REALIZATION OF THE JILES-ATHERTON HYSTERESIS MODEL APPLYING THE LABVIEW AND MATLAB SOFTWARE PACKAGE

Eszter Sárospataki* — Miklós Kuczmann

In this paper we will show a procedure developed under MATLAB and LabVIEW software package which is able to simulate the scalar ferromagnetic hysteresis applying the Jiles-Atherton model. The MATLAB realization has been developed to analyze the behaviour of model, the LabVIEW realization has been applied to simulate a toroidal shape core. The measurement system containing the core will be the basis of a controlling algorithm to realize sinusoidal form of the magnetic flux density.

Keywords: ferromagnetic hysteresis, Jiles-Atheron model, hysteresis measurements, LabVIEW

1 INTRODUCTION

The investigation and numerical analysis of the nonlinear magnetic field inside ferromagnetic materials will be the focus of this research work. The magnetic properties of ferromagnetic materials are described by the theory of hysteresis. Several models deal with the nonlinear characteristics of magnetic materials, for example the Preisach model, the Jiles-Atherton model, the Stoner-Wohlfarth model and so on [1].

In these physical and mathematical methods one of the most manifestly possibility of solutions is the Jiles-Atherton model. The theoretical background of the Jiles-Atherton model is the theory of Weiss and Langevin. The Jiles-Atherton model can be determined by five parameters. These parameters defining the hysteresis characteristics can be obtained from a set of experimental magnetization measurements [1, 2, 4].

As the first task of this research, the realization of Jiles-Atherton model has been completed in the frame of MATLAB and LabVIEW software package. The effect of the five parameters on the hysteresis loop has been analysed applying a function which has been developed in Matlab. This procedure will be used for identification as well.

By the help of the preliminary studies in MATLAB, and of the realization of Jiles-Atherton model in LabVIEW software package, the identification of the parameters, the completion of hysteresis measurements, and the comparison of the measured and the simulated data can be possible.

2 JILES-ATHERTON MODEL

The Jiles-Atherton model is widely used for modeling the nonlinear characteristics of magnetic materials. The quasi static form of this model can describe the *B-H* curve using five parameters. When the magnetic field intensity vector and the magnetization vector are parallel to each other, then the scalar hysteresis model can be used efficiently to describe the nonlinear and hysteretic relation between them. This situation can be imagined and can be supposed eg inside a toroidal shape core and in the case of numerical investigation of infinite half space. If the eddy current effect and other frequency dependent effects are playing no important role, then the so called rate-independent hysteresis model can be used for describing the phenomena.

The model is based on existing ideas of domain wall bending and translation, and exhibits all the main features of hysteresis [1, 2, 4].

The platform of theory is the energy balance equation. This equation declares that the external supplied battery energy per unit volume (δW_{bat}) covers the inner magnetic state of the ferromagnetic material (δW_{mag}) and the dissipating hysteresis loss per unit volume (δL_{mag}), and it can be written in the form

$$\delta W_{bat} = \delta W_{mag} + \delta L_{mag}. \tag{1}$$

The battery energy per unit volume can be expressed by the relation

$$\delta W_{bat} = \oint H \, \mathrm{d}B = \oint \mu_0 H \, \mathrm{d}(H+M) = -\oint \mu_0 M \, \mathrm{d}H \,, \tag{2}$$

where the integral has been calculated in one closed hysteresis loop, and the constitutive relationship

$$B = \mu_0 (H+M) \tag{3}$$

has been employed. Here H, B, M and μ_0 are the magnetic field intensity, the magnetic flux density, the magnetization and the permeability of vacuum.

The average magnetic moment per unit volume, ie the magnetization M can be comprised of an irreversible component M_{irr} and a reversible component M_{rev},

$$M = M_{rev} + M_{irr}. \tag{4}$$

The M_{rev} is related to the anhystertic or ideal magnetization by the following expression

*Laboratory of Electromagnetic Fields, Department of Telecommunication, Széchenyi István University, Egyetem tér 1, H-9024 Győr, Hungary, E-mail: kalah7@vipmail.hu, kuczmann@sze.hu

ISSN 1335-3632 © 2006 FEI STU

$$M_{rev} = c(M_{an} + M_{irr}) \,, \tag{5}$$

where c is a revesibility coefficient. The component M_{an} is the so called anhysteretic curve which is the average of the ascending and the descending parts of the major hysteresis loop, and it can be realized by the Langevin function,

$$M_{an} = M_s\left(\coth\frac{H+\alpha M}{a} - \frac{a}{H+\alpha M}\right). \tag{6}$$

Here M_s is the saturation magnetization, a is the shape parameter of the anhysteretic curve, and

$$H_e = H + \alpha M \tag{7}$$

is the effective field taking into account the domain interactions, and α is a model parameter.

After some mathematical formulation the following differential equation can be obtained

$$M_{irr} - M_{an} + k\delta\frac{\mathrm{d}M_{irr}}{\mathrm{d}H_e} = 0\,, \tag{8}$$

where the parameter k is linked to the coercive field, the parameter δ is equal to sign(H_e).

