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OPTIMIZATION OF POWER MODE OF MOTION Grab Bucket

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In this paper, we solve the problem of optimization mode motion capture grab by direct variational method. An optimal mode of movement hydraulic cylinder that controls the jaws of capture, which provides a minimum energy expenditure.

Optimizing mode of motion, variational method, Clam Bucket.

Problem. Complex mechanization and automation of loading and unloading, transport, storage and other activities is one of the pressing problems. Equipment for special lifting equipment lifting devices such as grab mechanisms contributes to the solution of this problem. Highly claw mechanisms are also applying for technological purposes. They are used for the preparation and filing of the charge on the charge and skrapnyh yards for work on ore yards, feeding and cleaning molding materials in foundries, etc. Grab mechanisms used at forestry, pulp and paper, wood and coal mines warehouses lisoperevalochnyh bases. These mechanisms are also used in agriculture and for special purposes - sinking vertical shafts, recovery of the species planted pits, lifting sunken ships. It should be noted that the claw mechanisms are the basis of executive mechanical robots and manipulators. Determining the optimal modes of motion claw mechanisms for energy consumption is an actual problem.

Analysis of recent research. Application hydraulic drives are the most common seizure. They differ in terms of cylinder, with a sloping, vertical and horizontal cylinders [1]. Theoretical aspects to be considered in the design grabs this structural properties, parameters and kinematics motion grab mechanism [2].

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Developing the concept of capturing grabs wood was first described by Tauber [3], and the definition of geometrical parameters claw mechanisms highlighted in the work of AP Asyatkyna [4] S. Hrytsiuk [5] and other authors. Research on optimization of various mechanical movement of dedicated work [6, 7, 8], which is considered optimal control traffic load, construction and handling machines. However, studies of optimization mechanisms grab movement is practically not carried out.

Purpose Research is to grab traffic optimization mechanisms for energy criterion.

Results. Grab device present in the form of a flat mechanism (fig. 1). It consists of five moving parts: 1 - rod cylinder; 2 - cylinder; 3 - right jaw; 4 - left jaw; 5 - the lever that provides symmetrical movement of the jaws 3 and 4 and the fixed link bunk frame construction. This mechanism has 7 kinematic pairs fifth grade (*O1, O2, A, B, C, D, E*). Define by formula PL Chebyshev degree of mobility of the mechanism [7]:

$$W = 3n - 2P_5 - P_4, \quad (1)$$

where *n*= 5 - the number of moving parts of machinery, *P5*= 7 - number of kinematic pairs fifth grade; *P4*= 0 - number of kinematic pairs fourth grade. Substituting numerical values into the formula (1), we obtain:

