NUMERICAL CHARACTERIZATION MODEL OF VECTOR HYSTERESIS FOR MAGNETIC MATERIALS

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Abstract - **The paper presents a numerical method based on Preisach model for the characterization and modelling of hysteretic magnetic materials exhibiting vector hysteresis, with acceptable accuracy, based on minimal material measurement data. The identification approach based on the Everett distribution function is a way to obtain accurate numerical solutions when the experimental data of the magnetic material are scarce, for instance: there are known only the initial magnetization curve and the upward major branch for two directions (rolling and transverse ones). The comparison between the measured and simulated major loop curves for another magnetization direction shows good agreements.**

I. INTRODUCTION

In recent years a renewed interest is observed in the scientific community for the study of materials showing the property of hysteresis which is closely related to a more common application: the process of recording (usually magnetic recording) and the property of memory.

From the modeling point of view, even if many hysteresis models have been developed, only very few are really used systematically in the laboratories (i.e. their integration into electromagnetic field analysis codes). The interest of many scientists has been concentrated to improve hysteresis models and to develop their ability to cover the most complex behavior observed experimentally in magnetic materials. However, the models are rarely covering all the range of magnetization processes observed experimentally. Most of them are dedicated simply to describe a hysteresis loop without any link to the physical processes involved. But a recording process is described in a proper manner by a vector model.

The Classical Preisach Model (CPM) is one of the most known hysteresis model, but a scalar one. Several vector hysteresis models starting from CPM have been proposed in the last decade [1], [2]. Mayergoyz proposed a vector model obtained as a superposition of scalar Preisach models continuously distributed along all angular directions [3].

In this paper, the Mayergoyz's Fourier angular expansion technique [3] is employed to characterize magnetic materials with vector hysteresis. The adopted model is combined with an identification procedure on analytical basis of Fourier coefficients into special grid of Preisach triangle [4], [5]. Because the experimental data of the magnetic material can be scarce, for instance: there are known only the initial magnetization curve and the upward major branch for two directions (rolling and transverse ones), the Everett distribution function [6] is used instead of the Preisach distribution function, in order to reduce the strong ill-posed of the identification process. The Everett function represents the integral of the Preisach weights function over a minor triangle from the Preisach triangle.

II. METHOD OF MODELLING OF VECTOR HYSTERETIC MAGNETIC MATERIALS

The Mayergoyz-type extensions of the Preisach model [1], based on a superposition of scalar Preisach models, represent the optimal solution for phenomenological modeling, especially in view of the practical applicability of the numerical models. The methods belonging to this category offer an optimal balance between the stability of the identification procedure, the requirements of experimental data and computation resources, on one side, and the accuracy of the model, on the other side.

In numerical analysis, it is necessary to solve with acceptable accuracy electromagnetic problems involving scalar and vector hysteresis, based on minimal material measurement data. To be able to ensure this convenience, the identification module heavily relies on the benefit of using the so-called Everett function [6], in connection with the classical Preisach model, for reducing the strong ill-posedness of the scalar model identification [5]. The vector model is identified based on only two or more scalar data sets on directions inside the rolling-transverse directions plane. Thus, the necessary user input data are: the point-by-point H-B description of the initial magnetization curve, and of the upward major branch, for each of the rolling/transverse directions.

The identification process employed consists in two stages:

- scalar identification: a scalar Preisach model is constructed for each of the two magnetization directions described by the user through the inputted raw data. The description of hysteresis using the Everett function is a variant of the Preisach approach. Instead of trying to reconstruct the Preisach distribution function itself, one is reconstructing for every node of the Preisach triangle the integral of the Preisach distribution, obtaining the so-called Everett distribution [6]. The identification approach based on the Everett distribution is probably the only alternative when the experimental information is scarce;

- vector identification: the approach is based on the proposal by Ragusa and Repetto [4], [5], whereby the Fourier coefficients for the vector Everett distribution functions are solved on a special mesh in the Preisach triangle. The expansion is limited to the 0th and 1st harmonics.

As the input data are initial magnetization curves and major loops for only two directions, the rolling and transverse ones, the computation of the 0^{th} and 1^{st} harmonics can be considered sufficient for this model.

