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REASONS FOR THE MAIN DIRECTIONS OF ENHANCEMENT OF MECHANISMS OF ORIENTATION OF TARE LOADS IN A PACKET CREATING MACHINES

Formation of steady transport packets provides, near binding of tare loads in a packet, their layout according to the appropriate scheme. Schemes in which loads are located to, joint providing bandaging compliance beforehand the loads concluded in a layer, are created of variously oriented tare loads. For change of orientation of a tare load in the horizontal plane, concerning its situation on the giving conveyor, in a packet creating machines apply various constructions of mechanisms of orientation. These mechanisms can tear a load on 90° or change situation concerning its original layout. Devices of orientation can be executed with passive, active and combined working organs.

Картонна коробка, пакувальна машина, магазин, конвеєр.

I. Introduction

Also orientations of a load can be executed both on one, and on several bearing planes of transport systems of packet creating machines.

From the point of view of nature of action of loads of loading that moves in orientation mechanisms, we can select frictional and inertial, kinematic and combined orientations

Frictional and inertial orientation is reached by support of simultaneous contact of a mobile load with the mobile and fixed bearing planes therefore load under the action of power of inertia and friction. Kinematic orientation is executed by special mechanisms with working items like capture or clamp.

A combined method of orientation of loads are used In the modern samples a packet of creating machines. This method is as follow during orientation the load contacts with two planes one of which is bearing, and another - a guide. Guide can be fixed (it`s used more often) or mobile. The combination of force influence of a directing surface, the frictional forces operating on a reference surface of a load from the bearing plane and inertial forces provide necessary load orientations in case of high performance of mechanisms of orientation and the machine as a whole. The orienting surface can be rectilinear (a coordinating oar) or the curvilinear (an orienting emphasis of the whip type or the curvilinear performances of side walls of construction). Preferential use of mechanisms of orientation of this kind is caused by simplicity of their construction, high performance, sufficient reliability in case of a correct choice of geometrical, kinematic and other design data of the mechanism of orientation. Process of orientation of tare loads is carried out under the influence of inertial forces, friction, responses of communication and is difficult plane movement of load orientation.

Key parameters with which it is possible to characterize operation of orientation of loads is productivity, that is the orientation duration, quality of orientation (a load turn on the given angle and relocation in the standard position) and costs of energy of operation execution. These parameters can be provided only in case of the correct assessment of all factors influencing orientation of a load.

II. Materials and methods

The technique of determination of parameters of movement of tare loads in devices of orientation of packet creating machines is given in scientific works [2-4]. Ways of intensification of operation of orientation aren't justified an aren`t formulated in the received results of researches
Considering that in any mechanisms of orientation of a load the load makes difficult plane movement in the packet creating machines, we will analyze the equations describing movement of a load in these mechanisms and we will define ways of influence on parameters of quality of orientation. On Fig. 1 the diagram of force impact on a tare load is given during its turn in the bearing plane by the whip emphasis. Movement of a load is characterized as difficult plane of a turn on the bearing plane and simultaneous sliding of its lateral face on an emphasis surface. For the mathematical description of movement of a load we will accept the assumption: the center of masses of a load is located in the geometrical center of a load; the load is a solid body; load friction coefficients on bearing and

orienting to the planes within change of the relative speeds of movement of a load are values constant; emphasis radius insignificant in comparison with the load sizes.

