Theory Lifting Mechanism Plants Product for Hydroponic

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In the production of hydroponic green fodder, which is increasingly used in animal husbandry developed countries of the world, using highly mechanized and automated tiered chute tower plant or mine type, which are equipped with hoists. The main purpose of such arrangements is the rise of seed to the upper tiers of hydroponic plants his crop, in the construction of other types of plants also discharge and lowering down of finished products. In this paper a theory hoist hydroponic plants, based on the construction of mathematical models that describe the nonlinear inhomogeneous systems of ordinary differential equations in the second fundamental problem of dynamics strands of variable length. This takes into account the elastic shaft hoisting and viscoelastic properties of the cable of variable length. Dynamic processes in elastic elements of double-drum hoist system described by the ten non-linear equations with two equations of unsteady relations. This system is suitable for the study of the dynamics of a single drum hoist with a split drums. The dynamics of a single drum hoist is described by nine nonlinear equations with the equations of unsteady relations. A further solution obtained by systems of differential equations will determine how dynamic forces in the viscoelastic ropes of variable length, and the time of the elastic forces in the shaft hoisting.

Keywords: *hydroponic green fodder, installation, hoist, rope, a mathematical model, dynamic, differential equations, calculating.*

Introduction. The most time-consuming process in the production of hydroponic green fodder in the trough or multilevel conveyor installations is the delivery of the raw material to the upper tiers and planting. These labor-intensive processes can be mechanized, when the production line for the manufacture of feed, including mobile winch with lifting capacity of special design. Lifting capacity should allow unloading seed tray or directly into the seeding device if the plant is equipped with hydroponics installations Transportig type. A distinctive feature of the winch is that its mass must be much less than that of opening and closing containers with seed.

Problem formulation. Currently hydroponic greenhouses tower type reach considerable heights. Thus, the height of the towers for the hydroponic production of green fodder, which are widely used in the world today reaches 240 m or more. Existing aquifers (usually a waste of mine), where is the hydroponic installation, all at a depth of 200 to 600 meters.

Delivery of the initial seed to such heights and depths, as well as export crops grown hydroponic products could be carried out only by means of lifting gear. These units are mounted on the upper levels of the towers, or on the surface. In many countries of the world in installations for the production of hydroponic green fodder used double-drum, single drum and gearless hoisting machine.

In order to create a reasonable engineering method for calculating lifting systems for tower and underground hydroponic greenhouse plants, consider, first of all, the existing types of construction of these facilities, but with other quantitative and qualitative characteristics. The analysis of these designs will allow to justify the equivalent mechanical and mathematical models to advance a number of hypotheses and assumptions, which are indispensable for the study of real systems.

Elevator installation, as a complex mechanical system, can be roughly separated into two parts: a lifting device with a drive and loads at the ends of the ropes. The lifting device is in fact a machine (the machine) that converts the rotation of the motor shaft in the forward movement of cargo through the end of the rope winding onto a rotating drum. Usually, between the motor and the drum set gear with toothing on one or two stages of reduction. Connecting the motor and gear reducer and a drum by means of couplings. The shafts on which the drums are mounted, gear shaft and the motor, gears and couplings have a certain elasticity. Weights shafts are negligible in comparison with the clearly lumped rotor, gear motor, gearbox and drums, which allows them to bring a lot to the weight of the car, which will be considered concentrated.

Hoisting ropes are directed into the subterranean shaft via guide pulleys mounted at a certain height above the ground. The plot of the rope from the point of exit from the drum to the pulley is usually 10 – 20 meters, so we can assume it weightless, but has a certain stiffness.

The guide pulley will be regarded as concentrated flywheel mass. Ropes are rather complicated construction aggregate. The design type of rope determines its physical properties and its place in the dynamic processes, however, can take into account the characteristics of its integral indicators of viscoelastic parameters. During winding onto the drum free ropes pitches change with time of the cycle.

Currently, the service hydroponic towers and underground hydroponic plants in foreign countries are used, as mentioned above, double-drum and single drum lifting equipment. Machines of these installations for underground shops are set on the ground. A tower for greenhouses – on top of their tier.

Mechanical model and design scheme two-drum setup is shown in Fig.1. By the concentration of the mass is the rotor I_1, gearbox I_2, drums I_3 and I_4 guide pulleys I_5 and I_4, guide pulleys I_5 and I_6, limit loads Q_1 and Q_2.

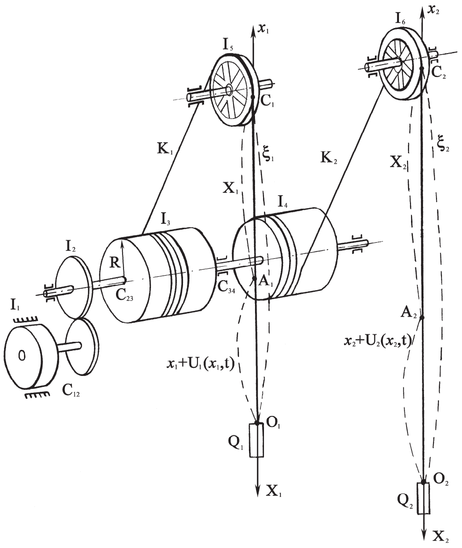

Fig. 1 – Mechanical model of two-drum elevator installation for the production of hydroponic green fodder

With flywheel mass moments of inertia I_i interconnected respectively stationary constraints torsional and longitudinal stiffness C_{12}, C_{23}, C_{34}, K_1, K_2. Limit the weight of loads Q_1 and Q_2 linked to the lifting mechanism unsteady viscous-elastic ties - ropes. By weight I_1 applied torque of the motor $M_1(t)$. The power flow from the electric motor through elastic coupling tends to end goods, with the result that the entire elevator installation is set in motion. With drum I_3 recoiling rope, omitting end load Q_1. Simultaneously, the drum I_4 the second branch of the rope is wound, producing a rise in cargo Q_2.

Thus, the lifting mechanism operates as if in oscillation mode, in turn raising the payload is one, then another rope.