III. NUMERICAL RESULTS

Figure 1 shows the VSM (Vibrating Sample Magnetometer) measurements data (the initial magnetization curves and the major loops) for a metro card specimen (semi-hard magnetic recording film) for various angles, provided by the UPB team: 0°, 90° (rolling and transverse directions), 30°, 60° (intermediate directions). The experimental data used for the identification of the vector Everett distribution functions are the initial magnetization curves and the major loops for only the rolling and transverse directions (angles 0° and 90°).

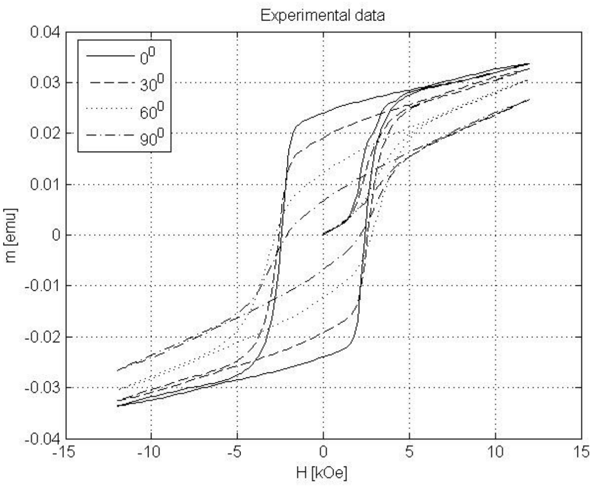

Fig.1. VSM measurements data for various angles

Figure 2 shows the simulated initial magnetization curves and the major loops for various magnetization directions (angles 0°, 30°, 60°, 90°), obtained based on the vector identified Everett distribution functions starting from the experimental data for the rolling and transverse directions.

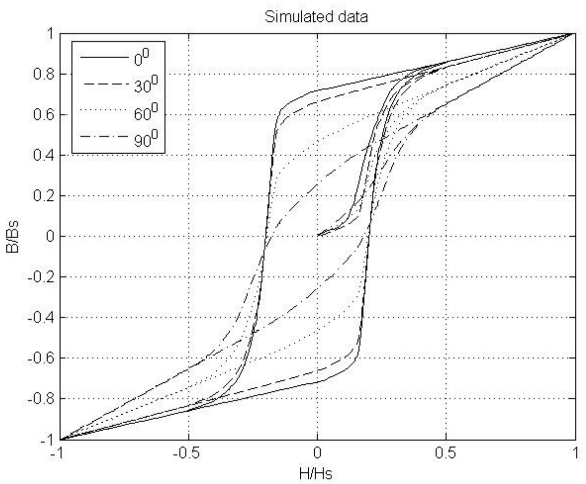

Fig.2. Simulated data for various angles (normalized values).

Figure 3 shows the comparison between the simulated data (the initial magnetization curve and the major loop) and the measured ones, for an intermediate direction (angle 30^0). Good agreements are observed between the two sets of data.

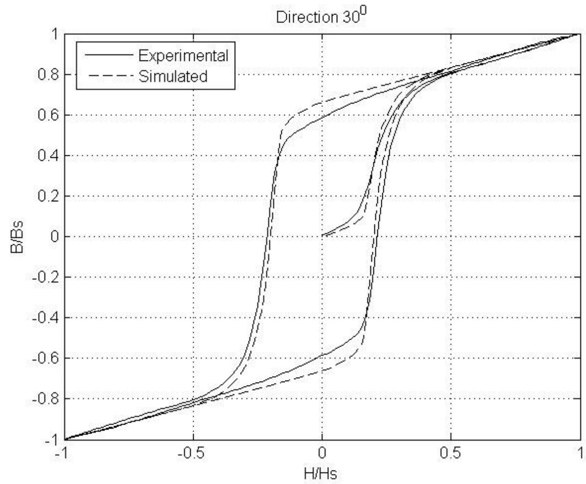

Fig.3. Simulated and measured data for an intermediate direction (angle 30^0)

III. CONCLUSIONS

A numerical approach based on an extension of the Preisach model proposed by Mayergoyz Classical Preisach model is introduced for the characterization of magnetic materials with vector hysteresis, starting from a minimal material measurement data.

There are used only the initial magnetization curve and the upward major branch for two directions (rolling and transverse ones, angles 0^0 and 90^0) in the vector identification process.

The identification approach based on the Everett distribution function is a way to obtain accurate numerical solutions when the experimental data of the magnetic material are scarce.

The reconstructed initial magnetization curves and major loops are in good agreement with the measured data for an intermediate direction (angle 30°).

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