KINEMATIC ANALYSIS GRABS FOR TIMBER

V. Loveykin, P. Lymar

In paper described the kinematic analysis of hydraulic grapple with a horizontal cylinder arrangement and different modes of motion of the drive.

***Keywords**: claw mechanisms, jaw, timber, mode of movement.*

One of the most time-consuming operations during logging is loading and unloading of timber and timber assembly. When loading wood claw working bodies there are significant efforts in the hydraulic system and the mechanism as a whole, it is important to reduce the strain and energy costs of carrying out these operations by developing new and optimizing existing designs grab loader pressure. Because the capture process is closely linked with bunk design parameters and modes of work, so you need to perform kinematic analysis of movement of parts. This will best meet the high standards of performance, reliability, accuracy and efficiency.

Hydraulic actuators are the most common seizure and vary in terms of hydraulic cylinder: with sloping, vertical and horizontal cylinders [5]. The theoretical aspects to be considered in the design process is the structural properties, parameters and kinematics motion claw mechanism [6]. Developing the concept of capturing grabs wood was first described by Tauber [4]. Also, the determination of geometrical parameters claw mechanisms highlighted in the work of A. Asyatkyn [1], S. Grytsiuk [2] and other authors. In general, the claw mechanism parameters are determined based on the rated capacity and the physical and mechanical properties of materials that are addicted to grab. The main geometrical parameters are bunk width jaw opening size of jaws, jaw shape, the distance from the hinge of the jaw attachment to the point of application of force closing the distance between the mounting jaw joints [4]. Equally important in the design of claw mechanisms is to study and determine the optimum movement which considerable attention is given in [3].

The purpose of research. Construct a mathematical model of the motion of the jaws bunk. To analyze the kinematic characteristics claw mechanism for different modes of movement over the jaws.

Material and methods studies. To determine the kinematic characteristics of the claw mechanism uses the mathematical model of the motion of the jaws. Analysis of the jaws held for optimum power, optimum dynamic and optimal jerk motion mode over the jaws. Charts angular coordinates were built with the software Mathematica.

Studies. Grab device is present in the form of a plane mechanism (Fig. 1). It has five moving parts: 1 - rod cylinder, 2 - cylinder, 3 - right jaw, 4 - left jaw, 5 - lever that provides symmetrical movement of the jaws 3 and 4 and the fixed link frame construction bunk.

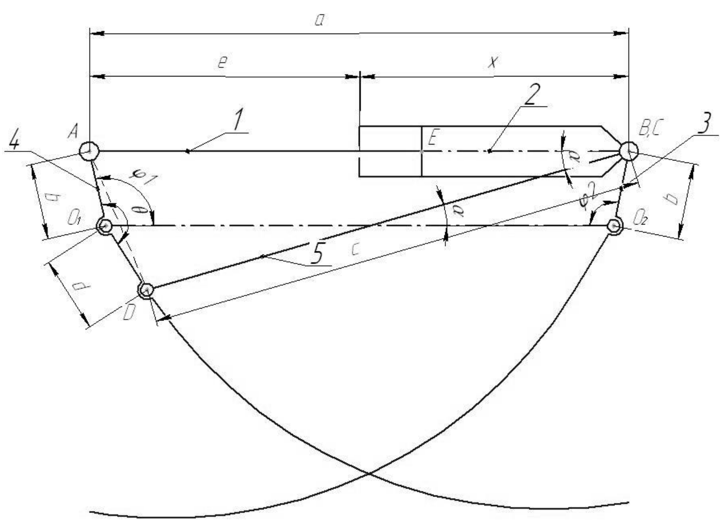


Fig.1 Scheme claw mechanism

This mechanism has 7 kinematic pairs of the fifth class (O1, O2, A, B, C, D, E). Define the formula to P. Chebyshev`s degree of mobility of this mechanism:

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

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

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

This mechanism has one degree of mobility that is a driving link. That link is the rod cylinder. Establish the dependence of the angular displacement, velocity and acceleration of jaw bunk depending on the displacement rod hydraulic cylinder, which is characterized by the coordinate x, and moving jaws defined by coordinates φ1 and φ2.

