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METHOD FOR OPTIMIZING PARAMETERS OF AN AC STABILIZER WITH INDUCTION LEVITATION

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Abstract- The presented work shows the characteristics of stabilizers with levitation winding, as well as technical and economic indicators of devices for automatic control systems, test benches and galvanic elements [12-15]. Determination of output characteristics, analytical expressions of parameters and initial data of an electromechanical device with a levitation element when considering design issues is one of the necessary steps in the algorithm for solving the problem. The initial data for calculating an AC stabilizer with induction levitation are: the range of mains voltage change ΔU_c, load currents I_{load1}, I_{load2}, ... I_{loadn}, mains voltage frequency ω, load resistance R_{load} (or power P_{load}), travel of the X_M moving part. The main task of designing an AC stabilizer with induction levitation is to determine the analytical relationships between geometric dimensions and initial data.The equations of functional relationships between the cross section of the core and windings (S_c, S_o), conductivity λ, stroke X_M and current density j_1 are determined. The ranges of change defined for conductivity λ, current density j_1 and stroke X_M retain the principle of proportionality of the geometric dimensions used in the design of the stabilizer. The relationship between the ratio $\frac{\Delta U_1}{X_M}$ and the load current I_{load}=I_1 shows that with an increase in the nominal values of the stabilized load current, the voltage drop ΔU_1 decreases.

Key words: method, optimizing, parameter, AC stabilizer, induction levitation, levitation coordinate, levitation winding, excitation winding, analytical expression, core.

1. INTRODUCTION

The basis of the issue of solving design problems is the establishment of the relationship of analytical expressions between the initial data, geometric dimensions and parameters. For this purpose, it is necessary to develop a mathematical model of a system of expressions, the solution of which allows you to establish analytical relationships between the initial data and parameters such as x_M, P_b, S_o and S_c, P_M. The initial parameters for calculating an AC stabilizer with a levitation element include: ΔU_c, I_{load1}, I_{load2}, …, I_{loadn}, ω, R_{load} or P_{load}, as well h_M or $h_{\min}$ [9-13].

The stability of the load current is a distinctive condition for ensuring the specified accuracy of the equipment, for testing, etc. Therefore, in various calculation methods, when solving problems, non-linear current-voltage characteristics of the elements used in stabilizer circuits are used. The movable anchor under the action of weight forces P_b and F_e determines the equilibrium position $F_e = P_b$ (levitation condition).

2. CALCULATION OF SECTIONAL EXCITATION WINDING

Figure 1 shows the distribution schemes of stray magnetic fluxes and the dimensions of the sectional coils. Number of coils turns [5, 9-11]:

$$W_{10} = \frac{F_0}{I_{10}}; W_{20} = \frac{F_0}{I_{20}}; W_{30} = \frac{F_0}{I_{30}} \tag{1}$$

where, $W_{30} > W_{20} > W_{10}; W_{10} = W_{\min}; W_{30} = W_{\max}$;

$$I_{10} = I_1 = I_{\max}; I_{30} = I_{\min}; F_0 = \sqrt{\frac{2P}{\lambda}}.$$

According to height h_{10}, h_{21}, h_{32} the number of turns is determined W_{21} and W_{32} [1-3]:

$$W_{10} = W_1 = \frac{F_1}{I_1}; W_{21} = W_{20} - W_{10}; W_{32} = W_{30} - W_{20} \tag{2}$$

At $I_{10}>I_{20}>I_{30}$, to reduce the size is accepted $j_{10}=j_{20}=j_{30}$ and then $q_{10}<q_{20}<q_{30}$, because:

$$q_{10} = \frac{I_{10}}{j_1}; q_{20} = \frac{I_{20}}{j_1}; q_{30} = \frac{I_{30}}{j_1}; j_1 = \frac{I_1}{q_1} \tag{3}$$

Given that $q_{30}<q_{20}<q_{10}$ the copper filling factors of sectional coils k_3 are different. In practice, for most brands of wire windings with processed insulation, a fairly accurate coefficient k_3 is determined by the formula:

$$k_3 \approx 0.62\sqrt[4]{d} = 0.64\sqrt[8]{q} = 0.54\sqrt[8]{I} \tag{4}$$

where, $d = 1.13\sqrt{q}$ is wire diameter without insulation.

