INFLUENCE OF STRUCTURAL NON-HOMOGENEITIES ON FIELD DISTRIBUTION AND SPECIFIC FORCES OF ELECTROMAGNETIC SYSTEMS

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***Abstract* – The paper presents the influence of the structural non-homogeneities of ferromagnetic cores both on the field distribution - for electromagnetic systems - and on the specific forces developed by these systems. The analysis is aimed at finding new solutions for building electric machines with relatively high technical performances, of low environmental impact both during fabrication and exploitation.**

Keywords*: *electromagnetic systems; homogeneous core; non-homogeneous core.

1. INTRODUCTION

The magnetic field distribution in electromagnetic systems depends significantly on the quality of flux field concentrator. In their turn, the performances of magnetic flux field concentrator – in actual electromagnetic systems (static electric machines, rotary electric machines etc.) – depend on a variety of factors whose harmonization should eventually confer to it the characteristics of a homogeneous environment. Practically, this is a hypothesis widely used in modelling actual electromagnetic systems. Unfortunately, the technologies employed, specific solutions for building flux concentrators, do not offer – for the real electromagnetic system – this quality of a homogeneous environment. Thus, in this case the question arises if these structural non-homogeneities (of course, for an electromagnetic system, some other non-homogeneities can also be taken into account for other constituting subsystems) influence the magnetic field distribution and, implicitly, the internal energy of the machine and, eventually, for rotary machines influences drastically the specific forces developed. In this paper we provide an answer to the above question, by using simple electromagnetic systems. Moreover, the paper presents a comparative analysis of the influence of these field non-homogeneities distribution, for an electromagnetic system without air gap (rotary machines case).

Paradoxically, such an approach is justified nowadays, so as to find new solutions to build these magnetic flux concentrators, new constructive solutions for electromagnetic systems (in particular, rotary electric machines), new technologies for building these modern electromagnetic systems, technologies allowing for obtaining a performant electromagnetic system both from the point of view of the useful effect developed (technically wise) but also from the point of view of the impact on the environment (economic impact, eventually, but not the single effect).

2. MODELLING ELECTROMAGNETIC SYSTEMS

In order to make a comparative analysis simple electromagnetic systems have been considered, so as the obtained result to be the pre-requisites for a more complex approach to be presented in a future paper. In this stage of our analysis, the reference structure is given only by the magnetic field source (in principle, a coil run through by an electric field flows) and the flux concentrator. For the flux concentrator two cases have been considered: a) homogeneous environment – for which magnetic permeability is constant; b) non-homogeneous environment – for which the concentrator structure shows small „islands" of magnetic permeability different from adjacent areas. Moreover, in this latter case, a certain variation law was taken into account for the relative magnetic permeability of the material inside the small „islands" (dependent on the gradient of the magnetic vector potential). Together with this primary comparative analysis, a secondary comparative analysis was performed for the electromagnetic systems that do not presents airgaps, and those that are not built with airgaps respectively.

In order to determine the magnetic field distribution the following equation needs to be solved:

$$\Delta\overline{A} = -\mu \cdot \overline{J}, \qquad (1)$$

where $\overline{A}$ is the magnetic potential vector, $\overline{J}$ is the vector of the power density and μ is the absolute magnetic permeability of the environment. For the fields in which the power distribution is equal to zero, the equation becomes $\Delta\overline{A} = 0$. On the basis of the magnetic potential vector it can be further determined the magnetic induction, as

$$\overline{B} = \mathrm{rot}\overline{A}, \qquad (2)$$

$\overline{B}$ is the magnetic induction (flux density) vector.

From the law of connection, $\overline{B} = \mu \cdot \overline{H}$ it can be determined the magnetic field intensity vector,

$$\overline{H} = \frac{\overline{B}}{\mu} . \tag{3}$$

The problem being bidimensional, all the parameters will take the form $P(x, y)$, where P is any of the above components.

The unknown parameter of the problem being the magnetic potential vector, the initial condition is imposed $A(x, y) = 0$.

