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MODELLING OF THREE DIMENSIONAL ELECTROMAGNETIC FIELD DISTRIBUTION IN THE ACTIVE PART ELECTROMECHANICAL DISINTEGRATOR

Developed three-dimensional finite element mathematical model of electromechanical disintegrator. Obtained the results of the spatial distribution of electromagnetic field in its active portion. Identified the features distribution of eddy currents and electromagnetic forces in the working conductive camera of disintegrator.

Key words: *electromechanical disintegrator, three-dimensional finite element model, eddy currents, electromagnetic forces.*

The problem and its relation to scientific and practical tasks. One of the ways to implement the various processes fine and superfine grinding, homogeneous mixing of liquid and solid powder materials (preparation of emulsions, suspensions, etc.), acceleration of chemical reactions is the use of a fundamentally new class of electromechanical energy converters — electromechanical disintegrator (EMD) multifactor impact [1, 2, 3]. Work area EMD is an area in which are counter running electromagnetic fields affecting workers ferromagnetic body (WFB), which in turn become magnetic dipoles and interact with the resultant field — the original source of energy. This results in a number of effects which, in addition to mechanical and thermal effects of the WFB, acting directly on the material, changing its physic and chemical properties.

With using the two-dimensional mathematical modelling, given in [4, 5], determine the complexity of the electromagnetic field distribution in the active part of EMD taking into account all the spatial components of the eddy current in the conductive working camera, is almost impossible. This problem makes it necessary to develop a three-dimensional mathematical model of EMD.

Statement of the problem. The objective of this work is to create a three-dimensional finite element model of EMD and determination based its features of electromagnetic field distribution in the active part.

Presentation of the material and its results. The general form of the nonlinear differential equation of the electromagnetic field in the partial derivatives to the vector magnetic potential A can be represented as

$$\mathrm{rot}\left(\frac{1}{\mu}\mathrm{rot}\,\vec{A}\right)-\gamma\frac{\partial\vec{A}}{\partial t}-\gamma(\vec{v}\times\mathrm{rot}\,\vec{A})=-\vec{J}_{ext},$$

where $\mu = \mu_0 \cdot \mu_r$ — absolute permeability; γ — specific conductivity; $\vec{v}$ — vector velocity of the electroconductive medium relative to the magnetic field source; $\vec{J}_{ext}$ — density extraneous current.

Algorithm for the numerical calculation of electromagnetic fields EMD, the physical properties of computational domains, as well as boundary conditions similar to those considered in [4]. Material working camera — nonmagnetic stainless steel with the conductivity — $1{,}1\cdot10^7$ S/m.

To reduce the design time calculations and size of the needed amount of hardware resources, three-dimensional electromagnetic field calculation is made for a bipolar version of EMD. To create a three-dimensional finite element model was used software package Comsol Multiphysics 3.5a. On figures 1 and 2 presents the three-dimensional geometry and finite-element mesh of model, respectively.

It should be noted that the use of a PC based 4-core processor, AMD Phenom II X4 955 yielded good results for the three-dimensional model with a high degree of sampling grid elements. Thus, for comparison on figures 3 and 4 show the distribution curves of the normal component of the magnetic induction in the middle of the air gap in the yoke and along one pole EMD, respectively, for the three- and two-dimensional electromagnetic calculation options.

