Influence of the geometric parameters of a vertical rotational single sheet tester on sample field homogeneity

Guilherme Costa Ayres Tolentino, Guillaume Parent, Olivier Ninet, M Rossi, Jean Vianei Leite, Jonathan Blaszkowski

INFLUENCE OF THE GEOMETRIC PARAMETERS OF A VERTICAL ROTATIONAL SINGLE SHEET TESTER ON SAMPLE FIELD HOMOGENEITY

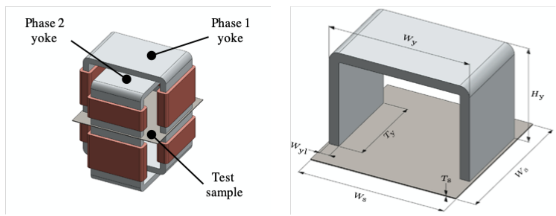
Guilherme C. A. Tolentino*, Guillaume Parent*, Olivier Ninet*,
Mathieu Rossi*, Jean V. Leite† and Jonathan Blaszkowski‡

*Univ. Artois, UR 4025, Laboratoire Systèmes Électrotechniques et Environment (LSEE), F-62400, Béthune, France
†Universidade Federal de Santa Catarina, GRUCAD, Florianópolis, Santa Catarina, CEP: 88040-970, Brasil
‡Thyssenkrupp Electrical Steel, F-62330 Isbergues, France

***Abstract*—The horizontal Rotational Single Sheet Tester (RSST) suffers from weaknesses such as the reduced size of test samples, measurement disturbances due to magnetic flux leakage and non-homogeneity of field in the measurement area. Although the vertical RSST allows to overcome the first two aforementioned drawbacks, the heterogeneity of the field in the test sample remains an issue. Additionally, there is still a lack of device standardization to ensure test repeatability, as already is well established with the Epstein frame. In this paper, a finite element model of this device is developed in order to investigate the influence of several parameters on the field homogeneity in the test sample, such as the geometrical dimensions of the yokes and the presence of holes drilled for B-coil placement. It is expected that this study will contribute to the optimization and standardization these devices.**

I. INTRODUCTION

The vertical RSST has been introduced in the early 90s [1] but is still under consideration in recent publications [2]–[4]. According to the literature, the advantages of this setup compared to the horizontal RSSTintroduced in the 80s are numerous [5]. Firstly, its ease of implementation due to similarities to the standardized Single Sheet Tester (SST). Secondly, a better homogeneity of both magnetic field **H** and magnetic flux density **B** at the center of the test sample is expected [6]. Thirdly, higher flux density levels can be reached in the test sample than with the horizontal SST [2]. It has to be noted that each publication related to that device brings its own setup in terms of numbers and dimensions of the yokes as well as on dimensions of the sensors [7], [8], denoting the lack of standardization of structure and measurement system. Nevertheless, the trend emerging from all those publications is that the larger the width of the yokes the better. Indeed, in [9] the authors evaluate the accuracy of miniature SSTs dedicated to the characterization of small size test samples and highlight that the difference with the results obtained using an Epstein frame can be up to 5 %. The same trend is highlighted on vertical RSSTs in [7], [8]. Moreover, large yokes allow to "eliminate the influence of the demagnetizing field" [10], leading to a better characterization of large test samples [1]. However, the standard relative to the regular SST allows the use of yokes of any size "as long as the relevance of the results is ensured" [11]. To the authors' knowledge, almost no quantitative study of the influence of those parameters on the field homogeneity in the measurement area has been published except in [7], [8] in which the focus is made on the deflection of the mean value at the center of the test sample only. Above all, in all of the aforementioned studies, no link is made between the field non-homogeneity in the test sample and the actual field values that would be measured with actual sensors, which is after all the key point when characterizing a material. In particular, none of those works takes into account that the sensors employed to evaluate **H** and **B** are not of the same dimensions nor do they account for the fact that the more often **B** is evaluated by means of a coil requiring to drill the test sample. Yet, there is no doubt those holes have a great influence on field homogeneity.



(a) Topology of the studied vertical RSST

(b) Dimensions of the test sample and a half of a yoke

Fig. 1. Studied vertical RSST

II. TOPOLOGY OF THE STUDIED VERTICAL RSST AND FINITE ELEMENT MODEL

An overview of the topology of the studied vertical RSST is presented in Fig. 1a. It is composed of two magnetic yokes, i.e. one per phase. Each yoke consists of two C-shape cores (see Fig. 1b) arranged along each side of the test sample. Due to geometrical constraints and for the sake of magnetic balance between the two yokes, the two cores share every dimensions W_{yl}, W_{y} and T_{y} but the height H_{y}. The test sample is square with side and thickness denoted W_{s} and T_{s} respectively. All dimensions are summarized in table I.

