Preisach Model for Patterned Media (PM²) – non-parametric identification procedure

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Abstract — In this paper we present an identification procedure of the Preisach distribution based on the First Order Reversal Curves (FORC) diagram technique. The systems with both statistical and mean field interactions are described by a Preisach-type model which includes, in a simple manner, state dependent magnetizing or demagnetizing type interactions. In each case, the typical features of FORC diagrams are highlighted and the effect of the mean field interaction in the system is evaluated.

Keywords — FORC diagram, identification procedure, Preisach model

I. INTRODUCTION

The technique based on the measurement of a set of First Order Reversal Curves (FORC) was proposed more than ten years ago as a purely experimental method for the evaluation of interparticle interactions in particulate ferromagnetic systems [1]–[3]. This method was in fact known as an identification method of the Preisach distribution for systems correctly described by the Classical Preisach Model (CPM). For systems in which the wiping-out and the congruency properties are obeyed, named CPM systems [4], the FORC and Preisach distributions are identical.

A FORC usually starts from the descending branch of the Major Hysteresis Loop (MHL) at a reversal field \( H_r \), then the field is increased to achieve again the saturation state. The sample’s magnetic moment on a FORC for a given reversal field is a function of two variables noted with \( m_{\text{FORC}}(H, H_r) \), where \( H \) is the applied field during the measurement. The FORC distribution is calculated as the second order mixed derivative of the magnetic moment measured for a set of FORCs:

\[
\rho(H, H_r) = \frac{1}{2} \frac{\partial^2 m_{\text{FORC}}(H, H_r)}{\partial H \partial H_r}. \tag{1}
\]

Even if the FORC and the Preisach diagrams (the contour plots of the corresponding distributions) are identical for CPM systems, there still is a fundamental difference between them in the general case.

In CPM, for a given particulate system, it is a unique and precisely defined Preisach distribution of switching and interaction fields \( \rho(h, h_r) \) that represent that system. For better describe real magnetic systems, many Preisach-type models have been developed, with the origin in CPM but including supplementary elements in order to provide a relaxation of the congruency property. We mention here the well known Moving Preisach Model (MPM) that adds a mean interaction field which moves the distribution during the magnetization processes [5], and the Variable Variance Preisach Model (VVPM) that takes into account the dependence of the interaction field distribution variance versus the magnetic moment of the sample [6]. Essentially one can say that the Preisach distribution is specific for a given particulate system, but it is dependent on the magnetic state of the system. By contrast, the experimental FORC distribution is uniquely linked to the measured sample and basically is not dependent or related to any theory. The FORC diagram is the contour plot of the distribution (1), in which the magnetic moments on the FORCs are measured.

The problem we analyze in this paper is related to the state dependence of the interaction field distribution. Due to the technological interest in the use of magnetic patterned media as ultra-high density recording media, studies have shown that the state dependence is stronger and a complex structure of the interaction field distribution with more than one peak was observed [7]–[9]. Our goal is to interpret the shape of the experimental FORC diagram and to find the way in which physical quantities can be extracted from that, for systems described by a Preisach-type model named Preisach Model for Pattern Media (PMPM or PM²).

II. THE PM² MODEL

To perform a systematic study of the relation between the FORC distribution and the interaction field distribution we have used the recently developed PM² model [9]–[11], that can include in a straightforward manner Preisach bimodal distributions dependent on the magnetic state of the sample.

As in the CPM, the position of one physical entity (named hysteron) in the Preisach plane is given by the switching fields of the particles \( H_s \) and \( H_p \). Instead of the positive and negative switching field distributions one uses the distributions of coercive fields \( H_c = (H_s - H_p)/2 \) and

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the two types of distributions (Gauss-Gauss and Lognormal-Gauss), as we see in Table I.

IV. CONCLUSION

In this paper, we have presented two different identification methods for PM\textsuperscript{2} irreversible distribution. For systems with demagnetizing-type mean interaction field, a geometrical analysis of the experimental FORC diagram is more appropriate. On the other hand, for systems with magnetizing-type mean interaction field, it is first required to transform the experimental FORC diagram in an operative plane. It was proven that the operative FORC diagram is an accurate estimate of the PM\textsuperscript{2} irreversible distribution if the transformation is made using a moving parameter value that makes the operative FORC symmetrical with respect to $H_s = 0$ axis, having an insignificant negative region.

It was shown that the effect of a bimodal interaction field distribution can be compensated by a moving term of opposite sign in a certain range of interactions intensity. The effects due to the variable interaction field distribution variance in the magnetization processes simulated with PM\textsuperscript{2} will be the subject of further analysis.

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