B. I. Mokin, Dr. Sc. (Eng.), Professor; O. B. Mokin, Dr. Sc. (Eng.), Professor; O. M. Kryvonis

MODEL ING OF THE CRANE ELECTRIC DRIVE CONTROL SYSTEM OPERTATION MODES, TAKING INTO ACCOUNT TIME CHANGES AT THE MOMENT OF INERTIA OF THE ROTATING MASSES

The given paper contains the survey of the available publications, devoted to the study of the processes, occurring in the electromechanical systems of the cranes during lifting/lowering of the load. The analysis of the research carried , showed that the authors of these publications did not take into consideration the change in time of the equivalent moment of inertia of the electric drive system rotating masses, and it is not correct. As in the process of lifting/lowering of the load the moment of inertia of the rotating masses and moment of loading become the time functions it is necessary to perform the simulation of the operation modes of the crane electric drive control system, taking into consideration the varying parameters, caused by changes in the time of the equivalent moment of inertia and loading moment of tractive electric motor in the process of lifting/lowering of the load.

In the considered sections of the given study the operation modes of the electric drive control system of the crane are considered in details, simulation of the operation modes of the electric drive control system of the crane is performed, taking into account variable parameters, stipulated by the changes in time of the equivalent moment of inertia and loading moment of the traction electric motor in the process of lifting/lowering of the load. Using the obtained general equations of the dynamics and taking into consideration the given relations for the determination of the electric motors torques the simulation models for the asynchronous electric motor of КМ АИР250М type are constructed. The simulation models are constructed in the Matlab environment, using Simulink, it enables to perform further analysis with maximum efficiency and minimum expenses of time.

The results of the research are given, taking into account the parameters of the motor while acceleration, braking, maximum speed, idle motion and reverse of the electric traction drive. The comparative comprehensive analysis of the results obtained is carried out.

Key words: *model, control system, electric motor, traversing mechanism.*

Introduction

Analysis of the publications, devoted to the study of the processes, taking place in the electromechanical systems of the cranes during lifting/lowering of the load, generalized in [1], showed that the authors of these publications did not take into consideration the change in time of the equivalent moment of inertia of the rotating masses of the electric drive system, as they use mathematical model of the dynamics in the form:

$$J\frac{d\omega}{dt} = M_{ed} - M_{w} = \Delta M \tag{1}$$

where ω – is the angular speed of the electric motor shaft, and M_{ed}, M_{w}, – are electric motor tractive effort torque and load torque, created by the force of the load weight. But, as in the process of load lifting and coiling of the cable on the drum, connected across the reduction gear with the motor shaft and decoiling of a cable from the drum during load lowering, the inertia moment of the rotating masses of the electric drive and load moment become the functions of time then, as it is shown in [2], actually, for the assessment of the processes, occurring in the electromechanical system of the crane, it is necessary to use the equation of the electric drive system dynamics not in the form (1) but in the form –

$$J(t)\frac{d\omega}{dt}+\omega(t)\frac{dJ}{dt}=M_{ed}-M_w(t)=\Delta M(t)\,. \quad (2)$$

Solution of the problem

According to the operational cycle of the electric motor of the crane mechanism for the process of load lifting /lowering, shown in Fig.1, we will find the general dynamic equation for each section of the time.

