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# Correction of Thin Shell Finite Element Magnetic Models via a Subproblem Method

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**Abstract**— A subproblem finite element method is developed for correcting the inaccuracies peculiar to thin shell models, near edges and corners, for both magnetostatic and magnetodynamic problems. A thin shell solution, supported by a simplified mesh near the thin structures, serves as a source of a correction problem with the actual volumic thin regions alone in a homogeneous medium, concentrating the meshing effort on the thin regions only. Improvements of local fields are efficiently achieved and all-low accurate force and loss calculations.

## I. INTRODUCTION

Thin shell (TS) finite element (FE) models are commonly used to lighten the meshes of thin structures [1]-[3]. Indeed, the fields in the thin regions are approximated by a priori known 1-D analytical distributions (along shell thickness), that generally neglect end and curvature effects. Their interior is thus not meshed and is rather extracted from the studied domain, being reduced to a zero-thickness double layer with interface conditions (IC) linked to the inner analytical distributions [3]. The resulting TS model suffers from inaccuracies in the vicinity of geometrical discontinuities, edges and corners, increasing with the thickness, which limits its validity domain. The aim of this contribution is to develop a method to correct such inaccuracies in any case, for both magnetostatic and magnetodynamic problems, in particular for the magnetic vector potential formulations.

## II. THIN SHELL SOLUTION AND ITS CORRECTION

Once obtained, the TS solution is to be added a correction solution that overcomes the TS assumptions. The subproblem approach developed in [4] offers the tools to perform such a model refinement, thanks to simultaneous surface and volume constraints: ICs opposed to the TS discontinuities, to suppress the TS representation, in parallel to volume sources in the added volumic shell, accounting for the associated permeability and conductivity. With such a problem splitting, the characteristics of the required meshes totally differ: for the TS problem, the mesh describes the details of the source and is simplified near the TS regions, whereas the correction problem mesh focuses on the actual volumic thin region, finely discretizing it in a homogeneous medium. The required sources for the correction problem are transferred from the TS mesh to the correction mesh via a projection method [4]. A rigorous expression of these sources is of key importance for the efficiency of the method, which will be justified in the extended paper.

## III. APPLICATION EXAMPLE

As an illustration, three disjoint magnetic plates are located close to an inductor (2-D model, Fig. 1). They are first consid-

ered via a TS FE magnetostatic model, with a resulting lighter mesh. Then a correction subproblem replaces the shell FEs with classical volumic FEs covering the actual plates and their neighborhood, with an adequate refined mesh, that does not include the inductor anymore. The inaccuracies of the TS model, that grow with the plate thickness, particularly near the plate ends and corners, are perfectly corrected whatever their importance (Fig. 1, *bottom*, for two plate thicknesses). Local corrections of several tens of percents are typical.

The proposed scheme can be applied up to 3-D and eddy current problems, to lead to accurate field and current distributions in critical regions, the edges and corners of plates, and so of the ensuing forces and Joule losses distributions, with significant simplifications of mesh operations. All the steps of the method will be detailed, illustrated and validated in the extended paper for both static and dynamic problems, with applications in magnetic shielding and induction heating. The TS correction can constitute a particular step of the subproblem refinement method developed in [4], which gives significant benefits in parametric analyses on geometrical and material parameters.

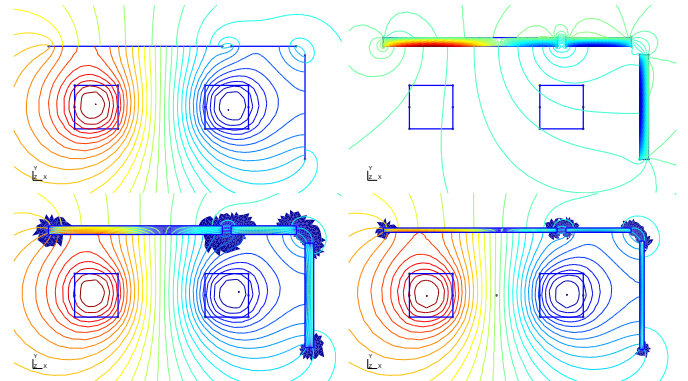


Fig. 1. Field lines for the thin shell model (magnetic flux density  $b_1$ , *top left*) and the correction solution ( $b_2$ , *top right*) (plate thickness 2 mm and relative permeability 1000), leading to the total solution ( $b_1 + b_2$ , *bottom left*), with a colored map pointing out the regions with a relative correction higher than 1% (in the plates and the vicinity of their ends); these regions are also shown for a lower plate thickness (1 mm) (*bottom right*).

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