It is investigated trajection-kinematic characteristics of movement of part of mineral fertilizers on rough internal surface of inclined elliptic cylinder.

Movement of particles, surface roughness, elliptic cylinder, trajectory, speed.

UDC 62-187.3

AnalogFrom a mathematical model of the dynamics lifting crane span

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The paper built a dynamic model of lifting mechanism, which is represented as a lumped masses connected by elastic bonds. Based on the dynamic model is the mathematical modeling of the dynamics Lift, performed span crane. The mathematical model is multi-layered, in which each phase is described by differential equations. Also recorded initial and final conditions of individual mass movement. The analysis of the mathematical model, which showed that the phase tension rope and lifting does not allow for pre-specified end traffic conditions reduced weight and axle load.

Pidyom cargo, mathematical modeling, differential equations, Cauchy problem.

Resolutionska problem. PEid runtime navantazhuvalno- handling vehicle are often used cranes. They can increase the efficiency of traffic flow in the enterprise.

Printeraction and cargo and vehicle suspension last occurring heavy loads. They can break elements of the vehicle. In addition, elements of the crane (cargo rope bridge crane, hoist transfer of cargo) is also exposed to dynamic loads. Therefore it is necessary to establish the cause of dynamic loads in a vehicle and crane in order to reduce their effect. Construction and analysis of a mathematical model of the system "lifting mechanism - load - vehicle "allows consti optimization of motion elements of the system in order to increase the efficiency of its operation.

AnaLiz recent research. Beforeand study the dynamics Sectionidyomu cargo cranes span associated with the names of MS Komarova [1] SA Kazak [2] MM Gohberg [3].

In [1] built trymasova dynamic model of lifting and derived the equations of motion of individual masses (drive axle and cargo). Dissipative properties of the lifting mechanism and dynamic deformation of metal not included.

Atled in [1] the results can be used for a first approximation calculation of dynamic lifting mechanism. SA Kazak in [2] The detailed calculations lifting mechanism, in which the influence of alternating efforts regarding the magnitude of dynamic loads and dependence rope tension of its length. Detail the method of calculating the load when switching a circuit thlektroobladnannya crane.

MM. Gohberg in [3] investigated cases peak lifting mechanism when lifting from the base load and braking load that falls. In both cases the cable drum speed is constant. Research conducted for dvomasovoyi dynamic model.

Among foreign works on the dynamics of lifting equipment should be allocated Book Schefflera M., H. dressing and Kurt F. [4]. The study authors used single and dynamic models dvomasovu lifting mechanism. Dynamic processes described when lifting and lowering, the researchers divided into several phases. The final results of the research are analytical expressions for the coefficients of dynamic efforts and rope bridge span crane.

In the.F. Gaydamak investigated dynamic force arising in the lifting mechanism, provided that the rate of decrease length of rope hoists in stage dovidryvniy cargo traffic is constant, and pislyavidryvniy - is a constant driving force [5]. Lifting mechanism represented as dvomasovoyi dynamic model.

M.A. Lobov in [6] developed a method for calculating the maximum load cranes lifting mode of aboutAgain. In this paper, the author analyzes the reasons for the discrepancy between theoretical and experimental research results lifting mechanism.

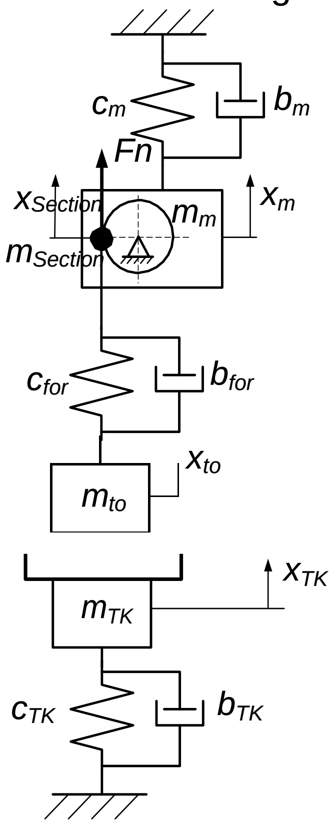
DyneMika movement mechanism for lifting investigated Odessa schools MMT led by Professor R. Gerasimyak [7, 8]. The results of these Studies indicate that the greatest impact on the character

MDPzhnyh fluctuations trymasovoyi electromechanical system, which presents lifting mechanism during its rise "picked out" with the stiffness of the mechanical characteristics of the electric drive, rigidity and flex rope angle boom crane. LY Budikov [9] conducted a study of the dynamics of the movement mechanism lifting overhead crane. In [9] constructed a dynamic model trymasova lifting mechanism and the corresponding mathematical model. Numerical integration of differential equations that fit both dynamic models lifting mechanism, and therefore show a match in the future by using only model with lumped parameters. It must be said that in all the above work is ignored or insufficiently taken into account the impact of the base, which is performed with lifting.

