A multiscale model with geometrical domain decomposition in grain-oriented materials

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In this abstract, we present a multiscale model which accounts for the geometrical domain decomposition in grain-oriented material. The demagnetization field is considered in the Boltzmann distribution which drives the geometrical domain decomposition thanks to the magnetic domain volume fraction. The self-consistent scheme is employed to couple the domain scale with the grain scale. The model is validated in term of magnetization and magnetostriction for different magnetic field orientation.

Keywords: Grain-oriented material; Magnetic anisotropy; Magnetic domain; Magnetostriction; Multiscale model

1. Introduction

Grain-oriented electrical steel sheets are mainly employed in electric transformers thanks to their high permeability and their low magnetic losses [1]. Depending on the orientation of the applied magnetic field, the magnetic domains present different sizes and configurations [2-3]. In [4], a multiscale model of the grain-oriented material considers the shape anisotropy effect by applying the same demagnetization tensor in every domain. However, the identification of the shape anisotropy terms needs measurement along different directions.

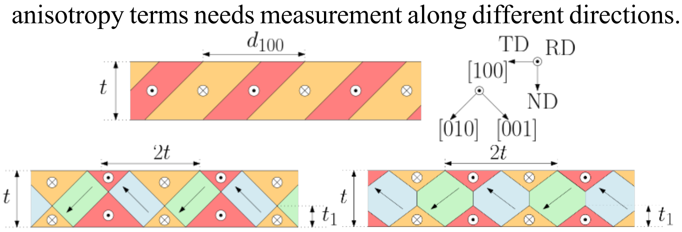

Figure 1: Domain geometrical decomposition in the sheet cross section [2]. A magnetic field is only applied along the RD (top). The magnetic field contain one component applied along the TD with small amplitude (bottom left) and with large amplitude (bottom right)

In this abstract, we propose to improve the multiscale model by considering the demagnetization field in each domain. The model requires a single parameter identified from the measurements along the RD.

2. Results and discussion

Figure 1 presents the domain configuration employed to decompose the domain volume fraction into magnetic domains, based on [2]. The effective field $\boldsymbol{h}_{\text{eff-}i}$ in the domain i is computed following the localization rule in [5]. It accounts for the applied field h_e, the magnetization $\boldsymbol{m}_i$ at saturation in the domain i, the mesoscopic magnetization in the grain $\boldsymbol{M}$ and the susceptibility tensor of the grain $\boldsymbol{\chi}$. The energy in the domain i is the sum of the magnetocrystalline anisotropic energy W_{an} and the magnetostatic energy $W_{\text{h}} = -\mu_0 \boldsymbol{h}_{\text{eff-}i} \,.\, \boldsymbol{m}_i$, μ_0 is the vacuum permeability. The volume fraction f_i of the domain i is computed with Boltzmann distribution, similarly as in [4]. Then, the volume fraction of the domains are decomposed into the domain configuration represented in Figure 1. The grain can contains a subfraction of each configuration due to the symmetric nature of the configurations represented in the bottom of Figure 1. The demagnetization tensors are updated based on the configuration geometry. Finally, the self-consistent scheme is applied. In Figure 2, the model presents the characteristic magnetic behaviour of grain-oriented materials, furthermore, the peak of the magnetostriction is validated with the measurement of [3]. The full paper will include experimental validation of the magnetic properties and more details of the model.

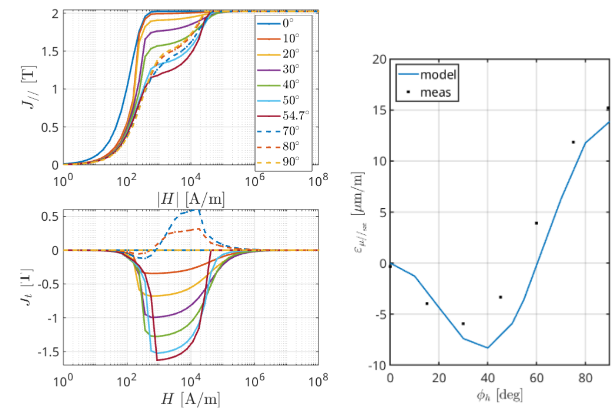

Figure 2: Magnetic polarization components simulated by the multiscale model with the domain decomposition for different magnetic field direction (left). Simulated and measured [4] magnetostriction at saturation for different direction of the magnetic field. The subscript // and t indicated the component parallel and perpendicular to the magnetic field.

References

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