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About the Electromagnetic Operating Shaft (EMWSH) System

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ABSTRACT: For overhead technological cranes, the most promising is the use of a coordinated rotation system in the electric drive of the crane movement mechanism based on the principle of an electromagnetic working shaft (EMWSh). 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 the movement mechanisms of overhead cranes.

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

I. INTRODUCTION

The principle of operation of the EMWSh system. A fundamentally new system of synchronous rotation of asynchronous motors has been developed - an electromagnetic working shaft (EMWSh). A distinctive feature of the EMWSh is the connection of the rotor windings of two or more motors to the power windings of an induction or electromagnetic rheostat (IR). IR is an electromagnetic energy converter and is characterized by the ability to change its active and inductive resistances as a function of the rotor current frequency, which in turn is proportional to the motor slip. The depth of penetration of an electromagnetic wave into the body of the rod reaches at a frequency of 50 Hz - 1 ... 2 mm, at lower frequencies - 10 ... 11 mm. Based on this, the thickness of the IR rods is selected. It is known to use induction rheostats in single-engine electric drives, including crane mechanisms, as starting resistances that provide smooth start-up and acceleration of engines to nominal speed, i.e. exit to natural characteristics.

The EMWSh system is based on a new design of an induction rheostat - with two power windings on each rod. In this design, the IR is a ferromagnetic core, magnetized simultaneously by two fields of different commensurate frequencies. With the flow of rotor currents through each of the groups of power windings of the IR, an electromagnetic connection is formed between them, between the windings of the rotors there is a continuous mutual influence and a continuous exchange of electromagnetic energy. A change in the rotor current of one of the motors leads to a change in the rotor current of the other motor, which in turn leads to the alignment of their rotation speeds. Between the rotor windings, with different loads on the motor shafts, an equalizing current appears, which will raise the speed of a more loaded motor and slow down the motor with a lower load. The condition for coordinated work is the equality of emf. in rotary circuits.

With an increase in the load of one of the engines, its rotary emf. increases, but, due to the relationship of magnetic fields in the EMR, an additional counter emf is introduced into the rotor circuit of the second, less loaded engine, which in turn leads to a decrease in its rotation speed. This process occurs until the speeds of both engines are equalized.

The start of the IR system is carried out without preliminary angular synchronization of the positions of the rotors, since the flux linkages of the magnetic fields formed by the power windings of the IR are of decisive importance, and not the amplitude and phase shift of the rotor emfs, as with an electric shaft. During the start-up, when the rotor currents reach significant values, the mutual induction flux linkage has a decisive influence on the establishment of the coordinated operation mode. After acceleration, when the rotor currents have nominal values, the mutual induction flux linkage decreases and the motors work in concert until the total flux linkage reaches a critical minimum value, after which coordinated operation is impossible.

After completion of the start, in the mode of coordinated rotation, the angular mismatch, as well as in the electric shaft, affects the rotor currents and the moments developed by the motors. In the event of a synchronization failure, a heavily loaded motor decelerates to the same speed as it would have in single operation. An engine with less load, on the

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contrary, accelerates. A characteristic feature of EMWSh is that when the equality of loads is restored, the engines again enter the coordinated operation mode, which is not the case with the electric shaft.
Thus, the EMWSh system is distinguished by the possibility of starting motors without preliminary angular synchronization of the rotor positions, the possibility of "synchronization on the go", the possibility of reverse at different loads on the shafts.

II. RESEARCH PROBLEM AND METHOD

Calculation of the main parameters of EMWSh. To determine the main indicators of a multi-motor electric drive without electrical connection between the rotors in a steady state, we will draw up a complete electric drive circuit and an equivalent circuit for one phase. We will assume that the system includes two identical motors with a phase rotor, in rotor circuits, which include identical electromagnetic rheostats.