$$W = 3 \cdot 5 - 2 \cdot 7 = 1.$$

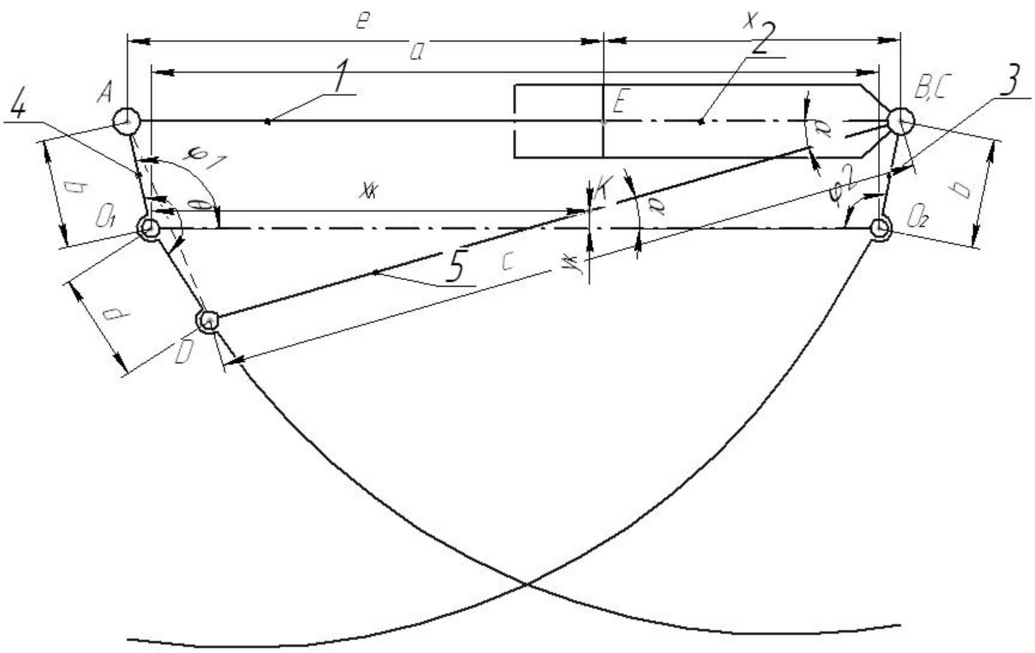


Fig. Figure 1. Grab Bucket.

This mechanism has one degree of mobility, that is a leading link. That link is the cylinder rod. Initial data defining geometrical parameters is bunk: *b*=*d* =0.12 *e*= 0.6m, *c*= 0.79m, *θ = 160 °, a*= 0.8m. Move the cylinder rod characterized coordinate *x,* and moving jaw defined by coordinates φ_1 and φ_2Defined dependencies:

$$\varphi_1 = \arccos\left(-B + \sqrt{\frac{B^2 - AC}{A}}\right); \quad (2)$$

$$\varphi_2 = arccos\{\frac{1}{b}[a - dcos(\theta - \varphi_1) - \frac{e+x}{2} - \frac{c^2-b^2-d^2+2bdcos\theta}{2(e+x)}]\}, \quad (3)$$

where to simplify expressions use the following equation:

$$A = b^2 - 2bdcos\theta + d^2;$$

$$B = \frac{1}{2}(b - dcos\theta)(e - x - \frac{c^2 - b^2 - d^2 + 2bdcos\theta}{e + x});$$

$$C = \frac{1}{4}(e + x - \frac{c^2 - b^2 - d^2 + 2bdcos\theta}{e + x})^2 - d^2\sin^2\theta,$$

where *and* - The distance between the axes of rotation bunk; *b*,*d* - Distance from the axis of rotation of the jaws to the axes of their connection with other parts bunk; *c* - The length of the lever 5; *th* - The length of the cylinder rod; *θ* - Turn left jaw angle between kinematic pairs *A* and *D.*

Angle *α,* showing the tilt lever 5 to the horizon is determined by the following expression:

$$\alpha = \arccos\left(\frac{(e + x)^2 + c^2 - b^2 - d^2 + 2bdcos\theta}{2c(e + x)}\right). \quad (4)$$

The lever 5 performs plane-parallel motion - translational movement of the center of mass (point *K*) And rotation around the center of the angular coordinate *α*. The coordinates of *K* determined by the following relationship:

$$\begin{cases} x_K = dcos(\theta - \varphi_1) + \frac{1}{2}ccos\alpha; \\ y_K = -dsin(\theta - \varphi_1) + \frac{1}{2}csin\alpha. \end{cases} \quad (5)$$

Find also summarized in terms of speed *K*:

$$\begin{cases} \dot{x}_K = \dot{\varphi}_1 dsin(\theta - \varphi_1) - \frac{\dot{\alpha}}{2}csin\alpha; \\ \dot{y}_K = \dot{\varphi}_1 dcos(\theta - \varphi_1) + \frac{\dot{\alpha}}{2}ccos\alpha. \end{cases} \quad (6)$$

Jaws 4 and 3 perform rotational movement relative to points O_1 and O_2 and characterized by angular coordinates φ_1 and φ_2. 1 cylinder rod performs translational motion and its mass center coordinates the coordinates of the point *And*. Sleeve 2 cylinder performs translational motion and its mass center coordinates the coordinates of the point *B*. Neglects possible to turn the rod and cylinder liners because they are virtually absent.

