Comparison Between Integral Equation and FEM Solvers for Electromagnetic-Micromagnetic Coupled Equations

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Micromagnetics is concerned with the modeling of the dynamics of magnetic systems which are governed by the Landau-Lifshitz-Gilbert (LLG) equation. The LLG equation states that the rate of change of the magnetic moment is proportional to the torque due to different interactions, one of which is the torque due to the magnetic field. The magnetic field is a solution of the Maxwell equations, which themselves contain the magnetic moment, making the LLG and Maxwell equations a set of coupled equations which must be solved together.

This work explores the pros and cons of using different Maxwell equations solvers, namely based on integral equations or based on the finite element method, in the context of a coupled Maxwell-LLG equations solver. The formulations for such coupled solvers will be presented, both in terms of how the Maxwell equations and the LLG equation are coupled and how the Maxwell equation solvers are formulated for the specific use of coupling with a LLG solver.

In the proposed solver, the quasistatic Maxwell equations are solved exactly and coupled to the FastMag micromagnetic simulator. Criteria to determine when it is appropriate to consider either the static or quasistatic approximations will be discussed. The solver allows to compute the magnetization as well as the eddy current dynamics in conductors, as shown in Fig. 1. Simulation results will be presented and compared with analytical results to demonstrate the validity of the approach, as shown for example in Fig. 2. The effect of eddy currents on magnetization dynamics will be discussed. Examples of the use of this solver to study different devices and structures will be shown.

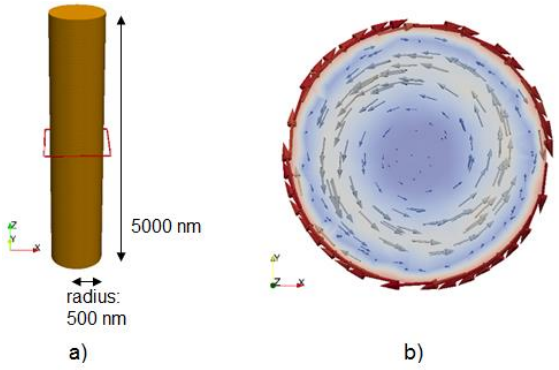

Figure 1. a) Simulated structure b) Current in the cross section shown in red in a). Excitation by a 1 GHz magnetic field.

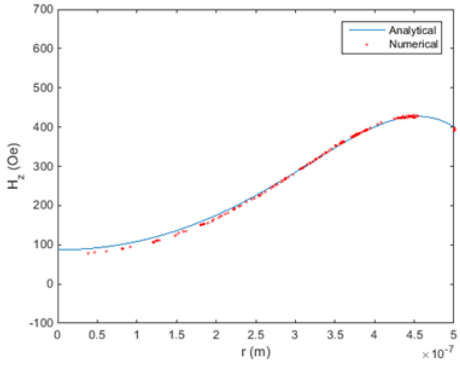

Figure 2 – Numerical and analytical result for eddy current fields in a ferromagnetic cylinder