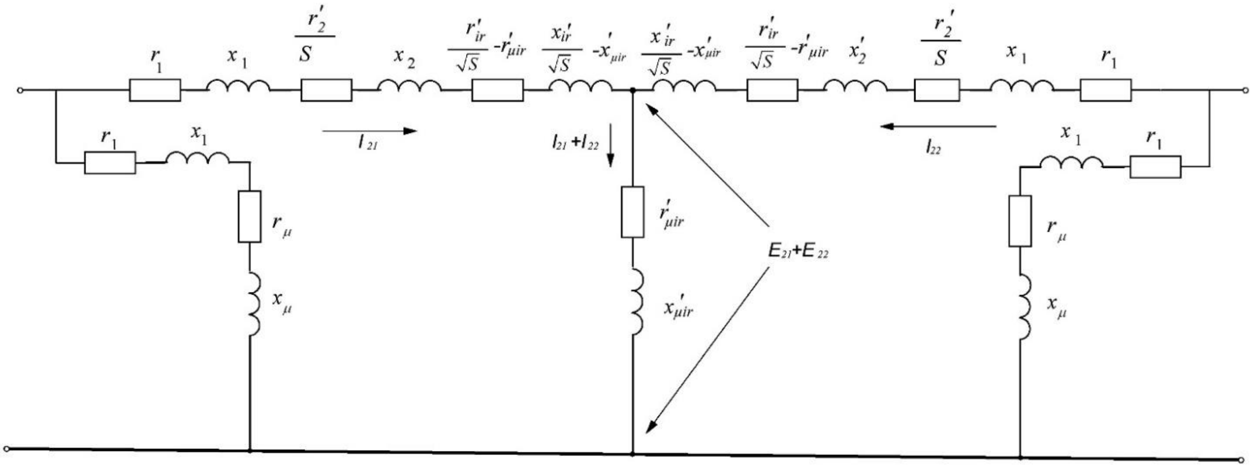

Fig.1. Equivalent circuit of EMWSh.

On the electrical equivalent circuit of the EMRV (Fig. 1) r_1 and jx_1 - active and inductive resistances of the stator; r'_2/S and jx'_2 - active and inductive resistances of the rotor; r_{ir} and jx_{ir} - active and inductive resistances of IR; r_μ and jx_μ - active and inductive resistance of the magnetizing circuit; and are the active and inductive resistances of the mutual inductance of the IR, since according to this equivalent circuit, the electromagnetic connection between the circuits is replaced by an electrical connection.

Stress balance equations:

$$U = I_1 \cdot \left(r_1 + r'_2/S + r_{ir}/\sqrt{S} - r_{\mu ir} \right) + jI_1 \cdot \left(x_1 + x'_2 + x_{ir}/\sqrt{S} - x_{\mu\, ir} \right) + \\ + \left(I_1 + I_2 \right) \cdot \left(r_{\mu\, ir} + jx_{\mu\, ir} \right) \tag{1}$$

$$U \cdot e^{j\alpha} = I_2 \cdot \left(r_1 + r'_2/S + r_{ir}/\sqrt{S} - r_{\mu\, ir} \right) + jI_2 \cdot \left(x_1 + x'_2 + x_{ir}/\sqrt{S} - x_{\mu\, ir} \right) + \\ + \left(I_1 + I_2 \right) \cdot \left(r_{\mu\, ir} + jx_{\mu\, ir} \right) \tag{2}$$

III. RESULT AND DISCUSSION

After all the transformations, we obtain expressions for the currents and moments of the EMWSh system. At the same time $x_1 + x'_2$, we call $x_к$; α is the mismatch angle between the angular positions of the rotors.

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$$I_1 = \frac{U}{2} \cdot \left[\frac{1 - e^{j\alpha}}{z_к} + \frac{1 + e^{j\alpha}}{z_к + 2z_{\mu\ ir}} \right] \quad (3)$$

$$I_2 = \frac{U}{2} \cdot \left[\frac{1 - e^{-j\alpha}}{z_к} + \frac{1 + e^{-j\alpha}}{z_к + 2z_{\mu\ ir}} \right] \quad (4)$$

$$I_{st1} = \frac{U}{z_{st} + z_\mu} + I_1$$

$$I_{st2} = \frac{U}{z_{st} + z_\mu} + I_2$$

Where $$z_к = \left(r_1 + r_2'/S + r_{ir}/\sqrt{S} - r_{\mu\ ir} \right) + j\left(x_к + x_{ir}/\sqrt{S} - x_{\mu\ ir} \right)$$

$$z_к + 2z_{\mu\ ir} = \left(r_1 + r_2'/S + r_{ir}/\sqrt{S} + r_{\mu\ ir} \right) + j\left(x_к + x_{ir}/\sqrt{S} + x_{\mu\ ir} \right)$$

