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ANALYSIS OF THE MOVEMENT OF COTTON SEEDS UNDER THE INFLUENCE OF A SCREW CONVEYOR

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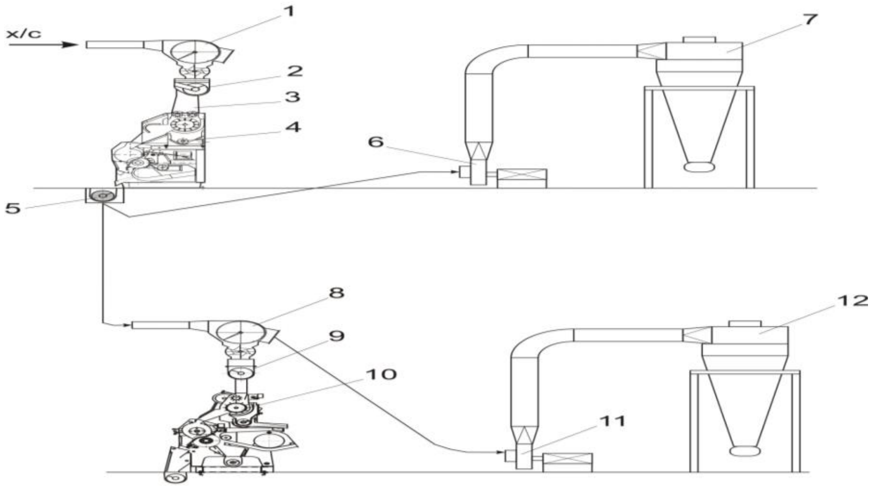
Abstract: This article presents the results of an experiment conducted to analyze the movement of cotton seeds under the influence of a screw conveyor. It should be noted that an increase in work productivity leads to an increase in the pressure force on the cotton seeds on the surface of the screw, which in turn causes seed clogging. Therefore, optimizing work efficiency by selecting the appropriate screw rotational speed based on its angular velocity is of great importance. During the study, it was observed that correctly choosing the screw speed corresponding to different productivity values (Q1, Q2, Q3) helps to reduce seed clogging.

Keywords: screw conveyor, cotton seed, seed fibers, lint quality.

Introduction. We will consider the issue of sorting cotton seeds under the influence of a screw conveyor. To prevent the seeds from getting stuck in the screw, the screw diameter was selected as **300 mm**. A gap of **9–15 mm** was set between the screw edge and the center of the tube. The filling coefficient has been $\kappa = 0.35 \div 0.4$ determined accordingly. For the separation of cotton seeds in the screw conveyor, a coefficient of $\rho = 300 \div 400\ кг/м^3$ was used for medium-fiber cotton seeds, while a coefficient of $\rho = 440 \div 540\ кг/м^3$ was applied for fine-fiber varieties. Adjusting the screw conveyor speed during the sorting of these fibered cotton seeds helps eliminate clogging between the screws.

Proper selection of the screw conveyor speed ensures the efficient separation of cotton seeds while also preventing clogging. The transmission rate was chosen within the $Q = 9 \div 12\ т/с$ range.

Before linting, seed cleaning devices include the following:



