2. *Kastornov NV* Efficiency and competitiveness of dairy skotovodstva / NV Kastornov // breast and Meat skotovodstvo. - 2004. - № 7. - S. 25-31.
3. *A. Krasnov* Increase of the effectiveness LINES doenyya and milk Monitor / AU Krasnov, EI // Sat cabbage. scientific. tr. ACHHAA "Improvement processes and tehnycheskyh funds in agriculture." - Zernograd, 2006. - P. 10-11.
4. *Privalov OE* Efficiency and milk production factors, uh opredelyayuschye / OE Privalov, YA Belyaev // natural science and humanyzm: Sat. scientific. tr. - Tomsk, 2005. - P. 46-48.
5. *Tkachenko TV* Features of the market in milk and milk products Ukraine. // TV Tkachenko, AV Arnaut // Scientific Papers of the Second International Scientific Conference of the National University of Life and Environmental Sciences of Ukraine. - K., 2012. - Charles J. - P. 90-91.

In Article predlozhenы Technological scheme of production breast production kotorыe vnedrenы in Uchebn-LF is industrial podrazdelenyy NUByP Ukraine "Crimean ahrotehnolohycheskyy University" putem creation Uchebn is industrial-scientific complex zhyvotnovodcheskoho, as well as Uchebn-technological laboratory Converting milk.

Breast raw materials, molochnaya out production poholove animals, sebestoymost, profit.

The paper consisted technological production scheme of dairy products, which are embedded in training and production unit SB NULES of Ukraine «Crimean AgroTechnological University» by creating educational, scientific and industrial livestock complex, as well as educational and technological laboratory processing of milk.

Livestock raw, livestock products, number of animals, average cost, profit.

UDC 621.87

OPTIMIZATION MODE MOTION HINGE-ARTICULATED JIB TOWER CRANE SYSTEM FOR DYNAMIC CRITERION

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The paper solved variational problems in optimization mode motion hinge-articulated jib tower crane system for dynamic criterion in which fluctuations are eliminated cargo. The results show graphics solution dependencies.

Fluctuations, cargo traffic law, tower crane.

Problem. Tower cranes-rigid articulated boom system used for building construction [1]. Boom crane system consists of the following main and auxiliary sections, connected by a hinge (Fig. 1). Auxiliary section is horizontal (connected by four-mechanism) on which moves cargo truck.

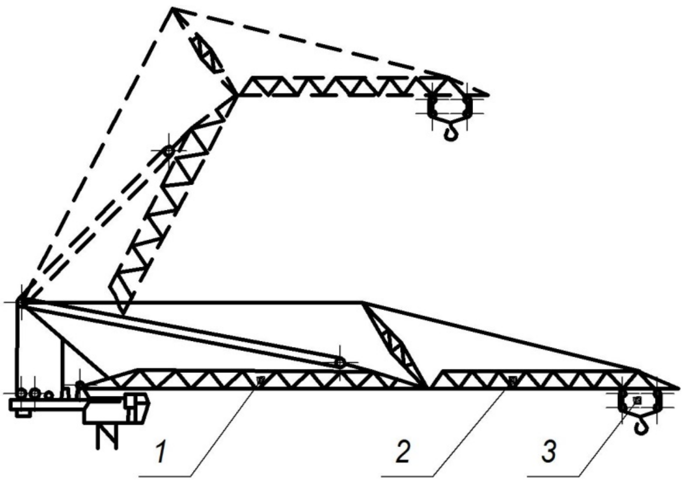


Fig. 1. Hinged articulated boom system: 1 - the main section; 2 - auxiliary section; 3 - cargo truck.

Changing the departure of taps carried out both by driving the cart, and by lifting (lowering) the boom system. If you change the departure by moving the boom system load oscillations occur which last for the entire period and affect the movement of the mechanism uneven lifting boom system, as well as dynamic forces in metal levels and mechanisms [2]. To address these shortcomings need to optimize motion mode-hinged articulated boom system.