To optimize the power mode of motion capture use grab integral criterion, which is the average of the time value of the kinetic energy of motion

$$I_T = \frac{1}{t_1}\int_0^{t_1} T dt, \quad (7)$$

where *t* - Time; t_1= 5s - the length of the rod cylinder movement from one extreme position to another; *T* - Kinetic energy bunk.

Define kinetic energy Grapple

$$T = \frac{1}{2}m_1 V_A^2 + \frac{1}{2}m_2 V_B^2 + \frac{1}{2}J_{O2}\dot{\varphi}_2^2 + \frac{1}{2}J_{O1}\dot{\varphi}_1^2 + \frac{1}{2}m_5(\dot{x}_K^2 + \dot{y}_K^2) + \frac{1}{2}J_K\dot{\alpha}^2, \quad (8)$$

where m_1= 15kg, m_2= 20 kg, m_5= 10kg - under weight rod, cylinder liners and instruments; *JO1*=*JO2*= 6,54kh · m2 - moments of inertia relative to the axes of rotation of the jaws; *JK*= 0,52kh · m2 - the moment of inertia of the lever relative to the center of mass; *VA*,*VB* linear velocity of points *And* and *In the* Grapple jaw (Figure 1); $\dot{x}_K$,$\dot{y}_K$- Horizontal and vertical components of the velocity of the center of mass of the lever; $\dot{\varphi}_1$,$\dot{\varphi}_2$,$\dot{\alpha}$- Angular velocity respectively left, right arm and jaw.

Speed points *And* and *In the* jaws bunk defined dependencies:

$$\begin{cases} V_A = \dot{\varphi}_1 b \\ V_B = \dot{\varphi}_2 b' \end{cases} \quad (9)$$

where *b* - The length of the arm cylinder of focus.

After substituting dependence (6) and (9) in the expression (8), we obtain

$$T = \frac{1}{2}(m_1 b^2 + m_5 d^2 + J_{O1})\dot{\varphi}_1^2 + \frac{1}{2}(m_2 b^2 + J_{O2})\dot{\varphi}_2^2 +$$
$$+\frac{1}{2}({m_5 c^2}/_4 + J_K)\dot{\alpha}^2 + \frac{1}{2}m_5 c d \dot{\varphi}_1 \dot{\alpha}\cos(\theta + \alpha + \varphi_1). \quad (10)$$

If we accept

$$\begin{cases} \dot{\varphi}_1 = \dot{x}\frac{\partial \varphi_1}{\partial x} \\ \dot{\varphi}_2 = \dot{x}\frac{\partial \varphi_2}{\partial x} \\ \dot{\alpha} = \dot{x}\frac{\partial \alpha}{\partial x} \end{cases}, \quad (11)$$

then the kinetic energy is as follows:

$$T = \frac{1}{2}(m_1 b^2 + m_5 d^2 + J_{O1})\dot{x}^2(\frac{\partial \varphi_1}{\partial x})^2 + \frac{1}{2}(m_2 b^2 + J_{O2})\dot{x}^2(\frac{\partial \varphi_2}{\partial x})^2 +$$
$$+\frac{1}{2}({m_5 c^2}/_4 + J_K)\dot{x}^2(\frac{\partial \alpha}{\partial x})^2 + \frac{1}{2}m_5 c d \dot{x}^2 \frac{\partial \alpha}{\partial x}\frac{\partial \varphi_1}{\partial x}\cos(\theta + \alpha + \varphi_1). \quad (12)$$

To find the optimal power grab mode motion mechanism applicable classical calculus of variations. To do this, define the necessary condition for a minimum criterion (7) - Euler-Poisson [7], in view of (12). The condition of minimum criteria *IT* equation is:

$$\frac{d}{dt}\frac{\partial T}{\partial \dot{x}} - \frac{\partial T}{\partial x} = 0. \qquad (13)$$