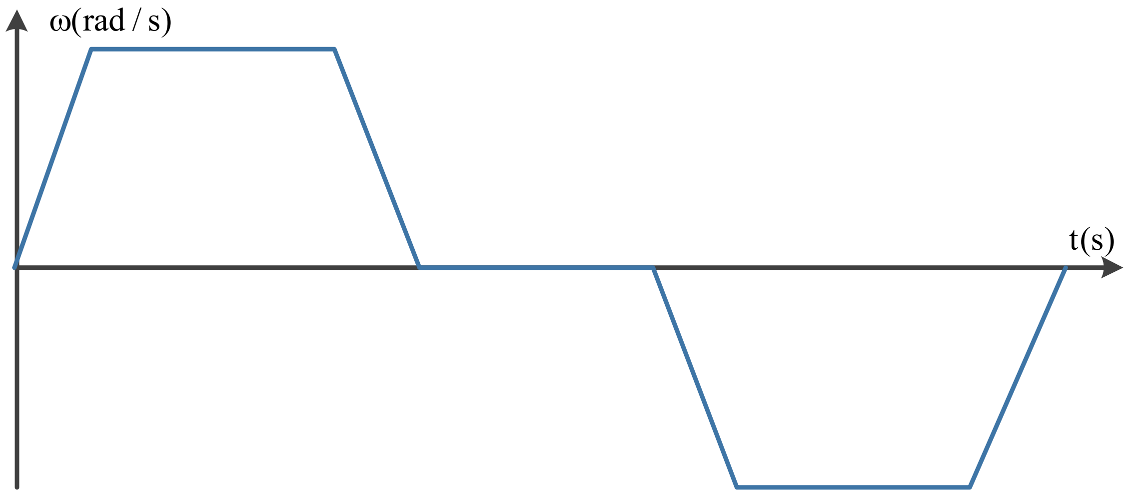

Fig. 1. Operational cycle graph of the electric motor shaft rotation of the crane electric drive system

The first section to be considered , is the section from the start-up moment to the moment of reaching the set angular speed of the traction electric motor, according to [2]:

$$\frac{d\omega}{dt}=const\,, \quad (3)$$

i. e. at the given timespan the load is lifted or lowered with a constant angular acceleration, it means that the equivalent moment of inertia will change with a stable acceleration $\frac{d^2J}{dt^2}=const\,,$ (4)

from which by means of the double integration we obtain the function

$$J(t)=J_0\pm c_1t\pm\frac{c_2}{2}t^2\,, \quad (5)$$

and load moment

$$\frac{d^2M_W}{dt^2}=const\,, \quad (6)$$

from which by means of double integration we obtain the function

$$M_g(t)=M_{g0}\pm\alpha_1t\pm\frac{\alpha_2}{2}t^2\,. \quad (7)$$

Taking into account the specified functions $J(t)$, $M_W(t)$, $\omega(t)$ we find the general dynamic equation for the starting torque:

$$\left(J_0 \pm c_1 \cdot t \pm \frac{c_2}{2} \cdot t^2\right)\frac{d\omega}{dt} \pm \left(c_1 + c_2 \cdot t\right) \cdot \omega(t) = \\ = M(t) - M_{W0} \pm \alpha_1 \cdot t \pm \frac{\alpha_2}{2} \cdot t^2. \qquad (8)$$

Taking into consideration the dependences (3), by means of integration $\frac{d\omega}{dt}$ we obtain the function

$$w(t) = w_0 \pm \varepsilon \cdot t\,, \qquad (9)$$

in the process of coiling/decoiling of the cable on the drum, correspondingly, where ε – is angular acceleration while electric motor shaft rotation, w_0 – is initial value of the angular speed.

Substituting the expressions (5) in the equation (4), we obtain the equation

$$\left(J_0 \pm c_1 \cdot t \pm \frac{c_2}{2} \cdot t^2\right)\frac{d\omega}{dt} \pm \left(c_1 + c_2 \cdot t\right) \cdot \omega(t) = \\ = M(t) - M_{W0} \pm \alpha_1 \cdot t \pm \frac{\alpha_2}{2} \cdot t^2. \qquad (10)$$

We will consider the variant where at the initial moment of time of the value

$$J_0, c_1, w_0, \alpha_1 = 0 \qquad (11)$$

the system is in the state of rest.

Taking into account 7, the equation 6 for the moment start/brake of the electric motor during load lifting/lowering is written as:

$$\frac{3}{2} c_2 \cdot \varepsilon \cdot t^2 = M(t) - M_{W0} \pm \frac{\alpha_2}{2} \cdot t^2\,. \qquad (12)$$

