International Conference on Renewable Energies and Power Quality (ICREPQ'16)
Madrid (Spain), 4th to 6th May, 2016
Renewable Energy and Power Quality Journal (RE&PQJ)
ISSN 2172-038 X, No.14 May 2016

Methodology for Electrical Special Machines Project Optimization

Neto, J. M.[1-2], Schaeffer, L.[2], Dias M. M.[3] Spacek, A. D.[1-2],, Ando Junior, O. H.[2].

[1] Departament of Mechanic and Automation
SATC, Beneficent Association of Santa Catarina Coal Industry
Street Pascoal Meller, 73. Criciúma-SC (Brazil)
Phone/Fax number: +55 48 3431-75.50, e-mail: anderson.spacek@satc.edu.br, joao.neto@satc.edu.br,

[2] School of Engineering
UFRGS, Federal University of Rio Grande do Sul
Av. Osvaldo Aranha, 103. Porto Alegre-RS (Brazil)
Phone/Fax number: +55 51 3308-31.29

[3]Institute of Exact Sciences and Technology,
Universidade Feevale,
Novo Hamburgo – RS – Brazil
Phone/Fax number: +55 51 35868800 Fax: – e-mail: moisesdias@feevale.br

Abstract

The present study lies in the evaluation of a so-called scale model methodology to validate different aspects of the core topology of phase planar actuator, which has a movement on the plane with two degrees of freedom from a single device traction being formed by a carriage, called primary, composed of two independent three-phase windings and a stator also called secondary, formed by a flat aluminum plate mounted on a ferromagnetic core also plane, enclosing the primary drive area. Thus, the work focuses on the analysis of experimental and numerical modeling of electromagnetic phenomena involved with employing a core reduced as the complete core validation methodology. In order to measure their performance is evaluated by force propelling the two models cores.

.

Keywords

Planar actuator, planar movement, planar traction force

1. Introduction

Recently, the development of special electric machines projects become desirable in several industrial segments. Among these projects the induction planar actuator phase (IPA) highlights from the other ones. Since the use of this design project allows eliminate the mechanical components, usually employed in the displacement based on Cartesian coordinates [1, 2].

In the process of designing electrical machines of special use, it is important to estimate in the project components and electrical losses. However, estimating the core loss becomes difficult due to its complexity [3]. The use of new magnetic materials used in the core, contributes in a direct way in performance and efficiency of such electrical devices. Thus, the materials used in core's manufacture should direct and maximize the magnetic field and, consequently, results in better conversion of electrical energy into kinetic energy [4].

However, an inhibitor to greater industrial integration of these electric machines is due primarily to its low performance, and prototypes manufacturing complexity for experimental validations.

To contribute with development of special planar electrical machines it is presented a methodology to validate the performance of the IPA proposed by [5], with simultaneous bi-directional displacement (see fig. 1), from the construction of the reduced model. Then, the relevant factors are evaluated as planar thrust. So the project will be validated before a costly proposal to build of the complete machine with magnetic composites.

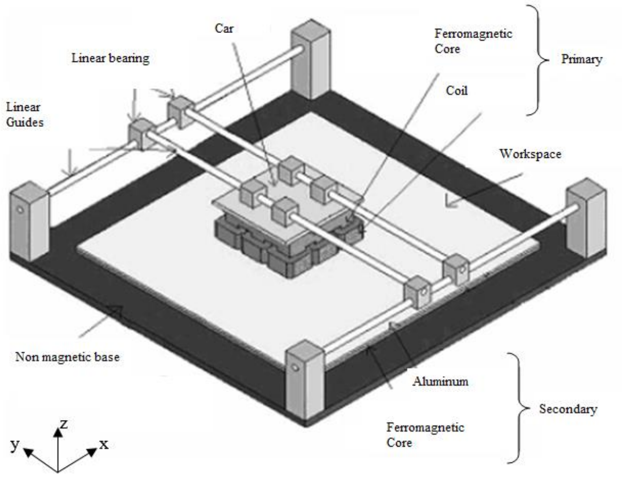

Figure 1: View of the planar actuator Induction and yours parts [5]

By way of methodology of validation called reduced model, are presented the results of comparative analysis of an IPA project, developed by [5], through purely numerical method with the numerical and experimental methodology proposed, using as a comparison parameter the planar thrust [6,7,8].