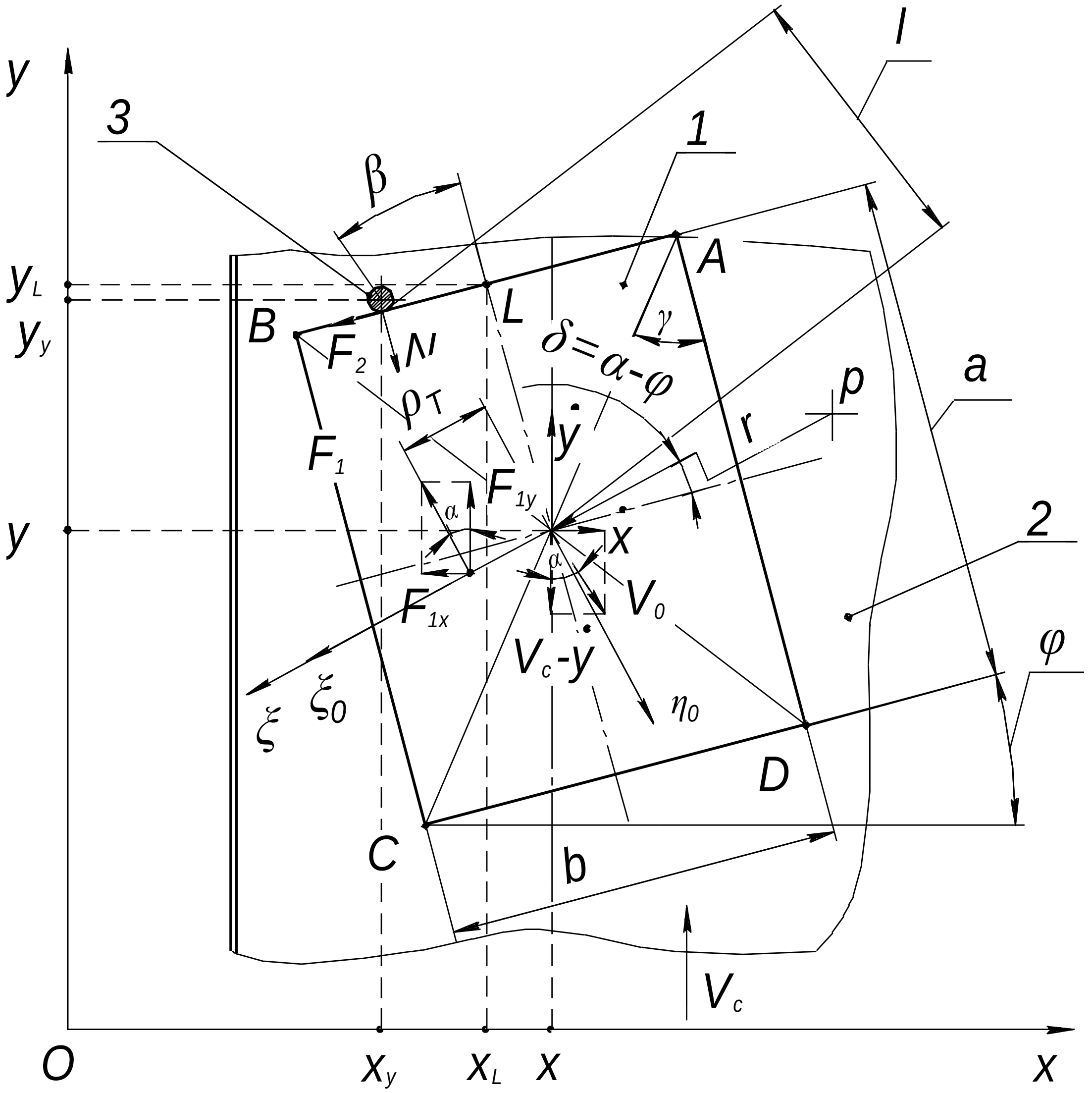

Fig. 1. The diagram of interaction of forces in case of a turn of a tare load an immovable emphasis on the bearing plane of a packet creating machines:
1 – tare load; 2 – the bearing plane of the conveyor; 3 – fixed bearing

On accepted conditions the load is affected by a normal component *N and tangent* F_2 full reaction R from a support, principal vector of sliding frictional forces F_1 reference surface of a load on the bearing plane of the conveyor. Principal vector of frictional forces F_1 is sent to the opposite side of a vector of the relative speed V_0 reference surface of a load of rather bearing plane also it is enclosed in the point located at distance ρ_T from geometrical center of a reference surface of a load.

Distance ρ_T is characterized as the radius of friction and is defined:

$$\rho_T = L / F_1 - r, \tag{1}$$

where L – moment of frictional forces of a reference surface of a load relatively the instantaneous center of motion speeds of a load; r – the radius defining distance from the instantaneous center p of speeds to geometrical center of a reference surface of a load, is defined as:

$$r = \frac{1}{\dot{\varphi}} \sqrt{\left(V_c - \dot{y}\right)^2 + \dot{x}^2} \tag{2}$$

V_c – traverse speed of the bearing plane of the pipeline;

$\dot{x}$, $\dot{y}$ – projections to axes *Ox*, *Oy* traverse speeds of geometrical center of a reference surface of a load;
$\dot{\varphi}$ – angular speed of rotation of a load of rather geometrical center of a reference surface of a load.

In a general view the moment of frictional forces and the principal vector of frictional forces can be determined by formulas:

$$\begin{cases} L = \int\limits_{\eta_1}^{\eta_2}\int\limits_{\psi_1(\eta)}^{\psi_2(\eta)} f_1 \cdot q(\eta,\xi)\cdot\sqrt{\eta^2+\xi^2}\,d\xi\;d\eta + \int\limits_{\eta_2}^{\eta_3}\int\limits_{\psi_4(\eta)}^{\psi_2(\eta)} f_1 \cdot q(\eta,\xi)\cdot\sqrt{\eta^2+\xi^2}\,d\xi\;d\eta + \ldots \\ \ldots + \int\limits_{\eta_3}^{\eta_4}\int\limits_{\psi_4(\eta)}^{\psi_3(\eta)} f_1 \cdot q(\eta,\xi)\cdot\sqrt{\eta^2+\xi^2}\,d\xi\;d\eta; \\ F_1 = \sqrt{F_{1x}^2 + F_{1y}^2}, \end{cases} \tag{3}$$

