COMPARISON OF THE CURRENT FORMATION DEPTH WITH ACCOUNT FOR THE SKIN EFFECT WITH ROTOR ALUMINUM AND COPPER WINDING

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The use of the skin effect in the rotor winding to increase the active resistance is based on the fact that at the beginning of the start-up, the current frequency in the rotor $f_r=s \cdot f_s$ is close to the mains frequency($s_{start}=1$). The current in the rod creates a leakage flux $\Phi_{\sigma r}$,

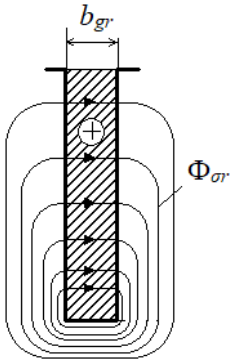


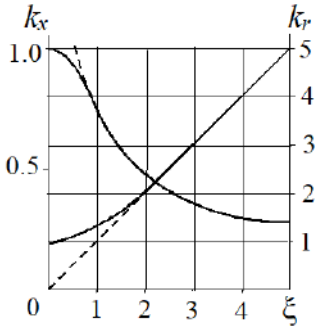
Fig.1

Fig.1. Part of the rod section near the groove bottom is linked to the maximum number of field lines, so its inductive resistance will be the largest. The upper elements of the rod section have the smallest inductive resistance. Since at large slips ($s \approx 1$) the current in the rod elementary layers is distributed inversely proportional to the inductive resistance of the layer, its density in the lower layers will be less than in the upper ones.

The rotor winding active resistance R_r' and its inductive leakage resistance $x_{\sigma r}'$ can be represented:

$$R_r'=k_r \cdot R_{rqr}'+ R_{ra}' \text{ and } x_{\sigma r}'= k_x \cdot x_{\sigma gr}'+ x_{\sigma a}';$$

where k_r, k_x – coefficients that take into account the change in resistance under the influence of current displacement. These coefficients are non-linear functions of the dimensionless parameter $\xi=h_{gr}/h_{sk}$, where h_{sk} – skin effect current penetration depth, m:



$$h_{sk} = \sqrt{\frac{1}{\mu_0 \cdot \gamma \cdot \pi \cdot f_s \cdot s}};$$

$\gamma=1/\rho$ – specific conductivity of the rod, (S/m); s – slip, r.u.; $f_s=50$ Hz; h_{gr} – rotor slot height, m; $\mu_0=4\pi \cdot 10^{-7}$ H/m. The dependencies $k_r(\xi)$ and $k_x(\xi)$ are shown in fig.2. If the rotor winding is made of copper, for which $\rho_{Cu}=0{,}02 \cdot 10^{-6}$ S/m, then the current penetration depth, m:

$$h_{sk} = \sqrt{\frac{0{,}02 \cdot 10^{-6}}{4\pi \cdot 10^{-7} \cdot \pi \cdot 50 \cdot s}} \approx \sqrt{\frac{1}{s}},$$

Then $\xi_{Cu}= h_{gr} \cdot \sqrt{s}$. For aluminum rod, bearing $\rho_{Al}=2 \cdot \rho_{Cu}$, we have:

$$\xi_{Al} = h_{gr} \cdot \frac{\sqrt{s}}{\sqrt{2}} = 0.71 \cdot h_{gr} \cdot \sqrt{s}.$$

In the operating range ($\xi=1 \div 4$) coefficients $k_r(\xi)$ and $k_x(\xi)$ can be determined by the approximate relations $k_r \approx \xi$; $k_x \approx 3/(2 \cdot \xi)$. According to these ratios, in IM with deep grooves, at $h_{qr}=5$ cm, the active resistance of the slot part of the winding at the initial moment of start-up increases by $k_r=5$ times, and the inductive resistance decreases by $1/k_x=3.33$ times. As the slip decreases to the nominal value, k_x decreases.

When sliding $s \leq 0.06 \div 0.08$, the skin effect practically does not manifest itself, the current density in the rods will be constant, and their active resistance becomes minimal.