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Batistela

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Implementation of the Magnetic Anisotropy in 2D Finite Element Method Using the Theory of Orientation Distribution Functions

G. C. A. Tolentino¹, J. V. Leite², G. Parent¹, N. J. Batistela²

¹Univ. Artois, EA 4025, Laboratoire Systèmes Électrotechniques et Environnement (LSEE), F-62400 Béthune, France

²Universidade Federal de Santa Catarina, GRUCAD, Florianópolis, Santa Catarina, CEP: 88040-970, Brasil
guilherme_costaayrestolentino@ens.univ-artois.fr

Abstract—In this work the magnetic anisotropy phenomenon in ferromagnetic materials was modeled using orientation distribution function (ODF). The ODF is a methodology that can be used to model the first magnetization curve of electrical steel sheet along a several different angles. The model is inserted in a Finite Element (FE) field calculation software (2D) with potential magnetic vector formulation.

Index Terms—Magnetic anisotropy, Grain oriented steel (GO).

I. ORIENTATION DISTRIBUTION FUNCTION (ODF)

The ODF theory can be employed to model any physical property of a polycrystalline material [1]. In particular, Bunge [1] states that the ODF theory can be used to express the magnetic induction density inside an electrical steel sheet as a series of i^{th} order :

$$B(H, \theta) = \sum_{i=1}^n A_i(H) \cos[2(i-1)\theta] \quad (1)$$

where θ is the angle between the magnetic field H and some reference and A_i is a coefficient depending on the considered material. In [2], the authors used (1) at an order equal to 3 to express the magnetic flux density in Grain Oriented (GO) steel sheets. In [3], the authors showed that a 3 order is not enough to correctly represent the behavior of modern GO steel sheets. They improved the method by expressing coefficients A_i as cosine series as well and by determining them by using FFT from experimental data.

In [2] and [3], the authors focused on the representation of the behavior of the electrical steel sheets. This communication present the insertion of ODF into a field calculation tool.

II. FINITE ELEMENT COUPLING

In several works the coupling between the material modeling and the FE computation was accomplished through a 2D permeability tensor [4,5]. In the present work the ODF model coupling with FE was performed assuming that there is no interdependence between the magnetic permeability for different directions of excitation, which means that outside of the main diagonal of the tensor, the terms of the permeability tensor are null. This simplification must be done, since the ODF model in its origin requires BH curves obtained with alternating fields (usually by using an Epstein's frame). Such a relationship is valid as it considers that the induction and field are collinear. This approach leads to the permeability representation by a scalar, which is dependent of the angle of field with respect to a given origin.

When carrying out FE calculation, for each element on mesh at each time step, the magnetic induction vector inside a finite

element is obtained. With the induction module and the angle θ , the ODF coefficients are obtained by $B(\theta) = \mu(\theta)H(\theta)$.

With the calculated coefficients it is possible to obtain the corresponding BH curve for any desired angle θ . It is possible to obtain from the generated curve BH, the field component for the respective induction value in the element. With the H tracked on the BH curve generated by the ODF model, one can then find the permeability $\mu(\theta)$ for the considered θ angle through the defined permeability.

III. RESULTS

For illustration of the methodology here proposed it was implemented an ODF model on MEF, using 10 order approach. Fig. 1a show results for a Rotation Single Sheet Tester (RSST) with a magnetic flux pulsation at 45° with respect to the rolling direction. The BH curve obtained at the middle of the sample is showed in Fig. 1b. The results are quite promising. More details about the numerical implementation and its challenges will be given in the full paper.

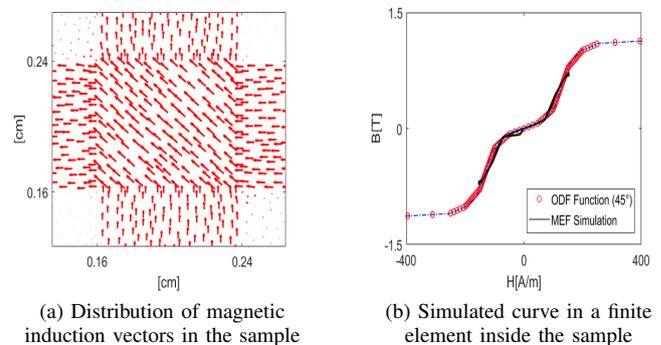


Fig. 1. Results of the simulation the ODF function on FEM

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