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ANALYSIS OF THE MOVEMENT PATTERN OF FUZZY COTTONSEED ON A SINUSOIDAL SCREEN

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Abstract. *The article proposes the use of a vibrating screen with a sinusoidal cross-sectional surface for cleaning fuzzy cottonseeds. The analysis of the movement of seeds in the proposed screen design is carried out. The laws of the change in the friction force in the spatial movement of the seed at different values of the screen vibrating force and angular velocity are obtained. Analytical laws are obtained expressing the displacement, speed and acceleration of the seed on the screen surface. The connection graphs are presented based on the numerical solution of the obtained analytical laws. The specific parameters of the proposed screen are based on.*

Keywords. *Cottoseed, cleaning, vibration, device, spreading, layering, interaction, transition, sinusoid, cosinusoid, vibration force, amplitude of vibration force, friction, displacement, speed, acceleration, amplitude of sinusoidal surface.*

Introduction. Fine-grained cleaning devices are used in almost all sectors of agriculture and the oil industry. Vibrating screens are widely used for cleaning and sorting purposes. In oil production, the incomplete removal of seeds from harmful impurities increases the content of harmful substances in the oil that seriously affect human health. It is precisely the specific physical and mechanical properties of seeds that prove their high ability to retain various impurities. When cleaning fuzzy cottonseeds, it is important to take into account their physical and mechanical properties. The research work carried out is aimed at developing an effective design of a vibrating cleaning device and, in turn, analyzing the movement of the longitudinal and transverse cross-sectional surfaces of the seeds on a screen with a harmonic character.

It is a topical issue to study the relationship between the interaction of the seed and the screen during the cleaning of the seed heap. According to the studies [1-7], the cleaning process is divided into four stages:

Spread – the even distribution of the seed cluster on the screen surface;

Stratification – the movement of various impurities through the gaps in the grain stack and towards the screen surface;

Interaction – refers to the collision of particles and small impurities near the screen surface, with some of them hitting the screen surface and small impurities falling out of the holes;

Passage – the process of passing small impurities through the holes. It is through these four stages that the seeds are cleaned of small impurities.

Filtration is a key step in the refining process, and scientists have conducted many studies on it. Mosby [1, 2] presented some factors that characterize the stratification phenomenon and put forward the following important points regarding the Sieving process:

The wide distribution of the scattering products across the screen surface intensifies the layering;

The scattering product is the same, layering becomes difficult;

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The dispersed products have a stronger effect on the stratification process than density and shape;

The layering process of dispersible products mixed with moisture or liquid is very difficult.

Laurence and Beddoe [3] found that Flokkulierung occurs best when the fine particle content is in the range of 15–30 % and almost does not occur when the fine particle content is 60 % or more. Chen Yanhua and Tong Xin [4, 5] briefly state that Flokkulierung in the cleaning process is the process of small particles passing through large particles and reaching the screen surface. The accumulation of fine particles near the screen surface is the result of flocculation, and the closer they are to the surface, the easier it is to pass through the screen holes. Rao [6] has shown that several factors affect flocculation, such as particle size, shape, and density. In most papers, flocculation is evaluated by the amount of fine particles in a given thickness of material on the screen surface.

The longitudinal and transverse sectional surfaces are cosine and sinusoidal-shaped screens, respectively. In order to increase the efficiency of the above-mentioned processes in the cleaning process, the screen design shown in Figure 1 below was proposed. The grain falling on the screen surface is initially spread along the convex-concave surface at an angle for even distribution over the working surface. Then, the longitudinal and transverse cross-sectional surfaces of the screen move along the working surface of cosine and sinusoidal shapes, respectively [7]. The proposed surface of the screen is aimed at ensuring that the fuzzy grain pile is distributed widely and evenly across the working surface, and that the impurities are intensively separated and fall out through the holes under the influence of the convex-concave surfaces during movement.

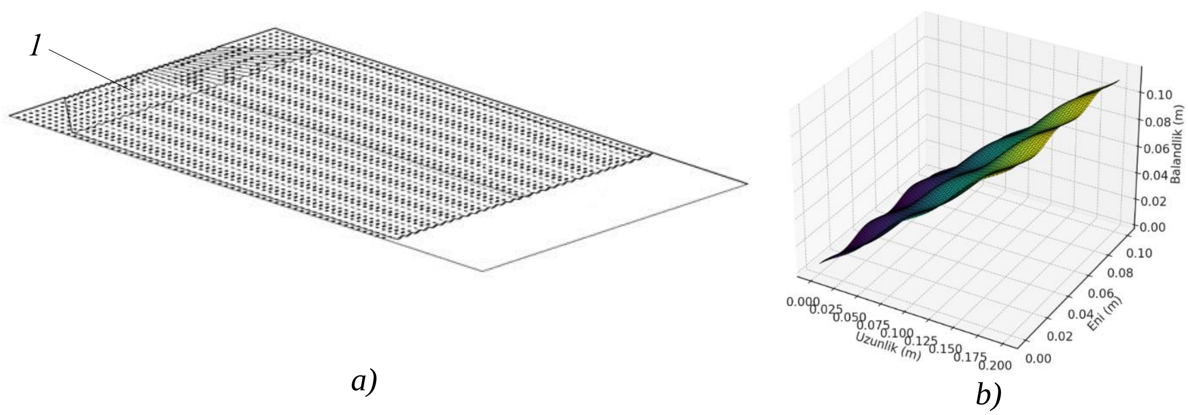

Figure 1. Screen for cleaning seeds from small impurities (a), the longitudinal and transverse cross-sectional surfaces have cosine and sinusoidal shapes, respectively

The main purpose of the above seed cleaning device is to ensure that the seed mass is evenly distributed along the sieve surface during the flow and to increase the efficiency of cleaning from foreign rocks. First, we analyze the movement of cotton seeds on the surface of the vibrating screen for the existing device.

