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Influence of geometrical dimensions of a vertical rotational single sheet tester on its performances

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View Abstract

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TITLE: Influence of geometrical dimensions of a vertical rotational single sheet tester on its performances

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ABSTRACT BODY:

Digest Body: Nowadays, the use of computer simulation is common when designing an electrical machine. Whatever simulation method is involved (analytical equations system, finite element method, lumped parameter equivalent circuit, etc. . .) the Achilles heel of such computations lies in the behavioural model that is used to represent the constitutive equations and in particular the relation between the magnetic field H and the magnetic flux density B . In fact, in order to develop an accurate behavioural model of electrical steel in terms of magnetic properties that accounts for rotational magnetization and/or anisotropy, it has to be built on relevant measurements made with a two-dimensional characterization device [1]. In this way, it is possible to access both H and B as vectors and hence to quantify the spatial phase shift between them for different magnetizing directions.

For this reason, the two standardized devices – the Epstein frame and the Single Sheet Tester (SST) – are not suitable for that kind of measurements. Indeed, in both cases, only the scalar values of H and B can be measured [2]. Moreover, such approach to a characterization of anisotropic magnetizing properties requires a large amount of test samples cut at different angles with respect to the rolling direction of the electrical steel sheet [3]. Lastly, in the case of the Epstein frame, H and B are assumed to be colinear, which might not be the case in presence of anisotropy [4]. Several two-dimensional characterization devices have then been proposed in the literature, each one having its pros and cons [5]. The horizontal Rotational Single Sheet Tester (RSST) [6] suffers from two main issues: the small size of the test sample, which limits the representativity of the measurement results in case of grain oriented electrical steel sheet with large grains, and the flux leakage between the adjacent salient poles and the non-homogeneity of the magnetic field inside the test sample. Another approach, allowing to partially overcome this drawback, consists in considering a topology similar to a conventional three-phase induction machine [7], the rotor being simply replaced by a round-shape test sample. A variant of this topology consists in magnetizing the same kind of round-shape test sample by a system of electromagnets working as a Halbach array of magnets [7]. Nevertheless, in both cases the homogeneity of the magnetic field in the test sample remains an issue. The vertical RSST [3,8], as for it, derives from the standard SST. It is made of one or two pairs of C-shape yokes, the poles of which are positioned on the surface of the test sample, nearby its edges, and shifted from each other by an angle of 90° (Fig. 1). According to the literature, the advantages of this setup are its cost, its ease of implementation and a good homogeneity of the fields in the middle of the test sample [5]. It has to be noted that each publication brings its own setup in terms of number and dimensions of the yokes as well as on dimensions of sensors. To the author's knowledge, almost no quantitative study of the influence of those parameters in the homogeneity of the field seen by the sensors has been published except in [8]. This is the aim of this communication. The study is performed by means of finite element analysis.

As previously mentioned, the studied vertical RSST is presented in Fig. 1. The test sample is square with side length and thickness denoted L_s and T_s respectively. W_y , H_y and T_y are the width, the height and thickness of the yokes. W_{yl} is the width of the yoke leg. A coil is wound around the top of each yoke, such that it is possible to magnetize the test sample under either pulsating or rotating conditions. The finite element model allows to take into account the non linear behavior of the sample material through its first magnetization curve. Note that for this study the material constituting the test sample is isotropic.

Due to the digest size limitation, only the influence of the size of the leg section – $W_{yl} \times T_y$ – is addressed. The other parameters previously defined are set as follows: $L_s = 300$ mm, $T_s = 0.35$ mm, $W_y = 290$ mm and $H_y =$

233 mm. Two yoke cross sections $W_{y1} \times T_y$ configurations are studied here: $52 \times 52 \text{ mm}^2$ and $20 \times 200 \text{ mm}^2$. Moreover, a pulsating magnetization with a spatial phase of 45° with respect to both the x-axis and z-axis (Fig. 1) is applied to the test sample by supplying the windings with currents such that $i_{yk} = I_{yk} = \sin[2\pi f t + (k - 1)\pi/2 + \pi/4]$, where f is the excitation frequency and $k \in [1; 2]$. A square area with a side length of 50 mm located in the center of the test sample is defined (Fig. 1). It represents the area that would be seen by a magnetic field sensor (H-coil). In Fig. 2, all the couples (B,H) seen by that simulated sensor for different values of I_{yk} are presented in red marks. The green mark represents the couple of mean value ($\langle H \rangle$, $\langle B \rangle$) that would be given by the real sensors. Finally, the black mark represents the couple (H,B) at the center of the test sample. Fig. 2 shows that the configuration $20 \times 200 \text{ mm}^2$ leads to better field homogeneity, especially for low magnetic field values.

In the extended paper, various configurations will be discussed. Moreover the influence of other parameters will also be studied, such as the size of the square zone seen by the sensor in the center of the test sample. The influence of drilled holes in the test sample, which are necessary to place a magnetic flux density sensor (B-coil) will also be addressed.

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KEYWORDS: Magnetic measurements, Electrical steel, Rotational magnetization, RSST.

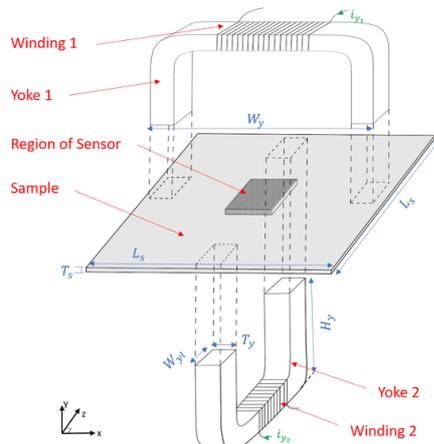


Fig. 1 Studied vertical RSST

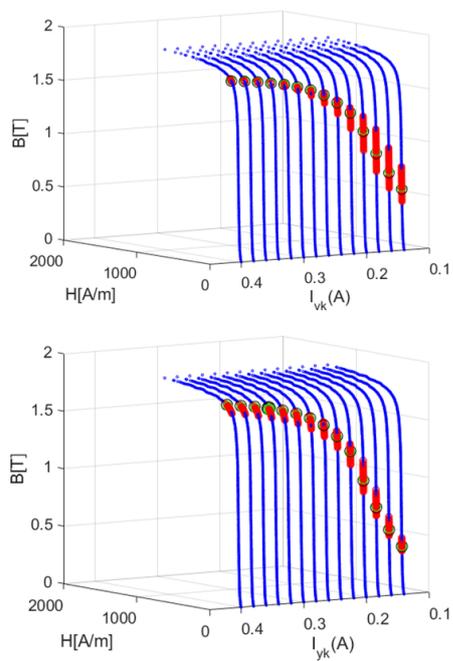


Fig. 2 Distribution of H and B

IMAGE CAPTION:

Fig. 1 Studied vertical RSST

Fig. 2 Distribution of H and B

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