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IDENTIFICATION OF THE GENERALISED PREISACH MODEL PARAMETERS FOR SYSTEMS WITH MAGNETOSTATIC INTERACTIONS

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This paper presents the testing of a recently developed Preisach identification algorithm. The algorithm uses the properties of the Integral Generalized ΔM plot that is very sensitive to interactions and thus produces a more accurate choice of parameters. The parameters obtained in the identification produce simulations that fit first and second order magnetization processes with reasonable precision. For some of the metal particle recording media studied with negative ΔM curves, a good fit can only be obtained using negative mean field interactions. This is different from most acicular systems where a positive mean term is usually required.

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1. Introduction

The Preisach model takes into account the recording media as a statistical ensemble of particles with critical fields defined by the coercive field of the isolated particle and the interaction field. It is considered that medium has a distribution of coercive fields and a distribution of interactions. Physical micromagnetic modeling has shown that the interactions between the magnetic entities within any recording media can be discussed using two parameters, one linked to the statistical interactions and the other with the mean field interactions. In Preisach modeling the first parameter is the dispersion of the interaction field distribution and the second is the moving parameter. The present study was performed because some modern recording media have shown characteristics different from those well known in classical particulate recording media. We have identified the possibility that the mean field is negative in previous micromagnetic studies [2]. The proper evaluation of the interaction parameters for modern recording media is of great importance for obvious technological reasons.

The Integral Generalized ΔM plot (IGDM) [3] has been introduced due to its sensitivity to interactions and to the fact that it allows the separate identification of the effects of the mean field and statistical interactions. One point on the IGDM curve represents the integral of a Generalized ΔM plot (GDM) [4, 5]. The GDM is obtained by substituting the dc demagnetization (DCD) curve in the classic ΔM plot formula [6] with a new DCD like plot, called the DCD' which is obtained using:

$$m_{DCD'} = m_{rs} - \left[m_+(H) - m_-(H)\right] \tag{1}$$

where $m_+(H)$ and $m_-(H)$ are the forward and reverse dc remanent moments produced by magnetization processes starting from the dc demagnetized state (i.e. saturate the sample in the positive direction and then apply a negative field and remove it to obtain zero remanent magnetic moment) and m_{rs} is the remanent saturation magnetic moment. All moments are normalized to saturation of the sample (m_s).

In [7] we have developed a simplified identification algorithm for the Generalized Moving Preisach Model (GMPM) [8] parameters using the properties of the IGDM plot. The GMPM model

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uses the basic hypotheses of the Preisach model, but adds a reversible component to explain the behavior of imperfectly aligned particle systems. The algorithm uses two points on the IGDM plot, the one corresponding to the initial remanent saturated state of magnetization and the one corresponding to the initial dc demagnetized state of the system. We used these points as check points for the simulations. We applied the algorithm to experimental measurements for different particulate recording media.

2. Measurements and simulations

Figs. 1 and 2 present the experimental and simulated curves for a BaFe particulate recording medium. Note the good agreement between experimental points and simulations for the magnetization curves and for the IGDM plot. The parameters identified are presented in Table 2. In Fig. 1 the IRM_{ac} starting from the ac demagnetized state, which is a first order magnetization process, are presented. The IRM_{dc} starting from the dc demagnetized state, which is a second order magnetization process, is also shown. It can be seen that the set of identified parameters fit reasonably for both of them. In Fig. 2 we present the experimental and simulated IGDM plot for the same BaFe sample. The identification for the mean field parameter gives a large value which is in agreement with a clearly positive ΔM plot.

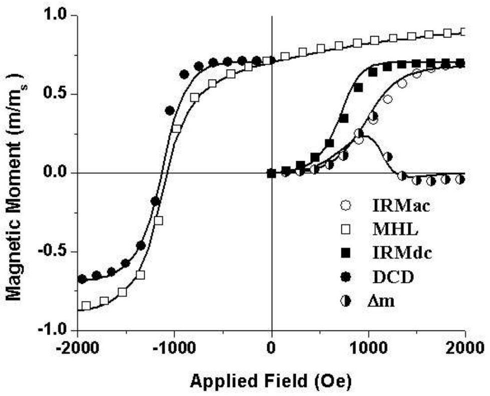

Fig. 1. Experimental (marks) and simulated (lines) magnetization processes for a BaFe particulate recording medium.

