Dynamics Effects on Magnetostriction Under Rotational Magnetization

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Abstract – As well known, losses of g.o. SiFe tend to rise if alternating magnetization (AM) includes distortions. As well, they rise if rotational magnetization (RM) shows uneven angular velocity. Here we studied whether such dynamics have also effects on magnetostriction (MS). Investigations were carried out by means of a rotational single sheet tester on two grades of transformer core steel. In general, the results indicate restricted effects on the intensity of MS, but distinct ones on the harmonics. In special, increases of the maximum angular velocity of the vector ***B*** yield a tendency of decreased peak-to-peak MS, due to a decreased fundamental component (100 Hz). However, the higher harmonics increase in distinct ways by up to about 300%. As a conclusion, the usual modelling with even angular velocity tends to under-estimate the higher harmonics of vibrations which are of specific acoustic relevance for the physiology of the human ear.

1 Introduction

As well known, the *losses* of grain oriented SiFe show distinct increases in cases of enhanced dynamics of magnetization. For alternating magnetization (AM), this is valid for distortions. As well, it is valid for rotational magnetization (RM) - as being typical for T-joint areas of transformer cores - if the induction vector ***B*** shows high values ω_{MAX} of maximal angular velocity [1]. The present study was aimed on the question whether increased dynamics have also effects on magnetostriction (MS). A focus was put on two grades of transformer core steel.

Earlier measurements of MS have shown, that MS-caused strain rises in very strong ways with increasing axis ratio $a=B_{TD}/B_{RD}$ of RM, in special for strain λ_{RD} in rolling direction (RD) [1]. While being relevant for losses, the *shape* of induction pattern showed little relevance for MS. This means that the measurements of this study could be restricted to the - easily definable - elliptic case, in spite of the fact that transformer cores tend to show rhombic patterns.

2 Methodologies

Magnetization patterns of elliptic shape with B_{RD} up to 1.7 T were simulated with a=0.3 by means of a 3-phase excited rotational single sheet tester. A software-controlled approximation algorithm generates patterns with a mean square error of 0.2%. Thus it allows an exact variation of the angular velocity ω of the vector ***B***(t). The peak-to-peak MS λ_{RD} and λ_{TD} is evaluated as a function of the maximal angular velocity ω_{MAX} which arises in practice when ***B*** passes through the transverse direction (TD).

MS measurements were carried out with strain-gauges of type LY42-50/120 of high length (50 mm) for averaging over the large grains of material. They were placed in a quarter bridge circuit together with dummy gauges for temperature compensation. The strain gauges were arranged on the top of hexagonal samples of about 160 mm diameter of scribed highly grain oriented (SHGO) material 23ZDKH90 and conventional grain oriented (CGO) material 30M5.

3 Results

Fig.1 shows examples of the studied magnetization patterns. Fig.1a shows the case of constant ω_{MAX} = 18°/ms, Fig.1b the "even" case of low ω_{MAX} = 37°/ms, as resulting from sinusoidal induction components, and as investigated by most authors. However both cases lack practical relevance. Model core tests revealed that practice exhibits high dynamics, corresponding to ω_{MAX} of at least 100°/ms (Fig.1c,d).