The initial data defining the geometric parameters bunk is: b = d = 0.12m, e = 0.6m, c = 0.79m, θ = 160 °, a = 0.8m.

Design the length of the links bunk on the coordinate x, as a result we obtain two equations:

$$b\cos\varphi_2 + b\cos\varphi_2 + e + x = a\,;$$

$$b\cos\varphi_2 + d\cos(\theta - \varphi_1) + c\cos\alpha\,, \tag{2}$$

where a - the distance between the axes of rotation of the jaws bunk; b and d - the distance from the axis of rotation of the jaws to make their connection with other parts of bunk; c - length of the lever 5; e - length of the cylinder rod; θ - angle of the left jaw spread between the kinematic pairs of A and D; α - angle lever 5 to the horizontal (x-axis).

Find the distance between kinematic pairs A and D for the cosine theorem:

$$AD = K = \sqrt{b^2 + d^2 - 2bd\cos\theta}\,, \tag{3}$$

use for Δ ABD cosine theorem:

$$k^2 = c^2 + (e + x)^2 - 2c(e + x)\cos\alpha \tag{4}$$

and find the equation of the resulting angle to the horizontal lever

$$\cos\alpha = \frac{(e + x)^2 + c^2 - b^2 - d^2 + 2bd\cos\theta}{2c(e + x)} \tag{5}$$

Substituting the resulting expression into the second equation of the system (2), resulting in'll have:

$$b\cos\varphi_2$$

$$b\cos\varphi_2 + d\cos(\theta-\varphi_1) + \frac{(e+x)^2 + c^2 - b^2 - d^2 + 2bd\cos\theta}{2(e+x)} = a.$$

From the resulting equation we find the expression

$$b\cos\varphi_2 = a - d\cos(\theta-\varphi_1) - \frac{(e+x)^2 + c^2 - b^2 - d^2 + 2bd\cos\theta}{2(e+x)}$$

and substitute it into the first equation of system (2), then we have $b\cos\varphi_1 + a - d\cos(\theta-\varphi_1) - \frac{(e+x)^2 + c^2 - b^2 - d^2 + 2bd\cos\theta}{2(e+x)} + e + x = a.$

Let's make some transformations last equation and write

$$b\cos\varphi_1 - d\cos\theta\cos\varphi_1 - d\sin\theta\sin\varphi_1 + e + x - \\ - \frac{(e+x)^2 + c^2 - b^2 - d^2 + 2bd\cos\theta}{2(e+x)} = 0. \qquad (6)$$

Solve the equation (6) and find $\cos\varphi_1$. In this expression $\sin\varphi_1$ through $\cos\varphi_1$.

$$(b - d\cos\theta)\cos\varphi_1 + e + x - \frac{c^2 + (e+x)^2 - b^2 - d^2 + 2bd\cos\theta}{2(e+x)} = d\sin\theta\sin\varphi_2; \qquad (7)$$

$$\sin\varphi_1 = \sqrt{1-\cos\varphi_1}; \qquad (8)$$

$$(b - d\cos\theta)\cos\varphi_1 + e + x - \frac{c^2 + (e+x)^2 - b^2 - d^2 + 2bd\cos\theta}{2(e+x)} = d\sin\theta\sqrt{1-\cos\varphi_1^2}; \qquad (9)$$

$$(b - d\cos\theta)^2\cos\varphi_1^2 + 2(b - d\cos\theta)\left[e + x - \frac{c^2 + (e+x)^2 - b^2 - d^2 + 2bd\cos\theta}{2(e+x)}\right]\cos\varphi_1 + \\ + \left[e + x - \frac{c^2 + (e+x)^2 - b^2 - d^2 + 2bd\cos\theta}{2(e+x)}\right]^2 = d^2\sin\theta^2\left(1-\cos\varphi_1^2\right); \qquad (10)$$