Metand mathatmatic lit.idzhen modelhi there is Sectionidyomu anaLease cargo crane performing span.

DTo achieve this goal it is necessary to solve the following bytask: to build a dynamic model of the system; based on a dynamic model to find a mathematical model; to analyze mathematical models.

Rezultaty dperssurvey findings. Dll abouttransaction tofor Research use a dynamic model, which is shown in Fig. 1.



Ric. 1. Dynamic model of "lifting mechanism - Load - vehicle ".

Fig. 1 shows the following notation: *TSW*,*sk*,*cm* - Shows the stiffness of the vehicle, trucks and rope bridge crane respectively; btz,b_{for},b_m- Given damping vehicle cargo rope bridge and crane respectively; mtz,m_{to},$m_{Section}$,m_m- Reduced mass of the vehicle, cargo, drive mechanism lifting crane and bridge respectively; HTZ,x_{to},$x_{Section}$,x_m- Generalized coordinates corresponding masses; $F_{Section}$- Reduced to about efforts drum hoist cargo. To build a complete picture of the dynamic processes of lifting cargo must separate the process at some stage. We give a detailed description of these stages.

BeforeStep Lift lasts until the rope is sample weaknesses. This only shows the moving mass of matter. This stage is characterized by zero initial conditions:

$$x_{Section}(0)=\dot{x}_{Section}(0)=0. \tag{1}$$

Mathematicalon the model of the first stage is written as follows:

$$m_{Section}\ddot{x}_{Section}=F_{Section}. \tag{2}$$

In the second stage, the tension of the rope to the weight of the load force. At this stage, all moving masses dynamic system. However, since the cargo is on the vehicle, the reduced mass of the cargo and the vehicle moving synchronously, ie just for this phase equation:

$$x_{to}=CT_{from}. \tag{3}$$

Initial-governmental movement conditions for reduced weight and axle load are:

$$\begin{cases} x_{to1}(t)=-\dfrac{(m_{to}+MT_{from})g}{with_{TK}}; \\ \dot{x}_{to}(t_1)=0; \\ x_{m1}(t)=-\dfrac{m_m g}{with_m}; \\ \dot{x}_m(t_1)=0, \end{cases} \tag{4}$$

where t_1- The duration of the first stage.

The final terms of reduced mass movement for the first drive phaseis in the initial conditions for the second stage.

Mathematicalon the model of the mass movement in the second stage consists of three differential equations (5). The third equation of (5) reflects the fact that the load acting elastic-viscous force suspension of the vehicle. The system of equations (5) present the initial conditions of the movement of cargo and over the bridge. Indeed, at this stage pulling force of the rope starts to increase from zero from-identification. Dla Providetion ciyeyi UMOyou UGAhalneni Koridynaty cargo, over the bridge and deducted from their initial conditions (4).

$$\begin{cases} m_{Section}\ddot{x}_{Section} + b_{for}(\dot{x}_{Section} + \dot{x}_m - \dot{x}_{to}) + CK((x_{Section} - x_{Section}(t_1)) + (x_m - x_m(t_1)) - \\ - (x_{to} - x_{to}(t_1))) = F_{Section}; \\ m_m(\ddot{x}_m + g) + b_{for}(\dot{x}_{Section} + \dot{x}_m - \dot{x}_{to}) + b_m\dot{x}_m + CK((x_{Section} - xp(t_1)) + \\ + (x_m - x_m(t_1)) - (x_{to} - x_{to}(t_1))) + c_m x_m = 0; \\ (m_{to} + m_{tfrom})(\ddot{x}_{to} + g) - b_{for}(\dot{x}_{Section} + \dot{x}_m - \dot{x}_{to}) - c_{for}((x_{Section} - x_{Section}(t_1)) + \\ + (x_m - x_m(t_1)) - (x_{to} - x_{to}(t_1))) + bt_{from}\dot{x}_{to} + ctz\,Xv = 0. \end{cases} \quad (5)$$

The end of the second phase is the time of separation from the surface of the cargo vehicle.

