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Article *in* Physica B Condensed Matter · January 2004

DOI: 10.1016/j.physb.2003.08.069

Peter Kis
Budapest University of Technology and…

Miklos Kuczmann
Széchenyi István University, Gyor

Amália Iványi
University of Pécs

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Physica B 343 (2004) 357–363
PHYSICA B
www.elsevier.com/locate/physb

Hysteresis measurement in LabView

Péter Kis[a,*], Miklós Kuczmann[a], János Füzi[b], Amália Iványi[a]

[a] Department of Electromagnetic Theory, Budapest University of Technology and Economics, P.O. Box 49, H-1525 Budapest, Hungary
[b] Research Institute for Solid State Physics and Optics, P.O.Box-49, H-1525 Budapest, Hungary

Abstract

This paper deals with the computer-aided automated magnetic scalar hysteresis measurement on ferromagnetic toroidal-shape material. The measurement has been developed in LabView environment using National Instrument Data Acquisition Cards. The measurement technique of symmetric minor loops and first-order reversal curves are presented. It is necessary to measure the magnetic hysteresis curves of ferromagnetic material to describe the material from magnetic point of view. The measured scalar hysteresis characteristics taking into account the nonlinearity of the material can be used in further simulations in numerical field computations.

PACS: 07.55

Keywords: Hysteresis measurement; LabView programming; Computer-aided measurement

1. Introduction

A procedure of automated computer-aided ferromagnetic hysteresis measurement is presented in this paper. Task of computer in the frame of the measurement is driving all phases of the measurement process, e.g. controlling data acquisition cards, saving the measured data to file and post-processing of experimental data. The voltage of measuring coil and the current of excitation coil are measured and the magnetic field intensity H and the magnetic flux density B are calculated according to the excitation and Faraday's laws. The main advantage of the digital measurement consists in the measurement driving and the post-processing, because the digital data can be manipulated easily. The scanning rate must be chosen carefully because the down-sampled analog signals are imprecise at the same time in the case of over-sampling the size of data files become needlessly large.

The hysteresis curves, minor loops, reversal curves describe the magnetic feature of ferromagnetic materials. Our examination details a type of scalar hysteresis measurement of toroidal-shape ferromagnetic steel. The measurement requires two coils (excitation and measuring) on the examined material. Magnetic measurement system has been built up in our Magnetic Lab. The components of the measurement are Personal Computer with measuring cards, software and power supply.

The automated magnetic hysteresis measurement is controlled by personal computer. The excitation signal can be generated with the help of

*Corresponding author. Fax: +36-1-463-3189.
E-mail addresses: kpeti@evtsz.bme.hu (P. Kis), kuczman@evtsz.bme.hu (M. Kuczmann), fuzi@power.szfki.kfki.hu (J. Füzi), ivanyi@evtsz.bme.hu (A. Iványi).

0921-4526/$ - see front matter
doi:10.1016/j.physb.2003.08.069

the computer and the desired signals can also be measured. The applied KIKUSUI PBX 2020 power supply can amplify analog control signal ensuing the required power for excitation. The current of the first coil is generated by the power supply. The data acquisition and the generation of excitation current can be performed simultaneously, but some common problems can be occurred during the magnetic hysteresis measurement in the digital signal processing part, e.g. the question of correct sampling rate, the noises and so on.

2. Magnetic hysteresis measurement

The measuring arrangement of magnetic hysteresis can be seen in Fig. 1. The investigated ferromagnetic material has toroidal shape. The magnetic field inside of the toroid (outer/inner diameters are 60/40 mm. Height is 16 mm) is uniform with a scalar value H and directed along the axis of the toroid. The average magnetic moment per unit volume has a scalar value M and is also directed along the axis. H is assumed to be equal to the magnetic field of external origin in the material, as the demagnetizing field is equal to zero for the shape under consideration.

The first coil is controlled by the current of the Kikusui power supply. The second coil is used for measuring the effect of excitation. In this case the induced voltage of coil is measured. The amplitude of excitation current must be measured as a voltage of the R resistance. The value of R resistance is regarded to be constant, which is independent of the ambient temperature and the voltage.

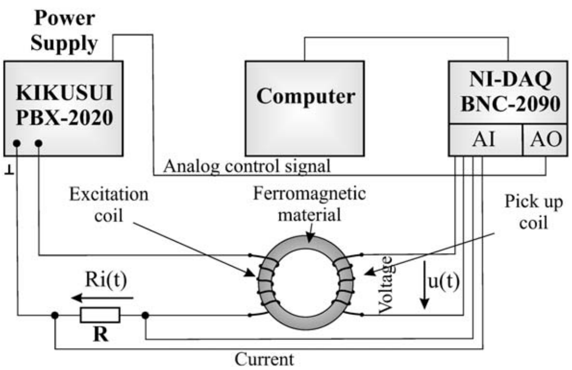

Fig. 1. The arrangement of the automated computer-aided magnetic hysteresis arrangement.

