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Modeling the moving mechanism of lifting equipment at the best LAW

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In the article the modeling the bridge crane with optimal control. Manage the movement of the crane modeled using frequency converter scalar type. The influence of the frequency converter configuration options for dynamic, energetic and kinematic parameters of the crane.

Optimal control, overhead crane, frequency converter, asynchronous electric.

Problem. Overhead cranes are widely used in various fields of production that are associated with the movement of goods. Quite often work overhead crane is a "bottleneck" of the entire production process, it is desirable to crane operation took place with the least dynamic loads that lead to reduced reliability and productivity of the crane.

Most of bridge cranes operated currently equipped with outdated electrical relay control systems. This control is characterized by low energy efficiency.

One problem that lower performance overhead cranes are swinging load on flexible suspension. The use of optimum laws of the crane, which load fluctuations are eliminated during the transition process, allows to address the problem. However, before spending the practical implementation of optimal laws of motion simulation should be taken to specify the basic settings of frequency-controlled crane drive.

Analysis of recent research. Study of dynamics of bridge cranes are devoted [1-10]. In some of these studies [4, 6-10] also solved the problem of optimal control valves span type. However, in these studies synthesized optimal laws of the crane increase in dynamic load crane elements by reducing the duration transients of the crane.

Practical implementation of optimal control, of course, brings about changes in laws best of the crane. The specified questions explored in [6].

However, it is necessary to conduct some detail modeling of optimal control valve using frequency-controlled drive.

The purpose research is to study the law of motion of the optimal mechanism for moving the crane, which is equipped with frequency-controlled induction drive.

In accordance with the objectives include the following problem: to modeling the mechanism for moving crane frequency control; analyze the results; on the basis of the analysis indicate the frequency setting rational reason for implementing optimal control.

Results. For the study we use a dynamic model of the bridge crane movement, which is shown in Fig. 1.

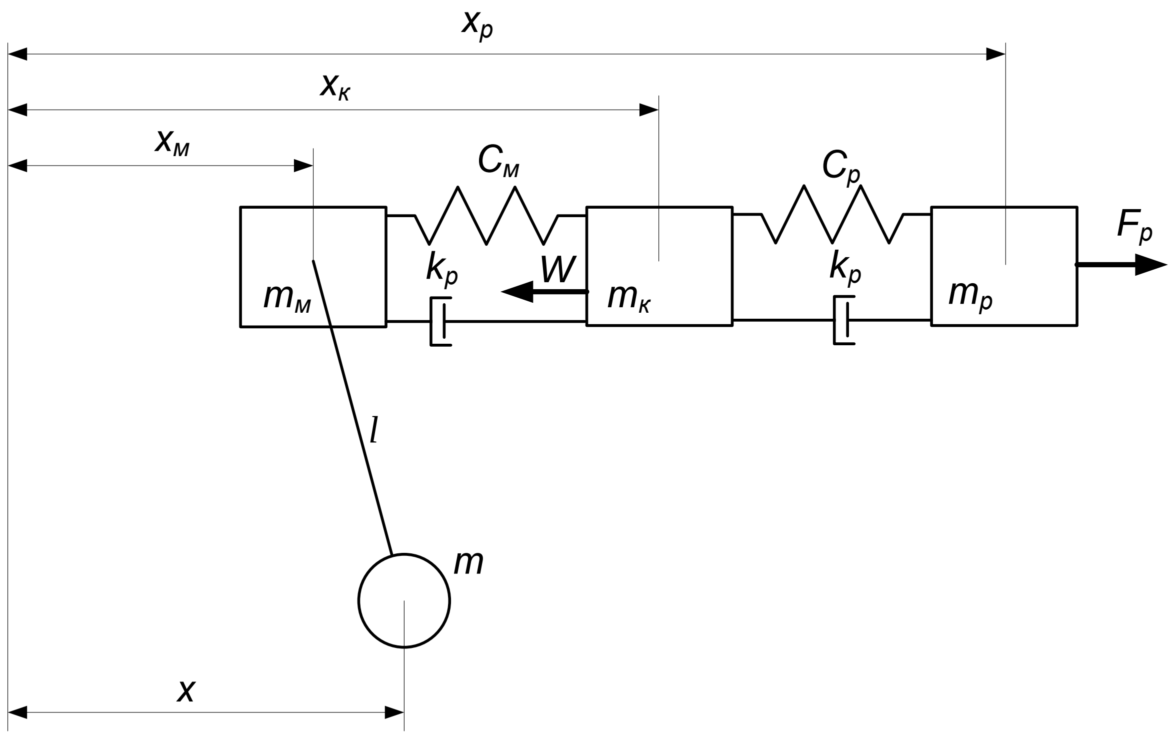

Fig. 1. Chotyrymasova dynamic model of traffic traveling crane with a load on a flexible suspension.