2. Proposed Methodology

In order to attenuate the engineering costs related to preparation of the special electrical machine's design and consequently reduce the search time and technical expenditures used in the assembly of relatively complex cores, it proposes a method called reduced model. In this case, being applied to the IPA with simultaneous bi-directional displacement.

This reduced model comprises a core composed of one third of the full core. Thus, it aims to significantly simplify the manufacturing process. As the validation of the electric engine performance with emphasis on planar thrust. The Fig. 2 shows the complete core architectures (Fig. 2a) with the reduced model (Fig. 2b).

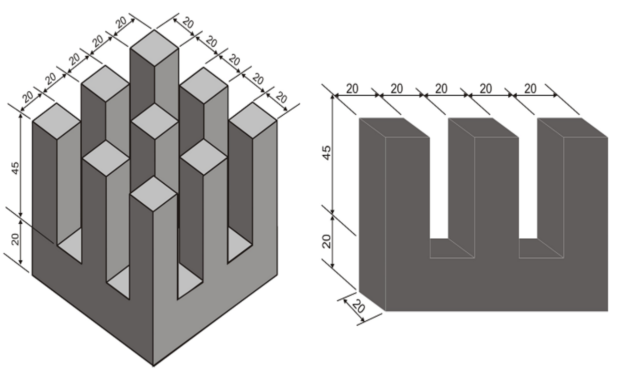

Figure 2: Perspective drawing of the core architecture: (a) full core; (b) Reduced model [8]

The method of the reduced model and complete model differ in the aspect of the number of the windings and electrical connections used in the full and reduced cores. So the IPA built with the original core is composed of 9 winding to perform the movements in the X and Y axes respectively. However, the reduced model is composed of 3 windings, responsible for movement in one axis, due to their design to minimize costs to complete validation.

In this conception, there is a reduction of inputs involved in the possible formulations of SMCs, which have better electrical characteristics to achieve gains in IPA performance. Thus, it becomes possible to experimentally simulate and validate the API's core, contemplating the proposed changes with less onerosity and greater flexibility in achieving the validation of results and comparison between composites [7,8]

2.1 Composite materials employed in cores

The 1P Somaloy 500 produced by the Swedish company Höganäs is a ferromagnetic composite material magnetically soft, which applies to frequencies in the range of 5Hz to 400Hz, due to its low total magnetic losses in this range.

The 1P Somaloy 500 appears as magnetically soft composite (SMC) isolated oriented grain. In the basic preparation of this composite is employed iron in high purity level [9]. The powder particles are bonded by a binding material which imparts to the material characteristics of electrical insulation.

In operation at lower frequencies bands, their advantageous properties are: electrical, magnetic and thermal isotropy, low eddy current, high magnetic permeability, reduction in size and weight, low coercivity, high Curie temperature. This magnetic isotropy allows to establish a magnetic field distribution of the volume, with independent permeability and resistivity of the direction and way of the field, keep performing well because of other characteristics [6, 10].

The magnetization curves, analysis of key data in the magnetic material properties that relate to magnetic flux density, B, in magnetic field, H, are important for defining the operating point of the material, the saturation value of the material and magnetic permeability.

Figure 3 shows the data of the material under discussion. The compressions that generated three different specific weights are: 400MPa, 600MPa and 800 MPa, and that increased pressure results in higher density.

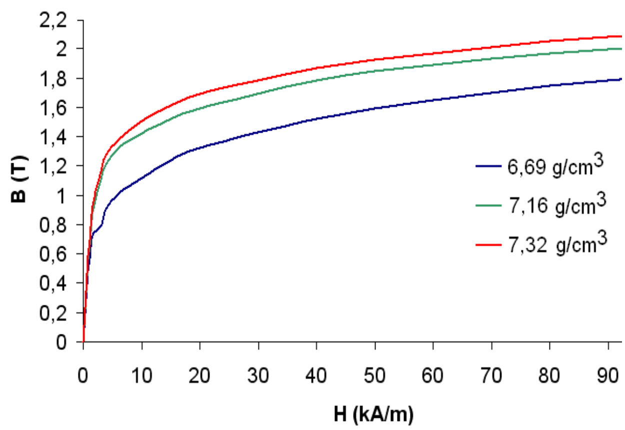

Figure 3. Magnetization curve of Somaloy 500 + 0,5% kenolube with thermal treatment at 500ºC for 30 minutes in the air, in the density[11]

2.2 Cores parameters simulation

This section presents the procedure for comparative validation between the dynamics of numerical models of the reduced and full core. It is therefore emphasized the region encompassing the car (primary), the air gap and armor. Thus, it is analyzed in induction planar actuator the planar pushing force according to the three-phase voltage applied to the electric coils.

