Improving loss properties of the Mayergoyz vector hysteresis model

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I. Introduction

It has been long known that the behaviors of hysteresis loops and energy dissipations under rotational flux differ greatly from that under alternating flux. Based on the Stoner-Wohlfarth model, Mayergoyz [1] devised a neat idea to model vector hysteresis. In the model, the magnetic field strength $\boldsymbol{H}$ is projected in all feasible directions while using a scalar Preisach model that keeps its history in each direction. The magnetic flux density $\boldsymbol{B}$ is calculated as the vectorial sum of the projected components. The vector model is widely known as the vector Preisach model; here, we prefer to call it the Mayergoyz model, because the model can be applied with, in principle, any scalar hysteresis model, not only with Preisach ones.

II. Problem

In spite of its elegance and appeal both physically and phenomenologically, the Mayergoyz model has been put under scrutiny for its loss properties [2]. The rotational losses calculated by the model under circular flux remain high even when the ferromagnetic material is saturated, a result that contradicts with the experimental observation. The model keeps producing a hysteretic behavior at saturation and, therefore, the vector fields $\boldsymbol{H}$ and $\boldsymbol{B}$ remain unparallel and the losses stay constant at a specific value. This problem led to the introduction of a new, supposedly more general version of the Mayergoyz model in order to control the rotational loss. The generalized Mayergoyz model [3] was meant to circumvent the problem by increasing the contributions of the projected magnetic field strength.

In this paper, we show that the increase of the contributions of the projected components in the generalized Mayergoyz model reduces the rotational loss slightly at saturation, but causes anisotropy, and thus undermines the model's ability to produce accurate prediction. In other words, the generalized Mayergoyz model changes the characteristics of the isotropic vector model in a way that makes the B-H loops and the loci of the magnetic fields become totally different from those predicted by the Mayergoyz model [1]. For example, if a circular flux is applied to the Mayergoyz model, the loci of the magnetic field strength will be circular. On the other hand, if the same circular flux is applied to the generalized Mayergoyz model, then the magnetic field strength will not be circular but rather flower-shaped, leading to peculiar, nonphysical outcomes.

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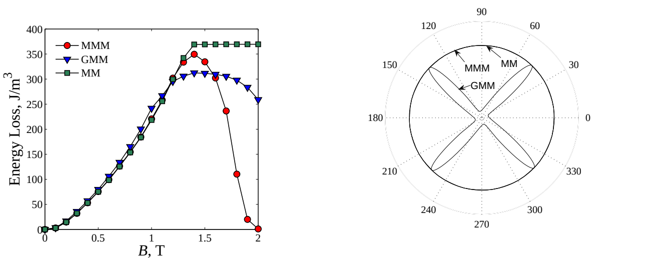
III. Proposal

Here, we introduce a different approach to control the rotational loss without confronting the latter problem. A sufficiently small phase shift is introduced between the directions of the projected magnetic field strength and the directions of the calculated flux density. The new model is here referred to as the modified Mayergoyz model.

The three models, the Mayergoyz model (MM) [1], the generalized Mayergoyz model (GMM) [3], and the modified Mayergoyz model (MMM), all identified from 1-D and 2-D experimental hysteresis loops of a non-oriented electrical steel [4], have been implemented in an inverse manner in order to enforce a circular flux density excitation. The numerical results are shown in Fig. 1. The proposed model (MMM) has satisfied the rotational loss property as well as produced a circular magnetic field strength, as desired. The GMM, on the other hand, improved the rotational loss slightly while it created severe anisotropy as seen in the loci of the magnetic field.



(a) (b)

Fig. 1. (a) Rotational losses of a quasi-static circular flux density computed by the Mayergoyz model (MM), the generalized Mayergoyz model (GMM), the modified Mayergoyz model (MMM). (b) The normalized loci of the magnetic field strength predicted by the three models when magnetized by a quasi-static 1.5-T circular flux density.

IV. Conclusion

The proposed model is based on compensating the observed phase angle persisting between the fields $\boldsymbol{H}$ and $\boldsymbol{B}$ at saturation. In the extended version of the paper, a detailed description of the proposed model and its implications will be shown and supported by experimental results.

References

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