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Static Stability of Coordinated Rotation Systems Based on an Electromagnetic Working Shaft

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ABSTRACT: Any electromechanical system must be stable under load conditions. This work will help to formulate the goal and objectives of the upcoming research and the creation of a new reliable system of coordinated rotation for production mechanisms and to identify the possibilities of statically stable operation. The most promising is the use of a coordinated rotation system in the electric drive of the mechanism for moving the crane on the principle of an electromagnetic working shaft (EMWSh).

KEY WORDS: Electromagnetic working shaft, multi-motor electric drive, synchronous rotation, induction rheostat, ferromagnetic core, mutual induction, minimum required load.

I. INTRODUCTION

In industries, multi-motor electric drives of mechanically unrelated production mechanisms are used, they work on the principle of an electric shaft [8,9].

Existing systems and devices have not found practical application due to their complexity of starting, stopping and a narrow range of coordinated work. The solution to this problem is the creation of a coordinated system with multiple electro-electromagnetic combinations of connections. All these technical areas are united by common laws, a single physics is based on electromagnetic induction [4,5].

An accurate description of processes in a real system is complicated by a set of three-dimensional, interconnected electrical and magnetic circuits with variable magnetic permeability [11].

The dynamic modes of the system depend on many parameters of both engines and the system as a whole. The analysis of such a multi-element system requires the development of special methods for studying electromagnetic processes in the system [15, 17].

As in any electromechanical system, a certain stable load mode, the operation of the EMWSh system is possible if the following stability conditions are met [8,9]:

— balance or equality of all acting and driving moments;

— static stability (if the state of equilibrium is disturbed, the torques are directed towards restoring the equilibrium position);

— dynamic stability (oscillations that arise when the system is perturbed must decay in time).

Equilibrium conditions for each of the engines of the system are possible at:

$$\left.\begin{aligned} M_1 - M_{\text{load1}} &= 0 \\ M_2 - M_{\text{load2}} &= 0 \end{aligned}\right\} \qquad (1)$$

These conditions at two points of the mechanical characteristic are satisfied both with negative and positive stiffness of the mechanical characteristics [6,9]. But the system is statically stable only on the falling part of the mechanical characteristic, so the equilibrium condition is valid for:

$$\frac{d(M_1 - M_s)}{d\omega} < 0 \qquad (2)$$

where: ω is the angular velocity of the system.

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II. RESEARCH PROBLEM AND METHOD

The static stability of the EMWSh system is determined by the quantities:
— maximum admissible mismatch angle for statically stable mode;
— maximum driving moment of the system;
— maximum leveling moment;
— the minimum required load on the motor shafts.
The moments of the system engines are determined by the dependencies:

$$M_1 = A + B\cos\alpha + C\sin\alpha \qquad (3)$$
$$M_2 = A + B\cos\alpha - C\sin\alpha$$

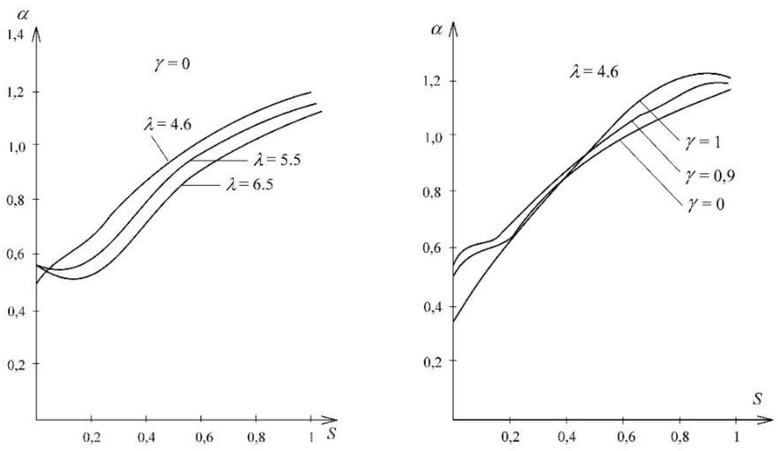
The maximum allowable mismatch angle for the static stability of the EMWSh is:

$$\alpha_{max} = \text{arctg}\left|\frac{C(J_1+J_2)}{B(J_1-J_2)}\right| \qquad (4)$$

If the rotating masses of both engines of the system are equal $j_1 = j_2$ and $\alpha = 90°$. With very different load masses, i.e. when $j_1 \gg j_2$ we have:

$$\alpha_{max} = \text{arctg}\left|\frac{C}{B}\right| \qquad (5)$$

III. RESULT AND DISCUSSION



a) b)

Fig. 1. Mismatch angle characteristics.