For sectional coils h_{12}, h_{23}, h_{30} high, you can write [2]:

$$k_3' = 0.54\sqrt[8]{I_{10}}; k_3'' = 0.54\sqrt[8]{I_{20}}; k_3''' = k_{31} = \sqrt[8]{I_{30}} \tag{5}$$

Dimensions are determined h_{12}, h_{23}, h_{30} [5]:

$$h_{10} = \frac{I_{10}W_{10}}{j_1 c_1 k_3'}; h_{21} = \frac{I_{20}W_{21}}{j_1 c_1 k_3''}; h_{32} = \frac{I_{30}W_{32}}{j_1 c_1 k_3'''} \tag{6}$$

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The total height of the sectional excitation winding:

$$h_{30}=h_{10}+h_{21}+h_{32}=h_{20}+h_{32} \tag{7}$$

where,

$$h_{20}=h_{10}+h_{21} \tag{8}$$

Section leakage inductance:

$$L'_S=W_{10}^2\lambda_S\frac{h_{10}}{3};L''_S=W_{20}^2\lambda_S\frac{h_{20}}{3};L'''_S=W_{30}^2\lambda_S\frac{h_{30}}{3} \tag{9}$$

The number of turns and currents are different, so for each section the levitation coordinate is determined separately. From expressions [10]:

$$\begin{aligned}
I_{10}&=\frac{k_uU_{\max}}{\omega W_{10}^2\lambda\left(h'_{\max}+\dfrac{h'_{12}}{3n_\lambda}\right)}\\
I_{20}&=\frac{k_uU_{\max}}{\omega W_{20}^2\lambda\left(h''_{\max}+\dfrac{h''_{12}}{3n_\lambda}\right)-x_{c2}}\\
I_{30}&=\frac{k_uU_{\max}}{\omega W_{30}^2\lambda\left(h'''_{\max}+\dfrac{h'''_{12}}{3n_\lambda}\right)-x_{c2}}
\end{aligned} \tag{10}$$

defined:

$$h'_{\max}=m_{\max}I_{10}-\frac{h'_{12}}{3n_\lambda} \tag{11}$$

$$h''_{\max}=m_{\max}I_{20}-\frac{h''_{12}}{3n_\lambda}+\frac{x_{c2}}{\omega W_{20}^2\lambda} \tag{12}$$

$$h'''_{\max}=m_{\max}I_{30}-\frac{h'''_{12}}{3n_\lambda}+\frac{x_{c3}}{\omega W_{30}^2\lambda} \tag{13}$$

where,

$$m_{\max}=\frac{k_uI_{10}}{\omega\lambda F_0^2} \tag{14}$$

From Equations (11) and (12) under the condition $h'_{\max}=h''_{\max}$ we have:

$$x_{c2}=\omega W_{20}^2\lambda\left[U_{\max}\left(m'_1-m'_2\right)-\frac{h''_{12}-h'_{12}}{3n_\lambda}\right] \tag{15}$$

From Equations (11) and (13) under the condition: $h'_{\max}=h'''_{\max}$ we have:

$$x_{c3}=\omega W_{30}^2\lambda\left[U_{\max}\left(m'_1-m'_3\right)-\frac{h'''_{12}-h'_{12}}{3n_\lambda}\right] \tag{16}$$

