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DYNAMIC CALCULATION OF THE HYDRAULIC SYSTEM OF THE UNLOADING DEVICE OF TRAILERS

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Abstract: Work is accomplished by hydraulic machines using liquid fluid power. A typical example is heavy construction equipment. The hydraulic fluid in this kind of machine is pushed to numerous hydraulic motors and hydraulic cylinders located all around the machine and are pressured in accordance with the resistance present. Through hoses, tubes, or pipes, the fluid is distributed and is directly or automatically regulated by control valves. With applications and significant ramifications for many industrial, civil, and environmental engineering problems, hydraulic dynamics is developing as a fundamental topic.

The article presents the dynamic calculation of the hydraulic system of the trailer unloadingdevice using equations of force and moments, fluid flow equations and fluid flow balance equations describing the dynamics of the hydraulic system.

Key words: Transient process, hydraulic cylinder, rod, rod driving force, conditional center of gravity, dynamic factors.

Introduction. It is important in the production of modern, high-capacity, energy and resource-efficient trailers for transporting various loads of the national economy, taking into account the dynamic loads generated during lifting, determining the alternative parameters of strength and reliability of trailer structures. During the overturning of the trailers, the hydraulic cylinder stock is affected by the load generated by the load through the platform on the one hand, and by the load coming from the hydraulic pump on the other hand. In carrying out the overturningprocess completely, reliably, safely and evenly, it is necessary to take into account the influence of all the dynamic factors generated during the operation of the hydraulic cylinder.

The analysis of the available technical literature, published scientific works and internet data shows that this issue has not been fully researched [4, 6 , 7, 9, 10, 12, 13, 14, 15, 16].

Methodology & empirical analysis.

For the reliable and stable operation of the hydraulic system of trailers, it is important to accurately calculate the force exerted by the hydraulic cylinder, as well as the correct choice of parameters of other elements of the hydraulic system. This work is carried out by performing dynamic calculations during the operation of the hydraulic system of the trailer unloading device [13, 16].

The unloading system of the trailer unloading device is carried out by means of a hydraulic cylinder acting on the hydraulic pressure. The calculation of the lifting force generated by the drive is carried out by sequential determination of the forces and moments in the hinged links under the influence of the gravitational force applied to the conditional center of gravity in the kinematic scheme of the lifting mechanism (figure 1).

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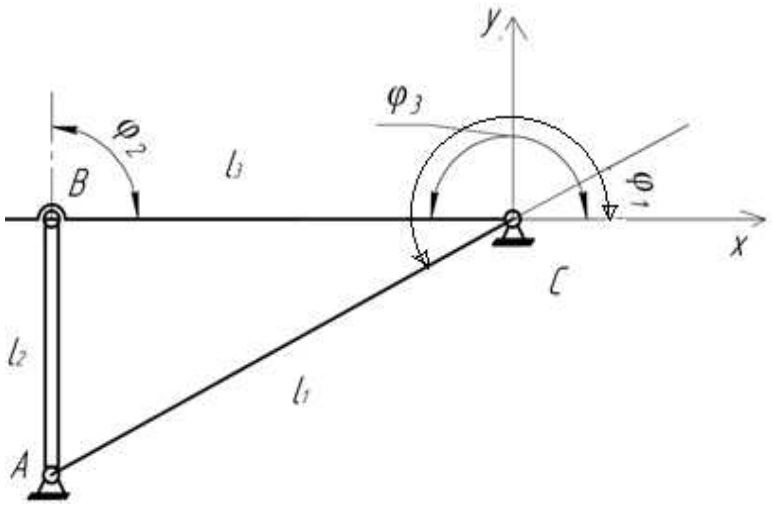


Figure 1. Kinematic calculation scheme of the lifting mechanism of trailers

I. Results.

The equation of forward and rotational motion of the hydraulic system of the hydraulic system ofthe trailer unloading device is based on the equations of forces and moments, fluid flow and fluid flow balance, as well as the initial and boundary [4]. In this case, if we choose the hydraulic cylinder rod as the drive link:

$l2=l2(t)$

will be [5] (figure 2).