Force analysis of a moving seed under vibration on a screen surface. The screen of the vibrating device is located at an angle to the horizontal plane $\alpha = 30°$. The center of gravity of the screen of the cleaning device is affected by a sinusoidal vibration force. The value of this force is interpreted as follows:

$$F = \lambda sin(\omega t), \quad (1)$$

where , $\lambda$is the amplitude of the vibration force (N), ω −angular velocity (of the force causing the oscillation),$\left(\frac{rad}{sek}\right)$.

forces act mainly on the seed r: gravity (mg), normal force , (N)friction that resists slipping power ($F_f = \mu N$), vibration force $F = \lambda sin(\omega t)$. The law that describes the movement of seeds is determination **The coordinate system** for it is chosen along the slope, as shown in Figure 2. According to the equilibrium equation of forces in the direction perpendicular to the screen surface, the normal force $N$is:

$$N = mgcos\,\alpha + \lambda sin\,\alpha sin(\omega t). \quad (2)$$

In this case, if $N \leq 0$ If , the seed separates from the screen and enters a free-fall state. According to Newton's second law, the equation of motion of a particle $x$along its axis is expressed as:

$$m\ddot{x} = mgsin\alpha - F_f + \lambda cos\alpha sin(\omega t) \quad (3)$$

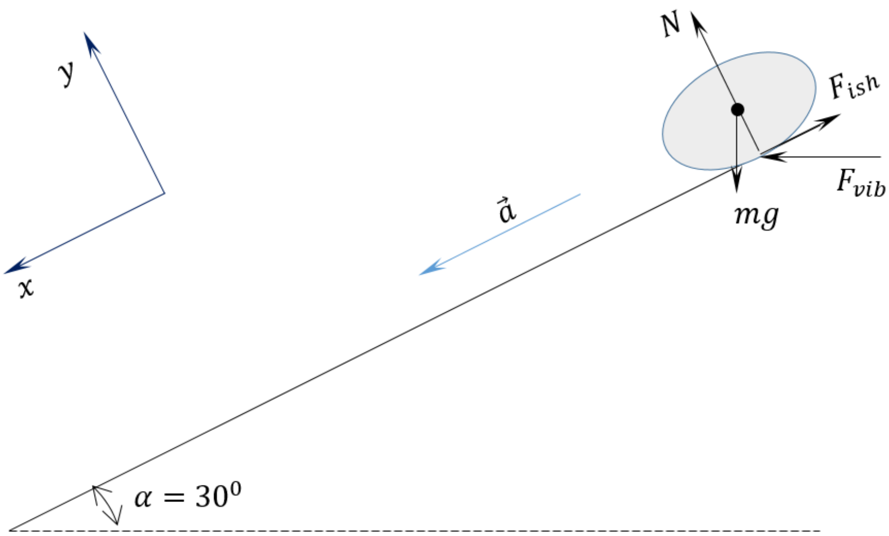

Figure 2: Force analysis diagram of a grain on a screen surface

Here, the value of the friction force is determined according to expression (2) as follows:

$$F_f = \mu N = \mu\big(mgcos\alpha + \lambda sin\alpha sin(\omega t)\big). \quad (4)$$

(3) and (4), we obtain the differential equation of motion of the seed:

$$m\ddot{x} = mgsin\alpha - \mu\big(mgcos\alpha + \lambda sin\alpha si(\omega t)\big) + \lambda cos\alpha sin(\omega t), \quad (5)$$

of the expression to mass, we obtain the following differential equation:

$$\ddot{x} = gsin\alpha - \mu gcos\alpha - \mu\frac{\lambda}{m}sin\alpha sin(\omega t) + \frac{\lambda}{m}cos\alpha sin(\omega t) \quad (6)$$

consider the law of motion of a seed for three main cases :

If the friction force is sufficient, the seed will move with the screen. The condition for the seed not to slip is as follows:

$$mgsin\alpha - \lambda cos\alpha sin(\omega t) \leq \mu N; \quad (7)$$

If this condition is met, the particle will vibrate together with the screen and its acceleration will be zero:

$$\ddot{x} = 0;$$

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If the above condition is violated, the grain will start to slide. In this case, the equation of motion can be written as:

$$\ddot{x} = gsin\alpha - \mu gcos\alpha + \frac{\lambda}{m} cos\alpha sin(\omega t). \tag{8}$$

(8) From the expression, we can see that the friction force acts in the opposite direction to the motion.

is zero , the particle will separate from the screen surface and will fall freely. The condition for the separation of the particle from the screen surface is given by the following expression:

$$mgcos\alpha + \lambda sin\alpha sin(\omega t) \leq 0, \tag{9}$$

this equation, the vibration amplitude required for the grain to separate from the screen surface can be determined. Based on the expressions obtained, it can be concluded that the movement of the grain on the screen surface depends on the angle of the screen relative to the horizontal plane α, the amplitude of the vibration force λ , the angular velocity ω, and the coefficient of friction. μThe smaller the vibration amplitude of the screen, the more the seed is forced to simply slide. To reduce the amount of impurities in the seed pile, it is necessary to increase the vibration amplitude to an optimal value. Increasing the vibration amplitude causes the seed to separate from the screen and move in a parabolic manner. Increasing the vibration frequency causes the seed to move evenly along the screen.

To determine the speed of the particle's movement on the screen surface, we integrate expression (9) with respect to time:

$$\dot{x}(t) = \int \left(gsin\alpha - \mu gcos\alpha + \frac{\lambda}{m} cos\alpha sin(\omega t) \right) dt. \tag{10 }$$

We integrate each component of the expression separately. Invariant component integral:

$$\int (gsin\alpha - \mu gcos\alpha)dt = (gsin\alpha - \mu gcos\alpha)t. \tag{1 1}$$

The integral of the component causing the oscillation is as follows :

$$\frac{\lambda}{m} cos\alpha \int sin(\omega t)dt = -\frac{\lambda}{m\omega} cos\alpha cos(\omega t). \tag{12 }$$

Thus, the law expressing the speed of the seed is:

$$\dot{x}(t) = (gsin\alpha - \mu gcos\alpha)t - \frac{\lambda}{m\omega} cos\alpha cos(\omega t) + C_1. \tag{13}$$

where is $C_1$the initial velocity (v_0), i.e. $\dot{x}(0) = v_0$.
Then the speed of the particle on the screen surface is:

$$\dot{x}(t) = v_0 + (gsin\alpha - \mu gco\alpha)t - \frac{\lambda}{m\omega} cos\alpha cos(\omega t). \tag{14 }$$

