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AD-09 Optimized magnetic hysteresis management for electromagnetic space discretization simulation tool.

P. Fagan^{1,2}, B. Ducharne^{2,3}, A. Skarlatos¹

¹Université Paris-Saclay, CEA, List, F-91120, Palaiseau, FRANCE.

²Laboratoire de Génie Electrique et Ferroélectricité, INSA Lyon, FRANCE.

³ELyTMaX UMI 3757, CNRS – Université de Lyon – Tohoku University, International Joint Unit, Tohoku University, Sendai, JAPAN.

The treatment of hysteresis models in the numerical solution of Maxwell equations represents major issues as large computational times and significant memory space allocations are required [1][2]. Stability issues of the iterative solution are also a non-negligible source of concern. The Jiles-Atherton (J-A) [3] and the Preisach models [4] are the most used and commented hysteresis models. On the one hand, memory management in the Jiles-Atherton model is simple but convergence often goes through large temporal discretization. On the other hand, Preisach model can work with a limited time discretization but it requires huge memory space and complex memory management. In [5][6], authors proposed an interesting way to take into account hysteresis solving both the J-A and the Preisach models issues. Hysteresis is taken into account through the following hypothesis: the slope dB/dH (reciprocally dH/dB) inside and over the major hysteresis loop envelope is supposed to be dependent on only three parameters: the magnetic excitation field H , the magnetic induction field B , the sign of the time derivation of the model input (B or H). Based on this simple assumption, a new way to take into account the quasi-static scalar hysteresis for ferromagnetic materials was described. This new method also called DSHM for “Derivative Static Hysteresis Model” is an elegant alternative technique, it can be implemented with a simple memory management and reduced memory allocation demands in respect to more classical approaches. Convergence and precise simulation results can be reached with a relatively coarse temporal discretization. This hysteresis taken into account is also easily reversible (from $B(H)$ to $H(B)$) and easily exportable.

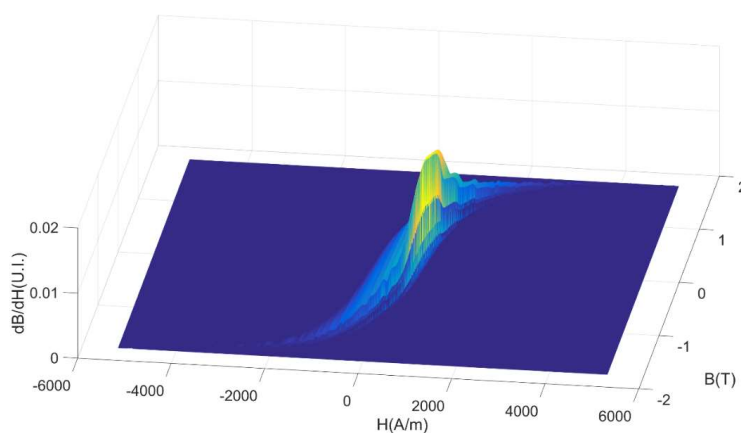


Fig. 1 – Illustration of the DSHM matrix.

Up to now, the filling step of the DSHM matrix (Fig. 1) has always been through a set of experimental first-order reversal curves (as illustrated in [5]). It is evident that getting such experimental results can be complicated in particular situations, including electromechanical converters design or electromagnetic nondestructive testing but in this study we propose to fill the DSHM model's matrix with a reduced number of experimental data thanks to assumptions also used to parameter the Preisach and the Jiles-Atherton models. The principles of the new method can be detailed as follows:

_ The Preisach or the J-A models are implemented first. It implies to determine an adequate combination of parameters for the J-A model or an adequate triangle density for the Preisach model. Such implementation can be done with a limited number of experimental results (a single major hysteresis cycle in the extreme case).

_ Reversal curves are plotted numerically using the classic hysteresis models.

_ The numerical reversal curves are used to fill the DSHM matrix.

The DSHM model provides correct simulation results even under unsymmetrical waveform situations. Implemented in a nonlinear dynamic finite differences numerical scheme for the resolution of the magnetic field diffusion through the cross section of a magnetic lamination [7][8], it allows considerable speed-up of the simulation process while conserving very reasonable level of accuracy.

To summarize: the hysteresis law is considered in a generalized input vector space, in which an interpolation matrix is constructed with the columns and rows denoting respectively the discrete values of H and B and whose values stand for the dB/dH (reciprocally dH/dB) slope at the corresponding points.

In the end of this study, the resolution of the non-linear magnetic field diffusion through a ferromagnetic lamination is chosen as a benchmark simulation. It allows to compare the performances of space discretized based numerical solvers and to confirm the improved efficiency of the proposed method versus the J-A and the Preisach ones.

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