In this case, the system of differential equations describing the motion of the hydraulic cylinder is as follows [13, 17]:

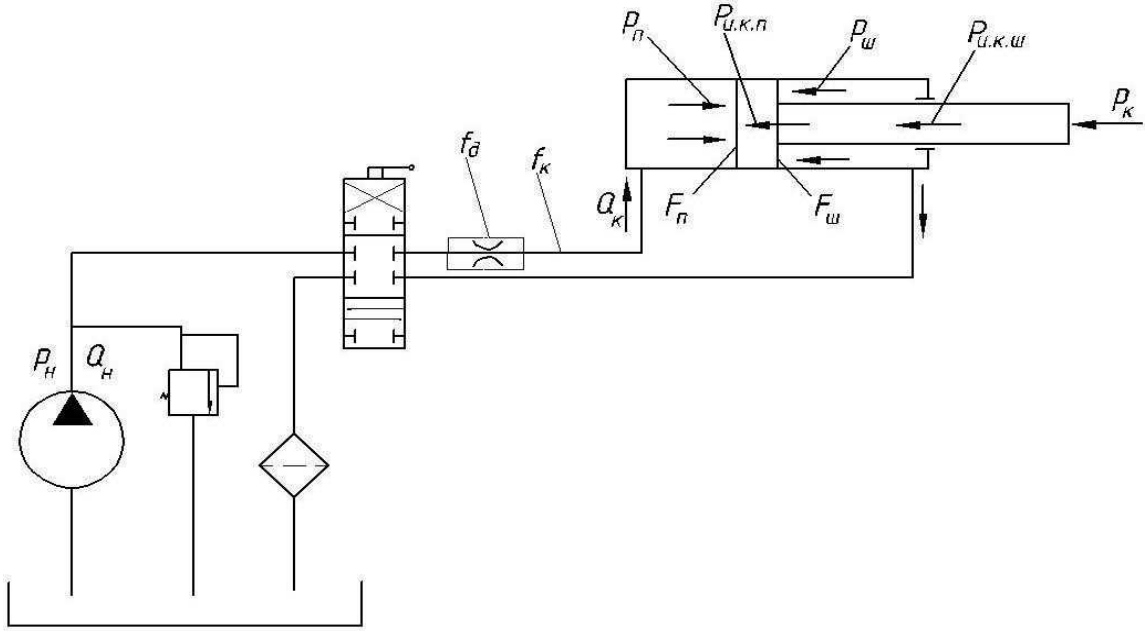


Figure 2. Calculation scheme of hydraulic system

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$$
\begin{aligned}
&m_{\text{пр}} v_2 \frac{dv_2}{dl_2} = P_{\text{д}} - k_{\text{в}} v_2 - P_{\text{тр}} \operatorname{sign} v_2 - P_{\text{с}} \\
&J_{\text{пр}} v_2 \frac{d\omega_2}{dl_2} + \frac{\omega^2}{2} \frac{dJ_{\text{пр}}}{d\varphi_2} = M_{\text{д}} - M_{\text{с}} \\
&\frac{d\,\text{p}_1}{dt} = \frac{E_{\text{ж}} \left(Q_1 - v_2 F_1\right)}{V_{01} + l_2 F_1} \\
&\frac{d\,\text{p}_2}{dt} = \frac{E_{\text{ж}} \left(v_2 F_2 - Q_2\right)}{V_{02} + \left(l_{\max} - l_2\right) F_2}
\end{aligned}
\qquad (1)
$$

here:

$$
m_{пр} = \sum_{i=2}^{n} m_i \left(v_i / v_2\right)^2 + J_i \left(\omega_i / v_2\right)^2, \quad J_{\text{пр}} = \sum_{i=2}^{n} m_i \left(v_i / \omega_2\right)^2 + J_i \left(\omega_i / \omega_2\right)^2,
$$

$$
P_{\text{Д}} = p_1 F_1 - p_2 F_2, \quad P_{\text{с}} = \sum_{i=2}^{n} P_i v_i \cos\varphi_i / v_2 + M_i \omega_i / v_2
$$

