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Theoretical Aspects Of The Displacement Of Corn Cobs In A Plant For Sorting With A Working Surface Of Variable Curvature.

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ABSTRACT

The article provides prerequisites and assumptions for the theoretical justification for the sorting of corn cobs and suggests a solution in the form of a working surface of varying curvature consisting of a descending and ascending surface. The conditions under which the sparing mode is created for reloading the cobs are determined, the dynamic parameters for moving the cobs along the descending and ascending surfaces and by the grapho-analytical method are determined by intervals of their values corresponding to the sparing regime. The obtained dependences take into account the physical and mechanical properties of corn cobs.

Keywords: sorting, corn cobs, sparing mode, working descending surface, working ascending surface.

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INTRODUCTION

Almost all lines for the processing of seed corn, designed for multi-tonal flows, operate on the same technology, differing in sets of machines and devices that leading world manufacturers develop under their own brands. But these lines are united by one common and characteristic feature - manual sorting is used to sort out the flow of cobs coming out of the cobblestones (leshchilnikov or haskerov). In general, the bulkhead is performed on belt conveyors (parallel or ring) [3, 4, 5].

Thus, the means for their direct processing continue to remain weak links in post-harvest seed maize processing technologies. If modern serial cleaning devices, both combines and fixed installations, did indeed ensure compliance with the initial requirements, then the re-purification and re-cleaning operation would not be included in the processing technology. In addition, cob purifiers designed for multitone flows of processed material, unlike threshing separating machines of combine harvesters, can not be converted for lots of hundreds of kilograms. Therefore, technical support in the latter case is developed and completed individually.

The need to develop fundamentally new technical solutions for the processes of sorting cobs of corn, which are theoretically grounded and based on a deeper investigation of the biometric and physico-mechanical properties of the plant material being processed, is obvious and relevant. Therefore, we proposed an installation for sorting cobs with a working surface of variable curvature [1, 2].

MATERIAL AND METHODS

The transition from solutions in the form of bulkhead tables or conveyors with the use of manual labor to the structures providing mechanization and automation of the process requires the solution of the following tasks: mandatory orientation of the cobs before entering them for sorting; moving in sparing mode over working surfaces.

When solving questions of interaction between working bodies and cobs, the classical positions of theoretical mechanics, analytical geometry and mathematical analysis were applied.

The theoretical solution of the problem of the process of moving the cobs along the working surfaces of the separator with the analysis of the obtained regularities and their graphic interpretation was carried out in the following sequence: 1) dynamic and linear parameters were determined at which a safe reboot of the cob from the conveyor-dispenser onto the inclined plane takes place; 2) the conditions for rolling the cobs along an inclined surface are investigated; 3) dynamic and linear parameters are determined, under which rolling occurs without sliding on the descending surface of the separator; 4) the dynamic and linear parameters are determined, under which rolling occurs without sliding on the ascending surface of the separator.

As assumptions were adopted: the cylindrical shape of the corn cobs, as in modern hybrids the size of the conicity is less than one degree on the reference surface - the surface to which the cob touches working planes; The equations of motion are compiled for the center of gravity of the cobs.

RESULTS AND DISCUSSION

Theoretical studies were carried out on the basis of the works of V.P. Goryachkin, V.G. Ivashkov, V.S. Kravchenko, V.S. Kurasov, I.A. Petunina, E.V. Truflyak and other authors.

A safe reboot of the cob from the dispenser to the inclined plane is possible in the absence of impact loads.

Considered a situation where when rebounding the cobs, an oblique impact occurs on the surface and they fly a certain distance (Figure 1). And then a second touch occurs. Moving them along an inclined surface occurs if the recovery coefficients do not exceed the values at which the cobs break away from the guide.

