

Simulation of the Magnetic Characteristics and Properties of the Neodymium Compensator of the Stiffness

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Abstract. This research is devoted to consideration of the possibility to use the software ELCUT for development of the magnetic compensator of the stiffness based on neodymium magnets. The software represents precision enough apparatus to solve the issues of the magnetostatic. The solution of these issues is the most important phase at the stage of the designing and calculation of the magnetic compensator of the stiffness, so as at the beginning we need to find the traction force of the interaction between magnet and magnetic materials to provide necessary falling traction characteristic of the compensator. In this paper the simulated models of the neodymium magnets are shown; the view of the field are calculated, the plots of the distribution and directions of the magnetic field strength and induction vectors are presented. Results, which were obtained during of the simulation, further will be used for designing and creation of the magnetic compensator of the stiffness based on supermagnets. Research & Development is under the scholarship of the President of Russian Federation, order №184 from 10th of March 2015.

Introduction

Nowadays the one of the actual issue is vibrations, created by power installations of transport vehicles. Frequently enough the vibration leads to premature damages of the machinery and equipment, emergency situation. At that moment the different research groups are developing big enough amount of the vibroprotectors and vibration isolation devices [1, 5-10]. However, the vibration isolators, based on zero stiffness effect, are most perspective. Accordingly the theory of the vibration isolation, the devices to reduce of the mechanical oscillations, must operate in conformity with effect of the zero stiffness, when ideal vibration isolation from random spatial oscillations of the absolute hard body will be provide, if at any time the sum of the projections of all forces applied to it on arbitrary coordinate points and the amount of the axis with relatively to these axes are equal to zero [3, 4]:

$$\sum P_x = 0, \quad (1)$$

$$\sum P_y = 0, \quad (2)$$

$$\sum P_z = 0, \quad (3)$$

$$\sum M_x(P) = 0, \quad (4)$$

$$\sum M_y(P) = 0, \quad (5)$$



$$\sum M_z(P) = 0, \quad (6)$$

To provide the area of the zero stiffness within amplitude of the oscillations, the vibration isolators must consist of resilient element and compensator of the stiffness connected in parallel with the same stiffness falling traction characteristic so as resilient element, but with negative sign. So, the linear increasing characteristic is compensated by falling characteristic under the same angle relatively abscise axis. It will leads to comply of the condition (1)-(6) at any spatial movements of the vibrating object relatively of the protected object.

Nowadays, there are many different designs of the correctors of the stiffness, which are presented in different versions, based on principles of mechanics, hydraulics, and pneumatics [7]. However, the most efficiency device should be considered the electromagnetic compensator of the stiffness, because it has many benefits over the previously proposed: automatic tuning to variable load, absence of the friction forces and additional inertia.

With all of these achievements the application of this compensator of the stiffness is a bit difficult due to significant sizes and additional supply. In [2] the change of the basic components of the stiffness compensator (electromagnet coils with cores on neodymium magnets, which are rare-earth element magnets, consists of alloy neodymium-boron) was suggested. On the figure 1 the schematic of the supermagnets position is shown. Here the distance between two magnets is calculated from parameters of the supposed vibrations, and metallic plate is thin enough (the thickness of the plate is negligible in contrast of thickness of the magnets).

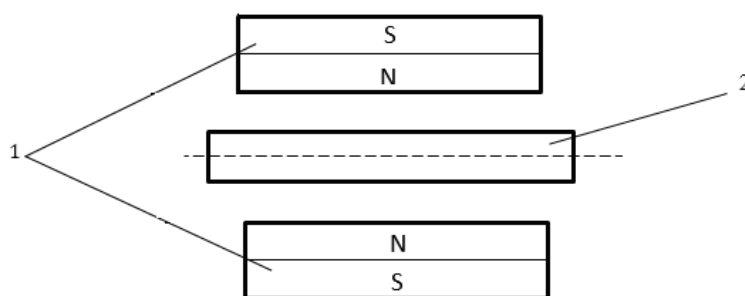


Figure 1. Interaction of the two magnets with flat anchor:
 1 – is the pair of the oppositely directed magnets; 2 – is the flat iron anchor

The application of these components, which have magnetic properties, leads to necessity of the solving of the issues of the magnetostatics. For the solution of the similar tasks we can use the software «ELCUT».

