An Approach for Step-Lap Joints Using the Multiscale Finite Element Method Based on the Magnetic Vector Potential

Karl Hollaus, and Markus Schöbinger

Technische Universität Wien, Analysis and Scientific Computing, 1040 Vienna, Austria karl.hollaus@tuwien.ac.at

***Abstract*—The multiscale finite element method has shown to simulate the eddy currents in laminated iron cores efficiently. In this work the integration of step-lap joints in the framework of the multiscale finite element method is studied. A feasible approach is proposed and some simulation results based on a small example are presented.**

***Index Terms*—Laminated iron cores, magnetic vector potential, multiscale finite element method MSFEM, step-lap joints.**

I. Introduction

The step-lap-technique is applied to reduce losses and noise. Several parameters (overall size, number of laminates, overlap length, lamination factor, sheet width, number of overlap steps, air-gap length, etc. [1]) have an impact on the losses and noise. Therefore, the optimal design of the joint regions is very important and requires a detailed simulation. An early study of step-lap joints (SLJs) with the finite element method was carried out by [2]. The multiscale finite element method (MSFEM) has shown to cope with the eddy current problem in laminated cores representing a quasi-periodic structure. The MSFEM allows to reduce the computational costs of very large problems substantially and also provides time very accurate solutions [3], [4]. The aim of this work is to find a feasible approach of SLJs to be integrated into the framework of MSFEM.

II. MSFEM and Step-Lap Joints

The first order MSFEM approach based on the magnetic vector potential (MVP) $\mathbf{A}$ reads as

$$\widetilde{\mathbf{A}} = \boldsymbol{A}_0 + \boldsymbol{A}_1\phi_1 + \mathbf{grad}(w_1\phi_1), \tag{1}$$

see also [4]. The idea is to integrate the influence of SLJs on the field distribution by adding

$$\boldsymbol{A}_{SL}\phi_{SL} + \mathbf{grad}(w_{SL}\phi_{SL}), \tag{2}$$

where the index SL stands for step-lap. The micro-shape functions ϕ_1 and ϕ_{SL} are represented in Fig. 1. The difficulty is to find a proper ϕ_{SL}. The approach (2) should ensure that the magnetic flux is reduced in the air gap due to the SLJ. The major part of the magnetic flux in the concerned sheet has to be split into two halves which are essentially guided in the neighboring sheet. The eddy current distribution should be modified according to the SLJ leading to increased losses.

III. Simulation Results

The laminated core consists of three iron sheets. A frequency $f = 50$ Hz, a thickness $d = 0.25$ mm of the iron sheets with a fill factor of 0.9, a conductivity $\sigma = 2 \cdot 10^6$ S/m

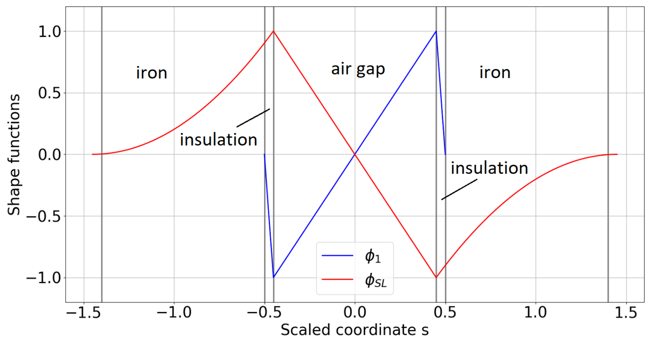

Fig. 1. Shape functions, the width corresponds to 3 iron sheets with 2 insulation layers in between. The period of ϕ_1 is 1.0, that of ϕ_{SL} is 3.0 in scaled coordates.

and a relative permeability of 1,000 have been assumed. Results are shown in Fig. 2. A satisfactory agreement can easily be seen between the reference solution, where each sheet is discretized by finite elements, and that of the MSFEM.

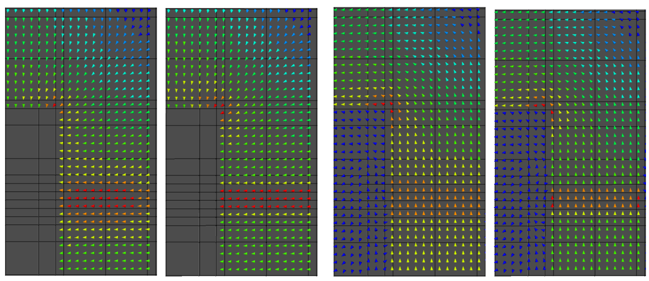

Fig. 2. Field distributions in a neighboring iron sheet next to the air gap: Eddy currents (first two), magnetic flux density (second two), reference solution (left) and MSFEM (right) in each case, only one quarter is shown, the same scaling of the respective results holds.

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