Soft Magnetic Materials 21

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A DYNAMIC MAGNETIZATION MODEL OF CONDUCTING NON-ORIENTED FERROMAGNETIC STEEL SHEETS

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The reliable description of transformers, rotating electrical machines and other devices containing ferromagnetic cores requires the consideration of magnetic hysteresis, eddy currents and so-called excess (anomalous) loss, which is caused by the domain structure of ferromagnetic materials [1]. In the widespread case when the shortest and longest magnetic flux paths in the core are not too different, the analysis of its magnetization is reduced to the modeling of the transient behavior in a single sheet of the lamination [2]. The ideal solution of such a problem would be a model, which allows predicting both, the specific loss and the shape of this loop at arbitrary magnetization regimes. A sufficiently accurate description of transients in the laminated non-oriented (NO) steel can be obtained using a magneto-dynamic model (MDM) [2]. However, when analyzing devices with branched magnetic topology, the dimension of the problem increases proportionally to the number of branches leading to a quite complicated and time-consuming model. Substantial simplification of the problem, while keeping sufficiently accurate solution, can be achieved using a thin sheet model (TSM), which links the magnetic field on the sheet surface $H(t)$ and the mean magnetic induction $B(t)$ along its cross section [1, 3, 4]. The magnetic field $H(t)$ in such a model is represented by the sum of hysteresis, eddy-current (classical) and excess components, $H(t)= H_h+H_{clas}+H_{exc}$. However, the shortcoming of this approach lies in the fact, that the usual skin effect observed in a magnetically linear medium is absent here, leading to wrong predictions of the eddy current field using the classical approach. For this reason, this paper proposes a TSM, improving the eddy current field description on the basis of physical ideas in the framework of the saturation wave model (SWM) [5]. In order to represent the layer-to-layer nature of the magnetization reversal, the classical eddy current component is replaced by the expression arising from the SWM. The hysteresis component is modeled by means of the static history-dependent hysteresis model (SHM) [6]. The effectiveness of the proposed algorithm will be confirmed in the full paper by modeling two NO steels, described in [2], and grain-oriented steel studied in [4]. Furthermore the ability of the model to reproduce dynamic hysteresis loops at complex waveforms of the magnetization voltage will be stressed by a comparison between calculated and experimental loops corresponding to pulse-width modulation (PWM) voltages.

[1] BERTOTTI, G.: *Hysteresis in magnetism*. San Diego, CA: Academic Press, 1998.

[2] ZIRKA, S. E. – MOROZ, Y. I. – MARKETOS, P. – MOSES, A. J.: “Viscosity-based magnetodynamic model of soft magnetic materials,” *IEEE Trans. Magn.*, 2006. vol. 42. no. 9, pp. 2121-2132.

[3] ZIRKA, S. E. – MOROZ, Y. I. – MARKETOS, P. – MOSES, A. J. – JILES, D. C.: “Measurement and modeling of B-H loops and losses of high silicon non-oriented steels,” *IEEE Trans. Magn.*, 2006. vol. 42. no. 10. pp. 3177-3179.

[4] ZIRKA, S. E. – MOROZ, Y. I. – MARKETOS, P. – MOSES, A. J. – JILES, D. C. – MATSUO, T.: “Generalization of the classical method for calculating dynamic hysteresis loops in grain-oriented electrical steels,” *IEEE Trans. Magn.*, 2008. vol. 44. no. 9, pp. 2113-2126.

[5] WOLMAN, W. – KADEN, H.: “ Über die Wirbelstromverzögerung magnetischer Schaltvorgänge,” *Z. Tech. Phys.*, vol. 13, pp. 330–345, Jul. 1932.

[6] ZIRKA, S. E. – MOROZ, Y. I. – MARKETOS, P. – MOSES, A. J.: “Congruency-based hysteresis models for transient simula-tions,” *IEEE Trans. Magn.*, 2004. vol. 40. no. 2. pp. 390-399.

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