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Magnetostriction of grain-oriented Fe-Si under rotational magnetization with DC-bias

Introduction

Apart from magneto-static forces, magnetostriction is the most significant source for transformer core noise. The latter gains relevance due to increased environmental consciousness and due to the fact that increasing energy demand brings transformers closer to residential centres. Thus capitalization of noise approaches that of losses.

Highly grain oriented (HGO) core steel offers low values of magnetostriction-caused strain λ in limbs where magnetization is given in rolling direction (RD). However, distinct increase of λ was observed under rotational magnetization (RM) as reported in [1]. In special, the T-joint regions of transformer cores can be assumed to be affected.

A further impact factor is given by possible DC components of magnetisation. Such „bias" may arise due to non-compensated thyristor switches and - in an occasionally extreme manner – due to geomagnetically induced currents (GICs). The aim of the present work was to determine magnetostriction under the influence of DC-bias for both AM (alternating magnetization) and RM for practically relevant magnetization patterns (elliptic and rhombic). Focus was put on laser scribed core material (SHGO).

Experimental

Exactly defined magnetization patterns $\boldsymbol{B}(t)$ were generated by a 3-phase excited rotational single sheet tester equipped for simulation of DC-bias. The latter was imposed in RD or TD according to a DC/AC excitation ratio r_{DC} varied up to about 0,5.

MS-measurements were carried out with strain gauges of high length (64 mm) in order to average over the large grains of the given type of material (23 ZDKH; NSC). The gauge was placed in a quarter bridge circuit together with a dummy gauge for temperature compensation arranged on top. One set was applied in RD, a second one in TD (transverse direction). SHGO material involves very small values of λ as a source of very weak and noisy signals. This was met by digital signal processing with specific evaluation of harmonics. Evaluation was restricted to peak-to-peak values λ_{RD} and λ_{TD}.

Results and discussions

Fig.1 shows peak-to-peak values λ_{RD} and λ_{TD} for unbiased elliptical RM as a function of the peak-value axis ratio $a = B_{TD}/B_{RD}$. The latter was varied up to 0,5 – the maximum value as arising in practice. With increasing *a,* MS shows non-linear increases which rise with the induction peak values in strong ways. Compared to AM, RM with B_{RD} = 1,7 T and a = 0,5 yields an increase of λ_{RD} from about 0,5 ppm up more than 6 ppm, i.e. by a factor close to 12. Smaller factors result from smaller B_{RD} and a, respectively. As well, the TD shows a reduction of MS by about 50% which indicates that similar values can be expected for the normal direction (assuming zero volume MS).

Under rhombic magnetization patterns, MS proved to be just slightly increased compared to the elliptic case. This shows that the relevance of the *shape* of the magnetization pattern is restricted to the harmonic content of MS.

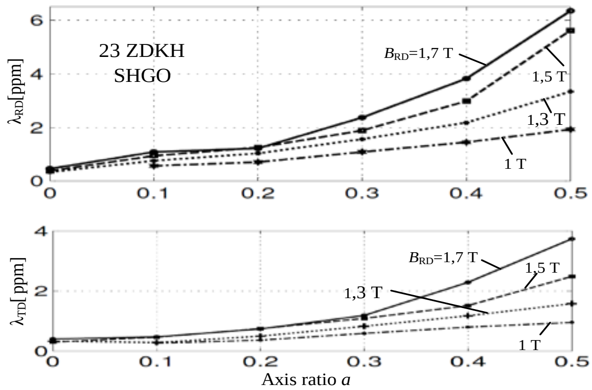

Fig.1. Peak-to-peak MS in RD and in TD as a function of the axis ratio a and induction B_{RD} for SHGO (23ZDKH) under elliptic magnetization.

Fig.2. shows some results for the relative MS-increase $\Lambda_{RD} = \lambda_{RD}(AC/DC)/\lambda_{RD}(AC)$ as determined for DC-bias in RD. Two dashed curves give measured data for two values of bias current I_{DC} , which however correspond to unsystematic variations of the excitation ratio r_{DC}. A full curve is extrapolated for the case r_{DC} = 0,2 , an order which may arise in practice. For a = 0 (AM), Λ_{RD} proves to be close to 0,5 corresponding to an increase of MS as strong as 50%. On the other hand, with increasing a , Λ_{RD} sinks distinctly and reaches the order of 10% for a = 0,5.

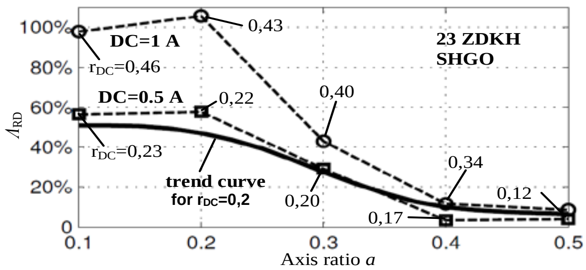

Fig.2. Relative increase Λ_{RD} of λ_{RD} (in %) due to DC-bias as a function of the axis ratio a for B_{RD}=1,7 T.

As a main conclusion, magnetostriction of SHGO core material tends to be distinctly increased if the order of DC-bias exceeds 10% of the AC excitation. The increase is most pronounced for alternating magnetization while it sinks with increasing axis ratio of rotational magnetization.

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REFERENCES

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