



HAL
open science

Numerical scheme for the simulation of the Eddy Current Magnetic Signature (ECMS) non-destructive micro-magnetic technique

Takanori Matsumoto, Benjamin Ducharne, Tetsuya Uchimoto

► **To cite this version:**

Takanori Matsumoto, Benjamin Ducharne, Tetsuya Uchimoto. Numerical scheme for the simulation of the Eddy Current Magnetic Signature (ECMS) non-destructive micro-magnetic technique. 2019 Joint MMM-Intermag, Jan 2019, Jan 2019, Washington, United States. hal-02560984

HAL Id: hal-02560984

<https://hal.science/hal-02560984>

Submitted on 7 May 2020

HAL is a multi-disciplinary open access archive for the deposit and dissemination of scientific research documents, whether they are published or not. The documents may come from teaching and research institutions in France or abroad, or from public or private research centers.

L'archive ouverte pluridisciplinaire **HAL**, est destinée au dépôt et à la diffusion de documents scientifiques de niveau recherche, publiés ou non, émanant des établissements d'enseignement et de recherche français ou étrangers, des laboratoires publics ou privés.

Numerical scheme for the simulation of the Eddy Current Magnetic Signature (ECMS) non-destructive micro-magnetic technique

Takanori Matsumoto¹, Benjamin Ducharme² and Tetsuya Uchimoto^{3, 4}

¹*Graduate School of Engineering, Tohoku University, Japan*

²*Laboratoire de Génie Electrique et Ferroélectricité, France*

³*Institute of fluid science IFS, Tohoku University, Japan*

⁴*ELyTMaX UMI 3757, CNRS, Université de Lyon, Tohoku University, International Joint Unit, Tohoku University, Sendai, Japan*

E-mail: benjamin.ducharme@insa-lyon.fr

Keywords: Eddy current magnetic signature (ECMS), hysteresis model, mechanical stress

Residual stresses inevitably occur in metallic components due to industrial machining or heat treatment processes. These local micro-residual stresses affect real-life performance of industrial parts. Measurements and analysis of residual stresses are necessary for quality assurance and maintenance anticipations.

Local magnetization processes are highly dependent on the distribution of the residual stresses. Consequently, the use of micro-magnetic techniques such as the Magnetic Barkhausen Noise (MBN) [1][2] or the Magnetic Incremental Permeability (MIP) [3][4] has increased exponentially in the industrial field. In [5], authors propose a new micro-magnetic technique called Eddy Current Magnetic Signature (ECMS) particularly effective for the mapping of these residual stresses. The ECMS experimental setup is similar to the MIP's one

The ECMS method consist on plotting the evolution of the real versus imaginary part of the EC probe impedance during minor loop situation.

The industrial use of the micro-magnetic characterization techniques is very empirical: based on experimental data obtained from well-known samples, operators set thresholds of validation. Once rejected, the targeted samples are destroyed and no extra investigations are done to determine the origin of the defects.

In the extended version of this abstract, a precise description (experimental setup, data treatment ...) of the ECMS method will be done first.

Then, a numerical method relying on physical properties will be proposed for the simulation of the ECMS technique. As ECMS is a particularly sensitive experimental method, the accuracy of the model is a key property. A Time domain, 1 dimension space discretized resolution is proposed. The Jiles-Atherton (J-A) scalar hysteresis model is used for the quasi-static contribution (hysteresis losses) [6]. The dynamic behavior is simulated by the simultaneous resolution of both the diffusion equation (classical losses) and a material law (excess losses) [7], [8].

For this study, a carbon steel SB410 (JIS G3103) has been investigated (Tab. 1)

Carbon steel, SB410 (JIS G3103), chemical composition (%)									
C	Si	Mn	P	S	Cu	Ni	Cr	Mo	B
0.17	0.26	0.87	0.013	0.004	0.001	0.002	0.003	-	-

Tab. 1 – Carbon steel SB410, manufacturer properties

Figure 1, shows as a first validation of the model, a comparison measure/simulation for a virgin sample of carbon steel SB410.

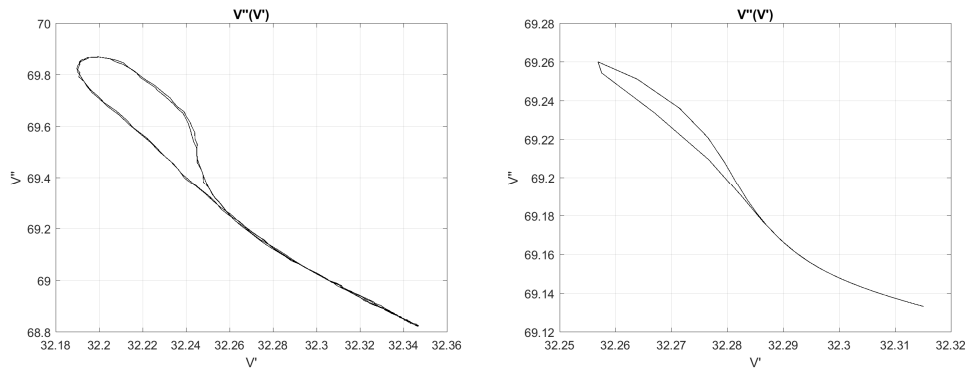


Fig. 1 – Comparison measure (left) / simulation (right) for ECMS on a virgin carbon steel SB410.

References

- [1] B. Ducharne, M.Q. Le, G. Sebald, P.J. Cottinet, D. Guyomar, Y. Hebrard, “Characterization and modeling of magnetic domain wall dynamics using reconstituted hysteresis loops from Barkhausen noise”, *J. of Mag. And Mag. Mat.*, pp. 231-238, 2017.
- [2] B. Zhang, B. Gupta, B. Ducharne, G. Sebald, T. Uchimoto, “Dynamic magnetic scalar hysteresis lump model, based on JilesAtherton quasi-static hysteresis model extended with dynamic fractional derivative contribution”, *IEEE Trans. on. Mag*, iss. 99, pp. 1-5, 2018.
- [3] T. Matsumoto, T. Uchimoto, T. Takagi, G. Vertesy, “Evaluation of chill structure in ductile case iron by incremental permeability”, vol. 52, pp. 1599-1605, 2016.
- [4] T. Matsumoto, T. Uchimoto, T. Takagi, S. Abe, H. Yuya, “Nondestructive evaluation of residual strain in carbon steel by eddy current magnetic signature method”, *Proceeding of 14th Annual conference. Japan Society of Maintenology*, pp. 260-261, 2017.
- [5] T. Matsumoto, T. Uchimoto, T. Takagi, G. Dobmann, S. Oozono, H. Yuya, “Investigation of magnetization methods to evaluate residual strain in carbon steel by eddy current magnetic signature method”, *Proceeding of 14th International conference on Flow Dynamics*, 2017.
- [6] D. C. Jiles, D.L. Atherton, “Theory of ferromagnetic hysteresis”, *J. Mag. And Mag. Mater.*, vol. 61, no. 1-2, pp. 48-60, Sep. 1986.
- [7] M. A. Raulet, B. Ducharne, J.P. Masson, and G. Bayada, “The magnetic field diffusion equation including dynamic hysteresis: a linear formulation of the problem”, *IEEE Transactions on Magnetism*, vol. 40, n° 2, pp. 872 – 875, 2004.
- [8] B. Ducharne, G. Sebald, D. Guyomar, G. Litak, “Fractional model of magnetic field penetration into a toroidal soft ferromagnetic sample”, *Int. J. of Dyn. And Cont.*, pp. 1-8, 2017.