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Segregation of the bulk cargo on a belt conveyor under the vibro-pulse impact

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Abstract. The dynamics of interaction of the large lumps of the bulk cargo with a conveyor belt while passing through roller supports of the conveyor linear sections is often a cause of damage on the conveyor belt. In order to reduce the negative impact it is proposed to isolate the conveyor belt surface from the large lumps by filling small fractions of the bulk cargo by means of adding a shock device to the conveyor structure that causes increased segregation of the bulk cargo. A mathematical model of the segregation of the bulk cargo located on the conveyor belt and in zone of impact of the shock pulses has been developed. The model considers a change in the rotation direction of the large lump when applying shock pulses to the characteristic points of the lump lower face. Herewith it takes into consideration weakening of the shock pulse by a layer of the bulk cargo small fractions. The presented model has received experimental confirmation. Analytically and experimentally the height of filling of the bulk cargo small fractions under a large lump when passing the vibrating impact device located on the conveyor belt has been determined.

Introduction

The material segregation occurs when a cargo is moved by different models of transport [1−10]. Transportation of the bulk cargo by belt conveyors is no exception to this rule. In the process of the bulk cargo transportation by the belt conveyor, there is a segregation of particles by size, herewith the large lumps of the bulk cargo are tuned out above the small pieces [11]. But, as practice shows, the formation of the filling under the large lump occurs during some time, and the cargo manages to travel a sufficiently long distance. The segregation of the material by size can have a positive influence on the dynamics of interaction of the large lumps bulk cargo with the conveyor belt when passing roller supports of the linear sections. Since in this case, when the large lump meets with the roller support it affects the belt throughout a layer of the formed under it filling. Should the large lump is directly on the belt surface, then at meeting with the roller support, the lump may cause minor damage to the belt, but when further passing through the roller support, the

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damage adds up and becomes significant, fatigue stresses may occur on the belt even prior to formation of the sufficient height to smooth the impact of the filling [12]. In order to speed up filling formation from the small fractions of the bulk cargo, it is proposed to install a device under the conveyor belt that transmits vibration shock pulses to the bulk cargo after a certain period of time in the immediate vicinity of the loading site. An example of a device [13] for generating vibration shock pulses is shown in Fig. 1. The shock mechanism consists of a direct-current (DC) motor 1. Through the V-belt transmission 2 engine is connected to a working shaft 3. Two disks 4 are fixed on the shaft, on which four pins are hinged 6. A pin has a slot in its upper part in which roller axis is fixed 5. The design of the roller 5 is similar to a standard one of the conveyor linear part, but only with a reduced diameter of 51mm. The availability of the spring connection 8, which is performed in a form of the spiral cylindrical or plate spring, allows the rollers to return to their original position faster after contact with

Fig. 1. Pilot unit to segregate bulk cargo by size on the conveyor belt

the belt and creates a minor vibration. As a result of pulse propagation along the belt, the large lump, being at a certain distance from the device, starts to absorb the shock pulses, but of a much smaller amplitude than in the immediate vicinity of it. As a result, there is a rise of the lump together with the surrounding small fractions of the bulk cargo, but with different lifting and lowering velocity. A similar process occurs after the lump leaves the impact device. When the lump passes the device along its lower face (or through a layer of the formed filling under it), a certain number of hits will be applied, depending on the belt velocity, frequency of the shock pulses and the large lump length, since lumps are usually placed on the belt with the long side along it when loading on the conveyor.

