From magnetic Barkhausen noise to quasi-static vector Preisach hysteresis model distribution

Bhaawan Gupta, Benjamin Ducharne, Gaël Sebald, Tetsuya Uchimoto, Yoann Hebrard

From magnetic Barkhausen noise to quasi-static vector Preisach hysteresis model distribution

Bhaawan GUPTA[1, 2], Benjamin DUCHARNE[1],

[1]*LGEF INSA Lyon, 8 rue de la Physique, 69100, Villeurbanne, France*

Gael SEBALD[2], Tetsuya UCHIMOTO[2]

[2]*Elytmax, Tohoku University, JAPAN*

Yoann HEBRARD[3]

[3]*SKF-Aerospace, 22 rue Brillat SAVARIN, 26958 VALENCE, France*

Abstract. Preisach quasi-static hysteresis model is highly used in the electromagnetic simulation community. To run hysteresis Preisach model, one firstly needs to describe the Preisach triangular distribution followed by experimental results (hysteresis loops). Unfortunately, nondestructive technique control (*NDT*) situations forbid access to such experimental hysteresis loops. In this article, a new technique based on magnetic Barkhausen noise measurement is proposed to describe Preisach distribution. This technique allows to implement Preisach model without experimental hysteresis loops.

1 Preisach model

Beyond a threshold frequency of external excitation (in the decreasing direction) the density of hysteresis losses through a ferromagnetic material become frequency independent. This behavior is called the quasi-static state. Different approaches are available in the literature for the simulation of the quasi-static hysteresis behavior [1]. Preisach's model has been widely used to describe the hysteresis phenomenon in magnetic materials [2]. It assumes that the material magnetization is determined by the contribution of a set of elementary hysteresis loops having a distribution function over the Preisach's triangle. In order to model precisely the magnetic material behavior, it is necessary to accurately determine the distribution function from experimental data. There are mainly two ways to determine this distribution function. The first way assumes that the distribution function has a particular form (Lorentzian, Gaussian) and then determines the parameters of the chosen function in order to depict the average hysteretic behavior. The second way discretizes the distribution function in a finite set of values which are determined by suitable experimental data (symmetrical or unsymmetrical hysteresis cycles). In this article, we propose a new technique to obtain the Preisach distribution based on Barkhausen noise measures and which avoid surrounding coils required for the hysteresis cycles characterization.

2 From Barkhausen noise to quasi-static *B(H)* hysteresis cycles

The Barkhausen noise *BN* effect corresponds to the noise in the magnetic output of a ferromagnetic material when it is excited by an external alternating applied magnetizing force. *BN* originates from sudden changes in the size and orientation of ferromagnetic domains. *BN* occurs under the continuous process of magnetization or demagnetization and provides direct evidence of the existence of ferromagnetic domains which have previously only been postulated theoretically. It also gives interesting information about the movements of the domain walls and the energy related to this movement [2].

The Barkhausen noise signal coming from the pickup coil sensor is very weak. A high-level of amplification is required to obtain an observable signal. An analog multiplier provides the square of the magnetic Barkhausen noise. The signal is integrated and the drift is numerically corrected in order to keep just the Barkhausen noise contribution. By numerically inversing the sign of the integrator output derivation as soon as the excitation field variation sign is negative, a hysteresis loop called Barkhausen noise energy hysteresis cycles $MBN_{energy}(H)$ is obtained. A correction coefficient is employed then to set the maximum value of the $MBN_{energy}(H)$ loop equal to the maximum value of classic $B(H)$ hysteresis loop. Once this operation is done, both hysteresis loops $MBN_{energy}(H)$ and $B(H)$ can be compared with regard to their shape. This coefficient is only dependent on the measuring set-up, it can be adjusted on a given well known material and then conserved for new materials.

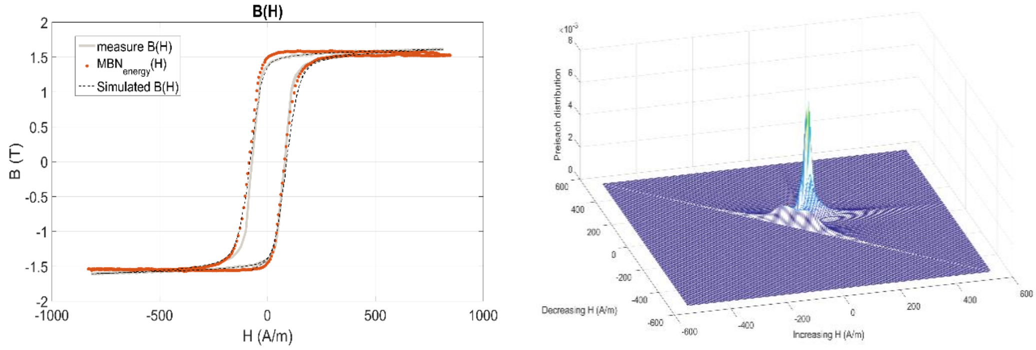

Fig. 1 - a Comparison measure $B(H)$ hysteresis cycle, $MBN_{energy}(H)$ hysteresis cycle and Preisach $B(H)$ simulated cycle. 1 – b Preisach distribution.

3 Barkhausen noise $MBN_{energy}(H)$ to Preisach distribution

Centered renormalized $MBN_{energy}(H)$ cycles are obtained from Barkhausen noise signal. Centered cycles are required for the Preisach distribution computation technique, such as Everett technique or centered cycles proposed technique by Bernard et al in [1]. The proposed method needs about ten centered cycles to accurately describe the hysteretic behavior. Once, these ten cycles are obtained, correct simulation results are obtained with a Preisach's triangle discretized into about 200 elements. Finally, Barkhausen measure is a vector measure. This property is particularly interesting for the extension of scalar Preisach model to its vector version (linear superposition of scalar models).

4 Conclusion

This article presents a new technique to obtain Preisach distribution from Barkhausen noise measures. This distribution is required to model and understand *NDT* situations. Barkhausen noise can be measured using local and surface sensor regardless of the size of the test sample on the contrary to surrounding coils limited to small size elements.

Acknowledgements

The authors are highly thankful to JSPS Core-to-Core Program, A. Advanced Research Networks "International research core on smart layered materials and structures for energy saving" and LGEF laboratory (INSA Lyon) for the support of this research work.

References

[1] Y. Bernard, H. Maalej, L. Lebrun, B. Ducharne, "Preisach modelling of ferroelectric behavior", International Journal of Applied Electromagnetics and Mechanics, vol. 25, Iss. 1-4, pp. 729-733, 2007.
[2] M. Birsan, J.A. Szpunar, T.W. Krause, D.L. Atherton, "Magnetic Barkhausen noise study of domain wall dynamics in grain oriented 3% Si-Fe", IEEE Trans. on Mag. 32 (1996) 527-534.