Analysis of recent research. Optimization of motion hoisting machines subject of many studies [3-7]. For example, in [4] the optimum driving mode change mechanism departure that minimize deflection flexible suspension of cargo from the vertical. In [5] a way to reduce the load fluctuations on flexible suspension mechanism at work turning the crane boom during the transition process by optimizing mode starting and braking on dynamic criteria. In [6] solved variational problem of determining the optimal mode of movement mechanism of lifting machines with electric DC. In [7] performed modeling the bridge crane where the optimal driving force tap implemented method of frequency regulation electric motor. The evaluation of the efficiency of optimal control for energy, electrical, dynamic and kinetic parameters. Installed rational reason for setting quality implementation of optimal control.

Based on earlier studies, it is proposed to optimize flight regime change crane with hinged rigid boom boom system when driving on dynamic criteria.

The purpose of research-identify the optimal mode change departure crane with hinge-Rigid boom system when working mechanism for lifting boom system, minimizing dynamic loads and vibrations load removal.

Results. For the optimization of traffic hinge-articulated boom suspension system with flexible cargo select trymasovu dynamic model (Fig. 2). It consists of the main and auxiliary sections boom system with masses m_0 and m_1 in accordance with trolley weight m_2 and a mass m_3 Suspended from a flexible rope length l. In the main section operates driving time Mp. We believe that the cables neroztyazhni, weightless and completely flexible load is concentrated at one point, load fluctuations are small and occur only in the plane of movement of the trolley. Elasticity elements driving mechanism is neglected because of their frequency oscillations about an order of magnitude larger than the oscillation frequency and load fluctuations do not affect the latter [8]. For generalized coordinates of the model adopted angular coordinates moving hinge-jointed system a And deviation from the vertical suspension load ν.

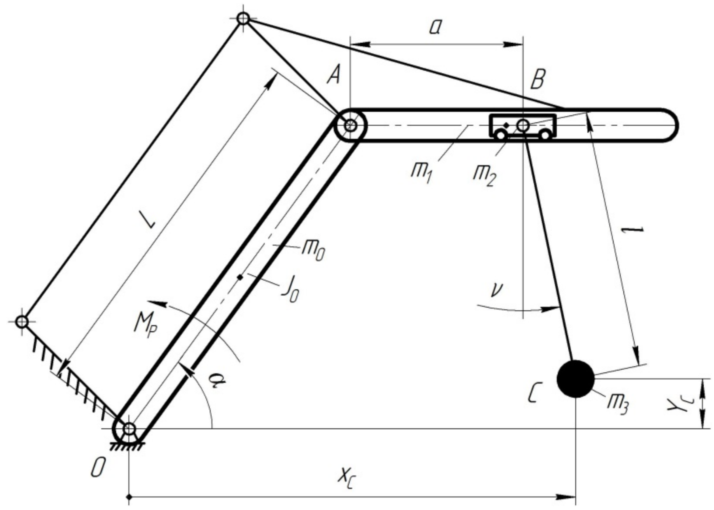


Fig. 2. Dynamic model motion hinge-articulated jib tower crane system.

We define the basic speed of the system. Given that the cargo truck does not move relative to the main section hinge-articulated boom system is written:

$$v_B = v_A. \tag{1}$$

Speed points A and C determined by the following expressions:

$$v_A = \dot{\alpha} L; \tag{2}$$

$$\begin{cases} x_C = a + L\cos\alpha + l\sin\nu; \\ y_C = L\sin\alpha - l\cos\nu; \end{cases} \quad (3)$$

$$\begin{cases} \dot{x}_C = -\dot{\alpha}L\sin\alpha + \dot{\nu}l; \\ \dot{y}_C = \dot{\alpha}L\cos\alpha; \end{cases} \quad (4)$$

$$v_C = \sqrt{\dot{x}_C^2 + \dot{y}_C^2} == \sqrt{(-\dot{\alpha}L\sin\alpha + \dot{\nu}l)^2 + \dot{\alpha}^2L^2\cos^2\alpha} = \\ = \sqrt{\dot{\alpha}^2L^2 + \dot{\nu}^2l^2 - 2\dot{\alpha}\dot{\nu}Ll\sin\alpha}, \quad (5)$$

where L – the length of the main section boom system.