The computer communicates with the measuring environment through NI-DAQ BNC – 2090 panel, which wired directly to the DAQ cards. PBX 2020 power supply is applied for generating the excitation for the magnetic specimen. This device can generate 20 V and 20 A bipolar signals with arbitrary signal shapes. It can be controlled by voltage (CV mode) or current (CC mode) depending on the task. In case of magnetic hysteresis loop measurement CC mode has been applied, because the current is proportional to the magnetic field intensity. 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 16 analog input and two analog output channels. There are some digital channels as well but these are not important here, because only the analog channels have been used for this measurement. One analog output channel controls the power supply and two analog input channels are used for measuring voltage and current of the coils. The experimental symmetric hysteresis curves can be seen in Fig. 2. The characteristics was measured on C19 structural steel at 1 Hz. Each measurement in this paper has been performed with 20000 sample/period.

3. LabView realization

The controlling of measurement and post-processing of measured data are performed in LabView environment. Magnetic flux density and magnetic field intensity are calculated from measured data during the post-processing phase with the following relationships:

$$H(t) = \frac{N_e i(t)}{l}, \tag{1}$$

$$B(t) = B_0 + \frac{1}{AN_m}\int_0^t u(\tau)\,d\tau, \tag{2}$$

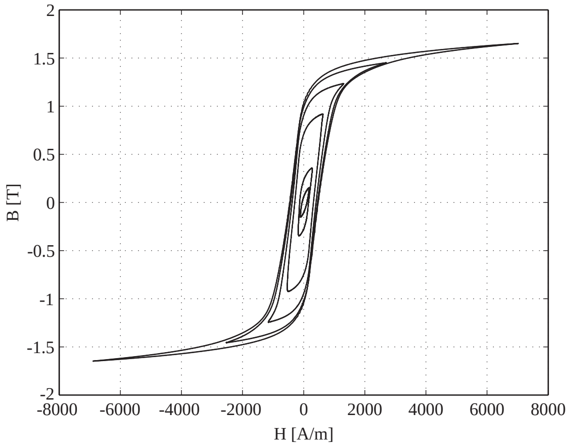

Fig. 2. Measured symmetrical minor loops on C19 structural steel at 1 Hz.

where l is the equivalent magnetic length of the toroidal-shape material, N_e and N_m are the number of turns of the excitation and the measuring coils, $i(t)$ is the excitation current, B_0 is integration constant, A is the cross-section of the material and $u(t)$ is the voltage of the measuring coil.

The front-end of magnetic hysteresis measurement software can be observed in Fig. 3. There are five plots in the graphical user interface. Four plots can be found in the left group. In this group, the calculated magnetic flux density (2) can be seen at left side top. The calculated magnetic field intensity (1) is plotted at left bottom. All of the measured signals appear at right bottom and the measured induced voltage can be observed after