Calculation and simulations

To make precise traction characteristic of the compensator of the stiffness based on permanent magnets, there is neediness to make some simulation with software «ELCUT». The creation of the compensator model allows determining of the strength of fields magnets interaction. Further simulation for different values of the air gap between the bodies, allows us to determine the force acting on the anchor at the different movements relative neodymium magnets. These data will be the basis for building, the necessary falling traction stiffness compensator characteristics relatively from the position of the anchor on the axis.

This software allows making the engineer analysis and simulation by the finite element method (FEM), so as 2D and 3D models of the different magnets, and compensators of the stiffness based on it. The capability of «ELCUT» allows determining necessary properties and parameters of the magnetic fields as electromagnets and permanent magnets [1, 2]. This software consider neodymium

magnet as element, which has permeability, coercive force and remanence. In software, it is possible to find the strength of the magnetic field at any point of the space around simulated object, its induction, strength and direction by integration method along the contour of the element.

Simultaneously, with mentioned above, there are possibility to plot the deviation of the induction, strength, permeability and energy axially.

Let us to use the software «ELCUT» for simulation of the neodymium magnet cylinder of the type N42 and analysis of its magnetic properties.

The parameters is used as original data:

- radius of the magnet (steel cylinder):2,25 cm;
- height of the magnet (steel cylinder):2 cm;
- remanence: 1.36 T;
- the coercive force of the magnet: 955 kA/m;
- relative magnetic permeability of the medium: 1;
- relative permeability of the steel: 1000;
- the distance between the magnet and the magnet (steel):1 cm.

The first step in simulation of the magnetic system of the stiffness compensator elements is creation of the magnetic field of the elements. On the figure 2, 4 and 5 the shape and values of the magnet fields, created by neodymium magnet (interaction between magnet, steel cylinder and two magnets) is presented.

On the figures the models of the cylinder bodies are presented. These models is presented with help of the areas with permanence, coercive force and residual induction, and the lower bound is the axis of rotation of the body that allows us to simulate portion of the magnetic body, and the result is a parameter that is valid for the entire body.

From figure 2, 4 and 5 we can see, that the plot of the magnetic field is changing from parametric data: single magnet, interaction with steel cylinder or another similar magnet. It is caused by difference of the magnetic conduction, and also by distribution of the induction vectors and strength, created by components of the devices.

Let us consider these issues. The modelling system «ELCUT» allows showing the vector of the magnetic induction for single magnet, and also the plot of the distribution of the magnetic induction axially. The results are shown on figures 1 and 2.

