RESEARCH OF ELECTROMECHANICAL DEVICES WITH LEVITATION ELEMENTS IN CONTROL SYSTEMS

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Abstract

The work examines the main technical indicators of electromechanical converters callers with levitation elements, a generalized design method has been developed tions, as well as design diagrams and functional dependencies of the main varieties of electromechanical devices with elements of levitation. Analytical expressions for the levitation coefficient as a function of the dimensions of the magnetic core and coefficient factor of force multiplicity, technical characteristics of levitation material element, set superheat temperature. A mathematical model has been compiled for based on the parameters of the current mode and forces from the equations of electrical, magnetic, mechanical and thermal circuits of the magnetic system. As a result, the main dimensions of the magnetic system and dimensionless quantities. Analytic expressions for the main dimensions, the specified values of the winding overheating temperature are taken into account, input and output parameters, the condition of uniformity of the magnetic field in the working air nom gap. The optimal values of the dimensions of the magnetic circuit, active resistors have been determined winding voltages are minimal, resulting in minimization of losses active capacities.

Key words: levitation element, electromechanical apparatus, research, method, magnetic system, mathematical model, current mode, force mode, stability, mechanism.

I. Introduction

The widespread use of electromechanical devices with levitation elements in automatic control systems ensures high reliability, accuracy, and stability during control and regulation of parameters and the technological process as a whole.

The designs of electromechanical devices with a levitation screen are more effectively involved in solving these problems, since in these devices there are no friction forces, the working stroke of the moving part is automatically controlled and additional elements are not required (for example, mechanical springs, guides, gearboxes, supports, etc.) [5-18].

Automation of technological processes requires automatic control of the vertical positions of the moving parts of working mechanisms using external force and alternating current voltage. In this case, there is a need to measure external force, stabilize the current on a variable load and obtain several nominal values of the current on the load. The design of a simple electromechanical device with a levitation element consists of a vertically located magnetic circuit 1, a stationary alternating current winding 2 and a levitation element 3 (fiqure 1). In the force mode, the levitation element is made in the form of a solid aluminum frame, and in the current mode - in the form of a short-circuited winding. When the device is turned on to the power source, the levitation element may strike the upper yoke of the magnetic circuit.

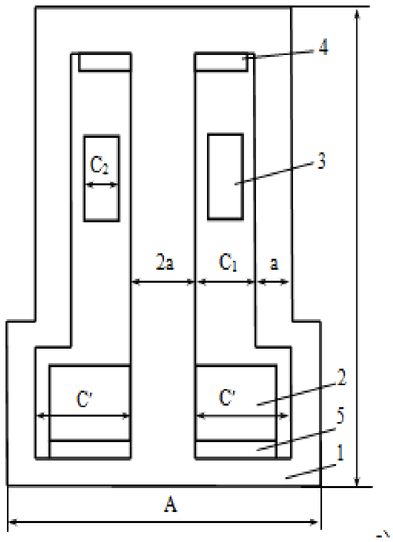

Figure 1. *Design of a simple electromechanical device with LE*

A magnetic system with a levitation element (straight and stepped forms) is shown in figure 2. To eliminate this undesirable phenomenon, a compensation winding 4 is placed near the yoke, which is connected in series with the power winding 1; a signal winding 5 is also provided. During operation of the device with the levitation element, the compensation winding is turned off. The AC winding (or excitation winding) is powered by an AC voltage source U_1 and is made of several sections, by switching which a family of control characteristics is achieved [1-4, 9].