We write the expression for the kinetic and potential energies hinge-articulated boom system with trolley and load:

$$T = \frac{1}{2}J_0\dot{\alpha}^2 + \frac{1}{2}(m_1 + m_2)\dot{\alpha}^2L^2 + \frac{1}{2}m_3(\dot{\alpha}^2L^2 + \dot{\nu}^2l^2 - 2\dot{\alpha}\dot{\nu}Ll\sin\alpha), \quad (6)$$

where J_0 – moment of inertia of the main section boom system relative to the axis of rotation.

$$\Pi = \frac{1}{2}m_0gL\sin\alpha + (m_1 + m_2)gL\sin\alpha + m_3g(L\sin - l\cos\nu). \quad (7)$$

Simplifying the expression (7) we get:

$$\Pi = \{[\frac{1}{2}m_0 + (m_1 + m_2) + m_3]L\sin\alpha - m_3l\cos\nu\}g. \quad (8)$$

Based on the Lagrange equations of the second kind will make the equation of motion of the system.

$$\begin{cases} \dfrac{d}{dt}\dfrac{\partial T}{\partial\dot{\alpha}} - \dfrac{\partial T}{\partial\alpha} = \mathrm{Mp} - \dfrac{\partial\Pi}{\partial\alpha}; \\ \dfrac{d}{dt}\dfrac{\partial T}{\partial\dot{\nu}} - \dfrac{\partial T}{\partial\nu} = -\dfrac{\partial\Pi}{\partial\nu}. \end{cases} \quad (9)$$

Define all elements of the system of equations (9):

$$\begin{aligned} &\frac{\partial T}{\partial\alpha} = \frac{1}{2}m_3(2L^2\alpha - 2lL\cos\alpha\dot{\alpha}\dot{\nu}); \quad \frac{\partial T}{\partial\nu} = 0; \\ &\frac{\partial T}{\partial\dot{\alpha}} = J_0\dot{\alpha} + L^2(m_1 + m_2)\dot{\alpha} - m_3\dot{\nu}lL\sin\alpha; \quad \frac{\partial T}{\partial\dot{\nu}} = \frac{1}{2}m_3(l^2 - 2lL\sin\alpha\dot{\alpha}); \\ &\frac{\partial\Pi}{\partial\alpha} = gL\cos\alpha(\frac{m_0}{2} + m_1 + m_2 + m_3); \quad \frac{\partial\Pi}{\partial\nu} = m_3gL\sin\nu. \end{aligned} \quad (10)$$

Substituting expression (10) in the system of equations (9) and perform mathematical simplification then obtain:

$$\begin{cases} (J_0 + L^2(m_1 + m_2 + m_3))\ddot{\alpha} - m_3lL\sin\alpha\ddot{\nu} = \\ = \mathrm{Mp} - gL\cos\alpha(\dfrac{m_0}{2} + m_1 + m_2 + m_3); \\ L(\cos\alpha\dot{\alpha}^2 + \sin\alpha\ddot{\alpha}) - l\ddot{\nu} = g\sin\nu. \end{cases} \quad (11)$$

Assume that the angular coordinate system moving boom α when changing departure boom angle changes to the system $\Delta\alpha$ Ie:

$$\alpha = \alpha_0 + \Delta\alpha. \quad (12)$$

where α_0- Angle shift the main section boom system at the beginning of the movement.