$$\left[\left(b-d\cos\theta\right)^2+d^2\sin\theta^2\right]\cos\varphi_1^2+2\left(b-d\cos\theta\right)\left[e+x-\frac{c^2+\left(e+x\right)^2-b^2-d^2+2bd\cos\theta}{2\left(e+x\right)}\right]\times$$

$$\times\cos\varphi_1-d^2\sin\theta^2+\left[e+x-\frac{c^2+\left(e+x\right)^2-b^2-d^2+2bd\cos\theta}{2\left(e+x\right)}\right]^2=0; \quad (11)$$

$$\left[b^2-2bd\cos\theta+d^2\left(\cos\theta^2+\sin\theta^2\right)\right]\cos\varphi_1^2+2\left(b-d\cos\theta\right)\times$$

$$\times\left[e+x-\frac{c^2+\left(e+x\right)^2-b^2-d^2+2bd\cos\theta}{2\left(e+x\right)}\right]\cos\varphi_1-d^2\sin\theta^2+ \quad (12)$$

$$+\left[e+x-\frac{c^2+\left(e+x\right)^2-b^2-d^2+2bd\cos\theta}{2\left(e+x\right)}\right]^2=0;$$

Resemble those expressions and find the angles φ_1 i φ_2:

$$\begin{cases} A=b^2-2bd\cos\theta+d^2; \\ B=\frac{1}{2}\left(b-d\cos\theta\right)\left[\left(e+x\right)-\frac{c^2-b^2-d^2+2bd\cos\theta}{e+x}\right]; \\ C=\frac{1}{4}\left[\left(e+x\right)-\frac{c^2-b^2-d^2+2bd\cos\theta}{e+x}\right]-d^2\sin\theta^2. \end{cases} \quad (13)$$

$$A\cos\varphi_1^2+2B\cos\varphi_1+C=0; \quad (14)$$

$$\left(\cos\varphi_1\right)_{1,2}=-B\pm\sqrt{\frac{B^2-AC}{A}}; \quad (15)$$

$$\varphi_{1,1}=arccos\left(-B+\sqrt{\frac{B^2-AC}{A}}\right); \quad (16)$$

$$\varphi_{1,2}=arccos\left(-B-\sqrt{\frac{B^2-AC}{A}}\right); \quad (17)$$

$$\left(\cos\varphi_2\right)_1 = \frac{1}{b}\left[a - d\cos\left(\theta - \varphi_{1,1}\right) - \frac{e+x}{2} - \frac{c^2 - b^2 - d^2 + 2bd\cos\theta}{2\left(e+x\right)}\right] \qquad (18)$$

$$\left(\cos\varphi_2\right)_2 = \frac{1}{b}\left[a - d\cos\left(\theta - \varphi_{1,2}\right) - \frac{e+x}{2} - \frac{c^2 - b^2 - d^2 + 2bd\cos\theta}{2\left(e+x\right)}\right] \qquad (19)$$

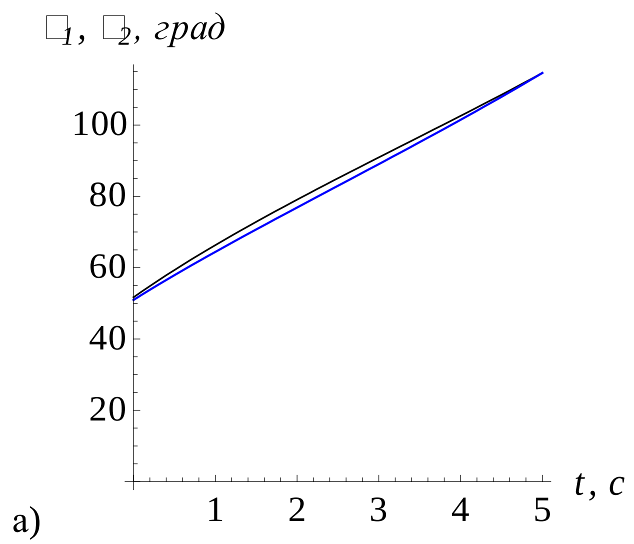
$$\varphi_{2,1} = arccos\left\{\frac{1}{b}\left[a - d\cos\left(\theta - \varphi_{1,1}\right) - \frac{e+x}{2} - \frac{c^2 - b^2 - d^2 + 2bd\cos\theta}{2\left(e+x\right)}\right]\right\} \qquad (20)$$