A distinctive feature-drum elevator installation is that cabling and winding ropes occurs on one drum, so kinematic scheme-drum installed on one concentrated mass is less than two-drum. Mechanical model and design scheme-drum setup is shown in Fig. 2.

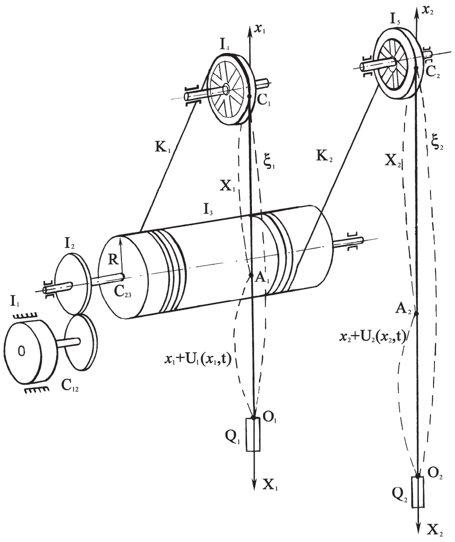

Fig. 2 – Mechanical model of single-drum hoisting plant for the production of hydroponic green fodder

Analysis of research and publications on this issue.

In [1] the dynamics of the two-and single-drum plants. Payment schemes are presented in the form of torsional multibody systems, with the weight of the ropes are the masses of end goods, but a change in the length of the rope is not considered.

In [2] examined the dynamic forces in weighty visco-elastic rope of variable length separated from the lifting machine, where the mutual influence is inevitable.

In [3] clearly stated, "The second major problem is the dynamics of the rope of variable length", but later studied particular problems of the dynamics of war.

In the present study, in contrast to the above, we derive the differential equations of dynamics of hoisting units as a single complex electromechanical: machine – ropes – Limit loads.

Further research hoists and other equipment for the production of hydroponic plants green was presented in [4-12].

The purpose of research.

Creating a dynamic theory of calculation of double-drum and single-drum lifting equipment systems for hydroponic forage production on the basis of differential equations describing the dynamic processes in all the elastic elements of the elevator installation in a single complex.

Research methods. We used the methods of mathematical modeling of nonlinear differential equations, asymptotic methods of nonlinear and analytical mechanics, the theory of oscillations and stability of motion, computational mathematics and numerical analysis.

The results of the study and discussion.

In this study, derived differential equations of the dynamics of hoisting units as a single complex electromechanical machine – ropes – end loads (h capacity grain planting or hydroponic finished products).

The main hypotheses and assumptions, selection of frames and generalized coordinates.

The solution of all problems of mechanics begins with the construction of the computational model of the physical system under study, based on certain hypotheses and the objectives pursued by the task.

In the derivation of the differential equations of dynamics of hoisting units will be based on the following key assumptions:

1) concentrated masses of large structural assemblies lift systems are perfectly rigid body;

2) compounds of concentrated masses cars – absolutely weightless elastic connection with constant coefficients of rigidity;

3) external friction and aerodynamic drag forces are absent;

4) the hoisting ropes are of variable length – weight, ideally flexible, rotation-resistant, visco-elastic yarn, subordinate hypothesis Vogt;

5) there are no transverse vibrations of ropes;

6) the rope at points of attack and exit does not slip relative to the surface of the winder;

7) compliance of the machine feet and the guide pulley is negligible in comparison with the supple elastic ties field line of the elevator installation.

Separately, one or another of these assumptions has been used by different authors in the private problems of the dynamics of war or machines, are confirmed by theoretical or experimental studies [1-3].

Let us turn to the choice of reference systems and the generalized coordinates. Consider the mechanical model of the two-drum elevator installation shown in Fig. 1. Place the origin of the axes of the fixed coordinate system at points of attack C_2 descent C_1 with ropes and pulleys. Axles C_1X_1 and C_2X_2 downward plumb rope. Home axes moving coordinate system put at the connection points with vessels O_1 and O_2 ropes. Axles O_1x_1 and O_2x_2 send up the kanatam. Osi and send up the ropes.

Then, for arbitrary points of the cross sections of ropes A_1 and A_2 we have:

$$X_1 = \xi_1 - x_1 - U_1(x_1, t),$$
$$X_2 = \xi_2 - x_2 - U_2(x_2, t), \tag{1}$$

where ξ_1 and ξ_2 – the absolute coordinates of the points O_1 and O_2, x_1, x_2 – the relative coordinates of the points A_1 and A_2 for undeformed rope; U_1 and U_2 – deformation lengths of rope parts O_1A_1, O_2A_2.

Connection between ξ_1, ξ_2 and variable-length ropes expressed the following relationship:

$$\xi_1 = l_1(t) + U_1(l_1, t),$$
$$\xi_2 = l_2(t) + U_2(l_2, t). \tag{2}$$

In accordance with the assumption of slippage in the vanishing point of attack and rope pulleys have the following relationship:

$$\frac{d\xi_1}{dt} = V_1 + \frac{\partial U_1}{\partial t}\bigg| x_1 = l_1,$$
$$\frac{d\xi_2}{dt} = V_2 + \frac{\partial U_2}{\partial t}\bigg| x_2 = l_2, \tag{3}$$

where V_1 and V_2 − the circumferential speeds of pulleys.

If we denote the absolute angles of rotation corresponding to concentrated masses through $\varphi_K \left(K = 1,2,3,...,6\right)$, the variable lengths of ropes defined by the formulas:

$$\left. \begin{aligned} l_1 &= l_{01} + \varphi_5 \cdot r, \\ l_2 &= l_{02} - \varphi_6 \cdot r, \end{aligned} \right\} \tag{4}$$

where l_{01} and l_{02} – initial length of rope pitches; r – the radius of the pulleys.

Bearing φ_K, X_1, X_2 for the generalized coordinates, we proceed to the conclusion of differential equations of the dynamics of the elevator installation for underground hydroponic plants.

The output of differential equations of the dynamics of the elevator installation for underground hydroponic plants. Consider the mechanical model of the two-drum elevator installation shown in Fig. 1.