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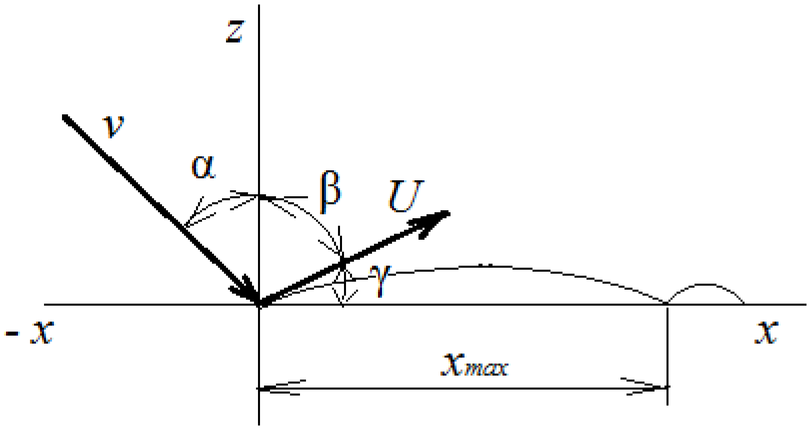

Figure 1: Scheme of the cob impact on the inclined surface

From the theory of impact it is known that the reflection modulus at the first touch can be expressed as

$$U = v \cdot \sqrt{\sin^2 \alpha + k^2 \cdot \cos^2 \alpha}\,, \qquad (1)$$

where U – speed of reflected cob, m/s; v – cob impact speed at the moment of touch, m/s; α – angle of incidence, degrees; k – coefficient of recovery.

Having obtained from (1) the equation of motion of the center of gravity of the cob in parametric form and transforming it, we determined:

vertical movement

$$z = \frac{k}{tg\alpha} \cdot x - \frac{gx^2}{2v^2 \sin\alpha \left(tg^2\alpha + k^2\right)}; \qquad (2)$$

horizontal movement

$$x_{\max} = \frac{v^2}{g} \cdot k \cdot \sin 2\alpha \left(tg^2\alpha + k^2\right). \qquad (3)$$

An analysis of the obtained law of motion of the cob is represented by a graph for the conditions k = 0,3; α = π/4; v_1 = 0,3 m/s; v_2 = 0,4 m/s; x = 0 – 0,007 m.

At impact velocities of 0.3 and 0.4 m/s, the reflected cob rises above the collision plane by 0.0042 m and 0.00055 m.

The values of the range of displacement in the velocity interval 0.3-0.5 m/s are calculated in mm. With the increase in speed and angle of inclination, the range is sharply increased.

Thus, speed intervals of 0.3-0.5 m/s and tilt angles of 30-45° are suitable for starting conditions of cob-motion.

Speed intervals for the gentle mode are highlighted in the picture with vertical lines.

The working surface for sorting the cobs is proposed in the form of a hill of variable curvature, which includes the accelerating section and the deceleration area (Figure 3).

The movement of the cob over such a surface can be represented as a plane-parallel one (Fig. 4 a, b).

The motion of the cob can be described by a system of three differential equations

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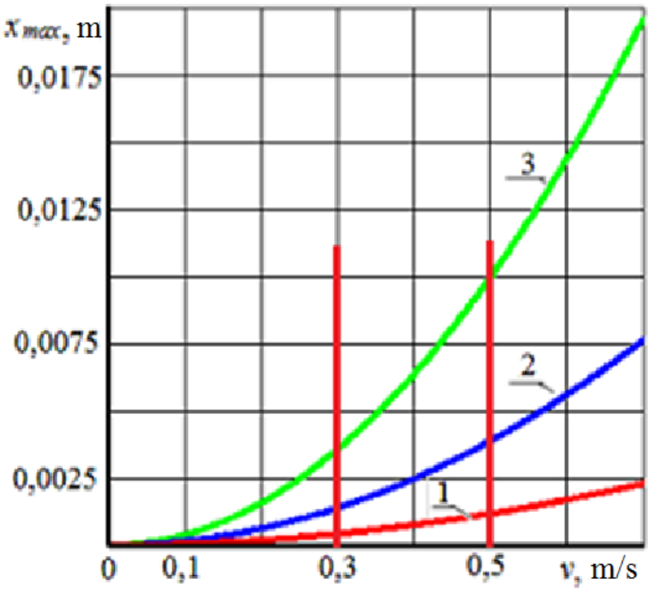
$$m\frac{d^2x}{dt^2}=\sum F_x, \quad (4)$$

