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Design and realisation of a test system for two-dimensional magnetic testing including temperature influence

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Keywords

Soft Magnetic Materials, Two-dimensional Testing, Temperature dependant Anisotropy

Abstract

I. Introduction

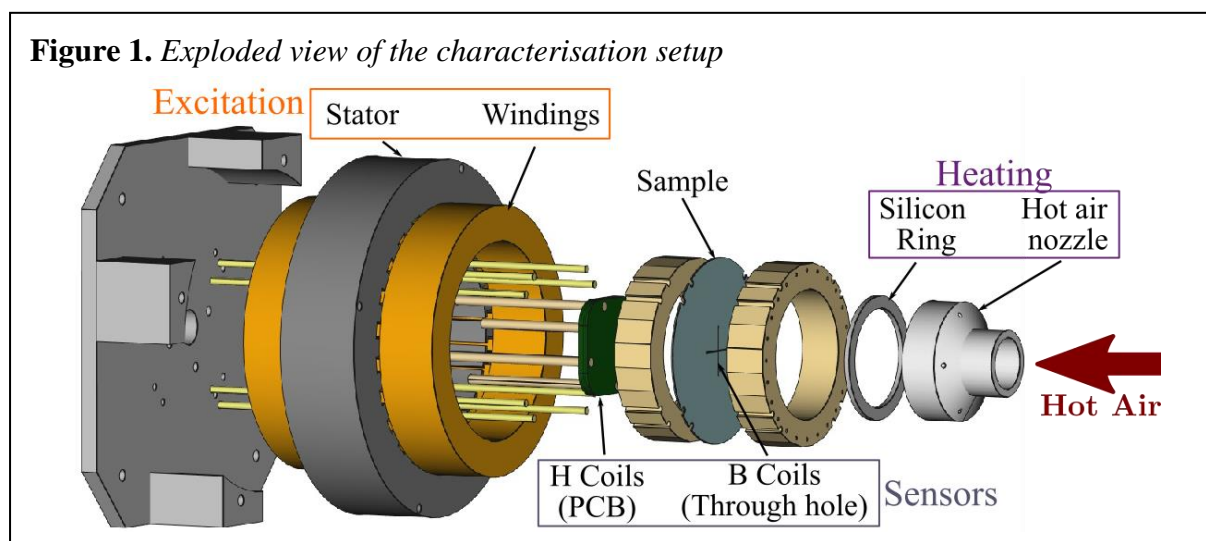
After several decades of experimentations in the field of two-dimensional magnetic measurements, very few studies have focused on the influence of temperature on magnetic anisotropy, despite well-known effects in unidirectional settings [1,2]. Moreover, characterisation of soft magnetic materials under rotating field and controlled temperature would provide meaningful data for stator core conception at different heating operating points. Nonetheless, the addition of a heating system to rotational sheet testers brings out new constraints, and requires some caution to forestall the effect of temperature, particularly those due to the thermal stability of the different elements. The choice of a local heating greatly lower the constraints, but it comes at the price of a diminished temperature homogeneity. To provide practical insight into these specific measurements, we present the design and realisation of an adequate test setup, shown in Figure 1, meeting the working range of Table 1.

Table 1. *Expected working range*

| Properties | Range | Focus |
|------------------|--------------------------|---------------------------------------|
| Sample thickness | 0.2 to 1 mm | -- |
| Temperature | Ambient to 200 °C | -- |
| Frequency | A few Hz to a few 100 Hz | Grid frequency |
| Induction level | 0.5 to 1.7 T | Usual operating point of the material |

II. Summary of the magnetic setup

The used rotational sheet tester was specially built for this study, based on literature examples [3-5]. The main design choices include the use of a two-phase stator for the magnetic field generation, and of B- and H-Coils as sensors. Depending on their proximity to the sample, the



components need to be able to support temperatures varying from 50 to 200 °C, a range that conditions the layout of the parts and the nature of the positioning elements. The desired flux waveform shape is achieved using an internally developed variation of iterative control [6]. Upon completion of the setup, the assessment of its good operation and performances includes geometrical misalignment measurements, some comparison to a unidirectional setup, a comparison with data from another laboratory, and the cartography of the field.

III. Heating system

The implementation of the heating system must not interfere with the magnetic measurements. Notably, this rules out direct resistive heating, induction heating, the use of magnetic and conductive elements, etc. To satisfy this constraint, we choose to bring heat to the sample by blowing hot air on its upper surface, through a nozzle. The main difficulty is to provide an air flux of sufficiently homogeneous temperature over the whole measurement area. Indeed, electrical sheet steel are so thin that a significant temperature gradient can easily develop across its size despite high thermal conductivity, especially given the highly heterogeneous environment of a rotational sheet tester. Thermal images of the opposite surface of the sample provided the necessary data to check this homogeneity and improve the nozzle.

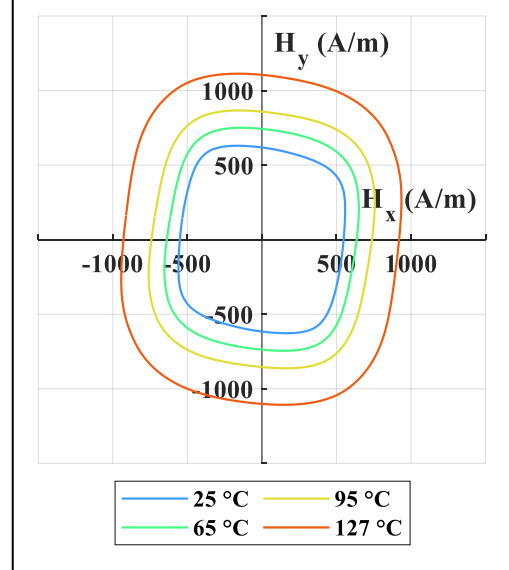
IV. Early results

An early series of measurements under circular flux density on a low-anisotropy iron-cobalt sample (see Figure 2) does not show significant changes in terms of directions of magnetization. On the other hand, the width of the $H_y = f(H_x)$ figures increases greatly, a phenomenon similar to the skewing of hysteresis cycles in unidirectional studies.

V. Perspectives

This work is an introduction to detailed studies of the behaviour of electrical steels under rotational excitation depending upon their temperature. With the setup completed and validated, a measurement campaign on several samples of industrial grades under a variety of test conditions will take place in the coming years. The focus of the study will encompass silicon-iron, nickel-iron and cobalt-iron, in frequency, induction level and temperature across the main operating points of these materials in industrial applications.

Figure 2. Recorded H loci for a subset of temperature, for a circular $B=1.5T$ (0.5 m thick FeCo sample)



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