Homogenization Approaches for Laminated Magnetic Cores using the Example of Transient 3D Transformer Modeling

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1 INTRODUCTION

A specific issue in transformer modeling using the finite element method is the consideration of electric sheets or other laminated core materials which are used to reduce eddy currents (Figure 1a). It would be impractical to explicitly model a large number of sheets as this would lead to unacceptable computational costs. Homogenization procedures overcome this problem. They substitute the laminated structure by a solid having nearly the same electro-magnetic behavior (Figure 1b). In our study, we have implemented several of them in a transformer model. Simulation results obtained with the different homogenization approaches are compared to those from models having explicitly modeled sheets and experimental test results as well.

2 ELECTROMAGNETIC TRANSFORMER MODEL

Figure 2 depicts the transformer samples which were both experimentally investigated and simulated. The core consists of stacked electric sheets which wear a closely wound secondary coil at one leg and a primary coil equally distributed over all legs of the ring core.

3 HOMOGENIZATION APPROACHES

In each of the approaches listed in Table 1, an orthogonal electrical conductivity \( \sigma = [\sigma_x, \sigma_y, \sigma_z] \) is proposed to adapt the behavior as desired. The magnetic material behavior is considered in \( H(\mathbf{B}) \) form by piecewise cubic interpolation of the measured static commutation curve.

4 SIMULATION RESULTS AND MEASUREMENTS

Figure 5 depicts exemplarily simulated dynamic hysteresis loops. The measured dynamic loops were reduced by the static portion of hysteresis for better comparability to simulation results.

5 CONCLUSIONS

The KIWITT, HAHN\textsuperscript{E} and WANG\textsuperscript{E} model fit best the dynamic hysteresis loops calculated with explicitly modeled sheets, even above the critical frequency when the penetration depth falls below the half sheet thickness. The KIWITT model meets best the dynamic power loss. The measured dynamic loops are wider than those found with explicitly modeled laminated material even if reduced by the static portion of the hysteresis. This is probably caused by considerable residual losses which are not modeled.

References