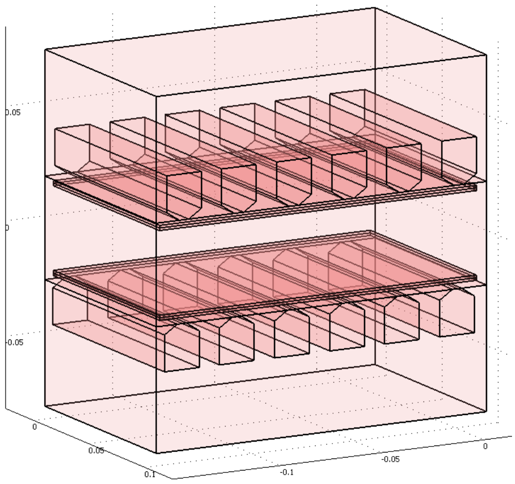

Figure 1 — Three-dimensional geometry

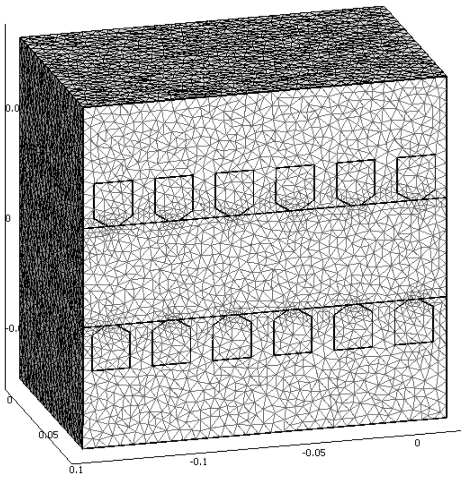

Figure 2 — Finite-element mesh of model

Figure 5 shows the distribution of the normal component of the magnetic induction in the active part of the EMD in several cross sections. The highest value of magnetic induction is observed in narrow areas of magnetic teeth — 2 T, value insignificantly decreases as we move towards the middle of the active part.

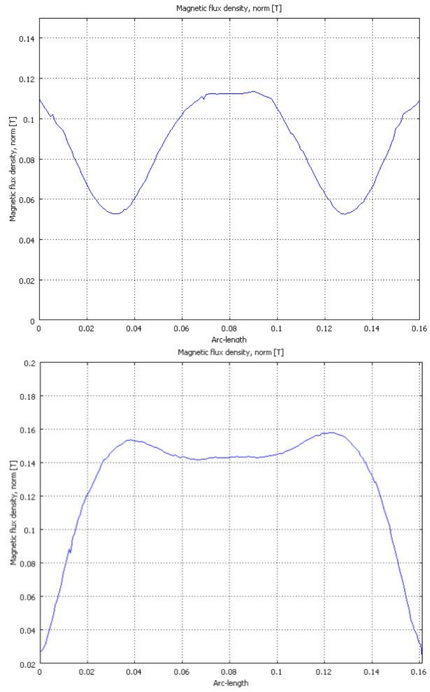

Figure 3 — Distribution of the normal component of the magnetic induction in the middle of the air gap (top) and in the yoke for three-dimensional calculation of EMD

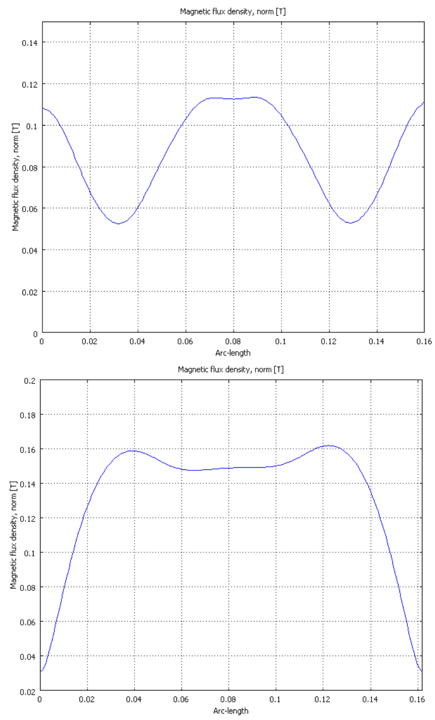

Figure 4 — Distribution of the normal component of the magnetic induction in the middle of the air gap (top) and in the yoke for two-dimensional calculation of EMD

