A Domain Model for Magnetostriction of GO SiFe Considering Rotational Magnetization

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1. Introduction

Recently the requirements on the transformer cores regarding the acoustic noise have become very high, considering the increased environmental awareness. It is well known that the main cause of no-load noise is the magnetostriction (MS), apart from magneto-static forces. The current work presents a model for magnetostriction based on magnetic domain analyses in cases of alternating magnetization (AM) and of rotational magnetization (RM) as being typical for T-joints and parts of the yokes of 3-phase transformer cores.

2. Magnetostriction model

As it is well known, the movements of the walls of main domains have no relevance for MS. On the other hand, rotation of atomic moments towards the magnetizing field and the density of oblique supplementary domains influence the magnetostriction in a specific way.

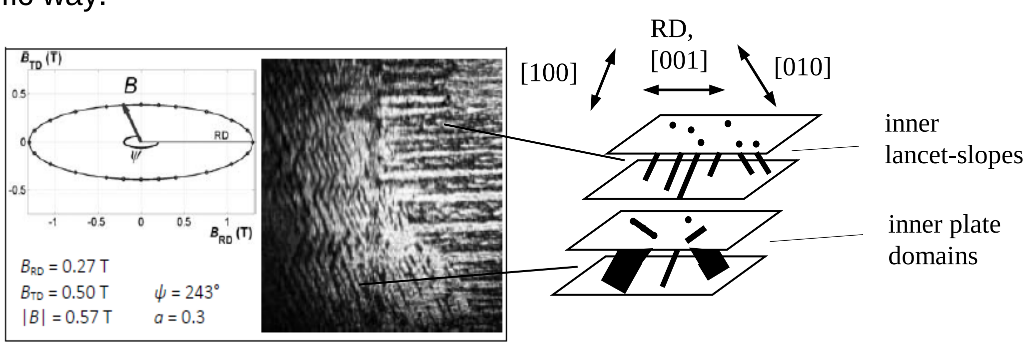

Fig. 1. A domain image under rotational magnetization for an instant when the induction vector ***B*** points out near to the transverse direction (TD).

Images of magnetic domains (Fig. 1) under rotational magnetization visualize main domains and two different types of oblique domains lancet spikes in [001] as indication of inner lancet slope domains (LSDs) in [100] or [010], and diagonal plate surface domains in [001] as an indication of inner plate domains (PDs) in [100] or [010]. It means that in the inner of the material, the atomic moments are withdrawn form the [001], which results in negative magnetostriction in rolling direction (RD) and positive in transverse direction (TD) and normal direction. In order to quantify these effects, we define the volume portion ρ_{OD} of magnetic moments in [100] or [001].

A. Alternating magnetization

Under AM, by raising magnetization B_{RD} we observe enhanced ρ_{OD} due to increased formation of LSDs. It yields increased negative magnetostriction λ_{RD} (Fig.2a). Approaching saturation yields decrease of ρ_{OD} since the atomic moments are turned to

H. The negative MS decreases as a consequence. Finally all LSDs are annihilated, and ρ_{OD} becomes zero. For very high B_{RD}, λ_{RD} becomes positive, since all atomic moments are rotated towards the direction of the field.

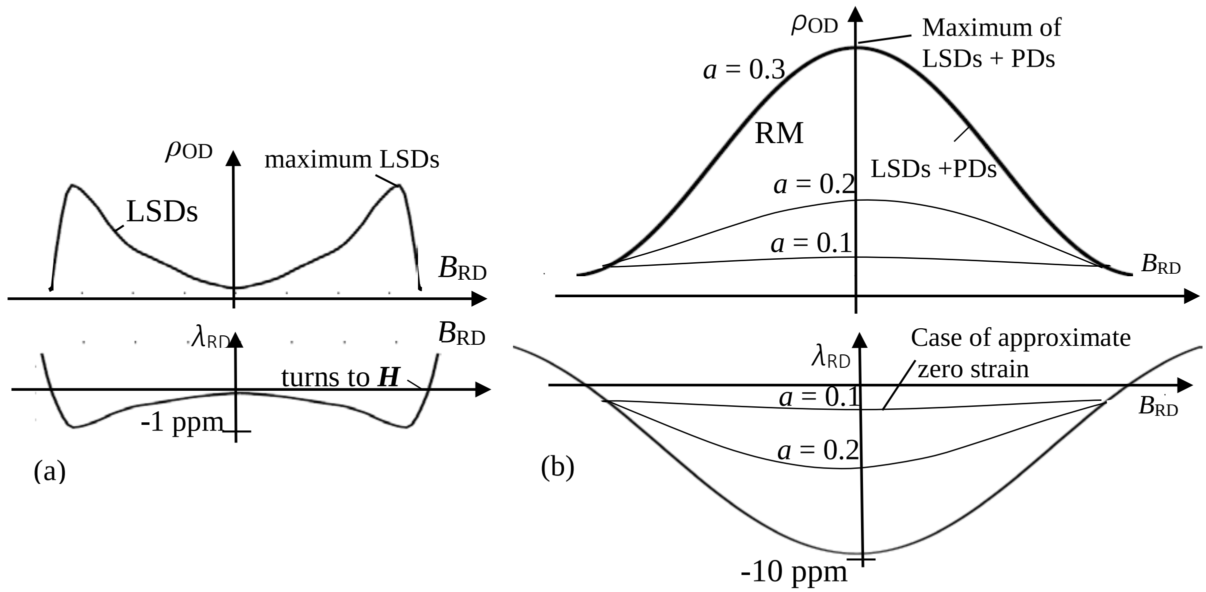

Fig. 2. A model for the volume portion ρ_{OD} of magnetic domains and the corresponding magnetostriction λ_{RD} in rolling direction. (a) Alternating magnetization. (b) Rotational magnetization (RM). Notice: different scale in very rough approximation for GO SiFe (see [1]).

B. Rotational magnetization

In the case of rotational magnetization (Fig.2b), a process of merging lancet-slopes into plate domains can be observed [2]. When ***B*** points out in TD (B_{RD} = 0), ρ_{OD} increases rapidly for axis ratios ***a*** > 0.1 becoming very high due to the many PDs. Increasing B_{RD} yields decreased ρ_{OD}, since the relative impact of B_{TD} becomes weaker which leads to annihilation of plate domains. For B_{RD} higher than 1.6 T, in a similar way to the case of AM, a further decrease of ρ_{OD} is observed due to decreases of LSDs. Due to these two effects, the amount of strong negative λ_{RD} decreases.

The MS-measurements performed in [1] (see figure 12) show very low values of the peak-to-peak MS for the case of RM with *a* = 0.1. According to our model (Fig. 2b), ρ_{OD} remains for a = 0.1 and B_{RD} up to 1.6 T almost constant. It means that the effect of annihilation of PDs and generation of LSDs in this induction range compensate each other. This explains that RM yields lower peak-to-peak values than mere AM for this specific case.

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References:

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[2] V. Galabov, H. Pfützner, G. Shilyashki, H. Yamaguchi, Y. Okazaki and S. Arai, Domain reconstructions of g.o. SiFe during rotational magnetization considering also 3-D flux components, *IJAEM,* JAE-141804 (2014), pp. 1-12.