$$m\frac{d^2y}{dt^2}=\sum F_y, \quad (5)$$

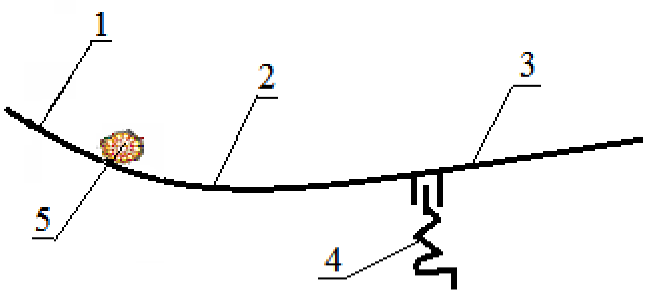
$$J_z\frac{d^2\varphi}{dt^2}=\sum m(F) \quad (6)$$

where t – time, s; ϕ – angle of rotation of the cob, degrees; J_z – moment of inertia about the axis, kg·m^2; ΣF_x – the sum of the projections of forces on the axis x, H; ΣF_y – the sum of the projections of forces on the axis y, H; $\Sigma(F)$ – sum of forces applied to a rotating cob, H; ω – rotational speed of the cob in rolling along an inclined plane, 1/s.



1 – α_1 = 30°; 2 – α_2 = 45°; 3 – α_3 = 60°

Figure 2: Analytical dependencies for moving corn cobs horizontally x from the speed v at different angles of incidence



1 - descending surface, 2 - transition area, 3 - ascending plane, 4 - mechanism for adjusting the inclination of the plane, 5 - cob

Figure 3: Slot scheme with variable curvature of the surface

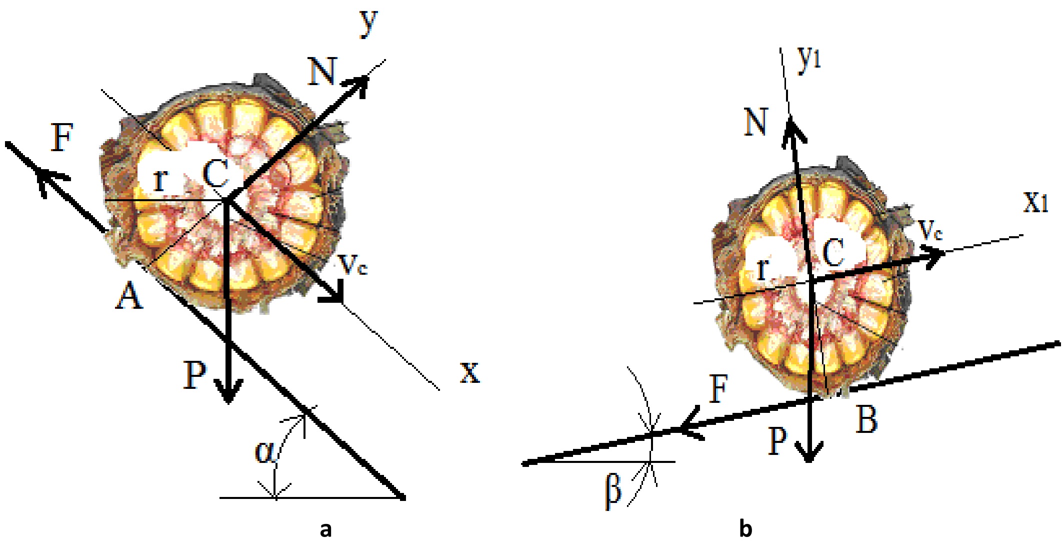
An investigation of the nature of the displacement of cobs over a surface with variable geometry consists in determining: the kinetic energy for rolling cobs with different physico-mechanical characteristics along a descending surface; the path on which this energy will be consumed while moving along the ascending surface, and the movement along the ascending surface will cease.