The dynamics of the crane in view of disturbing actions of induction motor with squirrel cage described by the following system of differential equations:

$$\begin{cases} \dfrac{di_{1\alpha}}{dt} = \dfrac{1}{\delta L_1}\left(u_{1\alpha} - i_{1\alpha}R_1 + k_r e_{2\alpha}\right); \\ \dfrac{di_{1\beta}}{dt} = \dfrac{1}{\delta L_1}\left(u_{1\beta} - i_{1\beta}R_1 - k_r e_{2\beta}\right); \\ \dfrac{di_{2\alpha}}{dt} = -\dfrac{1}{\delta L_2}\left(\left(u_{1\alpha} - i_{1\alpha}R_1\right)k_s + e_{2\alpha}\right); \\ \dfrac{di_{2\beta}}{dt} = -\dfrac{1}{\delta L_2}\left(\left(u_{1\beta} - i_{1\beta}R_1\right)k_s - e_{2\beta}\right); \\ 3pL_{12}\left(i_{1\beta}i_{2\alpha} - i_{1\alpha}i_{2\beta}\right)\dfrac{u\eta_{пер}}{r_{кол}} = m_p\ddot{x}_p + c_p\left(x_p - x_к\right) + k_p\left(\dot{x}_p - \dot{x}_к\right); \\ m_к\ddot{x}_к = c_p\left(x_p - x_к\right) + k_p\left(\dot{x}_p - \dot{x}_к\right) - c_м\left(x_к - x_м\right) - k_м\left(\dot{x}_к - \dot{x}_м\right) - W sign\left(\dot{x}_к\right); \\ m_м\ddot{x}_м = c_м\left(x_к - x_м\right) + k_м\left(\dot{x}_к - \dot{x}_м\right) - \dfrac{mg}{l}\left(x_м - x\right); \\ \ddot{x} = \dfrac{g}{l}\left(x_м - x\right), \end{cases} \quad (1)$$

where u - gear ratio mechanism for moving the crane; rkol - radius of the drive wheels of the crane; ηper - efficiency gear drive crane; W - resistance movement of the bridge crane, attached to the wheel end beams; l - length of flexible suspension of cargo; g - acceleration of gravity; i1α, i1β - projection generalized stator current vector on fixed axes α and β; i2α, i2β - generalized projection rotor current vector on fixed axes α and β; L1, L2 - inductance of stator windings and rotor; L12 - mutual; kr and ks - coefficients magnetic rotor and stator connection respectively ($k_r = \frac{L_{12}}{L_2};\ k_s = \frac{L_{12}}{L_1}$) M - electromagnetic torque of the engine; p - number of pole pairs of electric vehicles; u1α, u1β - generalized projection vector of the stator voltage on the coordinate axes α and β ($u_{1\alpha} = U_{max}\,cos\left(2\pi\int fdt\right), u_{1\beta} = U_{max}\,sin\left(2\pi\int fdt\right)$) Umax - phase voltage amplitude of the engine; f - frequency voltage motor; e2β, e2α - EMF induced flux rotor axes α and β respectively ($e_{2\alpha} = p\omega_{дв}\left(L_2 i_{2\beta} + L_{12}i_{1\beta}\right) + i_{2\alpha}R_2$, $e_{2\beta} = p\omega_{дв}\left(L_2 i_{2\alpha} + L_{12}i_{1\alpha}\right) - i_{2\beta}R_2$) R1 - resistance of stator winding; R2 - adjusted to the stator winding rotor resistance; δ - coefficient of dispersion ($\delta = 1 - \dfrac{1}{\left(1 + \dfrac{X_1}{2\pi f L_{12}}\right)\left(1 + \dfrac{X_2}{2\pi f L_{12}}\right)}$) X1 - inductive resistance of stator winding; X2 - brought to the stator winding rotor inductive reactance; mp, MC, mM, m - brought to translational motion of the mass of the drive mechanism, end beams, bridge and cargo respectively; hp, HC, uh, s - generalized coordinates that correspond to the masses mp, MC, and mM m; CP, UK cm - given the rigidity of the drive, end beams and bridge crane respectively; kp, km - given damping in the drive and crane bridge respectively. The dot over a symbol means differentiation with time.