Mathematical modeling

Developing a mathematical model of the bulk cargo segregation by size, the following assumptions are made:

- coefficient of filling of the conveyor belt cross-section with the small-pieces bulk cargo containing a large lump – 100%;
- the large lump is in the medium of the small-pieces bulk cargo, to which the laws of granular material is applied;
- the large lump has a shape of a parallelepiped with the ratio of length *a*, width *c*, and height *b* to the lump length $a/a : c/a : b/a = 1 : 0{,}67 : 0.43$;
- the large lump surrounds a sufficient amount of the "grainy" fraction of the bulk cargo;

- at a small height of the large lump lifting, the fractions of 0–6mm size penetrate from all sides into the gaps between it and the belt;
- at a low fraction content of 0 - 6 mm of the transported cargo under the lump lower face along its entire perimeter, a filling is formed with the placement of the particles at the angle of the natural slope when moving with shaking (also compaction of the filling is taking into account). In the central part under the lump, there may be a space free of small fractions, but since the impact extends over the entire width of the lump, so after a hit applied by the device, a choice of the gap between the lump and tape is neglected. The shock pulse is transmitted to the lump through the small fractions taking into account the attenuation.

The differential equations of the solid body HBC rotation will be:
for the phases 1-2

$$J\ddot{\alpha} = M_G(\alpha) + M_{Gvc}(\alpha) + \sum_{i=1}^{k} M_{Ftr\,i}(\alpha) + \sum_{i=1}^{n} M_{Fb_i}(\alpha) + M_{Fy}(\alpha, t), \tag{1}$$

for the phases 3–4

$$J\ddot{\alpha}' = M_{Gvc}(\alpha') + \sum_{i=1}^{k} M_{Ftr\,i}(\alpha') + \sum_{i=1}^{n} M_{Fb_i}(\alpha') + M_{Fy}(\alpha', t), \tag{2}$$

for the phases 5–7

$$J\ddot{\alpha}'' = M_G(\alpha'') + M_{Gvc}(\alpha'') + \sum_{i=1}^{k} M_{Ftr\,i}(\alpha'') + \sum_{i=1}^{n} M_{Fb_i}(\alpha'') + M_{Fy}(\alpha'', t), \tag{3}$$

where α, α', α'' – angle of lump rotation in the corresponding phases of the lump movement; t – current time; J – moment of the lump inertia; $M_G(\alpha)$, $M_G(\alpha')$, $M_G(\alpha'')$ – moment due to dead weight of the large lump; $M_{Gvc}(\alpha)$, $M_{Gvc}(\alpha')$, $M_{Gvc}(\alpha'')$ – moment created by overlying layer weight of the small-pieces bulk cargo acting on the large lump; $\sum_{i=1}^{k} M_{Ftr\,i}(\alpha)$, $\sum_{i=1}^{k} M_{Ftr\,i}(\alpha')$, $\sum_{i=1}^{k} M_{Ftr\,i}(\alpha'')$ – sum of moments from friction forces acting on all the large lump faces; $\sum_{i=1}^{n} M_{Fb_i}(\alpha)$, $\sum_{i=1}^{n} M_{Fb_i}(\alpha')$, $\sum_{i=1}^{n} M_{Fb_i}(\alpha'')$ – sum of moments acting on side faces of the large lump from pressure forces of the bulk material; $M_{Fy}(\alpha, t)$, $M_{Fy}(\alpha', t)$, $M_{Fy}(\alpha', t)$ – moment from impact force.