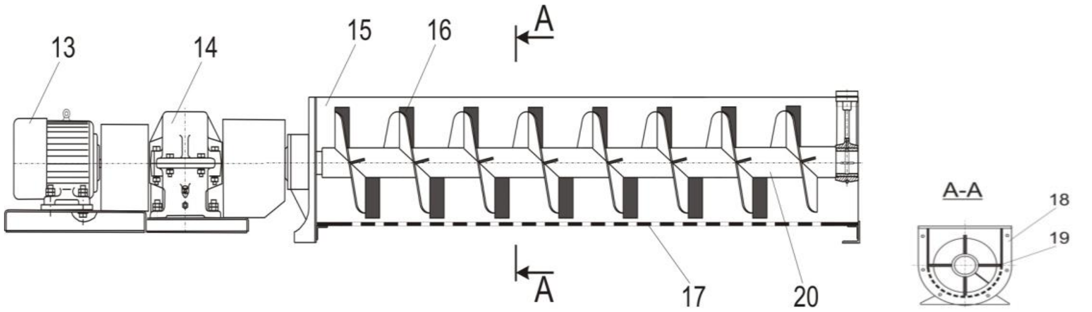


Figure 1. Improved schematic of the screw conveyor

1- Separator, 2- Raw cotton, 3- Shaft, 4- Gin cleaning section, 5- Seed auger, 6- Fan, 7- Cyclone installation, 8- Seed separator, 9- Seed auger, 10- Linter, 11- Fan, 12- Cyclone installation, 13- Electric motor, 14- Gearbox, 15- Drilling, 16- Drill blades, 17- Mesh grooves, 18- Flange, 19- Gasket.

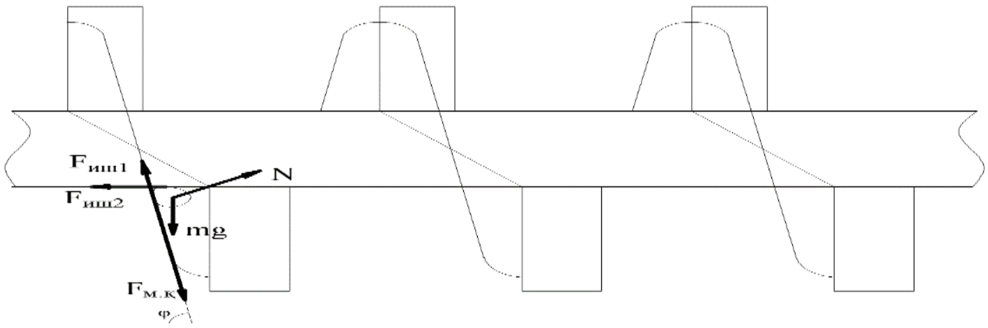


Figure 2. Schematic of cotton seeds movement in the screw conveyor

The movement speed of cotton seeds on the screw surface, depending on the screw speed, is determined by the following formula.

$$k = \frac{Q}{900 \cdot \pi \cdot d^2 \cdot \vartheta \cdot \gamma \cdot C} \quad (1)$$

Where:

- **Q** – Conveyor productivity, t/s
- **d** – Conveyor diameter, m
- **λ** – Filling coefficient of the space between blades
- γ – Bulk density of the transported load, t/m³
- **S = 0.9** – Spillage coefficient of the load

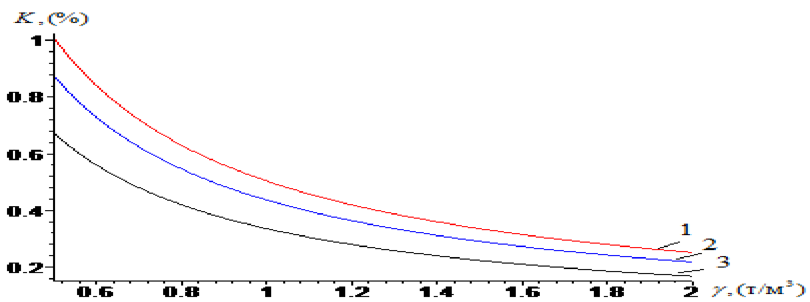


Figure 3. Filling coefficient of cotton seeds moving in the screw conveyor at different productivity values $Q_1 = 3$ т/с $Q_2 = 5$ т/с $Q_3 = 7$ т/с graph of the relationship between cotton seed bulk densit and the filling coefficient at different productivity values