Assuming that the drive torque $M_1(t)$, attached to the rotor, and the braking torques $M_3(t)$ and $M_4(t)$, attached to the drums, are known functions of time, we can write the general equation of the dynamics of the system:

$$\begin{aligned} &\left[I_1\ddot{\varphi}_1 + C_{12}(\varphi_1 - i\varphi_2) - M_1(t)\right]\delta\varphi_1 + \left[I_2\ddot{\varphi}_2 + C_{23}(\varphi_2 - \varphi_3) - \right. \\ &\left. -iC_{12}(\varphi_1 - i\varphi_2)\right]\delta\varphi_2 + \left[I_3\ddot{\varphi}_3 + C_{34}(\varphi_3 - \varphi_4) - C_{23}(\varphi_2 - \varphi_3) + K_1 R(\varphi_3 R - \right. \\ &\left. -\varphi_5 r) + M_3(t)\right]\delta\varphi_3 + \left[I_4\ddot{\varphi}_4 - C_{34}(\varphi_3 - \varphi_4) + K_2 R(\varphi_4 R - \varphi_6 r) + \right. \\ &\left. +M_4(t)\right]\delta\varphi_4 + \left[I_5\ddot{\varphi}_5 - K_1 r(\varphi_3 R - \varphi_5 r) - S_1(l_1,t) r\right]\delta\varphi_5 + \left[I_6\ddot{\varphi}_6 - K_2 r(\varphi_4 R - \right. \\ &\left. -\varphi_6 r) - S_2(l_2,t) r\right]\delta\varphi_6 + \int\limits_{o_1}^{l_1}\left[\left(q - \frac{\partial S_1}{\partial X_1} - \frac{q}{g}\frac{\partial^2 X_1}{\partial t^2}\right)\delta X_1 + \right. \\ &+\left[Q_1 - S_1(O_1,t) - \frac{Q_1}{g}\ddot{\xi}_1\right]\delta\xi_1 + \int\limits_{o_2}^{l_2}\left[\left(q - \frac{\partial S_2}{\partial X_2} - \frac{q}{g}\frac{\partial^2 X_2}{\partial t^2}\right)\delta X_2 + \right. \\ &+\left[Q_2 - S_2(O_2,t) - \frac{Q_2}{g}\ddot{\xi}_2\right]\delta\xi_2 = 0, \end{aligned} \tag{5}$$

where i – the gear ratio; $C_{12}, C_{23}, C_{34}, K_1, K_2$ – elastic stiffness relevant links; R – the radius of the drum; Q_1, Q_2 – end valves; q – the weight of one meter of rope; S_1, S_2 – efforts in the ropes.

In accordance with addictions (1), (2) and (4) we can write the general expression:

$$X_1 = X_1\left(\Phi_1, \Phi_2, l_1, t\right), \qquad X_2 = X_2\left(\Phi_3, \Phi_4, l_2, t\right),$$
$$\xi_1 = \xi_1\left(\Phi_1, \Phi_2, l_1, t\right), \qquad \xi_2 = \xi_2\left(\Phi_3, \Phi_4, l_2, t\right). \tag{6}$$

Here $\Phi_1, \Phi_2, \Phi_3, \Phi_4$ – unknown function of time in the formulas proposed G.N. Savinym [3], for the absolute extension of sections of cables:

$$U_1 = X_1\Phi_1 + X_1^2\Phi_2,$$
$$U_2 = X_2\Phi_3 + X_2^2\Phi_4. \tag{7}$$

Given the equality (6), we find $\delta X_1, \delta X_2, \delta\xi_1, \delta\xi_2$, then substitute the expression obtained in (5), and equating to zero the value of the generalized forces, define the following system of integral-differential equations:

$$
\begin{aligned}
&I_1\ddot{\varphi}_1 + C_{12}(\varphi_1 - i\varphi_2) = M_1(t),\\
&I_1\ddot{\varphi}_2 + C_{23}(\varphi_2 - \varphi_3) - iC_{12}(\varphi_1 - i\varphi_2) = 0,\\
&I_3\ddot{\varphi}_3 - C_{23}(\varphi_2 - \varphi_3) + C_{34}(\varphi_3 - \varphi_4) + K_1R(\varphi_3R - \varphi_5r) = -M_3(t),\\
&I_4\ddot{\varphi}_4 - C_{34}(\varphi_3 - \varphi_4) + K_2R(\varphi_4R - \varphi_6r) = -M_4(t),\\
&I_5\ddot{\varphi}_5 - K_1r(\varphi_3R - \varphi_5r) - S_1(l_1,t)r + \int_{o_1}^{l_1}(q - \frac{\partial S_1}{\partial X_1} - \frac{q}{g}\frac{\partial^2 X_1}{\partial t^2})\frac{\partial X_1}{\partial l_1}\frac{\partial l_1}{\partial\varphi_5}dx_1 +\\
&+\left[Q_1 - S_1(O_1,t) - \frac{Q_1}{g}\ddot{\xi}_1\right]\frac{\partial\xi_1}{\partial l_1}\frac{\partial l_1}{\partial\varphi_5} = 0,\\
&I_6\ddot{\varphi}_6 - K_2r(\varphi_4R - \varphi_6r) - S_2(l_2,t)r + \int_{o_2}^{l_2}(q - \frac{\partial S_2}{\partial X_2} - \frac{q}{g}\frac{\partial^2 X_2}{\partial t^2})\times\\
&\times\frac{\partial X_2}{\partial l_2}\frac{\partial l_2}{\partial\varphi_6}dx_2 + \left[Q_2 - S_2(O_2,t) - \frac{Q_2}{g}\ddot{\xi}_2\right]\frac{\partial\xi_2}{\partial l_2}\frac{\partial l_2}{\partial\varphi_6} = 0,\\
&\int_{o_1}^{l_1}(q - \frac{\partial S_1}{\partial X_1})\frac{\partial X_1}{\partial\Phi_1}dx_1 - \frac{q}{g}\int_{o_1}^{l_1}\frac{\partial^2 X_1}{\partial t^2}\frac{\partial X_1}{\partial\Phi_1}dx_1 + \left[Q_1 - S_1(O_1,t)\right]\frac{\partial\xi}{\partial\Phi_1} - \frac{Q_1}{g}\ddot{\xi}_1\frac{\partial\xi_1}{\partial\Phi_1} = 0,\\
&\int_{o_1}^{l_1}(q - \frac{\partial S_1}{\partial X_1})\frac{\partial X_1}{\partial\Phi_2}dx_1 - \frac{q}{g}\int_{o_1}^{l_1}\frac{\partial^2 X_1}{\partial t^2}\frac{\partial X_1}{\partial\Phi_2}dx_1 + \left[Q_1 - S_1(O_1,t)\right]\frac{\partial\xi_1}{\partial\Phi_2} - \frac{Q_1}{g}\ddot{\xi}_1\frac{\partial\xi_1}{\partial\Phi_2} = 0,\\
&\int_{o_2}^{l_2}(q - \frac{\partial S_2}{\partial X_2})\frac{\partial X_2}{\partial\Phi_3}dx_2 - \frac{q}{g}\int_{o_2}^{l_2}\frac{\partial^2 X_2}{\partial t^2}\frac{\partial X_2}{\partial\Phi_3}dx_2 + \left[Q_2 - S_2(O_2,t)\right]\frac{\partial\xi_2}{\partial\Phi_3} - \frac{Q_2}{g}\ddot{\xi}_2\frac{\partial\xi_2}{\partial\Phi_3} = 0,\\
&\int_{o_2}^{l_2}(q - \frac{\partial S_2}{\partial X_2})\frac{\partial X_2}{\partial\Phi_4}dx_2 - \frac{q}{g}\int_{o_2}^{l_2}\frac{\partial^2 X_2}{\partial t^2}\frac{\partial X_2}{\partial\Phi_4}dx_2 + \left[Q_2 - S_2(O_2,t)\right]\frac{\partial\xi_2}{\partial\Phi_4} - \frac{Q_2}{g}\ddot{\xi}_2\frac{\partial\xi_2}{\partial\Phi_4} = 0.
\end{aligned}
\tag{8}
$$

