Investigating a Tensor Formulation to Describe the Magnetic Structure of Soft Magnetic Materials

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Abstract

Most of existing material representations [1], even including the dynamic hysteresis and iron losses [2], ignore local microscopic non-uniformities. These concern the magnetic structure (domains and walls [3]) and are mainly due to surface effects, anisotropy and exchange [4]. One previous contribution [7] proposed to cope with the problem of soft magnetic materials heterogeneity in terms of domains structure at a static equilibrium. This non-uniformity expresses itself with space variations of domains geometry and properties from the bulk towards the surface. It involves a material parameter kappa, which represents a new material mesoscopic property that can be related to a ratio between the anisotropy and the exchange energy density of walls, taking the grain size and boundaries into account. In the second part of previous contribution [8], a way is proposed to couple static and dynamic relationships between the magnetic field and the magnetic polarisation to domains and walls structuring. This theory is supposed to provide a deterministic method that predicts the geometry dependent vector behaviour, including static and dynamic hysteresis and iron losses, of every soft materials.
We investigate further this possibility to describe a magnetic structure from a mesoscopic point of view. Magnetic objects have got typical and characteristic physical properties that we propose to describe thanks to one tensor variable [L2], statistically gathering main topological information. We thus introduce the typical subdivisions by defining a tensor state variable [V2]=[L2]-1 with 6 unknowns. The material structuring can be explained thanks to energy tendencies, for a given value of the tensor components at the surface of the sample. The aim of this paper is to derive and implement a weak formulation compatible with classical numerical methods and especially the Finite Element Method used in COMSOL. This model provides a way to either identify or analyse and quantify the impact of a surface magnetic structure modification induced by laser onto the volume magnetic structure and consequently onto the global magnetic behaviour.
In this work we propose to:
- Introduce the theory, the physics and the formulation
o Tensor state variable
o Energy tendencies and materials properties
o Symmetries, Constraints and borders conditions

o Governing equations and weak formulation
- Develop and Implement the formulation for 1D test case with NO and GO materials
o Degrees of freedom and dependencies
o 1D Test case (symmetries, constraints, limit conditions, EDP)
o FEM and analytical solutions, comparisons, figures and discussions
- Develop and Implement the formulation for 2D test case with NO and GO materials
o Degrees of freedom and dependencies
o 2D Test case (symmetries, constraints, limit conditions, EDP)
o FEM and analytical solutions, comparisons, figures and discussions

References

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Figures used in the abstract

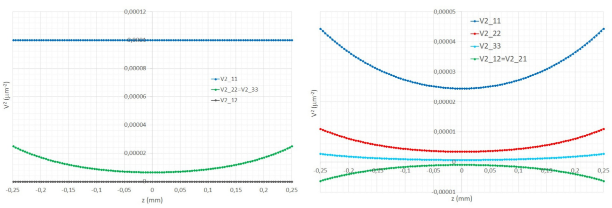

Figure 1: Tensor components for one oriented material (left) and one non oriented material (right) within the thickness of a magnetic sheet.