Differential equations of motion of the cob on a descending surface

$$m\frac{d^2x}{dt^2} = mg\sin\alpha - F, \quad (7)$$

$$m\frac{d^2y}{dt^2} = mg\cos\alpha - N, \quad (8)$$

$$J\frac{d\omega}{dt} = Fr. \quad (9)$$



a - descending surface; b - ascending surface;
m - cob weight, kg; P - attractive force of the cob, H; r - cob radius, m; F - friction force, N; v_c - cob rolling speed, m/s; α - angle of inclination of the descending surface, deg; β - angle of inclination of the ascending surface, deg; x - axis parallel to the descending plane; y - axis of coordinates perpendicular to the descending plane; z - axis of coordinates perpendicular to the xoy plane; x_1 - axis of coordinates parallel to the ascending plane; y_1 - axis of coordinates perpendicular to the ascending plane; z_1 - axis of coordinates perpendicular to the surface x_1oy_1; β is the rising angle of the ascending surface, deg; C - center of gravity of the cob

Figure 4: Distribution of forces in rolling the corn cob

Solving equations (7-9), we determined:
cob speed at the end of the descending surface

$$v_c = v_0 + gt\sin\alpha, \quad (10)$$

where v_0 – initial cob speed, m/s;
way *s*, which will pass the cob

$$s = v_0 t + \frac{gt^2}{2}\sin\alpha \quad (11)$$

We analyzed the theoretical dependences of the speed and path traveled by the cob for different modes (Figures 5, 6).

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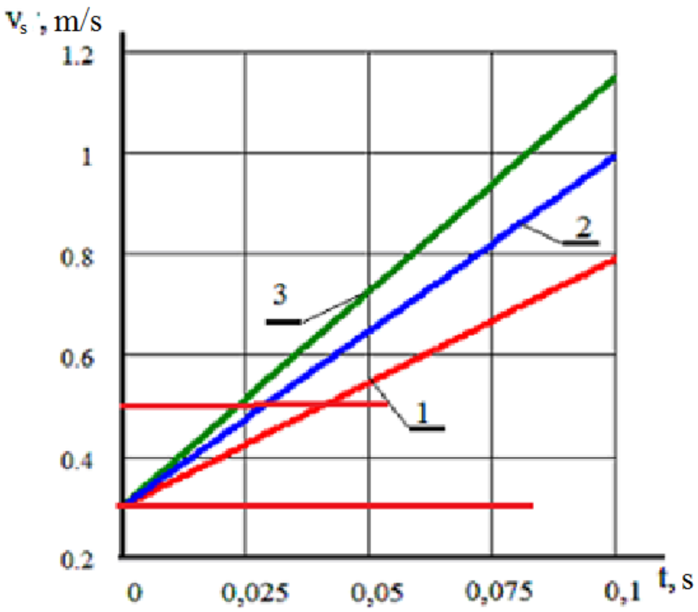
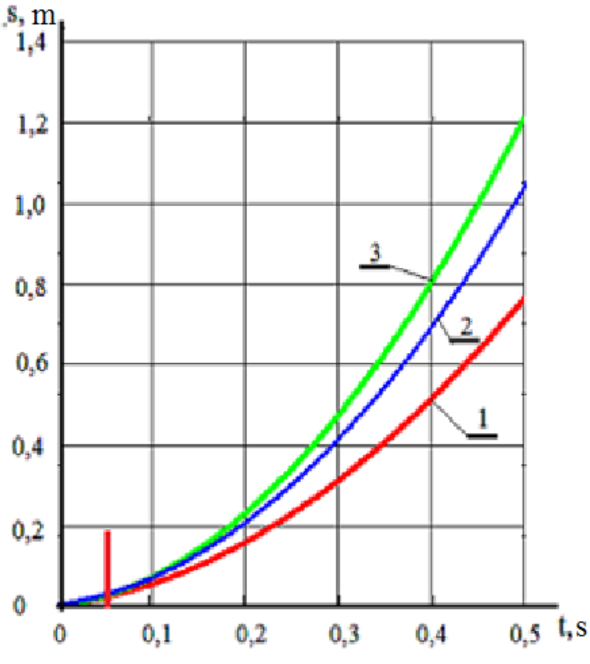