$$\eta_1 = -0{,}5\cdot\sqrt{a^2+b^2}\cdot\cos(\delta-\gamma);\quad \eta_2 = -0{,}5\cdot\sqrt{a^2+b^2}\cdot\cos(\delta+\gamma);$$

$$\eta_3 = 0{,}5\cdot\sqrt{a^2+b^2}\cdot\cos(\delta+\gamma);\quad \eta_4 = 0{,}5\cdot\sqrt{a^2+b^2}\cdot\cos(\delta-\gamma);$$

$$\delta = \alpha-\varphi;\quad \alpha = arctg\left(\dot{x}/(V_c-\dot{y})\right);\quad \gamma = arctg(b/a);\quad \psi_1(\eta) = -\eta\cdot ctg\delta + r - (0{,}5a/\sin\delta);$$

$$\psi_2(\eta) = \eta\cdot tg\delta + r + (0{,}5b/\cos\delta);\quad \psi_3(\eta) = -\eta\cdot ctg\delta + r + (0{,}5a/\sin\delta);$$

$$\psi_4(\eta) = \eta\cdot tg\delta + r - (0{,}5b/\cos\delta);$$

f_1 – sliding friction coefficient of a reference surface of a load on the bearing plane of the conveyor;
$q(\eta,\xi)$ – pressure upon a reference surface of a load determine:

$$q(\eta,\xi) = q_0 + \eta\left(\frac{M_{\xi 0}}{I_{\xi 0}}\cdot\cos\delta) - \frac{M_{\eta 0}}{I_{\eta 0}}\cdot\sin\delta\right) + \\ ..+(\xi-r)\cdot\left(\frac{M_{\xi 0}}{I_{\xi 0}}\cdot\sin\delta + \frac{M_{\eta 0}}{I_{\eta 0}}\cdot\cos\delta\right) \tag{4}$$

where q_0 – pressure upon a reference surface of a load in case of uniform distribution of load of it, generally determine as $q_0 = \frac{m\cdot g}{a\cdot b}$; *a, b* – overall dimensions of a load; $M_{\xi 0}$, $M_{\eta 0}$ – the principal moments of external forces concerning axes ξ_0, η_0, carried out through geometrical center of a reference surface; $I_{\xi 0}$, $I_{\eta 0}$ – inertia moments of a reference surface of a load concerning axes ξ_0, η_0.

Difficult plane movement of a load on the bearing plane of the conveyor can be described the equations:

$$\begin{cases} \frac{d^2x}{dt^2} = \frac{1}{m}\cdot\left(N\cdot\sin\varphi - F_2\cdot\cos\varphi - F_{1x}\right); \\ \frac{d^2y}{dt^2} = \frac{1}{m}\cdot\left(F_{1y} - N\cdot\cos\varphi - F_2\cdot\sin\varphi\right); \\ \frac{d^2\varphi}{dt^2} = \frac{12}{m\cdot c^2}\left(N\cdot l_\varphi + F_2\cdot 0{,}5\cdot c\cdot\sin\varphi - M_0\right), \end{cases} \tag{5}$$

where $c = \sqrt{a^2+b^2}$; $F_2 = f_2\cdot N$; f_2 – sliding friction coefficient of a lateral surface of a load on a surface of a fixed emphasis; l_φ - distance from the line of action of normal response *N* to center of masses of a load; M_0 – the moment of frictional forces concerning center of masses of a load.

The moment of frictional forces M_0 can be defined from expression:

$$M_0 = F_1\cdot\rho_T = L - F_1\cdot r. \tag{6}$$

III. Results and discussion

On the basis of the analysis of expressions (5) and (6) it is possible to draw an output that it is necessary for increase in angular acceleration of rotation of a load, in case of the given constructional parameters of the mechanism of the orientation, the bearing plane of the conveyor and load parameters, to reduce the moment of frictional forces M_0. And it is possible on condition of reduction of radius of friction ρ_T. of reduce radius ρ_T is possible due to pressure redistribution on a reference surface and due to change of a field of the relative speeds of movement of a reference surface. On Fig. 2 diagrams of change of angular coordinate of a load are given during its turn by an immovable emhasis in case of uniform distribution of pressure and non-uniform, but a load responding to static stability in the bearing plane [5]. Diagrams are constructed on the basis of numerical calculations of the non-linear differential equations describing multi-stage process of orientation [2] provided on Fig. 2.