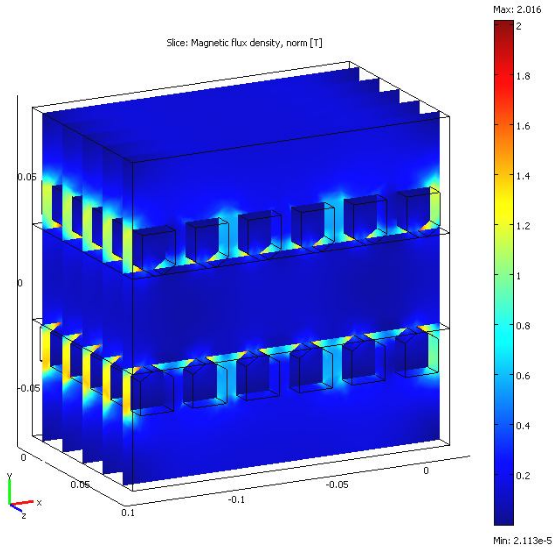

Figure 5 — Distribution of the normal component of the magnetic induction in the active part of the EMD in several cross sections

Three-dimensional graph of the distribution of the magnetic induction in the air gap EMD is shown on figure 6. Distribution of the vector magnetic potential in the active part of EMD in a three-dimensional graph shown on figure 7.

Calculation of the eddy currents in the conductive camera EMD work is shown on figure 8, distribution of instantaneous *z*-component of the current density (left), as well as a line current (right) corresponding to the classic "contours" of eddy currents.

A consequence of the interaction between the running magnetic fields of inductor and eddy currents flowing in the conductive camera walls (adjacent to the inductor), is the occurrence of the characteristic deflection of the camera walls within each pole pitch under the action of electromagnetic forces.

Distribution curve deflection depth along the length of the wall of the working camera EMD, built on the results of experimental measurements [5] and the nature of the distribution of electromagnetic forces obtained by solving the three-dimensional field problem by finite element method (figure 9), shown qualitative agreement and confirmed the presence of localization of existing efforts within the pole dividing inductors.

Comsol Multiphysics allows defining the resultant force which acts on a conductive working camera by integrating elementary forces by volume, as well as efforts to separate spatial components, we are interested most. To deformation of the working camera EMD causes efforts normal to the surface of the camera wall. Numerical calculations showed on the pole pitch in a conductive camera distributed force action that reaches 25 newtons.

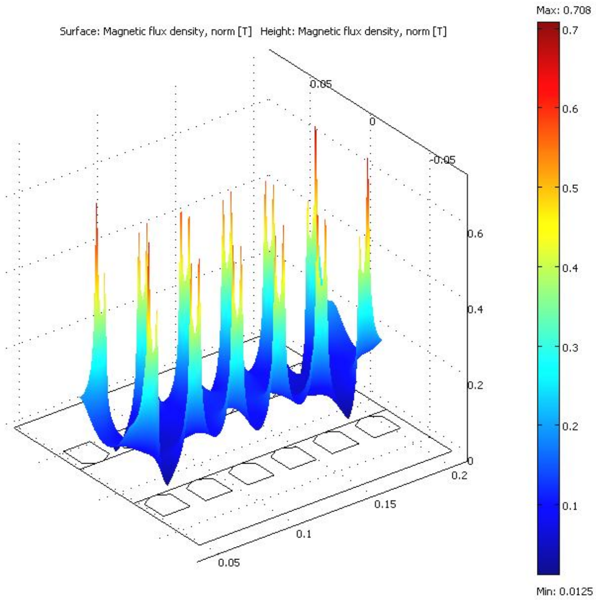

Figure 6 — Three-dimensional graph of the distribution of the magnetic induction in the air gap EMD

