Semifield Mathematical Model of High Field electromagnet

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***Abstract*--Semifield mathematical model of electromagnet is proposed. Interpolar interval of device describes by quazistationary equations of electromagnetic field and other construction remainder by equations of electromagnetic circles. Results of computer simulation are given.**

***Index Terms*--mathematical model, electromagnet, electromagnetic field.**

I. INTRODUCTION

THE measuring of main parameters strong magnetic materials doing on samples very simple geometric form (parallelepiped, cylinder) in reserved magnetic circle, using electromagnet of permanent current with relatively small interpolar interval (10-30 mm) and complicated configuration of pole tips. Electromagnet construction’s must provide field magnetic tension of H = 2000-2500 field kA/m and high his homogeneous in interpolar space [1]. Designing electromagnet of strong fields, which satisfies the set requirements, calls for deep topography analysis of magnetic field (distribution of vectors **B** and **H**) and calculation of his non-homogeneous distribution in set volume. This lends a possibility right to fix on sizes of pole tips and size of aerial interval. To solve such a task only possible on foundation of mathematical model of electromagnet, which sufficiently exactly describes a physical process.

By modeling object is continuous electromagnet with cylindrical poles and permenduring tips (27KX). Construction of electromagnet is given on fig. 1.

Magnetic systems consist of yoke 1, poles 2, pole tips 3 and winding of electromagnet 4. Electromagnet has two sections winding, summary active resistance of which attached to successive puts together r = 2,2 Ω, number of coils w = 2200.

II. MATHEMATICAL MODEL

By us worked up semifield mathematical model for computation of transitional and stationary processes in magnetic system on the combination of theory of electromagnetic circles and the theory of electromagnetic field. Methods of electromagnetic field use only for description of physical processes in space between poles of electromagnet magnet system.

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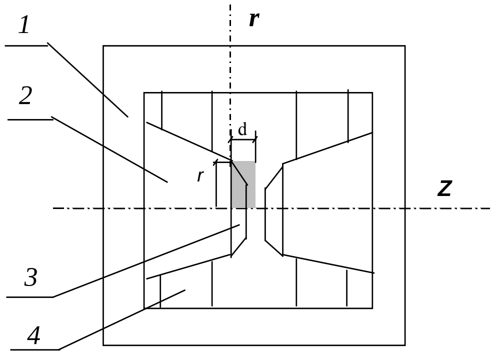

Fig. 1. Magnetic system of electromagnet

The main differential equation for computation of electromagnetic field in interpolar space is formed relatively of vector potential in cylindrical co-ordinates system [2]

$$\frac{\partial A}{\partial t}=\frac{1}{\gamma}\left(\frac{\partial \nu}{\partial z}\frac{\partial A}{\partial z}+\nu\frac{\partial^2 A}{\partial z^2}+\frac{\partial \nu}{\partial r}\frac{\partial A}{\partial r}+\nu\frac{\partial^2 A}{\partial r^2}\right)+$$
$$+\frac{1}{\gamma}\left(\frac{1}{r}\left(\frac{\partial \nu}{\partial r}A+\nu\frac{\partial A}{\partial r}\right)-\frac{1}{r^2}\nu A\right) \qquad (1)$$

where A is axial component of vector potential of electromagnetic field; γ is material conductivity in axial direction, ν is reverse magnetic permeability (reluctivity), r, z are spatial coordinates.

The equation (1) describes electromagnetic field in zones of ferromagnetic tips (shaded zones on the fig. 1). In aerial spacious integration zones equation (1) simplify

$$0=\nu_0\left(\left(\frac{\partial^2 A}{\partial r^2}+\frac{1}{r}\frac{\partial A}{\partial r}+\frac{\partial^2 A}{\partial z^2}\right)-\frac{A}{r^2}\right) \qquad (2)$$

where ν_0 is reverse magnetic permeability of air.

Taking into account axial and radial symmetry of electromagnetic field in cross section of magnetic system equation (1), (2) solve on the interpolar interval (Fig. 2).

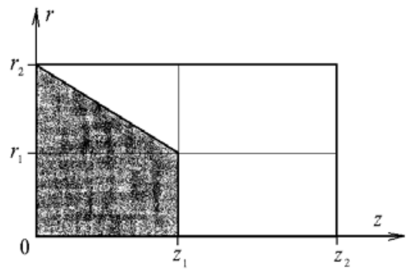

Fig. 2. Integration zone

Boundary condition for equation (1), (2) in axial direction along overhead border has appearance

$$A(r_2, z, t) = \frac{\Phi(t)}{2\pi r_2} \quad (3)$$

where Φ is magnetic flux of magnetic conductor.