1 – α = 30°; 2 – α = 45°; 3 – α = 60°

Figure 5: Cob speed on the descending surface as a function of travel time



1 – α = 30°′; 2 – α = 45°; 3– α = 60°

Figure 6: The path passed by the cob, depending on the time of motion at different angles of inclination of the surface

On the graphs, zones of values of speed and time of hire of the cob are marked, corresponding to the sparing regime.

The moment of inertia of the cob has been determined as

$$J_c = \frac{mr^2}{2}. \quad (12)$$

The path that the cob passes after touching the surface of the descending inclined plane depends on the initial speed and the time of its movement. Then the kinetic energy of the cob of the rolling cube downward along the descending surface is equal to:

$$T = \frac{1}{2}\left(mv^2 + J\omega^2\right) = \frac{1}{2}m\left(v^2 + \frac{1}{2}r^2\omega^2\right) = \frac{3}{4}mv^2. \qquad (13)$$

The motion of the cob on an ascending surface is described by differential equations

$$m\frac{d^2x_1}{dt^2} = -mg\sin\beta, \qquad (14)$$

$$m\frac{d^2y_1}{dt^2} = -mg\cos\beta. \qquad (15)$$

$$J\frac{d\omega}{dt} = -N_1 f_k. \qquad (16)$$

Solving equations (14-16), we determined:
cob speed on an ascending surface

$$v_c = v_0 - g\cdot t\cdot\sin\beta, \qquad (17)$$

Time of rolling the cob to the full stop on the ascending surface

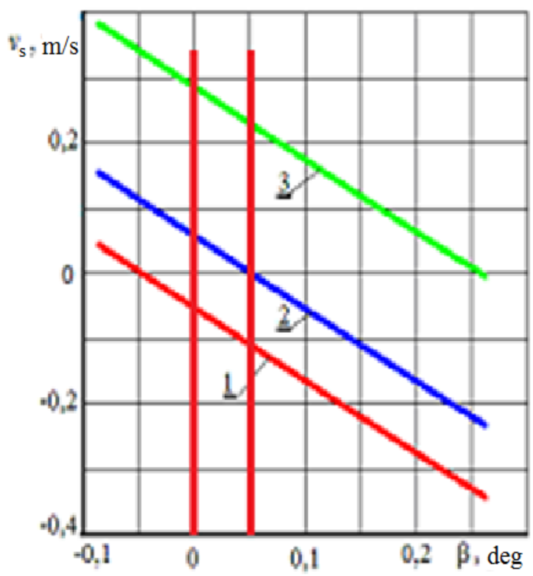
$$t = \frac{v_0}{g\cdot\sin(\beta)}, \qquad (18)$$

way the cob passes to the full stop

$$x_1 = v_0 t_1 - \frac{gt^2}{2}\sin\beta, \qquad (19)$$

angular velocity of the cob

$$\omega_n = \omega_0 - \frac{g\cdot t\cdot f_k}{r^2}\sin\beta. \qquad (20)$$



1 – *v* = 0,1 m/s; 2 – *v* = 0,3 m/s; 3 – *v* = 0,5 m/s

Figure 7: Analytical dependencies of the cob speed on the ascending surface on the angle of inclination of the surface β

From the graphs of the analytical dependences of the cob speed on the ascending surface from the angle of inclination of the surface, it can be determined that the deceleration begins at an inclination of 7 degrees.

The total kinetic energy of the cob will be equal to the work of all forces.