On fig. 1.a shows the curves $\alpha_{max} = f(S)$ constructed for the cases $\lambda_1 = 4,6;\ 5,5;\ 6,5$. They show that the shape of the curves does not change for different λ_1 values, their numerical values change only within a small range.

On fig. 1.b shows the curves $\alpha_{max} = f(S)$ for the case $\lambda_1 = 4,6$, for various values of γ. At $\gamma = 0$, the nature of the curve is the same as in the previous figure. As γ changes, the character of the curve changes insignificantly, and the numerical values α_{max} at different slip points somewhat differ from their values at $\gamma = 0$. The deviation, in this case, has a positive effect on the static stability of the system.

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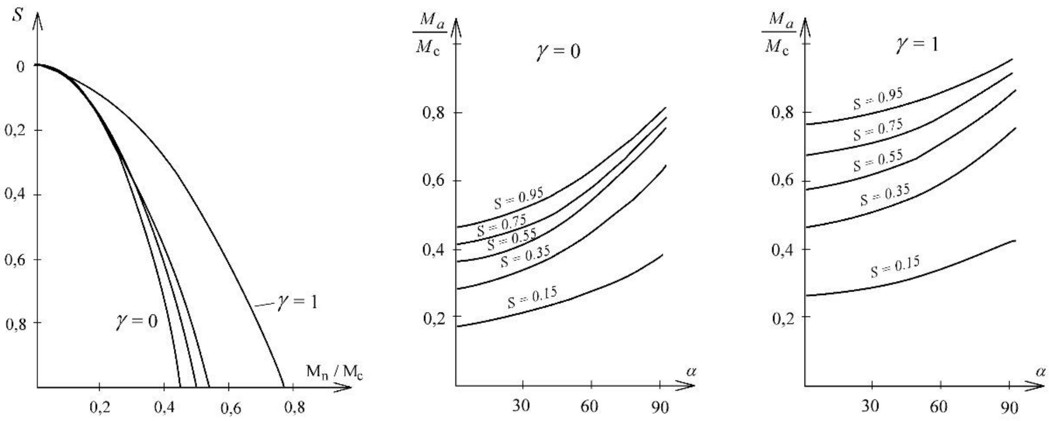


a) b) c)

Fig. 2. Mechanical characteristics of EMWSh.

Drive (asynchronous) moments of the system are determined by adding the moments of the system M_1 и M_2:

