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Numerical advanced characterization of magnetic recording media

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The paper presents some considerations about the classical Preisach model accuracy for floppy disk and bank card materials. The numerical Preisach function is identified on a uniform Preisach triangle mesh, using 40 experimental first-order reversal curves (FORC) which are obtained by a vibrating sample magnetometer. The tests include the major cycle, minor cycles of first order and an open path including reversal curves of first, second and third order.

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1. Introduction

The spectacular magnetic recording improvement [1] involves an accurate modeling of the magnetic material, including the hysteresis phenomenon. The properties of the magnetic recording material [2] impose a carefully modeling of the material relationship in the numerical computation of the magnetic field. Fortunately, the same properties simplify the hysteresis model which may be a scalar one if one considers independent recording tracks. The implementation of such a phenomenological model into a CAD software, based for example on Finite Elements Method, still remains an open problem, due to the complex numerical details which arise both in the model identification phase and in the electromagnetic problem computation.

For an engineer, a good hysteresis model signifies not only an accurate model but also an efficient model from the point of view of time and resources consumption. This is the reason of an extensive use of the scalar and static hysteresis models in Electrical Engineering CAD. But in a real magnetizing process, besides changing its value, the applied field could rotate generating a more complex material relationship - vector hysteresis.

2. Preisach model identification

The classical Preisach model [3] considers that a ferromagnetic material is made up of dipoles (hysterons) having a magnetic behavior described by a rectangular hysteresis cycle. The distribution of these elementary operators with respect to their up- and down-switching values (*a,b*) identifies the modeled material. From the experimental point of view, it is more convenient to use as the model output the normalized magnetization $m=M/M_s$, where M_s corresponds to the saturation. The model definition is:

$$m(H) = \iint_{S_+(H)} P(a,b)\cdot \mathrm{d}a\cdot \mathrm{d}b - \iint_{S_-(H)} P(a,b)\cdot \mathrm{d}a\cdot \mathrm{d}b \quad (1)$$

where $P(a,b)$ is Preisach distribution function and S_+, S_- are the areas corresponding to the positive and negative saturated hysterons in the Preisach triangle ($-H_s \le b \le a \le +H_s$). The boundary between S_+ and S_- is a staircase line depending of all the previous values of the magnetic field H (model input).

The Preisach function identification may be done by analytical or numerical approximation. In the first case, one can determine the Preisach function by double differentiation of experimental Everret functions [4] or identifying the parameters of particular density functions (e.g. a factored –Lorentzian or a lognormal-Gauss distributions [5]); the first procedure amplifies the inherent measurement noises and the other presents unpredictible modeling errors because it isn’t real justification for assuming one particular distribution function [6]. The numerical approximation involves a step-function defined on the meshed Preisach triangle and may use limited experimental data [7].

In our study, the numerical Preisach function is identified on a uniform Preisach triangle mesh, using 40 experimental FORC which are obtained by a vibrating sample magnetometer (VSM-7300, LakeShore®).

3. Experimental and numerical tests

The complex structure of the recording media doesn’t allow the separation of the active magnetic layer, so the measured magnetic moment must be normalized. Our study is focused on two materials:

- a floppy disk material (isotrop) having saturation point at (3000 Oe, 0.0048 emu) and coercivity of about 750 Oe.

- a bank card material (anisotrop) having saturation point at (4000 Oe, 0.024 emu) and coercivity of about 2425 Oe.

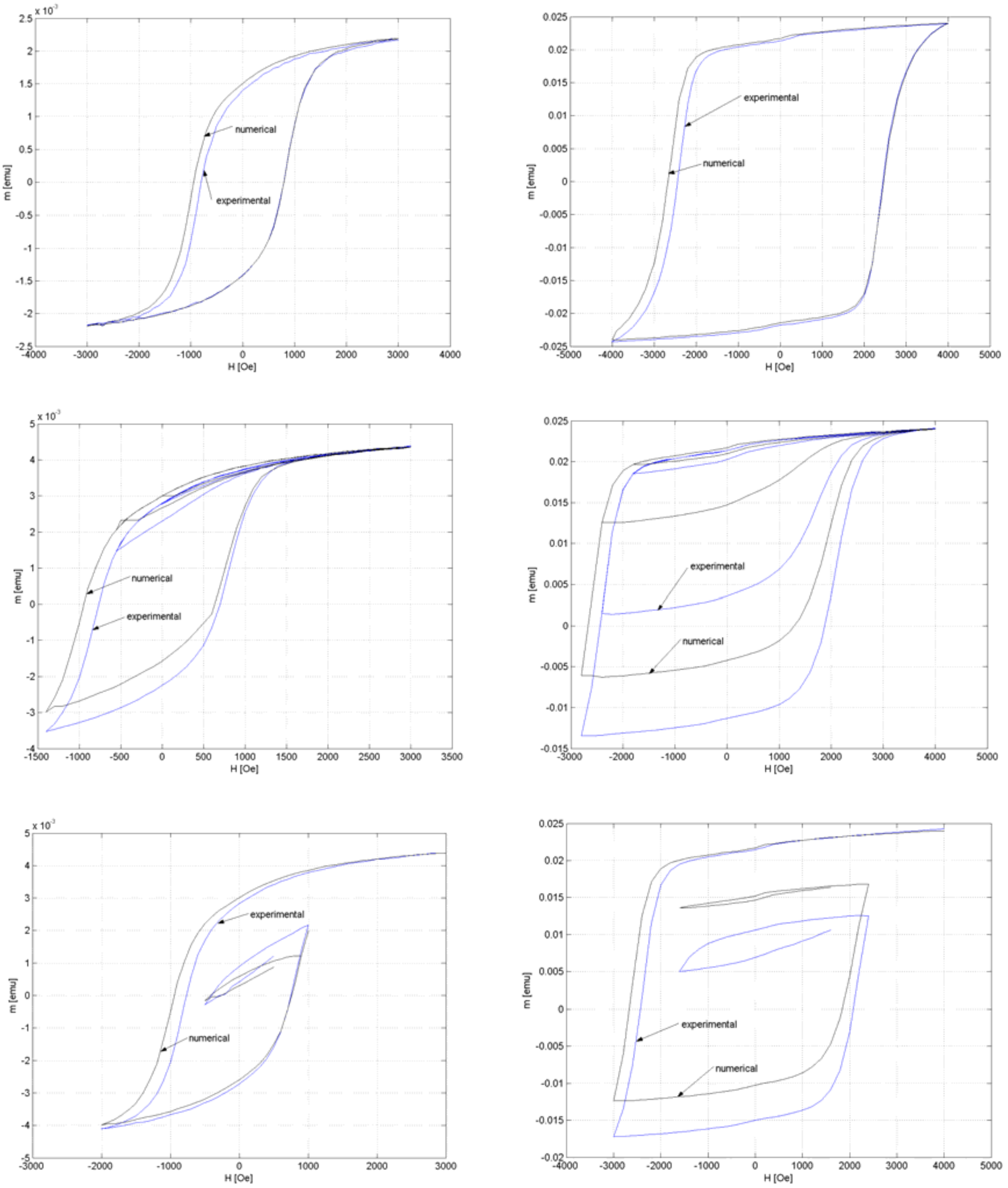
The tests followed 3 scenarios:

I) - the major (saturation) cycle;

II) - the input path (*H* values) includes 3 minor cycles of first order (one of the reversal points is on the descending branch of the major (saturation) cycle);

III) - the input path is an open path including reversal curves of first, second and third order.

The experimental curves, obtained by VSM, are compared with the numerical curves in Fig. 1. The numerical identification of Preisach distribution function uses 40 experimental FORC, corresponding to the uniform mesh with 40 cells per axis of the Preisach triangle.



(a) (b)

Fig. 1. Experimental and numerical hysteresis curves for the 3 scenarios: a) floppy disk; b) bank card.

The Preisach modeling accuracy can be estimated by the relative mean-square error between the modeling and experimental values of the output (magnetic moment) for the same input path (*H* values). The obtained errors for each segment of the path are done in Table 1 for all scenarios.

Table 1. Relative mean-square errors.

a) floppy disk material

Scenario I		*Scenario II*		*Scenario III*	
H path [Oe] (initial : step : final)	Error [%]	H path [Oe] (initial : step : final)	Error [%]	H path [Oe] (initial : step : final)	Error [%]
3000 : -150 : -3000	12.22	3000 : -150 : 0	2.69	3000 : -100 : -2000	14.23
-3000 : 150 : 3000	2.36	0 : 150 : 3000	1.44	-2000 : 100 : 1000	3.88
		3000 : -50 : -550	4.57	1000 : -100 : -500	32.97
		-550 : 50 : 3000	6.8	-500 : 100 : 500	28.36
		3000 : -100 : -1400	15.2		
		-1400 : 100 : 3000	13.6		

b) bank card material

Scenario I		*Scenario II*		*Scenario III*	
H path [Oe] (initial : step : final)	Error [%]	H path [Oe] (initial : step : final)	Error [%]	H path [Oe] (initial : step : final)	Error [%]
4000 : -100 : -4000	15.87	4000 : -200 : -1800	1.50	4000 : -200 : -3000	15.02
-4000 : 100 : 4000	3.72	-1800 : 200 : 4000	2.68	-3000 : 200 : 2400	35.15
		4000 : -200 : -2400	10.36	2400 : -200 : -1600	46.8
		-2400 : 200 : 4000	62.56	-1600 : 200 : 1600	101.7
		4000 : -200 : -2800	14.57		
		-2800 : 200 : 4000	43.66		

4. Conclusions

The hysteresis cycle shape influences the modeling errors: for bank card material – more rectangular cycle – the errors are greater than for floppy disk medium because the discrete mesh of Preisach triangle, including the state staircase line, has a greater influence.

The modelling accuracy strongly depends on the input history: for the first order minor cycles (scenario II) the mean error is 8.88% for floppy disk material, but for the second order reversal curves (in scenario III) the error increases to 32.97%; the same tendance one can see for bank card medium – 24.5% and 31.75% The result is explained by the identification procedure which uses only FORC. This is visible in scenario I (major cycle) where the descendant branch is more innacurate than the ascendant one.

Another domain of high error is arround the coercivity point; the high curve slope in this zone imposes a more refined meshing of the Preisach triangle. For the segments with low curve slope, the refining has a small influence. From CAD point of view, a too fine uniform mesh could increase very much the computation time and a non-uniform mesh could complicate the model handling, with the same result – computation effort increasing.

The tests show a poor general accuracy of the classical Preisach model, especially for high order minor cycles, if an uniform discrete Preisach meshing is used. A better accuracy imposes a non-uniform meshing of Preisach triangle which may complicate the numerical algorithms.

Acknowledgements

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