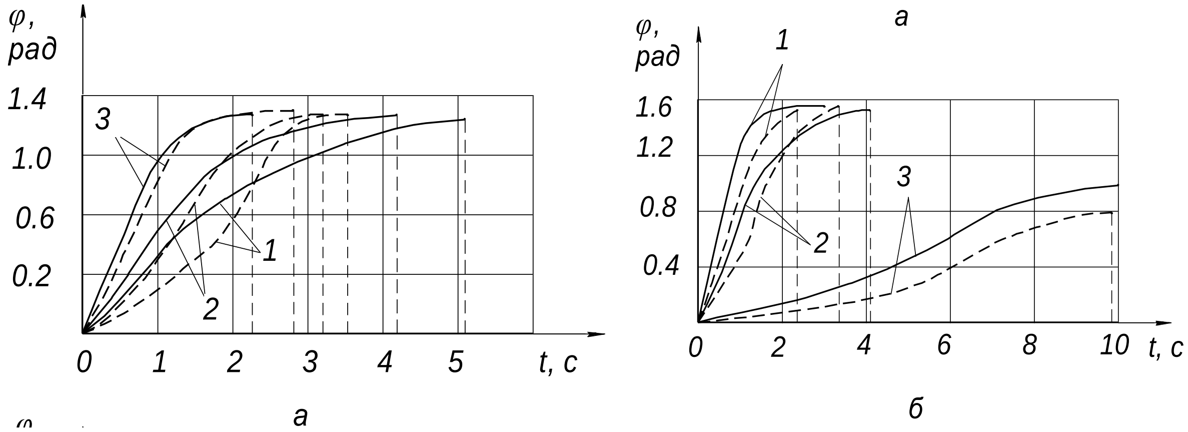

Fig. 2. Diagrams of change of angular coordinate of a load in the course of its turn an immovable emphasis:

а) V_c = 0,5 *м/с: 1*- β = 0,139 *рад*; 2- β = 0,241 *рад*; 3- β = 0,337 *рад*;

б) β = 0,139 *рад: 1*- $V_л$ = 1,0 *м/с; 2*- $V_л$ = 0,5 *м/с; 3* - $V_л$ = 0,1 *м/с*

(solid lines correspond to uniform distribution of pressure $q = q_0$,

the shaped – non-uniform pressure distribution $q(\eta,\xi) = q_0 + \eta \cdot \frac{M_{\xi 0}}{I_{\xi 0}}$)

From Fig.2 it is possible to draw an output that in case of the appropriate ratios of motion speed of the bearing plane and pressure redistribution on a reference surface of a load is possible to reduce activity duration of orientation on 20... 35%.

Different constructional elements that are used in a packet creating machines of average productivity intensify operation, so for example: the bearing plane is executed in the form of the conical rollers located on the appropriate diagram; on pipelines set the special fixed planes; pressing elements and etc.

The specified measures sometimes are ineffective (especially in case of small values of speed of the bearing plane of the conveyor V_c < 0,2 *м/s*). In that case it is necessary to use combined option of force impact on a load, that is it is necessary to set in addition in the mechanism the active working organ, for example, push rod.

On Fig. 3 the diagram of the mechanism of orientation of a tare load by an immovable emphasis with additional action on a load is provided push rod.

In this case, as well as in cases with passive working organs, operation of orientation can be given set of such characteristic stages:

- direct noncentral shock of the load moving with a speed of V_c bearing planes of the conveyor, on fixed an emphasis [6];
- difficult plane movement of a load on the bearing plane of the pipeline in case of simultaneous sliding of its lateral surface on a surface of an emphasis and action of a pusher;
- difficult plane movement of a load on the bearing plane of the pipeline after its lift-off from an emphasis surface.

The main difference of mathematical simulation of movement of a tare load in such mechanism of orientation is the accounting of force impact on a load of a push rod.

In case of such design features of the mechanism of orientation the load is affected by normal components of responses N_2 and N_3 and tangents

$$F_2 = f_2 \cdot N_2; \quad F_3 = f_3 \cdot N_3,$$

respectively from a fixed support and pucher and principal vector of sliding frictional forces F_1 reference surface of a load on the bearing plane of the conveyor.