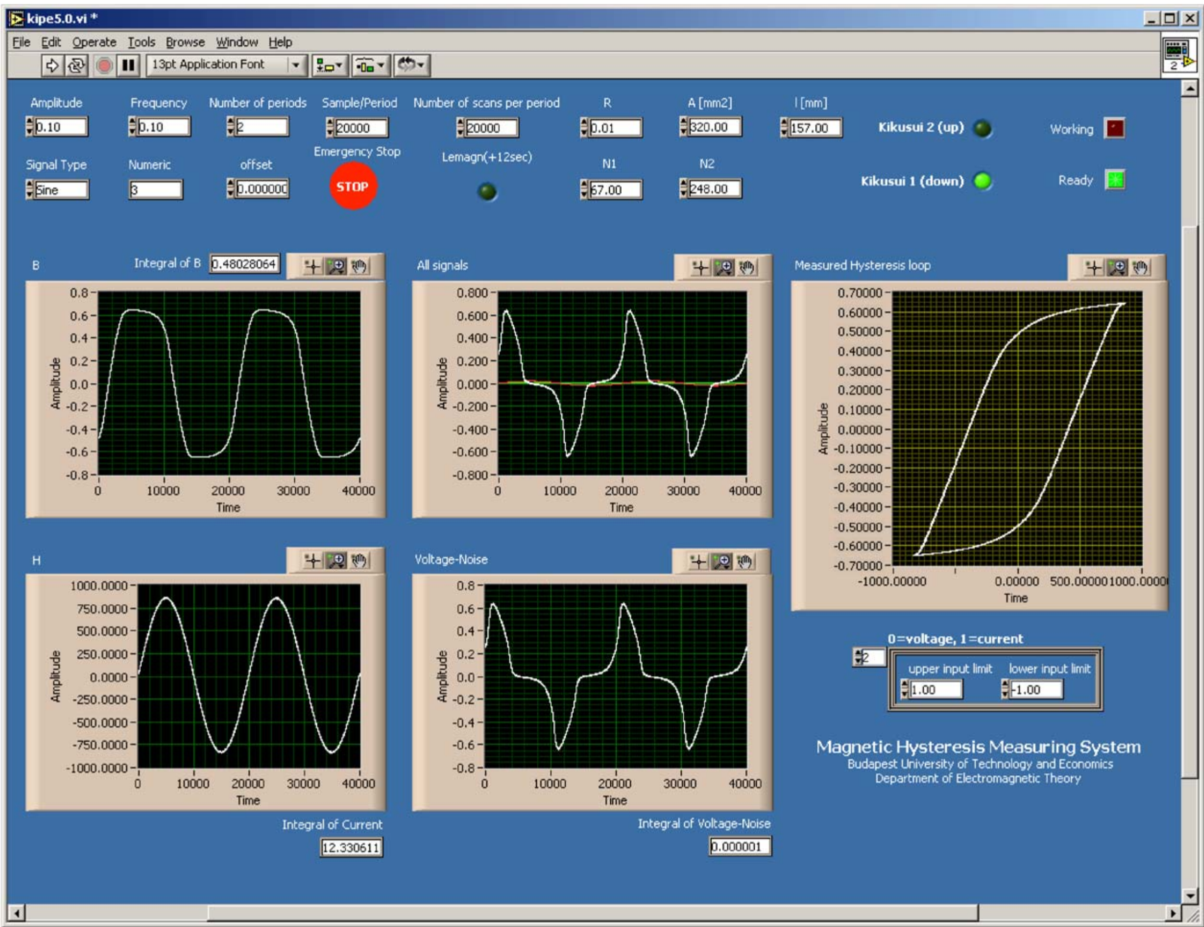

Fig. 3. The front end of LabView measurement software, which ensure convenient graphical user interface.

the noise compensation at right bottom. Finally, the fifth plot shows the measured hysteresis. The most important input parameters can be manipulated through the graphical user interface. These parameters are the amplitude and frequency of excitation, the scanning and sampling rates, the parameters of demagnetization process and reversal curves [1,2].

The most important part of the LabView realization is the generation of excitation signal and acquiring measured signals. The LabView programming does not mean command line programming. The software programming bases on virtual instruments (VI). The instruments can be placed and wired together depending on the task. The block scheme of the analog input ports can be seen in Fig. 4, which is responsible for the data acquisition. Four virtual instruments can be found in analog input program Fig. 4. The data acquisition can be started (AI Start VI) after port configuration (AI Config VI). The ''AI Read'' is placed in a while loop and collects data from the ports until the loop is running. The acquisition is stopped when an error occurs or the user pushes the stop button on the interface. AI Clear VI clears port configuration and the measurement stops. The block scheme of analog output port generating excitation can be observed in Fig. 5. The function of the port writing is very similar to the above detailed port reading.

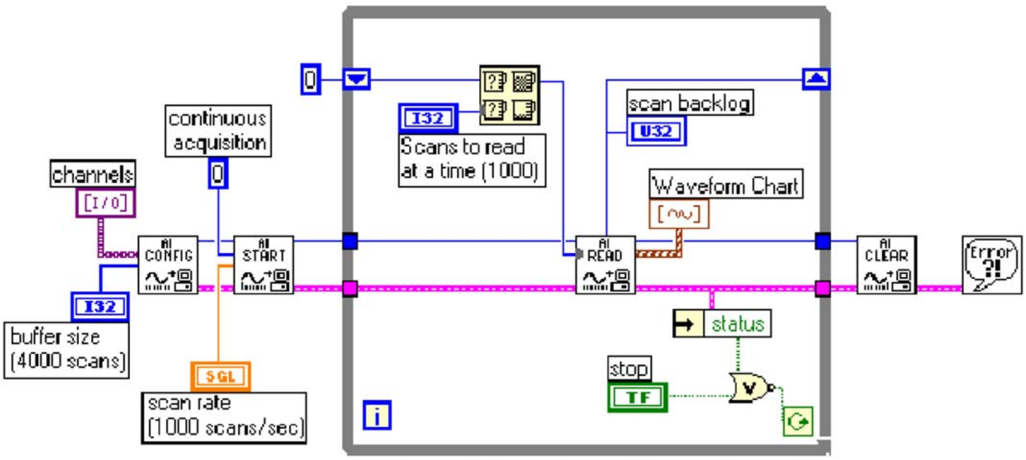

Fig. 4. Realization of analog input reading from analog ports in LabView.

