in Formula (3).

$$B_m = \frac{U_1}{4 \times f \times A_e \times N_1} \quad (3)$$

where

U_1 is the average rectification value (ARV) of the arbitrary AC waveform exciting voltage, in volts (V).

4.3 Measuring equipment

4.3.1 General provisions

Voltage meter or voltage-measuring equipment shall be of high internal impedance. In order to reduce measurement error, probes shall be of high input impedance. Additionally, the bandwidth of the voltage meter or voltage-measuring equipment shall cover the frequency of harmonics whose amplitude is 1 % of the amplitude of the fundamental wave.

4.3.2 Voltmeter

In order to measure the RMS, average value and peak value of the excitation voltage accurately, a voltmeter with accuracy of 0,2 % is recommended.

4.3.3 Data acquisition unit

In order to measure the RMS, average value and peak value of the excitation voltage accurately, the sampling rate of the data acquisition unit shall be not less than 256 points per cycle, and the resolution shall be not less than 12 bits.

4.4 Sensor

4.4.1 Sampling resistor

The error of the resistance of the sampling resistor shall be less than 0,1 % (including the temperature drift of resistance). The parasitic inductance of the sampling resistor shall meet both Formula (4) and Formula (5).

$$L \le \frac{R}{2 \times \pi \times f}\sqrt{2 \times \delta_{\mathrm{a}}} \qquad (4)$$

$$L \le \frac{R \times \tan(\delta_{\varphi})}{2 \times \pi \times f} \qquad (5)$$

where

L is the parasitic inductance of the sampling resistor, in henrys (H);

R is the resistance of the sampling resistor, in ohms (Ω);

δ_{a} is the allowable relative error of the voltage drop across the sampling resistor at the test frequency (no unit);

δ_{φ} is the phase difference of voltage and current on the sampling resistor at the test frequency, in radians (rad).

EXAMPLE

For δ_{a} = 0,1 %, δ_{φ} = 4,363 × 10^{-4} rad = 0,025°, R = 1 Ω, f = 500 kHz, then:

$$L \le \frac{1}{2 \times \pi \times 500 \times 10^{3}}\sqrt{2 \times 0{,}001} = 14{,}2\ \mathrm{nH} \qquad (6)$$

$$L \le \frac{1 \times \tan(0{,}025^{\circ})}{2 \times \pi \times 500 \times 10^{3}} = 0{,}139\ \mathrm{nH} \qquad (7)$$

So the parasitic inductance of the sampling resistor at 500 kHz meets $L \le 0{,}139$ nH.

4.4.2 Current transformer

The amplitude error (ratio error) of a current transformer shall be less than 5 %. The phase shift (phase error) shall be less than 0,000 436 rad or 0,025°.

NOTE Clause I.3 describes the rationale of “less than 5 %”.