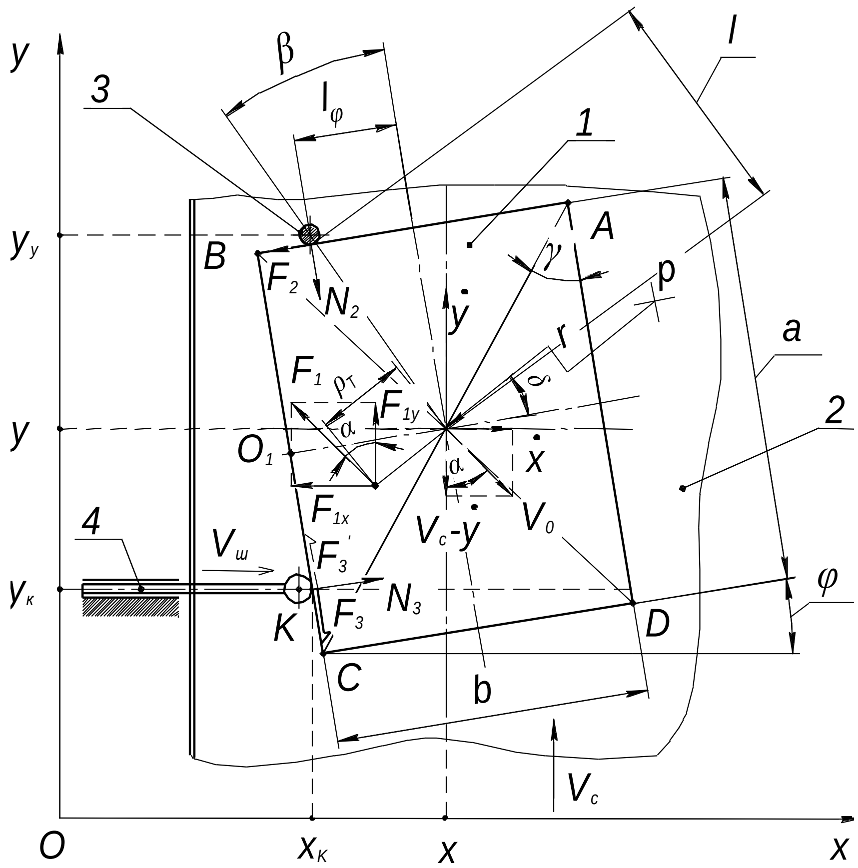

Fig.3. The diagram of interaction of forces in case of a turn of a tare load an immovable emphasis on the bearing plane of the conveyor a packet of the creating machine in simul taheus action of a pusher:
1 − tare load; 2 − the bearing plane of the pipeline; 3 − fixed support; 4 − pusher

Difficult plane movement of a load on the bearing plane under such circumstances can be described in the equations:

$$\begin{cases} \dfrac{d^2x}{dt^2} = \dfrac{1}{m} \cdot \begin{pmatrix} N_2 \cdot \sin\varphi - F_2 \cdot \cos\varphi + .. \\ ...+ N_3 \cdot cos\varphi \pm F_3 \cdot \sin\varphi - F_x \end{pmatrix}; \\ \dfrac{d^2y}{dt^2} = \dfrac{1}{m} \cdot \begin{pmatrix} F_y - N_2 \cdot \cos\varphi - F_2 \cdot \sin\varphi + .. \\ //+ N_3 \cdot \sin\varphi \mp F_3 \cdot \cos\varphi \end{pmatrix}; \\ \dfrac{d^2\varphi}{dt^2} = \dfrac{12}{m \cdot c^2} \begin{pmatrix} N_2 \cdot l \cdot \sin\beta + .. \\ ..+ F_2 \cdot 0{,}5 \cdot c \cdot \cos\gamma + .. \\ ..+ N_3 \cdot l_{0'K} \pm F_3 \cdot 0{,}5 \cdot c \cdot \sin\gamma - .. \\ ..- M_0 \end{pmatrix}, \end{cases} \qquad (7)$$

Equations (7) is used for the decision of system of equations :

$$\sin\varphi \cdot \begin{pmatrix} y - y_k - 0{,}5 \cdot c \cdot \cos\gamma \cdot \sin\varphi + .. \\ .. + 0{,}5 \cdot c \cdot \sin\gamma \cdot \cos\varphi \end{pmatrix} = V_ш \cdot t;$$

$$y - y_y + 0{,}5 \cdot c \cdot \sin\gamma \cdot \cos\varphi - .. \qquad (8)$$

$$.._\left(x - x_y - 0{,}5 \cdot c \cdot \sin\gamma \cdot \sin\varphi\right) \cdot tg\varphi = 0,$$

also we will accept the following assumptions: initial contact of a pusher and load is shock-free; traverse speed of a pusher is a constant $V_ш=const;$ the direction of movement of a pusher is perpendicular to a velocity vector of the bearing plane.

The accepted assumptions simplify the solution of the task a little, along with it for full taking note of external factors pertinently to consider the possible direction of action of a pusher both under other angles and in case of variable speed of movement of a working organ of a pusher.

For beforehand accepted basic data and assumptions it is executed numerical calculations of system of equations (7). Graphic interpretation of results of calculation is given on a Fig. 4.

