International comparison on SST and Epstein measurements in grain-oriented Fe-Si sheet steel

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1. Introduction

Electrical sheet steels are sold and applied against properties typically measured through either the Epstein or Single Sheet (SST) testing methods, according to the IEC 60404-2 and IEC 60404-3 standards, respectively. Because of the different sample geometries and involved magnetic circuits, these two methods, while both ensuring good reproducibility, do provide different results. The obtained figures of power loss and apparent power, in particular, are in a complex relationship, depending on the type of material, the polarization value, the test frequency, the lamination thickness, and, for the SST method, the quality of the flux-closing yoke [1]. The problem bears special importance for grain-oriented (GO) Fe-Si grades, where the differences are larger. A previous investigation, performed by one metrological laboratory on a very large number of samples, led to an empirical power law for the relative difference of the 50 Hz power losses $\delta P_{SE} = (P_{SST} - P_{Eps})/ P_{Eps}$ versus the polarization value [2]. This was accounted for through an informative annex to the IEC 60404-3 standard. However, it was also recognized that significant statistical evaluation of the Epstein-SST relationship and its possible physical assessment could be achieved only through an international comparison exercise involving a suitably high number of metrological and industrial laboratories. A new IEC project was then started, where samples belonging to five different grades of GO laminations were circulated among ten different laboratories. In this communication we shall provide the main results and the statistical analysis of this comparison.

2. Methods and Results

Five different GO grades, with nominal thickness ranging between 0.23 mm and 0.30 mm, were tested by the participating laboratories according to the IEC 60404-2 and IEC 60404-3 standards. The power loss and the apparent power were measured at 20, 40, 50, 60, 80, 100 Hz for peak polarization values J = 1.3, 1.5, 1.7, and 1.8 T. Each laboratory was assumed to have appropriate traceability of measurements and was required to determine the measurement uncertainty according to the ISO/IEC Guide [3]. Fig. 1 shows the experimental relative standard deviation s_P of the laboratories reported values around the mean $<P_{Eps}>$ and $<P_{SST}>$ of the 50 Hz power

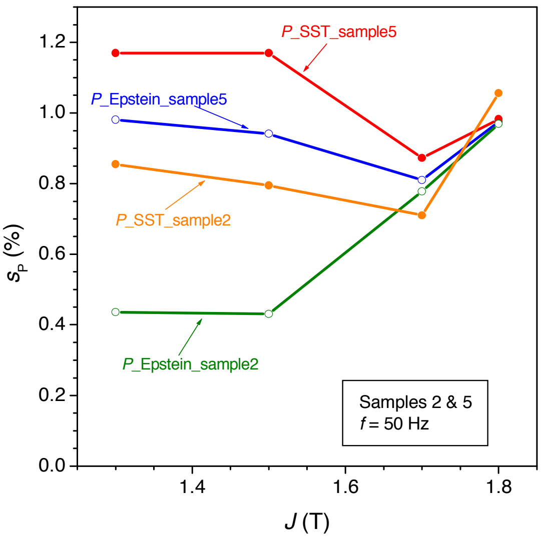

Fig. 1 - Experimental standard deviation s_P of the laboratory best estimates of the Epstein and SST 50 Hz power loss measurements (samples 2 and 5).

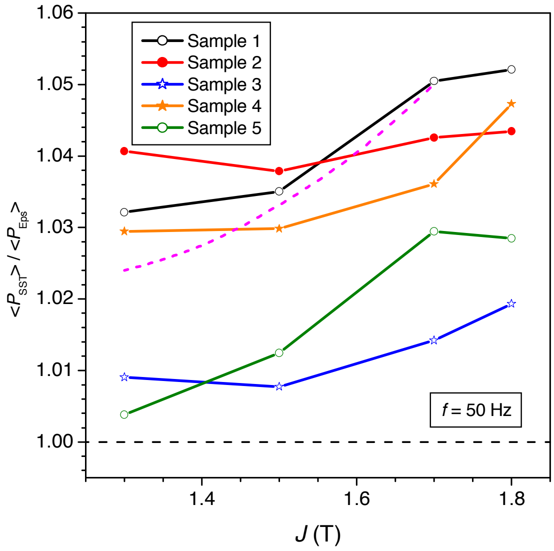

Fig. 2 - Ratio $<P_{SST}>/<P_{Eps}>$ of the mean values of the measured SST and Epstein 50 Hz power losses. The dashed line is the least square fit of previous literature results, used in the informative annex to IEC 60404-3) [2].

loss for two representative samples. These show the highest (sample 2) and the lowest (sample 5), loss figures, respectively. s_P is at most 1.2 % and it ranges, in particular, between 0.7 % and 0.9 % at J = 1.7 T. On the other hand, Fig. 2 shows that the ratio $<P_{SST}>/<P_{Eps}>$ is greater than 1 everywhere and increases with J. The conventional GO materials (samples 1, 2, 4) are observed to follow fairly well the average $<P_{SST}>/<P_{Eps}>$ trend (dashed line in Fig. 2) obtained in previous experiments and proposed in the informative annex to IEC 60404-3. A lower $<P_{SST}>/<P_{Eps}>$ ratio is instead exhibited at all J values by the high-grade samples 3 and 5. The experiments additionally show that $<P_{SST}>/<P_{Eps}>$ tends to decrease with the increase of the magnetizing frequency. Similar trends are observed in the behaviour of the apparent power and the related ratio $<S_{SST}>/<S_{Eps}>$, although on a significantly different scale. For one thing, the experimental standard deviation s_S is larger than s_P, especially for the SST measurements. The mean value $<S_{SST}>$ tends then to attain values from a few percent up to about 40% higher than $<S_{Eps}>$ on going from J = 1.3 T to J = 1.8 T. The reason for these large discrepancies is thought to reside in the inevitably different harmonic composition of the supply current signals ensuring sinusoidal secondary voltage in the two different magnetic circuits.

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