Systematic investigations of factors reducing data reproducibility in power loss measurements of electrical steel sheets

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Soft magnetic materials manufactured into electrical sheets are heavily used in generators, transformers and motors. The need of an all-electrical society to save energy at all levels demands a precise knowledge of those loss data for increased efficiency of the devices. In the following presentation, we examine external factors that influence power loss measurements and they are not (yet) specified in the standards.

Keywords: power loss measurements, Epstein frame measurements, soft magnetic materials, demagnetization

Introduction

In the past, comparisons of experimental loss data obtained by different laboratories have revealed deviations in the results that point to external factors as the origin [1]. These parameters must be identified and investigated in detail for further improvement of the standard[2] and higher data reliability and precision. Here, we evaluate on grain oriented (GO) and non-grain oriented (NO) electrical steel sheets the factors: one time Epstein frame loading versus multiple loading, and maximum demagnetization polarization that alter loss data and lead to deviations not covered by the measurement uncertainties (MUs).

Discussion

Data was taken on Epstein samples using an Epstein frame with 100 turns per leg. This way, other influences can be minimized and data is inter comparable. Demagnetization and measurement frequency was chosen to be 50 Hz and the maximum demagnetization polarization was 1.7T and 1.9T for NO and GO material, respectively. Repeated measurements on one GO Epstein sample loaded into the Epstein frame once, was carried out for low polarization at 1T and high values at 1.9T. Data reproduce excellent and MUs obtained according to GUM type B method fully cover statistical deviation indicated as standard deviation σ line in both cases.

Additionally, it is expected that small changes of the position of individual sheets within the Epstein frame have an effect on the loss data, because the magnetic flux that leaves one sheet and penetrates the next at the corner of strips uses different grain paths. In a rough assumption, all those effects average over large surface areas, however, grain size in GO material is up to cm size and this could have an influence on the loss estimate. Therefore, we conducted test measurements and removed the sample after each measurement and put it back for the next one. Note, a specific loading pattern is used, e.g. all 4th strip number are located in the same pile. We find that the scattering for low polarization is larger for reloaded Epstein samples compared to not reloading the frame, but still within the systematic MU estimation. With increasing polarization, the scattering effect is less pronounced. In the case of GO material, we observe reduced loss values compared to the previous study and significantly enhanced scattering. Next, we investigated the influence of the demagnetization process before each measurement on the loss. We show loss data at three different polarizatons: 1 T, 1.3 T, and 1.9T as a function of maximum demagnetization J_{demag} values. Scattering of the loss data is most pronounced for 1T and 1.3T data, but shows signs of saturation for J_{demag} higher 1.8 T. The loss at 1.9T is not affected by the demagnetization process, because the magnetic domains are fully aligned in the sheet during one full hysteresis loop.

Further systematic investigations of loss in Epstein and SST samples should include temperature studies in the range allowed by standard (23±5)◦ C, and loss dependence on the demagnetization frequency. Later effect is known especially for GO material as domain refinement [3], where higher frequencies lead to reduced domain width and smaller magnetic loss.

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