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THEORETICAL AND EXPERIMENTAL RESEARCHES OF VOICE-FREQUENCY SIGNAL CURRENT TRANSFER IN RAIL LINES

In this work the results of theoretical and experimental researches for transfer of voice-frequency signal current in rail lines and electromagnetic field distributions around rails are presented. The mathematical model was realized as the computer program. The computer program for modelling of electromagnetic processes in rail lines proved the satisfactory coincidence of experimental and theoretical results.

TEORETYCZNE I EKSPERYMENTALNE BADANIA PRZESYŁU SYGNAŁU O CZĘSTOTLIWOŚCI GŁOSOWEJ W LINIACH KOLEJOWYCH

W niniejszej pracy przedstawiono wyniki badań teoretycznych i doświadczalnych przesyłu prądu sygnalizacyjnego o częstotliwości głosowej w liniach kolejowych i rozkład pola elektromagnetycznego wokół szyn. Opracowano model matematyczny realizowany jako program komputerowy. Program komputerowy do modelowania procesów elektromagnetycznych w liniach kolejowych okazał się zadowalającym połączeniem wyników doświadczalnych i teoretycznych.

1. INTRODUCTION

For the organization of high-speed train movement on existing low speed railways it is necessary to improve the automatic locomotive signal system for transfer on rail lines of the additional multiple-valued information. For this purpose it is necessary to developed new methods of coding of the information on physical and logic levels. Therefore a problem of transfer and noise protection of the information transferred by rail lines into locomotive cab is important for practice.

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2. INTRODUCTION

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3. THE PURPOSE OF THE WORK

The purpose of the present work is development of mathematical model described transfer of a signal current of a voice-frequency range on rail lines, and also EDF, directed by this current in reception coils of a locative. For achievement of this purpose in work the problem of calculation of an electromagnetic field induced around a rail line is solved at course of a signal current of a voice-frequency range.

4. MATHEMATHICAL MODEL

The sizes of the gauge of a magnetic field are smaller the linear sizes of a rail, therefore the gauge is better to have in the field of the maximal intensity of the magnetic field created by currents in a rail, taking into account its heterogeneity in near area around of a rail.

Intensity of a magnetic field is integration on volume V of a rail with a current.

$$\overline{H}(Q) = \frac{1}{4\pi}\mathrm{rot}_Q \int_V \frac{\overline{\delta}(M)}{r_{QM}} dV_M = \frac{1}{4\pi}\int_V \frac{[\overline{\delta}(M), \overline{r}_{QM}]}{r_{QM}^3} dM,$$

where:

Q - a point in which it is calculating $\overline{H}$

M - a point of the center of elementary volume dV_M with density of current $\overline{\delta}(M)$

r_{QM} - the module of the vector which has been lead from a point Q in point M.

In case of a stationary field of currents, when $rot_M \overline{\delta}(M) = 0$

$$\overline{H}(Q) = \frac{1}{4\pi}\int_V [\overline{\delta}(M), \mathrm{grad}_M \frac{1}{r_{QM}}] dV_M =$$

$$= -\frac{1}{4\pi}\int_V \mathrm{rot}_M\left(\frac{\overline{\delta}(M)}{r_{QM}}\right) dV_M + \frac{1}{4\pi}\int_V \frac{\mathrm{rot}_M \overline{\delta}(M)}{r_{QM}} dV_M = -\frac{1}{4\pi}\int_V \mathrm{rot}_M\left(\frac{\overline{\delta}(M)}{r_{QM}}\right) dV_M,$$

considering, that

$$Q \notin V \text{ and } \int_V \mathrm{rot}_M \bar{a} dV = \oint_S [\bar{n}, \bar{a}] dS$$

and also

$$\bar{H}(Q) = -\frac{1}{4\pi} \oint_S \frac{[\bar{n}_M, \bar{\delta}(M)]}{r_{QM}} dS$$

The configuration of a magnetic field in area around of a rail can be found a numerical method (Fig.1).