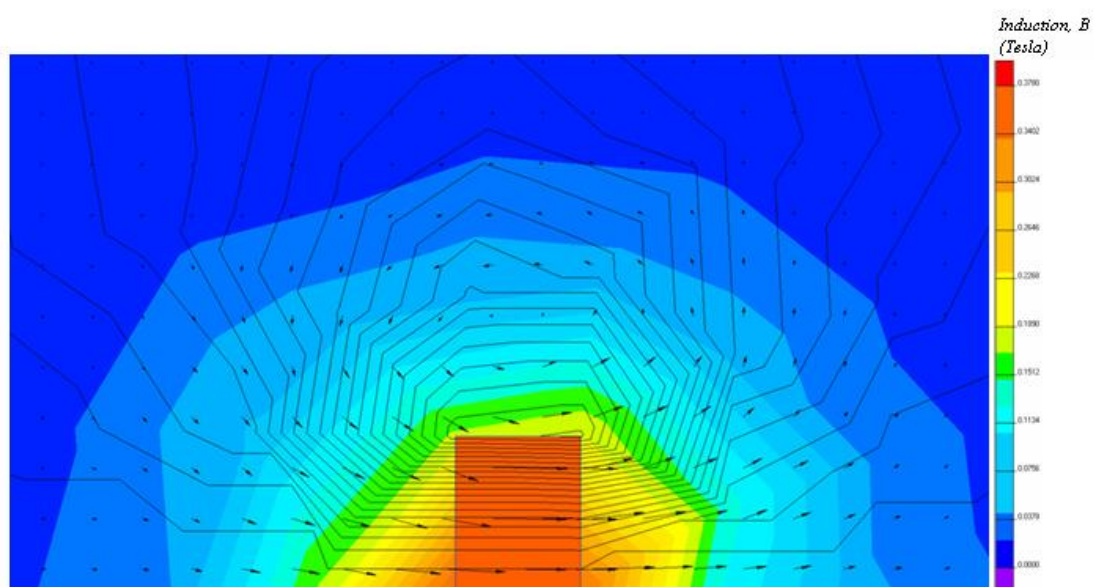


Figure 2. Distribution and vectors of the magnetic induction

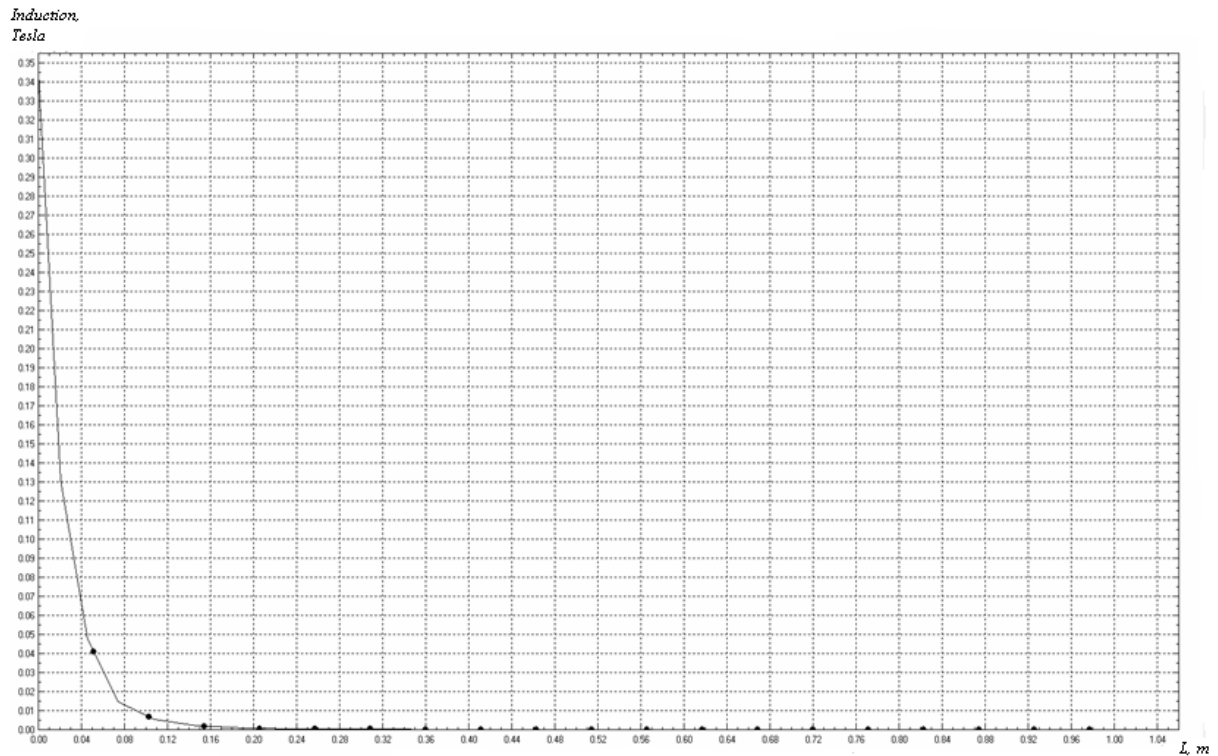


Figure 3. Plot of the distribution of the magnetic induction along cylinder magnet axis

The plot of the dependency, which is presented on figure 3, allows preliminarily calculate the value of the induction of the magnetic field along axis or contour. Also we can plot the model of the field, created by two similar magnets with counter directed vectors of the induction and magnetic field strength. The results are shown on figure 3. On the basis of this model we can obtain the direction and magnitude of the induction vectors and strength, and also the force, acted on these magnets. To obtain the results, the simulation of the two magnets with previously specified parameters and changed direction of the coercive force of the one magnet has been done.