Then the torque of each motor will be determined as

$$M_{1,2} = \frac{U^2 mp}{2\omega_o} \cdot \left\{ \frac{\left(r_2'/S + r_{ir}/\sqrt{S} - r_{\mu\ ir} \right) \cdot (1 - \cos\alpha)}{\left(r_1 + r_2'/S + r_{ir}/\sqrt{S} - r_{\mu\ ir} \right)^2 + \left(x_к + x_{ir}/\sqrt{S} - x_{\mu\ ir} \right)^2} + \right.$$

$$+ \frac{\left(r_2'/S + r_{ir}/\sqrt{S} + r_{\mu\ ir} \right) \cdot (1 + \cos\alpha)}{\left(r_1 + r_2'/S + r_{ir}/\sqrt{S} + r_{\mu\ ir} \right)^2 + \left(x_к + x_{ir}/\sqrt{S} + x_{\mu\ ir} \right)^2} \mp$$

$$\mp \left[\frac{x_к + x_{ir}/\sqrt{S} - x_{\mu\ ir}}{\left(r_1 + r_2'/S + r_{ir}/\sqrt{S} - r_{\mu\ ir} \right)^2 + \left(x_к + x_{ir}/\sqrt{S} - x_{\mu\ ir} \right)^2} - \right. \quad (7)$$

$$\left. \left. - \frac{x_к + x_{ir}/\sqrt{S} + x_{\mu\ ir}}{\left(r_1 + r_2'/S + r_{ir}/\sqrt{S} + r_{\mu\ ir} \right)^2 + \left(x_к + x_{ir}/\sqrt{S} + x_{\mu\ ir} \right)^2} \right] \cdot \sin\alpha \right\}$$

where ω_o -is the frequency usually equal to 314 1/s; m- is the number of phases, usually equal to 3; *p*- is the number of pairs of poles.

The 1st and 2nd fractions of formula (2.7) make up the drive torque M_a, which is the same in static mode for both engines; The 3rd and 4th fractions containing $\sin\alpha$, constitute an equalizing element (sign - for the 1st engine, sign + for the 2nd engine).

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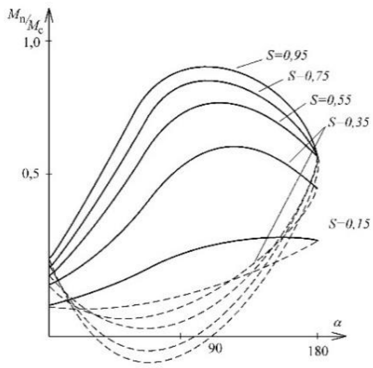

Fig.2. Angular characteristics of EMWSh.

From fig. (2) it can be seen that the range of stable operation of motors with EMWSh is small only in steady state at rated speed. At large values of S (motor start), it expands significantly and at α = 90° it covers the entire motor modeand part of the generator mode. With a certain choice of IR parameters, as will be shown below, the energy performance of IR is not inferior to the energy performance of EWSh, EWSh with IR and motors with starting resistors.

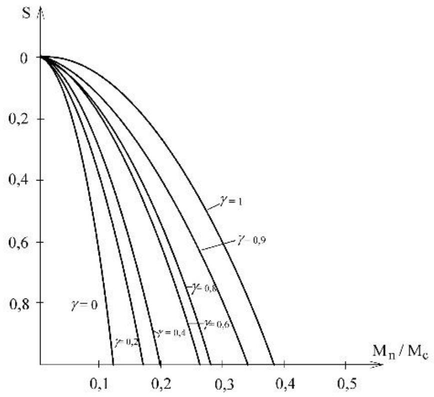

Fig.3. Mechanical characteristics of EMWSh.

On fig. 3. no longer angular, but mechanical characteristics of engines operating in the EMWSh system are given. These characteristics were taken with various combinations and in relation to, etc. in fact, from the geometry of the IR and the windings located on it. Without considering in detail this aspect, which has found its application in other studies of the authors of the work, we only note that the characteristics are of the nature of cranes. All of them in a wide range of speeds (from to) maintain the constancy of the moment. This is especially pronounced for curves related to IR, which have a high mutual inductance coefficient, and in addition, the mutual resistance is higher than its own (characteristics 5 and 4, respectively). However, in this case, the starting torque decreases, which can be seen from characteristics 1, 2 and 3.

The choice of the optimal characteristic is carried out in a very complex way and largely depends on the load, for example, on the parameters of the handling equipment.

IV. CONCLUSION

Thus, studies show that the EMWSh system is very effective for asynchronous motors with a phase rotor. It can be applied to many types of equipment, including materials handling.

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