Now we will consider another section from the moment of reaching the stable angular speed by the traction motor to the moment of braking, according to [2], on this section the electric motor runs with a stable angular speed

$$w = \text{const}\,, \qquad (13)$$

as a result the equivalent inertia moment will change in time with the stable speed

$$\frac{dJ}{dt} = \text{const}\,, \qquad (14)$$

from which by means of integration we obtain the function

$$J(t) = J\ + c\,t\,, \qquad (15)$$

and the moment of loading

$$\frac{dM_W}{dt} = \text{const}\,, \qquad (16)$$

from which by means of integration we obtain the function

$$M_g(t) = M_{g1} \pm \alpha_1 t_1 \qquad (17)$$

Taking into account 13 – 17, the equation 2 for the given period of time will be written as

$$\pm\left(J_1 + c_1 t_1\right) \cdot \omega = M(t) - M_{g1} \pm \alpha_1 t_1\,, \qquad (18)$$

taking into account 11, this equation will be rewritten as

$$\pm J_1 \cdot \omega = M(t) - M_{g1}\,. \qquad (19)$$

We consider the third time interval from the beginning of braking to the stop, for which general equation of dynamics will have the form analogous to the section of the acceleration only with the opposite signs.

As it is determined in [1, 2] d. c. series-excitation d.c. motors or separately excited d. c. motors, as well as short-circuited rotor motors or phase-wound rotor motors were used as the traction electric motors of the traversing mechanisms.

Applying the obtained general dynamic equations (8, 11) and taking into account the relations, suggested in [2] for the determination of the electric motors torques, the simulation models are constructed in the Matlab environment, using Simulink for the asynchronous electric motor of КМ АИР250М type , shown in Fig. 2 with the parameters:

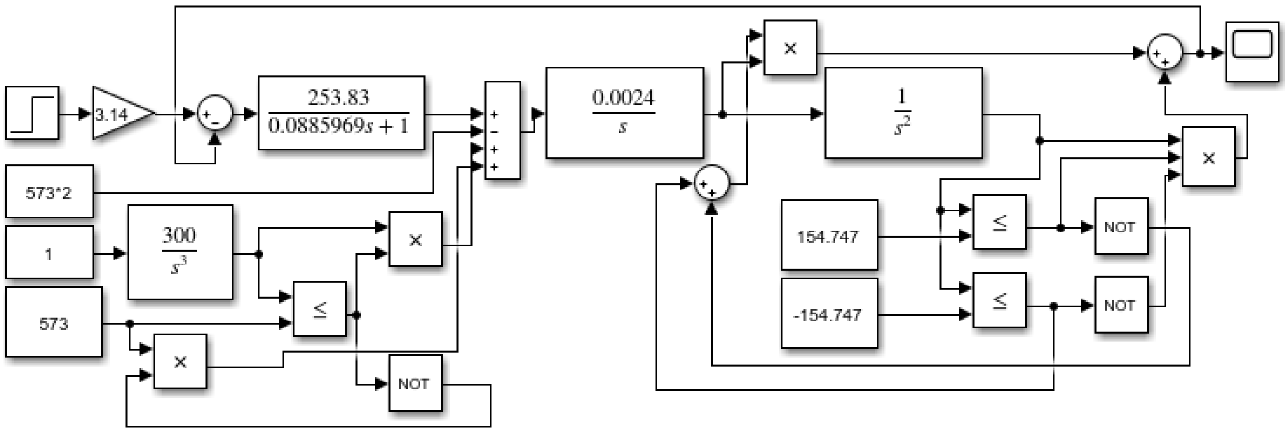

Fig. 2. Simulation mathematical model of the traction asynchronous motor of КМ АИР250М type

$$P = 90\ \text{kW};\ U = 380\ \text{V};\ I_H = 163,6\ \text{A};\ M_H = 573\ \text{Nm};\ J = 1,1\ \text{kg}\cdot\text{m}^2;\ n_c = 1500\ \text{rpm};$$

$$\cos\varphi_H = 0,89;\ \eta_H = 94\ \%;\ s_H = 1,5\ \%;\ \frac{M_{max}}{M_H} = 2,5.$$

The results of this model simulation can be evaluated applying the graph of the angular rotation speed of the shaft of the asynchronous electric motor in Fig. 3 where the modeling of the processes of lifting, stopping and lowering of the cargo with the nominal loading on the shaft and in idle mode is shown.