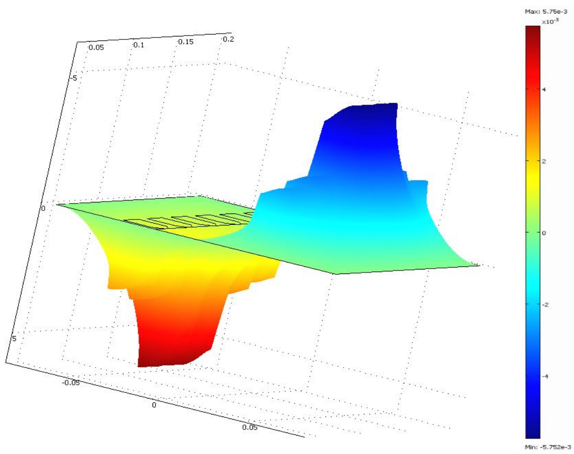

Figure 7 — Distribution of the vector magnetic potential in the active part of EMD in a three-dimensional graph

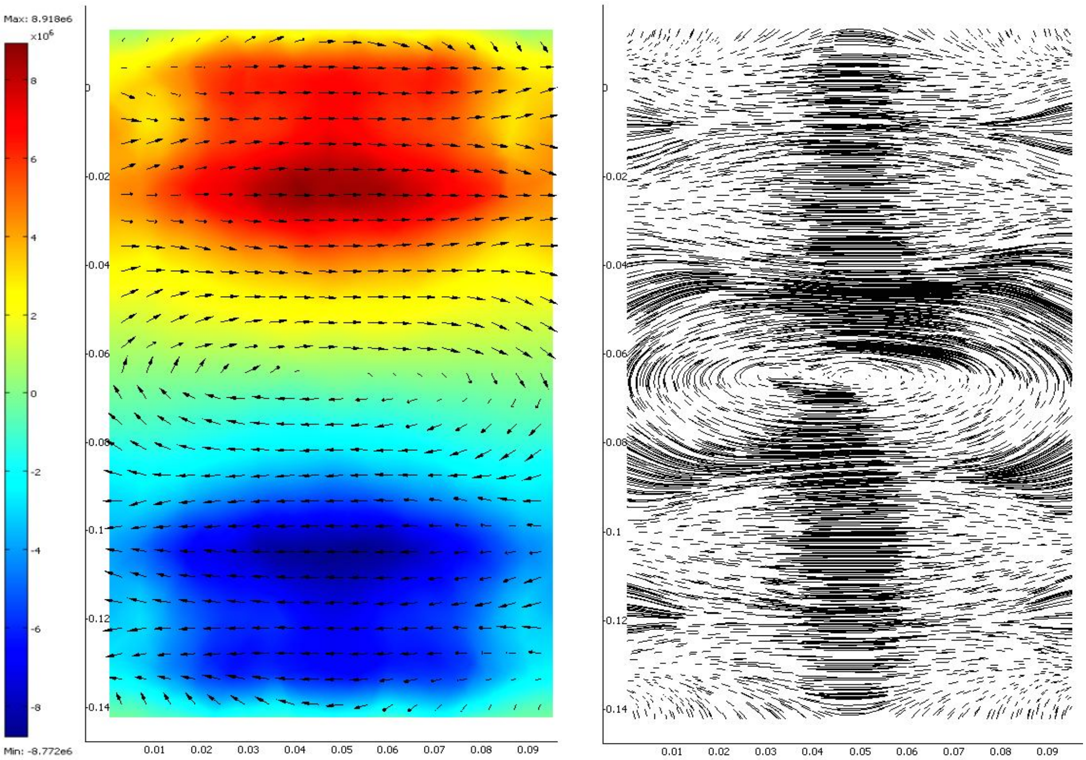

Figure 8 — Distribution of eddy current in the working conductive camera EMD

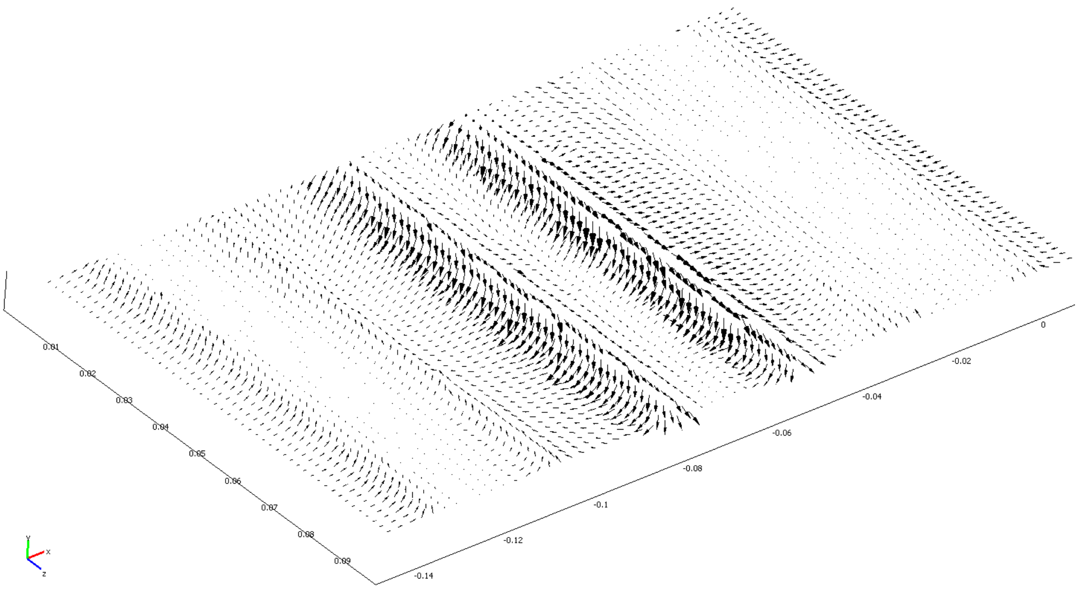

Figure 9 — Three-dimensional distribution of electromagnetic forces
in the working conductive camera EMD

Given the pulsatory character of the action forces and impact load, to ensure the mechanical strength of the working camera, one can recommend its manufacturing of non-magnetic material (stainless steel, titanium) with a minimum thickness of 4-5 mm.

Conclusions and directions for further research. Developed three-dimensional finite element mathematical model of electromechanical disintegrator. Obtained results of the spatial distribution of electromagnetic field in its active portion. The features of the distribution of eddy currents and electromagnetic forces in the working conductive camera disintegrator.

Further research should be aimed at a detailed study of the influence of the geometric dimensions of the active part of EMD on the power characteristics of the electromagnetic field in order to obtain needed operating properties.