After substitution of (12) in equation (13) we get:

$$\ddot{x}\left((m_1 b^2 + m_5 d^2 + J_{01})\left(\frac{d\varphi_1}{dx}\right)^2 + (m_2 b^2 + J_{02})\left(\frac{d\varphi_2}{dx}\right)^2\right.$$

$$+\left(\frac{m_5 c^2}{4} + J_K\right)\left(\frac{d\alpha}{dx}\right)^2 +$$

$$\left.+m_5 cd\frac{d\alpha}{dx}\frac{d\varphi_1}{dx}\cos(\theta+\alpha+\varphi_1)\right) + \dot{x}^2\left((m_1 b^2 + m_5 d^2 + J_{01})\frac{d\varphi_1}{dx}\frac{d^2\varphi_1}{dx^2} +\right.$$

$$+(m_2 b^2 + J_{02})\frac{d\varphi_2}{dx}\frac{d^2\varphi_2}{dx^2} + \left(\frac{m_5 c^2}{4} + J_K\right)\frac{d\alpha}{dx}\frac{d^2\alpha}{dx^2} + \frac{1}{2}m_5 cd \times$$

$$\times\left(\left(\frac{d\alpha}{dx}\frac{d^2\varphi_1}{dx^2} + \frac{d\varphi_1}{dx}\frac{d^2\alpha}{dx^2}\right)\cos(\theta+\alpha+\varphi_1) - \left(\left(\frac{d\alpha}{dx}\right)^2\frac{d\varphi_1}{dx} +\right.\right.$$

$$\left.\left.\left.+\left(\frac{d\varphi_1}{dx}\right)^2\frac{d^2\alpha}{dx}\right)\sin(\theta+\alpha+\varphi_1)\right)\right) = 0. \qquad (14)$$

The resulting equation is nonlinear homogeneous differential equation of second order. The solution of the given equation is quite a challenge that can not be solved in analytical form. Therefore, use the direct variational method proposed in [10]. Define the required boundary conditions:

$$\begin{cases} x(0) = x_0; \dot{x}_0 = 0; \\ x(t_1/2) = q_1; \\ x(t_1) = x_0 + s; \dot{x}_{t_1} = 0. \end{cases} \qquad (15)$$

According to the method, we find supporting function, which is the solution of the boundary value problem:

$$x(t) = \frac{16q_1 t^2(t-t_1)^2 - (2t-t_1)(st^2(4t-5t_1) + (8t^3 - 12t^2 t_1 + 2tt_1{}^2 + t_1{}^3)x_0)}{t_1{}^4}, \qquad (16)$$

where q_1 - The position of the cylinder rod; *s*= 0,25m - move the cylinder rod; *x0*= 0,05m - initial position of the cylinder. Substituting the law of motion in the integrand expression (12) functional (7) and find the integral. Functional turns into a complex function parameter q_1. In order to minimize the value of the integral equation to be solved

$$\frac{\partial I}{\partial q_1} = 0. \tag{17}$$

This equation is linear algebraic form, because we seek a minimum criterion directly substituting values q_1 the expression and functional criteria to compare values between them. This was designed algorithm is given below (Fig. 2).

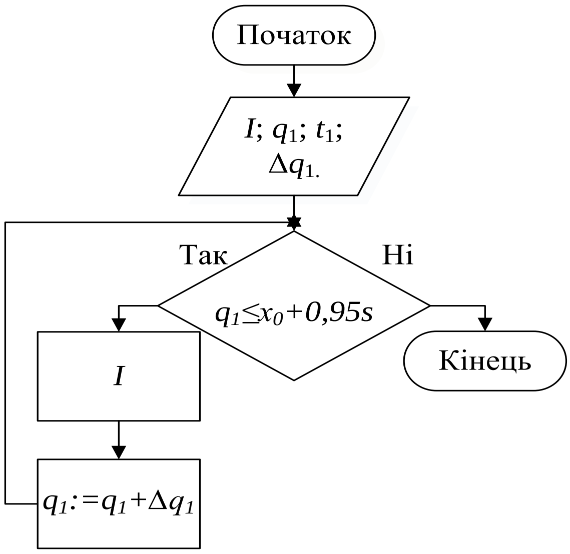


Fig. 2. Algorithm for finding the minimum criteria.