To these the border conditions of Dirichlet, and, respectively, Neumann types are added.

The magnetic power is determined by using the relation

$$W_m = \frac{1}{2} \cdot B \cdot H , \tag{4}$$

and when compared to a generalized coordinate α (in our case – the dimension of the air gap) the variation of this energy can be seen. As a result, there can be determined the generalized forces according to the two axis of the xOy plane:

$$f_x = -\frac{\partial W_m}{\partial x} ; \; f_y = -\frac{\partial W_m}{\partial y} . \tag{5}$$

The module of the specific force that is developed (force density), f, is determined in these conditions by using the relation:

$$f = \sqrt{f_x^2 + f_y^2} . \tag{6}$$

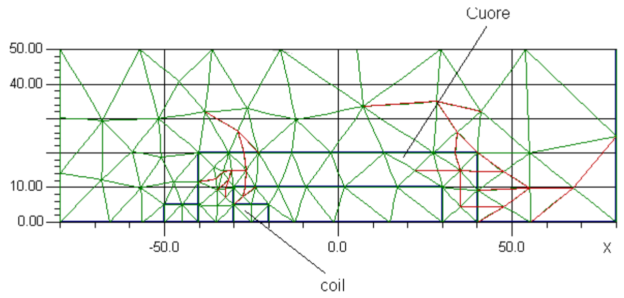
Solving field problems (bidimensional analysis) – for each particular configuration – was done by using the PDE-ase software.

3. RESULTS OBTAINED

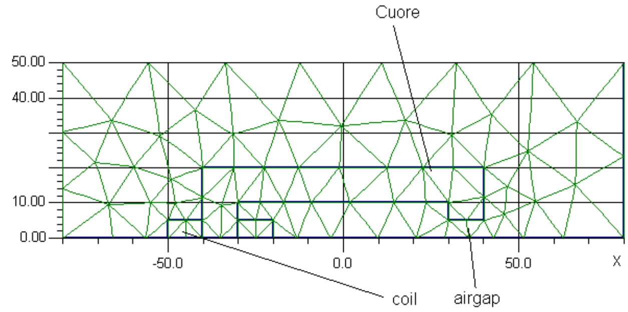
As a result of the analysis performed, results have been obtained allowing for new considerations of the approached topic. We will further present here just few of these results.

In fig. 1 we present the discretization domains in the case of electromagnetic systems showing homogeneous core, without airgap (fig.1, a) and, respectively, homogeneous core, but equipped with airgap (fig.1, b).

In fig. 2 are shown the discretization domains in the case of electromagnetic systems with non-homogeneous core without airgap (fig.2, a), respectively, non-homogeneous, but equipped with airgap (fig.2, b).

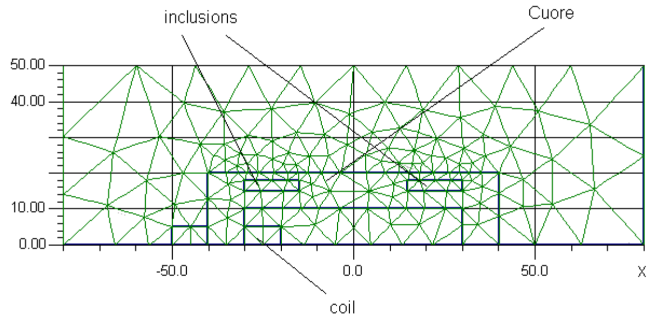


a)

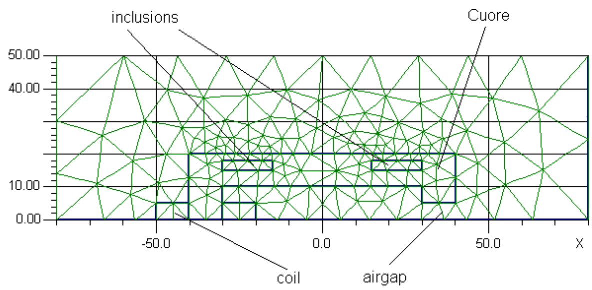


b)

Figure 1: Discretization domains for analyzed electromagnetic system
a) Homogeneous core without airgap;
b) Homogeneous core with airgap



a)



b)

Figure 2: Discretization domains for analyzed electromagnetic system
a) Non-homogeneous core without airgap;
b) Non-homogeneous core with airgap

Magnetic field distributions for the cases under consideration are presented in fig. 3 (H distribution) and fig. 4 (B distribution) – for the cases of homogeneous core structures, and in fig. 5 (H distribution) and fig. 6 (B distribution), respectively – in the case of non-homogeneous core structures.