The seed on the screen surface To determine the displacement, we integrate the velocity expression (14) with respect to time :

$$x(t) = \int \left(v_0 + (gsin\alpha - \mu gcos\alpha)t - \frac{\lambda}{m\omega} cos\alpha cos(\omega t) \right) dt. \tag{15}$$

At this stage, we also integrate each component of the expression separately. Invariant component integral:

$$\int v_0 dt = v_0 t. \tag{16}$$

Integral of a linear functional component :

$$\int (gsin\alpha - \mu gcos\alpha)tdt = \frac{1}{2}(gsin\alpha - \mu gcos\alpha)t^2. \tag{17}$$

The integral of the component causing the oscillation :

$$\int -\frac{\lambda}{m\omega} cos\alpha cos(\omega t)dt. \tag{18}$$

expression (18):

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$$-\frac{\lambda}{m\omega}cos\alpha\int cos(\omega t)dt = -\frac{\lambda}{m\omega^2}cos\alpha sin(\omega t). \quad (19)$$

Now we write the general equation for the displacement of the seed :

$$x(t) = x_0 + v_0 t + \frac{1}{2}(gsin\alpha - \mu gcos\alpha)t^2 - \frac{\lambda}{m\omega^2}cos\alpha sin(\omega t), \quad (20)$$

Where is x_0 the coordinate of the particle in the initial state. This equation describes the displacement of the particle with respect to time. The first two terms in the expression represent $x_0, v_0 t$ the initial velocity and the initial coordinate, the third term represents $\frac{1}{2}(gsin\alpha - \mu gcos\alpha)t^2$ the effects of weight and friction, and the fourth term represents the sinusoidal modulation caused by the vibration.

From the obtained law of motion, it can be concluded that the movement of the grain has a parabolically displacement that increases with time. The amplitude value of the vibration force λ ningvaries sinusoidally λ with time , which causes oscillations in the movement of the grain. If it is large , the grain can move oscillatingly and even move out of the working position. An increase in the friction (μ) of the hairy grain slows down the movement of the grain. An increase in the angle of the screen relative to the horizontal plane αaccelerates the downward movement of the grain. This reduces the cleaning process time, which reduces the cleaning index.

Let us consider how this affects the movement of cotton seeds if the screen surface has cosinusoidal and sinusoidal longitudinal and transverse cross-sectional surfaces, respectively, and has holes, as shown in Figure 1. The proposed screen surface produces the following effects on seed movement:

The presence of holes, along with small impurities, can cause small pieces of seed to fall into the holes or become clogged. These blockages resist the movement of the seed pile. At the same time, they also negatively affect the cleaning efficiency;

Since the longitudinal and transverse sections of the screen have a sinusoidal shape, the grain does not move in a straight line, but moves up and down in small jumps and slopes. This creates an additional dynamic effect, which is the main goal of the study;

The friction area varies due to the longitudinal and transverse sinusoidal shape of the screen surface with small amplitude and large period. In some places, the friction is greater , and in some places it is less. This in turn increases the efficiency of seed cleaning. The unevenness of the screen surface causes random movement of the seed and is consistent with the objectives of this study.

Taking into account the above factors, we introduce parameters into expression (20) that take into account the shape of the screen surface. The effect of irregularities on the additional acceleration is due to the fact that the screen surface is wavy. Since the motion is modulated by an additional sinusoidal effect:

$$a_{yuzasi} = A_y sin(kx) \quad (21)$$

here :

A_y— the amplitude of the screen surface (the height of the unevenness), k — the frequency associated with the wavelength, the value of which is determined by the following expression:

$$k = \frac{2\pi}{\lambda_y} \quad (22)$$

In this case, λ_y −the spatial wavelength is calculated, which indicates how large the distance over which the sinusoidal change in the friction coefficient is repeated. From experimental studies, it can be noted that the proposed screen surface provides optimal cleaning capabilities at the value of

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the longitudinal sinusoid $A_y = 3mm$, $\lambda_y = 40mm$ Expression (22) has a frequency value related to the wavelength $k = 0{,}157\ mm^{-1}$.

This additional component is added to the equation of motion. Also, the variation of friction can be expressed as :

$$\mu_{eff} = \mu_0 + \Delta\mu sin(kx(23\ )$$

Then the value of the friction force, in accordance with expression (5), will be as follows:

$$F_f = \mu_{eff}N = (\mu_0 + \Delta\mu\sin(kx))(mgcos\alpha + \lambda sin\alpha sin(\omega t)) \qquad (24)$$