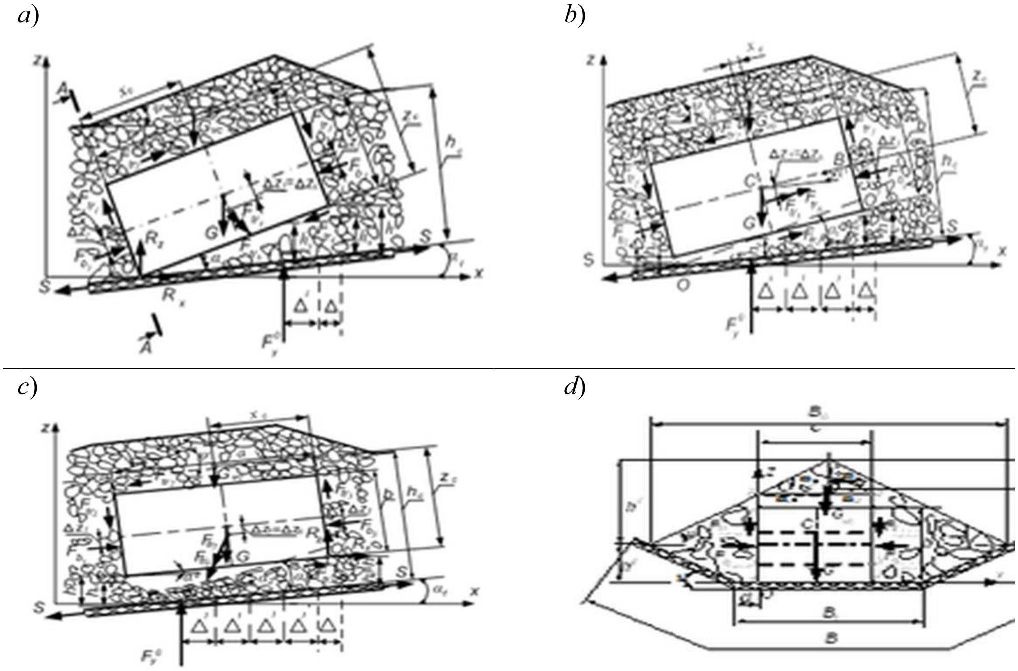


Fig. 2. Scheme of the forces action on a large lump: *a* – phase 1–2; *b* – phase 3–4; *c*– phase 5–7; *d* – cross-section A-A*

Moment from dead weight G of the large lump is defined as:

$$M_G = -G\cos(\alpha + \alpha_f(S,l_k)) \cdot \frac{a}{2} + G\sin(\alpha + \alpha_f(S,l_k)) \cdot \frac{b}{2}, \tag{4}$$

where α_f – angle of inclination of the belt in span between roller supports under influence of

* The upper "stroke" sign marks the corners of the parallelepiped face, opposite to those shown in Fig. 2, *a–в*.

the bulk cargo weight.

Moment from action of the overlying layer weight until the sum of angles $\alpha+\alpha_f$ reaches the angle of the natural slope ψ is defined as:

$$M_{Gvc}(\alpha) = (\Sigma\Omega_{vc} \cdot a \cdot \rho_0 \cdot g - (a+c)\cdot(h_c - b)^2 \cdot \rho_0 \cdot g \cdot m \cdot f) \times \\ \times (z_c \sin(\alpha \pm \alpha_f(S,l_k)) - x_c \cos(\alpha \pm \alpha_f(S,l_k))), \tag{5}$$

where $\Sigma\Omega_{vc}$ – total area of the overlying layer of the bulk cargo in cross-section A–A (Fig. 2, *d*); f – coefficient of internal friction; m – mobility coefficient; z_c, x_c – distance from center of gravity of the overlying layer of the bulk cargo to axis of rotation in two mutually perpendicular directions (Fig. 2, *a*); ρ_0 – bulk density of the transported granular material; h_c – height of the bulk cargo layer in the middle section. The moment from the overlying layer weight considering rolling of the load down when angle of the lump inclination relative to the horizontal is reached $\alpha+\alpha_f$ angle of the natural slope in motion ψ and taking into account the weight reduction of the overlying layer of the bulk cargo under influence of lateral pressure, which hold the layer along the lump perimeter, it is determined as:

$$M_{Gvc}(\alpha) = ((a\Sigma\Omega_{vc} - \frac{1}{4}a^2 \mathrm{tg}(\alpha + \alpha_f(S,l_k) - \psi)c)\rho_0 g - \\ -(a+c)(h_c - b)^2 \rho_0 g m f)(z_c \sin(\alpha + \alpha_f(S,l_k)) - x_c \cos(\alpha + \alpha_f(S,l_k))) \tag{6}$$

