LabView Based AC Magnetization Characteristics and Measurement for Soft Magnetic Materials

Abstract

This paper presents LabView based method combined with a simple analog circuitry to characterize the ac magnetization profile of soft magnetic materials. First, soft magnetic materials prepared as ring cores are wound with equal number of turns for the primary and secondary windings. The primary winding is excited with sinusoidal supply of varying voltage amplitude. The secondary winding is interfaced with the LabView for data acquisition and calculation. Graphical plotting and viewing of the hysteresis loop exhibited by the soft magnetic materials under test can be achieved using National Instrument NI6009 data acquisition card and LabView software. This research discusses the methods of measurement for flux density, magnetic field intensity and core permeability at different points of the ac magnetization. The measured results are then compared with those given by the manufacturer datasheets. Good agreement has been achieved to validate the proposed LabView based method.

***Keywords** - ac magnetization; hysteresis; soft magnetic materials; BH curve; permeability*

I. INTRODUCTION

Soft magnetic composites (SMCs) are a viable alternative to steel laminations for a range of new applications such as rotating machines, transformers, electronic filters, sensors and fast switching solenoids. Soft magnetic materials are central to nearly every aspect of modern electrical and electronics technology through their ability to concentrate and shape magnetic flux with great efficiency. It can be employed as an efficient flux multiplier in a large variety of devices, including transformers, generators and in a wide array of apparatus from household appliances to scientific equipment.

However, SMCs should exhibit good magnetic, electrical and mechanical properties compared to that of existing laminated steels. Hence, it is important to ascertain and measure the characteristics of ac and dc magnetization profile of SMC before being used for downstream applications. The measurement usually requires two coils wound on SMC under test. Several equipments for this measurement performed in this project are personal computer, NI6009 interface card, LabView software, ac power supply, variable transformer and analog circuits. The magnetic hysteresis loop, flux density, field intensity, excited current and core permeability are measured and computed by LabView, and later graphically displayed on a pc monitor.

II. SOFT MAGNETIC MATERIALS

Soft magnetic materials are basically iron powder particles separated with an electrically insulated layer. The powder metallurgy process has for long time been used to manufacture soft magnetic materials components for high frequency indicator applications. These materials consist generally of iron particles distributed in matrix of organic materials [1].

Magnetic materials have revolutionized our lives. The composites find increasing use in electrical motors, replacing existing laminated materials [2]. The soft magnetic materials are being developed in order to provide alternative solution with competitive magnetic properties such as good relative permeability and magnetic saturation, but with high electrical resistivity [3].

The materials that have been used in the project have been prepared from a series of soft magnetic composites formulated using GR grade Merack iron powder.

III. METHOD AND APPROACH

A. Cross sectional area, A_c

The cross sectional area of a core represents the area permeated with flux of one of its limbs. For the ring or toroid core, the area could be determined approximately as a product of the core height, *h* and the difference between the outer, D_o and inner diameter, D_i as shown in Figure 1.

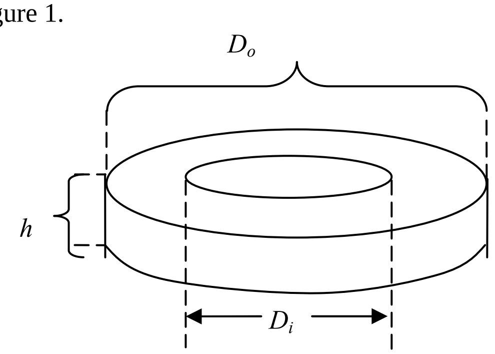

Figure 1. Example of toroid core

Hence, the equation for cross sectional area is:

$$A_C = h \times \left(\frac{D_o - D_i}{2} \right) \quad (1)$$

B. Magnetic path length, l_m

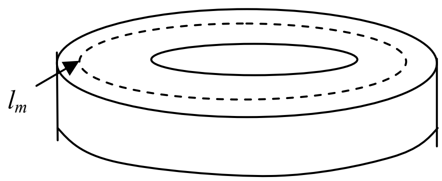

Figure 2. Magnetic path length

Magnetic path length is a measure of the distance which flux lines travel in making a complete loop as shown in Figure 2. For the toroid core, the average path length could be determined as:

$$l_m = \pi \times \left(\frac{D_o + D_i}{2} \right) \qquad (2)$$

C. Magnetic materials and permeability

The magnetic flux density *B,* is dependent on the magnetic field intensity, *H*. In general, the variation of *B* with *H* may not be linear and given by:

$$B = \mu H \qquad (3)$$

where μ may itself depend on *H*. The quantity of μ is known as the permeability of the medium in which *B* and *H* exist. The SI unit of permeability is Henry per meter (H/m). For air or free space, the permeability is a constant μ_0 which is given by :

$$\mu_o = 4\pi \times 10^{-7} \qquad (4)$$

Equation 3 indicates that larger flux densities can be produced for smaller mmf's (or magnetic field intensities) if the materials have higher values of permeability. Iron is one such material. Its large permeability is the primary reason for its use in the magnetic circuits of electric machines and transformer.