It follows that:

$$\dot{\alpha} = \Delta\dot{\alpha};\ \ddot{\alpha} = \Delta\ddot{\alpha}; \quad (13)$$

$$\sin\alpha = \sin(\alpha_0 + \Delta\alpha) = \sin\alpha_0 \cos\Delta\alpha + \cos\alpha_0 \sin\Delta\alpha; \quad (14)$$

$$\cos\alpha = \cos(\alpha_0 + \Delta\alpha) = \cos\alpha_0 \cos\Delta\alpha - \sin\alpha_0 \sin\Delta\alpha. \quad (15)$$

Since the deviation angles from the vertical suspension load and displacement hinge-articulated boom systems vary within small so we assume that

$$\sin\nu = \nu; \quad (16)$$

$$\cos\Delta\alpha = 1; \quad (17)$$

$$\sin\Delta\alpha = \Delta\alpha. \quad (18)$$

Rewrite the equation of motion (11) taking into account the expressions (12) - (18):

$$\begin{cases} (J_0 + L^2(m_1 + m_2 + m_3))\Delta\ddot{\alpha} - m_3 lL \times \\ \times(\sin\alpha_0 \cos\Delta\alpha + \cos\alpha_0 \sin\Delta\alpha)\ddot{\nu} = \\ = \mathrm{Mp} - gL(\cos\alpha_0 \cos\Delta\alpha - \sin\alpha_0 \sin\Delta\alpha)\times(\frac{m_0}{2} + m_1 + m_2 + m_3); \\ (\cos\alpha_0 \cos\Delta\alpha - \sin\alpha_0 \sin\Delta\alpha)L\Delta\dot{\alpha}^2 + \\ + (\sin\alpha_0 \cos\Delta\alpha + \cos\alpha_0 \sin\Delta\alpha)L\Delta\ddot{\alpha} - l\ddot{\nu} = g\nu. \end{cases} \quad (19)$$

For optimization criterion minimizing rms take the driving time during the period of motion:

$$\mathrm{I} = \left[\frac{1}{\mathrm{t}_1}\int_0^{\mathrm{t}_1} \mathrm{Mp}^2 dt\right]^{1/2} \to \min, \quad (20)$$

where t_1 - During the movement.

To eliminate vibrations cargo at the end of the movement is necessary and sufficient to ensure the following:

$$\nu(\mathrm{t}_1) = 0; \quad (21)$$

$$\dot{\nu}(\mathrm{t}_1) = 0. \quad (22)$$

Optimization perform through direct variational method [9]. To do this, take a baseline function changes the angular coordinates shift the main section boom system.

According to the task

$$\begin{cases} t = 0 : \Delta\alpha_Б = \alpha_0; \Delta\dot{\alpha}_Б = 0; \Delta\ddot{\alpha}_Б = 0; \\ t = t_1 : \Delta\alpha_Б = \alpha_{t_1}; \Delta\dot{\alpha}_Б = 0; \Delta\ddot{\alpha}_Б = 0. \end{cases} \quad (23)$$

where α_{t_1} - Angle shift the main section boom system at the end of the movement.

In addition to conditions (23) law of motion must fulfill three conditions (20) - (22) as a basis function should be three options that meet those criteria. Assume basis functions as:

$$\Delta\alpha_Б = \Delta\alpha + a_1\Delta\dot{\alpha} + a_2\Delta\ddot{\alpha} + a_3\Delta\dddot{\alpha} \quad (24)$$

where $a_1, a_2, a_3,$ - Basis function parameters.

The first term of (24) provides a non-zero boundary conditions, the rest - zero. Write the first and second derivative of basic functions:

$$\Delta\dot{\alpha}_Б = \Delta\dot{\alpha} + a_1\Delta\ddot{\alpha} + a_2\Delta\dddot{\alpha} + a_3\Delta\alpha^{IV}; \quad (25)$$

$$\Delta\ddot{\alpha}_Б = \Delta\ddot{\alpha} + a_1\Delta\dddot{\alpha} + a_2\Delta\alpha^{IV} + a_3\Delta\alpha^{V}. \quad (26)$$

With conditions (23) - (26) it follows that to determine the basis function $\Delta\alpha_Б$ variable $\Delta\alpha$ should provide the following traffic conditions:

$$\begin{cases} t = 0 : \Delta\alpha = \alpha_0; \Delta\dot{\alpha} = 0; \Delta\ddot{\alpha} = 0; \Delta\dddot{\alpha} = 0; \Delta\alpha^{IV} = 0; \Delta\alpha^{V} = 0; \\ t = T : \Delta\alpha = \alpha_{t1} - \alpha_0; \Delta\dot{\alpha} = 0; \Delta\ddot{\alpha} = 0; \Delta\dddot{\alpha} = 0; \Delta\alpha^{IV} = 0; \Delta\alpha^{V} = 0. \end{cases} \quad (27)$$