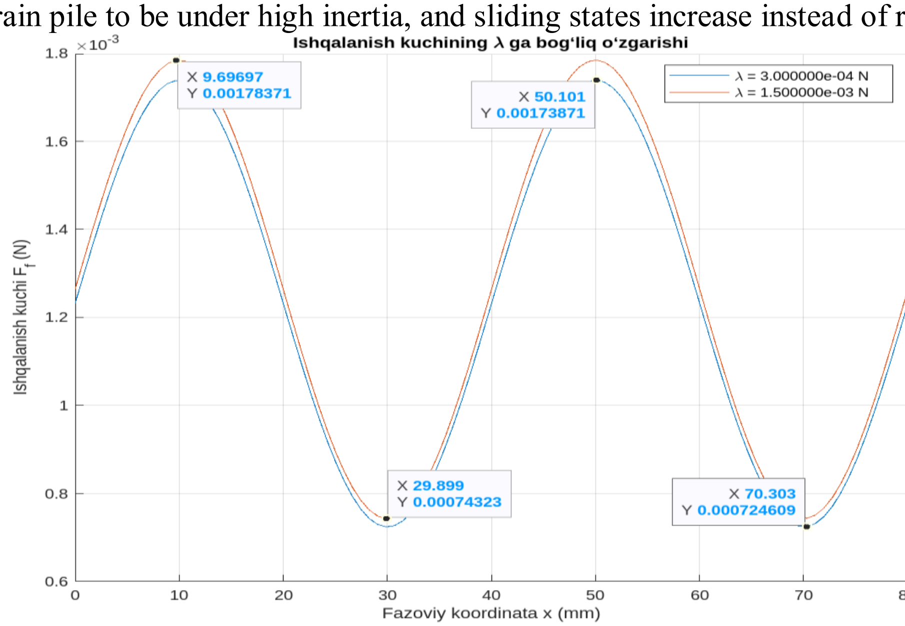
Here

$$\Delta\mu = \frac{\mu_{max}-\mu_{min}}{2}, \qquad (25)$$

The value of the coefficient of friction of a hairy seed is determined by $\mu_{max} = 0{,}3669$the expression [elmurod dissertation] and has the value. Based on the numerical solution $\mu_{min} = 0{,}2186$of expression (24), we consider the graph of the dependence of the friction force on the change in the amplitude value of the force vibrating the screen. In this case, the numerical value of the parameters was obtained as follows:$\mu_0 = 0{,}36$; $\Delta\mu = 0{,}1483$, $k = 0{,}157\ mm^{-1}$, $m = 0{,}4g$,
$\lambda = 3 \cdot 10^{-4} \div 1{,}5 \cdot 10^{-3}N,\ \omega = 17 \div 21rad/sek.$

From the graph in Figure 3 *a), it can be seen that the friction of the grain on the screen surface* is not constant, but varies sinusoidally along the friction coefficient $x$axis, and the normal force has a sinusoidal component depending on time. This, in turn, has a sufficiently positive effect on the cleaning efficiency. From the graph, it can be seen that when the grain moves 40 mm on the screen surface for one period, the friction force increases in the first 10 mm of movement, and the value of the friction force decreases in the next 20 mm. From this it can be concluded that an increase in the value of the friction force reduces the sliding of the grain and causes it to roll. The movement of the grain pile also changes proportionally to the same law.

In Fig. 3b *) can we see the rolling* and sliding states of the grain moving on a sinusoidal surface. Increasing the eccentric angular velocity of the screen $\omega = 17 \div 21\frac{rad}{sek}$in the interval accelerates the movement of the grain pile. However, an excessive increase in the angular velocity causes the grain pile to be under high inertia, and sliding states increase instead of rolling.



a)

COMMON GROUND

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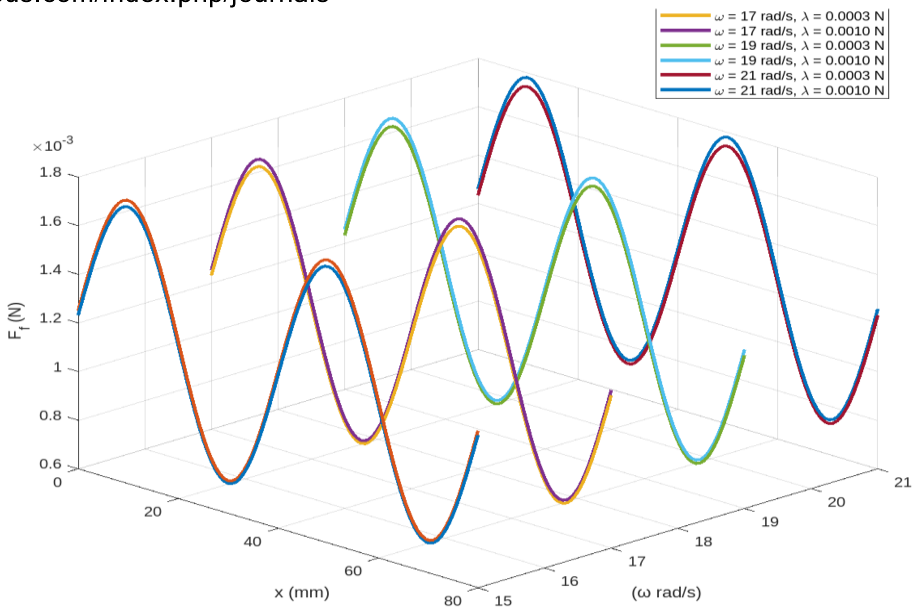

b)

Figure 3. Graph of the change in the friction force in the spatial movement of the grain at different values of the screen vibrating force *(a)* and angular velocity *(b)*

The vibration force $\lambda = 3 \cdot 10^{-4} \div 1 \cdot 10^{-3} N$within the range of values also leads to a proportional increase and decrease in friction with time. Analyzing the graph, it can be concluded that in order to ensure that the grain rolls more on the screen surface, $\omega = 17 \div 19 \frac{rad}{sek}$it is recommended to be in the range: $\lambda = 3 \cdot 10^{-4} \div 3 \cdot 10^{-4} N$

This can also cause the seed to jump up in some cases (possibility of contact loss).

Now, taking into account the sinusoidal shape of the screen, the differential equation describing the motion of the grain can be written as follows:

$$\ddot{x} = gsin\alpha - (\mu_0 + \Delta\mu sin(kx))gcos\alpha + A_y sin(kx) + \frac{\lambda}{m} cos\alpha sin(\omega t). \quad (26)$$

We determine the speed of the seed by integrating this equation:

$$\dot{x}(t) = v_0 + (gsin\alpha - \mu_0 gcos\alpha)t - \frac{\lambda}{m\omega} cos\alpha cos(\omega t) + \frac{A_y}{k} cos(kx). \quad (27)$$

Then, equation (24) representing the displacement of the seed can be written as follows by integrating the expression:

$$x(t) = x_0 + v_0 t + \frac{1}{2}(gsin\alpha - \mu_0 gcos\alpha)t^2 - \frac{\lambda}{m\omega^2} cos\alpha cos(\omega t) + \frac{A_y}{k^2} sin(kx_\alpha). \quad (28)$$

here is $x_\alpha = x(t)cos\alpha$ —the trajectory projection.