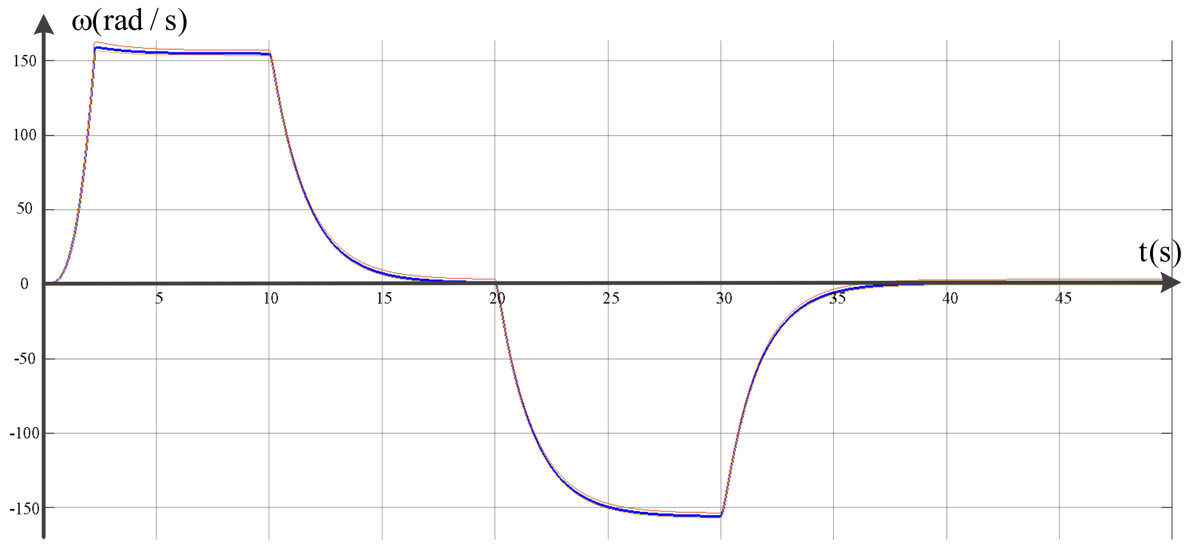

Fig. 3. Graph of the angular rotation speed of the shaft of the traction asynchronous electric motor of КМ АИР250М type of the lifting crane electric drive system, obtained by mathematical model simulation in Simulink environment (2)

Conclusions

Modeling of the operation modes of the lifting crane electric drive control system is carried out, taking into consideration the suggested general dynamic equation (2), by the results of the modeling, the graph, shown in Fig. 3, was obtained.

Comparing the graphs, shown in Fig. 1 and 3, it is seen that they differ greatly. This is the proof, that the control systems of the lifting cranes electric drives must be synthesized, applying not the mathematical model of the dynamics in the form (1), as it is generally accepted, but using the mathematical model of the dynamics in the form (2).

REFERENCES

1. Mokin B. I. Analysis of the main problems and their solutions in the process of gear mechanisms electric drives control [Electronic resource] / B. I. Mokin, O. M. Kryvonis//Materials of the XLVII Scientific Engineering Conference of the divisions of VNTU, Vinnytsia, March 14-23 2018. – Electronic text. Data. –2018. – Access mode: https://conferences.vntu.edu.ua/index.php/all-feeem/all-feeem-2018/paper/view/3937.

2. Mokin B.I. Synthesis of mathematical models for one class of electromechanical systems with variable parameters. Electrical and Computer Engineering (UKRCON) [Text] / B. I. Mokin, O. B. Mokin, O. M. Kryvonis // 2017 IEEE First Ukraine Conference on(YSF-2017). -2017. -DOI:10.1109/UKRCON.2017.8100504.

Editorial office received the paper 24.01.2020.
The paper was reviewed 08.02.2020.

Mokin Borys – Academician of NAPSU, Doctor of Science (Eng), Professor, Department of Renewable Power and Transport Electric Systems and Complexes, borys.mokin@gmail.com.

Mokin Oleksandr – Doctor of Science (Eng), Professor, Head of the Chair of Renewable Power and Transport Electric Systems and Complexes (RETESC), e-mail: abmokin@gmail.com.

Kryvonis Oleksandr — Post graduate with the Department of Renewable Power Generation and Transport Electric Systems and Complexes, e-mail: kryvonis.ol@gmail.com.

Vinnytsia National Technical University.