The finite element simulations are conducted using the softwares GMSH and GetDP. The model is fully 3D and the problem is solved by means of the magnetostatic scalar potential formulation. Moreover, the nonlinear behavior of the test sample is taken into account by means of its first magnetization curve.

III. SOME RESULTS

In the following, the test sample is made of M260 electrical steel whose first magnetization curve is presented in Fig. 2. Moreover, for the sake of relevance of the analysis, only the worst case in terms of field homogeneity in the test sample,

TABLE I
DIMENSIONS OF THE VERTICAL RSST

Name	Value
W_s	300 mm
T_s	0.35 mm
W_{yl}	20 mm
W_y	290 mm
H_y	150 mm (Small core) or 200 mm (Tall core)
T_y	Varies between 75 mm and 200 mm

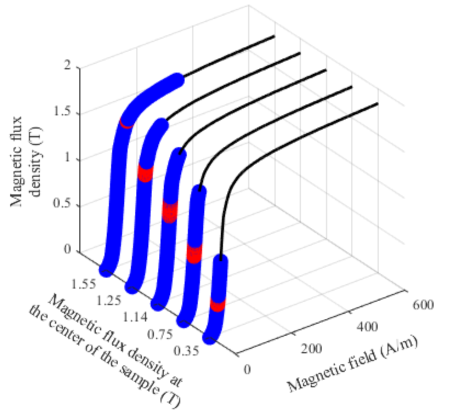


Fig. 2. Distribution of **H** and **B** inside different areas of the test sample.

that is the case in which the latter is magnetically excited along its diagonal, is considered and presented.

A. Field homogeneity inside the test sample

Fig. 2 shows the values of both **H** and **B** occurring in different areas of the test sample for different levels of magnetization and with $T_y = 200\,\mathrm{mm}$. The first magnetization curve of M260 steel is also shown for information purpose. It can immediately be noted on this figure that both **H** and **B** inside the whole test sample, shown in blue, are widely heterogeneous due its large size. One might consider that this is not so much an issue since an actual sensor would only cover a small area of the test sample. Indeed, the red marks in Fig. 2 show the values of **H** and **B** occurring in a square area with a size of 50 mm located at the center of the latter. It clearly highlights that even inside a limited are the heterogeneity is still noticeable. Moreover, the mean values of **H** and **B**, which correspond to the values that would be given by an actual sensor, do not match the ones at the center of the test sample.

B. Influence of the core length T_y

The values of **H** and **B** inside a square area with a size of 50 mm located at the center of the test sample with respect to T_y are represented as box and whisker plots in Fig. 3. T_y varies from 75 mm to 200 mm in increments of 25 mm and the magnetization level is such that $\|\mathbf{B}\| = 0.75\,\mathrm{T}$ at the center of the test sample. The first thing that can be notice in this figure is that outliers are always present whatever the value of T_y. There is no doubt those outliers have an influence on the value given by actual sensors. The second thing is that the homogeneity of both **H** and **B** increases with T_y. Nevertheless, Fig. 3 also highlights that as soon as T_y is superior to half the width of the test sample the results are much the same.

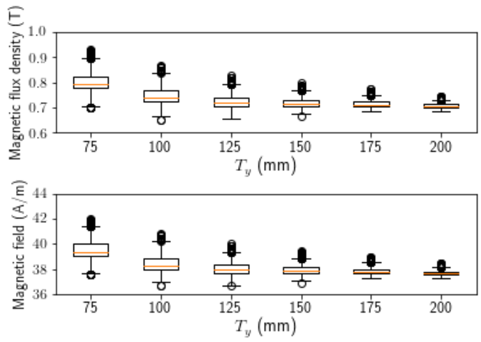


Fig. 3. Evolution of the values of **H** and **B** inside a square area of size of 50 mm located at the center of the test sample with respect to T_y. $\|\mathbf{B}\| = 0.75\,\mathrm{T}$ at the center of the test sample.

IV. CONCLUSION AND OUTLOOKS

The accuracy of the results given by a vertical RSST largely depends on its dimensions as well as on the dimensions of the sensors used for the measurements. In the final paper, the study of the field homogeneity inside limited areas presented in Section III-A will be extended to different size and shape for the sake of comprehensiveness and relevance with respect to actual sensors. As an example, an H-coil is usually square but a B-coil is not. Moreover, the study of the influence of T_y will also be extended to different magnetization levels. It will be shown that the higher T_y the better the accuracy of the measurement has to be weighted to the magnetization level as well as the size of the sensors. Finally, the influence of drilled wholes, which are required to place a B-coil in the test sample, will also be addressed.

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