Let's see an analysis of the law of motion of a seed:

If the amplitude value on the sinusoidal surface of the screen is very small , the grain will tend to move as if it were on the existing screen;

the amplitude value on the sinusoidal surface of the screen is large, the particle will experience additional jumps and decelerations in its trajectory.

the seed and the proposed design screen, the seed may slide faster in some places, and stop in some places. Therefore, it is necessary to determine the optimal amplitude value of the proposed sinusoidal surface screen. The proposed screen surface creates its own unique characteristics of the seed movement. The variety of holes and convexities brings additional sinusoidal modulation to the movement of the seed. The friction dynamics change, which slows down the seed in some places and

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accelerates it in some places. Obtained (28) a differential equation can represent the actual motion of the seed.

the proposed screen surface: The grain moves along a sinusoidal surface for a distance of 2 meters, and then, under the influence of inertia and the acceleration of free fall, it moves to the next technological stage. Taking into account the length of the screen as 2 m, the expressions representing the displacement, velocity and acceleration of the grain can be written as follows:

Migration Expression:

$$x(t)=\begin{cases} x_0+v_0t+\frac{1}{2}(gsin\alpha-\mu_0 gcos\alpha)t^2-\frac{\lambda}{m\omega^2}cos\alpha cos(\omega t)+\frac{A_y}{k^2}sin(kx_\alpha), x(t)\le 2 \\ x_0+v_0t+\frac{1}{2}(gsin\alpha-\mu_0 gcos\alpha)t^2-\frac{\lambda}{m\omega^2}cos\alpha cos(\omega t), \qquad x(t)>2 \end{cases}$$

Speed expression:

$$\dot{x}(t)=\begin{cases} v_0+\frac{1}{2}(gsin\alpha-\mu_0 gcos\alpha)t-\frac{\lambda}{m\omega}cos\alpha sin(\omega t)+\frac{A_y}{k}cos(kx_\alpha)\cdot\frac{dx_\alpha}{dt}, x(t)\le 2 \\ v_0+(gsin\alpha-\mu_0 gcos\alpha)t-\frac{\lambda}{m\omega}cos\alpha sin(\omega t), \qquad x(t)>2 \end{cases} \quad (29)$$

Acceleration expression:

$$\ddot{x}(t)=\begin{cases} gsin\alpha-\left(\mu_0+\Delta\mu\sin\left(kx(t)\right)\right)\cdot gcos\alpha+\frac{\lambda}{m}cos\alpha\cdot\omega\sin(\omega t)+A_y kcos(kx_\alpha)\cdot\dot{x}(t)cos\alpha, x(t)\le 2 \\ gsin\alpha-\mu_0 gcos\alpha+\frac{\lambda}{m}cos\alpha\cdot\omega\sin(\omega t), \qquad x(t)>2 \end{cases}$$

Here, $\Delta\mu$ –the sinusoidal variation of the friction of the seed on the screen surface is taken into account.

Graphical analysis of the movement of a grain on a screen with a cosine and sinusoidal shape of the longitudinal and transverse cross-sectional surfaces, respectively. According to the results of theoretical and practical research, the following numerical parameters were used to study the movement of a grain on the proposed screen surface:

Numerical values of the parameters of the seed equation of motion

Table 2

No.	Parameter name	Marking	Value
1.	Initial coordinate	x_0	0
2.	Initial speed	v_0	0
3.	Acceleration of free fall	g	$9{,}81 m/s^2$
4.	The angle (tilt) of the screen relative to the horizon	α	30°
5.	The coefficient of static friction of the seed on the screen surface	μ_0	0.34
6.	Amplitude of the force vibrating the screen	λ	$7\cdot10^{-4}, 9\cdot10^{-4}$, $1{,}1\cdot10^{-3}N$

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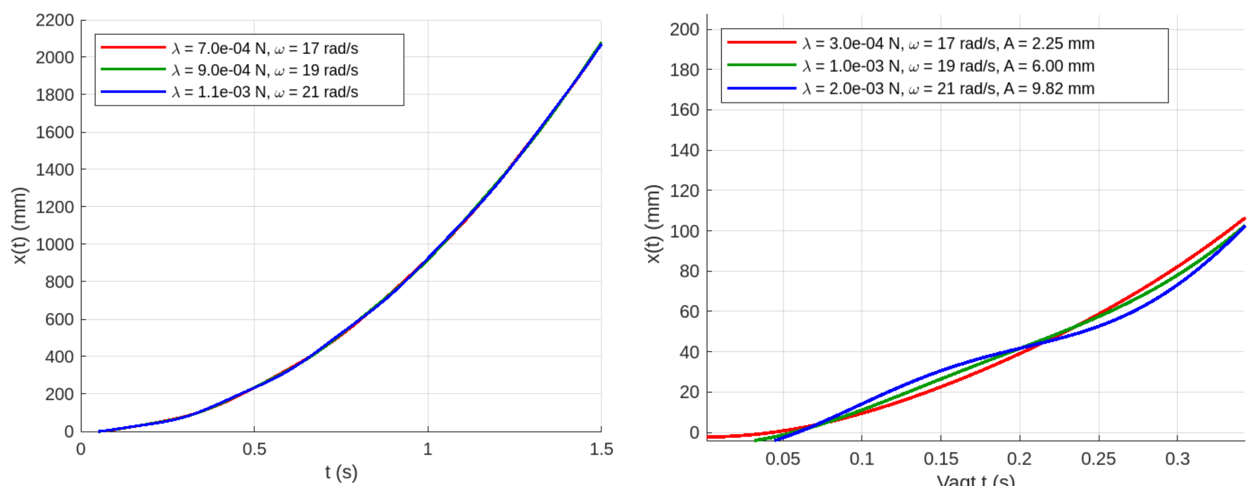
7.	Eccentric rotation frequency	ω	$17, 19, 21 \frac{rad}{sek}$
8.	One grain of rice	m	$4 \cdot 10^{-4} kg$
9.	Amplitude of the screen sinusoidal surface	A_y	$2,3,4 \cdot 10^{-3} m$
10	Phase frequency (wave number) of the screen surface	k	$0,157\ mm^{-1}$
11	Trajectory projection of the screen surface	x_α	

The obtained differential equations expressing the motion were mathematically modeled as the laws of motion of a hairy seed. A graph of the movement of a hairy seed was obtained in the Mathlab program (Fig. 3,*a*). The parameters that provide the possibility of external changes in the expression: the value of the force acting on $\lambda = 7; 9; 11 \cdot 10^{-4} N$, a seed and the values of the angular velocity of the eccentric $\omega = 17; 19; 21 \frac{rad}{sek}$ were obtained. Although the connection graphs presented in Fig. 3*a* appear as a line in macro form, they change with a specific sinusoidal law. Fig. 3*b* presents graphs that clearly demonstrate the differences between the Graphen.