$$\varphi_{2,2} = arccos\left\{\frac{1}{b}\left[a - d\cos\left(\theta - \varphi_{1,2}\right) - \frac{e+x}{2} - \frac{c^2 - b^2 - d^2 + 2bd\cos\theta}{2\left(e+x\right)}\right]\right\} \qquad (21)$$

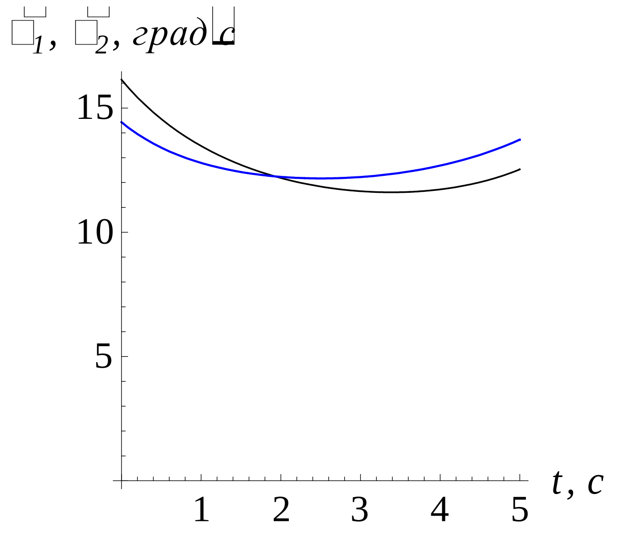
Since the equations have two solutions, we choose are those that match the specified design bunk, ie (16) and (20).

Analyze change in angular coordinates φ_1 and φ_2 and their derivatives with respect to time for various modes of movement over a given time t_1 cylinder displacement from the initial position x_0 in the position x_1.

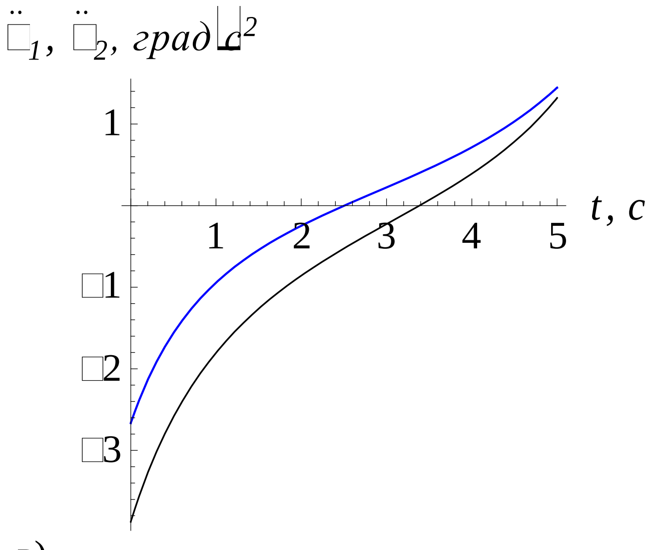
Consider the optimal power mode motion [6] - a movement with constant speed cylinder rod across the gap (Fig. 2): $x(t) = \mathrm{x}_0 + vt$; $\dot{x}(t) = v = const$, where t – time; v – steady-state velocity of the rod cylinder. For such a mode of motion defined angular position, velocity and acceleration of the jaws (Fig. 2)



а)



б)



