# Core Tester Iron Losses Segregation by Finite Element Modeling

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**Abstract — A new designed core tester and its feeding and control devices are presented in this paper. With this workbench, mounted single phase induction motor stators can be magnetically fed with controlled induction levels in order to evaluate their quality in the industrial environment. As the measured data involves the machine stator as well as the core of the testing apparatus, Finite Element and iron losses modeling are employed in this paper in order to distinguish the losses of the rotor under test and the losses of measurement device itself. Therefore, the main goals of this paper are to propose a new tester design as well as the way allowing the separation of the losses in the stator under test and the losses inherent to the tester itself.**

## I. INTRODUCTION

Iron losses in electrical machines can vary for several reasons. Among them, differences in iron sheet characteristics between two different batches, aging of punching tools and assembling yield different performances for the same motor design. For this reason, quality tests are required, at least in statistical manner, to investigate the motor losses and to control the quality of the device.

In order to evaluate the losses in assembled (but not yet winded) stators of single phase induction motors, an experimental device was designed. It is composed by a laminated low loss magnetic core with two identical 90 electrical degrees shifted primary windings shown in Fig. 1. Notice that such windings do not belong to the motor but they are part of the tester. They are fed by two independently controlled electrical sources and are placed in the external part of the slots. Two 90 degrees shifted secondary windings are also placed in the inner part of the same core tester. These windings are not fed but their voltage waveform can be controlled.

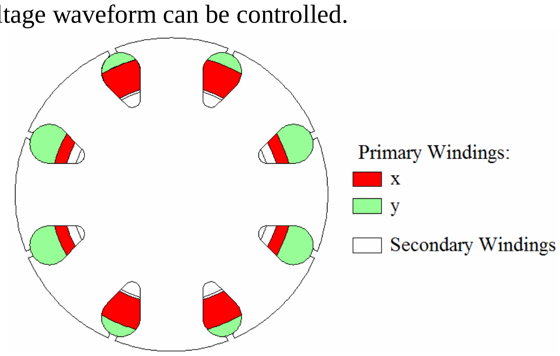


Fig. 1. Core tester geometry and windings.

The stator under test is embedded externally to the core tester as shown in Fig. 2. Alternating and rotating magnetic fields can be imposed to the device. The total measured losses $w_m$ are evaluated from the primary currents $i_x, i_y$ and the secondary windings voltages $v_x, v_y$ integrated over an acquisition period $T$ as follows

$$w_m = \frac{1}{T}\int_0^T \left(v_x i_x + v_y i_y\right) dt \tag{1}$$

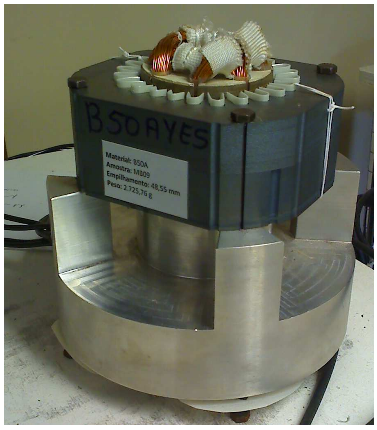

Fig. 2. Core tester and embedded stator.

When calculating the losses by the measured currents and voltages, the stator and the core tester losses are included on the same result of Eq. (1). It is virtually impossible to distinguish the stator core losses from the tester losses. Therefore Finite Element simulations are here used. With such calculations the losses in these two different parts can be evaluated by a relatively simple and precise post processor methodology.

## II. LOSSES EVALUATION

From time stepping voltage fed 2D Finite Element simulations, $B_r$ and $B_t$, the radial and tangential magnetic induction components in each element, are stored for an electrical period. The total calculated losses $w_t$ are obtained by adding $w_h, w_f, w_e$, respectively, the hysteresis, eddy currents and anomalous losses components. The hysteresis losses are evaluated after the decomposition of the induction waveform in $N$ harmonics as given by (2)

$$w_h = \sum_{k=1}^{N}\left[1 + R_{bk}\left(r_{hk} - 1\right)\right] w_{hk}^{a} \tag{2}$$

where $R_{bk}$ and $r_{hk}$ depend on the alternating or rotating behavior of the induction loci [1], [2]. The alternating hysteresis losses $w_{hk}^{a}$ are calculated at each harmonic frequency $kf$ using Steinmetz equation considering dc-biased induction values $B_{dc}$ [3], [4]:

$$w_{hk}^{a} = C_h B_{k\max}^{\alpha} kf \left[ 1 + 0.65 B_{dc}^{2.1} \right] \quad (3)$$

The other losses components are obtained from the induction vector radial and tangential components using (4) and (5).

$$w_f = C_f \frac{1}{T} \int_0^T \left( \frac{\partial \mathbf{B}}{\partial t} \right)^2 dt = C_f \frac{1}{T} \int_0^T \left[ \left( \frac{\partial B_r}{\partial t} \right)^2 + \left( \frac{\partial B_t}{\partial t} \right)^2 \right] dt \quad (4)$$

$$w_e = C_e \frac{1}{T} \int_0^T \left| \frac{\partial \mathbf{B}}{\partial t} \right|^{1.5} dt = C_e \frac{1}{T} \int_0^T \left[ \left( \frac{\partial B_r}{\partial t} \right)^2 + \left( \frac{\partial B_t}{\partial t} \right)^2 \right]^{\frac{3}{4}} dt \quad (5)$$

Material characterization were made for obtaining parameters $\alpha$, $C_h, C_f$ and $C_e$.

