Dynamics Effects on Magnetostriction
Under Rotational Magnetization

Georgi Shilyashki, Helmut Pfützner, Franz Hofbauer,
Viktor Galabov, Edin Mulasalihovic, Martin Palkovits
Institute of Electrodynamics, Microwave and Circuit Engineering (EMCE),
Vienna University of Technology, Austria
(georgi.shilyashki@tuwien.ac.at)

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 $\omega_{\text{MAX}}$ 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 $a=B_{\text{TD}}/B_{\text{RD}}$ of RM, in special for strain $\lambda_{\text{RD}}$ 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 $B_{\text{RD}}$ 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 $\omega$ of the vector $B(t)$. The peak-to-peak MS $\lambda_{\text{RD}}$ and $\lambda_{\text{TD}}$ is evaluated as a function of the maximal angular velocity $\omega_{\text{MAX}}$ 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 $\omega_{MAX} = 18^\circ$/ms, Fig.1b the "even" case of low $\omega_{MAX} = 37^\circ$/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 $\omega_{MAX}$ of at least $100^\circ$/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 $B$ with time spacing of 1ms; a square for the start point). Increasing dynamics of $B(t)$ correspond to increasing maximal angular velocity $\omega_{MAX}$ in TD. (a) Constant $\omega$. (b) "Even" case $\omega_{MAX}=37^\circ$/ms. (c) Practice-like $\omega_{MAX}=100^\circ$/ms. (d) High $\omega_{MAX} = 300^\circ$/ms.](image)

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Fig.2a shows examples for peak-to-peak MS $\lambda_{RD}$ as a function of $\omega_{MAX}$ for CGO and SHGO material. (b) Percentage increase of harmonics, related to the "Even" case, for SHGO material.

![Fig.2. Examples of results. (a) Peak-to-peak MS $\lambda_{RD}$ as a function of $\omega_{MAX}$, for CGO and SHGO material. (b) Percentage increase of harmonics, related to the "Even" case, for SHGO material.](image)

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