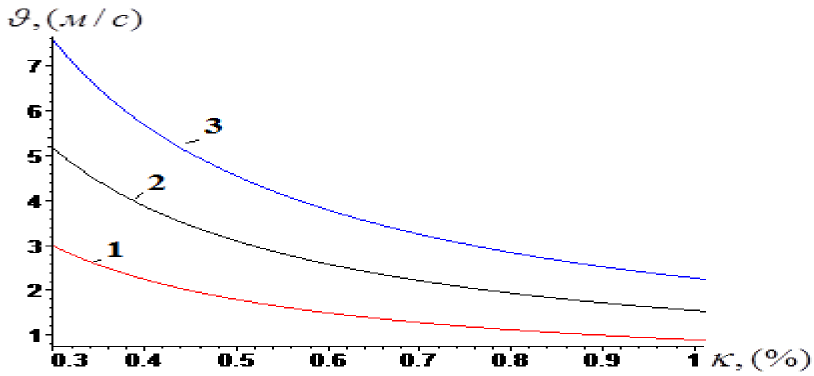


Figure 4. Graph of the relationship between the speed of cotton seeds moving in the screw conveyor and the filling coefficient of the space between blades at different productivity values $Q_1 = 3$ т/с, $Q_2 = 5$ т/с, $Q_3 = 7$ т/с

From the graphs, it can be emphasized that increasing productivity requires considering the relationship between bulk density and screw speed. The increase in productivity also necessitates maintaining a sufficient speed to ensure the uniform transfer of cotton seeds in the screw conveyor. Selecting the appropriate screw speeds corresponding to different productivity values $Q_1 = 3$ т/с $Q_2 = 5$ т/с $Q_3 = 7$ т/с helps reduce seed clogging. For example, as seen in the graph, selecting a screw speed of $\vartheta = 3.5$ м/с for transporting $Q_1 = 3$ т/с fiber seeds ensures the uniform transfer of various seeds.

The fuzzy seeds move a certain distance during their rotation in the screws. We formulate the differential equation of the fuzzy seed movement in the screw conveyor (Figure 2).

$$\begin{cases} m \cdot \dfrac{d^2x}{dt^2} = -N \cdot \cos\beta + F_{ish2} - F_{ish1} \cdot \cos\omega t \\ m \cdot \dfrac{d^2y}{dt^2} = -N \cdot \sin\beta - m \cdot g + F_{ish1} \cdot \sin\omega t \end{cases} \quad (2)$$

Here $\varphi = \omega \cdot t$ - The inclination angle of the moving helical line of the fuzzy cotton seed; β- The inclination angle of the helical line along the outer edge; mg- The gravitational force of the fuzzy cottonseed; g - Free fall acceleration; $F_{ш1}$- Friction force of the fuzzy seed on the screw surface; N - The reaction force generated on the screw surface under the influence of the fuzzy seed; $F_{ш2}$ - The friction force generated on the inner surface of the conveyor casing by the fuzzy seed is expressed by the following equations; f - The friction coefficient of the fuzzy seed on the surface of the screw conveyor; $F_{ш1} = f \cdot N$; $N = G \cdot \sin\omega t = m \cdot g \cdot \sin\omega t$; Is equal to. Determined; $F_{ш1}; F_{ш2}$ we substitute the obtained values into expression (2) to determine the pressure force of the fuzzy seed on the screw surface. We analyze the process of separating impurities under the influence of pressure force. When determining the normal pressure force, we use the condition we use the condition.

$$\begin{cases} -N\cdot\cos\beta + F_{ish2} - F_{ish1}\cdot\cos\omega t = 0 \\ -N\cdot\sin\beta - m\cdot g + F_{ish1}\cdot\sin\omega t = 0 \end{cases} \quad (3)$$

By simplifying the system of equations (3), we determine the normal pressure force acting on the fuzzy cotton seed.

$$N = \frac{m\cdot g\cdot\left[f\cdot\cos\omega t\cdot(\cos\omega t\cdot\sin\beta + \cos\omega t\cdot\sin(\omega t-\beta)) - \cos\beta\right]}{\sin 2\beta} \quad (4)$$

From expression (4), the normal pressure force is analyzed in the process of uniformly transferring fuzzy cotton seeds, considering their mass, φ– the inclination angle of the moving helical line of the fuzzy cotton seed, β – the inclination angle along the outer edge of the helical line, and the dependence on the friction coefficient.