D. Magnetic field intensity, H

The magnetic field intensity is given by:

$$H(t) = \frac{i_p(t) \cdot N_p}{l_m} = \frac{v_{R_1}(t) \cdot N_p}{R_1 \cdot l_m} \qquad (5)$$

where $i_p(t)$ is the primary current, N_p the number of primary turns, l_m the magnetic path length, and $v_{R1}(t)$ the voltage drop across the current-sensing resistor R_1 as shown in Figure 4. The plot of *B* versus *H* forms the dynamic hysteresis loop of the ring core.

E. Flux density, B

The magnetic induction *B* can be determined from the voltage according to the law of induction as follows:

$$B(t) = \frac{1}{N_s \cdot A} \int v_s(t)dt \qquad (6)$$

where $v_s(t)$ is the induced voltage on the secondary winding with the number of secondary turns N_s and *A* is the area permeated with the flux [4].

Measuring *B* is a bit more difficult but it can be shown that if the core is wound as a transformer, the voltage on the secondary (if lightly loaded so that no appreciable current is drawn) is proportional to the rate of change (derivative) of *B* versus time. Thus, by integrating *B*, with, for example, an *RC* integrator, it is possible to determine *B*.

Let Φ be the flux (webers) in the specimen, e_2 the emf in secondary winding, i_2, the secondary current, then

$$e_e = -N_2 \frac{d}{dt}(\phi) \cong i_2 R_2$$

or, $$\phi = -\left(\frac{1}{N_2}\right) \int i_2 R_2 dt \text{ webers} \qquad (7)$$

If the constant of integration is made zero, the voltage across the capacitor *C* is

$$e_c = \left(\frac{1}{C}\right) \int i_2 dt \qquad (8)$$

and flux density

$$B = \frac{\phi}{A_c} \qquad (9)$$

where, A_c is the cross sectional area. From equation 7-9, it is evident that the voltage across capacitor V_c is proportional to the flux density [5]. So, the equation for flux density can be summarized to be:

$$B = \frac{e_c CR}{N_S A_C} \qquad (10)$$

where *R* is integrating resistor, *C* is integrating capacitor and e_c is integrator output in milivolts.

IV. EXPERIMENTAL SET-UP AND LABVIEW

The test samples of soft magnetic materials are formed in ring or toroid shape. The ring cores are then applied with primary and secondary windings. Both windings carry equal coil turns as shown in Figure 3.

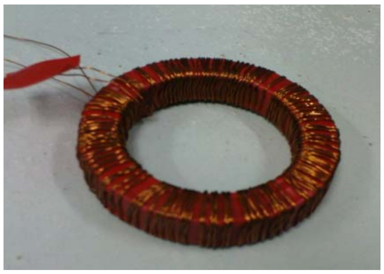

Figure 3. Primary and secondary winding were applied in the ring core

The measurement of the BH curve of the ring cores are implemented by using ac source of a preset voltage preferably at mains frequency. The hardware implementation is as shown in Figure 4. The test core is excited by a frequency-variable voltage applied to the primary winding, the magnetic flux being generated in the core. The input a.c current determining the applied magnetic field H is read via a resistor R_1 so it reads directly in volts and displays on x-axis of an x-y chart in units of ampere –turns per meter.

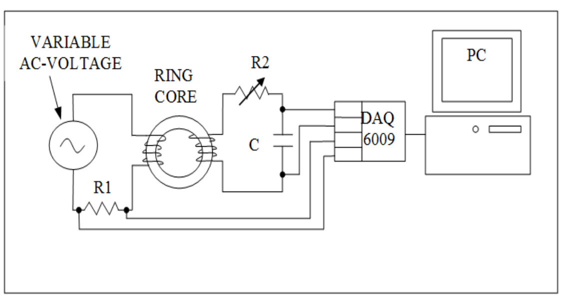

Figure 4. Schematic circuit for experimental set-up

The induced voltage is measured on the secondary via an RC integrator and the integrated voltage which is proportional to flux density B in tesla units for the y-axis display.

The impedances of the integrating capacitor should be around 1% of the resistance of R_1 and R_2, at the test frequency. R_2 should be chosen so that the secondary current is negligible in comparison with the primary current. R_2 value should be larger than C_1 impedance at the operating frequency with ratio approximately 40:1. The impedance can be calculated as below:

$$X_c = \frac{1}{2\pi f C} \qquad (8)$$

where f is frequency at the test and C is the capacitor value of C_1.