In [7] synthesized optimal law of the crane with a load on flexible suspension that eliminates fluctuations in load on flexible suspension, and used dvomasova dynamic model. Optimal law of motion is represented as a piecewise continuous function:

$$\dot{x}_1 = \begin{cases} V\dfrac{t^3\left(6t^2 - 15tT_1 + 10T_1^2\right)}{2T_1^6}, \ \textit{при} \ t \in [0;\ T_1]; \\ v/2, \ \textit{при} \ t \in [T_1;\ T_1 + \Delta T]; \\ \dfrac{V}{2T_1^6}\left(6t^5 - 30T_1^5 - 120T_1^4\Delta T - 180T_1^3\Delta T^2 - 130T_1^2\Delta T^3 - 45T_1\Delta T^4 - 6\Delta T^5 + 30t \times \right. \\ \times \left(T_1 + \Delta T\right)^2\left(2T_1 + \Delta T\right)^2 - 15t^4\left(3T_1 + 2\Delta T\right) - 30t^2\left(T_1 + \Delta T\right)\left(2T_1 + \Delta T\right)\left(3T_1 + 2\Delta T\right) + \\ \left. + 10t^3\left(13T_1^2 + 18T_1 + 6\Delta T^2\right)\right), \textit{при} \ t \in [T_1 + \Delta T;\ 2T_1 + \Delta T], \end{cases} \quad (2)$$

where T1 - duration of acceleration to the intermediate rate, which is equal to half established; ΔT - driving time at the intermediate rate (total duration of the transition process is 2T1 + ΔT). Note that the function (2) has a valuable property -yiyi implementation is not associated with a change in the sign of the dynamic component of the driving force of the crane, which, in turn, reduces the dynamic load of the crane elements.

Function (2) terminal delivers absolute minimum criteria:

$$\begin{cases} F_{дин}^2(0) \to abs\min; \ \dot{F}_{дин}^2(0) \to abs\min; \\ \dot{F}_{дин}^2(T_1) \to abs\min; \\ \dot{F}_{дин}^2(T_1 + \Delta T) \to abs\min; \\ F_{дин}^2(2T_1 + \Delta T) \to abs\min; \ \dot{F}_{дин}^2(2T_1 + \Delta T) \to abs\min, \end{cases} \quad (3)$$

where Fdyn - dynamic component of efforts to drive dvomasovoyi model of the crane with a load on flexible suspension:

$$F_{дин} = m_1\ddot{x}_1 + m_2\ddot{x}_2, \quad (4)$$

where m1, m2 - brought to translational motion of the crane and cargo weight, respectively; x1, x2 - corresponding coordinates of the centers of mass.

Explore whether it is possible to use the law of motion (2) to optimize traffic control chotyrymasovoyu model crane. To do this, an optimum law of motion must be put: m1 = mp + MC + mM, m2 = m, x1 = hp. Also, take into account the nature and frequency change voltage output when implementing optimal motion control valve.

In order to "work out" non-standard (not written in the frequency converter) the variation of supply voltage frequency, you must convert the continuous law in discrete form. The process control engine speed drilling will be to "send" on the frequency converter discrete frequencies, and the transition between adjacent frequency values will occur linearly. Described nuances into account when modeling the crane performed with frequency-controlled drive.

Evaluation of the use of optimal control traffic overhead crane carried on energy, electric, dynamic and kinematic indicators. Calculated experiments conducted under the condition that the length of the flexible suspension changes over time, decreasing during acceleration increases with the crane and its braking.