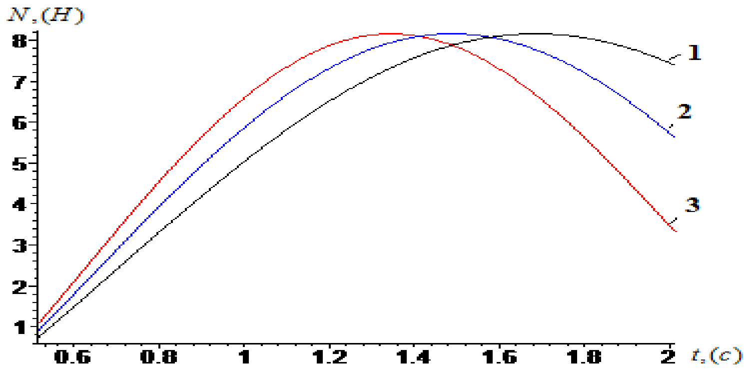


Figure 5. Graph of the dependence of the pressure force of cotton seeds on the screw surface on time at different productivity values of $Q_1 = 3$ т/с $Q_2 = 5$ т/с $Q_3 = 7$ т/с.

From the graph, we can emphasize that an increase in productivity leads to an increase in the pressure force on the cotton seeds on the screw surface, which in turn causes clogging of the cotton seeds. Therefore, sorting based on the angular velocity of the screw is of great importance.

The speed of the movement of cotton seeds on the screw surface around the conveyor axis is determined as follows. $F_{ишl} = f\cdot N$ here $N = F_{m.q} + m\cdot g\cdot\sin\omega t$ It is equal to, and the friction force on the screw surface is expressed as follows.

$$F_{ишl} = f\cdot(F_{m.q} + m\cdot g\cdot\sin\omega t) \quad (5)$$

Here, $F_{m.q} = \dfrac{m\cdot\vartheta^2}{r}$ represents the centrifugal force of the fuzzy seed resulting from the screw rotation.

By substituting this equation into expression (5), we derive the dependence of the friction force of cotton seeds on the screw surface on acceleration.

$$F_{\text{ш}1} = \mathrm{f} \cdot (m \cdot g \cdot \sin \omega t + \frac{\mathrm{m} \cdot \vartheta^2}{\mathrm{r}}) \qquad (6)$$

By substituting equation (6) into equation (3), we determine the expression for the dependence of the motion speed of cotton seeds on the screw surface during sorting.

$$r = \frac{\vartheta^2 \cdot (\mathrm{f} \cdot \sin \omega t - \sin \beta)}{\mathrm{g} \cdot (\sin \omega t \cdot \sin \beta - \sin^2 \omega t)} \qquad (7)$$

In equation (7), the movement speed of cotton seeds on the screw surface is analyzed using graphs in the Maple software for seed separation.

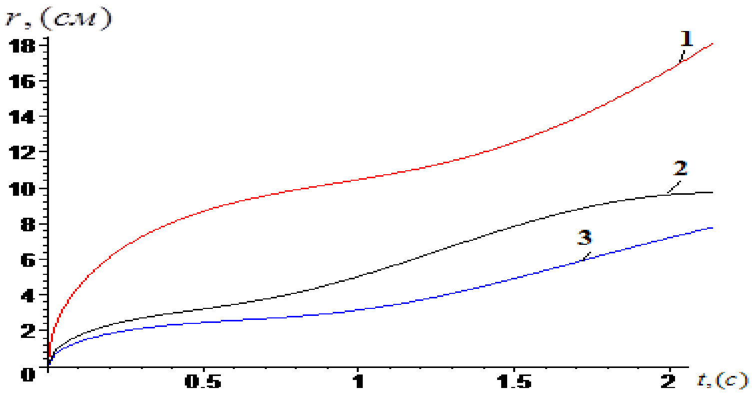


Figure 6. Graph of the dependence of time on the linear velocity of the screw in the movement of cotton seeds on the screw surface at different values $\vartheta_1 = 8$ м/с $\vartheta_2 = 6$ м/с $\vartheta_3 = 4$ м/с

