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Disturbance of rotating magnetic field by magnetic impurities

***Abstract**. The six pole inductor with magnetic impurities in active zone is investigated. The finite element method is used to solve magnetostatic 2-D problem. The symmetrical three-phase alternating current system is simulated to create rotational magnetic field. The influence of group magnetic impurities to the magnetic flux density mean value and magnetic energy is investigated in the inductor active zone. The active zone mean magnetic flux density value and magnetic energy are calculated for each time moment.*

Streszczenie.** Wpływ zanieczyszczeń magnetycznych w strefie aktywnej na wirujące pole magnetyczne w sześciobiegunowym układzie wzbudzenia został poddany analizie w tym artykule. Zastosowano metodę elementów skończonych do rozwiązania magnetostatycznego dwuwymiarowego układu równań, który pozwolił na określenie gęstości strumienia magnetycznego i energii magnetycznej.**(Zakłócenia wirującego pola magnetycznego spowodowane zanieczyszczeniami magnetycznymi)

Keywords: rotating magnetic field, magnetic flux density, magnetic particles, inductor
Słowa kluczowe: wirujące pole magnetyczne, gęstość strumienia magnetycznego, cząstki magnetyczne, stojan.

Introduction

The use of the rotating magnetic field for technological purposes enlarges in the latter years. There is very wide area: sewage treatment, oilfield chemistry, the crushing of different materials, pharmacological industry, food industry, production of cosmetic, chemical industry and other. We name the processing of different materials by rotating magnetic field as process activating and the area in which the process activating performs as active zone.

The some concentration of ferromagnetic materials is used frequently in the active zone of technological device with rotating magnetic field. It is named as vortex layer because there is proceeded intensive movement of the magnetic particles in different directions. The mean magnetic flux density and mean magnetic flux values should be investigated inside inductor in case of ferromagnetic materials are used in active zone. The additional magnetic particles in the inductor active zone could grind or mill materials. However, uniform distributed magnetic field in the inductor active zone would be distorted due to magnetic particles.

Mathematical background

The aim of this paper is numerical simulation of salient-pole inductor fig. 1. Computation area is two-dimensional. Coils U, V and W are excited by symmetrical three-phase current system:

$$\begin{cases} i_{\mathrm{U}} = I_{\mathrm{m}} \sin(\omega t + \psi_{\mathrm{i}}); \\ i_{\mathrm{V}} = I_{\mathrm{m}} \sin(\omega t + \psi_{\mathrm{i}} - 120^{o}); \\ i_{\mathrm{W}} = I_{\mathrm{m}} \sin(\omega t + \psi_{\mathrm{i}} + 120^{o}); \end{cases} \tag{1}$$

here ψ_{i} is current initial phase, I_{m} is current magnitude. Pairs of poles are shifted on a circle of an inductor by 120º. Stroke-through area of magnetic circuit cross section in fig. 1 represents the electric steel of magnetic circuit.

Numerical simulation of two-dimensional magnetic field of an inductor is performed. Governing equation of the field is the following:

$$\nabla \times (\mu_0^{-1} \mu_{\mathrm{r}}^{-1} \nabla \times \mathbf{A}) = \boldsymbol{J}_{\mathrm{z}}^{e} e_{\mathrm{z}}; \tag{2}$$

here $\mathbf{A}$ – the vector magnetic potential; $\boldsymbol{J}$ – external current density z component; μ_0 is permeability of vacuum; μ_{r} is magnetic permeability.

Current density in each coil of the pole (Fig. 1) is linearly dependent on the current i:

$$J = \frac{i \cdot N}{S_{\mathrm{c}}}; \tag{3}$$

here N – number of turns in the unit area of cross section of the coil, S_{C} – an area of cross section of the coil.

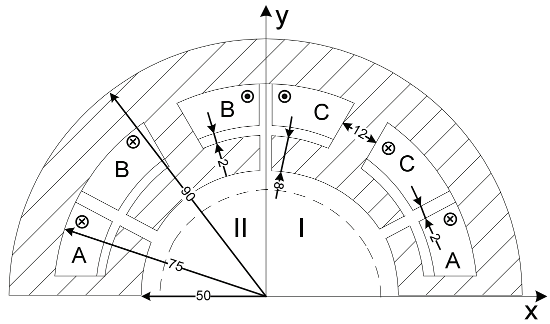

Fig. 1. View of inductor cross section

The coil fill factor is not evaluated in the article. Substituting values of phase currents from equation (1) into (3) values of current density may be determined for each instant of time.

The rotational magnetic field is computed using (2). The calculations of three different cases are performed: three particles in the active zone and five particles in the active zone. The equations (4-5) are used to calculate magnetic energy and magnetic flux.

$$W_{\mathrm{m}}(t) = \frac{1}{2} \int_S \vec{B}(t) \cdot \vec{H}(t) \mathrm{d}\vec{S}; \tag{4}$$

$$\Phi_{\mathrm{m}}(t) = \int_{S_A} \vec{B}(t) \mathrm{d}\overrightarrow{S_A}; \tag{5}$$

here $B(t)$ and $H(t)$ - the active zone magnetic flux density and magnet field for each time moment; S - cross section of active zone; S_{A} – cross section of the cylinder, surrounding the active zone.