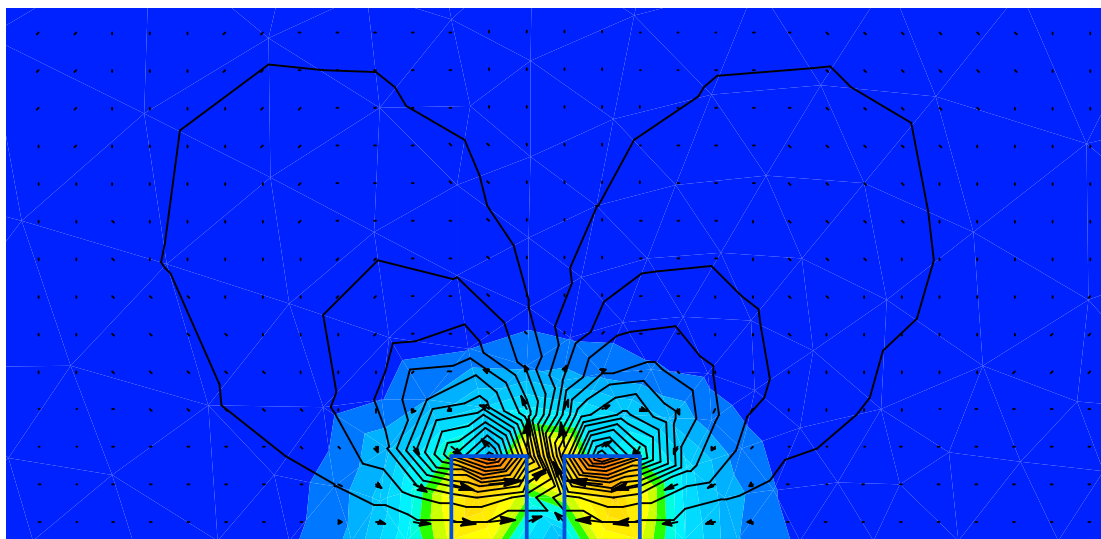


Figure 4. Distribution and direction of the induction vectors

Parameters, obtained from software are precise data of the interaction of the two magnets, which are precisely enough to give the required number of magnets to create the desired strength of their interaction (attraction/repulsion), that allow to have resilient elements of the necessary stiffness to create the compensator of the stiffness with necessary characteristics.

At the modelling of the magnets this software allows investigation of the ferromagnetic materials, such as iron and steel. Results of the modelling of the interaction of the steel cylinder and neodymium magnet are shown on figure 5 and 6. The lines of the magnetic field, which is created from interaction of the magnet and steel, are shown on these figures. The vectors of the inductions and magnetic field are shown also. This model, as previous one, allows to determine the direction and value of the force vector of the interaction of the steel and magnet.