The input parameters to the API set is composed of a primer made of a single block, with electrical isolation between it and the coils .The three windings are made of copper wire 22 AWG, with 460 whorls and allocated on a winding for a dent. The windings are fed with balanced three-phase sinusoidal alternating current and lagged 120º to each other. The secondary is formed by a plate of AISI 1020 steel 8mm thick, overlaid with another aluminum plate with thickness of 1mm.

The figure 4 and 5 illustrate the reduced and full cores inserted into MAXWELL V 13's software respectively.

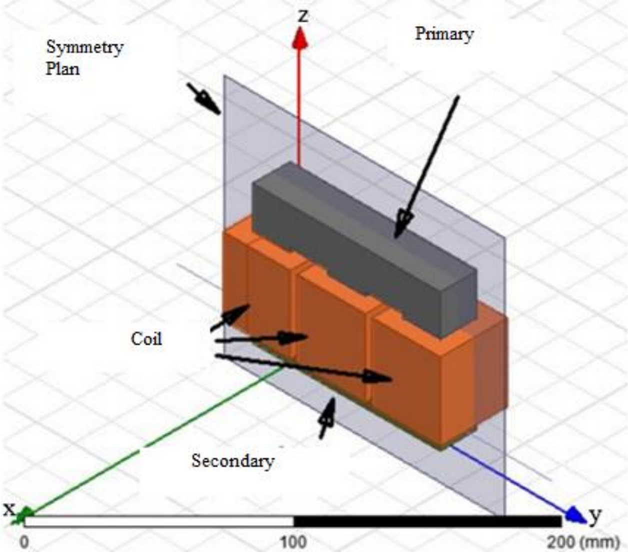

Figure 4: Reduced core model in the projection plane of symmetry.

The simulated model was executed by planar mode, with a depth of 20mm. The mesh was automatically generated with the establishment of 17,015 elements, containing 8646 knots.

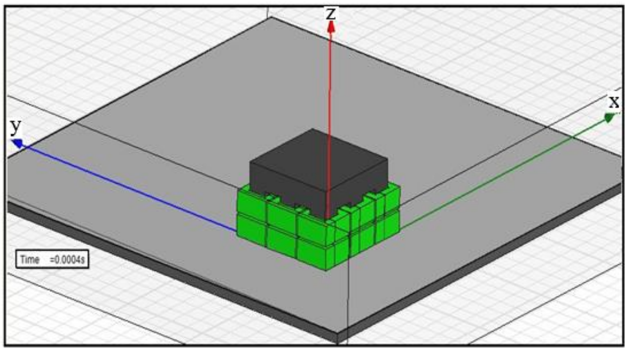

Figure 5: Full Model Implemented in MAXWELL V13.

2.3 Experimental Validation

To perform the experimental test properly, a mechanical structure was constructed and an instrumentation system to perform validation of the results obtained by modeling related to operation of the IPA, regardless of the adopted core architecture. The figure 6 shows the final assembly of the prototype, including the load cell and the data acquisition board.

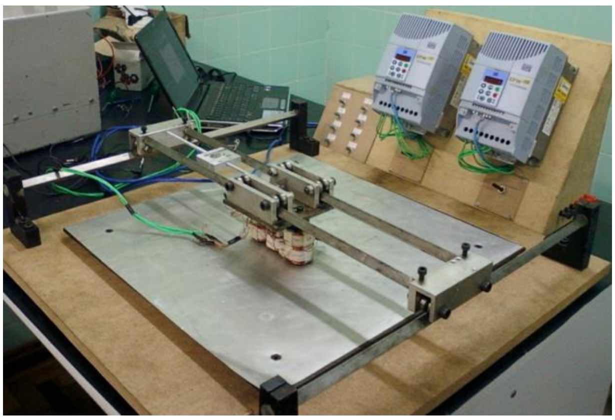
Figure 6 - Overview of the prototype built for the test of the Induction Planar Actuator

This structure allows to monitor several variables along the process. Among the variables can be highlighted the voltage and frequency supplied to the winding, just like current consumption and the strength of planar propulsion for the same.

3. Discuss of results

The tests developed with the planar actuator induction aim to characterize the device and its operating properties with the two core models for comparison of the same. Thus, it allows to compare functioning and force planar of propulsion of the electric machine with two core models (reduced and complete), contributing to validate the methodology of the reduced model for the analysis of special electric machines proposed in this study.