A *b*

Figure 4. Screen on the surface seed to time related without migration graph

Seed to move sinusoidal surface effect macroscopic. It is not noticeable at first glance (Figure 6a), but micromovements in positions (Figure 4*b*) are noticeable at the level that it is changing shows. Small time drawn in the space ($0 - 0,3\ s$) $x(t)$ graph seed in motion sinusoidal surface effect more precisely to the eye to be thrown away showed. Every parameter for vibration amplitudes is defined as follows:

Effect provider power $\lambda = 3 \cdot 10^{-4} N$, and eccentric corner speed $\omega = 17 \frac{rad}{sek}$ when seed sinusoidal movement amplitude $A = 2,25 mm$ what, effect provider power $\lambda = 1 \cdot 10^{-3} N$, and eccentric corner speed $\omega = 19 \frac{rad}{sek}$ when seed sinusoidal movement amplitude $A = 6mm$ what, effect provider

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power $\lambda = 2 \cdot 10^{-3}N$, and eccentric corner speed $\omega = 21\frac{rad}{sek}$ when seed sinusoidal movement amplitude $A = 9{,}82\ mm$ what organization. These results show that the sinusoidal λ force and, as the angular velocity ω increases, the amplitude of the sinusoidal oscillation in the movement auch increases. In this case, the grain moving on the Sieb surface does not slide smoothly, sondern begins to move with oscillation. Based on the above graphical analysis and mechanical modeling, the advantages of sinusoidal surface sieves in grain cleaning can be expressed as follows:

the sinusoidal surface, the grain moves on the screen surface in an oscillating manner, which enhances the separation of dust and impurities from the grain pile;

λ and ω by controlling the parameters, the amount of seed piles remaining on the screen surface is reduced, as the number of rolling events during seed movement increases;

allows you to select optimal modes for different cotton varieties through various harmonische

of the seeds ensures that small impurities and dust fall out of the holes.

its velocity has not only a continuously increasing but also a periodically varying component. This can be clearly seen from the graph in Figure 3. The amplitude of the harmonic force vibrating the screen $\lambda = 7; 9; 11 \cdot 10^{-4}N$, is proportional to the angular velocity of the eccentric $\omega = 17; 19; 21\frac{rad}{sek}$, so the velocity locally forms Maximum-Minimum-Werte in the graph.

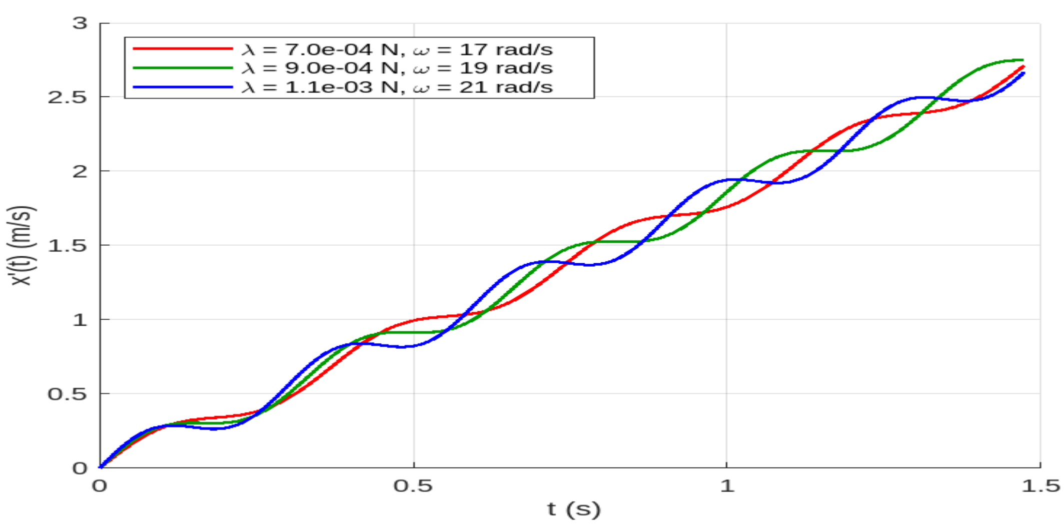

Figure 5. Velocity graph of seed movement

From the graph we can see that at maximum values of speed the inertial force of the particle is maximum. is the point wo. In these cases, the grain moves in a rolling motion. This, in turn, has a positive effect on the cleaning process of small impurities in the grain pile. At minimum values of the speed, the grain speed decreases slightly, temporarily. This is located at the top of the sinusoidal surface and the grain is “pulled back” for a short time. The movement slows down and the grain encounters more friction relative to the screen surface. At this point, the grain vibrates. If we pay attention to the amplitude differences, λ and As ω increases, the difference between the maximum and minimum Δvalso increases. This indicates that the impulse force imparted by the screen surface

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to the grain increases and, as a result, the mutual separation force in the grain pile increases. These oscillations create a vibratory motion of the grain on the sieve surface.