The well known differential equation of Jiles-Atherton model can be written in the form

$$\frac{dM}{dH_e} = \delta_M\frac{M_{an}-M}{k\delta} + c\frac{dM_{an}}{dH_e}\,. \tag{9}$$

Here

$$\delta_M = \begin{cases} 0: H_e < 0 & \text{and} \quad M_{an} - M > 0, \\ 0: H_e > 0 & \text{and} \quad M_{an} - M < 0, \\ 1: & \text{otherwise.} \end{cases} \tag{10}$$

3 IMPLEMENTATION OF THE MODEL IN MATLAB AND IN LABVIEW ENVIRONMENT

MATLAB is a high-level technical computing language and interactive environment for algorithm development, data visualization, data analysis, and numeric computation and so on. MATLAB can be used in a wide range of applications, including signal and image processing, communications, control design, test and measurement, financial modeling and analysis, and computational biology.

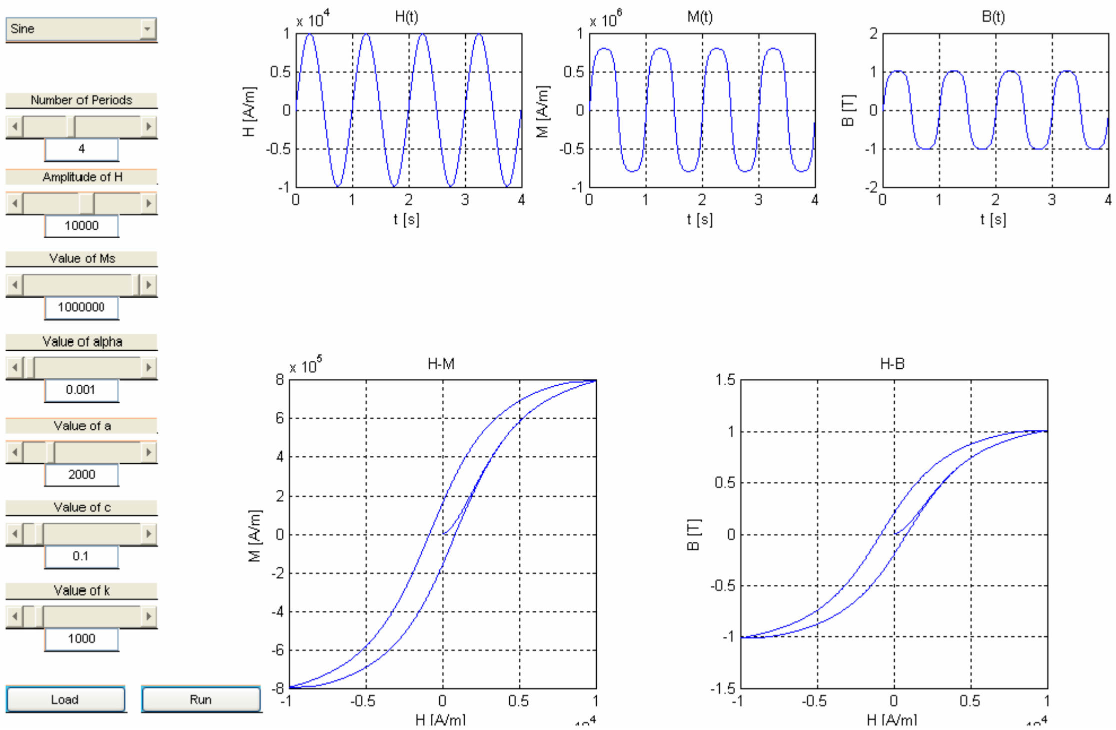

Fig. 1. The graphical user interface implemented in MATLAB

The graphical user interface developed in MATLAB ca be seen in Fig. 1. The parameters of Jiles-Atherton model can be changed with sliders or can be they written in editboxes as well. The type of the signal of magnetic field intensity can be sinusoidal or triangular, but this palette can be increased. After the number of periods is given the program is running and the time functions of the magnetic field intensity, the magnetization and the magnetic flux density, moreover the resulting hysteresis loop is plotted. The program with a set of new parameters is running again, if the pushbutton with a text “Run” is pressed. By means of the comparison of the simulated curves according to different value of the parameters, the effect of changing of parameters can be studied.

The equations of the Jiles-Atherton model are not usable in the direct form which can be found in the references at the stage of simulation. Procedures must be used to cover the continuity in the running of the program, for example: commands for, if, while and so. This procedure has been developed first in Matlab, because Matlab is a well known software to design engineering applications. In the next step the system of equations of the model has been developed in LabVIEW software package, because the measurements will be made in this software as well.

After understanding the equations, parameters and procedures of the Jiles-Atherton model of hysteresis, the aim is to implement the model in LabVIEW environment.