The hysteresis measurement is controlled by personal computer. Tasks of computer are to acquire measurements via data acquisition cards, to save the measured data to file and to post-process the experimental data for further analysis. The software programming bases on virtual instruments (VI). The instruments can be placed and wired together depending on the task. The front panel and block diagram of LabView can be seen in Figure 5 and Figure 6.

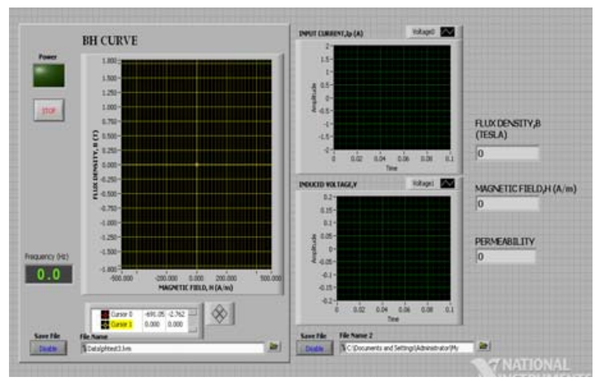

Figure 5. The front panel of LabView

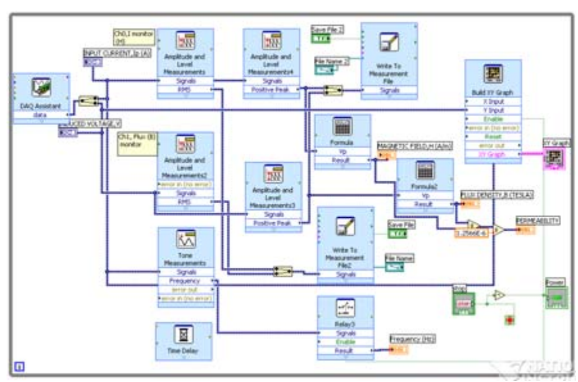

Figure 6. The block diagram of LabView

The LabView software communicates with the measuring circuits through NI-DAQ 6009 panel which is wired directly to the DAQ card. The excitation signal is generated by LabView. The LabView generates analog output on DAQ (Data AcQuisition) card through the card-driver.

DAQ measuring card is connected to patch panel, which contains eight analog input and two analog output channels. There are some digital channels as well, but only the analog channels have been used for this measurement. Two analog input channels are used for measuring voltage and current of the coil [6].

V. RESULTS

The test has been done on the laminated ring core of grade 35JN250 with outer/inner diameters of 60/44mm and thickness 10.5mm respectively. Figure 7 shows the experimental set-up.

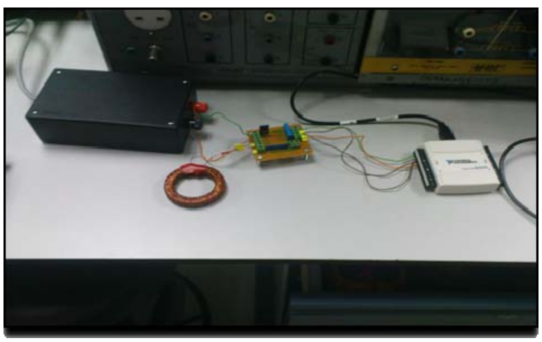

Figure 7. Experimental set-up

The LabView program has been configured to plot three graphical charts as shown in Figure 8. The first plot shows the hysteresis loop whereas the other two plots indicate the waveforms and values of the voltage at R_1 and C respectively. Actual values for flux density B and magnetic field intensity H can be deduced from equations (5) and (10).

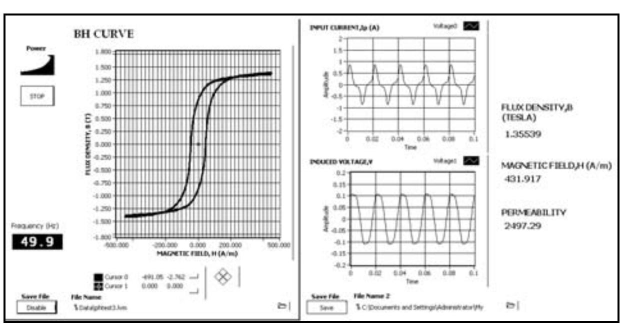

Figure 8. Graphical plots by LabView

VI. CONCLUSIONS

In this paper, an ac magnetization characteristics and measurement for soft magnetic materials using LabView has been discussed. The experiment has been applied successfully to measure hysteresis loop for laminated steel ring core of grade 35JN250. The components' tolerances and quality affect measurement accuracy. Therefore, the components with tight tolerances have been used in the circuit. The flux density B and magnetic field intensity H are calculated according to the excitation and Faradays's laws and the core permeability can be determined from the measured B and H values. Hysteresis loss and its dependent on applied frequency can be predicted with relative ease by computing the dynamic loop sizes at different excitation frequencies.

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