в)

angle φ_1 ———

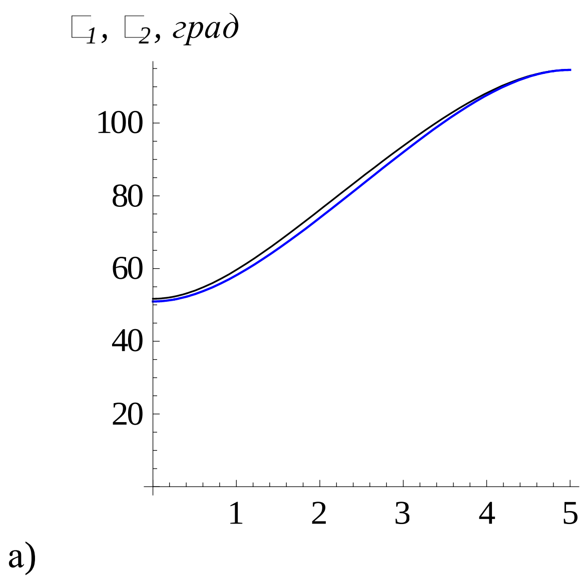
angle φ_2 ———

Figure. 2 Charts angular changes coordinates (a), velocity (b) and acceleration (a) at the optimum energy mode of motion of the rod cylinder.

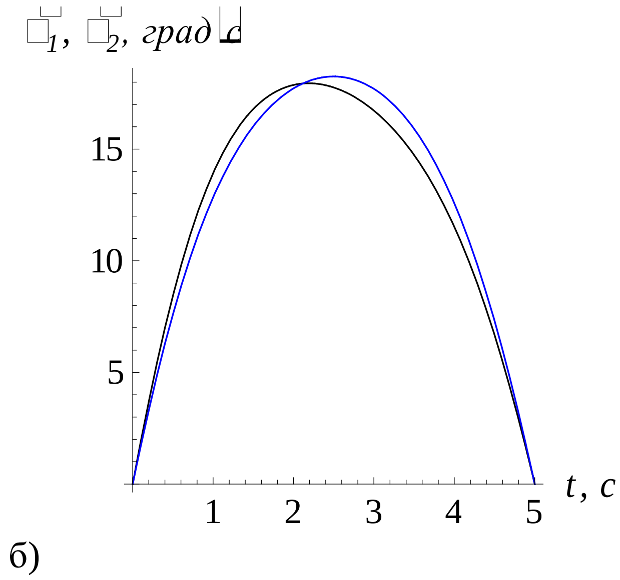
Optimal dynamic mode [6] - a change of the cylinder rod at a rate that varies according to a parabolic law:

$$\begin{cases} x(t) = x_0 + (x_1 - x_0)\left(3 - 2\dfrac{t}{t_1}\right)\dfrac{t^2}{t_1^{\,2}}; \\ \dot{x}(t) = 6(x_1 - x_0)\left(1 - \dfrac{t}{t_1}\right)\dfrac{t}{t_1^{\,2}}; \\ \ddot{x}(t) = 6(x_1 - x_0)\left(1 - \dfrac{2t}{t_1}\right)\Big/ t_1^2. \end{cases} \qquad (22)$$

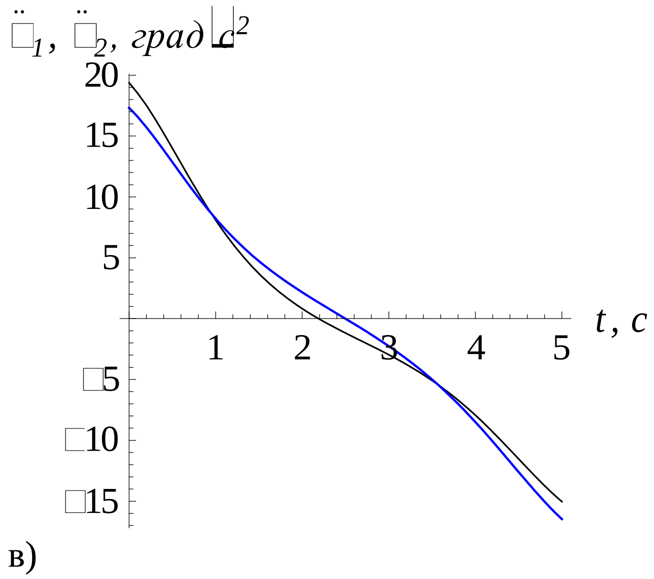
At the optimal dynamic mode motion rod cylinder angular coordinates, velocity and acceleration are of the form (Fig. 3).