The relationship between the war effort S_1, S_2 and strains $U_1(X_1,t)$, $U_2(X_2,t)$ take the form:

$$
\begin{aligned}
S_1 &= K\frac{\partial U_1}{\partial X_1} + \alpha\frac{\partial^2 U_1}{\partial X\partial t},\\
S_2 &= K\frac{\partial U_2}{\partial X_2} + \alpha\frac{\partial^2 U_2}{\partial X_1\partial t}.
\end{aligned}
\tag{9}
$$

Differentiating the expression (1) in the corresponding arguments and taking into account the formula (3), (9) and substituting the results obtained in (8), we obtain the following system of nonlinear differential equations:

$$
\begin{aligned}
&I_1\ddot{\varphi}_1 + C_{12}(\varphi_1 - i\varphi_2) = M_1(t),\\
&I_2\ddot{\varphi}_2 + C_{23}(\varphi_2 - \varphi_3) - iC_{12}(\varphi_1 - i\varphi_2) = 0,\\
&I_3\ddot{\varphi}_3 + C_{34}(\varphi_3 - \varphi_4) - C_{23}(\varphi_2 - \varphi_3) + K_1R(\varphi_3R - \varphi_5r) = -M_3(t),\\
&I_4\ddot{\varphi}_4 - C_{34}(\varphi_3 - \varphi_4) + K_2R(\varphi_4R - \varphi_6r) = -M_4(t),
\end{aligned}
$$

$$I_5\ddot{\varphi}_5 - K_1 r(\varphi_3 R - \varphi_5 r) = Q_1\left[1 - \frac{1}{g}(\ddot{l}_1 + \dot{l}_1\dot{\Phi}_1 + l_1\ddot{\Phi}_1 + 2l_1\dot{l}_1\dot{\Phi}_2 + l_1^2\ddot{\Phi}_2)\right]r +$$

$$+ql_1\left[1 - \frac{1}{g}(\ddot{l}_1 + \dot{l}_1\dot{\Phi}_1 + \frac{1}{2}l_1\ddot{\Phi}_1 + 2l_1\dot{l}_1\dot{\Phi}_2 + \frac{2}{3}l_1^2\ddot{\Phi}_2)\right]r,$$

$$I_6\ddot{\varphi}_6 - K_2 r(\varphi_4 R - \varphi_6 r) = -Q_2\left[1 - \frac{1}{g}(\ddot{l}_2 + \dot{l}_2\dot{\Phi}_3 + l_2\ddot{\Phi}_3 + 2l_2\dot{l}_2\dot{\Phi}_4 + l_2^2\ddot{\Phi}_4)\right]r -$$

$$-ql_2\left[1 - \frac{1}{g}(\ddot{l}_2 + \dot{l}_2\dot{\Phi}_3 + \frac{1}{2}l_2\ddot{\Phi}_3 + 2l_2\dot{l}_2\dot{\Phi}_4 + \frac{2}{3}l_2^2\ddot{\Phi}_4)\right]r,$$

$$\frac{l_1}{g}(Q_1 + \frac{ql_1}{3})\ddot{\Phi}_1 + \left[\frac{\dot{l}_1}{g}(Q_1 + \frac{ql_1}{2}) + \alpha\right]\dot{\Phi}_1 + K\Phi_1 + \frac{l_1^2}{g}(Q_1 + \frac{5ql_1}{12})\ddot{\Phi}_2 +$$

$$+l_1\left[\frac{2}{g}(Q_1 + \frac{ql_1}{2})\dot{l}_1 + \alpha\right]\dot{\Phi}_2 + Kl_1\Phi_2 = (Q_1 + \frac{ql_1}{2})(1 - \frac{\ddot{l}_1}{g}), \tag{10}$$