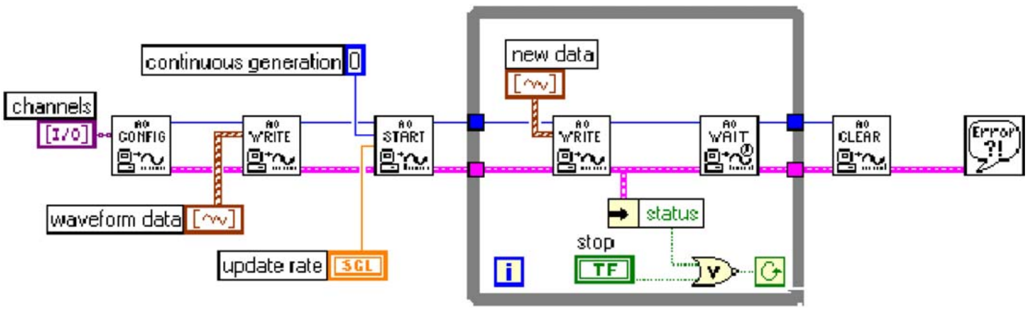

Fig. 5. Realization of analog output writing to analog ports in LabView.

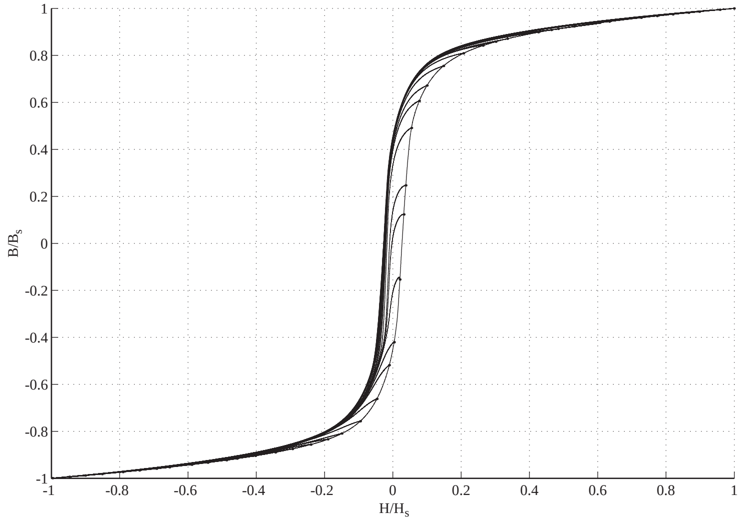

Fig. 6. The measured first-order reversal curves at 0.2 Hz, $n = 20$.

4. Measurement of first-order reversal curves

The first-order reversal curves current can also be measured by modifying excitation. This type of curves are needed for identification of some hysteresis models e.g. Preisach model. The required first-order reversal curves are obtained with the input function

$$H(t) = H_s\left[\frac{\alpha - 1}{2} + \frac{\alpha + 1}{2}\sin(\omega t + \pi/2)\right], \qquad (3)$$

where H_s is the magnetic field intensity in saturation state, ω is the frequency of excitation, $\alpha = k/n$ and $k \in [-n, n]$ is an integer, and n denotes the number of reversal curves [3].

Measurement results can be observed in Fig. 6. The measurement was performed at 1 Hz excitation frequency and $n = 20$ reversal curves are plotted [4].

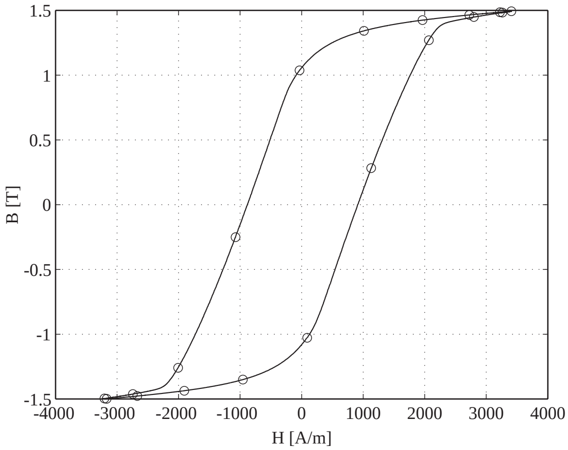

Fig. 7. Measured hysteresis loop with sinusoidal H. None-quidistant points. Small circles denote the distribution of the measured points.