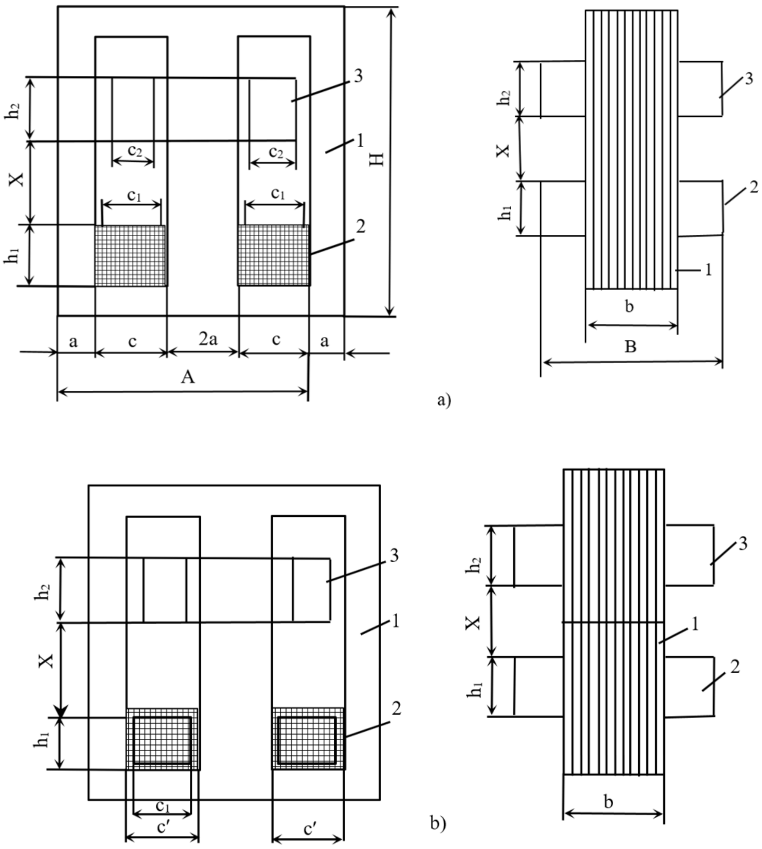

Figure 2. *Magnetic system with levitation element (straight (a) and step b))*

II. Formulation of the problem

When the excitation winding (EW) is connected to the power source, currents flow through the EW and the levitation element (LE), which significantly exceed the rated currents. As a result, losses in the LE sharply increase and all the energy released in it goes to heating it. Depending on its size, the temperature can reach a high value and, before reaching the steady-state value, the LE can melt. Therefore, the minimum dimensions of the LE must be limited.

In accordance with the insulation class, the permissible values of the LE overheating temperature are set. To reduce it, it is necessary to reduce the lateral heat transfer surface of the LE, which in turn is associated with an increase in the aspect ratio $n_{e2}=h_2/c_2$ under the condition $S_{02}=c_2 \cdot h_2=const$ and this can lead to an increase in the height of the magnetic system and a deterioration in the lateral stability of the LE. To determine the optimal relationship between the main dimensions of the LE c_2 and h_2, the dependence of the dimensionless quantity n_{e2} on the geometric dimensions of the magnetic circuit (a, b, c), the force multiplicity factor n_p, the physical and technical characteristics of the LE material and the given overheating temperature τ_2 is determined.

III. Problem solution

Based on the established dependencies of dimensions and parameters, a mathematical model is compiled for certain parameters of current and force modes:

$$\tau_2 = \frac{P_2}{k_T S_{T2}} = F_1^2 \frac{b_2^2 \rho_2}{k_{32} k_T} \left(\frac{l_2}{S_2 S_{T2}} \right) \tag{1}$$

$$F_1^2 = \frac{2}{\lambda} \left(P_x + P_T \right) = 2 g \gamma k_{32} n_p \frac{S_2 l_2}{\lambda} \tag{2}$$

Here generally accepted designations. Force multiplicity factor:

$$n_p = 1 + \frac{P_x}{P_T} \tag{3}$$

As is known, for LE made of copper and aluminum:

$$(S_2 l_2) = 2 c_2^3 n_{e2} k_u \tag{4}$$

Accordingly we have:

$$\left(\frac{l_2}{S_2 S_{T2}} \right)_m = \frac{1}{2 n_{e2}^2 c_2^3 \left(1 - n_{e2} \right)} \tag{5}$$

