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Calculation of Electromechanical Characteristics on Overband Magnetic Separator with Finite Elements

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Abstract – **In this paper will be presented an approach to improved nonlinear magnetic field analyses of the Overband Magnetic Separator, on the basis of FEM as a represent of the numerical methods. By using iterative procedure Finite Element Method, it will be calculated the nonlinear distribution of magnetic field, under rated excitation of the Separator. The electromagnetic field on the basis of the fluxes and flux densities in the particular domain of the separator will be defined. The electromagnetic forces on the x and y directions will be calculated.**

Keywords – **Electromechanical characteristics on overband magnetic separator.**

I. Introduction

The development of different Overband Magnetic Separator, has caused an appearance and an expansion of special different types of Magnetic Separator with enormous possibilities for their application. One of these particular is the Overband Magnetic Separator OMS. The exact analytic methods are almost improper.

The rated data of the Overband Magnetic Separator OMB which is going to be analyzed in this paper are: 7 kW input power and 220 V operating voltage. Maximum clearance distance is x=420 mm.

The cross-section of the separator and its dimensions are presented in Fig. 1.

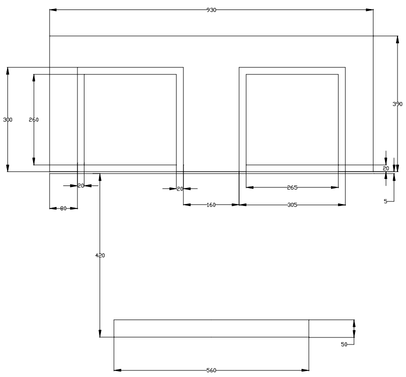

Fig. 1 Cross-section and dimensions on Overband Magnetic Separator

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In order to determine electromagnetic characteristics of the Overband Magnetic Separator as accurate as possible, the Finite Element Method (FEM) is used. The nonlinear interacttive procedure is applied. The calculation are carried out quasistatically, at given band position.

At the beginning, FEM is used at separately energized windings. The calculations continue when two couple winding are energized with rated current as well as with several other values.

Flux density in different Overband Magnetic Separator parts is calculated. Additionally electromagnetic forces and torque is calculated.

II. Modeling of Electrmagnetic Field

A. Preprocessing

FEM 4.0 has possibility to solve magnetic vector potential and consequently magnetic flux density by solving relevant set of Maxwell equations for magnetostatic case as well as for time harmonic case. In magnetostatic case field intensity $\mathbf{H}$ and flux density $\mathbf{B}$ must obey:

$$\nabla\, x\, \mathbf{H} = \mathbf{J} \qquad (1)$$

$$\nabla\, x\, \mathbf{B} = 0 \qquad (2)$$

subject to a constitute relation between B and H for each material:

$$\mathbf{B} = \mu\, \mathbf{H} \qquad (3)$$

and for nonlinear material (saturating iron) permeability μ is actually function of $\mathbf{B}$.

FEM goes about finding a field that satisfies Eqs. (1)-(3) via a magnetic vector potential. Flux density is written in terms of the vector potential $\mathbf{A}$, as:

$$\mathbf{B} = \nabla x \mathbf{A} \qquad (4)$$

This definition of $\mathbf{B}$ always satisfies Eq. (2). Then Eq. (1) can be rewritten as:

$$\nabla\, x \left(\frac{1}{\mu(\mathbf{B})} \nabla\, \mathbf{A} \right) = \mathbf{J} \qquad (5)$$

The advantage of using the vector potential formulation is that all the conditions to be satisfied have been combined into a single equitation. If **A** is found, **B** and **H** can be deduced by differentiating **A** .

In order to determine electromagnetic characteristics, in FEM pre-processing separator geometry should be first input. Afterwards all materials in all separator domains must be defined (Fig. 2).

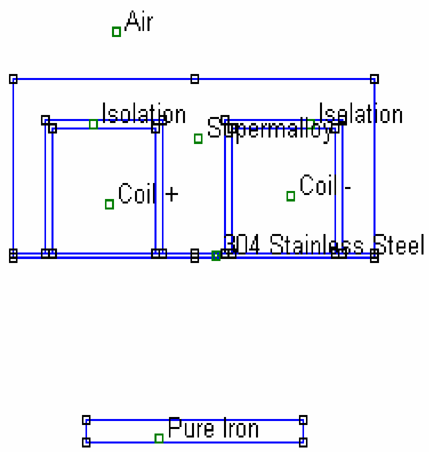

Fig. 2 Defining of material properties in different area of the OMS

This is enabled with program blocks which contain all necessary information regarding electrical and magnetic materials including magnetization curve (Fig. 3), as well as material conductivity.