$$M_a = M_1 + M_2 \quad (6)$$

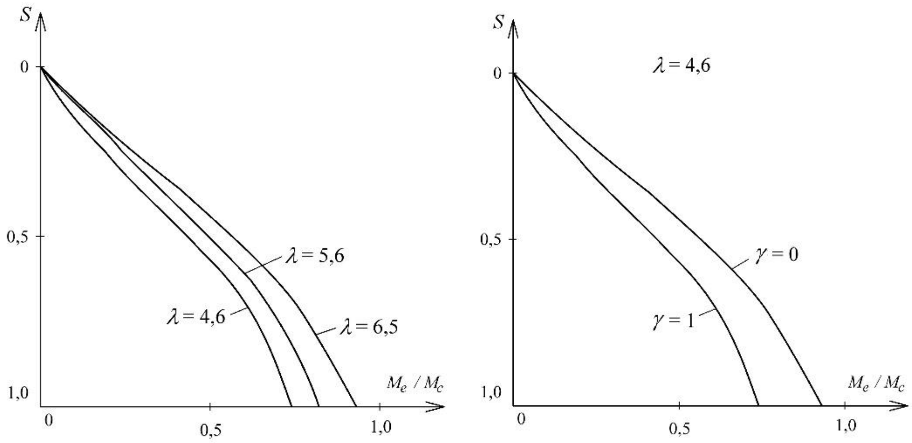
or

$$M_a = 2\left(A_1 + B_1 \cos\alpha\right) \quad (7)$$

On fig. 2.a. the mechanical characteristics of the drive moment of the system with a symmetrical load for the case $\lambda_1 = 4,6$ are given. When $\gamma = 0$ the drive torque of the system has a minimum value. But with a change in the value of γ, the magnitude of the drive torque will increase, that is at $\gamma = 0$, the resistance in the circuit of the third winding of the induction rheostat has a maximum value, and at $\gamma = 1$, it has a minimum value. In this case, the value of the drive torque will be maximum.

On fig. 2.b. the curves of the driving moments of the system are given $M_a = f\left(\alpha\right)$ for $\gamma = 0$. As can be seen from these graphs, the values M_a are increasing in the entire range of slip change. Therefore, the system is statically stable.

On fig. 2.c. the same curves are shown, but at $\gamma = 1$. These curves, in turn, show that the given moments are ascending over the entire slip range. It can be seen from the given curves that the system is statically stable over the entire range of γ.



a) b)

Fig.3. Characteristics of the equalizing moment EMWSh.

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The equalizing (synchronizing) component of the moment is determined by subtracting M_1 from M_2 /5, 8/:

$$M_e = M_2 - M_1 \quad (8)$$

When $\alpha = 0$, M_e is equal to zero, and when $\alpha = 90°$ has M_e a maximum value.

Figure 3.a shows the curves of the equalizing moment at $\alpha = 90°$, from which it can be seen that the shape and magnitude of the equalizing moment in the zone of small slips practically does not depend on the change in the magnitude of the IP parameters, that is λ_1. Only in the zone of large slips, especially at the time of launch, there are slight changes in the magnitude of the PA depending on λ_1. At the same time, the maximum PA falls in our case on $\lambda_1 = 4,5$. With a decrease in γ, the value of the equalizing moment increases over the entire range of slip variation.

This is explained by the fact that with an increase in the resistance value in the DC circuit, that is in the switch circuit, the main part of the current will flow through the IP windings [6,9]. Thus, the energy exchange between the rotor windings increases and, accordingly, the magnitude of the circulating current also increases. It can be seen from the figure that the maximum leveling moment is $\gamma = 0$ achieved at for any values of λ_1. The minimum required moment on the shafts of the motors of the system is determined as:

$$M_{\min} = \frac{M_a - M_e}{2} \quad (9)$$

where: M_a - the maximum drive torque of the system engines at $\alpha = 0$;

M_e - the maximum leveling moment of the system engines at $\alpha = 90°$.

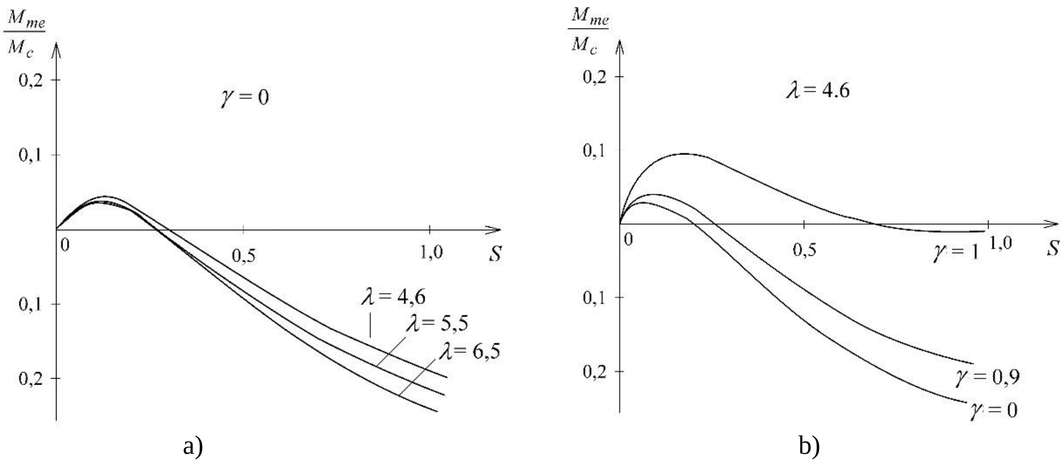

Fig.4. Characteristics of the minimum required load of EMWSh engines.