$m_{\text{пр}}$, $J_{\text{пр}}$– masses and moments of inertia of moving links on the hydraulic cylinder rod; l_2, v_2, ω_2 – displacement, velocity and angular velocity of the hydraulic cylinder; $k_{\text{в}}$ – coefficient of viscous friction; $P_{\text{тр}}$ – is the dry friction force; $P_{\text{д}}$– is the driving force of the hydraulic cylinder piston; $P_{\text{с}}$– is the applied resistance of the hydraulic cylinder; p_1, p_2 – pressures in the pressure and flow cavities of the hydraulic cylinder; F_1, F_2 – useful surfaces of pressure and drainage cavities; $E_{\text{Ж}}$ – is the modulus of volumetric elasticity of the fluid; V_{01}, V_{02} – initial fluid volumes of pressurized and discharge cavities;; m_i – is the mass of the i-ring; J_i – is the moment of inertia of the i-ring with respect to the axis passing through the center of gravity; v_i – is the center of gravity of the i-link; ω_i – is the angular velocity of the i-ring; P_i, M_i – are the values of active forces and moments acting on the links; φ_i – is the angle between the reference force P_i and the velocity v_i; l_i – is the length of the i-ring; $M_{\text{д}}$– is the moment of driving force; M_c – is the moment of resistance.

The centers of gravity of the links of the hoisting mechanism of trailers are determined by the following formula [5].

$$
\begin{aligned}
&x_{\text{ц}} = \sum_{i=2}^{3} G_i x_i / \sum_{i=2}^{3} G_i, \\
&y_{\text{ц}} = \sum_{i=2}^{3} G_i y_i / \sum_{i=2}^{3} G_i.
\end{aligned}
\qquad (2)
$$

The velocities and moments of inertia of the centers of gravity of the links of the lifting mechanism of trailers are determined by the following formulas [5]:

$$
v_i = l_i \omega_i / 2, \quad (3), \quad J_i = m_i \left[\left(x_{\text{ц}} - x_{i\text{ц}}\right)^2 + \left(y_{\text{ц}} - y_{i\text{ц}}\right)^2\right] \quad i = 2...3, \quad (4)
$$

бу ерда–*i*-звенонинг оғирлик маркази координаталари.

here: $x_{i\text{ц}}$, $y_{i\text{ц}}$ - are the coordinates of the center of gravity of the -i-ring.

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In the study of the motion of a fluid in a pipe, the fluid is considered to be compressible and concentrated in a short length. In this model it is possible to take into account air bubbles insoluble in liquids [13, 17]:

$$\rho\ell\frac{d^2x}{dt^2}+27{,}5\frac{\ell\mu}{f}\frac{dx}{dt}+\ 0{,}443\frac{k_\varepsilon\mu}{\sqrt{f}}+0{,}5\varsigma\rho\quad\frac{dx}{dt}\quad^2\operatorname{sign}\frac{dx}{dt}+p_{\text{вых}}=p_{\text{вх}},\quad(5)$$

$$\frac{dp}{dt}=\quad\frac{E_{\text{ж}}\delta_{\text{Т}}E_{\text{Т}}}{E_{\text{Т}}\delta_{\text{Т}}+d_{\text{Т}}E_{\text{ж}}}\quad\frac{(Q_{\text{вх}}-Q_{\text{вых}})}{V_{\text{ж}}},\quad(6)$$

here: $\operatorname{sign}\frac{dx}{dt}=\begin{matrix}1 & v>0,\\ -1 & v<0;\end{matrix}$ $p_{\text{вх}}$, $Q_{\text{вх}}$– pressure and flow of fluid entering the pipe; $p_{\text{вых}}$, $Q_{\text{вых}}$–pressure and flow of fluid out of the pipe; t–time; ρ, $E_{\text{Ж}}$ – is the modulus of fluid density and volumetric elasticity; $d_{\text{Т}}$, $\delta_{\text{Т}}$, $E_{\text{Т}}$ – modulus of pipe diameter, wall thickness and elasticity of the material, respectively; k_ε – approximation coefficient, depending on the relative roughness ε of the hydraulic main; ζ– local resistance coefficient; f and l – is the surface and length of the pipe; $V_{\text{Ж}}$ – is the volume of liquid in the pipe; μ – is the dynamic viscosity of the liquid.

The flow of fluid in the system through the hydraulic distributor is determined as follows [11, 18, 19]:

$$Q_p=\eta_p f_p(y)\sqrt{2|p_{\text{н}}-p_{\text{вх}}|/\rho},\quad(7)$$

here: $p_{\text{н}}$ – is the pump pressure; $f_p(y)$ – is the cross-sectional area of the conductor; η_p – is the current coefficient.