The National Instruments LabVIEW software is a graphical programming language sold by National Instruments. It is used extensively in research and in industry. To help in the design of programs, the LabVIEW software provides an extensive library of functions and tools for data analysis, report generation, data acquistion and file input/output and so on.

The algorithms and the graphical user interface of measurement of scalar hysteresis characteristic have been developed in LabVIEW environment using National Instrument Data Acquisition card inserted into a computer which controls the whole measurement tasks [3]. The block diagram of the measurement system can be seen in Fig. 2. The controlling of measurement and post processing of measured data are carried out in LabVIEW functions. Magnetic field intensity and the magnetic flux density are determined from measured data during the post-processing phase with the following relationships

$$H(t) = \frac{N_1}{2r\pi}\frac{u_1(t)}{R}, \tag{11}$$

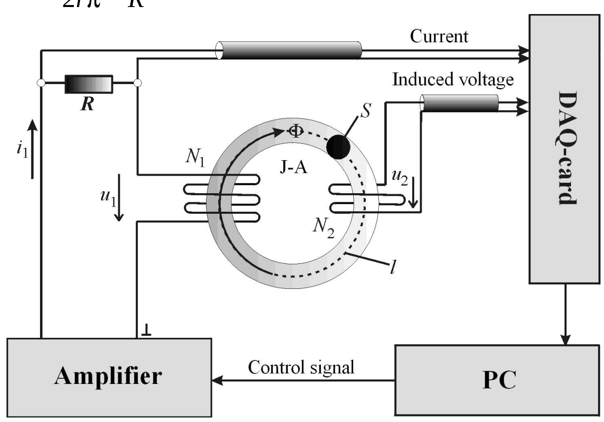

Fig. 2. The block diagram of measurement system under construction

and

$$B(t) = B_0 + \frac{1}{SN_2}\int_0^t u_2(\tau)\,\mathrm{d}\tau, \tag{12}$$

where $l = 2r\pi$ is the equivalent magetic length of the material, N_1, N_2, R, and S are the turns of the exciting primary coil, the secondary coil, the shunt resistor, and the cross section of the core (see Fig. 2.).

The core has been simulated by the developed Jiles-Atherton model. The magnetic field intensity ie the input of the model can be determined from (11) and the magnetic flux density can be determined by the model. The induced voltage of the secondary coil can be calculated from the magnetic flux density as

$$u_2(t) = -\frac{\mathrm{d}}{\mathrm{d}t}B(t)S\,N_2\,. \tag{13}$$

The voltages $u_1(t)$ and $u_2(t)$ has been sent to the measurement card as output and then they have been measured, ie the toroidal shape core has been simulated.

The graphical user interface of the Jiles-Atherton model implemented in LabVIEW can be seen in Fig. 3.

4 CONCLUSIONS

The implementation of the Jiles-Atherton model has been performed in two ways. The first one is the MATLAB procedure which is able to study the effect of parameters. This function will be continued to apply it for the parameters identification of the model. This can be implemented after making measurements.

The second one is the implementation of the LabVIEW algorithm. This can be used to simulate the material under test which is now a toroidal shape core. These measurements are now under investigations.

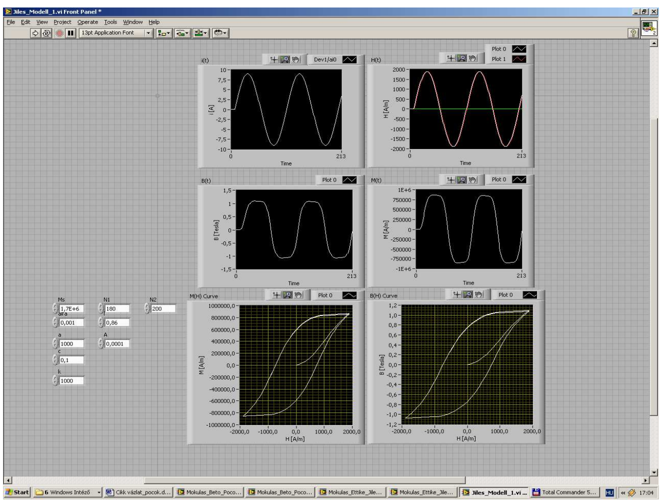

Fig. 3. The graphical user interface implemented in LabVIEW

The future work is to build up the measurements system in our laboratory then the identification and the application of the model.

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Received 7 November 2006

Eszter Sárospataki, born in Ajka, Hungary, in 1987. She is now BSc student at the Széchenyi István University. Member of the Laboratory of Electromagnetic Fields.

Miklós Kuczmann (MSc, PhD), born in Kapuvár, Hungary, in 1977. He is graduated at the Budapest University of Technology and Economics in 2000. He received the PhD degree in electrical engineering in 2005 under the guidance of Prof. Amália Iványi at the same University, Department of Electromagnetic Fields. His research activities are numerical electromagnetic field simulation, hysteresis modeling and measurements. He is now Assistant Professor of Fundamentals of Electrical Engineering at the Széchenyi István University, Győr.