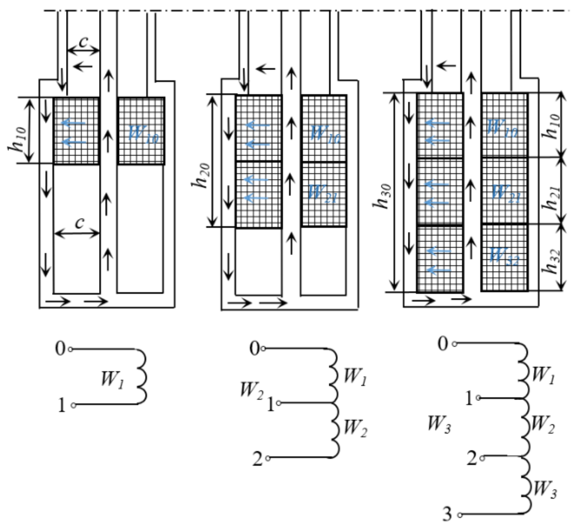
$$h''_{12}-h'_{12}=h_{20}-h_{10};h'''_{12}-h'_{12}=h_{30}-h_{10}$$

where, $U_{\max}\left(m'_1-m'_2\right)=\left(I_{10}-I_{20}\right)m_{\max}$

$U_{\max}\left(m'_1-m'_3\right)=\left(I_{10}-I_{30}\right)m_{\max}$

then;

$$\begin{aligned}
x_{c2}&=\omega W_{20}^2\lambda\left[m_{\max}\left(I_{10}-I_{20}\right)-\frac{h_{20}-h_{10}}{3n_\lambda}\right]\\
x_{c3}&=\omega W_{30}^2\lambda\left[m_{\max}\left(I_{10}-I_{30}\right)-\frac{h_{30}-h_{10}}{3n_\lambda}\right]
\end{aligned} \tag{17}$$



(a) (b) (c)

Figure 1. Calculation of the sectional excitation winding

3. METHOD OF CALCULATION OF STABILIZER ON THE PRINCIPLE OF INDUCTION LEVITATION

Given: $U_{\max}$=250V; $U_{\min}$=160V; I_1=I_{10}=2A; I_{20}=1.5A; I_{30}=0.5A; ω=314; $\tau_1=\tau_2$=80 °C; B_c=1.5 Tl.

1. According to the calculated values [9-11], the following are selected: n_{e2}=5.167; m_a=2; m_c=2; σ_b=1.599; λ=8.03×10^{-6}.

2. The number of turns and mmf windings are determined:

$$W_1=\sqrt{\frac{k_u\Delta U}{\omega I_1X_p\lambda}}=\sqrt{\frac{0.96\times 90}{314\times 2\times 26\times 10^{-3}\times 8.03\times 10^{-6}}}=812$$

$F_1=I_1W_1=2\times 812=1624$; $F_2=b_2F_1=0.98\times 1624=1591.5$,

where, X_p=26×10^{-3}m.

3. The force of gravity of the middle rod of the magnetic circuit [4-7] and the cross section are determined:

$$P=n_kP_T=1.05\times 10.01=10.5$$

$$P_T=g\gamma k_{32}S_{02}l_{cp2}=9.81\times 8.9\times 10^3\times 0.6\times 1027\times 10^{-6}\times$$
$$\times 186.12\times 10^{-3}=10.01$$

$$S_c=\frac{k_u\Delta U_{\max}\sqrt{2}}{\omega k_cB_cW_1}=\frac{0.96\times 250\times\sqrt{2}}{314\times 0.92\times 1.5\times 812}=964.6\times 10^{-6}\,\text{m}^2$$

4. The geometric dimensions of the levitation winding are determined [6-8]:

$$c=\sqrt{\frac{S_cm_a}{2m_c^2}}=\sqrt{\frac{964.6\times 10^{-6}\times 2}{2\times 2^2}}=15.5\times 10^{-3}\,\text{m}$$

$$c_2=\frac{c}{n_{02}}=\frac{15.5\times 10^{-3}}{1.1}=14.1\times 10^{-3}\,m.;h_2=c_2n_{e2}=$$
$$=14.1\times 10^{-3}\times 5.167=72.85\times 10^{-3}\,\text{m}$$

$$l_{cp2}=2c_2n_{02}\frac{n_1}{m_a}=2\times 14.1\times 10^{-3}\times 1.1\times\frac{12}{2}=186.12\times 10^{-3}\,\text{m}$$

$$n_1 = 2m_a + 2m_c + m_a m_c = 2\times 2 + 2\times 2 + 2\times 20 = 12$$
$$b = m_c c = 2\times 15.5\times 10^{-3} = 31\times 10^{-3}\,\text{m}$$
$$a = \frac{b}{m_a} = \frac{31\times 10^{-3}}{2} = 15.5\times 10^{-3}\,\text{m}$$