The analysis of reduced core planar propulsive force is structured based on two procedures. The first step refers to the total validation of the computational model of the reduced core with the comparison of data from real tests with reduced physical prototype.

For complete the validation of the numerical model, set to three-phase supply voltage range of 25V to 130V will increment 15V, applied to the windings respect to the axis of displacement X. It can be seen in Figure 7 the values of the magnitude of the force to the core reduced under those conditions obtained by means of simulations and by measurements through a S-type load cell of the reduced core.

The comparative results of the reduced core in computational and experimental scope not converged in absolute values. However, the values are less than 12% difference. Therefore, this error does not compromise the results, since the computer model does not consider some harmonic interference and core heating. Is observed a higher difference between the results from the 100V level, a fact justifiable by an increase in *Foucault* current.

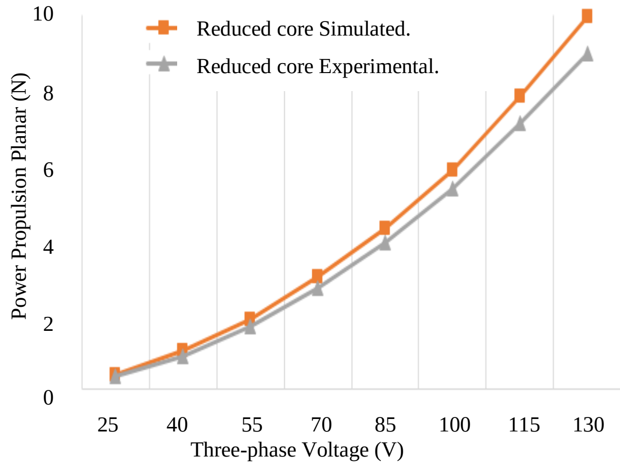

Figure 7: planar thrust graph of the simulated and experimental reduced core manufactured with 1P Somaloy

Another indirect point observed for the reduced model validation methodology refers to the electric current consumed by the winding. The results obtained with respect to the consumption of electric current in the computational and experimental with ammeter showed reduced core have good linearity (see fig. 8).

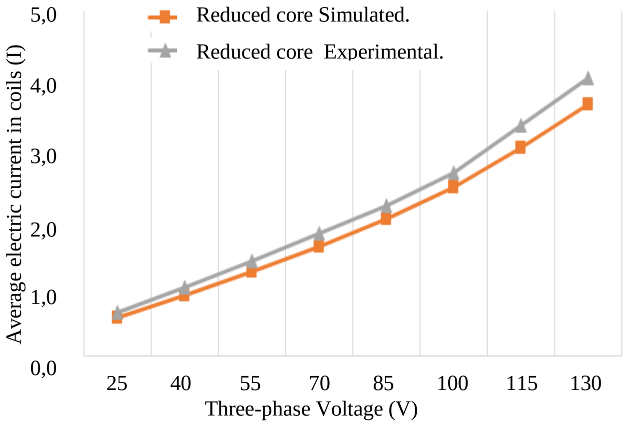

Figure 8: Average Graph of electric current consumed by the simulated and experimental reduced core manufactured with 1P Somaloy 500

The figure 9 shows the computational models of the reduced and complete core. Linearity is observed between the results.

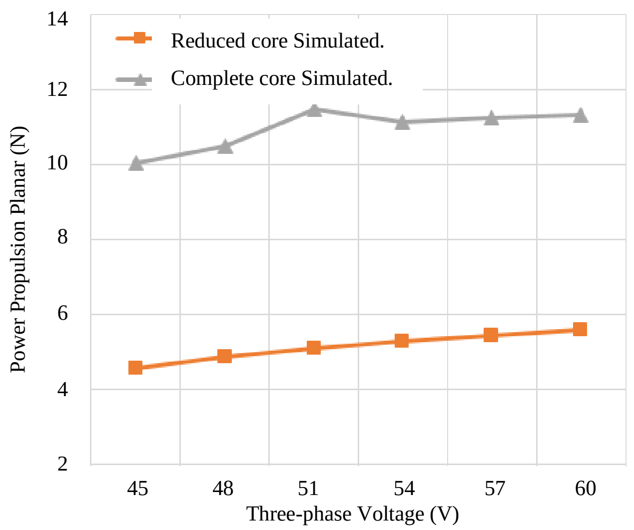

Figure 9: The planar graph of the reduced core propulsive force and complete simulated with 1P Somaloy 500

4. Conclusion

The numerical and experimental results presented in the article showed good consistency in comparisons of planar thrust between the results obtained by simulations and experiments. Therefore the method of the reduced model corroborate in the validation special of electric

25 40 55 70 85 100 115 130
Three-phase voltage (V)

actuator.