Total moment from friction forces:

$$\sum_{i=1}^{k} M_{F_{tri}} = -\mathrm{sign}(\dot{\alpha})\left(h_c - \frac{c\cdot \mathrm{tg}\psi}{2} - (B_0 - c)\frac{\mathrm{tg}\psi}{4} - \frac{B_0 - B_1}{4}\mathrm{tg}\lambda - a\sin\alpha\right)\cdot \rho_0 \cdot g \times$$
$$\times m\cdot a\cdot b\cdot f_1\cdot\sqrt{\left(\frac{a}{2}\right)^2 + \left(\frac{b}{3}\right)^2} - \mathrm{sign}(\dot{\alpha})\left(h_c - \frac{B_0\,\mathrm{tg}\psi}{4} - a\sin\alpha - \frac{b\cos\alpha}{2}\right)\cdot\rho_0\cdot g\times \tag{7}$$
$$\times(\sin^2\alpha + m\cos^2\alpha)c\cdot b\cdot a\cdot f_1 - \mathrm{sign}(\dot{\alpha})\Big((\sum\Omega_{vc}\cdot a - \frac{1}{4}a^2\mathrm{tg}(\alpha + \alpha_f(S,l_k) - \psi)c)\times$$
$$\times\rho_0 g - (a+c)(h_c - b)^2\rho_0 gmf\Big)\cos\big(\alpha + \alpha_f(S,l_k)\big)\cdot b\cdot f_1,$$

where ψ − angle of natural slope in motion with shaking; λ − angle of inclination of the side rollers; B_0 – width of the embankment in plan; B_1 – conveyor belt width, supported on central roller of a three-roller grooved roller support.

Depending on the movement nature, dry friction force changes its direction, so the function is used sign($\acute{\alpha}$).

For granular material with a free surface, the height of the material layer is calculated using an approximate method based on replacing the triangular cross-section with a rectangular one. The specified height of the material layer is put as the calculated height of the material layer. For example, the average reduced height of the material layer in order to determine the lateral pressure on the face 1–1^{I}–4^{I}–4 и 2–2^{I}–3^{I}–3 takes a form as follows:

$$h_{\text{пр}1-1^I-4^I-4} = h_c - \frac{B_0\mathrm{tg}\psi}{4} - \frac{b\cos\alpha}{2}; \tag{8}$$

$$h_{\text{пр}2-2^I-3^I-3} = h_c - \frac{B_0\mathrm{tg}\psi}{4} - a\sin\alpha - \frac{b\cos\alpha}{2}. \tag{9}$$

Total height of the filling is calculated (see Fig. 2) as:

$$h_c = h^I + h^{II}; \qquad h^I = \frac{B_0}{2}\mathrm{tg}\psi; \qquad h^{II} = \frac{B_0 - B_1}{2}\mathrm{tg}\lambda. \tag{10}$$

The point of application of the lateral pressure force is below the center of gravity the area of the lump face at a distance of $\Delta z = J/z\cdot S$, где J – inertia moment of the area S face relative to the corresponding axis; z – gravity center position of the lump face.

The expression to determine the bulk cargo moment of lateral pressure forces on a large lump at full load without consideration the moment from additional resistance to the face 2−2^{I}−3^{I}−3 (рис. 2) takes a form:

$$\sum_{i=1}^{n} M_{F_{bi}} = -a\sin\alpha\cdot\rho_0\cdot g(\sin^2\alpha + m\cos^2\alpha)\cdot c\cdot\frac{b^2}{6}. \tag{11}$$

For an ideal granular material mobility coefficient does not depend on the value of the normal pressure and for this material it is a constant value $m = 1 + 2f^2 - 2f\sqrt{1+f^2}$. The force from impact device is spent on the belt deformation and load, defined as $F_y(t,l,h_y) = F_0(t) - F_1(S,B_л) - F_2(t,h_y)$, where $F_0(t)$ – impact force developed by device; $F_1(S,B_л)$ – effort spent on the belt deformation; $F_2(t,h_y)$ – the force expended on the load deformation.