5. Sections are defined [7-8]:

$$S_{02} = c_2 h_2 = 14.1\times 10^{-3}\times 72.85\times 10^{-3} = 1027.2\times 10^{-6}\,\text{m}^2$$
$$S_{cool2} = h_2\left(l_{cp2} + 4c_2\right) = 72.85\times 10^{-3}\times$$
$$\times\left(186.12\times 10^{-3} + 4\times 14.1\times 10^{-3}\right) = 17667.58\times 10^{-6}\,\text{m}^2$$

6. Defined [7-8]:

$$j_2 = \frac{F_2}{k_{32}S_{02}} = \frac{1591.5}{0.6\times 1027.2\times 10^{-6}} = 2.58\times 10^{-6};$$
$$\rho_2 = 2.422\times 10^{-8}\,\text{Om}\times\text{m}$$
$$P_2 = b_2^2 F_1^2 \frac{\rho_2 l_{cp2}}{k_{32}S_{02}} = 0.98^2\times 1624^2\times\frac{\rho_2 l_{cp2}}{k_{32}S_{02}} = 18.51\ \text{Vt}$$

7. Checked [5-8]:

$$\tau_2 = \frac{F_2^2\rho_2 l_{cp2}}{k_{32}S_{02}k_T S_{cool2}} =$$
$$= \frac{1591.5^2\times 2.42\times 10^{-8}\times 186.12\times 10^{-3}}{0.6\times 1027.2\times 10^{-6}\times 13\times 17667.58\times 10^{-6}} = 80.6\ ^\circ\text{C}$$

8. When $I_2 = I_1 = 2$A, is determined [5-6]:

$$W_2 = b_2 W_1 = 0.98\times 812 = 796$$

9. Given $n=1$ and determined $h_1 = h_2 = 72.85\times 10^{-3}$ m.

10. In Equation (13) and (14), coefficients are calculated: $n_1=1.572$; $n_2=1.235$; $n_c=2.147$.

11. Dimensions are determined [6-7] :

$$c' = \left(n_c\times c\right) = \left(2.147\times 15.5\times 10^{-3}\right) = 33.28\times 10^{-3}\ \text{m}$$
$$c_1 = \frac{c'}{n_{01}} = \frac{33.28\times 10^{-3}}{1.03} = 32.31\times 10^{-3}\ \text{m}$$
$$l_2 = l_{cp2} - 4c = 186.12\times 10^{-3} - 4\times 15.5\times 10^{-3} =$$
$$= 124.12\times 10^{-3}\ \text{m}$$
$$l_{cp1} = l_2 + 4cn_c = 124.12\times 10^{-3} + 4\times 15.5\times 10^{-3}\times 2.147 =$$
$$= 257.23\times 10^{-3}\ \text{m}$$

12. For the excitation winding [2-6] are determined: S_{01} and S_{cool1}:

$$S_{01} = c_1 h_1 = 32.31\times 10^{-3}\times 72.85\times 10^{-3} = 2353.8\times 10^{-6}\,\text{m}^2$$
$$S_{cool1} = h_1(l_{cp1} + 4c_1) = 72.85(257.23 + 4\times 32.31)\times 10^{-6} =$$
$$= 28154.3\times 10^{-6}\ \text{m}^2$$