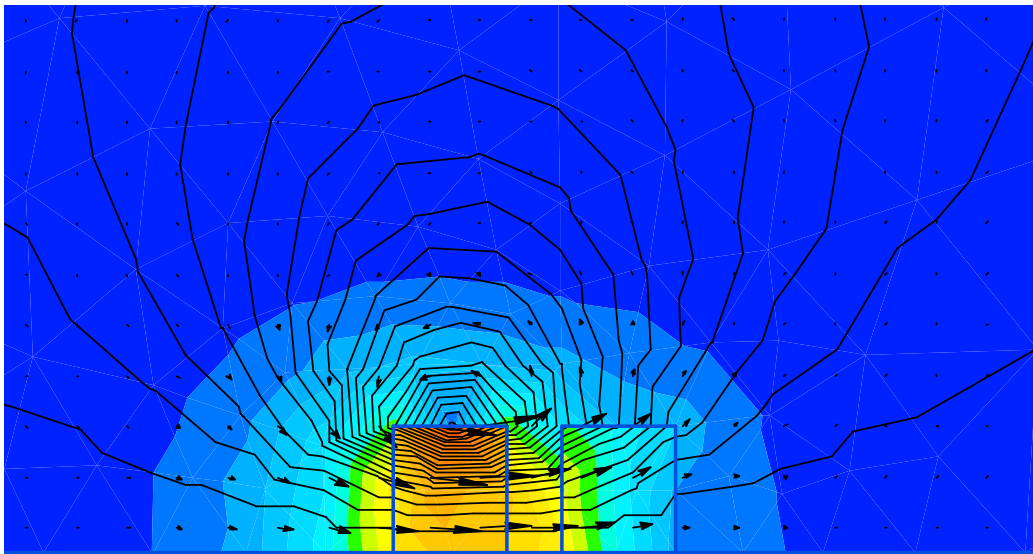


Figure 5. Distribution and vectors of the magnetic field induction of the magnet and steel cylinder

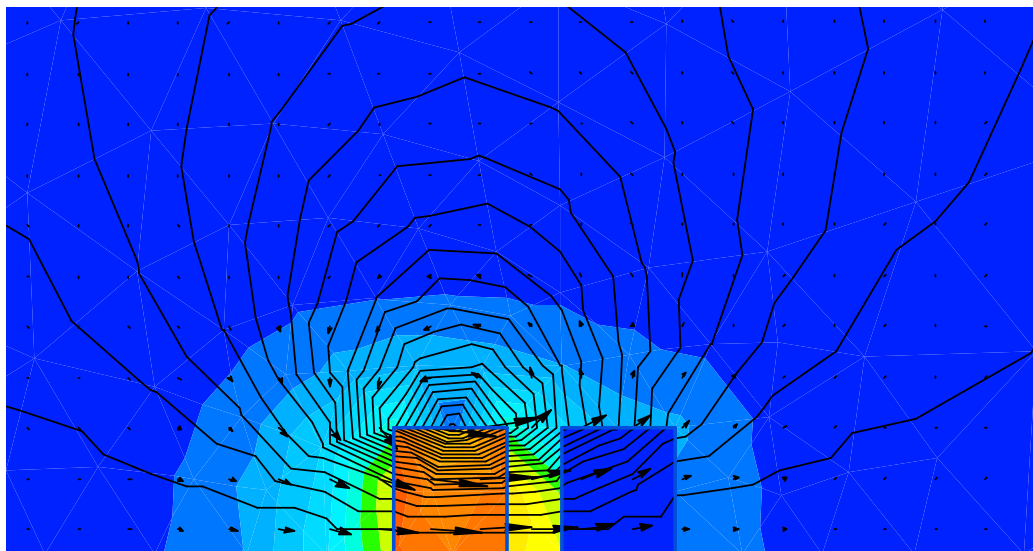


Figure 6. Distribution and vectors of the magnetic field induction of the magnet and steel cylinder

The lines of the elements net are shown on the plots. These elements net are built automatically and it is a basis for solving of the magnetostatics task by finite elements method, and gives the possibility to estimate the heat transfer processes inside of the device. The core of the method of the finite

elements is separation of the finite amount of the sub areas (elements) and calculation of the differential equations for each sub area. In simple case is the first-degree polynomial. Outside of the element the approximation function is zero. The values of these functions on the boards (at the nodes) are solutions.

Conclusion

Based on our results we can make the conclusion, that the software «ELCUT» is efficient tool to find the solution of magnetostatic tasks, one of this is development of the neodymium compensator of the stiffness based on neodymium magnets. The date, which was obtained during the simulation of the interaction of the different magnetic elements, will be the one of the bases for designing of the compensators of the stiffness based on the neodymium magnets.

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