The force $F_2(t, h_у)$ decreases on value $F_{упр.деф.}$, proportional to the elastic deformations of the small-pieces layer cargo, which can be found as $F_{упр.деф.} = k \cdot h_у$, where k – coefficient of stiffness of elastic rheological body.

The internal viscous stresses also occur in the bulk cargo environment $F_{вяз.}$, proportional in general to the relative and absolute rate of strain:

$$F_{вяз.} = c\frac{d\alpha}{dt} + c^*\left(\frac{d\alpha}{dt} + \alpha(t)\right), \tag{12}$$

where c – viscosity coefficient of a viscous rheological body that reproduces resistances proportional to relative rate of strain of the medium; c^*– viscosity coefficient of a viscous rheological body that simulates resistances proportional to the absolute rate of strain of the medium; $\alpha(t)$ – law of lump movement.

Due to the complex movements of the small fractions in various directions during the movement of the large lump under impact, and the weakly expressed elastic-viscous properties of the loosened rock mass, its viscous properties are not accounted for in the mathematical model of interaction of the large lump with bulk cargo in the future. Thus, in work $F_{вяз.}$ could be neglected and accepted that the impact force is absorbed by the small fraction of the bulk cargo that falls under the lump by the amount of $k_п h_y$, where $k_п$ – coefficient that takes into account weakening of the impact force acting on the lump due to deformation of the bulk cargo; h_y – height from the belt to the lower edge of the lump at the point of the impact force application.

To determine coefficient $k_п$ experimental studies have been conducted. Depending on the fractional composition of the small-pieces cargo, coefficient $k_п$ could be $5 \cdot 10^3$–$17.5 \cdot 10^3$ H/m and in general can be defined by an empirical formula: $k_п = 0.0385 \cdot F_у^0 - 1.83$.

In general, the dependence of the amplitude of the shock pulse on distance of the lump from the impact device can be written as $F_л(l,t) = F_л^{\max} - k_l\, l(t)$, where k_l – coefficient of transmission of the shock pulse on the belt.

Coefficient of transmission of the shock pulse along the belt depending on the direction of rotation of the impact device can be $1.3 \cdot 10^3$–$4.5 \cdot 10^3$ H/m.

As a result of the lump movement on the conveyor belt at the point of application of the shock pulse is continuously shifted along the lump length, so the moment from the impact force instantaneous value when the first half of the lump passes in the direction of the impact device will be determined as:

$$M_{F_y}(\alpha,t) = F_у(t,l,h_y)\cos(\alpha + \alpha_f(S,l_k)) \cdot (a - \Delta - (n-1)(\Delta^I + TV)), \tag{13}$$

where l – distance from impact device to lump; h_y – height from conveyor belt to the lump lower edge at the point of impact force application; Δ – distance between first hit and the point O^I (см. рис.2, *a*); Δ^I – distance traveled by lump between hits; n – number of hits on lump; T – hit duration; V – conveyor belt velocity.

The impact force shoulder at rotating without point of support could be taken as $\Delta + n\Delta^I - a/2$, and at rotating relative to the point O^I, respectively, as $\Delta + n\Delta^I$.

After the lump center of gravity passes impact device when the impact pulse is applied to the second half of the lump during movement, the center of instantaneous speeds becomes the point of support P, what leads to a change in the direction of forces. Herewith, point P changes its position along the lump length depending on the velocity values at the point O and point O^I. Based on the accepted assumption the point P coincides with the lump center of gravity (point C). In the process of hitting the second half of the lump in the direction of movement the point O^{I} continues its movement.

If in the previous calculations the value $h_c + a\mathrm{tg}(\psi - \alpha_f)$ did not exceed the value $b\cos\alpha - a\sin\alpha$, then all the faces remain submerged in the bulk cargo layer.