13. The current density, power, losses and overheating temperature of the excitation winding are determined:

$$j_1 = \frac{F_1}{k_{31}S_{01}} = \frac{1624}{0.6\times 2353.8\times 10^{-6}} = 1.15\times 10^6\ \text{A/m}^2$$
$$P_1 = F_1^2\frac{\rho_1 l_{cp1}}{k_{31}S_{01}} = 1624^2\,\frac{2.42\times 10^{-8}\times 257.23\times 10^{-3}}{0.6\times 2353.8\times 10^{-6}} = 11.6\ \text{Vt}$$
$$\tau_1 = \frac{P_1 + P_2}{k_T S_{cool1}} = \frac{11.6 + 18.51}{13\times 28154.4\times 10^{-6}} = 80.5\ ^\circ\text{C}$$

14. Coefficients are determined [5-9]:

$$m_c' = \frac{b}{c'} = \frac{31\times 10^{-3}}{33.28\times 10^{-3}} = 0.93$$
$$\sigma_b' = 1 + \frac{2.92}{m_c'}\lg\left(1 + \frac{\pi}{m_a}\right) = 1 + \frac{2.92}{0.93}\ln\left(1 + \frac{\pi}{2}\right) = 2.287$$
$$n_\lambda = \frac{\lambda}{\lambda_S} = \frac{8.03}{5.34} = 1.5$$

where,

$$\lambda_S = 2\mu_0 m_c'\sigma_b' = 2\times 1.256\times 10^{-6}\times 0.93\times 2.287 = 5.34\times 10^{-6}$$

15. Dimensions are determined:

$$h_{12} = h_1 + n_\lambda h_2 = (72.85 + 1.5\times 72.85)\times 10^{-3} = 182.1\times 10^{-3}\ \text{m}$$
$$h_{\max} = m'U_{\max} - \frac{h_{12}}{3n_\lambda} = 0.29\times 10^{-3}\times 250 - \frac{182.1}{3\times 1.5}\times 10^{-3} =$$
$$= 32.03\times 10^{-3}\ \text{m}$$
$$h_{\min} = m'U_{\min} - \frac{h_{12}}{3n_\lambda} = 0.29\times 10^{-3}\times 160 - \frac{182.1}{3\times 1.5}\times 10^{-3} =$$
$$5.93\times 10^{-3}\ \text{m}$$

where,

$$m' = \frac{k_u}{\omega F_1 W_1\lambda} = \frac{0.96}{314\times 1624\times 812\times 8.03\times 10^{-6}} = 0.29\times 10^{-3}$$

Examination [1-3]:

$$X_p = (h_{\max} - h_{\min}) = (32.03 - 5.92)\times 10^{-3} = 26.1\times 10^{-3}\ \text{m}$$

16. For wire turns W_{10}, W_{21}, W_{32} current densities are determined:

$$q_{10} = q_1 = \frac{I_{10}}{j_1} = \frac{2}{1.15\times 10^6} = 1.739\times 10^{-6}\ \text{m}^2$$
$$q_{20} = \frac{I_{20}}{j_1} = \frac{1}{1.15\times 10^6} = 0.87\times 10^{-6}\ \text{m}^2$$
$$q_{30} = \frac{I_{30}}{j_1} = \frac{0.5}{1.15\times 10^6} = 0.435\times 10^{-6}\ \text{m}^2$$

17. The coefficients are determined by Equation (5):

$$k_3' = 0.54\sqrt[8]{I_{10}} = 0.54\sqrt[8]{2} = 0.588$$
$$k_3'' = 0.54\sqrt[8]{I_{20}} = 0.54\sqrt[8]{1} = 0.54$$
$$k_3''' = 0.54\sqrt[8]{I_{30}} = 0.54\sqrt[8]{0.5} = 0.495$$

18. The number of turns of sections is determined:

$$W_{10} = \frac{F_1}{I_{10}} = \frac{1624}{2} = 812;\ W_{20} = \frac{F_1}{I_{20}} = \frac{1624}{1} = 1624;$$
$$W_{30} = \frac{F_1}{I_{30}} = \frac{1624}{0.5} = 3248$$
$$W_{21} = W_{20} - W_{10} = 1624 - 812 = 812$$
$$W_{32} = W_{30} - W_{20} = 3248 - 1624 = 1624$$

