MSFEM for a 2D1D Eddy Current Model Including Edge Effects

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So called 2D1D methods, which avoid the necessity of computing a full three dimensional problem in the simulation of eddy currents in steel sheets, date back to (O. Bottauscio, M. Chiampi and D. Chiarabaglio, "Advanced Model of Laminated Magnetic Cores for Two-Dimensional Field Analysis", in *IEEE Trans. Magn.*, vol. 36, no. 3, pp. 561-573, 2000). Their principle is to solve a two dimensional problem coupled with a one dimensional problem. A drawback of this method is the inability to model boundary effects in the sheet, leading to eddy currents which are not closed.

A novel approach to the 2D1D technique is done by including ideas of the multiscale finite element method (MSFEM). For the magnetic vector potential $\mathbf{A}$, the variation along the lamination thickness, i.e. the one dimensional problem, is not solved directly, but approximated using an expansion into micro-shape functions. In the first order case this takes the form

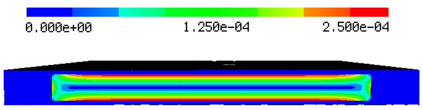
$$\mathbf{A}(x,y,z) = \begin{pmatrix} \phi_1(z)A_{1,1}(x,y) \\ \phi_1(z)A_{1,2}(x,y) \\ \phi_2(z)A_2(x,y) \end{pmatrix} \tag{1}$$

with the given polynomial micro-shape functions ϕ_1 and ϕ_2 and the unknown functions $A_{1,1}$, $A_{1,2}$ and A_2. The expansion (1) is used in the weak eddy curry problem

$$\int_\Omega \mu^{-1}\text{curl}\,\mathbf{A}\cdot\text{curl}\,\mathbf{v} + i\omega\sigma\mathbf{A}\cdot\mathbf{v}\,d\Omega = \int_\Omega \mu^{-1}\text{curl}\,\mathbf{A_0}\cdot\text{curl}\,\mathbf{v}\,d\Omega \tag{2}$$

with $\mathbf{A_0}$ being the solution of an auxiliary problem, prescribing for example the total magnetic flux. Integration in z direction reduces (2) to a two dimensional problem in the new unknown.

Figure 1 shows a good agreement with the reference solution and the ability of this approach to model the boundary effects.



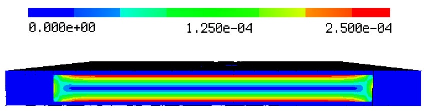


Figure 1: Absolute value of the electric vector potential $\mathbf{A}$ for the 2D1D method (left) and the 3D reference solution (right) at $100Hz$.