Round robin comparison of power losses performed by Epstein and SST above 50 Hz at room temperature

Michal Ulvr[a], Franziska Weickert[b], Korbinian Pfnuer[b], Joachim Lüdke[b], Katja Hoffmann[b], Stuart Harmon[c], Daniel Brunt[c], Adam Wilson[c], Massimo Pasquale[d], Carlo Appino[d], Chris Gerada[d], Ram Ramanathan Mathavan jeyabalan[e], Gaurang Vakil[e]

[a] CMI, Czech Republic. [b]PTB, Germany. [c]NPL, United Kingdom. [d]INRIM, Italy. [e]UNOTT, United Kingdom.

Epstein frame and single sheet tester are two methods used for measurement of power losses of the electrical steel sheets or strips. Both methods and the setups are described in the IEC standards. Each national metrology institute or other metrological laboratory has different setups for power losses measurement and the validation of its accuracy and parameters can only be done by comparisons. So far, every performed comparison was carried out only at 50 Hz or 60 Hz. Within the EMPIR project "HEFMAG", improved metrological structure for the determination of power losses using Epstein frame at induction values close to saturation and at frequencies ranging up to 2 kHz resp. 10 kHz was build. To validate the improved setups, a round robin comparison of power loss measurements was conducted by five laboratories.

Keywords: Comparison, Epstein, power loss, reference sample, SST

1. Introduction

The two most common experimental setups for the measurement of power losses in grain-oriented (GO) and non-oriented (NO) electrical steel are the Epstein frame and the single sheet tester (SST). Measurement of power losses at room temperature using Epstein frame up to 400 Hz is described in IEC 60404-2 [1] and up to 10 kHz in IEC 60404-10 [2]. Measurement of power losses at room temperature using SST is described in IEC 60404-3 [3] with no frequency range stated. To date, several international comparisons, promoted by EURAMET, COOMET and the IEC working group TC 68, have confirmed good reproducibility for both the Epstein and SST methods, with an uncertainty around 1 % in power loss measurements. These comparisons, however, have only focused on measurements at 50 Hz or 60 Hz and they have been carried out at room temperature [4]. Within the HEFMAG project, a new reference round robin comparison was performed using Epstein frame and SST at extended frequencies (Epstein up to 10 kHz, SST at 50 Hz and 100 Hz) using NO and GO samples and using improved setups.

2. Results and discussion

Four national metrology institutes (NMIs) – PTB Germany, INRIM Italy, CMI Czech Republic and NPL United Kingdom - improved their Epstein and SST measurement setup compared to the last RR comparisons. The 5th laboratory (UNOTT) used a custom built setup (a variant of MPG-200 type) from Brockhaus Messtechnik. All NMIs have experimental setups following standard regulation, but each is realized slightly differently. The form factor of the sine wave signal on the secondary of the Epstein frame must be maintained at 1.11 ± 1 % according to the standards [1-3]. This is achieved by using a feedback control. All NMIs apply different approaches to the feedback control and this also means that all NMIs achieve different levels of measurement uncertainties (MUs).

Three GO samples (with thickness of 0.18 mm and 0.3 mm) and two NO samples (with thickness of 0.2 mm and 0.3 mm) has been used in the comparison. One of the results is shown in Figure 1 with the reference value x_{ref} marked as red solid line and the uncertainty $u(x_{ref})$ for coverage value k = 2 as dashed red line. The data overall shows very good agreement between all participants at each frequency and corresponding E_n-values are smaller than 1. The RR comparison confirms calibration results at NMIs and validates their respective CMC entries.

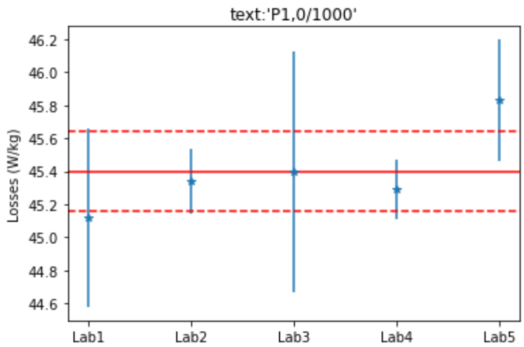

Figure 1: Comparison results of Epstein sample GO 0.3 at J_m=1.0 T at 1000 Hz.

References

[1] IEC 60404-2 Magnetic materials - Part 2: Methods of measurement of the magnetic properties of electrical steel sheet and strip by means of an Epstein frame.

[2] IEC 60404-10 Magnetic materials - Part 10: Methods of measurement of magnetic properties of electrical steel strip and sheet at medium frequencies

[3] IEC 60404-3 Magnetic materials - Part 3: Methods of measurement of the magnetic properties of electrical steel strip and sheet by means of a single sheet tester.

[4] C. Appino et al.: "International Comparison on SST and Epstein Measurements in Grain-oriented Fe-Si Sheet Steel", International Journal of Applied Electromagnetics and Mechanics 48, pp. 123 – 133, 2015.

Acknowledgements: This research work was partially supported by the 19ENG06 HEFMAG project, which was funded by the EMPIR program, and co-financed by the Participating States and the European Union's Horizon 2020 research and innovation program.