$$\frac{l_1}{g}(Q_1 + \frac{5ql_1}{12})\ddot{\Phi}_1 + \left[\frac{\dot{l}_1}{g}(Q_1 + \frac{2ql_1}{3}) + \alpha\right]\Phi_1 + K\Phi_1 + \frac{l_1^2}{g}(Q_1 + \frac{8ql_1}{15})\ddot{\Phi}_2 +$$

$$+l_1\left[\frac{2}{g}(Q_1 + \frac{2ql_1}{3})\dot{l}_1 + \frac{4}{3}\alpha\right]\dot{\Phi}_2 + \frac{4}{3}Kl_1\Phi_2 = (Q_1 + \frac{2ql_1}{3})(1 - \frac{\ddot{l}_1}{g}),$$

$$\frac{l_2}{g}(Q_2 + \frac{ql_2}{3})\ddot{\Phi}_3 + \left[\frac{\dot{l}_2}{g}(Q_2 + \frac{ql_2}{2}) + \alpha\right]\dot{\Phi}_3 + K\Phi_3 + \frac{l_2^2}{g}(Q_2 + \frac{5ql_2}{12})\ddot{\Phi}_4 +$$

$$+l_2\left[\frac{2}{g}(Q_2 + \frac{ql_2}{2})\dot{l}_2 + \alpha\right]\dot{\Phi}_4 + Kl_2\Phi_4 = (Q_2 + \frac{ql_2}{2})(1 - \frac{\ddot{l}_2}{g}),$$

$$\frac{l_2}{g}(Q_2 + \frac{5ql_2}{12})\ddot{\Phi}_3 + \left[\frac{\dot{l}_2}{g}(Q_2 + \frac{2ql_2}{3}) + \alpha\right]\dot{\Phi}_3 + K\Phi_3 + \frac{l_2^2}{g}(Q_2 + \frac{8ql_2}{15})\ddot{\Phi}_4 +$$

$$+l_2\left[\frac{2}{g}(Q_2 + \frac{2ql_2}{3})\dot{l}_2 + \frac{4}{3}\alpha\right]\dot{\Phi}_4 + \frac{4}{3}Kl_2\Phi_4 = (Q_2 + \frac{2ql_2}{3})(1 - \frac{\ddot{l}_2}{g}),$$

$$l_1 = l_{01} + \varphi_5 r, \qquad l_2 = l_{02} - \varphi_6 r. \tag{11}$$

The resulting system of nonlinear equations describing the dynamic processes in all the elastic elements of the elevator installation in a single complex, and can be used to study the dynamic loads in the elastic elements of the hoist and the rope at any time during the cycle upswing.

In the future, for the study of the resulting system of equations we confine ourselves to the pitch vibrations of ropes, that is, in the formula (7) we put $\Phi_2 = \Phi_4 = 0$. In addition, the masses of the guide pulley to the weight of the respective reels. Such a reduction would be the fairer, less weight pulleys and tighter links connecting them to the machine. Studies have shown [1 – 3], the exclusion from the scheme of mass guide pulleys and a corresponding reduction of their not making significant errors, as in real plants weight guide pulleys are usually two orders of magnitude smaller flywheel masses machine.

This simplified design scheme two-drum elevator installation takes the form shown in Fig. 3.

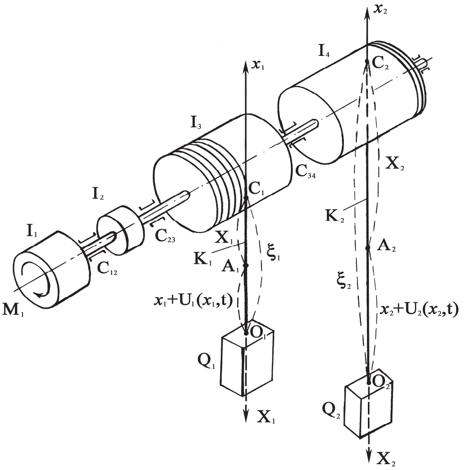

Fig. 3 – A simplified calculation scheme for two-drum hoisting installation of underground hydroponic shops

In view of these remarks the system (10) takes the form:

$$I_1\ddot{\varphi}_1 + C_{12}(\varphi_1-\varphi_2) = M_1(t),$$

$$I_2\ddot{\varphi}_2 + C_{23}(\varphi_2-\varphi_3) - C_{12}(\varphi_1-\varphi_2) = 0,$$

$$I_3\ddot{\varphi}_3 - C_{23}(\varphi_2-\varphi_3) + C_{34}(\varphi_3-\varphi_4) = Q\left[1-\frac{1}{g}\left(\ddot{l}_1+\dot{l}_1\dot{\Phi}_1+l_1\ddot{\Phi}_1\right)\right]R+$$

$$+ql_1\left[1-\frac{1}{g}\left(\ddot{l}_1+\dot{l}_1\dot{\Phi}_1+\frac{1}{2}l_1\ddot{\Phi}_1\right)\right]R-M_3(t),$$

$$I_4\ddot{\varphi}_4 - C_{34}(\varphi_3-\varphi_4) = -Q_2\left[1-\frac{1}{g}\left(\ddot{l}_2+\dot{l}_2\dot{\Phi}_3+l_2\ddot{\Phi}_3\right)\right]R-$$

$$-ql_2\left[1-\frac{1}{g}\left(\ddot{l}_2+\dot{l}_2\dot{\Phi}_3+\frac{1}{2}l_2\ddot{\Phi}_3\right)\right]R-M_4(t),$$

$$\frac{l_1}{g}\left(Q_1+\frac{ql_1}{3}\right)\ddot{\Phi}_1+\left[\frac{\dot{l}_1}{g}\left(Q_1+\frac{ql_1}{2}\right)+\alpha\right]\dot{\Phi}_1+K\Phi_1=\left(Q_1+\frac{ql_1}{2}\right)\left(1-\frac{\ddot{l}_1}{g}\right), \qquad (12)$$

$$\frac{l_2}{g}\left(Q_2+\frac{ql_2}{3}\right)\ddot{\Phi}_3+\left[\frac{\dot{l}_2}{g}\left(Q_2+\frac{ql_2}{3}\right)+\alpha\right]\dot{\Phi}_3+K\Phi_3=\left(Q_2+\frac{ql_2}{2}\right)\left(1-\frac{\ddot{l}_2}{g}\right).$$

These equations should also attach the equation of stationary contacts:

$$l_1 = l_{01}+\varphi_3 R\,, \quad l_2 = l_{02}-\varphi_4 R\,. \qquad (13)$$

By I_1 and C_{12} it should be understood the reduced moment of inertia and the reduced stiffness of the motor shaft to the gear portion of the rotor to the axis of the main shaft.