Reduced prototype for experimentation methodology allows to get the validation of numerical results obtained by software dedicated to calculations of complex electromagnetic devices. The comparison of the real values with the supplied via software allow to perform comparisons when structural features of the machine are changed.

Studies by the reduced model will allow us to delineate important parameters for designing special electric machines, allowing to predict possible failures and the implementation of improvements.

The use of electrical ferromagnetic materials with high resistivity and magnetic permeability, called 1P Somaloy 500, besides contributing to minimizing loses of Foucault currents, provides a low reluctance for the magnetic circuit path, positively contributing to the increase in magnetic flux density of the air gap and consequently to increase traction force planar [12, 13].

References

[1] C. Bailey, D. M. Saban, and P. Guedes-Pinto, "Design of high-speed direct-connected permanent-magnet motors and generators for the petrochemical industry," **Industry Applications, IEEE Transactions** *on*,vol. 45, no. 3, pp. 1159–1165, 2009.

[2] BAGGIO FILHO, Nolvi Francisco. Comparative analysis on the planar traction force in two planar actuators. **2013 Brazilian Power Electronics Conference**, [s.l.], p.896-902, oct. 2013. Institute of Electrical & Electronics Engineers (IEEE).

[3] CHOI, Wooyoung; LI, Silong; SARLIOGLU, Bulent. Core loss estimation of high speed electric machines: An assessment.Iecon 2013 - **39th Annual Conference Of The Ieee Industrial Electronics Society**, [s.l.], p.2691-2696, nov. 2013. Institute of Electrical & Electronics Engineers (IEEE).

[4] DLALA, E.. Comparison of Models for Estimating Magnetic Core Losses in Electrical Machines Using the Finite-Element Method. **Ieee Trans. Magn.**, [s.l.], v. 45, n. 2, p.716-725, feb. 2009. Institute of Electrical & Electronics Engineers (IEEE).

[5] BAGGIO FILHO, Nolvi Francisco; FLORES FILHO, Aly Ferreira. An Analysis on Electric and Magnetic Behaviour on an Induction Planar Actuator. **Journal of Microwaves, Optoelectronics and Electromagnetic Aplications.** São Paulo, v. 12, n. 1, p. 37-49, jun. 2013.

[6] MOTA NETO, Joao et al. Three-phase Planar Actuator's Reduced Model Validation Using Exploratory Coils and Evaluation Applying Somaloy500 as Core Material. **Renewable Energy And Power Quality Journal (re&pqj;).** La Coruña, p. 475-479. 25 may 2015.

[7] NETO, J. M et al. Numerical Analysis of Magnetic Compounds Used to Make Induction Planar Actuator Core With Two Degrees of Freedom. **Journal of Engineering and Science (irjes).** New York, v.3, n.10, p.40-49, oct. 2014.

[8] NETO, J. M. et al. Proposta de metodologia para validação do núcleo do atuador planar trifásico através de modelo físico reduzido. **10. ENCONTRO DE METALURGIA DO PÓ**, p.331-341 4. Conferência Internacional de Metalurgia do Pó - COMEP, Porto Alegre - RS, 2013.

[9] HOGÄNÄS. SMC Materials: Portfólio descritivo, 2013.

[10] VIJAYAKUMAR, K. et al. Two dimensional magnetic and thermal analysis of high speed switched reluctance motor using soft magnetic composite material. In: **TENCON 2008 - 2008 IEEE REGION 10 CONFERENCE**, p. 35-40, 2008.

[11] SHOKROLLAHI, H. & JANGHORBAN, K. 2007. Soft magnetic composite materials Journal of Materials Processing Technology, London (UK), Vol. 189,1-12 (Classificação SMC)

[12] FLORES FILHO, Aly F.; BAGGIO FILHO, Nolvi F.. Analysis of and Induction Planar Actuator. **XIX - International Conference On Electrical Machines**, Rome, p.978-984, 2010.

[13] Treviso, Felipe et .al. An Induction Planar Actuator For Surface Inspection. In: **Intermag** 2015, Beijin. Proceedings of the Intermag, 2015