Reliability of magnetic measurements of soft magnetic materials near resonance frequency using two-coil method

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Two-coil method has been commonly used to measure AC magnetic properties; however, its measurable frequency has been restricted by resonance. This paper gives a circuit analysis in high frequency region and, also demonstrates to obtain reliable permeability and magnetic losses using a variable capacitor connected parallel to the secondary coil.

Keywords: magnetic permeability, resonance frequency, two-coil method

1. Introduction

Power supply circuits for electrical applications are driven in high-frequency regime, and it is necessary to reduce their power loss consumption. Accurate measurement in high frequency region is a major topic for accurate evaluations of soft magnetic materials [1]. Two-coil method is casually used for this purpose [2], but it should overcome an upper limitation of measurable frequency due to the resonance. The number of the secondary coil is often reduced to make the resonance frequency high, but the reduction can cause inaccurate results [3]. This paper provides a method to accomplish an accurate analysis using data near the resonance frequencies.

2. Results and discussion

Fig. 1 shows measured relative permeability μ_r vs. frequency *f* at $B_m = 1$ mT for a troidal shaped soft magnetic-powder core CS234125 prepare by Chan Sung Co. Both the primary and the secondary coil have the same number *N* of winding turns. Since the measuring apparatus SY-8218 fabricated by Iwatsu Co. has an input impedance of C_i =18.5 pF, and it gives the resonance frequency of f_r = 3.6 MHz for *N* = 32 turns, 7.2 MHz for 16 turns, 14.4 MHz for 8 turns, respectively on this sample. Measured permeability was affected by the resonance between the secondary coil and C_i, and it was 9.1% higher for *N* = 32, and 0.9% higher for *N* = 16 compared to that for *N* = 8 at 1 MHz. The main reason for the inaccuracy in measured μ_r is due to current i_2 in the secondary coil. Both current in the primary coil i_1 and i_2 produce magnetizing field, therefore i_1 should be reduced to keep a constant B_m. Since the magnetic field is evaluated by using i_1, its reduction makes the measured permeability μ_r low.

Considering the mutual induction between primary and secondary coils, measured μ_r is given by

$$\mu_r = \frac{\mu}{\mu_0}\left(\frac{1}{1-\omega^2 CL_2}\right)$$
$$= \frac{\mu}{\mu_0}\left(1+\omega^2 L_2 C + \omega^4 {L_2}^2 C^2 + \omega^6 {L_2}^3 C^3 + \cdots\right), \quad (1)$$

where μ is permeability of the specimen, L_2 the induction of the secondary coil, *C* input capacitance of the apparatus, and ω = 2π*f*. As shown in Fig.2, measured μ_r varied owing to the change in *C*; and an analysis using eq. (1) gives a value of μ_r at *C* = 0, which means that the obtained value is not affected by the current of i_2. The extrapolated values for *N* = 32, 16, 8 show a good agreement. Moreover, magnetic losses were also analysed by using a linear function.

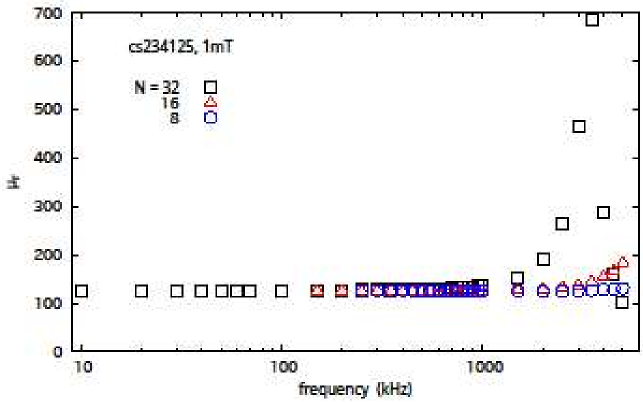

Fig. 1 Measured permeability vs. frequency.

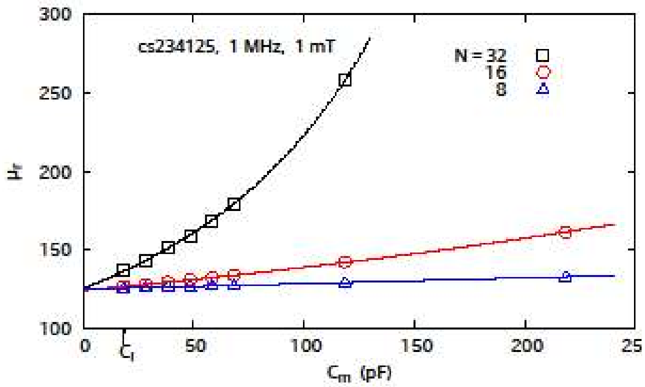

Fig. 2 Measured permeability vs. input capacitance.

References

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