19. The height of sections [7-10] is determined:

$$h_{10} = \frac{I_{10}W_{10}}{j_1 c_1 k_3'} = \frac{2\times 812}{1.15\times 10^6\times 32.31\times 10^{-3}\times 0.588} = 74.3\times 10^{-3}\ \text{m}$$
$$h_{21} = \frac{I_{20}W_{21}}{j_1 c_1 k_3''} = \frac{1\times 812}{1.15\times 10^6\times 32.31\times 10^{-3}\times 0.54} = 40.45\times 10^{-3}\ \text{m}$$

$$h_{32} = \frac{I_{30}W_{32}}{j_1 c_1 k_3'''} = \frac{0.5\times 1624}{1.15\times 10^6 \times 32.31\times 10^{-3}\times 0.495} = 44.15\times 10^{-3} \text{ m}$$

$$h_{30} = h_{10} + h_{21} + h_{32} = (74.3+40.45+44.15)\times 10^{-3} =$$
$$=158.9\times 10^{-3} \text{ m}$$

$$h_{20} = h_{10} + h_{21} = (74.3+40.45)\times 10^{-3} = 114.75\times 10^{-3} \text{ m}$$

20. Dimensions and coefficients are determined:

$$h_{12}' = h_{10} + n_\lambda h_2 = 74.3\times 10^{-3} + 1.5\times 72.85\times 10^{-3} = 183.6\times 10^{-3} \text{ m}$$

$$h_{12}'' = h_{20} + n_\lambda h_2 = 114.75\times 10^{-3} + 1.5\times 72.85\times 10^{-3} = 224.03\times 10^{-3} \text{ m}$$

$$h_{12}''' = h_{30} + n_\lambda h_2 = 158.9\times 10^{-3} + 1.5\times 72.85\times 10^{-3} = 268.2\times 10^{-3} \text{ m}$$

$$m_{\max} = \frac{k_u U_{\max}}{\omega F_0^2 \lambda} = \frac{0.96\times 250}{314\times 1624^2 \times 8.03\times 10^{-6}} = 36\times 10^{-3}$$

$$m_{\min} = \frac{k_u U_{\min}}{\omega F_0^2 \lambda} = \frac{0.96\times 160}{314\times 1624^2 \times 8.03\times 10^{-6}} = 23\times 10^{-3}$$

21. Capacitance resistances are determined [2-4]:

$$x_{c2} = \omega W_{20}^2 \lambda \left[m_{\max}\left(I_{10} - I_{20}\right) + \frac{h_{20} - h_{10}}{3n_\lambda} \right] = 314\times 1624^2 \times$$
$$\times 8.03\times 10^{-6} \times \left[36\times 10^{-3}(2-1) + \frac{114.75\times 10^{-3} - 74.3\times 10^{-3}}{3\times 1.5} \right] = 299.2$$

$$x_{c3} = \omega W_{30}^2 \lambda \left[m_{\max}\left(I_{10} - I_{30}\right) + \frac{h_{30} - h_{10}}{3n_\lambda} \right] = 314\times 3248^2 \times$$
$$\times 8.03\times 10^{-6} \times \left[36\times 10^{-3}(2-0.5) + \frac{158.9\times 10^{-3} - 74.3\times 10^{-3}}{3\times 1.5} \right] = 1936.46$$

4. CALCULATED VALUES AND DEPENDENCIES

The data in Table 1 can be used to determine the geometric dimensions of an inductive levitation AC stabilizer. For this purpose, the following sequence will be used: determining the course of the levitation winding X_M; current density based on stroke j_1; specific magnetic conductivity λ based on current density; product of sections of the core and windings ($S_{01}\times S_c$); determination of ampere turns, parameters A_1, A_2, S_1^*, S_2^*, S_{01} and S_{02}; dimensionless quantities m_a, m_c according to the value λ (from Table 1), geometric quantities [5, 9-13].

Table 1 shows the ranges S^*, j_1, λ for various X_M strokes. For calculations, the use of data ensures that the principle of proportionality is maintained.

