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Calculation Of Non-Stationary Magnetic Field Of The Polarized Electromagnet With The External Attracted Anchor

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Abstract. Approach to modeling of transition process of the polarized electromagnet of a direct current at a fixed value of a working gap through the solution of a problem of nonstationary magnetic field with the attached electric chain in a complex of the ELCUT 6.0 programs (the professional version) is considered. In the studied design of the polarized electromagnet with the external attracted anchor there are two independent magnetic fluxes. The working magnetic flux arises under the influence of the winding magnetizing forces of the managing director. The polarizing magnetic flux is created by two permanent magnets from magnetic NdFeB alloy (neodymium - an iron - pine forest). In the absence of current in a winding the anchor is affected by the attraction force created by the polarizing magnetic flux. Action of the polarized electromagnet depends on size and the direction of the working magnetic flux created by the magnetizing winding force. Considering wide circulation of electromagnets in various areas of the equipment, including the polarized electromagnets, expansion of opportunities of methods of their research in the established and transition processes represents a relevant task. On the basis of the solution of a problem of non-stationary magnetic field of the polarized electromagnet in a complex of programs ELCUT pictures of magnetic field are calculated and his temporary dependences at connection of a winding of management to a source of constant tension are received.

1. Introduction

The research of transition processes in electromagnets at inclusion of a winding on tension of the power supply is among the widespread tasks solved by students on a lecture and practical training when studying disciplines "Theoretical bases of electrical equipment", "Electrical equipment and electronics" and others. The academism of consideration of a training material on this subject often makes an impression at students that questions of transition processes in electromagnets are rather well studied and there is no need of expansion of knowledge for this area. However in fact the situation is different [1]. Electromagnets differ from each other in a variety of constructive decisions and practical use. Calculation of the established and transition process in electromagnets of different function is a kernel of the problem of their optimum design establishing interrelation of design data of electromagnets with power indicators of their work. In the polarized electromagnets the solution of a problem of optimum design becomes complicated existence in their design of permanent magnets. The offered mathematical model of dynamics of movement of an anchor of an electromagnet uses results of numerical calculation of a magnetic field in a complex of the ELCUT programs at the fixed values of a working gap within a course of an anchor and approximation of dependence of inverse inductance of the coil from an anchor course the straight line equation. Realization of the offered algorithm in a

Content from this work may be used under the terms of the Creative Commons Attribution 3.0 licence. Any further distribution of this work must maintain attribution to the author(s) and the title of the work, journal citation and DOI. Published under licence by IOP Publishing Ltd 1 Matlab/Simulink package gives good coincidence to experimental data that confirms legitimacy of the accepted assumptions at creation of model of dynamics of an electromagnet [2].

2. Fundamentals

Transition process at inclusion of a winding of the polarized electromagnet to a source of constant tension at a fixed value of a working gap happens not only in an electric chain of a winding, but also in the magnetic field distributed in the space surrounding winding rounds, the massive steel core (anchor) and a non laminated magnetic core. The physical processes happening in an electric chain and magnetic field of an electromagnet at transition process are among themselves interconnected. Therefore their separate consideration when calculating transition process with use of the assumptions simplifying a task isn't always justified and can not only exceed an admissible error of calculation, but also yield wrong result if not to consider influence of vortex currents in massive steel parts of a design of a magnetic conductor, steel saturation, true geometry of magnetic system of an electromagnet.

In this article calculation of non-stationary magnetic field of the polarized electromagnet with a motionless anchor with a fixed value of a working gap when giving on a winding of constant tension of the power supply is considered. The modern information technologies provided by a complex of the ELCUT 6.0 programs (the professional version) allow to calculate non-stationary magnetic field of the polarized electromagnet with the attached electric chain (fig. 1). When performing calculation of nonstationary magnetic field in a complex of programs ELCUT[3]the following assumptions are accepted: - magnetic field of the polarized electromagnet is plane-parallel;

- magnetic permeability and electric conductivity of the used environments are constants; - in the studied design of the polarized electromagnet the magnetic conductor is made laminate, that is he is taken from stamped sheets of electrotechnical steel therefore in calculation the of steel is small and other than zero. Calculation of non-stationary conductivity magnetic field is made by means of vector magnetic potential. The field of modeling is limited to a rectangle the sizes of 50 mm of 80 mm. Windings of an electromagnet consists of two consistently connected coils. The number of rounds of each coil is equal to 330.



Figure 1. Geometry of model of the polarized electromagnet and the attached electric circuit in ELCUT

3. Theory

Mathematical problem definition is based on the joint solution of the equations describing the magnetic non-stationary field of the polarized electromagnet and an electric chain of a winding at connection her to a source of constant tension under the set entry and boundary conditions in a complex of programs ELCUT [4 - 6]. At the time of switching current is equal in a winding to zero. On borders of settlement field of modeling for all the time of transition process the value of vector magnetic potential is equal to zero. Windows of a task of physical properties of the allocated objects are shown in a complex of programs ELCUT in Table 1.

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N⁰	Material	Property	Value
1	Air	Permeability	1
		Permeability	1
2	Coil 1	Electrical Conductivity, Siemens/m	5.8e+7
		Conductor Scheme	Serial
3	Steel	Permeability	1000
		Eelectrical Conductivity, Siemens/m	0.2
4	Magnet -	Permeability	1
		Coercive Force, A/m	8.55e+5
		Direction	90^{0}
		Electrical Conductivity, Siemens/m	70

4. Results

Results of calculation of non-stationary magnetic field and temporary dependence of current in a winding are shown in fig. 2 and 3.



Figure 2. The picture of magnetic field upon termination of transition process for timepoint 0.1 s





Figure 3. Results of calculation of non-stationary magnetic field of the polarized electromagnet: temporary dependences of current (a) and magnetic flux in the core (b)

5. Conclusions

The developed model of non-stationary magnetic field in a complex of programs ELCUT allows to determine by calculation temporary characteristics of the polarized electromagnet at transition process on the basis of the solution of a chain and field task. The presented mathematical model of the dynamics movements of the armature of an electromagnet, the results of a numerical calculation of the magnetic fields in the complex of ELCUT programs and approximation dependence of inverted coil inductance from the course of the anchor by the equation of a straight line, Possibility to construct an algorithm for solving nonlinear systems of differential equations of dynamics electromagnet during the transient process.

6. References

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