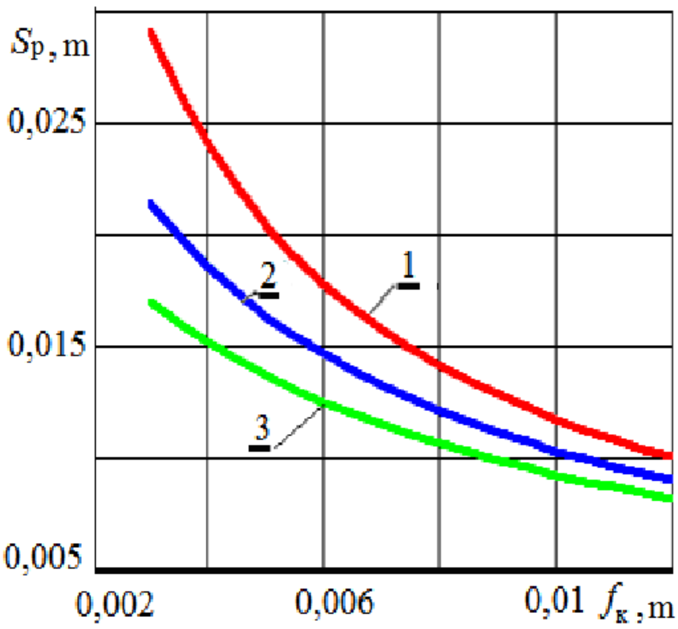
The kinetic energy of the cob of a rolling on an ascending surface at full stop will be zero. Then from condition

$$0-\frac{3}{4}mv_c^2=-mgs\sin\beta-N_1 f_k\frac{s}{r}=-g\left(\sin\beta+\frac{f_k}{r}\cos\beta\right)s\cdot$$

you can determine the value of the path to a complete stop of the cob

$$s_n=\frac{3v_c^2}{4g\left(\sin\beta+\dfrac{f_k}{r}\cos\beta\right)}. \qquad (21)$$

To analyze the expression (21) taking into account the physicomechanical properties of the cobs, graphs were constructed for different values of the rolling friction coefficients f_k and the slope angles of the ascending surface β (Figure 8).



1 – β = 5°; 2 – β = 10°; 3 – β =15°

Figure 8: Analytical dependences of the rolling range of the cob from the friction coefficient f_k and the inclination angle β of the ascending surface

As a result of the studies carried out by the method of graphical interpretation, it was established that a change in the surface roughness leads to a change in the rolling friction coefficients. This, in turn, leads to a change in the path that the cob passes along the ascending surface. An increase in the angle of inclination of the surface leads to a decrease in the cob track along the ascending surface.

The nature of the graphs clearly shows that with an increase in the angle of ascent, the difference in the path with a change in the rolling friction coefficient is insignificant. The smaller values of the elevation angles give a large difference in the path of the cob to the stop.

CONCLUSION

1. Installed, considering physical-mechanical properties, the law of motion of corn cob after collision with the surface of the inclined plane, describing the dependence (2) and (3). An analysis of the movement patterns is determined that safe restart cob carrier with devices for the sorting installation surface input occurs when it cobs speeds of 0.3 to 0.4 m/s. In this high-speed mode cobs rise above the plane amounts 0,0042-0,0055 m and trip distance respectively 0,004-0,0078 m, which has practically no influence on their further movement.

2. Established that rolling friction coefficients influence the rolling cobs, if their values differ for peeled By the theoretical dependence of the velocity and range for different modes rolling corn cob on the downlink and uplink working surfaces, which take into account the physical and mechanical properties of objects themselves vegetable and uncleaned cobs (10,11,17,18,21). When selecting the parameters and working surfaces of the cob-sorting plants, the initial values of the sparing mode should be taken into account.

3. The theoretical patterns for the calculation of linear and angular velocity values transport path and deceleration of the cob, which are described by equations which take into account the physical and mechanical properties can be used to determine the structural and dynamic parameters, and calculating the energy cost of the rolling plane cobs variable curvature.

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