5. Sinusoidal B

As it was mentioned before our hysteresis measurement has been driven by sinusoidal current, in the case of toroidal-shape magnetic core means sinusoidal H. However, there are some disadvantages of this configuration, namely the measured points are not distributed evenly on the hysteresis loop (Fig. 7). It means that a lot of points are at the saturation part of the curve and few points are located at the high slope part of the characteristics. This problem arises in hysteresis model identification. If the B is sinusoidal, then the distribution of the points becomes advantageous (Fig. 8).

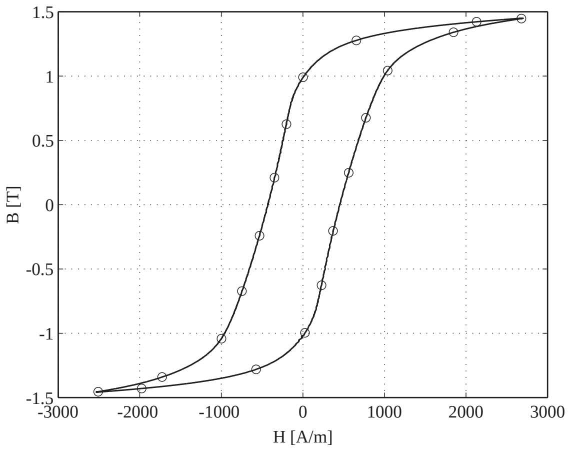

Fig. 8. Measured hysteresis loop with sinusoidal B. The points are distributed more evenly than in the case of sinusoidal H.

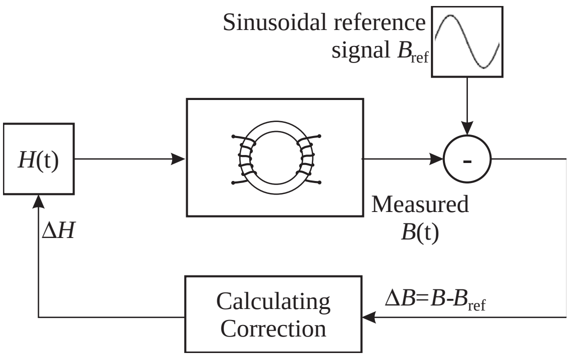

Fig. 9. Nonlinear feedback for generating sinusoidal B.

The sinusoidal shape of magnetic flux density can be generated by modifying the signal shape of the excitation current. A nonlinear iteration method has been built into our measurement, which modifies the excitation through a feedback. The block scheme of the measurement can be seen in Fig. 9. The iteration starts sinusoidal excitation and the differences between the prescribed reference sinusoidal signal B_{ref} and the measured quantities are calculated ($\Delta B = B - B_{ref}$), according to the ΔB difference the signal shape of excitation is modified in each time step. The iteration stops when the maximum value ΔB vector is small enough. The convergence of the method can be declared fast, approx. 10 cycles are needed for reaching less then 1% maximal difference between the sinusoidal reference signal B_{ref} and the measured B.

6. Conclusions

An automated computer-aided ferromagnetic hysteresis measurement is performed in LabView environment digital acquisition cards. Toroidal-shape magnetic material is investigated, which means scalar hysteresis measurement. The method can be used for identification of hysteresis models (e.g. Preisach, Jiles–Atherton and neural network based models) taking into account realistic materials.

The measurement of first-order reversal curves are presented, which are needed for parameter identification of the Preisach model. Arbitrary signal shape of the excitation current can be generated by the computer driven measurement. Therefore, the first-order reversal curves are measured successfully.

The programming possibilities of LabView ensure that the signal shape of magnetic flux density can be sinusoidal due to nonlinear control feedback. If the B is sinusoidal then the measured points of the hysteresis curve are distributed evenly.

The advantages of this type of measurement are the following. Each phase of the measurement are controlled by the PC. For this reason it is possible to build an automated hysteresis curve measurement. All of the data, the excitation and the measured are saved to file. It enables to further use of measured data. The data can be used in other environments e.g. Matlab. The reversal curves and symmetric minor loops can also be measured and investigated.

The cause of disadvantage of the computer-aided hysteresis measurement the error of A/D and D/A conversion can result undesired effects. This weak point can be eliminated the appropriate choice of the sampling and scanning rates.

Acknowledgements

The research work is sponsored by the Hungarian Scientific Research Fund, OTKA, Pr. No. T 034 164/2003.

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