Magnetic characterization of low permeability materials with a yoked-based measuring system

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In this investigation, a yoke-based measuring system is introduced to characterize the magnetic properties, including B-H characteristics and loss curves, of low permeability materials such as powders. The structure of the proposed system is discussed. Numerical simulations are performed to optimize the dimensions of the specimen, focusing on the homogeneity of averaged field quantities. Measuring coils are positioned around the sample to facilitate field quantity measurements. The measurement system is validated with powder samples, and a comparative analysis of their magnetic characterization is conducted through numerical simulations.

Keywords: loss curve; low permeability materials; magnetic characterization; optimization; yoked-based measuring system

1. Introduction

The characterization of magnetic properties of materials is crucial for designing electrical machines. Commonly utilized techniques include the Epstein frame tester, the single sheet tester, and the ring-shaped method. In another work, Petit et al. introduce a static sample magnetometer for characterizing ferrofluids and low permeability materials [1]. However, the determination of the local H-field is essential for the accurate magnetic characterization of the sample. This study proposes a yoke-based measuring system designed to evaluate the electromagnetic properties of low permeability materials. The goal is to measure the field densities in the sample up to 1.2 T at 2 kHz and 0.8T at 10 kHz. The target values correspond to the operating ranges of high-speed electric machines.

2. Methodology

The structure of the proposed measuring system consists of a laminated iron core with two movable yokes, as illustrated in Fig. 1 (left). A container filled with a low permeability sample is positioned between the faces of the adjustable yokes. An excitation coil is designed to generate an AC magnetic field. Two measuring coils are designed to measure the average local magnetic field $\overline{H}$ close to the surface of the sample and the average flux density $\overline{B}$ inside the sample. The values of $\overline{H}$ and $\overline{B}$ can be calculated from the induced voltage in the measuring coils.

Based on the numerical simulations, the dimensions of the sample are optimized to achieve the greatest possible homogeneity for the flux density B within the sample along two horizontal and radial directions (red and green lines, as depicted in Fig. 1 (right)). The sample's radius a, sample's length b, and air gap distance g are varied to identify the optimal parameter combination. The field homogeneity is quantified using:

$$\text{Homogeneity metric} = \frac{\max(B) - \min(B)}{\frac{\max(B) + \min(B)}{2}} \times 100\ \%$$

The metrics for both radial and horizontal directions across all combinations of simulation parameters are plotted in Fig. 2 (Left). The initial results reveal that low values of a correspond to high values of the metric in the horizontal direction and low values of the metric in the radial direction, and vice versa (Fig. 2 (Left)).

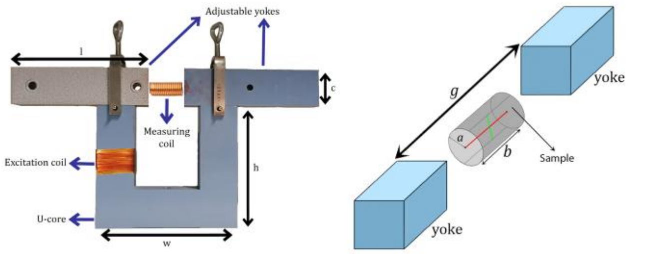

Figure 1: Left; the structure of the measuring system. Right; the sample (cylinder) positioned between two adjustable yokes. The green and red lines indicate the directions in which the flux density is calculated for the radial and horizontal orientations, respectively.

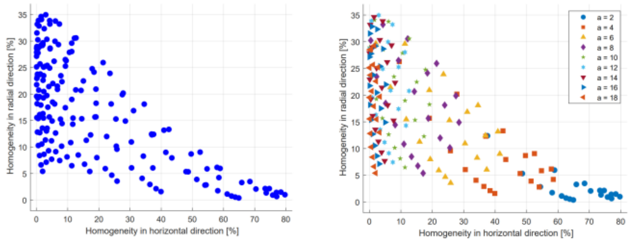

Figure 2: Left; homogeneity metrics in both radial and horizontal directions for all combinations of simulation parameters. Right; combinations with the same value of a are distinguished by color.

3. Outlook on results

The conference final paper will revolve around the design, construction, and optimization process of a measurement system for characterizing low permeability materials, such as powders. The measurement results obtained with the system regarding magnetic characterization, such as B-H characteristics and loss curves of the powders, will be validated using numerical simulations.

References

[1] Petit, Mickaël, et al. "Static sample magnetometer: a new characterization method for low permeability materials and ferrofluids." *IEEE transactions on magnetics* 50.4 (2014).

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