Figure 4.a shows the minimum required torque curves that each EMWSh engine has. To maintain its statically stable operation, the torque value should not be lower than the specified values. These curves are constructed for cases when λ_1 it is equal to 4.6; 5.5; 6.5. They show that with an increase in the value λ_1, the equalizing component of the moment increases, and the drive component decreases. Consequently, the value of the minimum required torque on the motor shafts also increases. When $\lambda_1 = 4,6$, the optimal value $M_{\min}$ is $M_{\min} = f(S)$ obtained.

In Fig.4. b. curves are presented at $\lambda_1 = 4,6$ for various values of γ. When $\gamma = 0$ has $M_{\min}$ the smallest value, and when $\gamma = 1$ has the maximum value. At the $S = 0,95$ minimum required torque is $M_{\min} = 0,016$.

Equations of equilibrium moments for EMWSh in steady state can be represented as:

$$\left.\begin{aligned} +M_a &= M_{m1} + M_{m2} = 2(A + B\cos\alpha) \\ -M_e &= M_{11} - M_{12} = 2C\sin\alpha \end{aligned}\right\} \quad (10)$$

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Eliminating the equality α from the system, we have:

$$\left(\frac{M_a+2A}{2B}\right)^2+\left(\frac{M_e}{2C}\right)^2=1 \quad (11)$$

The resulting expression is the equation of an ellipse. On fig. 5.a shows the load diagram for $\lambda_1=4,6$ and $\gamma=0$.

With a change in the value of γ, the drive and equalizing moments of the system change. Consequently, the load diagram will take on a different form. On fig. 5.b shows the load diagram for $\gamma=1$. Comparing the diagrams obtained (Fig. 5.a and Fig. 5.b), it can be noted that with a decrease in the value of γ, the ellipses are more elongated along the axis M_y. This indicates an increase in the leveling moment of the system, although the drive moment of the system is somewhat reduced. These diagrams clearly indicate that the EMWSh system operates in a statically stable zone over the entire range of slip values γ.

According to the presented load diagrams, it is possible to identify the possibilities of statically stable operation of the EMWSh at given loads on the motor shafts, if certain values of loads on the motor shafts M_{l1} and M_{l2} are given, then you can find the values of the necessary drive and equalizing moments from the following formulas:

$$\frac{M_a}{M_p}=\frac{M_{\text{load1}}+M_{\text{load2}}}{M_p}$$

(12)

$$\frac{M_e}{M_p}=\frac{M_{\text{load1}}-M_{\text{load2}}}{M_p}$$

(13)

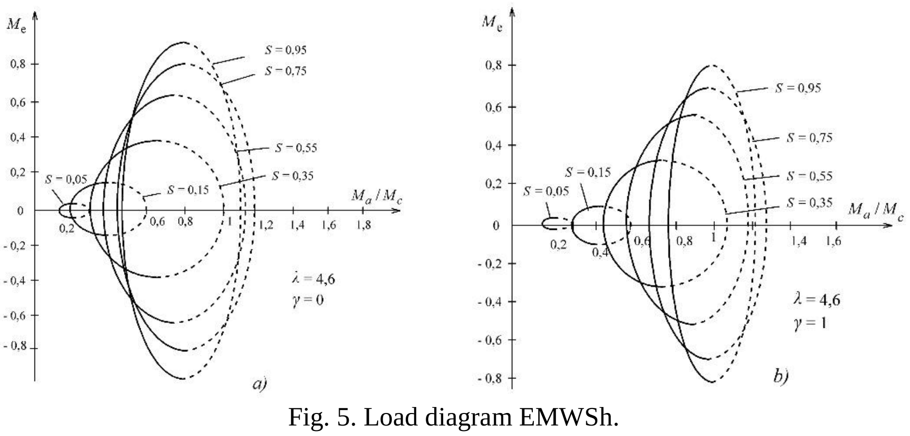

Fig. 5. Load diagram EMWSh.

