Field computation in presence of magnetic materials using semi-analytical formulae.

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The massive use of magnetic materials in the design of many different applications call for numerical methods able to cope with the promptness and accuracy requirements typical of design steps. Finite Elements Method offers ease of implementation and a simple matrices structure, but involves meshing of large volumes; Boundary Elements Method can exempt from air meshing, at the expense of dense matrix. In both FEM and BEM approaches, the effect of material is taken into account by enforcing the constitutive equation on the magnetic field.

A different class of methods models the magnetic materials as a set of "additional" sources contributing to the magnetic field. Semi-closed analytical expressions, available for a number of simple geometries and simple magnetization maps (e.g. uniform magnetization over hexahedral elements [1]), can be applied to effectively evaluate the contribution of the elementary sources. An example of such approach was proposed in [2]: the magnetic volumes are discretized into elementary sources, and the determination of the actual value of magnetization inside each brick, is obtained by enforcing the constitutive relationship in each elements using an under relaxed Picard approach, similar to what described in [3]. On the other hand, if using uniform magnetization, the field inside each element is not uniform, and a simple collocation point method can lead to spurious oscillation of field. An example is reported in Fig. 1, where the field inside a magnetized bar (10×10×40 cm, $\mu_{rel} = 100$), discretized by 4x4x16 elements and excited by an external solenoid fed by an AC current equal to 600 ATurns (left), is computed.

In this paper the origin of the spurious field oscillation are investigated and different approaches for their mitigation are compared, including different magnetization profiles inside each element and alternative ways to impose the constitutive relationship.

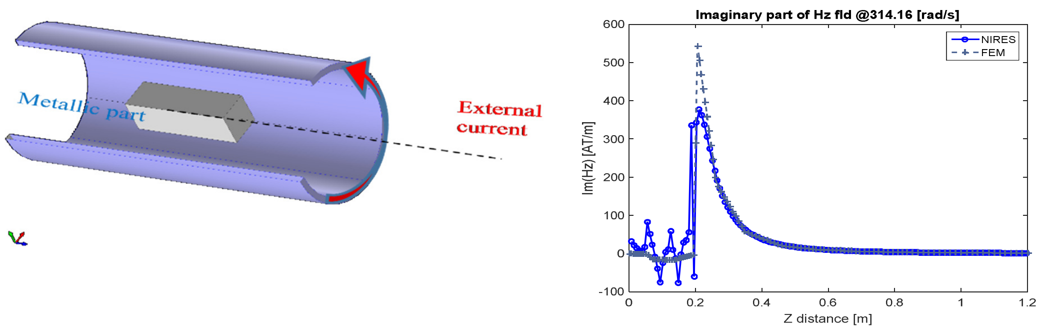

Fig. 1: Geometry of the test case (left) and Imaginary part of the magnetic field axial component along solenoid axis (continuous line: uniformly magnetized elements, dashed line: FEM package)

[1] M. Fabbri, "Magnetic Flux Density and Vector Potential of Uniform Polyhedral Sources", IEEE Trans. on Magnetics, Vol. 44 n° 1, pp. 32-36, Jan. 2008.

[2] A. G. Chiariello, A. Formisano and R. Martone, "A Fast, Semi-Analytical Method for Field Computation in Presence of Magnetic and Conductive Materials", Proc. of CEFC 2016, Miami (FL), November 2016.

[3] I. Mayergoyz, "Iteration Methods for the Calculation of Steady Magnetic Fields in Nonlinear Ferromagnetic Media," COMPEL, Vol. 1 n° 2, pp. 89-110, March 1982.