Modelling of unit differential reversal curves in the G2E hysteresis model

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Evaluation of losses in iron cores of contemporary electrical machines is essential to design machines which meet numerous requirements such as high efficiency, low production cost, appropriate size and weight, etc. The basis for calculation of losses in magnetic materials represent adequate hysteresis models. Many hysteresis models with different properties have been presented in literature in the past. This paper focuses on the modeling approach of the static part of the history-dependent hysteresis model developed by the G2Elab research group [1]. The history-dependent property of the broader dynamic Loss Surface (LS) model was introduced by the discussed static model and is based on the Madelung's rules. LS model in complete form is very promising due to its simple structure and adequate accuracy. Evidence for that is its implementation in the Altair Flux finite element software for hysteresis loss determination in the post-processing phase. The model is being gradually improved from its first appearance in the 1990s to the latest versions [1], [2]. A recent example of hysteresis loss determination of an interior permanent magnet synchronous machine is given in [3].

The static G2E hysteresis model follows the principle of field decomposition into the anhysteretic and complementary contributions. The anhysteretic part, as well as the major loop, can be represented with measured curves. The complementary part models the magnetic curves inside the static major loop and is described mathematically [1]. A part of the complementary magnetic field is the difference between the static major loop and any symmetrical hysteresis loop inside the major loop (Eq. (3) in [1]). To model this difference the concept of unit differential reversal curves (uDRC) was proposed. It is based on the relative values of the difference δh, magnetic field density δb and the magnitudes of inner symmetrical loops ΔB_r. An example of uDRCs for a NO27 electrical steel is shown in Figure 1. The uDRCs can be modelled by (1) [1].

$$f(\delta b) = \frac{\mathrm{e}^{-k_1}}{1-\mathrm{e}^{-k_1}}\left(\mathrm{e}^{k_1 \delta b}-1\right)\cdot\left[1+k_2\mathrm{e}^{-k_3}\left(\mathrm{e}^{-k_3(\delta b-1)}-1\right)\right] \tag{1}$$

The uDRC model (1) is dependent on three coefficients k_1, k_2 and k_3 and each of them is further dependent on three additional coefficients α_*, λ_*, and γ_* with $k_* = \alpha_* \cdot \mathrm{e}^{\lambda_* \cdot \Delta B_\mathrm{r}^{\gamma_*}}$, where * means the respective index of k. The model has nine degrees of freedom to fit experimentally measured curves.

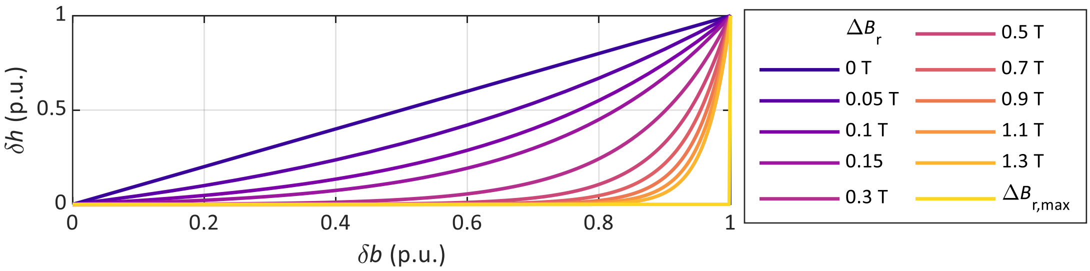

Figure 1: uDRC model for NO27 steel sheets

The aim of this paper is to investigate the modelling process of the uDRC curves. Further, we will analyse and compare the uDRC model proposed in [1] versus other modeling approaches (simplified mathematical functions, 2D look-up tables, etc.) in terms of implementation, computational cost, identification and accuracy. Based on the analysis, guidelines will be given which modelling approach is most suitable for the description of uDRC curves.

References

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