To bridge crane work performance was necessary that the length of the transition process was negligible. To put this condition - duration transient (acceleration and braking) crane should be 10% less than the period of free oscillations of cargo on a flexible suspension system for dynamic dvomasovoyi crane, which is from the expression:

$$T_{пер} = 2\pi\sqrt{\frac{m_1}{m_1+m_2}\frac{l}{g}}. \quad (5)$$

The stated condition in mathematical form is written as:

$$T_1 + \pi\sqrt{\frac{l}{g}} = 0{,}9\cdot 2\pi\sqrt{\frac{m_1}{m_1+m_2}\frac{l}{g}}. \quad (6)$$

We can find the length of acceleration to the intermediate speed T1:

$$T_1 = \sqrt{\frac{l}{g}}\left(0{,}9\cdot 2\pi\sqrt{\frac{m_1}{m_1+m_2}} - \pi\right). \quad (7)$$

Independent factors in the studies are: the initial length of the flexible suspension load l0, the initial voltage crane drive motor U0. Each independent factor varies at three levels.

It must be said that the rate of U0 is a function of supply voltage frequency drive crane engines:

$$U_{ж\,ивл} = U_0 + \left(U_{ном} - U_0\right)\frac{f}{f_{ном}}, \quad (8)$$

where U0 - initial voltage value; Unom - nominal output voltage (Unom = 380); fnom - nominal frequency voltage motor (fnom = 50 Hz).

Table 1 shows the parameters that are obtained by means of computational experiments. The three values in each cell of the table corresponding to the three primary voltage value 0, and 0,1Unom 0,3Unom [11].

1. Movement bridge crane for optimum law.

Performance	The initial length of flexible suspension load

	2.5 m	7.5 m	14.5 m
1	2	3	4
The cost of energy E J	516 918 472 103 432 262	439 361 417 675 342 407	414 643 375 978 179 121
Energy loss ΔE, J.	361 499 314 152 271 518	287 180 265 944 179 348	272 794 228 112 19 436
The relative energy loss $\tilde{E}$ %	69.93 66.54 62.81	65.36 63.67 52.37	65.79 60.67 10,85
The maximum electromagnetic torque Mmax engine, Nm	150 199 197	150 149 149	150 150 100
Multiplicity maximum motor torque, $\tilde{M}_{max}$	2.69 3.57 3.52	2.69 2.67 2.67	2.68 2.68 1.80
The maximum motor current Imax, A	243 244 247	245 242 243	243 242 63
Multiplicity maximum motor current, $\tilde{I}_{max}$	6.00 6.01 6.08	6.05 5.97 5.99	6.00 5.97 1.55
The maximum point in the high-speed shaft drive Mp.mah, Nm	423 451 384	425 368 317	370 357 80
Maximum harmonized efforts to bridge Rm.mah, H	52 534 68 954 54 231	34 660 32771 47 982	29 814 32 002 24 883
The maximum deviation from a rope with a load vertically, Δxmax, m	.330 .396 .246	.362 .538 .834	1.083 1,028 0.725
The maximum angle of the rope with a load of vertical, Δφmax, councils	.110 0,132 .082	0,045 .067 .104	0.072 0,068 0,048

End Table. 1

1	2	3	4
Linear amplitude residual vibrations rope with a load after a stop tap, Δxmax. (T> T), m	.254 .154 .095	.253 .271 .372	.372 0,413 0,029
The angular oscillation amplitude remaining rope with load after stopping the crane, Δφmax. (T> T), councils	0,084 0.051 0,031	0,031 0,033 0,046	0,024 0,027 0,001

Analyze the data presented in Table. 1. Comparing between an energy data, we conclude that increasing the length of the flexible suspension and primary voltage motors increases the energy efficiency of a crane.

Particular attention should be paid to the current experiment with the following parameters: l0 = 14,5 m, U0 = 0,3 Unom, as this load fluctuations almost completely eliminated, and work items tap is not accompanied by significant dynamic loads. Analysis of kinematic parameters of the crane with a load on flexible suspension shows the presence of residual vibrations load, the maximum amplitude of residual vibrations is 4.80. The cause of the residual load fluctuations are substandard optimal realization of the crane. From Fig. 2 it is clear that the change in the speed of the crane, obtained as a result of the settlement of the experiment does not match the given (optimal) its velocity.

Fig. 2 schedule specified speed of the crane shown gray line and schedule rate, obtained as a result of calculation experiment - Black.