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МОДЕЛЮВАННЯ ТРИВИМІРНОГО РОЗПОДІЛУ ЕЛЕКТРОМАГНІТНОГО ПОЛЯ В АКТИВНІЙ ЧАСТИНІ ЕЛЕКТРОМЕХАНІЧНОГО ДЕЗІНТЕГРАТОРА

Розроблено тривимірну кінцево-елементну математичну модель електромеханічного дезінтегратора. Отримано результати просторового розподілу електромагнітного поля в його активній частині. Визначено особливості розподілу вихрових струмів й електромагнітних зусиль в робочій електропровідній камері дезінтегратора.

Ключові слова: *електромеханічний дезінтегратор, тривимірна кінцево-елементна модель, вихрові струми, електромагнітні зусилля.*

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МОДЕЛИРОВАНИЕ ТРЕХМЕРНОГО РАСПРЕДЕЛЕНИЯ ЭЛЕКТРОМАГНИТНОГО ПОЛЯ В АКТИВНОЙ ЧАСТИ ЭЛЕКТРОМЕХАНИЧЕСКОГО ДЕЗИНТЕГРАТОРА

Разработана трехмерная конечно-элементная математическая модель электромеханического дезинтегратора. Получены результаты пространственного распределения электромагнитного поля в его активной части. Определены особенности распределения вихревых токов и электромагнитных усилий в рабочей электропроводящей камере дезинтегратора.

Ключевые слова: *электромеханический дезинтегратор, трехмерная конечно-элементная модель, вихревые токи, электромагнитные усилия.*