For the phases 3–4 the moment of lateral pressure forces of the bulk cargo on the large lump will be determined as:

$$\sum_{i=1}^{n} M_{Fb_i}(\alpha') = a\sin\alpha \cdot \rho_0 \cdot g(\sin^2\alpha' + m\cos^2\alpha') \cdot c \cdot \frac{b^2}{3}, \tag{14}$$

where α' –angle of inclination of lump when impact pulses are applied to the second half of lump to the direction of movement.

The total moment from friction forces:

$$\begin{aligned}\sum_{i=1}^{k} M_{F_{tri}} = &-\mathrm{sign}(\dot\alpha')\left(h_c - \frac{c\cdot \mathrm{tg}\psi}{2} - (B_0 - c)\frac{\mathrm{tg}\psi}{4} - \frac{B_0 - B_1}{4}\mathrm{tg}\lambda - \cdot \right.\\ &\left.-\left(\sqrt{a^2+b^2}\sin(\alpha_k+\alpha_1) - \sqrt{a^2+b^2}\sin(\alpha_k-\alpha') - a\sin\alpha'\right)\right)\rho_0\cdot g\times\\ &\times m\cdot a\cdot\frac{b^2}{3}\cdot f_1 - \mathrm{sign}(\dot\alpha')\left[\left(2h_c - \frac{B_0\mathrm{tg}\psi}{4} - b\cos\alpha'\right) - \left(\sqrt{a^2+b^2}\sin(\alpha_k+\alpha_1) - \right.\right.\\ &\left.\left.-\sqrt{a^2+b^2}\sin(\alpha_k-\alpha') - a\sin\alpha'\right)\right]\rho_0\cdot g\cdot(\sin^2\alpha' + m\cos^2\alpha')c\cdot b\cdot\frac{a}{2}\cdot f_1 -\\ &-\mathrm{sign}(\dot\alpha')\left(\left(\sum\Omega_{vc}\cdot a - \frac{1}{4}a^2\mathrm{tg}(\alpha_1 + \alpha_f(S,l_k) - \psi)c\right)\rho_0 g\right)\cos(\alpha' + \alpha_f(S,l_k))\cdot\frac{b}{2}\cdot f_1.\end{aligned} \tag{15}$$

where α_1 –angle of lump at the end of rotation relative to the point O; α_k – angle $O^{I}CB$ (Fig. 2, b).

The moment from weight of the overlying layer of the bulk cargo is determined as:

$$M_{Gvc}(\alpha) = G_{vc}\sin(\alpha \pm \alpha_f(S,l_k))\cdot z_c + G_{vc}\cos(\alpha \pm \alpha_f(S,l_k))\cdot x_c. \tag{16}$$

At the lump rotation relative to the point O^{I} moment of lateral pressure forces of the bulk cargo on the large lump will take a form as:

$$\sum_{i=1}^{n} M_{Fb_i}(\alpha'') = a\sin(|\alpha''|)\cdot\rho_0 g(\sin^2\alpha'' + m\cos^2\alpha'')\cdot c\cdot\frac{b^2}{3}. \tag{17}$$

The total moment from friction forces:

$$\begin{aligned}\sum_{i=1}^{k} M_{F_{tri}} = &-\mathrm{sign}(\dot\alpha'')\left(h_c - \frac{c\cdot\mathrm{tg}\psi}{2} - (B_0 - c)\frac{\mathrm{tg}\psi}{4} - \frac{B_0 - B_1}{4}\mathrm{tg}\lambda - \cdot\right.\\ &\left.-\left(\sqrt{a^2+b^2}\sin(\alpha_k+\alpha_1) - \sqrt{a^2+b^2}\sin(\alpha_k - |\alpha_2|) - a\sin(|\alpha''|)\right)\right)\rho_0\cdot g\times\\ &\times m\cdot a\cdot b\cdot f_1\cdot\sqrt{\left(\frac{a}{2}\right)^2 + \left(\frac{b}{3}\right)^2} - \mathrm{sign}(\dot\alpha'')\left[\left(h_c - \frac{B_0\mathrm{tg}\psi}{4} - \frac{b\cos\alpha''}{2}\right) - \right.\\ &\left.-\left(\sqrt{\left(\frac{a}{2}\right)^2+\left(\frac{b}{2}\right)^2}\sin(\alpha_k+\alpha_1) - \sqrt{\left(\frac{a}{2}\right)^2+\left(\frac{b}{2}\right)^2}\sin(\alpha_k - |\alpha_2|)\right)\right]\rho_0\cdot g\times\\ &\times(\sin^2\alpha'' + m\cos^2\alpha'')c\cdot b\cdot a\cdot f_1 - \mathrm{sign}(\dot\alpha'')\times\\ &\times\left(\left(\sum\Omega_{vc}\cdot a - \frac{1}{4}a^2\mathrm{tg}(\alpha_1+\alpha_f(S,l_k) - \psi)c\right)\rho_0 g\right)\cos(\alpha' + \alpha_f(S,l_k))\cdot b\cdot f_1.\end{aligned} \tag{18}$$

where α_2 –angle of lump at the end of rotation relative to the point *C*.

The moment from dead weight of the large lump is defined as:

$$M_G(\alpha'') = -G\cos(\alpha'' \pm \alpha_f(S,l_k)) \cdot \frac{a}{2} - G\sin(\alpha'' \pm \alpha_f(S,l_k)) \cdot \frac{b}{2} \cdot \tag{19}$$

The moment from weight of the overlying layer of the bulk cargo will take the following form:

$$M_{Gvc}(\alpha'') = -G_{vc}\sin(\alpha'' \pm \alpha_f(S,l_k)) \cdot z_c - G_{vc}\mathrm{coc}(\alpha'' \pm \alpha_f(S,l_k)) \cdot x_c \cdot \tag{20}$$

The equations (1-3) after substituting expressions (4-20) are solved by numerically improved Euler method. The calculation was performed utilizing the developed Delfi software. The initial conditions at $t = 0$ were set $\alpha_0 = 0$ and $\alpha_1 = 0$. The initial conditions at hitting the second half were defined as $\alpha^I{}_{i-1} = -\alpha_k$ и $\alpha^I{}_i = c_k \cdot \tau - \alpha_k$, where c_k – angular velocity; τ – time increment; *k* – number of iterations of the first movement phase.

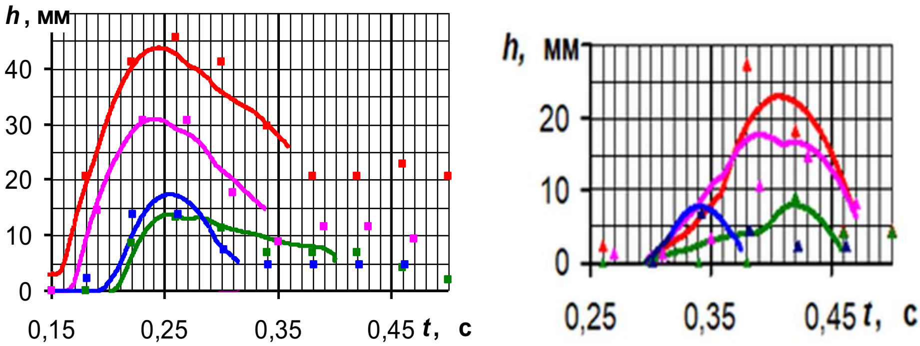
Results

The results of the mathematical and experimental modeling are shown in Fig. 3. Modeling the process, a simulator of a lump in a form of a parallelepiped with overall dimensions 300×105×129mm and density 1.5 t/m^3 was used. The belt velocity was 1.56 m/sec. In all cases, the first edge of the lump to the direction of movement approaches the impact device in 0.2 sec. Rate of rotation of the impact device varied from 165 to 500 min.$^{-1}$. The Fig. 3, *a* shows the movement of the first edge of the simulator in the course of movement of the large lump (point O^I).