By jointly solving equations (1)-(2) for LE made of copper and aluminum, we have:

$$n_{e2} = E_m M_m n_p \tag{6}$$

$$n_{e2} = E_a M_a n_p - 1 \tag{7}$$

where are the coefficients:

$$E_m = 2.2585 \cdot 10^{10} \left(\frac{\rho_2}{\tau_2} \right)_m \tag{8}$$

$$\left(\frac{\rho_2}{\tau_2} \right)_m = \frac{1.72 \cdot 10^{-8}}{\tau_2} (1.063 + 0.0042 \tau_2) \tag{9}$$

$$M_m = \frac{(m_a + m_c + 0.5 m_a m_c)}{(0.909 m_a + m_a + m_c + m_a m_c)\left[m_a m_c + 2.92 m_a \lg\left(1 + \frac{\pi}{m_a}\right)\right]} \quad (10)$$

$$E_a = 0.3432 \cdot 10^{10} \left(\frac{\rho_2}{\tau_2}\right)_a \quad (11)$$

$$\left(\frac{\rho_2}{\tau_2}\right)_a = \frac{2.8 \cdot 10^{-8}}{\tau_2}(1.063 + 0.0042\tau_2) \quad (12)$$

Expressions (6)-(12) when implemented using the appropriate calculation program make it possible to compile tables 1-3, which show the parameter values for LE made of copper and aluminum. Figure 3 respectively show the graphical dependences of the coefficient $n_{e2} = f(\tau_2)$ on the current at the stroke values [7-16].

Table 1. Values of coefficients Mm, Ma

m_c	m_a					
	2	3	4	5	6	M_m, M_a
2	0.573464	0.53438	0.518343	0.510589	0.506504	M_m
	0.938378	0.916929	0.914149	0.91672	0.920897	M_a
3	0.594826	0.530443	0.49976	0.482146	0.470856	M_m
	0.953061	0.89554	0.870198	0.85682	0.848954	M_a
4	0.608226	0.528249	0.489108	0.466072	0.450967	M_m
	0.962093	0.882866	0.844812	0.822862	0.808747	M_a
5	0.617415	0.526858	0.482207	0.455742	0.43828	M_m
	0.96821	0.874482	0.828279	0.800992	0.783072	M_a
6	0.624107	0.525901	0.477373	0.448546	0.429485	M_m
	0.972627	0.868526	0.816656	0.785732	0.765256	M_a

Table 2. Values of levitation element parameters depending on overheating temperature

Parameter	ρ_{20},Om·m	τ_2,^{0}C			
		80	90	100	110
$\rho_{20}\cdot 10^{-8}$Om·m	$1.72\cdot 10^{-8}$	2.420	2.494	2.567	2.642
$\rho_{20}/\tau_2\cdot 10^{-12}$		302.50	277.10	256.70	240.18
E_m		6.8323	6.2584	5.7977	5.4246
$\rho_{20}\cdot 10^{-8}$Om·m	$2.87\cdot 10^{-8}$	4.015	4.135	4.256	4.376
$\rho_{20}/\tau_2\cdot 10^{-12}$		501.890	459.510	425.620	397.880
E_m		1.7226	1.5771	1.4608	1.3652

Table 3. n_{e2} values for a levitation element made of copper and aluminum at $\tau_2 = 80^0$C and n_p=1

m_c	Material	m_a				
		2	3	4	5	6
2	Al	3.918	3.651	3.541	3.488	3.460
	Cu	0.615	0.578	0.574	0.570	0.585
3	Al	4.064	3.624	3.414	3.294	3.217
	Cu	0.641	0.542	0.498	0.475	0.462
4	Al	4.155	3.609	3.341	3.184	3.081
	Cu	0.656	0.520	0.454	0.417	0.393
5	Al	4.218	3.599	3.294	3.114	2.994
	Cu	0.667	0.505	0.426	0.379	0.348
6	Al	4.264	3.593	3.261	3.065	2.934
	Cu	0.675	0.495	0.406	0.353	0.318