Results of numerical calculations of the mathematical models describing movement of a load in mechanisms of orientation, confirm a hypothesis of opportunity effectively to intensify operation of orientation of tare loads on the bearing plane of the pipeline a packet of the creating machine due to the correct selection of motion speeds of a working organ of a pusher movements of a working organ of a pusher and choice of its rational provision of rather lateral surface of a load.

In the modern packets the creating machines providing high performance of automated product lines, to orientation of loads widely apply mechanical devices of capture.

In case of use of such mechanisms, orientation can be carried out with a load lift-off from the bearing plane and without lift-off apply mechanical devices of capture.

For high-quality orientation of a load it is important to justify scientifically a choice of drives and to provide rational parameters of movement of working organs of the mechanism of orientation.

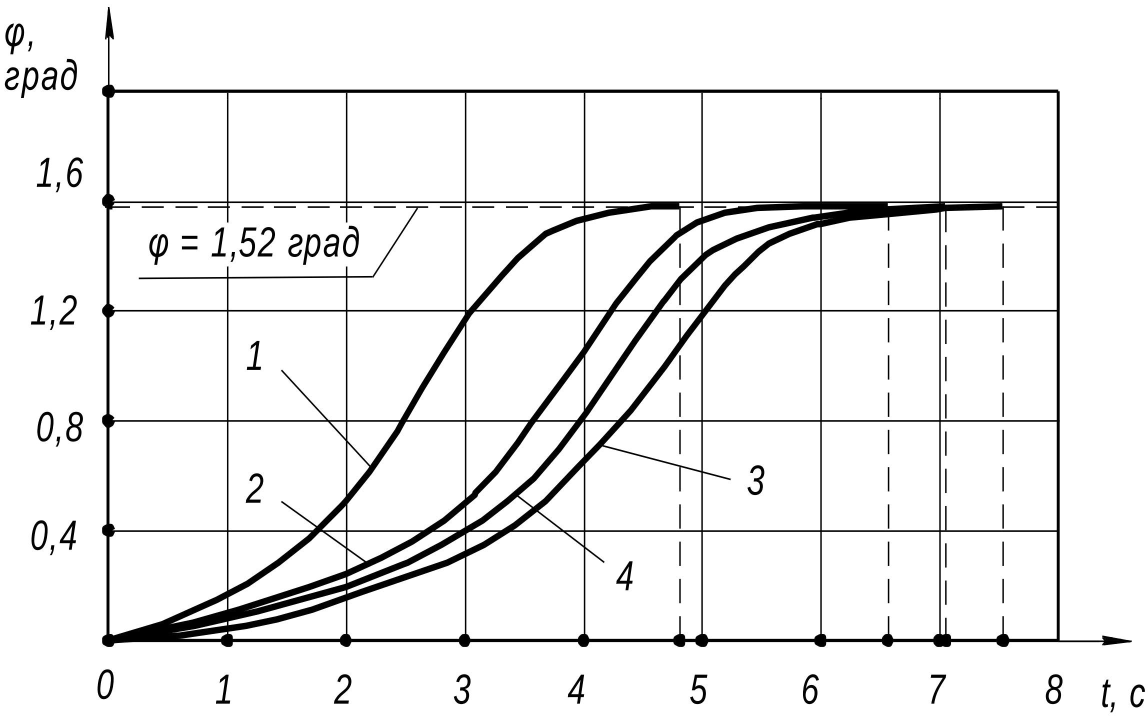

Fig. 4. The diagram of change of angular coordinate of a load during its turn an immovable emphasis and a pusher on the bearing plane:
1- $V_ш$ = 0,1 м/с; l_{0k} = 0,05 м; *2- $V_ш$ = 0,1 м/с; l_{0k} = 0,13 м;*
3- without pusher; *4- $V_ш$ = 0,3 м/с; l_{0k} = 0,05 м*

Mechanisms of orientation of the first look are widely applied in different functional groups as packages, and other technological machines.

Therefore the technique of determination of rational force, kinematic and geometrical parameters of these mechanisms are developed rather fully. Slightly more difficult with scientific reasons for parameters of movement of loads in mechanisms of orientation of the second look.

The main complexity of calculations need to consider the moment of frictional forces of a reference surface in case of load deployment round center of masses. On Fig. 5 the estimated diagram of the mechanism of orientation with captures by working organs is provided.

The drive and the carriage are a part of such mechanism of orientation for horizontal relocation of elements of capture; the drive provides load deployment on the given angle; the drive providing a clip of elements of capture to a load.