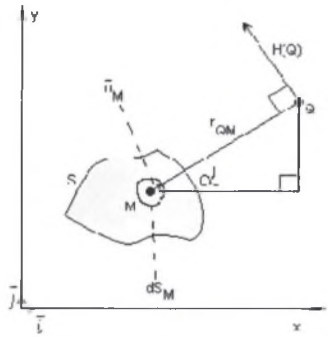

Fig.1. To calculation of intensity of EMF in a point

$$[\bar{n}_M, \bar{\delta}(M)] = \begin{vmatrix} \bar{i} & \bar{j} & \bar{k} \\ n_{Mx} & n_{Mx} & n_{Mz} \\ 0 & 0 & \delta_{Mz} \end{vmatrix} = \bar{i} \sin\alpha\delta_M - \bar{j}\cos\alpha\delta_M = \delta_M(\bar{i}\sin\alpha - \bar{j}\cos\alpha)$$

$$|\bar{r}_{QM}| = \sqrt{(x_Q - x_M)^2 + (y_Q - y_M)^2}$$

Whence we have by virtue of a principle of superposition:

$$\overline{H_X}(Q) = -\frac{1}{4\pi} \oint_S \frac{\delta(M)\cos(\alpha)}{\sqrt{(x_Q - x_M)^2 + (y_Q - y_M)^2}} dS = -\frac{1}{4\pi} \oint_S \frac{\delta(M)(x_Q - x_M)}{(x_Q - x_M)^2 + (y_Q - y_M)^2} dS$$

$$\overline{H_Y}(Q) = -\frac{1}{4\pi} \oint_S \frac{\delta(M)\sin(\alpha)}{\sqrt{(x_Q - x_M)^2 + (y_Q - y_M)^2}} dS = -\frac{1}{4\pi} \oint_S \frac{\delta(M)(y_Q - y_M)}{(x_Q - x_M)^2 + (y_Q - y_M)^2} dS$$

5. RESULTS OF MODELING

For modeling electromagnetic processes in a rail line at course of alarm current on the basis of the offered mathematical model the program has been developed. Some results of modeling are submitted on Fig.2.

On Fig.2 distribution of intensity of a magnetic field around of a rail is resulted. Apparently from figure, the greatest values of intensity of a magnetic field around of a rail created by a current are in the area of 1 and 2.

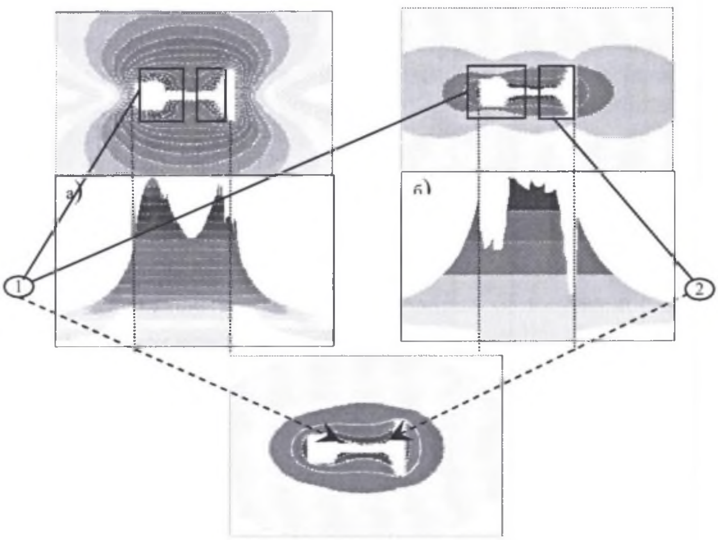

Fig.2. Distribution of intensity of a magnetic field around of a rail
(and - a X-making, - a Y-making, in - the module of vector H)

For an estimation of influence of superficial effect, we research a field around of a rail, the density of a current in which is distributed non-uniformly.

Taking into account, that intensity of a field in any point around of a rail changes with frequency of a current in a rail, and setting area of a nonzero current in section of a rail we receive dependence directed in framework EDF (Fig.3) from the area of zero density of a signal current.