The stator induced magnetic field varies in time. The magnetic particles influence on magnetic flux and magnetic field energy in active zone are evaluated as the mean value of time average. The magnetic energy $\bar{W}_{\mathrm{m}}$ is evaluated using (6) and the mean value of integral of magnetic flux density $\bar{\Phi}_m$ is evaluated using eq. (7).

$$M_{W\mathrm{m}} = \frac{1}{T} \sum_{t=0}^{T} W_{\mathrm{m}}(t); \tag{6}$$

$$M_{\Phi \mathrm{m}} = \frac{1}{T}\sum_{t=0}^{T}\Phi(t). \tag{7}$$

Farther on the investigations of the magnetic impurities in active zone influence to (4-6) magnitude are represented.

Investigation of group of particles influence to distribution of magnetic field in active zone

The parameters of model in fig. 1 are show in millimeter. Relative permeability of steel is $\mu_{\mathrm{r}} = 1000$. The magnitude of phase current I_{m} = 4 A, the number of turns in each pole phase winding is 350. The calculations are performed in time range of 0÷0.02s using time step 0.001s. The group consists of three and five particles are placed in 5 different positions in active zone as depicted in fig. 2. Each circular particle diameter d = 2 mm and permeability is μ_r =1000.

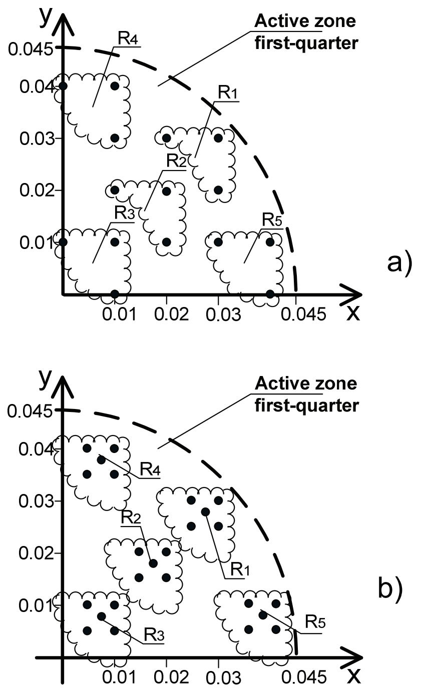

Fig. 2. Location points R_n of magnetic particles in the active zone I quarter

The magnetic flux and energy mean values are calculated using equations (3-4). The main task was to investigate the group of particles influence to distribution of magnetic field in the active zone.

The placement of group 1, 4 and 5 is in the same active zone radius. The mean flux and energy values at the points R_{n} = 1, 4, 5 are not equal as could be seen from fig. 3-4. This phenomenon could be described by small asymmetry of inductor magnetic system.

The deviation of magnetic flux between points 1 and 2 (fig. 2b) is less than 0.05% for three impurities (0.13% for five impurities) and is negligible. The deviation of magnetic energy at the same points is about 0.6% for three and 0.04% for five impurities. So the steady - state operation parameters of the inductor would be with small deviation.

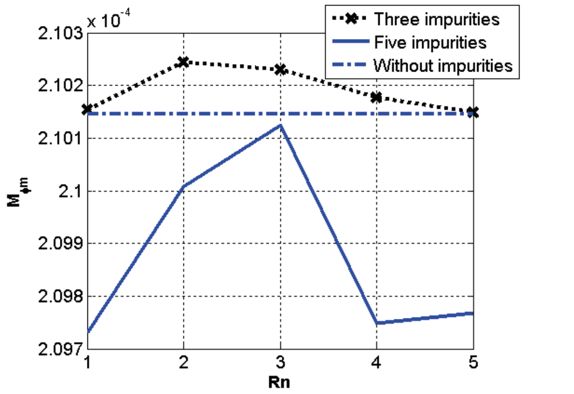

Fig. 3. The mean magnetic flux dependence on magnetic particles location point R_n

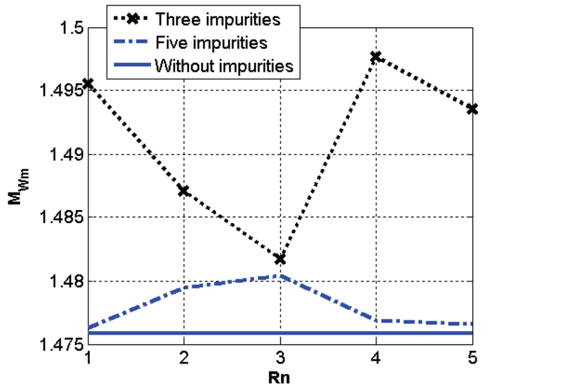

Fig. 4. The mean magnetic field energy dependence on magnetic particles location point R_n

Conclusions

1. The group of magnetic particles in the active zone increase the magnetic flux and energy comparing with flux and energy without particles.
2. The magnetic energy in active zone deviation depends on placement of group of particles. However, such deviation is less than 1%.
3. For investigation geometric influence of magnetic impurities to magnetic flux density distribution in inductor active zone, can the different particle shapes by ellipsoid approximate. This shape allows to generalize bodies of very different form. The limiting cases of ellipsoid are sphere, disc, cylinder, lamella and other.

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