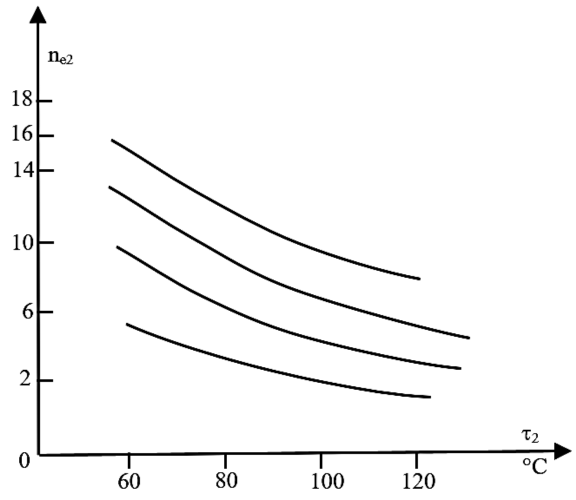

Figure 3. *Coefficient dependency $n_{e2} = f(\tau_2)$*

The patterns of changes in the values of the coefficients M_m, M_a from the dimensionless quantities m_a, m_c show that the smallest values of the coefficients M_m, M_a occur at $m_a = 6$, $m_c = 6$, and the largest values correspond to the values $m_a=2$, $m_c=6$. At $m_a=6$, $m_c=6$, the values of specific magnetic conductivity λ and cross-sectional area of the magnetic core rod S_c are minimal. At $m_a=2$, $m_c=6$, the values of these parameters, on the contrary, are maximum. Therefore, the overall dimensions in the first option are smaller than in the second. With increasing coefficients M_m, M_a and load capacity, the value of the coefficient n_{e2} increases, which leads to an increase in the overall size of the magnetic system. An increase in the overheating temperature leads to a decrease in the coefficients E_m, E_a, as a result, the overall size and dimensionless value n_{e2} decrease [6-14,18]. The given values of the coefficient n_{e2} in Table 3 allow you to pre-select the minimum values of the coefficient and the corresponding values of m_a, m_c. Next, the main dimensions of the magnetic system, other dimensions and parameters are determined, the minimum values of the coefficients, temperature, etc. are taken into account. in order to ensure the reliability of control of electromechanical devices in general.

IV. Conclusions

The obtained values take into account the minimum values of the coefficients n_{e1} and n_{e2}, the specified values of the overheating temperature τ_1 and τ_2, the working stroke x_p, the condition of uniformity of the magnetic field, the load current I_1, $m_a = 2 \div 6$; $m_c = 2 \div 6$. Electromechanical devices with levitation elements are low-current electrical devices, have simple designs, high accuracy, and stable performance characteristics. The active resistance of the excitation windings and the levitation element is minimal; as a result, losses of active power will also be reduced to a minimum.

Analytical expressions for the main parameters necessary for the design of electromechanical devices with levitation elements for various purposes are obtained. The calculation of electromechanical devices with levitation elements is significantly simplified by determining the optimal values for the height and thickness of the excitation winding and the levitation element.

References

[1] G.V.Mamedova, G.S. Kerimzade, N.M.Piriyeva."Electromagnetic calculation of tension devices for winding wires of small cross sections", International Journal on technical and Physical Problems of Engineering (IJTPE), Issue 53, Vol. 14, No.4, pp. 80-85, December 2022.

[2] G.V.Mamedova, G.S. Kerimzade, N.M.Piriyeva."Issues of electrical devices with levitation elements", International Journal on technical and Physical Problems of Engineering (IJTPE), Issue 56, Vol. 15, No.3,

pp.120-125, September 2023.

[3] N.M.Piriyeva,G.S. Kerimzade.”Methods for increasing electromagnetic efficiency in induction levitator”, PRZEGLAD Elektrotechniczny Publishing house of magazines and technical literature SIGMA-NOT. ISSN0033-2097,R.99 NR 10/2023.Warszawa.pp192-195.

