Improved Energy-Based Hysteresis Model and Parameter Identification for Magnetic Hysteresis Materials

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The inclusion of ferromagnetic hysteresis models in field computation codes is important for the accurate prediction of the performance of electromagnetic devices. The Jiles-Atherton and Preisach models are currently the most widely used models for this purpose. The former is simple to implement but can sometimes lead to nonphysical results while the latter describes more accurately the shape of hysteresis loops but requires a large amount of experimental data and is only built from a mathematical formalism. Furthermore, they are natively scalar and their vector extensions have still no connection with physical energy concepts. Due to their absence of a true thermodynamical background, these models, which can be qualified as empirical, suffer in general from poor accuracy when evaluated outside the configurations where measured data have been collected.

On the other hand, the naturally vectorial Energy-Based (EB) Hysteresis model considered in this paper, remains strongly related to the fundamental principles of thermodynamics, and therefore exhibits a wide applicability, with the ability to predict material responses beyond the measurements framework. The EB model regards the pinning of domain walls as the cause of hysteresis and discretized the distribution of pinning strength values in a finite number of cells. This number can be adequately chosen to reach a given level of accuracy while limiting its complexity. It is worth noting that this model constitutes thus a perfect candidate for an easy incorporation into Finite Element codes. A systematic parameter identification procedure has already been developed based on common material measurements (Epstein frame). Nevertheless, discrepancies will appear between measurements and EB model predictions due to the simplicity behind the EB model representation that cannot cover the overall hysteresis behavior complexity.

This paper aims first to clarify the transition between the thermodynamic balance from the mesoscale, at the scale of one cell, to the macroscale, at the homogenized level. Actually this homogenization can be tackled in different ways, leading to different construction of EB hysteresis loops, one approach being in better agreement with experimental data. Then, the observed asymmetry between ascending and descending branches in measured hysteresis loops, which cannot be accounted for by the original EB model, is further investigated. An extension of the EB model is proposed and a comparison with classical Jiles-Atherton results to material measurements will be shown. Additionally, the parameter identification technique will be adapted accordingly in the full paper.