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REFERENCE MATERIAL FOR MAGNETIC MEASUREMENTS IN EPSTEIN FRAME

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Abstract: The development of a reference material for magnetic measurements in an Epstein frame will enable Brazilian companies to obtain reliable, yet inexpensive calibrations of their equipment. By means of periodic measurements according to the standard NBR 5161, it will be possible verify the stability of the calibrations and the rated operating conditions from the behavior of the reproducibility graph and an interlaboratory comparison.

Keywords: total power loss; permeability; Epstein frame.

1. INTRODUCTION

Due to industry's need to increase the efficiency of electrical machines, new silicon steels with higher permeability (related to the capability of amplifying the magnetic field) and lower power loss are being developed.

The steel quality can be determined by magnetic measurements. The main magnetic properties are the magnetic permeability and the power loss, which can be obtained from hysteresis curves displaying the magnetic induction of the material as a function of the magnetic field. The internal area of the hysteresis curve corresponds to the energy dissipated during one cycle of hysteresis. After dividing this area by the material density and multiplying by the frequency, the result is equal to the power loss and is given in W/kg. These measurements are usually carried out in an Epstein frame and, in Brazil, according to standard NBR 5161. Most of the Brazilian laboratories perform the measurements with equipment specifically developed for that purpose. The reference material under development (non-oriented electrical steel) is to be used for calibrating this magnetic measurement equipment.

2. METHODS

Magnetic characterization was performed with a Brockhaus System MPG100D hysteresis tracer, using a 25cm Epstein frame with 700 windings at the Laboratory of Magnetism (LAMAG-DIMAT) of INMETRO. Measurements are traceable to the PTB (Germany) through a certified reference material.

The reference material chosen is a fully processed 2% silicon steel with medium quality magnetic properties and which is relatively inexpensive. This 2% silicon steel is widely consumed by electrical equipment manufacturers. This grade of electrical steel is referred to as E230 by its producer Acesita. The measured density was found to be 7.684 g/cm^3 and was obtained through the hydrostatic method according to NBR5161. The sample consisted of 16 strips, 30cm in length and 3cm in width, with a total weight of 560.32g. The strips had received a surface treatment to avoid oxidation. Total power loss and permeability for inductions of 1.0T, 1.3T, 1.5T and 1.7T at 50 and 60Hz were the measured magnetic properties. The behaviour of total power loss and permeability obtained at 1.5T and 60Hz are frequently used by equipment producers to verify the reproducibility of measurement results (figure 2).

For the measurement, the Epstein sample is surrounded by an inner secondary winding, while outside is the primary or magnetizing winding. Applying an electrical current in the primary winding at 60Hz, for this case, a magnetic field H in A/m will be produced as given by:

$$H = \frac{N.i}{l} \tag{1}$$

where N is the number of turns in primary winding; i is the rms value of exciting current in A and l is the effective magnetic path lenght in m. The maximum intensity of i must be enought for the induction B to reach 1.5T in the secondary winding. This induction value B may be determined from the voltage induced in the secondary winding, which is proportional to the time variation of the magnetic flux ($\phi = B.A$):

$$U = -N_2 \frac{d\phi}{dt} \tag{2}$$

where N_2 is the number of turns in the secondary winding; ϕ is the magnetic flux in Tm^2 and t in s. Integrating equation (2):

$$\Delta B = -\frac{1}{N_2 A} \int U dt \tag{3}$$

The relative permeability μ_r is obtained from:

$$B = \mu_0 \mu_r H \tag{4}$$

where μ_0 is the absolute permeability in vacuum ($4\pi 10^{-7}$ H/m).

3. RESULTS

The values of the electrical current i in the primary winding, the voltage U induced in the secondary and equations (1) and (3) can then be used to plot a hysteresis curve, such as that of figure 1.

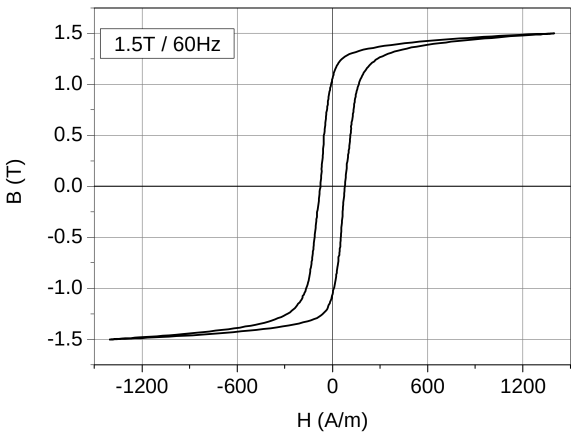

Figure 1. Typical hysteresis curve

As mentioned before the internal area of the histeresis curve corresponds to the dissipated energy and can be easily converted to magnetic power loss in W/kg. In the case of the Brockhaus system, the power loss is calculated directly by the internal wattmeter of the equipment. Some first results are shown in figure 2, where successive measurements correspond to successive days.

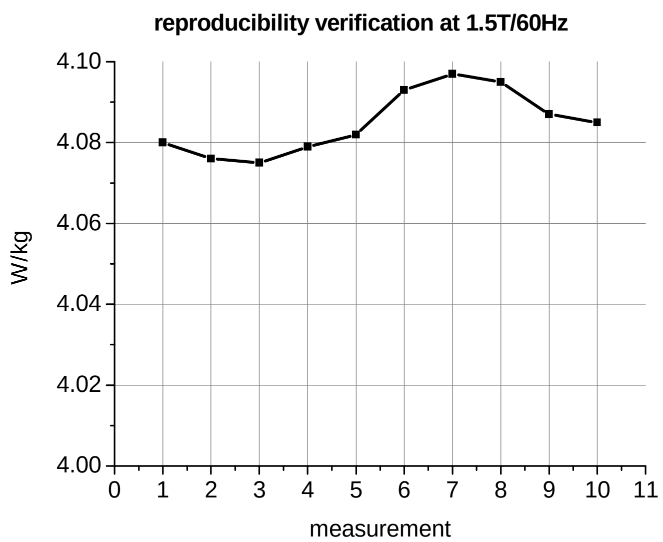

Figure 2. Losses at 1.5T/60Hz for reproducibility verification

Up to now the average value of total power loss at 1.5T/60Hz for E230 electrical steel is 4.0849 W/kg and the experimental standard deviation is 0.0079, corresponding to 0.2% of the average value. The relative permeability obtained under the same conditions is 854.5 and the standard deviation is 1.4. After a much more extensive reproducibility verification, producers equiped with Epstein frames in their laboratories will be invited to participate in an interlaboratory comparison of magnetic measurements on materials supplied by INMETRO.

4. CONCLUSIONS

The mission of INMETRO is to promote scientific and technological advance through the development of national metrological standards. To that end, E230 electrical steel is being examined for use as a reference material for magnetic measurements in an Epstein frame. At the end of the interlaboratory comparison a certified reference material will be offer to Brazilian steel producers and consumers.

To date, the average value of total power loss in E230 steel at 1.5T/60Hz presented a reproducibility around 0.2%.

ACKNOWLEDGMENTS

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REFERENCES

[1] Norma Brasileira NBR 5161 – Produtos Laminados Planos de Aço para Fins Elétricos - Verificação das Propriedades.