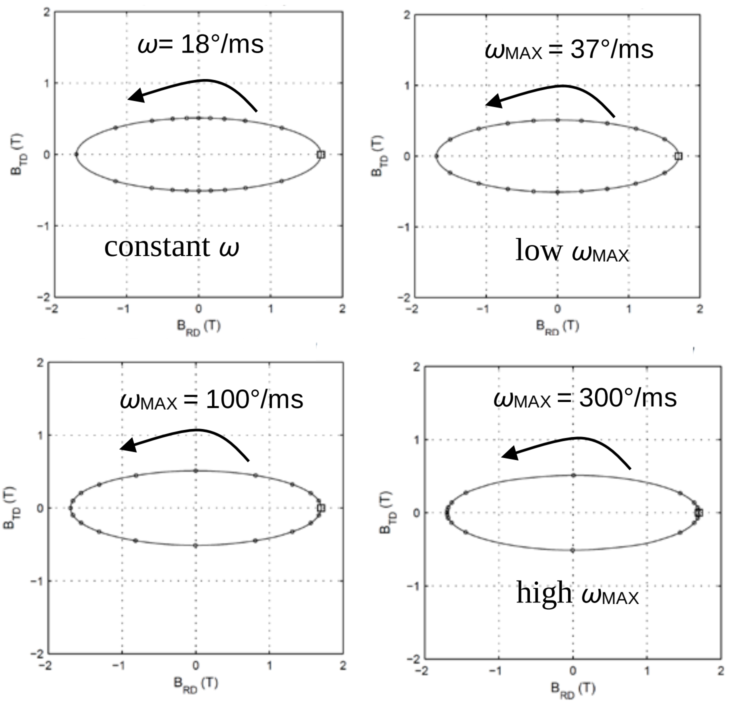

Fig.1. Examples for elliptic RM for B_{RD}=1.7 T and a=0.3 (20 instantaneous positions of the vector $\boldsymbol{B}$ with time spacing of 1ms; a square for the start point). Increasing dynamics of $\boldsymbol{B}(t)$ correspond to increasing maximal angular velocity ω_{MAX} in TD. **(a)** Constant ω. **(b)** "Even" case ω_{MAX}=37°/ms. **(c)** Practice-like ω_{MAX}=100°/ms. **(d)** High ω_{MAX} = 300°/ms.

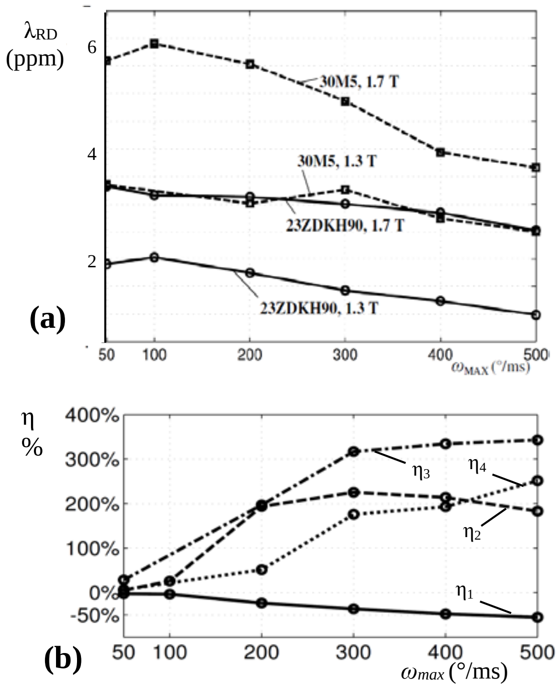

Fig.2. Examples of results.
(a) Peak-to-peak MS λ_{RD} as a function of ω_{MAX}, for CGO and SHGO material. **(b)** Percentage increase of harmonics, related to the "Even" case, for SHGO material.

Fig.2a shows examples for peak-to-peak MS λ_{RD} in RD as a function of ω_{MAX} . In a non-clarified way, both materials exhibited irregular variations of strain for ω_{MAX} < 100°/ms. However, higher dynamics yield a general tendency of decreased MS in RD and TD for both materials.

Spectral analyses (Fig.2b) revealed that the above decrease is due to decreases of the fundamental 100 Hz component of MS. In contrast to it, the higher harmonics (200 Hz, 300 Hz and 400 Hz) show a distinct enhancement with increasing ω_{MAX} . For example, a dynamics-increase from the "even case" ω_{MAX}= 37°/ms up to 300°/ms yields an increase η of about 300% for the 3rd harmonic.

The results indicate that increased dynamics of magnetization show effects on both losses and magnetostriction, but in very different ways. While losses are increased, MS is rather decreased in its intensity. However, the harmonics are increased. It can be assumed that this has practical relevance for transformer noise, considering that the human ear shows increased sensitivity for the range of higher harmonics.

Acknowledgement: The authors thank for support from the Austrian Science Funds FWF (Project No.P21546-N22) as well as from ABB Transformers.

[1] H.Pfützner, E.Mulasalihovic, H.Yamaguchi, D.Sabic, G.Shilyashki, F.Hofbauer. Rotational Magnetization in Transformer Cores – A Review. *IEEE Trans.Magn*. 47, pp.4523-4533 (2011).