The cross-sectional area of the hydraulic distributor can be expressed as follows [6]:

$$f_p(y)=\begin{matrix}0,\ \text{t}<\tau\ ,\\ \pi d_y{}^2(t-\tau)/(4(t_k-t)),\ \tau\quad t\quad t_k\ ,\\ \pi d_y{}^2/4,\ t>t_k\end{matrix}$$

here: d_y – Conditional conduction diameter; τ – delay time; t_k – full opening time of the transmission section.

This system of equations (1) - (7), together with the initial and boundary conditions, is a mathematical model for the dynamic calculation of the hydraulic system of tractor trailers. To solve it, a computer program in the algorithmic language "PASCAL" was developed, which used to calculate the numerical values of the change in force and resistance of the hydraulic cylinder rod of the hydraulic lifting mechanism of trailers, and obtained a diagram of the change depending on the load shedding during unloading (3- picture). The following values and initial values were taken for the links in the calculations: l_1=0,90 м, l_2=0,34 м, l_3=0,84 м, $\varphi_1 = 22^0 = 0{,}38$ рад, $\varphi_{20} = 90^0 = 1{,}57$ рад, $\varphi_{30} = 202^0 = 3{,}52$ рад, l_{12}=1,22 м, m_2=30 кг, m_3=700 кг, m_{12}=3900 кг, P_2=300 Н, P_3=7000 Н, P_{12}=39000 Н, t=0, τ=0,2, t_k=14, $p_{\text{н}}$ = 16 МПа, $p_{\text{вх}}= Q_{\text{вх}} = p_{\text{вых}} =Q_{\text{вых}} = l_2 = v_2 = \omega_2= p_1= p_2 = 0$.

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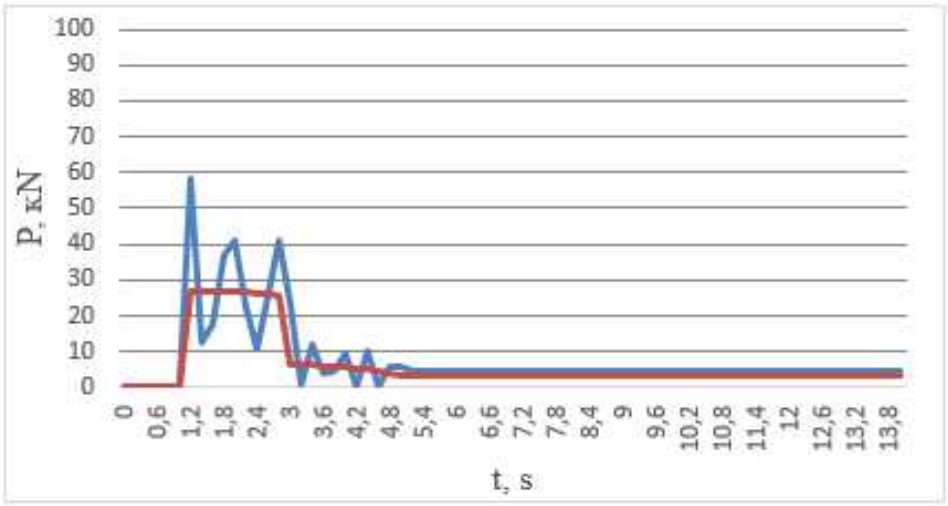


Figure 3. Dependence of the hydraulic cylinder stock on the change of momentum (Рд) and resistance force (Pc) with respect to time

III. Conclusion. The graphical analysis in figure 3 shows that at $P_{12}=39000H$ at $t=1,0...1,2$ seconds, the driving force begins to oscillate sharply to *58 кН* when the hydraulic distributor is started, taking into account the delay, and then over time until the end of the process (resistance force until it is equal to the value of) decreases and disappears. The numerical results obtained provide a qualitatively close representation of the working processes of the hydraulic system of the trailer lifting device.

The results determined on the basis of the developed mathematical model and its calculation method are close to the actual working process of the trailer lifting mechanism, and it is recommended to use it in design work.

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