System of consistent rotation of speeds of drive electric motors of movement mechanisms of overhead cranes

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Abstract. work is devoted to the study of the electric drive of overhead cranes and the creation of a new reliable system of a multi-motor electric drive with a coordinated rotation of the speeds of the drive motors of the movement mechanisms of overhead cranes. The electromechanical travel system of an overhead crane is a complex multi-mass elastically connected system controlled by a multi-motor electric drive, which is subject to a large number of force factors. The main trends in the development of the electric drive of overhead cranes are to increase the reliability of its operation and the range of speed control. The study of the electromechanical system of the mechanism of movement of the crane bridge indicates that the metal structure of the crane is subject to dangerous elastic transverse deformations, the limitation of which can be ensured by optimizing the electric drive system. 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 electric working shaft.

1 Introduction

Based on the principle of an electromagnetic shaft, a multi-motor electric drive system is recommended by the authors of the article for use in the mechanism for moving overhead cranes.

The efficiency of many technological processes at a number of industrial enterprises largely depends on the accurate, reliable and uninterrupted operation of lifting and transport mechanisms.

One such mechanism is a bridge type crane. The use of separate support drive mechanisms in such cranes without electrical synchronization of motor rotation speeds led to the emergence of a new type of load, the so-called skew forces or skew loads.

As a result of the action of skew forces, metal structures and running gears of the crane, as well as crane runways are loaded [1-4]. Some influence of the skew force is also exerted on the elements of the support drives.

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A characteristic feature for the mechanisms of movement are large moments of inertia, as well as the possibility of distortion of the crane structure due to unequal moments of static or differing characteristics of drive motors [5-12].

During normal operation of the crane, relatively large skew forces occur when the trolley with the load is located near the trolleys or above the cab. The skew forces reach a maximum and are oscillatory during periods of unsteady movement (starting, braking and reverse of the crane). They load the crane simultaneously with technological loads, both during movement and after stopping. The relative stress in the elements of the crane from the skew forces reaches 30%. One of the ways to eliminate the appearance of misalignment forces is to replace a separate electric drive with a multi-stage start with an electric drive with a synchronized rotational speed of the drive motors [9].

The coordinated rotation of two or more axes, arbitrarily located in space, the mechanical connection between which is undesirable or impossible at all, is implemented in practice by synchronous rotation systems, depending on the requirement for the accuracy of the coincidence of speeds or conditional turns to control in the consistency mode and other indicators, various schemes are used synchronous communication systems.

2 Methods

Currently, there are a number of systems that provide coordinated rotation of production mechanisms, but as a rule they have a number of significant drawbacks that make their use on cranes impossible, for example, a drive based on the use of DC electric machines has a complex and expensive control system, a system for coordinated rotation of asynchronous motors Coordinated Rotation of Induction Motors cannot be turned off and on on the move at the moment when other motors of the system are running, and coordinated rotation schemes of the "electric working shaft" type require pre-start synchronization of the angular positions of the rotors and it is impossible to achieve synchronization on the move and reverse.

These shortcomings to a certain extent hinder the widespread use of the "electric working shaft" in crane electric drives [7] and necessitate the development of other synchronous rotation systems that are inferior to the "electric working shaft" in synchronization accuracy, but with better performance.

A multi-motor AC electric drive based on a fundamentally new system of synchronous rotation of asynchronous motors - an electromagnetic working shaft has been developed.

The electromagnetic working shaft is based on a new design of an induction rheostat with two power windings on each rod. [9]. In this design, the induction rheostat is a ferromagnetic core that simultaneously magnetizes with two fields of different commensurate frequencies. When the rotor currents flow through each of the groups of power windings of the induction rheostat, 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 speed alignment. Between the rotor windings, with different loads on the shafts of asynchronous motors, 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 the electromotive forces in the rotor circuits. With an increase in the load on the shaft of one of the motors, its rotor electromotive force increases, but, due to the relationship of magnetic fields in the induction rheostat, an additional counter electromotive force is introduced into the rotor circuit of the second, less loaded motor, 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 electromagnetic working shaft 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 induction rheostat are of decisive importance, and not the amplitude and phase shift of the rotor electromotive forces, as in the electric working 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 in the induction rheostat reaches a critical minimum value, after which coordinated operation is impossible. After the completion of the start, in the mode of coordinated rotation, the angular mismatch, just 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 contrary, accelerates. A characteristic feature of the electromagnetic working shaft 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 working shaft".

The obvious advantages of such a system include the possibility of starting the engines without preliminary angular synchronization of the rotor positions, the possibility of "synchronization on the go", and the reverse of both engines with different shaft loads.

Schematic diagram of the electric drive based on the electromagnetic working shaft of the overhead crane movement mechanism is shown in Figure one.

