Soft Magnetic Materials 21

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A PARAMETRIC MAGNETODYNAMIC MODEL OF SOFT MAGNETIC STEEL SHEETS

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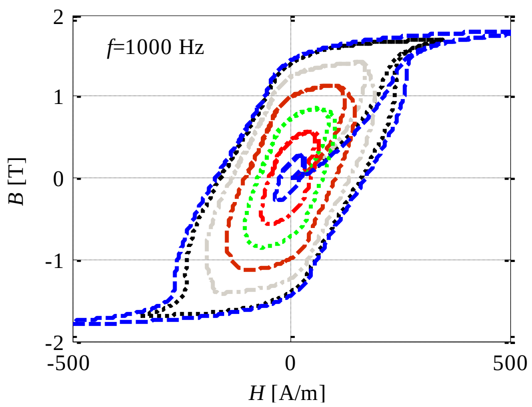
The aim of this work is to evaluate and further develop of the parametrical magnetodynamic model of soft magnetic steel sheets that is based on the methodology used for the iron core model presented in [1]. This methodology is promising from the engineering standpoint as it is relatively simple. It gives very good results for the application presented in [1] and is with further development very easy to implement. The influence of eddy currents on the magnetic field distribution in the conducting soft magnetic material is described by dividing the steel sheet into several virtual slices N_{sl}. When the steel sheet is adequately divided, the flux density B_{s} in each slice can be treated as uniform and equivalent eddy current i_{es} for each slice can be calculated. Based on Ampere's Law, this way the magnetic flux density distribution in the sheet can be calculated. The equation describing the equilibriums of magnetomotive forces in the slices of the sheet can be expressed as in (1)

$$\mathbf{L}_{\mathrm{m}} A_{\mathrm{Fe}} \frac{\mathrm{d}\bar{\mathbf{B}}}{\mathrm{d}t} + \bar{\mathbf{H}}\left(\bar{\mathbf{B}}\right) l_m = \mathbf{N}_1 i_1; \qquad \mathbf{N}_1 = N_1 \left[1\right]_{N_{\mathrm{sl}}\times 1} \tag{1}$$

where $\mathbf{L}_{\mathrm{m}}$ represents a linear tensor matrix of so called magnetic inductance, A_{Fe} is steel sheet cross section, $\bar{\mathbf{B}}$ is a vector of magnetic flux densities in the slices of the sheet, $\bar{\mathbf{H}}\left(\bar{\mathbf{B}}\right)$ is a vector of field strengths as nonlinear functions of the flux densities of the slices, l_{m} is length of the magnetic path, $\mathbf{N}_1$ is a vector with the number of excitation winding turns and i_1 is current in the excitation winding. Based on Faraday's Law, the coupling with the external electrical circuit completes the relation (2), where the induced voltage in the excitation winding is calculated.

$$u_{i1} = -N_1 \frac{\mathrm{d}\Phi_{\mathrm{m}}\left(\Theta\right)}{\mathrm{d}t} = -\frac{A_{Fe}}{N_{\mathrm{sl}}} \mathbf{N}_1^{\mathrm{T}} \frac{\mathrm{d}\bar{\mathbf{B}}}{\mathrm{d}t} \tag{2}$$



The nonlinear relationships for individual slices can be calculated using various static hysteresis models. The static hysteresis model is chosen carefully to represent the best fit for the measured static hysteresis of the analyzed sheets, which is discussed in the full paper. The figure shows the behavior of dynamic model of the hysteresis loop for a 0.23 mm thick NO steel sheet with sinusoidal voltage excitation of frequency 1000 Hz at different induction levels. In the full paper the magnetodynamic model is evaluated for various NO and GO steel sheets of different thickness over a wide frequency and magnetic flux density range, where accuracy and limitations of the discussed model are studied. The experimental results for the discussed evaluation are carried out on an Epstein frame and a single sheet tester.

[1] PODLOGAR, V., KLOPČIČ, B., ŠTUMBERGER, G., DOLINAR, D., IEEE Trans. Magn., **2**, (2010) 602-605.

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