Boundary conditions along other remainder borders of integration set as

$$\frac{\partial A(r,0,t)}{\partial z} = \frac{\partial A(r,z_2,t)}{\partial z} = 0\,,\ \frac{\partial A(0,z,t)}{\partial r} = 0 \quad (4)$$

Expressions for finding of components and vector module of magnetic induction have appearance

$$B_r = \left(\frac{\partial A}{\partial r} + \frac{A}{r}\right);\ B_z = -\frac{\partial A}{\partial z};\ B = \sqrt{B_r^2 + B_z^2}\,. \quad (5)$$

Making use of the spatial vector module distribution of magnetic induction B to find significance of reverse magnetic penetrability (relactivity) in zones with ferromagnetic medium

$$\nu(B) = \begin{cases} 1000, & |B| \le 1\ T; \\ 1000/B - 508{,}7(1 - B^4), & 1 < |B| < 1{,}5\ \ T; \\ 36607 - 50900/B, & 1{,}5 \le |B|\ T. \end{cases} \quad (6)$$

Significance of vector potential on zones border with diverse media characteristics descriptions to find after expression [3]

$$A_{i,k} = \frac{\left(\nu^- A_{i,k-1} + \nu^+ A_{i,k+1} / \Delta r\right)\sin\alpha +}{\left(\nu^- + \nu^+\right)\sin\alpha / \Delta r - \left(\nu^- + \nu^+\right)\cos\alpha / \Delta z}$$
$$+ \frac{\left(\nu^+ A_{i,k+1} - \nu^- A_{i,k-1} / r_{i,k}\right)\sin\alpha}{\left(\nu^- + \nu^+\right)\sin\alpha / \Delta r - \left(\nu^- + \nu^+\right)\cos\alpha / \Delta z} -$$
$$- \frac{\left(\nu^+ A_{i+1,k} + \nu^- A_{i-1,k} / \Delta z\right)\cos\alpha}{\left(\nu^- + \nu^+\right)\sin\alpha / \Delta r - \left(\nu^- + \nu^+\right)\cos\alpha / \Delta z}, \quad (7)$$

where ν^-, ν^+ are relactivites to the left and to the right side from border; i, k are indexes, which determine the knots of net; α is corner size between zones border and co-ordinate axis z.

Differential equation of induction coil has appearance

$$\frac{d\Psi}{dt} = u - Ri\,, \quad (8)$$

where Ψ, u, i are full linkage, voltage and current of coil; R is resistance.

Induction coil current to find so

$$i = (V + \rho\Phi)/w\,, \quad (9)$$

where ρ is magnetic resistance of concentrated ferromagnetic; w is number of coils; V – magnetic voltage.

Full linkage Ψ consist from main magnetic flux Φ and dissipation fluxes

$$\Psi = L_\sigma i + w\Phi\,, \quad (10)$$

where L_σ is inductance of dissipation.

Having solved together equation (9) and (10), we obtain expression for calculation of magnetic flux

$$\Phi = \frac{\Psi - L_\sigma V/w}{w + L_\sigma \rho / w}\,. \quad (11)$$

The magnetic voltage on border of itegration zone we find according to expression

$$V = \nu_0 \int_0^{z_2} B_z(r_2, t)\,dz\,. \quad (12)$$

III. SIMULATION RESULTS

On fig. 3 is shown spatial module distribution of magnetic field intensity. Maximum significance of magnetic field intensity acquires in aerial space between poles.

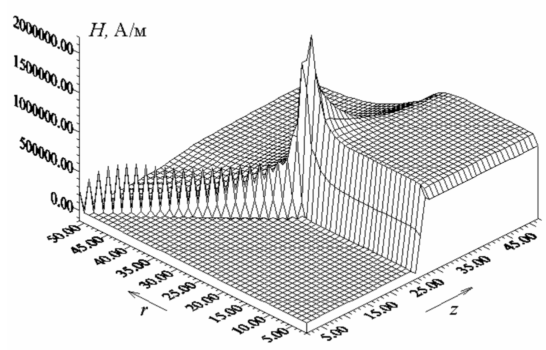

Fig. 3. Distribution of filed magnetic intensity in fixed moment

On results of computer simulation and experimental researches is possible to optimize the electromagnet construction, in particular to fix on length and diameter of working verge and others like that.

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