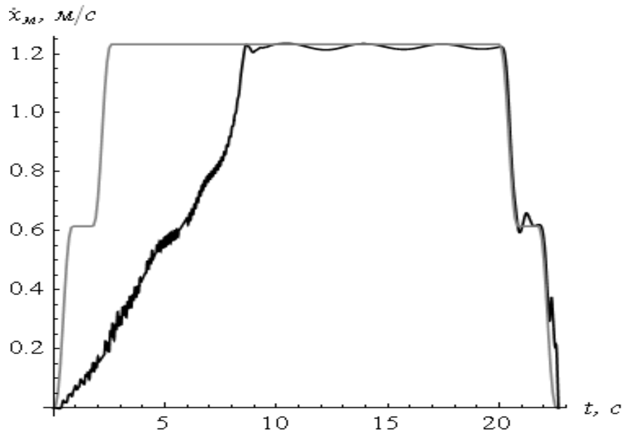

Fig. 2. Graphs change the speed of the crane bridge with the following parameters: l0 = 2,5 m, U0 = 0,1 Unom.

Conclusion. As a result of studies found that optimum use law of motion of overhead crane, which is represented by (2), it is useful only at considerable length flexible suspension load, it is necessary to set the maximum initial voltage drive crane engines. In other cases, the optimal implementation of the law of the crane (2) does not completely eliminate load fluctuations on flexible suspension, and the process of the crane is accompanied by significant dynamic loads and drive axle crane. Implementation of optimal control relies on mechanotronic crane system.

References

1. *Komarov MS* Dynamics lifting machines / MS Komarov. - M .: Mashinostroenie, 1969. - 206 p.
2. *Kazak S.A*. Dynamics mostovыh Crane / SA Kazak. - M .: Mashinostroenie, 1968. - 331 p.
3. Hruzopodъemnыe cranes. Bk. 2 / M. Scheffler, H. Dresyh, F. Kurt; [Trans. with German MM Runov, VN Fedoseev]; ed. MP Alexandrov. - M .: Mashynostoenye, 1981. - 287 p.

4. *Budykov L.YA*. Multiparameter analysis dynamics hruzopodъmnyh cranes bridge type / LY Budykov. - Lugansk: VUHU Publishing, 1997. - 210 p.
5. *Lobov NA* Dynamics lifting cranes / NA Lobov. - M .: Mashinostroenie, 1987. - 160 p.
6. *Gerasimyak R.P*. Analysis and synthesis e`lektromehanicheskij crane systems / *RP Gerasimyak, VA Leschëv*. - Odessa .: SMYL, 2008. - 192 p.
7. *Loveykin VS* Analysis and synthesis modes of motion hoisting machines / VS Loveykin, JO Romasevych. - K .: CB "KOMPRINT", 2012. - 298 p.
8. *Grigorov OV* Improvement characteristics of workers crane mechanisms: diss. on soysk. steppe. Dr. Sc. Sciences: 05.05.05 / Grigorov Otto Vladimirovich. - H., 1995. - 386 p.
9. *Melnikova LV* Automation of technological process SHIFT mechanism with cargo podveshenыm funds microprocessor control: diss. on soysk. steppe. Kandy. Sc. Science: 05.09.03 / Melnikova Love Vasylevna. - Odessa, 2000. - 116 p.
10. *Basil C.* Manage Elektroprivod tsyklychesky rabotayuschyh mechanisms of horizontal SHIFT: dIHS. on soysk. steppe. candidate. Sc. Sciences: 05.09.03 / Basile Shafyk. - Odessa - 1993. - 186 p.
11. Frequency converters FR-E7: Guide to ekspluatatsyy: Product Version 212650. B. Mitsubishi Electric Industrial Automation. - 2008. - 512 p.

In this article conducted Motion Simulation bridge crane with optimal control. Manage crane movement smodelyrovano with pomoshchju frequency converter scalar type. Effect of research parameters settings for frequency converter Dynamic, эnerhetycheskye kynematycheskye indicators and movement of the crane.

Optymalnoe Management, Mostovoy crane chastotnыy converter, asynhronnыy Elektroprivod.

Modeling of bridge crane movement with optimal control has been carried out in the article. Bridge crane movement has been modeled by mean inverter scalar kind. Influence of inverter's setting parameters has been researched on dynamic, energetic and kinematical indexes of crane movement.

Optimal control, bridge crane, inverter, asynchronous drive.

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IMPROVING METHODS AND ANALYSIS sub SUPERHARMONICHNYH VIBRATIONS VIBROUDARNYH nonlinear MECHANICAL SYSTEMS

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