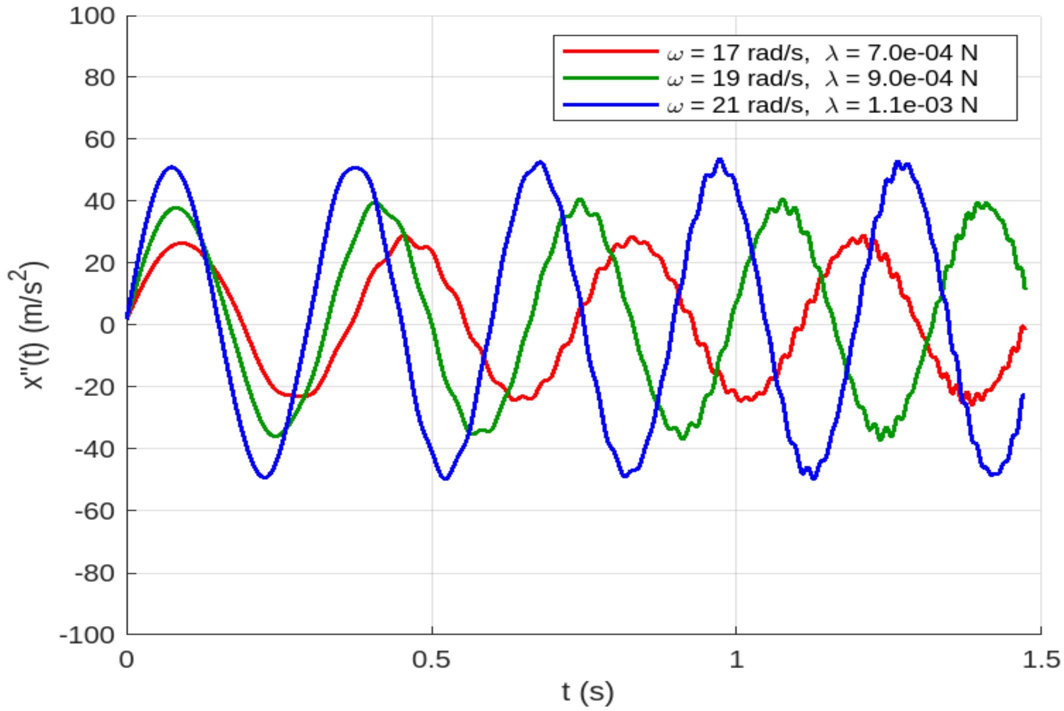

Figure 6. Acceleration graph of seed movement

The movement of a grain on a sinusoidal surface should be studied in depth not only in terms of displacement and speed, but also in terms of acceleration. It is the acceleration graph that reflects the impulsive effect of the sinusoidal surface on the grain. A graph was obtained that represents the acceleration of grain movement at the values of the angular velocity of the eccentric with $\omega = 17; 19; 21 \frac{rad}{sek}$ a harmonic force amplitude. From the graph, we can $\lambda = 7; 9; 11 \cdot 10^{-4} N$, see that the acceleration of the grain has a high frequency and large amplitude change as a result of sinusoidal oscillations. Strong impulses are observed in each graph. Increasing acceleration means that the grain is moving forward under the influence of the impulsive vibration force. At maximum values of acceleration, the grain rubs less on the screen surface, a kind of "Jumping"-Effect occurs. This, in turn, has the maximum beneficial effect on the separation of impurities in the grain heap. At minimum values of grain acceleration, the possibility of small impurities falling out of the hole due to the shaking force increases.

The eccentric angular velocity ω increases, the number of oscillations increases proportionally, which increases the frequency of oscillations. An increase in the harmonic force increases the acceleration amplitude and λ the impulse force transmitted with each oscillation. This increases the separation index of the grain stack.

reflects the mechanical contact of the seed with the screen surface. High frequency and amplitude acceleration causes frequent changes in impulse forces, which activates the vibratory motion . The seeds move in a jerky motion . Due to the sinusoidal variation of friction, the efficiency of cleaning the seed pile increases.

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Based on graph analysis Recommended optimal parameters for the proposed screen:
harmonic force amplitude $\lambda = 1{,}0 \cdot 10^{-3} N$;
angular velocity of the eccentric $\omega = 19 \frac{rad}{sek}$;
surface vibration amplitude $A = 3 \cdot 10^{-3} mm$.

$\lambda = 1{,}0 \cdot 10^{-3}\ N$ When the value is, the impulse force acts on the grain sufficiently, and the risk of it jumping out of the screen working surface is also prevented. $\omega = 19 \frac{rad}{sek}$ At the value, the grain vibrates synchronously on the screen surface at a frequency of, each sinusoidal wave has time to shake the grain. $A = 3 \cdot 10^{-3} mm$ screen The amplitude of the surface vibration allows the seed to be shaken by its own motion without impacting it. These values are the most optimal values based on graphs, MATLAB modeling, seed trajectory, velocity, and acceleration analysis.

When the amplitude $\ddot{x}(t)$value $-\lambda = 1{,}0 \cdot 10^{-3}\ N$of the harmonic force applied to the sinusoidal screen surface is, the eccentric angular velocity is $-\omega = 19\, rad/s$, and the screen surface vibration amplitude is $-A_y = 3\ mm$, the graphs of $\dot{x}(t)$the grain motion $x(t)$were obtained (Figure 7).

From the graph, we can see that the motion of the seed starts from position 0 and travels a distance of 2 meters in 1,5 seconds. This result confirms that the sinusoidal surface can effectively transmit impulse forces to the movement of the seed. Although the motion has a uniform, parabolic shape, we can see that it moves sinusoidally at micro positions. The parabolic curve of the overall motion means that the seed is experiencing a constant positive acceleration.