а)



б)



в)

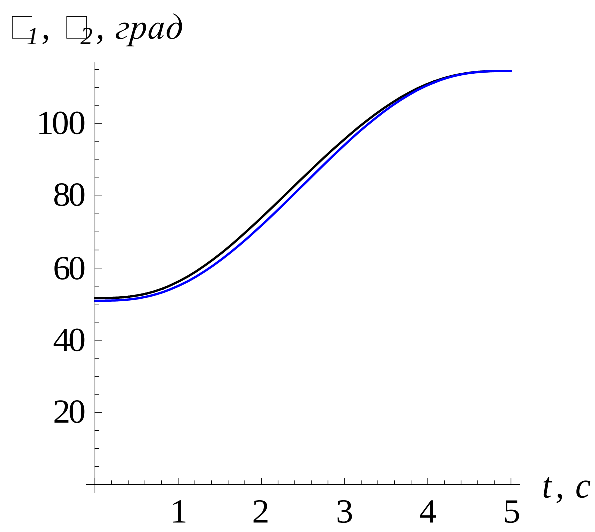
angle φ_1 ———

angle φ_2 ———

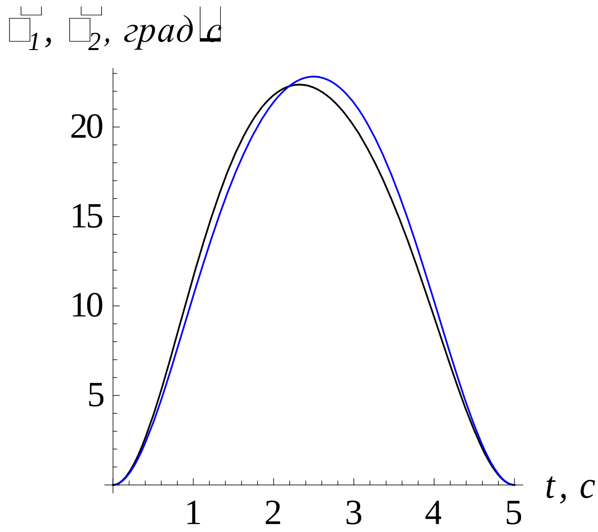
Figure. 3 Charts angular changes coordinates (a), velocity (b) and acceleration (a) at the optimum dynamic mode of motion of the rod cylinder.

Kinematic characteristics jaw grapple with optimal jerk mode motion [6] rod cylinder shown in Fig. 4.