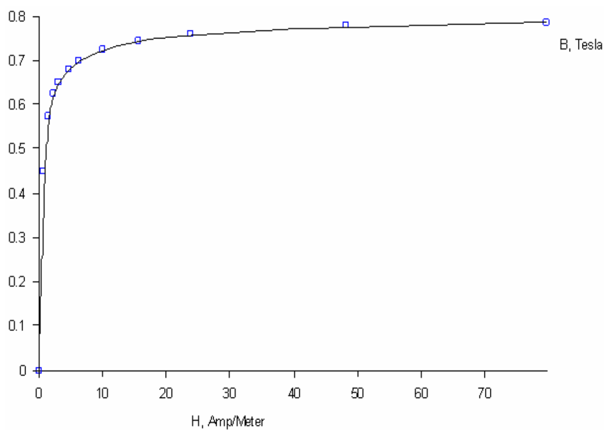

Fig. 3 Nonlinear magnetization characteristic

Afterwards a mesh of finite elements is generated. In this particular case mesh contains 31 418 nodes and 62480 finite elements (Fig.4).

In case when calculation of magnetic vector potential should be calculated more accurate mesh density should be increased especially on interface between two different materials.

In that case contour of integration passes at least two elements away from any interface or boundaries. Greater mesh density increases the computation time. So the good way to find mesh which is “dense enough” in order necessary accuracy to be achieved and still computation time to be reasonably small is comparation of results from different mesh densities. Than can be picked smallest mesh which gives convergence to the desired digit of accuracy.

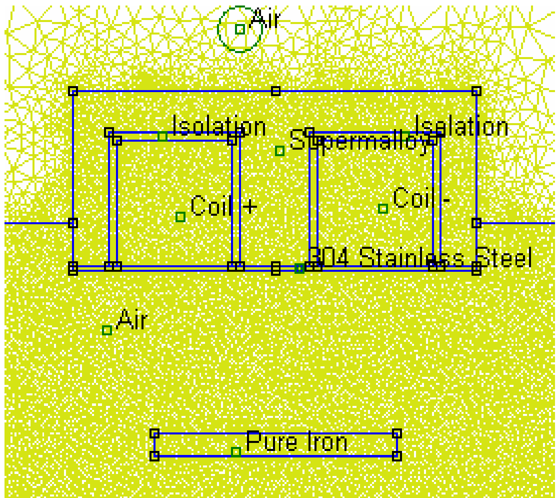

Fig. 4 Detailed cross section of the separator with increased mesh density

B. Post processing

Quasistatic analyses of the Separator at load condition is carried out in rated current.

Nonlinear iterative procedure enables “to enter inside the separator” and to carry out a deepened analyses of magnetic field distribution, taking into consideration the typical magnetic values, as magnetic flux and magnetic flux density.

From the flux distribution when the calculations continues when two couple winding are energized with rated current is presented in (Fig. 5).

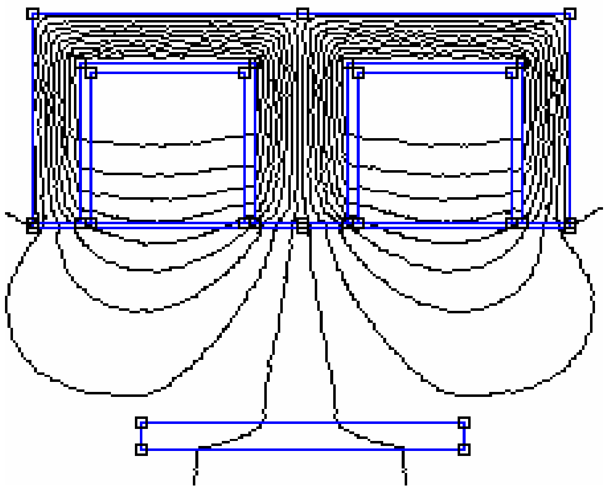

Fig. 5 Magnetic field distribution on Overband Magnetic Separator

On Fig. 6 are presented values of magnetic flux density when the coil is excited with rated current.

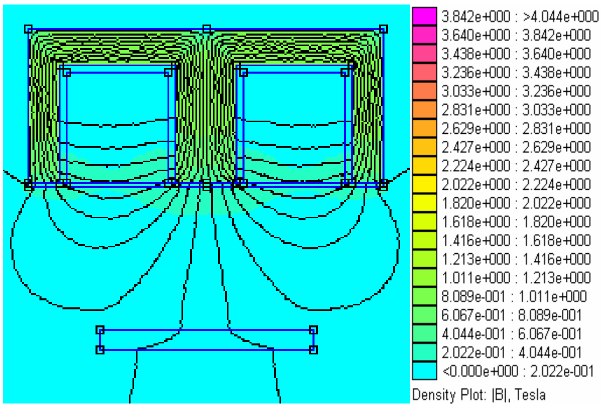

Fig. 6 Magnetic field density on Overband Magnetic Separator

The distribution of magnetic flux density when clearance distances are x=0 mm and x=420 mm is presented on Fig.7 and Fig. 8.

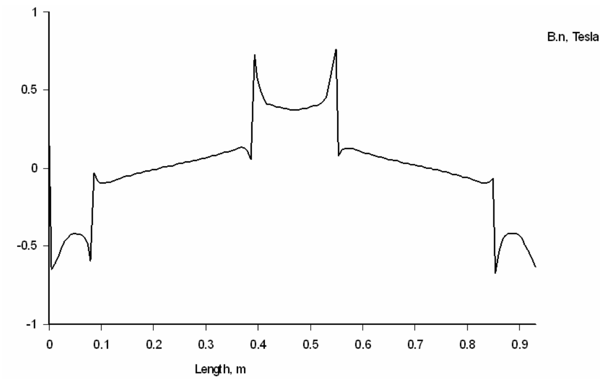

Fig.7 Distribution of flux density when clearance distance is x=0 mm.