The resulting system of equations was the basis for further studies of the dynamics two-drum winders.

Differential equations of the dynamics of a single drum lifting equipment.

Assuming that the rigidity of the main shaft in the area between the drums equivalent circuit of Fig. 1 infinity (Fig. 2), the equation (10), together with the conditions (4) for the single-drum winder according to the received symbols can be written as follows:

$$
\begin{aligned}
& I_1\ddot{\varphi}_1 + C_{12}\left(\varphi_1 - i\varphi_2\right) = M_1(t), \\
& I_2\ddot{\varphi}_2 + C_{23}\left(\varphi_2 - \varphi_3\right) - iC_{12}\left(\varphi_1 - i\varphi_2\right) = 0, \\
& I_3\ddot{\varphi}_3 - C_{23}\left(\varphi_2 - \varphi_3\right) + K_1R\left(\varphi_3R - \varphi_4r\right) + K_2R\left(\varphi_3R - \varphi_5r\right) = -M_3(t), \\
& I_4\ddot{\varphi}_4 + K_1r\left(\varphi_3R - \varphi_4r\right) = Q_1\left[1 - \frac{1}{g}\left(\ddot{l}_1 + \dot{l}_1\dot{\Phi}_1 + l_1\ddot{\Phi}_1 + 2l_1\dot{l}_1\dot{\Phi}_2 + l_1^2\ddot{\Phi}_2\right)\right]r + \\
& + ql_1\left[1 - \frac{1}{g}\left(\ddot{l}_1 + \dot{l}_1\dot{\Phi}_1 + \frac{1}{2}l_1\ddot{\Phi}_1 + 2l_1\dot{l}_1\dot{\Phi}_2 + \frac{2}{3}l_1^2\ddot{\Phi}_2\right)\right]r, \\
& I_5\ddot{\varphi}_5 - K_2r\left(\varphi_3R - \varphi_5r\right) = -Q_2\left[1 - \frac{1}{g}\left(\ddot{l}_2 + \dot{l}_2\dot{\Phi}_3 + l_2\ddot{\Phi}_3 + 2l_2\dot{l}_2\dot{\Phi}_4 + l_2^2\ddot{\Phi}_4\right)\right]r - \\
& - ql_2\left[1 - \frac{1}{g}\left(\ddot{l}_2 + \dot{l}_2\dot{\Phi}_3 + \frac{1}{2}l_2\ddot{\Phi}_3 + 2l_2\dot{l}_2\dot{\Phi}_4 + \frac{2}{3}l_2^2\ddot{\Phi}_4\right)\right]r, \\
& \frac{l_1}{g}\left(Q_1 + \frac{ql_1}{3}\right)\ddot{\Phi}_1 + \left[\frac{\dot{l}_1}{g}\left(Q_1 + \frac{ql_1}{2}\right) + \alpha\right]\dot{\Phi}_1 + K\Phi_1 + \frac{l_1^2}{g}\left(Q_1 + \frac{5ql_1}{12}\right)\ddot{\Phi}_2 + \\
& + l_1\left[\frac{2}{g}\left(Q_1 + \frac{ql_1}{2}\right)\dot{l}_1 + \alpha\right]\dot{\Phi}_2 + l_1K\Phi_2 = \left(Q_1 + \frac{ql_1}{2}\right)\cdot\left(1 - \frac{\ddot{l}_1}{g}\right), \\
& \frac{l_1}{g}\left(Q_1 + \frac{5ql_1}{12}\right)\ddot{\Phi}_1 + \left[\frac{\dot{l}_1}{g}\left(Q_1 + \frac{2ql_1}{3}\right) + \alpha\right]\dot{\Phi}_1 + K\Phi_1 + \frac{l_1^2}{g}\left(Q_1 + \frac{8ql_1}{15}\right)\ddot{\Phi}_2 + \\
& + l_1\left[\frac{2}{g}\left(Q_1 + \frac{2ql_1}{3}\right)\dot{l}_1 + \frac{4}{3}\alpha\right]\dot{\Phi}_2 + \frac{4}{3}Kl_1\Phi_2 = \left(Q_1 + \frac{2ql_1}{3}\right)\left(1 - \frac{\ddot{l}_1}{g}\right), \\
& \frac{l_2}{g}\left(Q_2 + \frac{ql_2}{3}\right)\ddot{\Phi}_3 + \left[\frac{\dot{l}_2}{g}\left(Q_2 + \frac{ql_2}{3}\right) + \alpha\right]\dot{\Phi}_3 + K\Phi_3 + \frac{l_2^2}{g}\left(Q_2 + \frac{5ql_2}{12}\right)\ddot{\Phi}_4 + \\
& + l_2\left[\frac{2}{g}\left(Q_2 + \frac{ql_2}{2}\right)\dot{l}_2 + \alpha\right]\dot{\Phi}_4 + Kl_2\Phi_4 = \left(Q_2 + \frac{ql_2}{2}\right)\left(1 - \frac{\ddot{l}_2}{g}\right), \\
& \frac{l_2}{g}\left(Q_2 + \frac{5ql_2}{12}\right)\ddot{\Phi}_3 + \left[\frac{l_2}{g}\left(Q_2 + \frac{2ql_2}{3}\right) + \alpha\right]\dot{\Phi}_3 + K\Phi_3 + \frac{l_2^2}{g}\left(Q_2 + \frac{8ql_2}{15}\right)\ddot{\Phi}_4 + \\
& + l_2\left[\frac{2}{g}\left(Q_2 + \frac{2ql_2}{3}\right)\dot{l}_2 + \frac{4}{3}\alpha\right]\dot{\Phi}_4 + \frac{4}{3}Kl_2\Phi_4 = \left(Q_2 + \frac{2ql_2}{3}\right)\left(1 - \frac{\ddot{l}_2}{g}\right).
\end{aligned}
\tag{14}
$$

By equation (14) to attach the constraint equations:

$$l_1 = l_{01} + \varphi_4 r, \quad l_2 = l_{02} - \varphi_5 r. \tag{15}$$

In order to simplify the system (14) will take the same assumptions as in the simplification of the system (12).