To Thirdin phaseand toandntazh moDRIvayetsya from ontop Maynsportnoho product. The initial conditions for this stage is forintsevi conditions for the second stage. The equations of motion that describe the movement of all four elements of the dynamical system are as follows:

$$\begin{cases} m_{Section}\ddot{x}_{Section} + b_{for}(\dot{x}_{Section} + \dot{x}_m - \dot{x}_{to}) + CK((x_{Section} - x_{Section}(t_1)) + (x_m - x_m(t_1)) - \\ - (x_{to} - x_{to}(t_1))) = F_{Section}; \\ m_m(\ddot{x}_m + g) + b_{for}(\dot{x}_{Section} + \dot{x}_m - \dot{x}_{to}) + b_m\dot{x}_m + CK((x_{Section} - xp(t_1)) + \\ + (x_m - x_m(t_1)) - (x_{to} - x_{to}(t_1))) + c_m x_m = 0; \\ m_{to}(\ddot{x}_{to} + g) - b_{for}(\dot{x}_{Section} + \dot{x}_m - \dot{x}_{to}) - c_{for}((x_{Section} - x_{Section}(t_1)) + \\ + (x_m - x_m(t_1)) - (x_{to} - x_{to}(t_1))) = 0; \\ MT_{from}(\ddot{x}_{tfrom} + g) + bt_{from}\dot{x}_{tfrom} + ctz\,xtz = 0. \end{cases} \quad (6)$$

In the fourth phase of motion of a dynamical system "mechanism lifting - load - vehicle" is off the motor and brake blending. Thus we believe that efforts $F_{Section}$fromminyuyetsya abruptly as brake blending duration of electromagnets AC does not exceed 0,015-0,02 seconds [10]. Braking torque is proportional to the braking force to the fourth stage is given by [8]:

$$M\,r = K_{from} Matthew \eta_{IUx}, \quad (7)$$

where K_{from}- The safety factor, which take equal Ks= 2 (for medium security work 5M lifting mechanism); M_{to}- Static moment when lowering the nominal load (20 tons) brought to the motor shaft (M_{to}= 834 nm); η_{fur} - Nominal efficiency mechanisms (η_{fur}= 0.9).

Dla addition, thatto fromFind Optimapoorer sound controlof didynamically
system "mechanism lifting - load - vehicle" is necessary to analyze the equations of motion of individual masses. Everyone

phasein the motion of the system are as defined above system of differential equations. For the mode of lifting the first phase is described by the differential equation (2). This allows you to perform a differential equation formulation of optimization problems and find solutions to them, as only a function of the drive force on the right side of equation (2) determines the motion of the engine. The duration of the second stage is negligible, so we can assume that the mass movement occurs without the action of dissipative forces.

Therefore, willMo, uabout$b_{for}=bm=btz=0$. Krafter addition, introduce Pos-identification efforts tensile rope:

$$F_{ê}=c_{ê}((x_{ï}-x_{ï}(t_1))+(x_{ì}-x_{ì}(t_1))-(x_{â}-x_{â}(t_1))).$$

Consideringand all that we can write the equation of motion for the mass of the second stage:

$$\begin{cases} m_{ï}\ddot{x}_{ï}+F_{ê}=F_{ï}; \\ m_{ì}(\ddot{x}_{ì}+g)+F_{ê}+c_{ì}x_{ì}=0; \\ (m_{â}+m_{òç})(\ddot{x}_{â}+g)-F_{ê}+c_{òç}x_{â}=0. \end{cases} \quad (8)$$

ProanaLisa system of equations (8). The second and third equations of system (8) can replace one:

$$\ddot{x}_{ì}+\Omega^2 x_{ì}=-\frac{(m_{â}+m_{òç})}{m_{ì}}(\ddot{x}_{â}+g)-\frac{c_{òç}}{m_{ì}}x_{â}-g, \quad (9)$$

where Ω_m- Frequency of oscillation of the bridge crane ($\Omega=\sqrt{\frac{\tilde{n}_{ì}}{m_{ì}}}$).

