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Mingyong Liu*†, Zuqi Tang*, Xavier Mininger*, Frédéric Bouillault* Olivier Hubert† and Laurent Bernard*
*GeePs, CNRS UMR 8507, CentraleSupelec, Univ. Paris-Sud, UPMC, 91192, France
†LMT-Cachan, CNRS UMR 8535, ENS-Cachan, Univ. Paris-Saclay, 94235, France

***Abstract*—Equivalent stress projections are developed for the numerical resolution of magneto-elastic coupled problems when magnetostriction induced deformation, material anisotropy and multi-layer inhomogeneity are considered. A comparison with classical force density projection is carried out to show the better performance in the application of a multi-layer transformer core.**

***Index Terms*—Magnetostriction, Magneto-elastic coupled problem, Finite element method, Equivalent stress projection.**

I. Introduction, Objectives and Methodology

Design of high-performance devices, such as power transformers and electric machines, requires to take into account magnetostriction induced deformations and vibrations. The modeling by finite element method (FEM) of these magneto-elastic coupled problems with both high accuracy and precision becomes important. Recently, a computer code chain [1] based on a sequential approach is proposed to deal with the magneto-elastic coupled problem, considering magnetostriction induced deformation, material anisotropy, as well as multi-layer inhomogeneity. For classical magneto-elastic coupled problems, Maxwell force density is obtained via magnetic resolution, then transmitted to the mechanical part as source term. In practices, for reasons such as efficiency and precision, meshes for magnetic and mechanical parts are not necessarily the same, which need to project the force density between different meshes [2]. However, in our magnetostriction excited magneto-elastic coupled problem, simplified multi-scale model [3] generates a free magnetostriction strain in magnetic part. This free magnetostriction strain is then transformed into magnetostriction equivalent stress $\boldsymbol{\sigma}^{\mu}_{\text{source}}$, instead of a force density as the previous one.

A projection technique (1) is developed here to transmit the equivalent stress from magnetic part to mechanic part as a pre-stress $\boldsymbol{\sigma}^{\mu}$, leading to nodal force for mechanical resolution. Given $\boldsymbol{\sigma}^{\mu}_{\text{source}} \in V_1$, find $\boldsymbol{\sigma}^{\mu} \in V_2$, such that

$$\int \boldsymbol{\sigma}^{\mu}_{\text{source}} : \boldsymbol{\sigma}^{\mu\prime} = \int \boldsymbol{\sigma}^{\mu} : \boldsymbol{\sigma}^{\mu\prime}, \forall \boldsymbol{\sigma}^{\mu\prime} \in V_2. \qquad (1)$$

II. Application and Results

A multi-layer 'E-I' transformer core, made of grain-oriented FeSi (rolling direction indicated by white arrow), is modeled in 2D with a homogenization technique. The transformer is excited only in central phase with 200 At at 400Hz. A fixed point is set as reference in the center of the transformer, by imposing a limited condition, as shown in Fig. 1. The modeling is performed using FreeFem++.

Displacements in directions 'x' and 'y' of a particular measure point are shown in Fig. 2 to compare three different approaches : a same well refined mesh for both magnetic and mechanical resolutions without projections, a coarser mesh for the mechanical resolution with the classical force density projection, as well as the equivalent stress projection. Numerical examples show that much closed results can be obtained using the proposed equivalent stress projection. However, the computational cost is much lower due to the used coarser mesh in the mechanical part. More numerical tests and detailed analyses will be shown in the full paper.

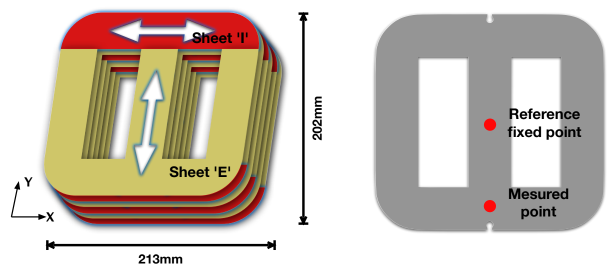

Fig. 1. Multi-layer transformer core structure (left) and measure point (right).

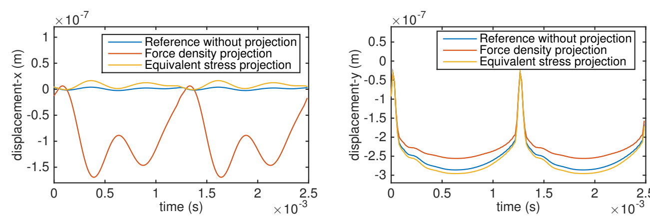

Fig. 2. Displacements as a function of time of the measure point in direction of 'x' and 'y'.

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