## III. RESULTS

Figure 3 shows the FE 2D study domain of the core tester with the stator as well as a field distribution for a calculation time.

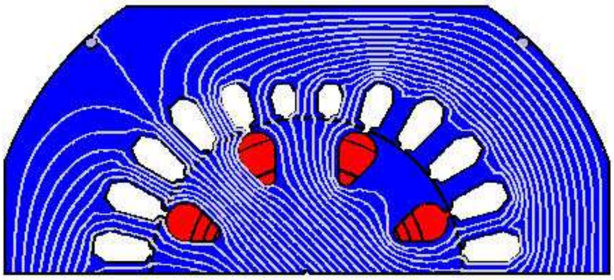

Fig. 3. FE study domain and field distribution.

The calculated and measured currents in the primary windings for two different operation conditions are shown in Fig. 4 and 5. For Ipx1 and Ipy1 the device operates at strong magnetic saturation level while for Ipx2 and Ipy2 the structure is globally linear.

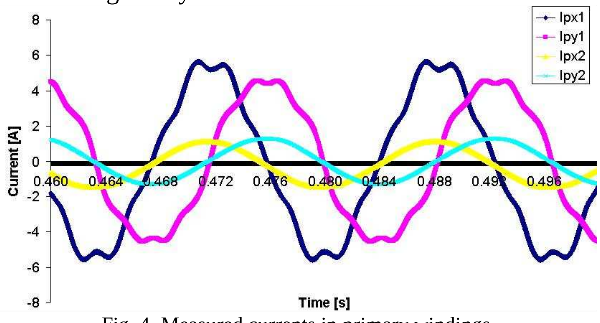


Fig. 4. Measured currents in primary windings.

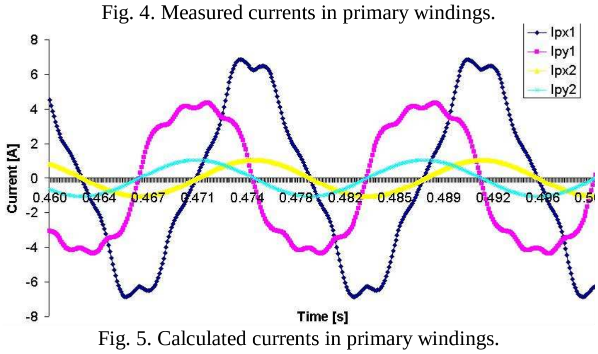


Fig. 5. Calculated currents in primary windings.

The calculated and measured total losses in the core tester and stator are presented in Fig. 6. As the motor is a commercial device, these results are given in terms of the normalized total losses as a function of the peak current.

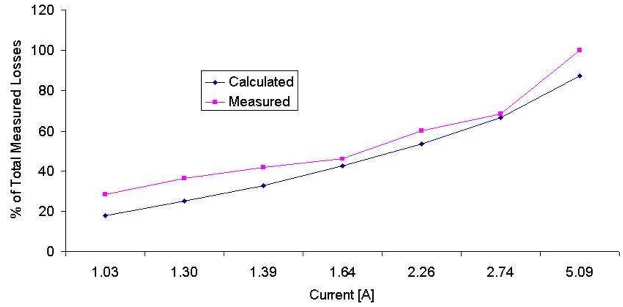


Fig. 6. Calculated and Measured total losses.

Figure 7 shows the distribution of the calculated losses between the core tester and the stator. From these results one observes that the distribution remains the same and that the core tester losses are always close to 20% of the total losses. It is an interesting result since it allows depicting the influence of the tester on the global measurements.

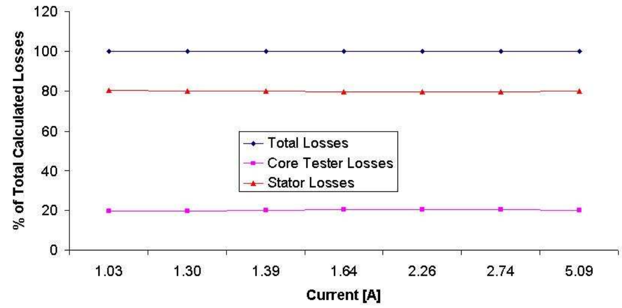


Fig. 7. Distribution of the losses between core tester and stator.

## IV. CONCLUSION

A newly designed apparatus for losses evaluation on mounted stators is presented in this work. As it is virtually impossible to separate, by experimental procedures, the losses in the core tester from those of the stator, a FE calculation methodology is employed. From simulations it is verified that the losses in the core tester represent about 20% of the total losses, regardless of the current (or magnetic induction) levels.

## V. REFERENCES


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