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MAGNETIC FIELD OF A REAL INDUCTOR OF INDUCTION FURNACES

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Abstract
This article is devoted to the study of the magnetic field of a real inductor in 6 ton induction furnaces during the smelting of steel grade 20GL at the subsidiary foundry and mechanical plant “LMZ” in Tashkent. This article is devoted to the study of the magnetic field of a real inductor and the filling factor of the inductor in order to increase the service life of the lining and increase the number of melts, which will lead to a more stable operation of the furnace itself and an increase in the productivity of the furnace metal.

Keywords : inductor design , coil, current deck, inductor losses , magnetic leakage , active power, reactive power, coefficients

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1. INTRODUCTION

To determine the magnetic field of a real inductor and the filling factor of the inductor, the location of the magnetic field lines of a multi-turn inductor made of a round and square conductor was used.

Inductor filling factor

In the designs of inductors, round, square, rectangular and oval busbar profiles are used; coils are connected in parallel (coil over coil, coil within coil in the same insulation, or each branch of the coil is individually insulated).

The square sections of the inductor tube are most appropriate when constructing multi-turn induction coils (Fig. 1) [4].

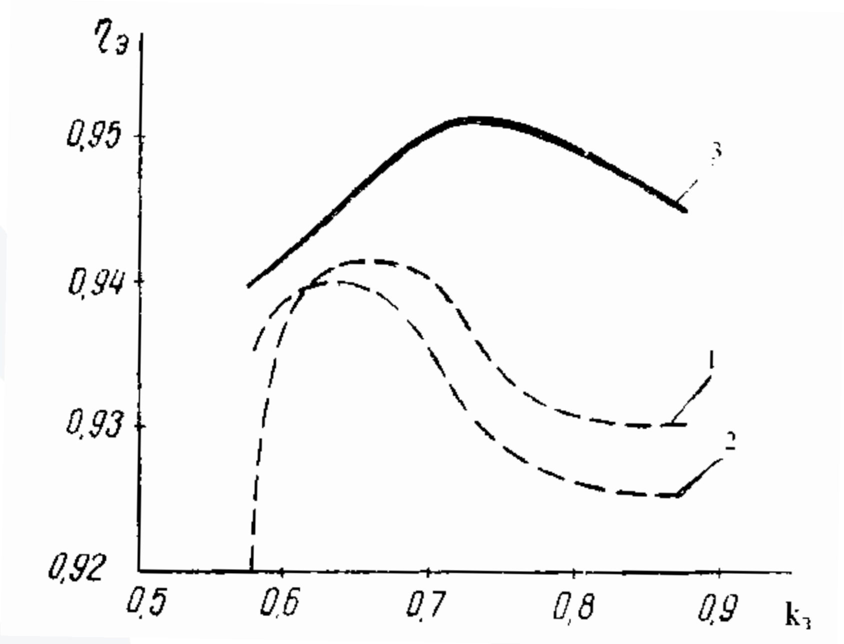

Figure 1- Dependence of electrical efficiency . $\eta_э$ on filling factor and coil profile: 1-round coil, 2-rectangular, 3-square

2. METHODS

A real inductor consists of several turns, which are placed with some gap to provide electrical isolation. In this case, the actual flooring of the current in the inductor increases, which entails an increase in active power losses P_i and an increase in the reactive power of the inductor Q_i. If the average value of the current flooring in the entire inductor height h_i is equal to

$$I_{i1} = \frac{(IN_1)}{h_i} = \frac{(IN_1)}{N_i \tau_{\text{в}}} = \frac{I}{\tau_{\text{в}}}, \quad (1)$$

where $\tau_в$ is the turn pitch of a cylindrical multi-turn inductor, then the flooring of the current in each turn with a height is $h_в$

$$I_{в1} = \frac{I}{h_в}, \qquad (2)$$

From here

$$I_{в1} = I_{и1}\frac{\tau_в}{h_в} = \frac{I_{и1}}{k_з}, \qquad (3)$$

where $k_з = \frac{h_в}{\tau_в}$ is the filling factor of the inductor.

In an ideal inductor made of a square wire (Fig. 2b) with a coil height equal to the inductor pitch ($k_з = 1$), there is no magnetic field distortion. With a decrease $k_з$, magnetic field distortion is observed, its inhomogeneity (violation of the parallelism of magnetic field lines) increases near the gaps between the turns and Accordingly, the area of the "active" surface increases the power of electrical losses in the inductor and decreases the electrical efficiency of the "inductor-metal" system.