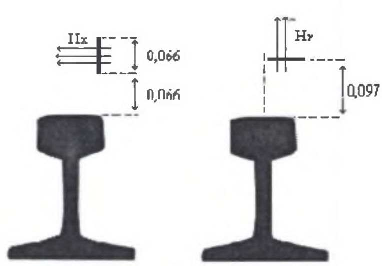

Fig.3. Arrangement of contours concerning a rail

A result of calculations the analysis of influence of distribution of density of a current in a rail on a configuration and size of a magnetic field around of a rail (Fig.4).

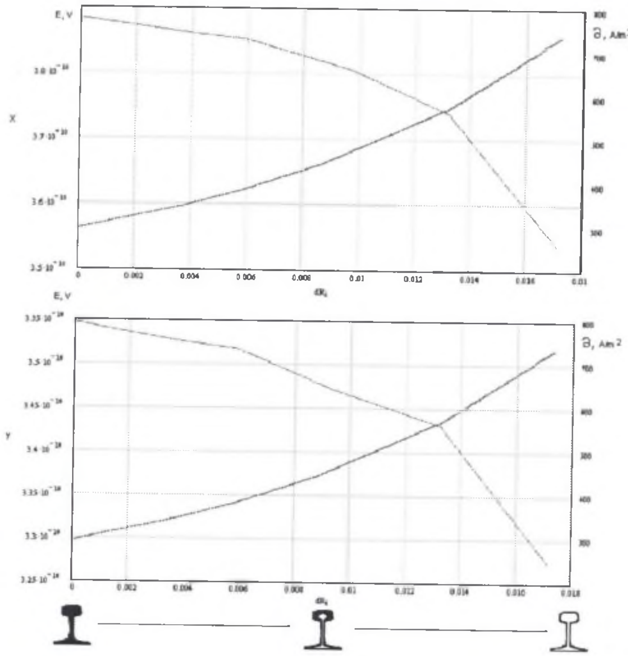

Fig.4. Dependence directed in coils (X, Y) EDF and density of a current in rails from the area of zero density of a current in section of a rail

Fidelity of the lead researches has proved to be true experimentally (Fig.6) - researches were carried in area 2 (Fig.2.) the air coil at which position concerning edge of a rail (Fig.5) varied.

Fig.5. Arrangement of the coil concerning a rail

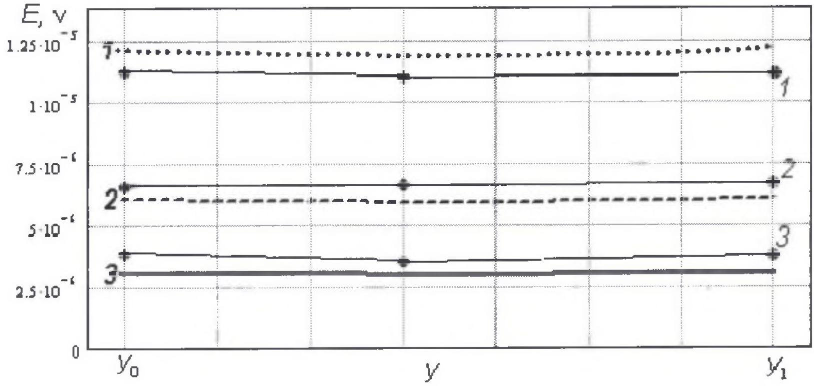

Fig.6. Dependence directed EDF in the coil with the air core from position of the coil

Fig.6 – the curves **1, 2, 3** are determinate theoretically, *1, 2, 3*-experimentally on frequencies 25, 50 and 100 Hz accordingly.

6. CONCLUSION

In work the mathematical model describing distribution of an electromagnetic field around of a rail with the account skin effect is developed.

On the basis of this model are made the computer program for calculation and modeling of distribution of an electromagnetic field around of a rail, and also directed in contours EDF at various arrangements of contours near a rail.

The modeling have shown, that the electromagnetic field around of a rail has a complex configuration, places of the greatest intensity of a field are shown, and also, that on distance of 0.01 m from a rail X and Y making H-lines of a magnetic field are approximately equal.

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