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DC-bias effects on losses and field patterns of silicon iron under rotational magnetization

Introduction

Magnetic cores of modern power transformers are produced from highly textured SiFe-laminates. In most core regions, the magnetic flux follows the materials rolling direction (RD) of very high permeability. However, parts of the yokes – in special the so called T-Joints - show magnetization components in transverse direction (TD), rotational magnetization (RM) yielding increased local losses *P*.

At present, increasing introduction of high-voltage DC transmission components yields rising interest in DC-components of transformer excitation. Strong short-time "bias" may also arise due to geo-magnetically induced currents (GICs). The aim of the present study was to investigate DC-impacts under exactly defined magnetization patterns generated by a Rotational Single Sheet Tester (RSST).

Experimental

Measurements were made on hexagonal samples of material of ca. 160 mm diameter. Two types of material were investigated: conventional grain oriented (CGO) SiFe 30M5 and laser scribed SiFe (SHGO) 23ZDKH90. A 3-phase-excited 6-pole-piece RSST was used for biased elliptic and rhombic RM-patterns ***B***(*t*). The corresponding field patterns ***H***(*t*) were detected by means of a pair of tangential field coils. DC-components were imposed in RD or TD, the DC/AC excitation ratio being up to about r_{DC} = 0,3.

Losses *P* were measured by the rise-of-temperature method. Short magnetization time (10 s) was used for an average over the homogeneous part of sample and for minimum heat transfer from the excitation coils.

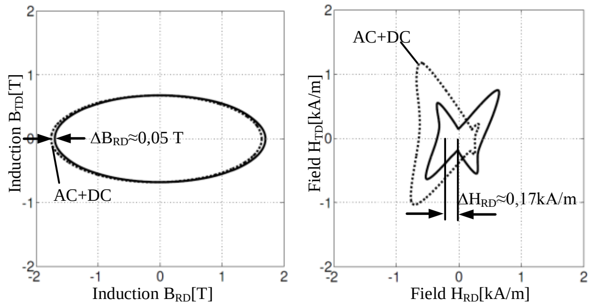

Fig.1. Example for a simulated elliptic magnetization pattern *B*(*t*) with B_{RD} = 1,7 T and *a* = 0,4 of CGO SiFe. Mere AC (through lines) is compared with AC + DC in RD with r_{DC} close to 0,15 (dotted). On the right side, the corresponding field patterns *H*(*t*).

Results

Fig. 1 shows an example of effects of bias in RD on the magnetization pattern ***B***(*t*). Though r_{DC} is as large as 0,2, a very small shift ΔB_{RD} of the given elliptic pattern is resulting. On the other hand side, the corresponding field pattern ***H***(*t*) is strongly influenced. Apart from a distinct shift in RD, strong asymmetry towards the TD-axis arises.

Fig.2 shows typical effects of bias in RD and TD, respectively on losses *P* as a function of the axis ratio *a* = B_{TD}/B_{RD}. In a general way, effects were very weak for CGO material, clear increases of *P* being restricted to the case of alternating magnetization (*a* = 0).

SHGO materials show strong increases of *P* with increasing *a* even for mere AC magnetization. Additional DC excitation yielded very strong further rises of *P* - even up to 100% - for moderate B_{RD} (below 1,6 T) if applied in RD. 1,7 T yielded much weaker effects, in special for high *a*. A tendency of generally weaker impact was found for DC in TD, however, differences being mantled due to the fact that r_{DC} was not kept constant in so far experiments.

Investigations were also made for rhombic RM as being more relevant for industrial practice. The increase of *P* with increasing *a* was distinctly smaller here. However, the impact of bias proved to be comparable to the elliptic case.

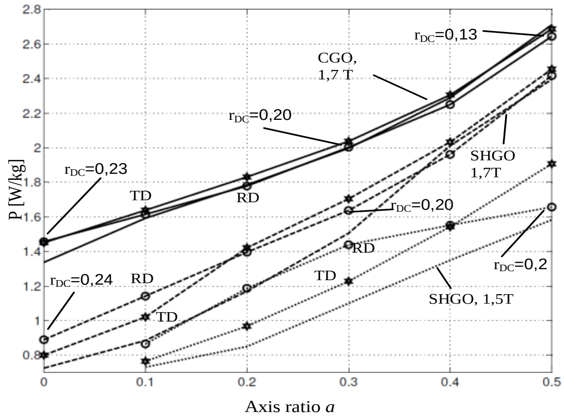

Fig.2. Losses *P* as a function of the axis ratio *a* for CGO SiFe (30M5) and for SHGO SiFe (23ZDKH90) with DC imposed in the RD and in the TD under elliptic RM. Notice that the DC/AC excitation ratio r_{DC} is not constant.

Conclusions

The main conclusions of this study are the following:

(a) Mere rotational magnetization without bias yields increases of losses *P* which increase with the axis ratio *a* in a non-linear way. The increases rise with the grade of texture, but sink with increasing B_{RD}. The elliptic case is more affected than the rhombic one.

(b) Additional DC excitation yields small shifts of the elliptic (or rhombic) magnetization pattern ***B***(*t*) while the field pattern ***H***(*t*) becomes strongly asymmetric.

(c) *P* shows strong increases, in special for small *a* and small B_{RD}, respectively.

(d) Bias is more effective if applied in RD than in TD due to higher permeability.

(e) Effects are more pronounced in the case of high texture which can be interpreted by the fact that a more ordered main domain configuration is "destroyed" by both rotation and bias.

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