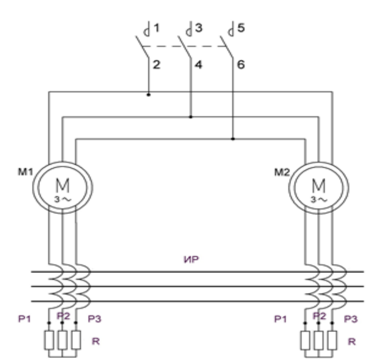

Fig. 1. Schematic diagram of the electric drive: M1 and M2 - electric motors, IR - Induction rheostat, R - starting resistances, P1, P2, P3 - starting resistance clamps.

Based on the circuit diagram of the electric drive, an equivalent equivalent circuit has been compiled [5] (Fig. 2)

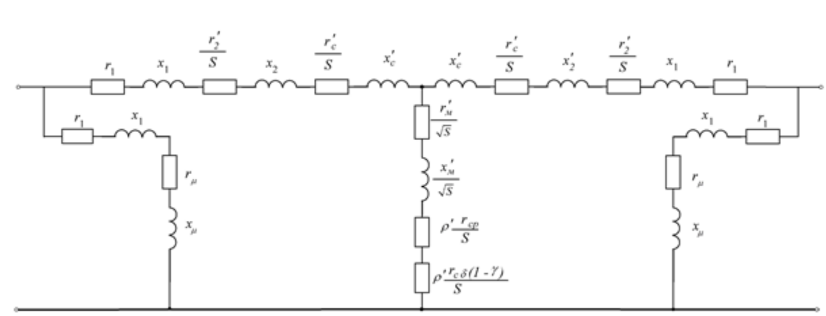

Fig. 2. The equivalent circuit of the electromagnetic working shaft.

The following assumptions have been made:

- the magnetic circuit of electric motors is not saturated, that is, the parameters are unchanged;
- stator and rotor magnetic circuits are smooth, that is, we neglect the influence of grooves, and assume uniform air gaps;
- the voltage applied to the stator of the motors, the electromotive force and the currents of the machines change according to a sinusoidal law;
- engines have identical parameters;
- power windings of the induction rheostat have the same number of turns and dimensions;
- Regulating resistors have identical symmetrical base resistances.

Based on the equivalent circuit of the electromagnetic working shaft, we write the system of stress equilibrium equations:

$$U_1 = I_{21}\left[r_1 + \frac{r_2'}{S} + \frac{R}{S} + \frac{r_o'}{S} + \frac{r_м'}{S} + j\left(x_1 + x_2' + x_o' + \frac{x_м'}{\sqrt{S}}\right)\right] - \\ -I_{22}\left(\frac{r_м'}{\sqrt{S}} + j\frac{x_м'}{\sqrt{S}}\right), \tag{1}$$

$$U_2 = I_{22}\left[r_1 + \frac{r_2'}{S} + \frac{R}{S} + \frac{r_o'}{S} + \frac{r_м'}{S} + j\left(x_1 + x_2' + x_o' + \frac{x_м'}{\sqrt{S}}\right)\right] - \\ -I_{21}\left(\frac{r_м'}{\sqrt{S}} + j\frac{x_м'}{\sqrt{S}}\right), \tag{2}$$

where:

r_1, x_1 - active and inductive resistance of the stator;

r_2', x_2'- active and inductive resistances of the rotor;

r_μ', x_μ' - active and inductive resistances of the motor magnetizing circuit;

r_o', x_o' - active and inductive leakage resistance (winding) of the induction rheostat;

$r_м', x_м'$ - active and inductive resistance of the magnetizing circuit of the induction rheostat;

R- is the resistance of control resistors;

S - engine slip;

U_1, U_2 - voltages of the first and second motors applied to the stators;

I_{21}, I_{22}- are the rotor currents of the first and second motors.

After all the transformations, we obtain the expressions for the moments of the engines of the electromagnetic working shaft.

$$M_{1,2} = \frac{mpU_Ф^2}{2\omega_o}\left\{\frac{\left(r_1 + \frac{r_2'}{S} + \frac{R'}{S} + \frac{r_o'}{S}\right)(1 - \cos\alpha)}{\left(r_1 + \frac{r_2'}{S} + \frac{R'}{S} + \frac{r_o'}{S}\right)^2 + (x_1 + x_2' + x_o')^2} + \right. \\ - \frac{\left(r_1 + \frac{r_2'}{S} + \frac{r_o'}{S} + \frac{R'}{S} + 2\frac{r_м'}{\sqrt{S}}\right)(1 + \cos\alpha)}{\left(r_1 + \frac{r_2'}{S} + \frac{r_o'}{S} + 2\frac{r_м'}{\sqrt{S}} + \frac{R'}{S}\right)^2 + \left(x_1 + x_2' + x_o' + 2\frac{x_м'}{\sqrt{S}}\right)^2} \pm \\ \pm\left[\frac{x_1 + x_2' + x_o'}{\left(r_1 + \frac{r_2'}{S} + \frac{R'}{S} + \frac{r_o'}{S}\right)^2 + (x_1 + x_2' + x_o')^2} - \right. \\ \left.\left. - \frac{x_1 + x_2' + x_o' + 2\frac{x_м'}{\sqrt{S}}}{\left(r_1 + \frac{r_2'}{S} + \frac{r_o'}{S} + \frac{R'}{S} + 2\frac{r_м'}{\sqrt{S}}\right)^2 + \left(x_1 + x_2' + x_o' + 2\frac{x_м'}{\sqrt{S}}\right)^2}\right]\sin\alpha\right\} \tag{3}$$