In a case when the turn of a load is carried out on the bearing plane of the conveyor, the necessary effort of its clip can be determined by working organs by expression:

$$N_1 = k_1 \cdot \frac{m \cdot g \cdot f_2}{2 f_1}, \qquad (9)$$

where k_1 – the dimensionless coefficient considering non-uniformity of a clip of working organs to a load during its movement; m – load mass; f_1 – sliding friction coefficient of a reference surface of a load on the bearing plane; f_2 – load sliding friction coefficient on clamping working organs.

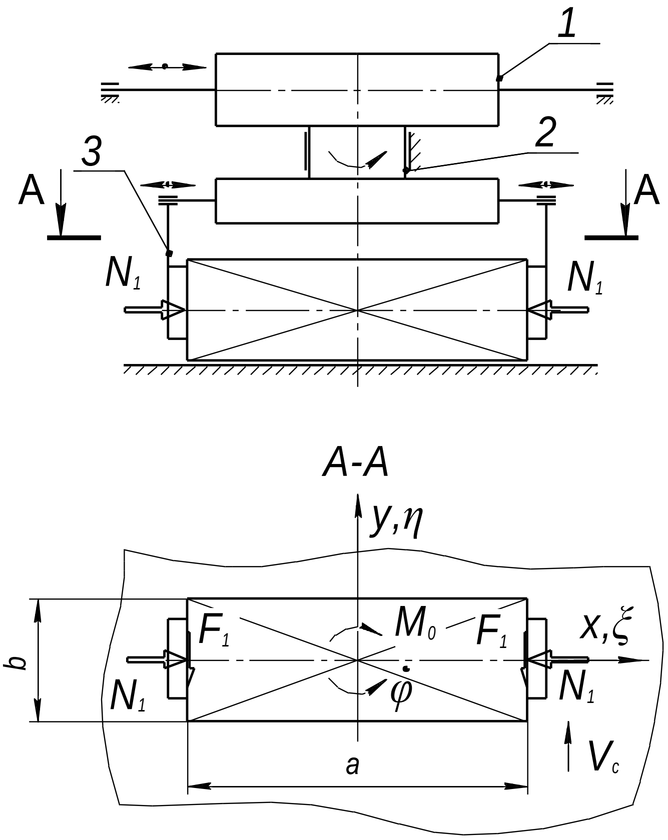

Fig. 5. The orientation mechanism with captures:
1 − the carriage for horizontal relocation of the mechanism of orientation;
2 − the drive of a turn of elements of capture with a load;
3 − capture elements.

Duration of a kinematic cycle of operation of orientation is defined as the amount of dlitelnost of each stage of movement of working organs of the mechanism of orientation:

$$T_k = t_n + t_3 + t_o + t_{x.з.} + t_{x.n}, \qquad (10)$$

where t_n − duration of relocation approximate carts in an orientation zone; t_3 – action of capture process of load; t_o − duration of capture of a load; $t_{x.з.}$ − duration of leadout of fascinating elements in home position; $t_{x.n}$ – duration of relocation horizontal carts in home position.

Depending on construction of the mechanism of orientation the structure of a formula (10) can be a bit different. Along with it a mandatory component of a kinematic cycle is orientation duration.

In a general view movement of a load and working organs in case of orientation can be written:

$$\frac{d^2\varphi}{dt^2} = \frac{1}{I_{np}}\left(T - M_0\right), \qquad (11)$$

where I_{np} – the given inertia moment of the bodies rotating together with a load; T – torsional moment on vertical to a shaft of the mechanism of orientation; M_0 – the moment of frictional forces of a reference surface of a load on the bearing plane of the conveyor in case of its deployment of rather geometrical center.

The moment of frictional forces of rather geometrical center of a load is determined by a formula.

$$M_0 = \int_{-b/2}^{b/2}\int_{-a/2}^{a/2} f_1 \cdot q(x,y)\sqrt{x^2+y^2}\,dx\ dy \qquad (12)$$

In case of uniform distribution of pressure on a reference surface the formula (12) will have an appearance:

$$M_0 = \frac{m \cdot g}{a \cdot b} \cdot f_1 \int_{-b/2}^{b/2}\int_{-a/2}^{a/2} \sqrt{x^2+y^2}\,dx\ dy. \qquad (13)$$

In case of constants of values I_{np}, T, M_0 and in case of basic data $t_n = 0$; $\varphi_n = 0$; $\frac{d\varphi}{dt} = 0$; $\varphi_\kappa = \pi / 2$ we will receive:

$$\frac{d\varphi}{dt} = \frac{1}{I_{np}}\left(T - M_0\right) \cdot t; \qquad (14)$$

$$\varphi = \frac{1}{I_{np}}\left(T - M_0\right) \cdot \frac{t^2}{2}; \qquad (15)$$

Then duration of orientation can be determined from expression:

$$t_\kappa = \sqrt{\frac{\pi \cdot I_{np}}{T - M_0}}. \qquad (16)$$

Similar design of the mechanism of orientation of this kind effectively apply to relocation of tare loads from one line item in another. The carriage of horizontal relocation and gripping elements is a part of such mechanism (Fig. 6). In certain cases mechanism construction, is given on Fig. 6, is the universal and can execute operations of a turn of a load on 90º and its relocation in other line item.

