Effects of Moderate DC Bias on Magnetostriction of Grain Oriented SiFe

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Abstract – As well known, long-term DC-bias deteriorates the performance of transformer cores, leading to increases of excitation, losses and noise. This study concerns effects of moderate bias on magnetostriction (MS) under alternating as well as rotational magnetization as being typical for T-joint regions. Investigations were performed on two grades of grain oriented transformer steel by means of a rotational single sheet tester (RSST). They reveal significant increases of MS for axis ratios *a* up to 0.3. For higher values, up to 0.5, the effects tend to cease. The relevance of RSST data was checked by strain gauge measurements of MS on 19 surface locations of a 3-phase, 3-limb model core. Moderate DC bias was restricted to the middle limb, corresponding to the so-called unbalanced case. It yielded distinct increases of MS with high scatter and strong regional differences. The orders of increases range from zero for the middle limb over 70% for the T-joint up to 150% for yokes and outer limbs.

1 Introduction

Rising implementation of electronics in electric power delivery yields DC-bias as a significant impact factor on the magnetic performance of transformers. Non-compensated thyristor switches or imperfect transistor sets may cause moderate bias as a long-term phenomenon. It is too weak to damage the machine, but it increases all three the excitation, the losses and the noise as caused by forces and magnetostriction (MS) (e.g. [1]).

In literature, studies on effects of bias on MS are restricted to a single work [2] where weak bias was tested for very weak alternating magnetization (AM). The aim of the present work was to study the practically relevant case of B = 1.7 T, considering also rotational magnetization (RM) as arising in T-joints and yokes of transformer cores.

2 Methodologies

MS measurements with strain gauges were performed on hexagonal samples of 160 mm diameter of conventionally grain oriented (CGO) core steel 30M5 and of scribed highly grain oriented (SHGO) steel 23ZDKH90. Simulations of elliptic RM with axis ratios *a* up to 0.5 were performed for B_{RD}=1.7 T by means of a rotational single sheet tester (RSST). Moderate bias was impressed in rolling direction (RD) according to excitation ratios $r_{DC}=(N_{DC}\cdot I_{DC})/(N_{AC}\cdot I_{AC})$ up to 1.

Further, strain measurements were made on a 3-phase model core stacked from 30M5. 19 strain gauges (12 placed in RD, and 7 in transverse direction (TD)) were arranged in different surface regions, each gauge in a quarter bridge circuit together with a dummy gauge for temperature compensation.

3 Results

Fig.1 shows results of RSST measurements. For RM, the MS-caused strain λ_{RD} showed very strong increases with rising *a*. About 10-fold values appeared for *a* = 0.5. Bias with

r_{DC}=1 caused approximately doubled values for low *a* (up to 0.1) while the effects tend to cease for strong RM (*a* > 0.3). In general, the CGO-material showed doubled MS compared to SHGO-material.

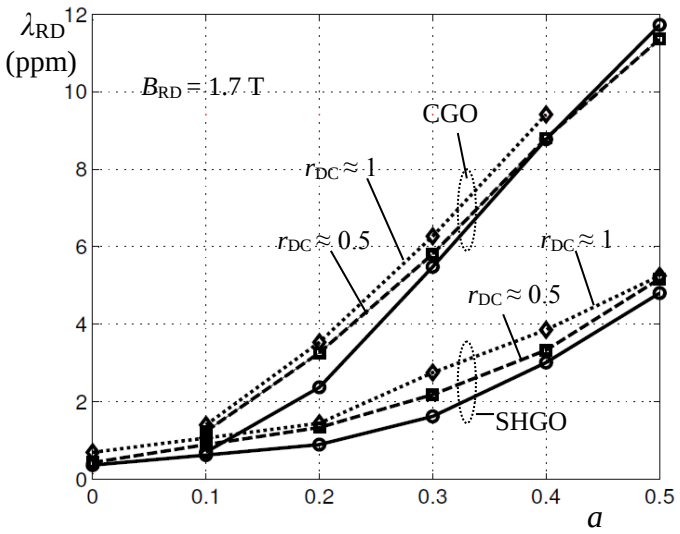

Fig.1. Peak-to-peak MS λ_{RD} in RD measured for CGO 30M5 and SHGO 23ZDKH90 for B_{RD}=1.7 T under RM of elliptical shape as a function of the axis ratio *a*. Results are given for moderate bias according to r_{DC}=0.5 and r_{DC}= 1.

Strain measurements on the CGO-core without bias (Fig.2a) revealed λ_{RD} below 1 ppm for outer limb and yoke, and up to 5 ppm in T-joint, all well corresponding with RSST measurements. Moderate bias with r_{DC}=1 imposed in the middle limb (corresponding to the so-called unbalanced case) caused significant increases in all regions except the middle limb. An order of +150% resulted for outer limbs and yokes of very low *a*, while about +70% resulted for the T-joint where the mean value of *a* may be close to 0.2. This means that rough agreement is given to RSST tests. Smaller values resulted for the TD, according to theory.

As a conclusion, moderate DC-bias as being possible as a long-term phenomenon may cause doubled values of magnetostriction. Main increases concern those regions were rotational magnetization is not given, corresponding to an over-all balancing effect.

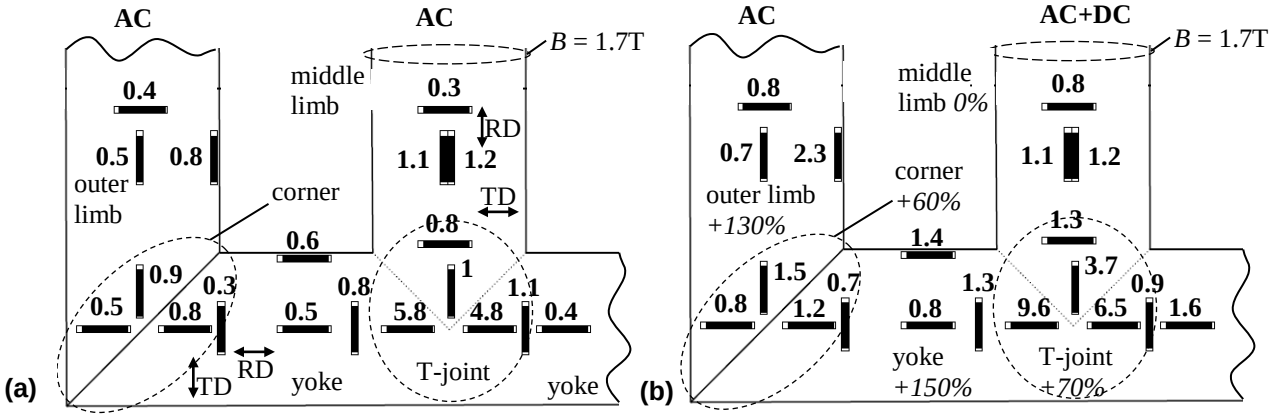

Fig.2. Measured peak-to-peak MS on a surface of a 3-phase, 3-limb model core stacked from CGO 30M5 for *B*=1.7T. **(a)** Without bias. **(b)** With bias (r_{DC}=1) imposed in the middle S-limb (unbalanced case). All strain values are given in ppm. Regional percentage increases of MS are given in italics.

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