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Analysis of Errors in Electromagnetic Sensors

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Abstract:

On the bases of the given dimensions of magnetic system, necessary to calculate a parameters of magnetic system,which let to obtain: first, maximum possibles working magnetic flux, and, secondly, desired degree of variability of the working magnetic voltage between of rods of magnetic cores (area of locations for measuring winding).

Keywords: magnetic system, electromagnetic transducer, parallel magnetic rods, magnetic circuit and three-phases current.

In practice often need to dipcide a solve of problems as to find optimal structural and magnetic parameters of electromagnetic transducers of three-phases current, with characteristics (for example, error) must have a minimum value. In this case, as a rule, in addition alley for input values, sets overall dimensions of electromagnetics transducer of three-phases current. Thus, the task: for given values of the operating range and the overall dimensions of the sensor design dimensions of the individual units on which possible obtain maximum consideration characteristics, such as a sensitivity.In this article proposed methodology of calculating of optimal parameters of magnetic system of the electromagnetic transducers of three-phases current with foal parallel rods, which geometric dimensions shown in fig. 1 [1].On the bases of the given dimensions of magnetic system, necessary to calculate a parameters of magnetic system, which let to obtain: first, maximum possibles working magnetic flux, and, secondly, desired degree of variability of the working magnetic voltage between of rods of magnetic cores (area of locations for measuring winding) [1-5].

To obtain of maximum working magnetic flux for given values of ampere-winds of the measure winding can be minimum value of the scattering coefficient of the magnetic field [4,7,9]. The degree of variability of the magnetic operating voltage along the length of the parallel magnetic rods of electromagnetic transducer of three-phases current (for the locations of measuring winding) can be defined as

$$\varepsilon_U, \% = \left[\left(1 - \frac{1}{ch\beta}\right) \Big/ \left(1 + \frac{sh\beta}{\beta ch\beta}\right) \right] 100\% . \ (1)$$

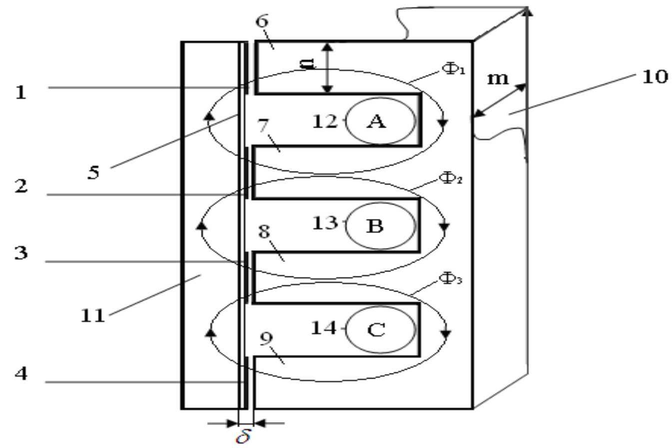

Fig. 1. The magnetic system of electromagnetic transducer: 1, 2, 3 and 4 - measuring secondary windings; 5 - insulation plate; 6, 7, 8 and 9 - four rods and 10 a common magnetic base; 11- core; 12 (phase A), 13 (phase B) and 14 (phase C) - the primary windings.

From equation (1) and graphics (fig.2) shows $\varepsilon_U = f(\mu)$ that ε_U - depends in the air cleans δ (fig. 2). Therefore, to find minimum of error for each chart is quite a challenge and its solution is necessary to consider a optimization. For define to optimization criterion and restrictions need structural dimensions of the magnetic system [2,11,13]. The sensitivity's of electromagnetic transducers depends on the phases current K_S, which should be taken as a criterion in the first stage of optimization. Since a significant change in the magnetic voltage in the working area of the magnetic system - one of the main reasons for the low accuracy of electromagnetic transducer of three-phases current, the optimization criterion of the second step need to select ε_U for a reduction of errors (sufficient condition $\varepsilon_U \leq 5\%$) values [8-12].

Generally, index optimization will be written as:

$$I_i = I(X, Y). \ (2)$$

Here, vector $X = \{X_1, X_2, ..., X_n\}$ - the constructive size and design parameters of magnetic system, which not have subject to optimization procedure, vector $Y = \{Y_1, Y_2, ..., X_m\}$, which Y_i - the design dimensions and parameters of the magnetic system, defining the optimization process: i.e. δ and μ. Thus, after the optimization procedure results dimensions and parameters should be minimized, K_S and ε_U while maintaining other desired characteristics within specified requirements [12-15].