A simplified design scheme-drum setup is shown in Fig. 4.

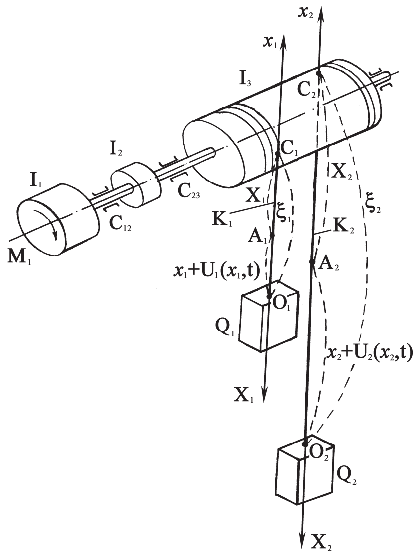

Fig. 4 – Simplified design scheme-drum elevator installation for underground hydroponic shops

As a result of simple transformations we obtain a system of two nonlinear equations:

$$I_1\ddot{\varphi}_1 + C_{12}\left(\varphi_1 - \varphi_2\right) = M_1\left(t\right),$$
$$I_2\ddot{\varphi}_2 + C_{23}\left(\varphi_2 - \varphi_3\right) - C_{12}\left(\varphi_1 - \varphi_2\right) = 0,$$
$$I_3\ddot{\varphi}_3 - C_{23}\left(\varphi_2 - \varphi_3\right) = Q_1\left[1 - \frac{1}{g}\left(\ddot{l}_1 + \dot{l}_1\dot{\Phi}_1 + \dot{l}_1\ddot{\Phi}_1\right)\right]R + \tag{16}$$
$$+ql_1\left[1 - \frac{1}{g}\left(\ddot{l}_1 + \dot{l}_1\dot{\Phi}_1 + \frac{1}{2}l_1\ddot{\Phi}_1\right)\right]R - Q_2\left[1 - \frac{1}{g}\left(\ddot{l}_2 + \dot{l}_2\dot{\Phi}_3 + l_2\ddot{\Phi}_3\right)\right]R -$$
$$-ql_2\left[1 - \frac{1}{g}\left(\ddot{l}_2 + \dot{l}_2\dot{\Phi}_3 + \frac{1}{2}l_2\ddot{\Phi}_3\right)\right]R - M_3\left(t\right),$$
$$\frac{l_1}{g}\left(Q_1 + \frac{ql_1}{3}\right)\ddot{\Phi}_1 + \left[\frac{\dot{l}_1}{g}\left(Q_1 + \frac{ql_1}{2}\right) + \alpha\right]\dot{\Phi}_1 + K\Phi_1 = \left(Q_1 + \frac{ql_1}{2}\right)\left(1 - \frac{\ddot{l}_1}{q}\right),$$
$$\frac{l_2}{g}\left(Q_2 + \frac{ql_2}{3}\right)\ddot{\Phi}_3 + \left[\frac{\dot{l}_2}{g}\left(Q_2 + \frac{ql_2}{3}\right) + \alpha\right]\dot{\Phi}_3 + K\Phi_3 = \left(Q_2 + \frac{ql_2}{2}\right)\left(1 - \frac{\ddot{l}_2}{q}\right).$$

These equations of the equation attach stationary contacts:

$$l_1 = l_{01} + \varphi_3 R, \quad l_2 = l_{02} - \varphi_3 R. \tag{17}$$

The resulting system of equations (14-15) and (16-17) describe the dynamics of single-drum hoisting plant, taking into account tangible viscoelastic varying lengths of ropes.

The dynamic equations of two-drum lifting equipment (12) and (13) are suitable for the study of the dynamics of single-drum hoisting units with split drum, but it should be noted that during the movement when fixed and transportability of the drum are interconnected wound rope, reduced stiffness C_{34} determined by the torsional stiffness of the rope.

If odnokontsevogo rise in the equations of the dynamics of the hoisting plant should put the weight of a cargo terminal, a variable length of the rope on which hung the cargo, as well as its relative deformation, equal to zero $\left(Q=0, \quad l=0, \quad \Phi=0\right)$.

Currently, for purposes of simplicity and reliability to automatic control, durability, and reduce capital costs, there is a tendency to create bezreduktortnyh hoisting units. Mechanical model of a elevator installation is shown in Fig. 5.

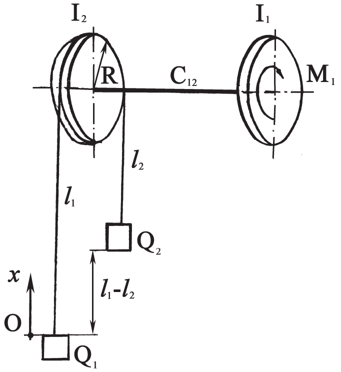

Fig. 5 – Design model of single-drum hoisting plant underground hydroponic shops

The dynamics of this installation is described by the following system of nonlinear differential equations:

$$
\begin{aligned}
& I_1\ddot{\varphi}_1 + C_{12}\left(\varphi_1-\varphi_2\right) = M_1(t), \\
& I_2\ddot{\varphi}_2 - C_{12}\left(\varphi_1-\varphi_2\right) = Q_1\left[1-\frac{1}{g}\left(\dot{l}_1+\dot{l}_1\dot{\Phi}_1+\dot{l}_1\ddot{\Phi}_1\right)\right]R+ \\
& +ql_1\left[1-\frac{1}{g}\left(\ddot{l}_1+\dot{l}_1\dot{\Phi}_1+\frac{1}{2}l_1\ddot{\Phi}_1\right)\right]R-Q_2\left[1-\frac{1}{g}\left(\dot{l}_2+\dot{l}_2\dot{\Phi}_3+l_2\ddot{\Phi}_3\right)\right]- \qquad (18)\\
& -ql_2\left[1-\frac{1}{g}\left(\ddot{l}_2+\dot{l}_2\dot{\Phi}_3+\frac{1}{2}l_2\ddot{\Phi}_3\right)\right]R-M_2(t), \\
& \frac{l_1}{g}\left(Q_1+\frac{ql_1}{3}\right)\ddot{\Phi}_1+\left[\frac{\dot{l}_1}{g}\left(Q_1+\frac{ql_1}{2}\right)+\alpha\right]\dot{\Phi}_1+K\Phi_1=\left(Q_1+\frac{ql_1}{2}\right)\left(1-\frac{\ddot{l}_1}{g}\right), \\
& \frac{l_2}{g}\left(Q_2+\frac{ql_2}{3}\right)\ddot{\Phi}_2+\left[\frac{\dot{l}_2}{g}\left(Q_2+\frac{ql_2}{2}\right)+\alpha\right]\dot{\Phi}_2+K\Phi_2=\left(Q_2+\frac{ql_2}{2}\right)\left(1-\frac{\ddot{l}_2}{g}\right),
\end{aligned}
$$

with the equations of stationary contacts

$$l_1 = l_{01}+\varphi_2 R, \quad l_2 = l_{02}-\varphi_2 R. \qquad (19)$$

It is interesting to note that the equation of motion of the elevator installation as an absolutely rigid system received the first academician M.M. Fedorovym, can be obtained from equations (10), respectively if all take infinitely high rigidity, i.e. $\varphi_1=\varphi_2=....=\varphi_n, \quad \Phi_K=0, \left(K=1, 2, 3, 4\right)$ and to lay down the first six equations.

Then, in our notation we have the following equation:

$$M = (Q_1 - Q_2)R - qR^2\varphi - q(l_{01} - l_{02})R - \left\{ I + \frac{[Q_1 + Q_2 + q(l_{01} - l_{02})]R^2}{g} \right\}\ddot{\varphi},$$

where $I = \sum_{K=1}^{N} I_K$ – moment of inertia, $M_1(t) - M_2(t) = M$ – moment of the driving forces.

The driving forces of the elevator installation.

The lifting mechanism driven by an electric AC or DC. The DC drive is usually used system GD. The AC drive most widely phase asynchronous motor with rotor (95% increase) to be included in various schemes.

In terms of dynamic processes in the mechanical part of the plant the most unfavorable induction motor contactor running on metal resistances because Switching on and resistance levels cause the abrupt application of an external perturbation (drive torque).

The most characteristic index of the dynamic properties of the mechanical system is the first maximum elastic vibrations arising in the elastic coupling due to external perturbations.

In this regard, the most interesting in problems of dynamics, consider a system with asynchronous drive.

We all studies assume that the drive torque of the electric motor during the fourth period of oscillation of the low-power remains constant (ie during the growth of a dynamic load to the first maximum can use the static mechanical properties of the engine).

With sufficient accuracy for engineering practice can be assumed that in the range of switches work areas starting characteristics straightforward.

For an absolutely rigid system this causes an exponential dependence of the dynamic component of the moment of lifting the engine in time:

$$M = M_{\partial} e^{-r_n t}, \tag{20}$$

where $M_{\partial} = M_1 + M_3 - QR(1 \pm \delta)$ – overweight or acceleration torque of the engine: δ – degree of static unbalance; r_n – rheostat setting characteristics.

Usually setting is potentiometer characteristics:

$$r_n = 0{,}1 \div 0{,}5.$$

Start asynchronous motor creates a non-periodic effect on the system. The closest to reality will be the case when excessive torque of the engine as a function of the rate of change in a straight line. The equation of a straight line in the coordinates $(M,\ \dot{\varphi})$ it makes it possible to express the change points in the form:

$$M = M_{\partial}\left(1 - \frac{\dot{\varphi}}{\dot{\varphi}_C}\right), \tag{21}$$

where $\dot{\varphi}_C$ – a synchronous motor speed.

In addition to the active driving forces act on the system forces lifted load, force unbalanced weight portions of the rope. The moment the engine has to achieve a desired tachogram recovery, taking into account all factors external force acting on the elements of the elevator installation. For this calculation engine and rotor resistance exercise stations, on the assumption of absolute rigidities of the system components in a known manner.

Later in the study of dynamic processes in elastic links of the lifting mechanism, we assume that the engine provides a predetermined time (average) acceleration of the moving cargo in accordance with the tachogram recovery.

Conclusions.

1. Preparation of system of differential equations describing the dynamics of lifting mechanisms of different designs of mechanical systems for the production of hydroponic production.

2. Choice of the start of the fixed axes at the points of attack on the body coiling ropes and exit from it, and moving to the point of suspension of cargo terminal, guiding axes respectively up and down the ropes, when presenting the motion dynamic movements in the form of an expansion of the forms of oscillations (the idea of the method points), possible to describe mathematical models of hoisting systems of nonlinear ordinary differential equations of inhomogeneous (instead of functional differential partial) in the second fundamental problem of dynamics strands of variable length.

3. Dynamic processes in elastic elements of double-drum hoist system described by the ten non-linear equations with two equations of unsteady relations. This system is suitable for the study of the dynamics of a single drum hoist with a split drums. The dynamics of a single drum hoist is described by nine nonlinear equations with the equations of unsteady relations.

4. In the study of dynamic processes in elastic elements of the hoist ropes and variable length with sufficient accuracy for practical purposes, can be limited to basic voice vibrations of ropes and pulleys rotating mass lead to the respective masses of the drums.

5. A further solution obtained systems of differential equations on the PC will determine how dynamic forces in the viscoelastic ropes of variable length, and the time of the elastic forces in the shaft hoisting. In addition, these equations generally apply for other tasks synthesis hoist.

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