IV. CONCLUSION

According to the load diagrams (Fig. 5), the found values of α lie to the left of the stability limit and, therefore, the EMWSh system operates in a statically stable zone over the entire range of slip change, it is stable and works satisfactorily. According to the presented load diagrams, it is possible to identify the possibilities of statically stable operation of the EMWSh with a wide range of changes in loads on the motor shafts.

REFERENCES

[1]"On measures for the further introduction of modern energy-efficient and energy saving technologies". "Decree of the President of the Republic of Uzbekistan dated". 2017. 32.
[2]K.R. Allaev. Modern energy and prospects for its development. "Under the general editorship of Academician". 2021. 952.

[3] K.R. Allaev. “Energy of the world and Uzbekistan. Analytical review”. 2006. 380
[4] Abidov K.G., Dadajanov K.S., Features of electric drives based on systems of coordinated rotation of asynchronous motors (SVAD). Collection of reports of the International scientific and technical conference “Actual issues of energy efficiency of automated electromechanical and electrotechnological systems” Tashkent 2022, pp. 53-55.
[5] Abidov K.G., Dadajanov K.S., Sabitov S.K. Mathematical model of electromagnetic working shaft system. Problems of energy and resource saving. 2022, No. 1, p. 65-73.
[6]K.G. Abidov, K.S. Dadadjanov, Features of construction and electromagnetic parameters of induction rheostats/ Technical science and innovation, No. 1, 2022, 198-203.
[7] Abidov K.G., Dadajanov K.S., Sabitov S.K., Power factor of multi-engine electric drives of the movement mechanism of overhead cranes of hydroelectric power plants and pumping stations based on an electromagnetic working shaft. / Scientific and technical journal "Uzbekhydroenergy" 2022*№2 (14).
[8] I.M. Sadovsky Coordinated rotation of asynchronous motors / M.-L.: Gosenergoizdat, 1948. 135 p.
[9]V. Ungru, G. Jordan Systems for matching the rotation of asynchronous electric motors / L., Energia, 1971. 182 p.
[10]L.Ya. Budikov Multiparametric analysis Dynamics of bridge cranes: Monograph / L.Ya. Budikov. - Lugansk, 2003, -210s
[11]K.S. Demirchyan, L.R. Neiman, N.V. Korovkin, V.L. Chechurin Theoretical foundations of electrical engineering. Volume 1. St. Petersburg: publishing house Peter, 2003. - 445 p.
[12]M.G. Chilikin, V.I. Klyuchev, A.S. Sandler Theory of automated electric drive / M., Energia, 1979. 614 p.
[13]N.G. Pavlov Examples of crane calculations / M.: Mashinostroenie, 1976. 320 p.
[14]V.P. Balashov Loads in bridge-type cranes with a separate electric drive of the movement mechanism //Tr. VNIIPTMash, 1970 N 1 (96) S. 96-103.
[15] I.A. Lobov. Dynamics of movement of cranes along the rail track. - M.: Publishing house of MSTU im. N.E. Bauman. - 2003.- 232p.
[16]V. I. Dvornikov, V. A. Gemmerling Simulation of dynamic processes in cranes with a movable lifting carriage. Proceedings of DonNTU, vol. 83. -Donetsk. -2004. pp. 71-81
[17] K.P. Mandrovskiy, Dynamics and mathematical modeling of machine movements in the assessment of stability / K.P. Mandrovskiy. – M.: MADI, 2012. – 72 p.
[18]V.P. Balashov Distortion forces of overhead stacker cranes. //Tr. VNIIPTMash N 7 (94), 1969
[19]L.R. Neiman Surface effect in ferromagnetic bodies / M.-L.: Gosenergoizdat. 1949. 190 p.
[20]N.S. Ushakov Overhead electric cranes / L.: Mashinostr.: 1980. 296 p.

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