At the same time in the design dimensions and parameters imposed constraints, that are dependent on the application. In particular, for magnetic system with parallel rods can be applied the following linear constraints:

$$5 \cdot 10^{-4} m \leq \delta \leq 2 \cdot 10^{-3} m, \ 10^2 \leq \mu \leq 1{,}5 \cdot 10^4, \ 1 \leq \mu_з \leq 10^2 .$$

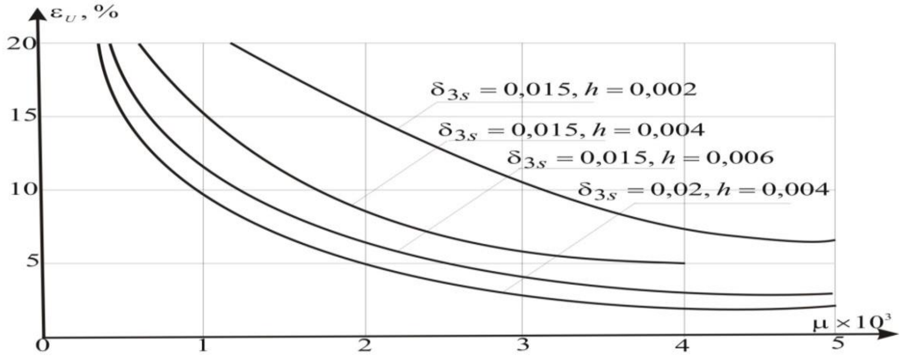

Fig. 2. Dependence of the degree of volatility of all working voltage of the magnetic permeability of steel

Optimality criterion, according to equation (2) is a nonlinear function of the design parameters of magnetic system of the electromagnetic current transducers. On the basis, above criteria of optimization provide error reduction in the conversion of electrical current in the magnetic pull in magnetic circuit of the current transformation of the electromagnetic transducer. The equations of the static characteristic of elementary transformation of the electric current in magnetic structure of the electromagnetic voltage current converter is described as follows:

$$U_{\mu} = K_{I_э U_{\mu}} I_э,\ U_{\mu} = wIэ. \quad (3)$$

Given impact of sources of error equation (2) is as follows:

$$U_{\mu\gamma} = (K_{I_э U_{\mu 0}} + \Delta K_{I_э U_{\mu}}) I_э, \qquad (4)$$

where $K_{I_э U_{\mu}}$ - coefficient of interchain link between the primary electric current I and magnetic intensity (magneto motive force) U_{μ}, $\Delta K_{I_э U_{\mu}}$ - a deviation from the predetermined number of turns, which is almost equal to zero; $I_{э\gamma}$ - current of the excitation coil - a primary electrical network with errors.

If primary current of electrical current unstabilized, additive some error, i.e.

$$I_{э\gamma} = (I_э \pm \Delta I_э)(1 + \gamma_{\alpha_R}), \quad (5)$$

and absented from temperature error multiplicative, error component is will equal to zero. Substitute (4) to (5), and neglecting the second any receive.

$$U_{\mu\gamma} = K_{I_э U_{\mu 0}} I_э + \Delta K_{I_э U_{\mu}} I_э + K_{I_э U_{\mu 0}} \Delta I_э. \quad (6)$$

The relative error is determinate from the formula

$$\gamma_{I_э U_{\mu}} = \frac{\Delta U_{\mu\gamma} - U_{\mu 0}}{U_{\mu 0}} = \frac{\Delta K_{I_э U_{\mu}}}{K_{I_э U_{\mu}}} + \frac{\Delta I_э}{I_э} = \gamma_{I_э U_{\mu}(\Delta K)} + \gamma_{I_э U_{\mu}(\Delta I)}. \quad (7)$$

For the component $K_{I_э U_{\mu}} \Delta I_э$ affected from external field. In production areas with high-voltage installations external magnetic field for $10^{-5} - 0{,}5 \cdot 10^{-4}$ Tesla [12,14]. This area can be induce in the windings of the electromagnetic current transducer e.m.f which equal

$$e = 2\pi f w S_0 B_m,$$

where S_0 - area of winding;

B_m - amplitude of magnetic induction of external field.

Well known [2], what in the magnetic flux density of the electromagnetic current transformers ranging from 0.01 to 1 Tesla. The proportion of external magnetic fields in absence of electromagnetic screen (0.005 - 0.05)%. When the screening body electromagnetic transducer current magnetic induction field inside the screen is determined as:

$$B_{эк} = B_m e^{-(\delta\sqrt{2\pi f\mu/2\rho})},$$

where in δ, ρ - respectively and electrical resistance of the material.

The share of external magnetic fields of two magnitude reduced by screening or differential circuits of electromagnetic current transducer [11]. Therefore, we can neglect the effect of errors on the external magnetic field.

Another component of the error, a part of the equation (7) is determined

$$\gamma_{I_{э\Delta}U_\mu} = \frac{K_{I_э U_\mu} \Delta I_э}{K_{I_э U_\mu} I_э} = \frac{\Delta I_э}{I_э}. \quad (8)$$

According to [12], the distribution of elemental electromagnetic conversion error which equal:

$$\gamma_{I_э U_э(\Delta I)} = \pm\left[\gamma_{I_э U_э} + \gamma_{U_э}\left(\left|\frac{U_{эm}}{U_{эв}}\right| - 1\right)\right].$$

When used a constant current, error is negligible, and the voltage stabilization current is determined by equation:

$$\Delta I_э = I_э(1 \pm \gamma_{\alpha_{\rho_{мед}}}).$$

As the results of practical research, for the case of aluminum wire, as the field of windings of the electromagnetic current transducer ($\alpha_\rho = 0{,}1 \cdot 10^{-4}$ $grad^{-1}$) error $\gamma_{I_{э\Delta}U_\mu}$ of 0.015% will change at 10^0C of temperature.

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