Organized by Sevilla University

23rd SOFT MAGNETIC MATERIALS *Conference*

Abstracts

Characterisation of Soft Magnetic Materials by Measurement: Evaluation of Uncertainties

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Magnetic measurements are indispensable for the characterization of soft magnetic materials. Resulting characteristic values are used for the parametrization of material models or as quality control during production. Arising uncertainties and errors in the measurements are directly reflected in the parameters of the material models, which consequently leads to inaccuracies in simulations. In this paper, the existing influencing factors in the standardised characterization of soft magnetic materials are named and their resulting uncertainty contributions are investigated.

For non-oriented electrical steel a standard deviation in the range of 1.5 % is currently defined by the standards. Considering the requested boundary conditions, the accuracy is limited to a range of flux densities up to 1.5 T and frequencies of 400 Hz. The Form-factor is currently used as the sole evaluation criterion of the measurement quality. However, in the field of rotating electrical machines increasing fundamental frequencies and magnetic utilisation require to characterise soft magnetic materials also at frequencies and magnetic polarisation levels above the currently defined standards. Consistently, the investigation of the resulting combined standard uncertainty of the measured specific losses is performed within the application range of frequencies and polarisations up to 10 kHz and 1.8 T. All measurements are carried out repeatedly to identify measuring errors and include the impact of statistical errors.

In the paper, two different Single sheet tester are analysed exemplarily. The fundamental mathematical model of the combined uncertainty can also be applied to the Epstein frame and ring core tester. Beside the Form-factor, the phase angle and secondary voltage are found to be crucial for the resulting uncertainties. In case of low polarisation and frequency levels, the measured secondary voltage is a key aspect. At magnetic polarisation levels above 1.5 T the rising phase angle between primary and secondary voltage results in a significantly increasing of the combined uncertainty of the specific iron losses. This effect is due to the IEC standard measuring principle of a transformer in open-circuit condition.

Furthermore, the impact of the measuring uncertainties on the iron loss parameters are studied in terms of hysteresis, eddy current, excess and saturation losses. The hysteresis loss component is determined by the uncertainties resulting from the quasi-static measurement. Classical eddy current losses can be identified analytically. Hence, the corresponding uncertainty can be calculated using the Type B evaluation. Excess losses are identified within the linear magnetisation area and at low frequencies where the resulting measurement uncertainties are low. Saturation loss parameters are determined at high polarisation and frequencies levels. The strongly increasing combined uncertainty of measured losses for polarisation levels above 1.5 T have a strong impact on the identified loss parameters. The analysis of the resulting uncertainty contributions can serve the operator as additional selection criteria for different measuring sensors. Furthermore, it is an important tool to consider in the assessment of the measuring results and the parameterization of material models.