The essence of the algorithm is that at every step of the cycle for each value q_1 added step $\Delta q1 = s \cdot 0{,}01$ and is determined by the value of the criterion. After completing all cycles value compared to each other and is the smallest value criterion (Fig. 3). Also, we construct a graph of speed repositioning rod cylinder q_1 (Fig. 4).

On the basis of the calculations determined that the lowest value criterion is reached at q_1= 0.1725 and built a graph (Fig. 3). For this value we present the kinematic features of movement of the jaws (Fig. 5 - Fig. 7).

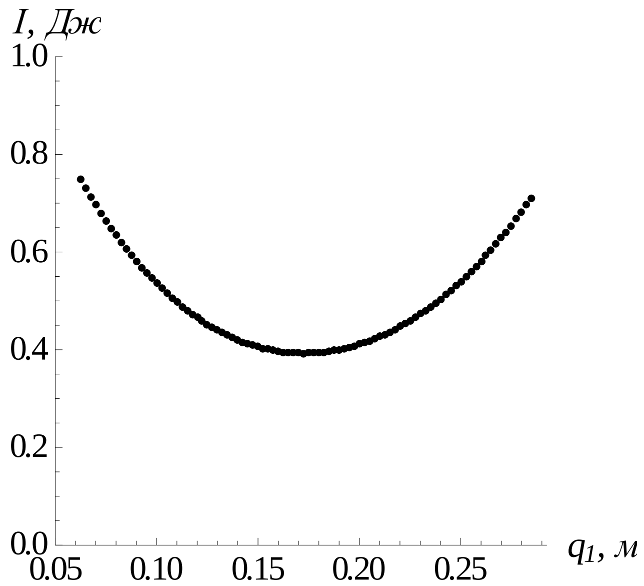


Fig. 3. A plot of the values of the parameter criteria q_1.

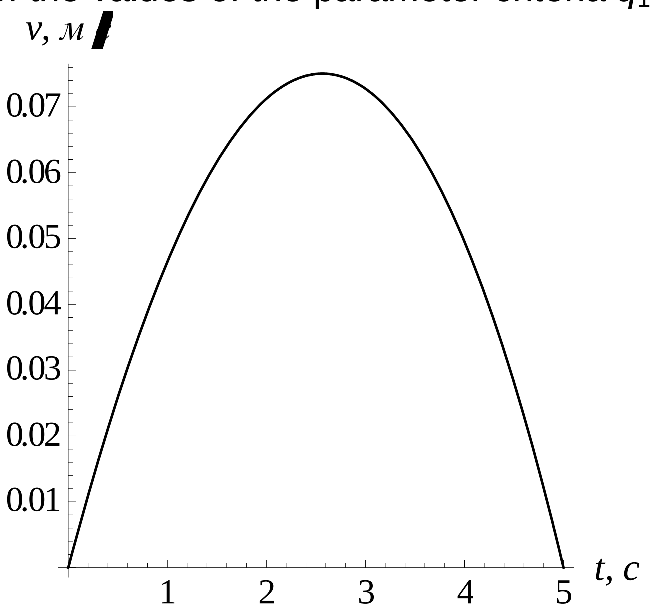
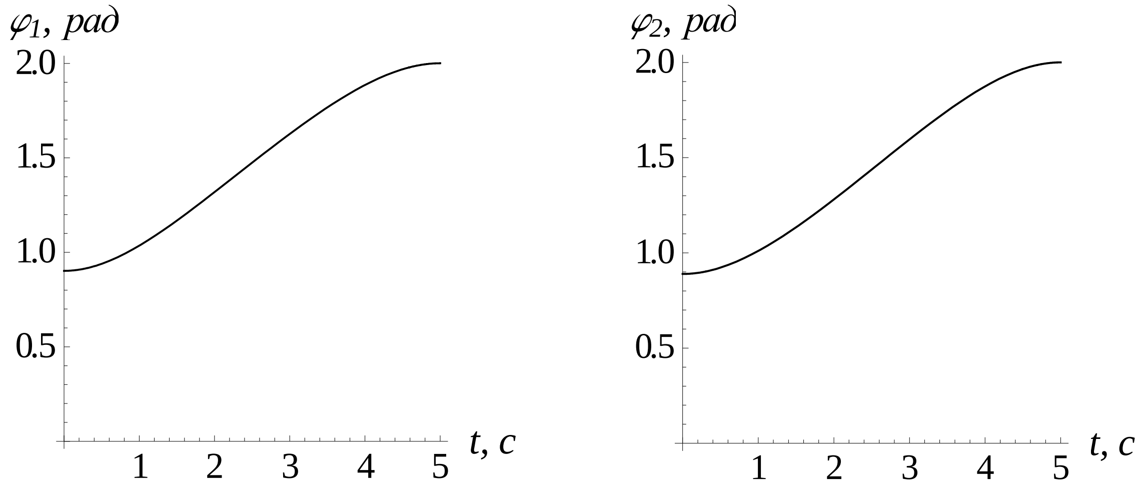