As conditions as twelve solve the differential equation twelfth order:

$$\Delta\alpha^{XII} = 0. \quad (28)$$

As a result, the solution of equation (28) we get:

$$\Delta\alpha = \frac{(252t^5 - 1386t^4t_1 + 3080t^3t_1^{\,2} - 3465t^2t_1^{\,3} + 1980tt_1^{\,4} - 462t_1^{\,5})}{t_1^{\,11}} \times$$
$$\times(\alpha_0 - \alpha_T)t^6. \quad (29)$$

Substituting (29) in relation (24), we obtain (30). Substituting expression (30) into the second equation of (19) and determine the angular coordinate deviation from vertical load for the following system parameters: $T = 25c$; $m_0 = 5500кг$; $m_1 = 2500кг$; $m_2 = 500кг$; $m_3 = 6000кг$; $L = 26м$; $l = 15м$; $g = 9.81м/c^2$; $\alpha_0 = 1{,}1рад$; $\alpha_T = \pi/2 \ рад$ and the initial conditions of motion: $\nu(0) = 0;\ \dot{\nu}(0) = 0.$

$$\Delta\alpha_Б = (\frac{(252t^5 - 1386t^4t_1 + 3080t^3t_1^{\,2} - 3465t^2t_1^{\,3} + 1980tt_1^{\,4} - 462t_1^{\,5})(\alpha_0 - \alpha_T)t^6}{t_1^{\,11}} +$$
$$+ a_1\left(\frac{2772t^5(t-t_1)^5(\alpha_0 - \alpha_{t_1})}{t_1^{\,11}}\right) + a_2\left(\frac{13860t^4(t-t_1)^4(2t-t_1)(\alpha_0 - \alpha_{t_1})}{t_1^{\,11}}\right) + \quad (30)$$
$$a_3\left(\frac{27720t^3(t-t_1)^3(9t^2 - 9tt_1 + 2t_1^{\,2})(\alpha_0 - \alpha_{t_1})}{t_1^{\,11}}\right).$$

As a result, we obtain the solution of polynomial order 31, which is too hromistkyy because the article will not give it. Write conditionally:

$$\nu_Б = f(a_1, a_2, a_3, t) \quad (31)$$

From the first equation of (19) determine the driving time and substitute it in expressions (30) and (31), with the result that we have:

$$Mp = -(J_0 + L^2(m_1 + m_2 + m_3))\Delta\ddot{\alpha}_Б + lLm_3(\sin\alpha_0 + \cos\alpha_0\Delta\alpha_Б)\ddot{v}_Б + \\ + gL(\frac{m_0}{2} + m_1 + m_2 + m_3)(\cos\alpha_0 - \sin\alpha_0\Delta\alpha_Б). \quad (32)$$

Then we define the integrand value criterion (20).

Next task is to determine the three factors that are the basis functions (a_1, a_2, a_3) That would provide the following:

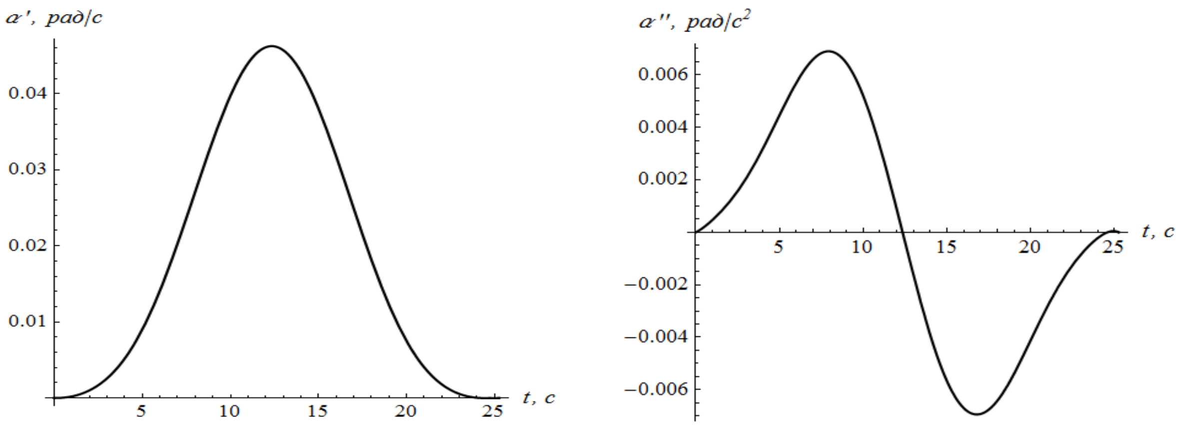
$$\begin{cases} v_Б(t_1) = 0; \\ \dot{v}_Б(t_1) = 0; \\ \dfrac{\partial I}{\partial a_3} = 0. \end{cases} \quad (33)$$

The first and second terms of equations (33) eliminates fluctuations in cargo movement at the end of the hinge-jointed boom system, and the third provides for optimization criterion (20).

Solving the system of equations transentdentnyh (29), we obtain the following results:

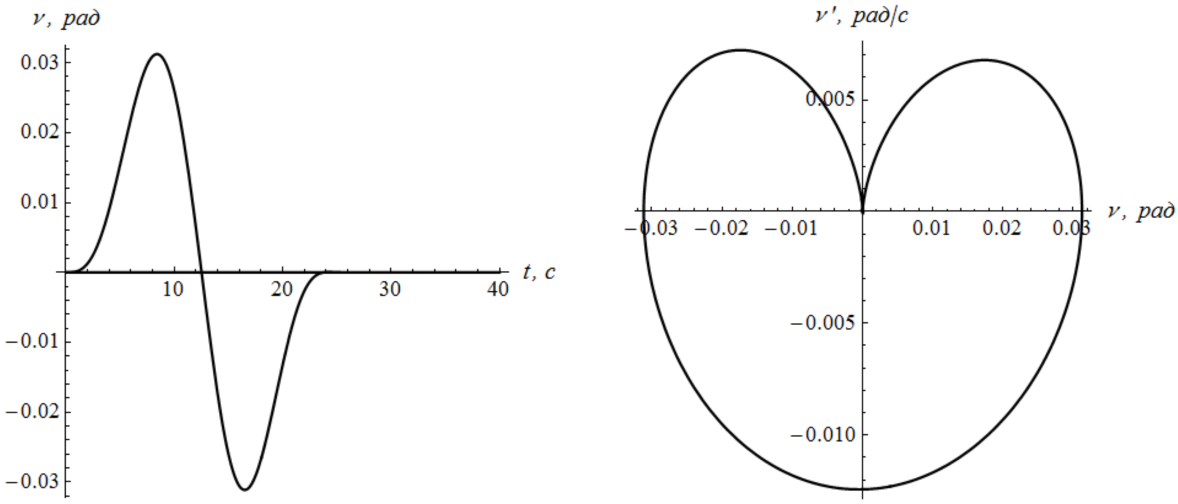
$$a_1 = 0.303; \\ a_2 = 1.367; \\ a_3 = 1.530. \quad (34)$$

Construct a graph (Fig. 3) Speed and acceleration main section hinge-articulated boom system, and a graph of angular coordinate deviation from the vertical suspension load and dynamic phase portrait of optimal cargo movement (Fig. 4) and graph (Fig. 5) changes the driving moment.



a) b)

Fig. 3. Charts speed change (b) and acceleration (a) the main section of the hinge-jointed boom system.



a) b)

Fig. 4. Schedule changes angular coordinate deviation from the vertical suspension load (a) and phase portrait of optimal dynamic traffic load (b).