The mass of small fractions that fall into the gap between the lump and the belt depends on the conveyor belt velocity and has a parabolic relationship of the following type: $m_\Pi = k_1 \cdot h^2 + k_2 \cdot h$, where k_1, k_2 – coefficients that depend on the conveyor belt velocity, determined experimentally, *h* – elevation of the point O^I.

Fig. 3, *b* shows the movement of the second edge to the direction of movement of the large lump (point *O*).

The rise height of the first rib in the direction of movement, depending on the shock pulses applied to the lump, was from 5 to 25 mm, the second rib in the direction of movement rose to a much lower height. Thus, the lump took an inclined position in the medium of the small-pieces cargo with a large rise of the front face. At the maximum rate of rotation of the impact device, the front face turned out to be isolated from the belt on 25mm height, and when passing the roller supports, the dynamics of interaction between the lump and the belt decreased by about 1.5 times.



a) *b*)

Fig. 3. Trajectory of the lump simulator: *a* – point O^{I}; *б* – point *O*; full lines show theoretical values of the rise height, and curly points show experimental values at the rate of rotation of the shaft of the impact device:
500 min^{-1}; 300 min^{-1}; 250 min^{-1}; 165 min^{-1}

The experimental data were obtained under laboratory conditions on a 1L80 conveyor with the installed impact device Fig.1. The simulator of the large lump in a form of a parallelepiped, as already noted herein, was placed with the long side on the belt and filled with small fractions of the bulk cargo. In order to detect the position of the lump in the medium of the bulk cargo during video shooting, led sensors were attached to its upper edges and on the upper lining of the conveyor belt.

a) *b*)

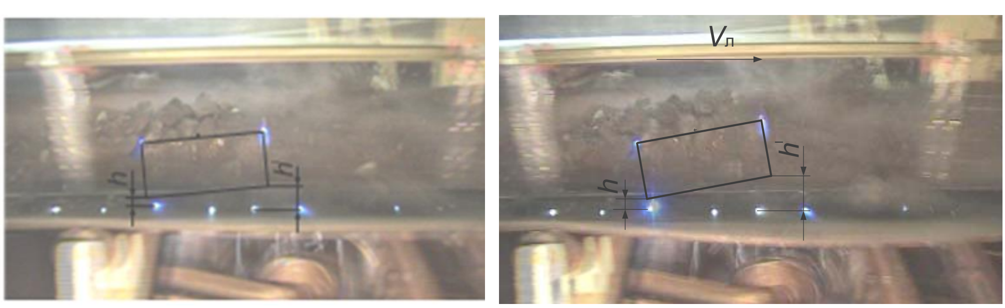


Fig. 4. Example of the experiment video recording storyboard at the rate of rotation of the impact device shaft 480 min^{-1} and the belt velocity $V_л$=1,6 м/c: *a* – previous frame; *b* – next frame in 0.04 sec.

Conclusions

1.The process of the large lump movement on the conveyor belt under the influence of the vibro-impact device should be considered in separate phases: hitting on the first half of the lump; hitting near the center of gravity until the contact of the first in the course of movement of the lower edge of the lump with the forming filling from the small-pieces cargo; the phase in which the sealing of the filling occurs; hitting on the second half of the

lump; the moment of contact of the second edge of the lower face with the forming filling, and the phase in which the sealing of the filling occurs under the second edge.
2.The developed model of the bulk cargo segregation on the conveyor belt allows you to determine the parameters of the shock pulse, at which the required under the condition of reducing dynamic loads on the linear rate of filling will be achieved.

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