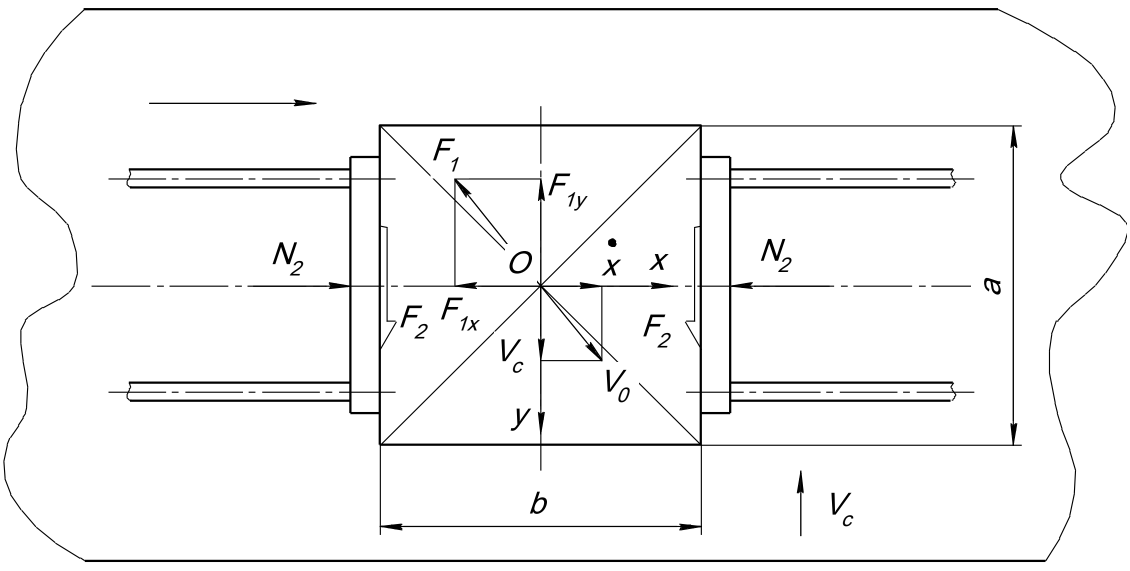

Fig. 6. The mechanism of relocation of a tare load from a line item on a line item

Clamping forces of a load can be defined from expression:

$$N_2 = \frac{m \cdot g \cdot f_1}{2 \cdot f_2} \cdot k_1 \cdot \frac{\dot{x}}{\sqrt{\dot{x}^2 + V_c^2}} \qquad (17)$$

where $\dot{x}$ – traverse speed of a load in the direction of an axis OX; k_1 – the coefficient considering non-uniformity of effort of a clip of capturing of an element to a lateral surface of a load.

Having accepted a driving force of relocation of a load a constant of its motion equation it is possible to define having solved a non-linear differential equation:

$$\frac{d^2x}{dt^2} = \frac{1}{m_{пр}} \cdot \left(P_{руш} - \frac{m \cdot g \cdot f_1 \cdot V_c}{\sqrt{\dot{x}^2 + V_c^2}} \right). \qquad (18)$$

In a case when the drive of the horizontal carriage is executed on the basis of the electric drive, its estimated power can be determined:

$$N_{дв} = m_{пр} \cdot \left(\frac{d^2x}{dt^2} + \frac{g \cdot f_1 \cdot V_c}{\sqrt{\dot{x}^2 + V_c^2}} \right) \cdot \frac{\dot{x}}{\eta_0}, \qquad (19)$$

where $m_{пр}$ – the specified mass of mobile elements of the mechanism of orientation of a load;

η_0 – performance coefficient of the drive of the carriage of horizontal relocation

IV. Conclusions

On the basis of the analysis of parameters influencing kinematics of movement of tare loads in orientation mechanisms the paketoformuyuchikh of machines, the following ways of intensification of operation of orientation are set:

Redistributions of pressure and change of a field of the relative speed of a reference surface of a load in case of its contact with the bearing plane of the pipeline;

Application of combined working organs of the mechanism of orientation, for example - a fixed emphasis, a pusher;

Application of the active working organs of the mechanism of orientation, for example - gripping elements.

Scientific reasons for kinematic and force parameters of constructional executions of mechanisms of orientation and synthesis and the analysis of cycles of operation give the chance to provide the given or highest productivity the paketoformuyuchikh of machines.

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