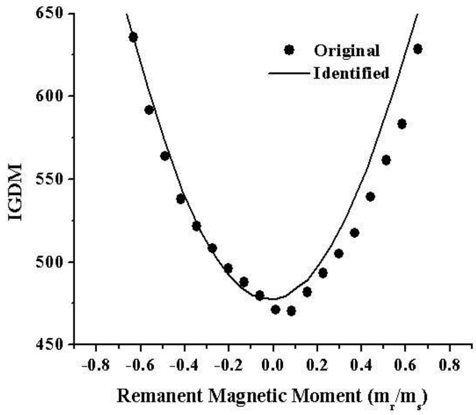

Fig. 2. The experimental and simulated IGDM plot for a BaFe recording medium.

Figs. 3 and 4 show the experimental and simulated curves for a recording media (MP) containing metal particles. MP is an 8mm metal particle tape for video Hi8 applications manufactured using double coating technology i.e. a thin magnetic coat on top of a thicker non-magnetic undercoat.

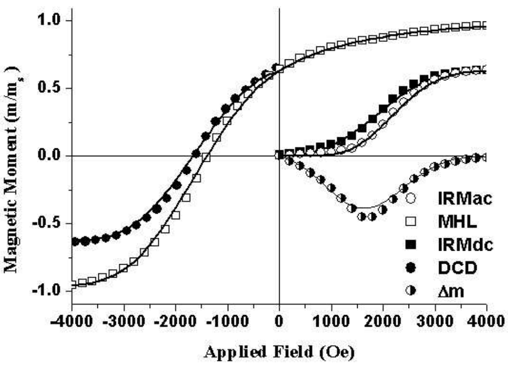

Fig. 3. Experimental and simulated magnetization processes for the MP tape.

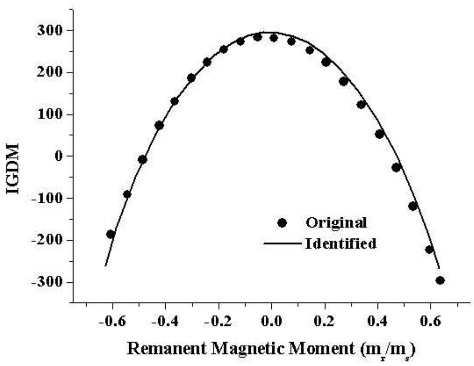

Fig. 4. The experimental and simulated IGDM plot for the MP tape.

In Table 2, the identified parameters for the metal particle system is presented together with the BaFe sample. It should be noted that the mean field parameter for MP tape is strongly negative. In most cases, simulations of acicular particulate systems generate a positive mean field term, but for certain geometric configurations of the particles, the mean field may be negative [2], [9]. For some of the recording media we have noticed that the DCD curve has a positive initial slope rather than zero. This is the case for the MP sample, which is an indication of a negative mean field. The mean local value that determines the reversal characteristics will be dependent on the geometric distribution of the near neighbors. In barium ferrite platelets with an easy axis perpendicular to the platelet face, this will result in positive interactions, whereas for acicular particles one might expect them to be negative (more adjacent to the sides than the ends), although it will be very dependent on the quality of the distribution. In most acicular particle systems, the positive mean field term suggests a disruption of the good geometry by agglomeration and poor dispersion of the particles in the matrix.

Table 1. Parameter identification for 3 particulate recording media.

	α(Oe)	$H_{\sigma i}$(Oe)	$H_{\sigma c}$(Oe)	H_{c0}(Oe)	S	$H_{r\sigma}$(Oe)
BaFe	460	128	446	1202	0.65	1490
MP	-330	325	280	1005	0.77	836

The fact that the metal particle samples have such strong local negative interactions suggests good local alignment of the particles. In order to further investigate the systems with negative mean field interactions we generated ensembles of particles with different relative positions and simulated first and second order dc magnetization processes solving the Landau Lifshitz Gilbert equation for equilibrium, taking into account magnetostatic interactions between particles.