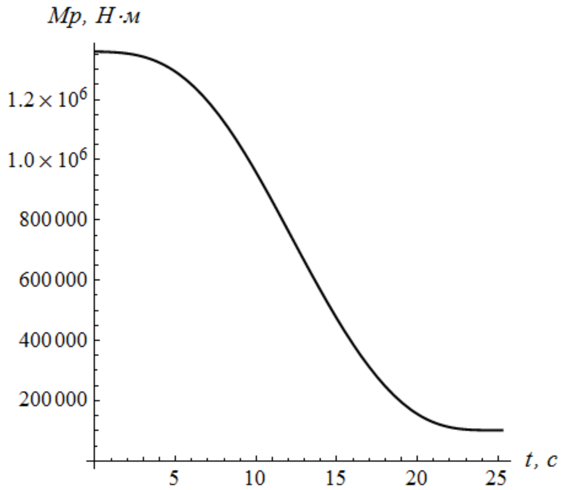


Fig. 5. Schedule changes the driving moment.

As can be seen from the graphs shown in Fig. 3 motion hinge-jointed system in areas transients is quite smoothly, initial and final velocity and acceleration of zero, and no plot steady motion.

During acceleration boom system load slightly deviates from the point of suspension (t.V) in the opposite direction of the boom system side (Fig. 4a), and during braking deviates from the suspension point in the direction of movement, but at the end of fluctuations cargo traffic absent (Fig. 4, B).

Fig. 5 non-zero initial due date of the driving time of the initial value of the resistance force of gravity boom system, trolley and load but when lifting boom system torque resistance decreases, which leads to a reduction of the driving torque.

Conclusions

As a result of the research optimization problem is solved reduce dynamic loads during flight changes crane with hinge-Rigid boom system that reduces the dynamic loads and eliminate fluctuations in load at the end of the movement.

The results can be used in the design of the control system drives crane with hinge-Rigid boom system.

References

1. *Nevzorov L.A.* Bashenные gage / L.A. Nevzorov. - K .: Higher School, 1980. - 326 p.
2. *Loveykin VS* Movement of departure crane boom hinge-rigid system / VS Loveykyn, OH Shevchuk // Mining, construction, road and agricultural machines. - 2013. - № 82. - P. 20-27.
3. *Smehov A.A.* Optymalnoe Management hoisting machines transportnыh / AA Smehov. - M .: Mashinostroenie, 1975. - 239 p.
4. *Romasevych YO* Optimization regime change departure cargo crane for single kinematic criteria / YA Romasevych, GV Shumilov // Motrol. - 2011. - Vol. 13B. - R. 167-173.
5. *Loveykyn VS* Dynamic Optimization mode turns jib crane / VS Loveykyn, VA Melnichenko // Motrol. - 2013. - Vol. 15. - №3. - R. 70-75.
6. *Loveykyn VS* Optimization equation of motion mechanisms lifting machines with Elektroprivod constantly conductors / VS Loveykyn, YU.A. Romasevych // Motrol. - 2013. - Vol. 15. - №3. - R. 65-69.
7. *Loveykyn VS* Optimization mode razhona odnomassovoy dynamycheskoy systemoy with yntehralnыmy Limit / VS Loveykyn, YU.A. Romasevych // Motrol. - 2012. - Vol. 14. - №3. - R. 158-163.
8. *Loveykyn VS* Raschetы optymalnыh regimes movement mechanisms of building machines / VS Loveykyn. - K .: CMD PA, 1990. - 168 p.
9. *Loveykyn VS* Optimization of acceleration odnomasovyh mechanical systems direct variational method / VS Loveykyn, JO // Romasevych automation of production processes in engineering and instrumentation. - 2011 - Vol. 45. - P. 96-102.

In Article varyatsyonnaya problem solutions in optimization mode motion articulated strelovoy system bashennoho tap on Dynamic Criteria at Kotor ustranyayutsya fluctuations cargo. Showing Results solutions hrafycheskymy dependence.

Fluctuations, cargo, the law of motion, Tower crane.

The paper solved the variation problem to determine mode of motion of articulated jib of tower crane in which removed payload oscillations. The results are demonstrated into graphical view.

Oscillations, load, mode of motion, tower crane.