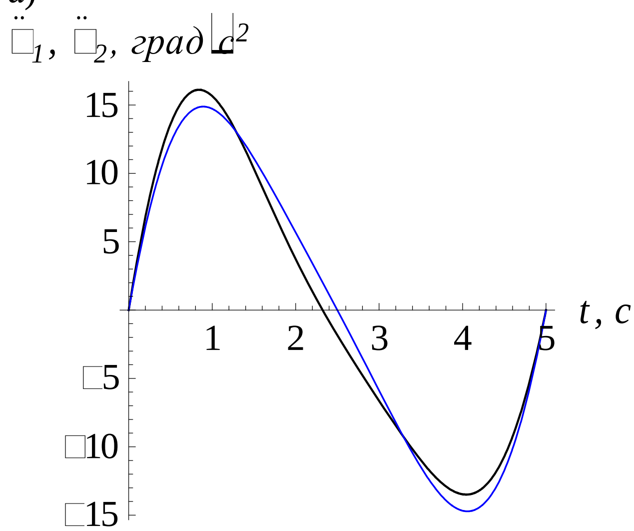
$$\begin{cases} x(t) = x_0 + (x_1 - x_0)\left(\dfrac{6t^2}{t_1^2} - \dfrac{15t}{t_1} + 10\right)\dfrac{t^3}{t_1^3}; \\ \dot{x}(t) = 30(x_1 - x_0)\left(\dfrac{t^2}{t_1^2} - \dfrac{2t}{t_1} + 1\right)\dfrac{t^2}{t_1^3}; \\ \ddot{x}(t) = 60(x_1 - x_0)(\dfrac{2t^2}{t_1^2} - \dfrac{3t}{t_1} + 1)t \Big/ t_1^3; \end{cases} \quad (23)$$



a)



б)



в)

angle φ_1 ———

angle φ_2 ———

Figure. 4 Charts angular changes coordinates (a), velocity (b) and acceleration (a) at the optimum jerk mode of motion of the rod cylinder.

Conclusions.

1. Optimal power mode about jaw movement impossible to implement in practice because it does not run and run-down areas, without which there can be cyclic motion.
2. Optimal dynamic mode can be implemented in practice, but in this mode there are enough large values of accelerations in the initial and final points of the movement, which had a negative impact on the wooden deck of the capture, damaging them and grab the mechanism as a whole.
3. Charts of jerk optimal mode of motion show that this mode of motion more accurately suited to claw mechanism because it ensures a planned change in

acceleration during movement. In the extreme points of the acceleration is zero, ensuring smooth pick-up and exact stop at the end of the movement.

References

1. Асяткин О.П. Исследование основных конструктивных и эксплуатационных параметров напорных грейферов для погрузки силоса на животноводческих фермах: автореф. дис. на соискание учёной степени канд. техн. наук: спец. 05.05.11 «Машини і засоби механізації сільськогосподарського виробництва» / О.П. Асяткин. – Краснодар, 1966. –25 с.
2. Грицюк С.И. Методика проектировочного расчета гидравлического грейфера для стеблевых грузив / С.И. Грицюк // Тракторы и с.х. машины. – 1975. – №12. – С. 22-24.
3. Ловейкин В.С. Расчеты оптимальних режимов движения механизмов строительных машин / Ловейкин В.С. – К.: УМК ВО, 1990. – 168 с.
4. Таубер Б.А. Грейферные механизмы. Теория, расчет и конструкции / Таубер Б.А.– М.: Машиностроение, 1967. – 424 с.
5. Wang, J. and G. Li. 1993. A review of log grapple used in China. J. of Forest Engineering. 4(2): 33-36.
6. Wang, J. 1990. Study on the theories of log grapples. Ph.D. Dissertation. Northeast Forestry University, Harbin, China. 311 – pp.

КИНЕМАТИЧЕСКИЙ АНАЛИЗ ГРЕЙФЕРА ДЛЯ ЛЕСОМАТЕРИАЛОВ

В.С. Ловейкин, П.В. Лымарь

В работе выполнен кинематический анализ гидравлического грейфера для древесины с горизонтальным расположением гидроцилиндра при различных режимах движения привода.

Ключевые слова: *грейферный механизм, челюсти, лесоматериалы, режим движения.*

КІНЕМАТИЧНИЙ АНАЛІЗ ГРЕЙФЕРА ДЛЯ ЛІСОМАТЕРІАЛІВ

В.С. Ловейкін, П.В. Лимар

У роботі виконано кінематичний аналіз гідравлічного грейфера для деревини з горизонтальним розташуванням гідроциліндра при різних режимах руху привода. Встановлено залежність положення щелеп грейфера від зміни вильоту штока гідроциліндра.

Ключові слова: *грейферний механізм, щелепи, лісоматеріали, режим руху*.