Fig. 4. Schedule speed cylinder rod.



a) to)

Fig. 5. Schedule changes angular coordinates of corners: a - *φ1*(*t*) b - *φ2*(*t*).

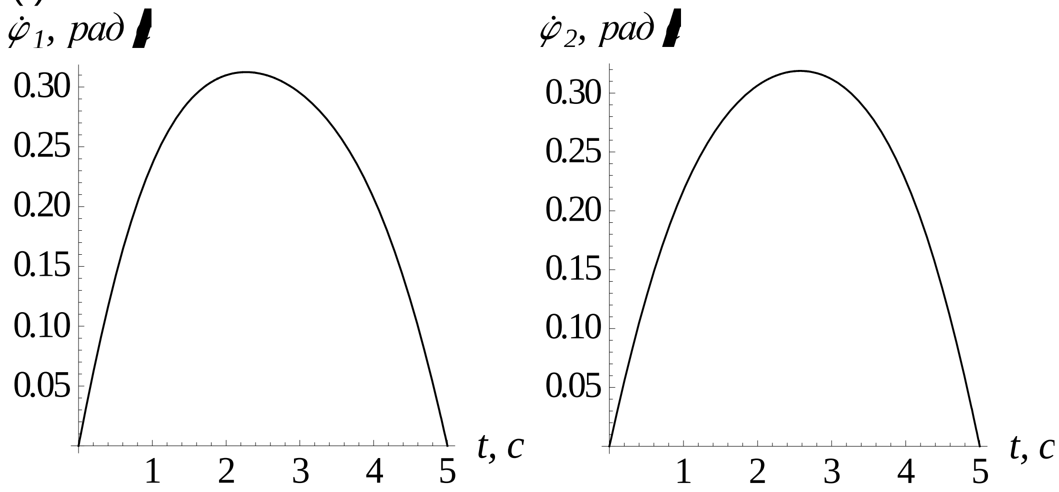


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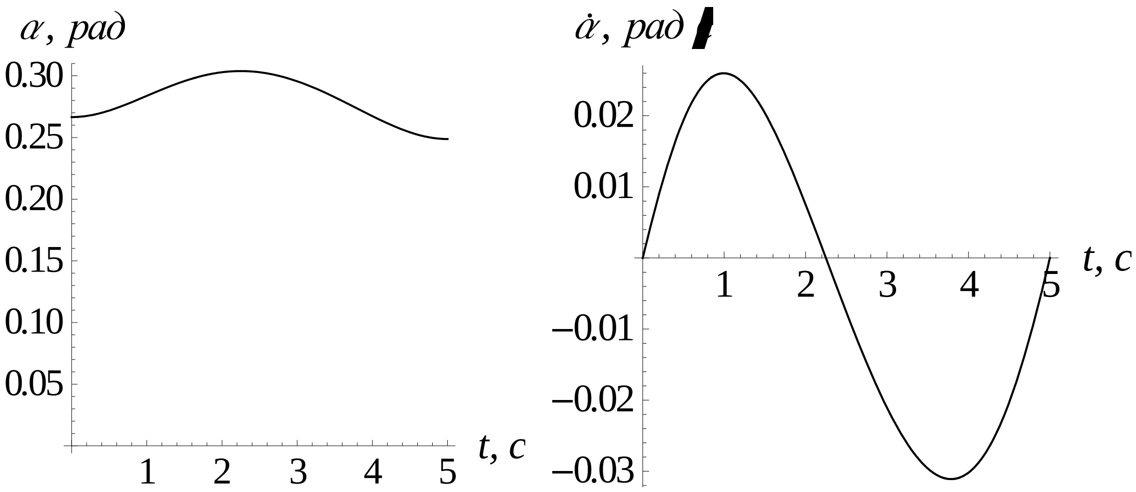
Fig. 6. Charts angular velocities: a - $\dot{\varphi}_1$ (*t*) b - $\dot{\varphi}_2$ (*t*).