Figure 2 shows the dependencies $S^*=f(X_M, j_1)$ and $\lambda_{\min}=f(X_M, j_1)$, $S^*=(50\div150)\times10^{-2}$ according to which, as X_M decreases, the power S^* decreases and $\lambda_{\min}$ increases. For the range $S^*=(50\div150)\times10^{-2}$, we have: $\lambda_{\min}=12.5\times10^6$ Hn/m., $j_1=(2.5\div4.0)\times10^6$A/m^2, $X_M=(8\div20)\times10^{-3}$ m.

5. CONCLUSIONS

For different variants of current stabilizers, different calculation steps are used. The connection of the excitation winding sections of these stabilizers allows you to get different rated currents. The implementation of the technical task for the device at the design stage is a stage in the algorithm for solving questions for the AC stabilizer on the principle of the effect of induction levitation, and this determines analytical expressions between parameters and initial data, as well as output characteristics.

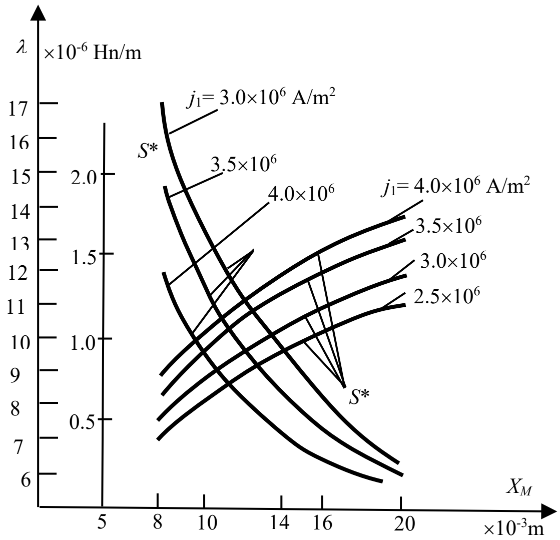


Figure 2. Dependencies $S^*=f(X_M, j_1)$ and $\lambda_{\min}=f(X_M, j_1)$

Table 1. Variation range of j_1, S^*, λ parameters for different X_M strokes

$X_M\times10^{-3}$, m	$j_1\times10^6$, A/m^2	$S^*\times10^{-2}$	$\lambda\times10^{-6}$, Hn/m
8	2.5 3.0 3.5 4.0	50 50÷58 50÷68 50÷78	20 17÷20 14.8÷20 12.5÷20
10	1.5 2.0 2.5 3.0 3.5 4.0	----- 50÷53 50÷65 50÷77 50÷93 50÷103	---- 19÷20 15.2÷20 13÷20 11÷20 9.5÷20
14	1.5 2.0 2.5 3.0 3.5 4.0	50÷53 50÷73 50÷58 50÷90 50÷108 50÷127 50÷144	19÷20 13.8÷20 11÷20 9.5÷20 8÷20 7÷20
16	1.5 2.0 2.5 3.0 3.5 4.0	50÷60 50÷80 50÷100 50÷120 50÷140 50÷160	16.5÷20 12.5÷20 10÷20 8÷20 7÷20 6.2÷20
18	1.5 2.0 2.5 3.0 3.5 4.0	50÷68 50÷93 50÷115 50÷138 50÷160 ------	14.5÷20 11÷20 9÷20 7÷20 6.2÷20 ----
20	1.5 2.0 2.5 3.0 3.5 4.0	50÷78 50÷106 50÷126 50÷152 53÷150 56÷150	13÷20 9.8÷20 7.8÷20 6.3÷20 6÷17 6÷15.8

For the design and calculation of the stabilizer on the principle of levitation, when performing the technical specifications, between the geometric dimensions and the main parameters of the device, analytical expressions of the ratios [12-15] are established. Based on the equations of the mathematical model, as well as the magnetomotive forces of the windings (currents, overheating, induction in the steel of the magnetic circuit and mechanical forces), an AC stabilizer with a levitation winding is calculated.

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