Let the optimization problem by setting need to move goods from one location, which describes the initial conditions (4), the other end which is described UMOyou:

$$\begin{cases} x_{â}(t_2)=-\frac{m_{â}g}{\tilde{n}_{òç}}; \\ \dot{x}_{â}(t_2)=0. \end{cases} \quad (10)$$

Atconditions mentioned above (10) correspond to the second stage without hesitation cargo. Suppose you find this feature cargo movement, which provides these initial and final conditions and delivers extreme some optimization criteria. Henceforth can fromFind atacceleration Funktsiyu vantazhu $\ddot{x}_{â}$ prand $t\in[t_1;\ t_2]$.

Knowing functions $x_{â}$tand $\ddot{x}_{â}$it is easy to find the right part of equation (9) asand acting "outside" disturbance to fluctuations reduced mass of the bridge crane. Solution inhomogeneous differential equation (9) should be sought in the form of the sum [11]:

$$x_{ì} = \tilde{o}_{ì}^{*} + \tilde{o}_{ì}^{**}, \qquad (11)$$

where $\tilde{o}^{*}_{i}$ – byshaping overall migra- solution of the homogeneous equation $\ddot{x}_i + \Omega^2 x_i$. That description free oscillations are reduced mass of the bridge crane; $\tilde{o}^{**}_{i}$ - Chastkovyy solution of the inhomogeneous equation (9), which characterizes the reduced mass movement under the bridge without disturbing forces free when fluctuations. Partially and Rose bundles Categories eodnoridnoho pivnyannya $\tilde{o}^{**}_{i}$ determined by the right-hand side of the differential equation (9). In the his Queues in heartburntal Rose bundles aboutdnoridnoho pivnyannya $\tilde{o}^{*}_{i}$ determined by the initial conditions of the bridge and its traffic parameters that directly affect the natural oscillation frequency Ω_m. The final terms of the movement of the bridge to the second phase of the movement are:

$$\begin{cases} x_i(t_3) = -\dfrac{(m_a + m_i)g}{\tilde{n}_i}; \\ \dot{x}_i(t_2) = 0. \end{cases} \quad (12)$$

Conditions (12) indicate that the crane bridge shakes at the end the second phase of the movement; it is loaded by its own weight and the weight of the load. However, powerak, Provideand inspeech (12) CategoriesUpperd impossible, aboutterm as $\tilde{o}^{*}_{i}$ in p ivnyanni (11) is "unmanageable." Through andnalohichni statements for the third and fourth rounds conclude that fully control the movement of the masses resulted bridge crane and cargo at these stages is impossible.

Conclusion. Hand based on the analysis of the mathematical model motionin the "lifting mechanism - load - vehicle" states that provide pre-defined end-cargo traffic conditions and crane bridge impossible. Mathematically, the inability to manage the end-state of reduced mass bridge crane shown in need of solving the Cauchy problem, not a boundary value problem. When setting optimal control problems this dynamic system it is necessary to consider this feature.

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In Article postroena dynamycheskaya model podъema mechanism of cargo, kotoraja presented in video sosredotochennыh mass, kotorыe soedynenы elastic connection. Based on dynamycheskoy models Invalid Mathematical Modeling dynamics podъema of cargo, kotoroe vыpolnyaetsya proletnыm tap. Matematycheskaya model mnohoэtapnaya in kotoroj Each Stage opysыvaetsya systemoy dyfferentsyalnыh equations. In addition, zapysannыe nachalnыe and konechnыe terms otdelnыh mass movement. Conducted analysis Mathematical models, kotorыy showed that, something Stage natyazhenyya rope and podъema of cargo not obespechyt zadannыe allows us to advance konechnыe terms pryvedennыh mass movement of the bridge and cargo.

Ondъem gRuza, mathatmatycheskoe FASHIONlyrovanye, dyfferentsyalnыe equation, the problem Koshы.

In paper have been carry out dynamic model of mechanism for cargo lifting. It is presented as few discrete masses, whitch connected with elastic constrains. On basis of dynamic model have been carry out simulation of lifting cargo dynamic. The mathematical model is multi-stage, in which each step is described by system of differential equations. In addition, initial and final conditions of masses movement are showed. Analisys of mathematical model have been cary out. The analysis of mathematical model, which showed that cable tension stage and lifting does not allow terminal conditions specified in advance motion of reduced masses crane bridge and load.

Cargo lifting, simulation, differential equations, Koshy

problem.