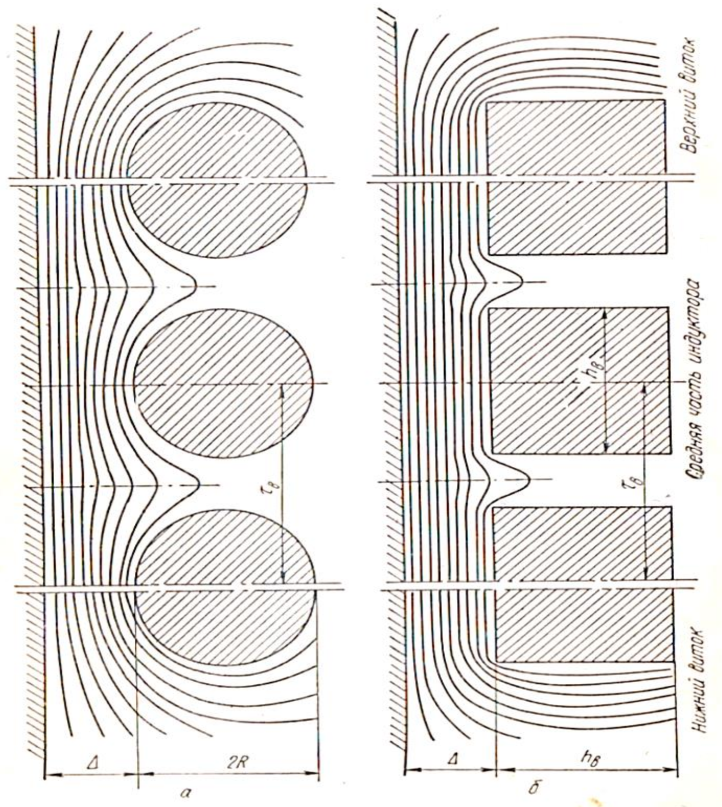

Figure 2 - The location of the magnetic field lines of a multi-turn inductor made of a round (a) and square (b) conductor [4]

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With a round wire (Fig. 2a) , when the turns are wound closely ($k_з = 1$), the losses in the inductor are 11.1% higher than with a square wire by the method obtained by modeling the electrolytic bath [1] . With an increase in the pitch of the inductor , the losses in the inductor also increase in inverse proportion to the duty cycle; at the same time, the losses in the inductor are always 5 ~ 11% higher than for a square conductor.

The use of a square conductor in inductors is more profitable than a round one, which corresponds to ICF-6 LMZ.

3. RESULTS AND DISCUSSION

Magnetic scattering coefficient

A comparison of the distribution of magnetic field lines in the middle part and at the end of a multiturn inductor (see Fig. 2) shows a significant difference in the distribution of losses in the extreme and middle turns of the inductor. In the extreme turn, much more power is lost than on average. This difference, according to G. I. Babat, will be the greater, the greater the ratio $\frac{\Delta}{h_в}$.

The weakening of the magnetic field near the ends of the inductor of finite size, caused by the magnetic leakage flux, also affects the amount of power released in the metal. Due to the fact that the magnetic field strength at the metal surface actually turns out to be much less than the magnetic field strength at the surface of the inductor, the active and reactive power in the metal will be less than calculated for an infinitely extended inductor.

Figure 3 shows the values of the magnetic scattering coefficient for the corresponding limits of the change in the geometric parameters of the ICF.

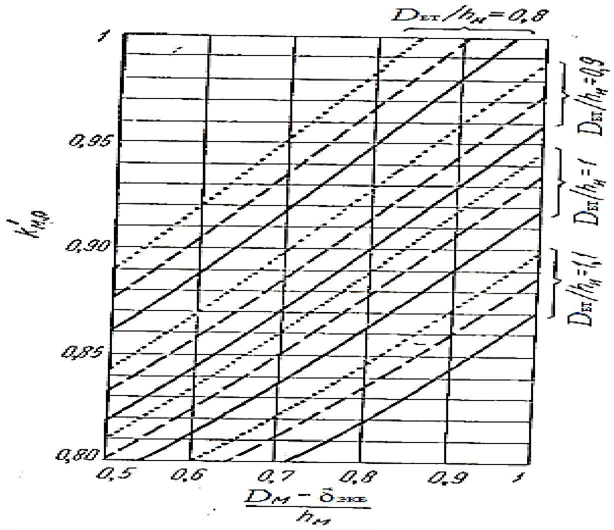

Figure 3 - Nomogram for determining the magnetic scattering coefficient depending on the ratios

$$\left(\frac{D_m-\delta_{ekv}}{h_m} = 1{,}1,\ \frac{D_{\text{вт}}}{h_i} = 1{,}2 \text{ and } \frac{h_i}{h_m} = 1{,}3\right)$$

$$\delta_{e.m} = \sqrt{\frac{2\rho_m}{\omega\mu_{abs}}}$$

Based on the technical parameters of the 6 ton induction furnace crucible for LMZ.
$k_{\text{м.р}} = 0{,}95$

$$\frac{D_m - \delta_{e.m}}{h_m} = \frac{1050 - 26{,}5}{1375} = 0{,}75$$

$$\frac{D_{\text{вт}}}{h_i} = \frac{1300}{1630} = 0{,}8$$

$$\frac{h_i}{h_m} = \frac{1630}{1375} = 1{,}2;$$

4. SUMMARY

The equivalent penetration depth of an electromagnetic wave in liquid steel is determined as follows:

$$\delta_{e.m} = \sqrt{\frac{2\rho_m}{\omega\mu_{abs}}} \approx 500\sqrt{\frac{\rho_m}{f}}$$

where f – is the current frequency.

For liquid steel grade 20GL , the frequency is 500 Hz. Equivalent electromagnetic wave penetration depth $\delta_{e.m} = 26{,}5\ mm$

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