Homogenization of 3D Laminated Cores Using the Heterogeneous Multiscale Method and *h*-Conforming Formulations

I. Niyonzima¹, A. Marteau¹, G. Meunier¹, O. Chadebec¹, N. Galopin¹, R. V. Sabariego², and C. Geuzaine³

 ¹ Univ. Grenoble Alpes, CNRS, Grenoble INP, G2ELab, F-38000 Grenoble, France.
E-mail: innocent.niyonzima@univ-grenoble-alpes.fr
² KU Leuven, Departement of Electrical Engineering (ESAT), Leuven & EnergyVille, Genk, Belgium.
³ University of Liège, Departement of Electrical Engineering and Computer Science, Liège, Belgium.

Accurate and performing multiscale models accounting for 3D geometrical effects, eddy currents losses and nonlinearities in electrical devices with composite magnetic materials can reduce the computational cost inherent to the use of classical numerical methods such as the FE method. One such a multiscale method is the Heterogeneous Multiscale Method (HMM) already used by some of the authors to solve 2D problems using a *b*-conforming formulation (I. Niyonzima, R. V. Sabariego, P. Dular, K. Jacques and C. Geuzaine, *Multiscale finite element modeling of nonlinear magnetoquasistatic problems using magnetic induction conforming formulations*, Multiscale Modeling & Simulation, 16(1), 300-326). This paper extends HMM to 3D problems with laminated cores using a *h*-conforming formulation. In this context, a nonlinear magnetostatic problem is solved at the macro-scale together with a series of nonlinear magnetodynamic problems defined on mesoscale domains defined around the Gauss points of the macroscale mesh. The homogenized problem is computed based on a coupling scheme that uses an inexact Newton–Raphson scheme. The method yields accurate homogenized and local fields. It also provides the possibility of computing accurate global quantities of such as the magnetic energy and eddy current losses (see Figure 1 for the computation of eddy current losses). The cost of the method is dramatically reduced by carrying out massive parallel resolution of the independent mesoscale problems.



Figure 1: Eddy current losses obtained using the classical FE method (Ref) and the HMM method (HMM).

In the extended version, we will study the accuracy of the method by comparing the results to those of the reference problem obtained using a classical FE methods on a dense mesh and the performance of the method resulting from the parallelization of the resolution of mesoscale problems .