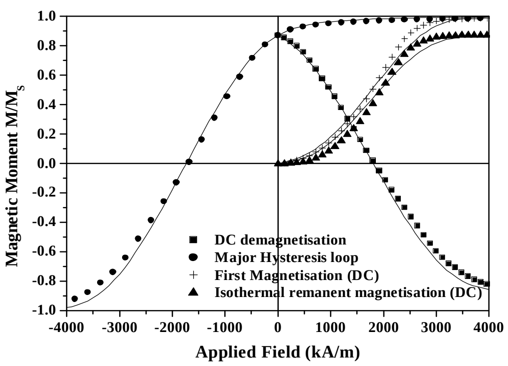

Fig. 5. Simulated DC magnetization processes for a system of particles generated with easy axes orientations within an angle of 25 degrees with respect to a preferential orientation, within a plane.

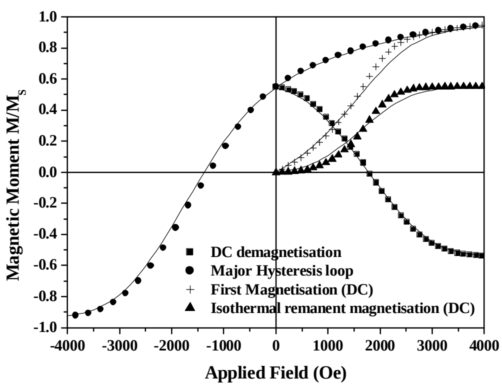

Fig. 6. Simulated DC magnetization processes for a system of particles generated with random oriented easy axes within a plane.

Figs. 5 and 6 show the dc demagnetization process (DCD), Major Hysteresis Loop (MHL), Isothermal Remanent Magnetization (IRM_{dc}) started from the dc demagnetized state of the system (i.e. one saturates the sample in one direction and applies a field in the negative direction until the zero remanent state is attained), and the First Magnetization (FM_{dc}) curve started from the dc demagnetized state. Fig. 5 presents the dc magnetization curves for a system of particles generated with the centers in the same plane and with the orientations of the easy axes within a certain angle with respect to a preferential orientation and Fig. 6 with in plane random orientations of the easy axes. We used these curves to identify the parameters of the Generalized Moving Preisach Model which would describe the system with the identification algorithm described in [7]. Then, we used the parameters identified to simulate the magnetization curves presented in Figs. 5 and 6 with lines. One observes relatively good agreement between the LLG and Preisach simulations.

We also identified, directly, the parameters related to coercivity and interactions by obtaining the distributions of the coercive fields and interaction fields using the LLG simulations. The distributions of interactions and coercive fields are found by calculating for each equilibrium value the switching fields H_α and H_β of each particle. H_α and H_β are the values of the external fields that determine the switching of the magnetic moment. Firstly, one calculates the vector of interaction field to whom each particle is subjected due to the rest of the particles. Then, one calculates the values of the applied field for which the particle would switch in one direction or the other one and, using $2H_i=H_\alpha+H_\beta$ and $2H_c=H_\alpha-H_\beta$, one calculates the interaction and coercive field and the interaction and coercive fields distributions are drawn. From the coercive field distribution one calculates the standard deviation ($H_{\sigma c}$) and the most probable value (H_{co}), and from the interaction field distribution one obtains the standard deviation ($H_{\sigma i}$), and the mean field parameter (α) as the ratio between the shift of the distribution and the total magnetic moment.

Table 2. Parameter identification for direct and Preisach identification.

Samples	Models	α(Oe)	$H_{\sigma i}$(Oe)	$H_{\sigma c}$(Oe)	H_{c0}(Oe)
Sample 1	Micromagnetic	-503	94-477	647	1841
Oriented easy axes	Preisach	-590	334	603	1775
Sample 2	Micromagnetic	-502	95-251	566	1659
Random easy axes	Preisach	-510	329	604	1709

One may notice a good agreement between the parameters obtained directly by using the results of the LLG simulations and the parameters obtained using the identification algorithm. In the case of the interaction field distribution, the LLG simulations provide a variable variance within the limits presented in Table 2, while the GMP model has a fixed variance and thus provides a value of the variance within the some limits.

3. Conclusions

The algorithm used in this paper has shown its capacity to evaluate distinctly and accurately the intensity of the statistical and mean field inter-particle interactions for various recording media with a wide range of geometrical distribution of particles, and to identify the systems with positive or negative mean field interactions. The set of parameters obtained, fit reasonably first and second order magnetization processes for systems with negative and positive mean field interactions. The LLG and Preisach simulations produced very close values of the parameters related to coercivity and interactions, even though the GMPM model is based on simplified hypotheses.

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