Introduction Of A Magneto-Elastic Constitutive Law In COMSOL Multiphysics® For The Numerical Simulation Of A Magneto-Mechanical Characterization Setup

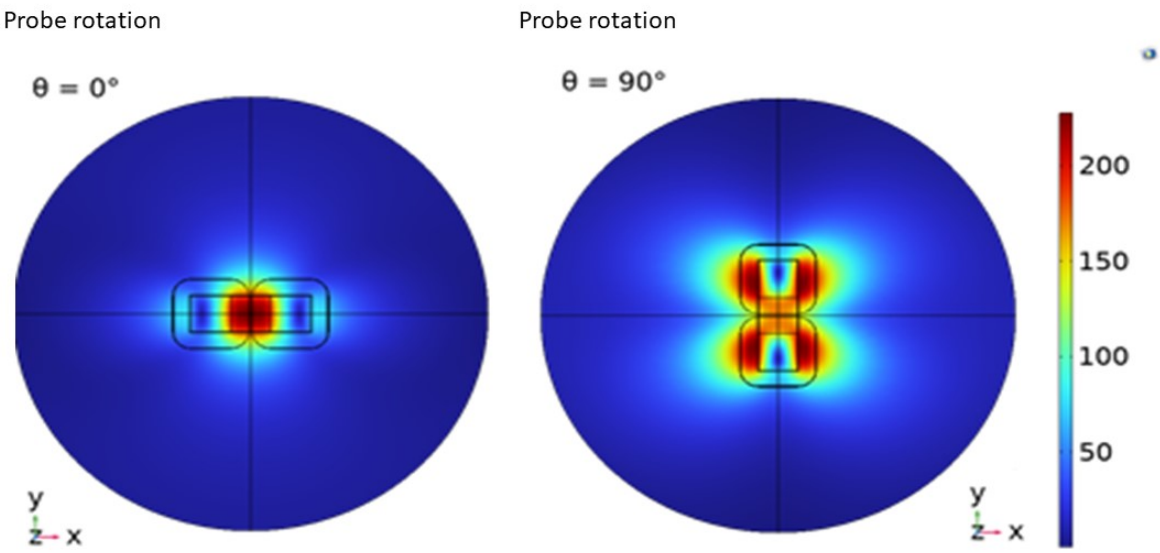
L. Santandrea[1], E. Wasniewski[2], L. Daniel[3]

[1]Laboratoire de Génie Electrique et Electronique de Paris, CNRS, Gif sur Yvette, France
[2]CETIM, Senlis, FRANCE
[3]Laboratoire de Génie Electrique et Electronique de Paris, CentraleSupélec, Gif sur Yvette, France

Abstract

As part of its research, the Group of Electrical Engineering - Paris (GeePs) uses the COMSOL Multiphysics® software for applications such as material modelling in Electrical Engineering, electromagnetic compatibility and electromagnetic non-destructive testing. Some problems involve ferromagnetic materials, prone to magnetic saturation and to the effects of mechanical stress. In the latter case, a magneto-elastic constitutive law must be used to define the material behavior. In this work, focused on an experimental setup for the characterization of ferromagnetic materials, a behavioral approach based on a multi-scale model (MSM) is used. In this behavioral model, the material is treated as a set of magnetic domain families. Each magnetic domain family alpha is defined by its magnetization Malpha and its magnetostriction strain Epsilon_alpha. The MSM is based on a free energy balance at the magnetic domain scale. The free energy is written as the sum of three major contributions: anisotropy energy, elastic energy and magnetostatic energy. The transition to the macroscopic scale is made by calculating the volume fraction of each domain family using a Boltzmann law. The coefficients of the Boltzmann distribution are defined experimentally on an unstressed material.
Regarding the numerical simulation of the material characterization device in COMSOL Multiphysics®, a low-frequency 3D model is used (AC/DC Module). It is based on a stationary study with a magnetic field and no current formulation. The geometry consists of a magnetic circuit exciting the ferromagnetic sample to be characterized. A nonlinear problem has to be solved because the magnetic permeability of the sample depends on the magnetic field H and on the stress state in each mesh element of the ferromagnetic domain. The Magnetic Field, No Currents interface allows calculating the H field at each nonlinear iteration, which will be one of the input to the MSM. The MSM is introduced in COMSOL Multiphysics® using an external material with a General B(H) Relation interface and a dynamic library for calculating the magnetic induction field B from which the magnetic permeability is deduced. This dynamic library is obtained by compiling a C code of the MSM.
The presentation will focus on the implementation of the study in COMSOL Multiphysics® and in the introduction of the MSM external magneto-elastic constitutive law. Some of the difficulties encountered and the corresponding solutions for implementing the external constitutive law will be detailed as well as the debugging of the external function or the mesh specification. Numerical results will be commented qualitatively and quantitatively.

Figures used in the abstract



Visualization of the magnetic anisotropy effect due to mechanical stress in a ferromagnetic material (Norm of the induction magnetic field)

Figure 1