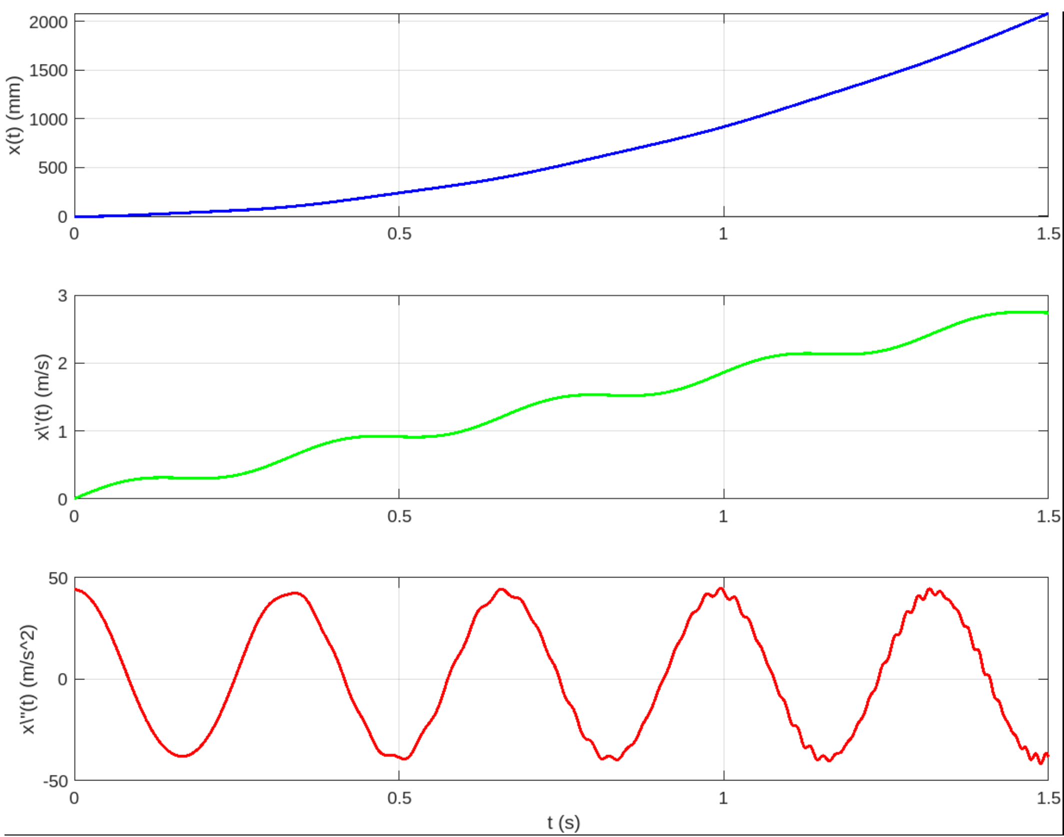

Figure 7. Displacement, velocity, and acceleration graphs of seed motion

COMMON GROUND

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The proposed screen $\alpha = 30°$is located at an angle to the horizontal plane, the speed of the grain increases over time $2.8\ m/s$to . The graph clearly shows sinusoidal oscillations, which means that the surface provides continuous movement through harmonische impulses. During the movement of the grain, the oscillation frequency is close to 4 Hz. These oscillations at this speed ensure that the grain does not slip through the holes, but shakes. The impulse forces during movement act as an impulse on the grain. This speed regime creates a favorable environment for the separation of fine impurities on the sieve surface. In particular, due to the sinusoidal movement, fine impurities gradually separate from the grain and fall into the sieve holes.

Among the obtained graphs, the acceleration graph reflects the most important dynamic process. The range of change of acceleration values $+45\frac{m}{s^2}$from$-45\frac{m}{s^2}$ varies sinusoidally up to . This is the process of expressing the effect of impulse forces on the grain pile, demonstrating the nature of the grain shaking. Positive values of acceleration give the grain an upward impulse. Negative phases press the grain against the screen surface, increasing the contact surface. Harmonic oscillations are sinusoidal in shape , ensuring the effective interaction between the grain and the screen surface. It is worth noting that the acceleration values, $\ddot{x} \leq |50m/s^2|$being in the optimal range: do not damage the grain, but are sufficient to separate impurities .

At selected parameters, sinusoidal surface motion provides the following positive aspects in the seed cleaning process:

- stable migration: full movement along the sieve is ensured;
- Harmonic changes in displacement, velocity, and acceleration effectively aid in the separation of contaminants;
- optimal impulse forces create effective vibrations that are essential for cleaning.

the harmonic power amplitude $\lambda = 1{,}0 \cdot 10^{-3}N$;for the proposed sinusoidal surface screen for the seed cleaning device angular velocity of the eccentric $= 19\frac{rad}{sek}$; surface vibration amplitude $A = 3 \cdot 10^{-3}mm$ values prove to be an effective choice.

Conclusion

A graph of the dependence of the amplitude $r = 1 \cdot 10^{-3}\ m$value of $A_\varphi$the proposed screen vibrating force on the angular vibration amplitude was obtained. Based on them, the values of the distance between the line of action of the screen vibrating force and the center of mass λ_m, the screen mass (with 12 kg of seeds) $m = 52\ kg$, the length of the screen $l - 2\ m$, and the amplitude of the force causing the vibration movement $\lambda_m = 150 \div 400\ N$ were obtained. Based on the analysis of the values, it can be noted that λ_m with the increase of , the vibration phase increases. This indicates that the mechanical system approaches the screen resonance phenomenon as the value of the vibrating force increases. Therefore, $\lambda_m = 180 \div 250\ N$it was determined that the value of the vibration-causing force is taken as a value to normalize the vibration phase on the screen. Also, graphs of the dependence of the vibration-causing $\lambda_m$force on the vibration amplitude were obtained. The differential equations expressing the obtained movement were mathematically modeled as the laws of motion of the fuzzy cottonseed. A graph of the displacement of the fuzzy cottonseed. was obtained in the Mathlab program. The parameters that provide the possibility of external changes in the expression: (the value of the force acting on $\lambda = 7; 9; 11 \cdot 10^{-4}N$, a single grain , the values of the angular velocity of the eccentric) $\omega = 17; 19; 21\frac{rad}{sek}$were obtained. The obtained connection graphs, although they appear as a line in macro form, change with a specific sinusoidal regularity. The graphs that clearly demonstrate their changes and the differences between the graphs were obtained. Based on the analysis of the graphs The optimal parameters recommended for the proposed screen were determined: harmonics power amplitude $\lambda = 1{,}0 \cdot 10^{-3}N$, angular velocity of the eccentric $= 19\frac{rad}{sek}$, surface vibration amplitude $A = 3 \cdot 10^{-3}mm$. Based on these values, the most optimal values were recommended anhand ofgraphs, MATLAB modeling, particle trajectory, velocity and acceleration analysis.

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