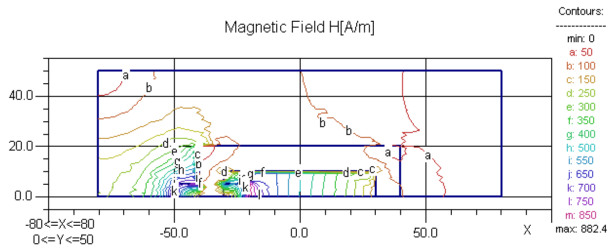


Figure 3: Distribution of the magnetic field intensity for homogeneous core structures lacking airgap

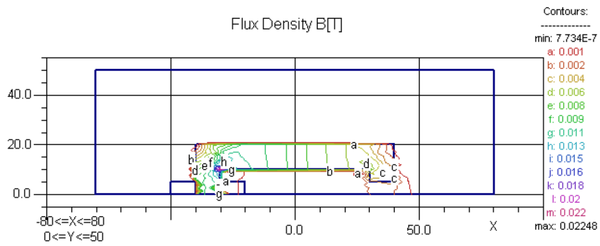


Figure 4: Distribution of magnetic induction for homogeneous core structures equipped with airgap

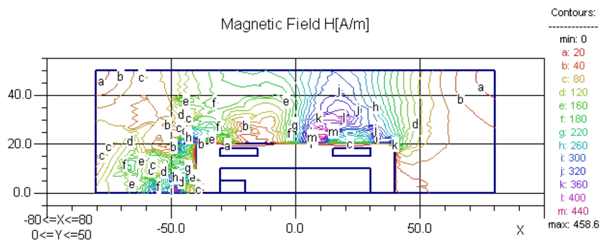


Figure 5: Distribution the magnetic field intensity for non-homogeneous core structures lacking airgap

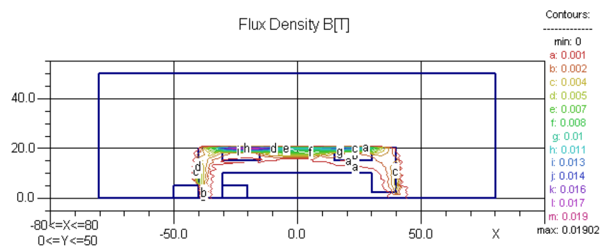


Figure 6: Distribution of magnetic induction for non-homogeneous core structures equipped with airgap

In the case of structures equipped with airgap, the specific forces developed for the two classes of analyze cores have been compared. In fig. 7 and 8 is shown the variation of these forces with the dimension of airgap, in the case of homogeneous core (fig.7), and non-homogeneous, respectively, in fig. 8.

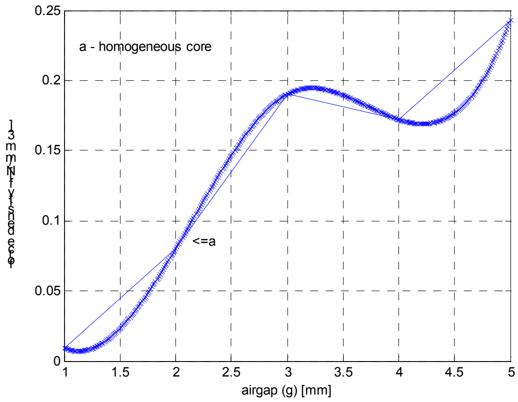


Figure 7: Distribution of specific forces for homogeneous core structures equipped with airgap