[4] N.M.Piriyeva,G.S. Kerimzade.” Electromagnetic efficiency in induction levitators and ways to improve it”, PRZEGLAD Elektrotechniczny Publishing house of magazines and technical literature SIGMA-NOT.ISSN0033-2097,R.99 NR 06/2023.Warszawa.pp204-207.

[5] N.M.Piriyeva,G.S. Kerimzade.” Mathematical model for the calculation of electrical devices based on induction levitators”, International Journal on technical and Physical Problems of Engineering (IJTPE), Issue 55, Vol.15, No.2, pp.274-280, Yune 2023.

[6] Ya.R. Abdullaev, G.S. Kerimzade, “Design of Electric Devices with LE”, Electrical Engineering, No. 5, pp.16-22, 2015.

[7] G.S. Kerimzade, G.V. Mamedova, “Working Modes for Designing Electrical Apparatuses with Inductionmi with Levitation Elements”, Bulletin Buildings, Vol. 17, No. 1, pp. 42-46, Baku, Azerbaijan, 2015.

[8] G.S. Kerimzade, G.V. Mamedova, “Analysis of the Parameters of Electric Devices with Levitational Elements”, News of Universities Instrumentation, No. 12, Vol. 61, pp. 67-71, Sant Petersburg, Russia, 2018.

[9] G.S. Kerimzade, “Analytical Connections of the Parameters and sizes of the Precision Stabilizer of Alternating Current Using the Effect of Inductive Levitation”, International Journal on Technical and Physical Problems of Engineering (IJTPE), Issue 52, Vol. 14, No. 3, pp. 175-184, September 2022.

[10] G.S. Kerimzade, “Analysis of the Methodology for Calculation Current Stabilizer with Induction levitation”, International Journal on Technical and Physical Problems of Engineering (IJTPE), Issue 53, Vol.14, No. 4, pp. 170-174, December 2022.

[11] G.S. Kerimzade, “Analytical Expressions of the Relationship to the Calculation of the AC Stabilizer with Induction Levitation”, International Journal on technical and Physical Problems of Engineering (IJTPE), Issue 54, Vol. 15, No. 1, pp. 135-139, March 2023.

[12] G.S. Kerimzade, “Controlled AC Stabilizers on the Principle of Induction Levitation”, International Journal Universum, No. 2, Issue 107, Vol. 5, pp. 31-35, Moscow, Russai, 2023.

[13] G.S. Kerimzade, “High Precision Current Stabilizers with Induction Levitation”, Journal of Renewable Energy, Electrical, and Computer Engineering, e-ISSN: 2776-0049, Vol. 3, No. 1, pp. 26-31, Indonesia, March 2023.

[14] G.S. Kerimzade, “Choice of Expressions of the Method of Calculation of the Current Stabilizer on the Principle of Induction Levitation”, News of Azerbaijan High Technical Educational Institutions. 2023. Volume. 4, pp. 71-76.

[15] G.S. Kerimzade, “Optimization of parameters of AC stabilizer on the principle of induction levitation”, The 19th International Conference on “TPE”. ICTPE-2023. Number 06. Code 01PES06. 31 October 2023, pp.32-36.

[16] G.S.Kerimzade.”Dependence of the overall dimensions of the control induction support”, Vestnik nauki. Issue 2(71), Volume 1.February,04-2024.Tolyatti. pp.613-618.

[17] G.S. Kerimzade.”Calculation of parameters of control induction support”, PRZEGLAD Elektrotechniczny Publishing house of magazines and technical literature SIGMA-NOT.ISSN0033-2097,R.99NR 03/2024.Warszawa. pp192-195.

[18] G.V.Mamedova, G.S. Kerimzade.”Design parameters for electromechanical devices with a levitation element”, PRZEGLAD Elektrotechniczny Publishing house of magazines and technical literature SIGMA-NOT.ISSN0033-2097, 2024.Warszawa.(print in edidion)