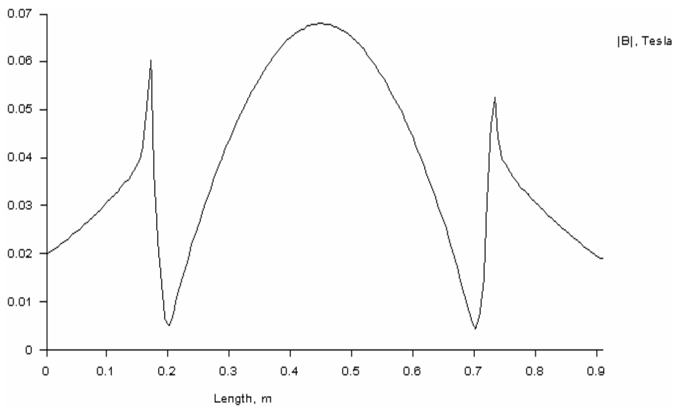

Fig. 8 Distribution of magnetic flux density when clearance distance is x=420 mm.

In this version of the FEM programme, this volume integral greatly simplifies the computation of forces and torques. Mearly select the blocks upon which force or torque are to be computed and evaluate the integral. No particular "art" is required in getting good force or torque results.

On limitation of the Weighted Stress Tensor integral is that the regions upon which the force is being computed must be entierly surrounded by air and/or abutting a boundary.

The differential force produced is:

$$dF = \frac{1}{2}\left(H\left(B \cdot n\right) + B\left(H \cdot n\right) - \left(H \cdot B\right)n\right) \qquad (6)$$

where n denotes the direction normal to the surface at the point of interest. The net force on an object is obtained by creating a surface totally enclosing the object of interest and integrating the magnetic stress over that surface Fig. 9.

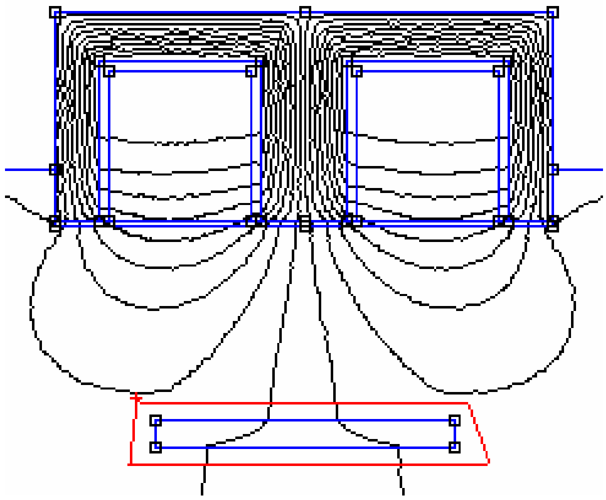

Fig. 9 The regions upon which the force are calculated

The electromagnetic forces in x-direction = 7.25658 N, and force in y- direction = 450.063N.

The upshot is that if stress tensor is evaluated on the interface between two different materials, the results be particularly erroneous. However, the stress tensor has the property that, for an exact solution, the same result is obtained regardless of the path of integration, as long as that path encircles the body of interest and passes only through air (or at least, every point in the contour is in a region with a constant permeability).

The second rule of getting good force result is used as fine a mesh as possible in problems where force results are desired.

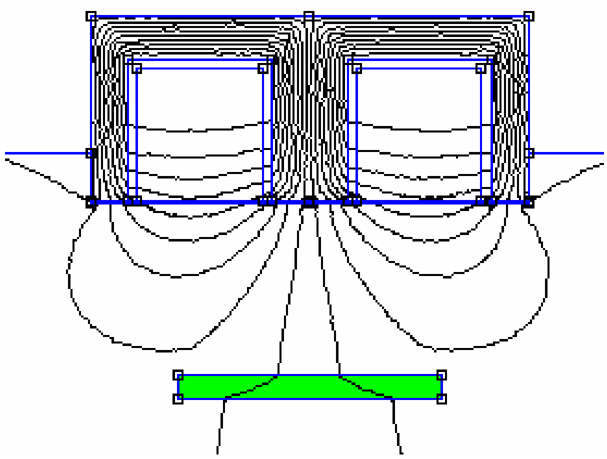

Fig. 10 Force and torque calculated via weighted stress tensor integral

The electromagnetic forces in x-direction =7.25658 N, and force in y- direction=450.063N.

The value of the electromagnetic torque about (0, 0) =3.12 Nm.

III. CONCLUSION

In this paper the non-linear magnetic field analyses and computation of electromagnetic, electromechanical characterristics are presented. For this purpose as the most suitable Finite Element Method is applied. This contemporary method enables exact magnetic quantities such as flux or flux density distribution to be evaluated in any part of the separator. Additionally electromagnetic force can be calculated for rated load current.

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