

Rotational magnetization in transformer cores – a review

Helmut Pfützner^a, Edin Mulasalihovic^a, H.Yamaguchi^b,
Damir Sabic^a, Georgi Shilyashki^a

^aUniversity of Technology, Vienna, Austria

Institute for Electrodynamics, Microwave and Circuit Engineering (EMCE)

^bSteel Research Lab. JFE Steel Corp., Mizushima, Kurashiki, Japan

Rotational magnetization (RM) is a well known phenomenon which has wide significance for rotating machine cores. Magnetization patterns of elliptical and even circular type may yield considerably increased losses. Intensive work has been made on RM simulations by means of so-called rotational single sheet testers (RSSTs), in most cases applying square 80 mm samples of non-oriented SiFe. A large number of publications [1] reports correspondences between induction patterns $\mathbf{B}(t)$ and field patterns $\mathbf{H}(t)$, as well as the corresponding losses P . The present paper reviews the specific case of RM as occurring in a more restricted way in transformer cores which are built up from highly grain oriented (HGO) SiFe.

In transformer cores, the origin of RM is a very specific one. As the most significant mechanism, the V-shaped ends of highly textured S-limb laminations represent an obstacle to flux through the yoke, a part of flux taking a detour into the inner of the S-limb. As well, the flux take-over from a yoke half to the S-limb is hindered, which may result in long detours into the second yoke half. This gives rise to RM in T-joints, in yokes and in the S-limb ends. Due to high anisotropy, the axis ratio $a = B_{TD} / B_{RD}$ (TD transverse direction, RD rolling direction) tends to be smaller than 0,4. The flux avoids the hard 55°-directions (HDs), i.e. instead of elliptic magnetization, rhombic or lancet-like patterns are arising. The out-of-RD time is significantly restricted which means that the angular velocity of the vector \mathbf{B} shows strong variations. Close to the V-zones, the axis of maximum B may deviate from the RD.

Simulation of the magnetization patterns by means of square 80 mm samples is disfavoured by the large grain size of HGO SiFe as well as by the strongly pronounced HDs. Instead, hexagonal samples of approximately 150 mm diameter prove to offer effective tools. A software controlled approximation algorithm allows the production of elliptic and rhombic patterns with physiological course of time, however, exact simulations being impossible. The detection of \mathbf{H} is without problems by means of double tangential coils. The high anisotropy impedes exact measurements of \mathbf{B} through the needle technique, a pair of search coils through smallest holes being more effective. Multi-directional magnetostriction can be detected by means of 50 mm strain gauges which yield a good average over the large grains.

Exactly defined magnetization patterns are restricted to elliptic $\mathbf{B}(t)$. For a close to 0,3, it may yield doubled P , which however over-estimates the relevance of RM. Lower P results from rhombic patterns which involve field levels of industrial practice. Magnetostrictive strain tends to be most pronounced in RD for the instant when \mathbf{B} passes through the TD. Its extent may exceed that for alternating magnetization by an order of magnitude. But the phenomenon of RM is a local one. For both losses and magnetostriction, strong values are restricted to the T-joint region where maximum temperature rise is linked with maximum vibration. However, international demands are given to reduce both core characteristics to a minimum: the building factor as well as the generation of audible noise.

Acknowledgement: The authors thank for support from Siemens Transformers.

-
- [1] A large number of papers in the proceedings of 2DM Workshops, Braunschweig (1991), Oita (1992), Torino (1993), Cardiff (1995), Grenoble (1997), Bad Gastein (2000), Lüdenscheid (2002), Ghent (2004), Czestochowa (2006) and Cardiff (2008).