An extended Steinmetz-based description of power losses in nanocrystalline ribbon ring cores with symmetrical gaps

R. Szewczyk,[1] A. Ostaszewska-Liżewska,[1] P. Zackiewicz,[2] A. Pilśniak,[3] M. Polak,[2] A. Radoń,[2] and A. Kolano-Burian[2]

[1] *Warsaw University of Technology, Faculty of Mechatronics, Institute of Metrology and Biomedical Engineering*

[2] *Łukasiewicz Research Network – Institute of Non-ferrous Metals*

[3] *Silesian University of Technology, Faculty of Electrical Engineering*

Nanocrystalline Finemet-type alloys are important materials for the inductive cores of chokes and transformers, where control of power losses is of primary importance. The functional properties of ribbon-wound nanocrystalline materials produced during the recrystallization of amorphous ribbons can be widely modified not only by the recrystallization parameters, but also by filling the spaces among the amorphous layers with epoxy-based resin.

Understanding the changes of magnetodynamic parameters under varying environmental conditions is critical from the industrial point of view. Therefore, the experimental measurements of power losses in the core as the function of the frequency were performed at temperatures of $-20°C$, $20°C$, and $60°C$, what is justified by the requirements of industrial applications. The investigation covered the ribbon ring-shaped cores in three distinct geometric configurations: with no gap, with two symmetrical gaps of 0.17 mm, and with two gaps of 0.47 mm.

Investigation was carried out on the base of open source software. A modeling toolchain covering NETGEN tetrahedral mesher, ELMER FEM solver, and GNU-OCTAVE control was created. As a result of the simulation, paper presents a new idea regarding the mathematical description of power losses. While the classical Steinmetz model assumes a linear dependence of power losses P_{loss} on frequency f in the log-log scale [1], the results of the investigation suggest that a second-order approximation is necessary for cores with gaps operating in the higher frequencies. For this reason, the original model was extended to a second-order polynomial form in the log-log scale:

$$\log(P_{loss}) = A \cdot (\log f)^2 + B \cdot \log f + C \tag{1}$$

The paper presents the modeling results compared to the experimental measurements. Moreover, the paper presents procedures and guidelines for the efficient finite elements-based modeling of the losses in nanocrystalline ribbon ring-shaped cores.

References:

[1] J. Long et. al., J. Appl. Phys. 103 (2008) 07E705.

This work was supported by the National Centre for Research and Development under European Funds for a Modern Economy (FENG SMART), project number: FENG.01.01-IP.01-A00H/23.