3 Analysis

The analyzes show that with a change in the parameters of the induction rheostat (geometric dimensions, winding data), it is possible to modify the shape of the mechanical characteristics of the motors of the drive system. With an increase in the resistance of the rheostat, the zone of unstable operation of the engine disappears on the characteristic, and a further increase leads to a "soft" mechanical characteristic, and it is also possible to limit the value of the starting torque. In this case, an additional indicator is obtained, such as the possibility of smooth start-up of engines and the electric drive as a whole, which is important for the operation of the electric drive of the overhead crane movement mechanism. But too much increase in resistance, that is, a decrease in torque, is also not desirable, while the synchronizing capabilities of the system deteriorate.

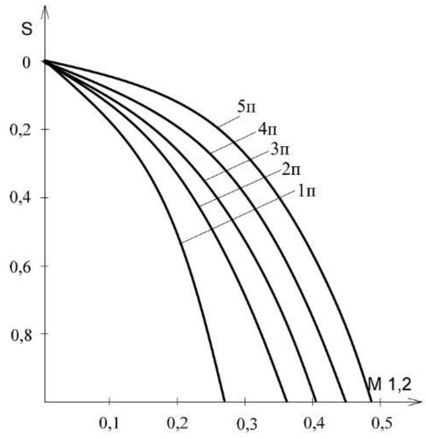

Fig. 3. Rheostatic mechanical characteristics of the crane electric drive; S is the slip of the rotor relative to the rotating field of the stator; M1,2 are the moments developed by the first and second engines; 1P-5P - positions of the controller of the crane movement mechanism.

Therefore, the resistance values of the rheostat must be chosen in such a way that the drive system simultaneously provides synchronization and the necessary starting torques, as well as smooth starting and braking.

Discussion. The rheostatic mechanical characteristics of the electric drive of the travel mechanism of overhead cranes are shown in Figure 3, based on the electromagnetic working shaft. According to the characteristics, it can be seen that with the introduction of an induction rheostat into the electric drive circuit, the performance of the system improves dramatically. Disadvantages such as the zone of unstable operation of electric motors are eliminated, unwanted large current surges are limited both in the start-up and reverse modes, soft start and smooth reverse of the motors, a smooth transition from one speed stage to another are provided.

On Figure 4 shows the angular mechanical characteristics of the crane electric drive based on the electromagnetic working shaft for each resistance level. According to the characteristics, it can be seen that at each stage of resistance the electric drive provides the required drive and equalizing moments of both motors, that is, a wide range of coordinated operation of the electric drive is provided at sharply different loads.

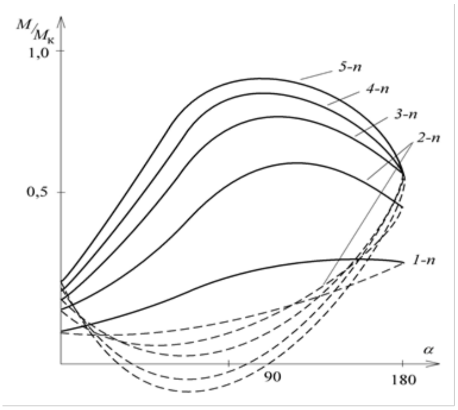

Fig. 4. Angular characteristics of the crane electric drive: M1, 2 - moments developed by the first and second engines; 1P-5P - position of the controller of the crane movement mechanism; a - the angle of mismatch of the rotors of the drive motors of the crane movement mechanism.

4 Discussion

The experience of operating the electromagnetic working shaft as part of the electric drive of the traveling crane movement mechanism shows that when using the electromagnetic working shaft, it is desirable to exclude the resistance of the first stage, since in this case the resistance of the induction rheostat itself is additionally introduced into the rotor circuit. With the exclusion of the first stage of resistance, all functions of the electric drive are preserved and its performance improves qualitatively. Due to the electromagnetic working shaft, a smooth start, reverse and minimum speed are provided.

5 Conclusion

Thus, the operation of a multi-engine electric drive of the traveling mechanism of overhead cranes based on an electromagnetic working shaft makes it possible to qualitatively improve the performance of overhead cranes, to synchronize the speed of rotation of the support motors, while providing large equalizing moments at sharply different loads. The durability of the rollers and drive motors increases, the dynamic loads on individual nodes and on the metal structures of the crane as a whole are sharply reduced, which also contributes to the possibility of reducing the metal consumption of individual crane nodes during their manufacture.

The proposed electric drive system was introduced as an electric drive for the movement of overhead cranes at the Tashkent Tractor Plant (34 cranes), the Uzbek Metallurgical Plant (22 cranes).

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