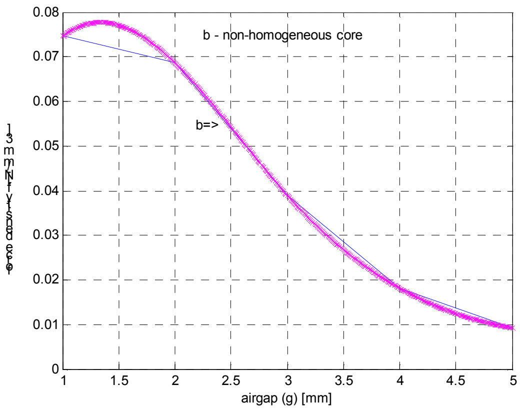


Figure 8: Distribution of specific forces for non-homogeneous core structures equipped with airgap

4. CONCLUSIONS

As a result of the analysis undertaken, the following conclusions resulted:

• The magnetic field distribution modifies radically, in the case of non-homogeneous ferromagnetic cores as compared to the homogeneous cores case;

• For the non-homogeneous cores, the magnetic field intensity diminishes by 48 % as compared to structures with homogeneous core (such as airgap structures);

• Magnetic induction, in its turn, is lower with approximately 15% for non-homogeneous core structures, as compared to structures with homogeneous core;

• Consequently, airgap specific forces - for non-homogeneous structures case – diminish as compared to homogeneous structures;
• Although lower in module, specific forces (by the Oy axis) show a practically aperiodic variation to airgap increase – for non-homogeneous structures case – as compared to the homogeneous ferromagnetic core structures in which specific forces oscillate, although show an increase together with the airgap;
• Electric machines may be built using cores that do not presente a homogeneous structure (for example, made of syntherized powders, by powders in colloidal solutions etc.) which, although with lower specific forces, will successfully work for specific applications;
• In order to diminish some negative effects of non-homogeneous structures (partial saturations etc.) it is necessary to find some specific geometric configurations for the electric machines that will be built by adopting such structures.

References

[1] I. Voncila, Cr. Munteanu, R. Buhosu – *Analysis of functional stability of permanent magnet bearings* – Petroleum – Gas University of Ploieşti Bullletin, Technical Series, vol. LVIII, No. 2 bis/2006, ISSN 1224-8495, pp. 295-300;

[2] I. Voncila, N. Badea, I. Paraschiv, I. Dobrota – *Nd-Fe-B the behaviour of frontal couplings with permanent magnets in high temperature corrosive environments* - Proceedings of MOC' 42, pp.175, Odessa, 2003;

[3] I. Voncila, N. Badea, I. Dobrota - *The behaviour of asymmetric frontal couplings with permanent magnets in magnetic powder and high temperature environments* - Proceedings of CNAE 2002, pp.251 - 255, Galati, 2002;

[4] Lovatt H.C, P. A. Watterson P.A, *Energy Stored in Permanent Magnets*, IEEE Trans.on Magnetics, vol. 35, january 1999;

[5]. F. Bancel, G. Lemarquand – *Three-dimensional analitycal optimization of permanent magnets alternated structure* - IEEE Trans. on Mag., vol 34, no 1, pp. 242-247, january 1998;

[6]. Y.D. Yao, D.R. Huang, C.M. Lee, S.J. Wang – *Magnetic coupling studies beetwen radial magnetic gears* - IEEE Trans. on Mag., vol 33, no 5, pp. 4236-4238, september 1997;

[7] ***PDE-ase., *Reference manual tutorial handbook of demonstration*, SPDE, Inc., 1995;

[8] Furlani, E.P.; Wang, R.; Kusnadi, M.: *A three-dimensional model for computing the torque of radial couplings*, I.E.E.E. Trans. Magn., vol.31, pp. 2522-2526, nr.5, september 1995;

[9] Furlani, E.P.; Reznik, S.; Kroll, A.: *A three-dimensional field solution for radially polarized cylinders*, I.E.E.E. Trans. Magn., vol.31, pp. 844-851, nr.1, january 1995.