a) to)

Fig. 7. Charts changing angular coordinates (a) and velocity (b) of the handle.

From these graphs shows that the resulting optimal mode of movement cylinder closing jaws bunk provides no significant change in angular coordinates and a smooth change of the angular velocity of the jaws.

Conclusions

Synthesized close to the optimal power mode, a mode of motion grab cylinder mechanism that controls the jaws, which gives minimum average value of the selected criteria kinetic energy on the move.

The law of motion (16) represents the optimal mode of movement, providing for minimum energy costs and makes it possible to increase the efficiency of the grab mechanism. It can be implemented by means of mechatronics.

References

1. *Wang, J.* and G. Li. 1993. A review of log grapple used in China. J. of Forest Engineering. 4 (2): P. 33-36.
2. *Wang, J.* 1990. Study on the theories of log grapples. Ph.D. Dissertation. Northeast Forestry University, Harbin, China. 311 pp.
3. *BA Tauber* Hreyferные Mechanisms. Theory, calculation and constructions / *BA Tauber*. - M .: Mashinostroenie, 1967. - 424 p.
4. *Asyatkyn AP* Study of major konstruktyvпыh and эkspluatatsyonпыh parameters for naporпыh hreyferov of loading silo zhyvotnovodcheskyh on farms. Author. Thesis. candidate. Sc. Science / *AP Asyatkyn*. - Krasnodar, 1966. - 25 p.
5. *Hrytsiuk SI* Methods proektyrovochnoho calculation of hydraulic grapple for steblevыh hruzyv / *SI Hrytsiuk* // Traktoгы and selskohozyaystvenпыe machine. - 1975. - №12. - P. 22-24.
6. *Grigorov OV* Optimal traffic control mechanisms of lifting equipment / *OV Grigorov, V. Loveykin*. - K .: Nauka, 1997. - 262s.
7. *Loveykyn VS* Raschetы optimal regimes of motion mechanisms of building machines / *VS.. Loveykyn*. - K .: CMD PA, 1990. - 168 p.
8. *Modeling* dynamics of hoisting machines / *VS Loveykin, Y. Chovniuk, MG Dikteruk, SI Pastushenko*. Kyiv - Nikolaev: MSAU, 2004. - 285 p.
9. *Loveykin VS* Optimization of transient states of motion of mechanical systems direct variational method / *VS Loveykin, AV Loveykin, JO Romasevych* // Herald of the Ternopil State Technical University. - 2010 - Vol 15. - №1. - P. 30-39.
10. *Loveykin VS* Optimization of transient states of motion of mechanical systems direct variational method / *VS Loveykin, JO Romasevych*. - Nizhin: Publisher Lysenko PP, MM, 2010. - 184 p.

In the work task optimization solutions grab mode motion capture with pomoshchju varyatsyonnoho direct method. Optymalnыy will provide a mode of motion cylinder, upravlyayuschyy mouth capture, kotoгыy obespechyvaet minimum of power machinery costs.

Optimization mode motion, varyatsyonпыy method hreyferпыy delight.

In paper solved the problem of optimization of motion mode clam Bucket by direct variational method. Try the optimal mode of motion hydraulic cylinder that controls the jaws of capture, which minimizes energy costs.

Optimization, drive mode, variational method, grapple.