Failure-detection in Soft Magnetic Steel by MF Single Sheet Tester with Experimental Window

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A novel so called Multi-Frequency Single Sheet Tester allows for precise loss tests on electric steel or amorphous ribbon, on 50 cm long samples of 10 cm up to 17 cm width. It is superior to other testers, due to full physical consistency, for frequencies up to 10 kHz, for high induction, and synthetized magnetization. Here we report on optional "Scientific Window (SW)" that gives access for sensors in the precisely defined magnetized sample center. Arbitrarily designed sensors can be arranged, for magnetic, mechanic, thermal or optical quantities. This paper discusses the example of mechanical failures through micro-grooves, that yield decreases of permeability for low frequency.

Keywords: grain-oriented electrical steel, automatic testing, failure detection, micro-groove effects

1. Introduction

Recently, a so-called Multi-frequency Single Sheet Tester (MF-SST) was developed that allows for tests of energy loss and other parameters [1] in soft magnetic, crystalline or amorphous bands that are magnetized for frequency f up to 10 kHz. As it is well known, the materials tend to be highly sensitive to mechanical defects like plastic stress, cracks or cuts. Corresponding traditionally performed analyses tend to need high expenditure of time and apparatus. Here we report the application of an optional Experimental Window (EW) of the SST. It is given by a central, 2 cm long and e.g. 12 cm wide SST-region that allows direct access to the surface of the precisely magnetized sample, of 50 cm length and e.g. 15 cm width, respectively. Arbitrarily designed sensors can be mounted, e.g., for local detection of field (by H-coils), induction (needle contacts, field plates), loss (thermistors, thermo-couples), magnetostriction (strain sensors), or also domains (colloid frame, Kerr effect).

2. Experimental

To study consequences of mechanical failures, sample strips were prepared with defects in their 75 mm x 75 mm middle region. Defects were placed at the right sample half, while the left one remained unaffected (Fig.1).

As an example of this abstract, grain-oriented SiFe bands were treated by micro-grooves, as applied for domain refinement [2]. However, here, scribing was not performed in transverse direction, as yielding domain refinement. On the contrary, 8 short grooves of ca. 200 µm width were arranged in diagonal direction, as a regional failure, e.g., with respect to permeability μ.

The sample was magnetized for a frequency f = 50 Hz and 400 Hz, respectively, for induction values between 1.5 T and 1.8 T, as used for transformer cores. The percentage permeability decrease $\Delta\mu$ was determined via a small tangential H-coil of about 15 mm x 40 mm size, shifted along the window (the global H-coil having about 300 mm x 140 mm size). μ was related to RMS field and to peak field, respectively. Corresponding, (very weak) local variations of induction were neglected.

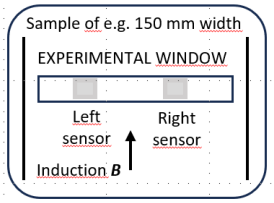

Figure 1. Schematic outline of experimental window, for the example of two sensors, for local comparison tests.

3. Results

As to be theoretically expected, all evaluated cases yielded negative changes $\Delta\mu$ of permeability, in particularly for the low f-value of 50 Hz due to low relevance of eddy currents. According to the corresponding Table 1, the decreases were more than 10%. Related to peak field, even stronger variations resulted, obviously due to sharp spikes of field intensity.

B (peak)	1,5 T	1.6 T	1.7 T	1.8 T
$\Delta\mu$ (RMS)	-12%	-15%	-12.6%	-9.5%
$\Delta\mu$ (peak)	-11.7%	-19%	-15%	-21%

Table 1. Local permeability decreases (for 50 Hz), as resulting from micro-grooves in the right sample half.

4. Conclusion

In clear ways, the results of this study demonstrate a high effectiveness of an „Experimental Window" in the SST center, for simple and rapid tests of various locally distributed failures, in thin soft magnetic bands. A significant advantage is given by the wide variability of magnetization frequency, as a source of versatile physical interpretation.

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