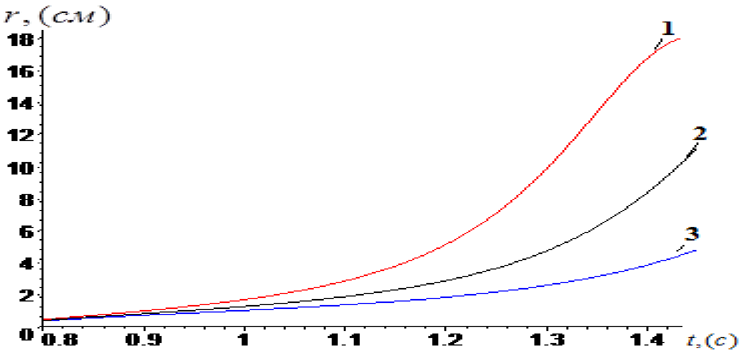


Figure 7. Graph of the dependence of the screw angle on the movement of cotton seeds on the screw surface at different productivity values $Q_1 = 3$ т/с $Q_2 = 5$ т/с $Q_3 = 7$ т/с

The process of cleaning cotton seeds from weeds and other impurities under the influence of a screw conveyor on the mesh surface.

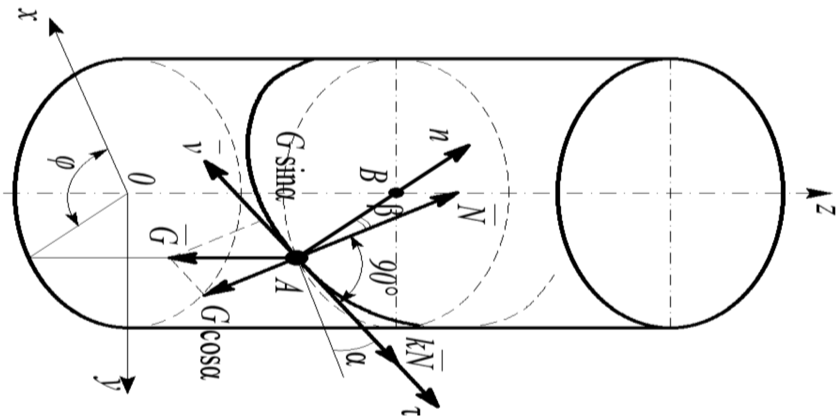


Figure 8. Diagram of the movement of cotton seeds on the mesh surface

We determine the equations using the motion on the mesh surface under the influence of the screw conveyor when separating impurities from cotton seeds.The equation of motion of cotton seeds along the OZ axis is expressed as follows:

$$z = a \cdot \varphi + f(r) \quad (8)$$

The pitch of the screw motion is determined as follows:

$$h = 2 \cdot \pi \cdot a \quad (9)$$

We determine the expression for the dependence of the pitch of the cotton seeds' screw motion $b = 2 \cdot \pi \cdot r_0$ on the screw motion pitch and the conveyor circumferential length.

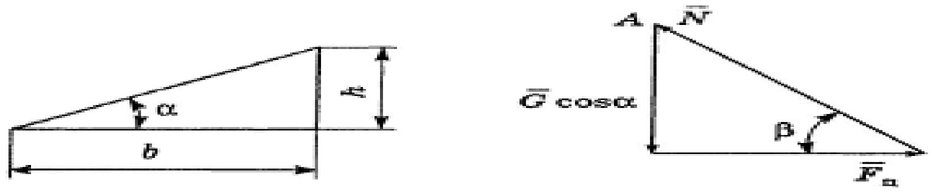


Figure 9. Diagram of the forces acting on cotton seeds along the screw pitch

We express the angle between the screw pitches.

$$tg\alpha = \frac{h}{b} = \frac{a}{r_0} \quad (10)$$

We formulate the differential equation of cotton seed movement in the screw conveyor. The movement of the cotton seed is expressed along the tangential, normal, and binormal axes.

$$\begin{cases} m \cdot \dfrac{d\vartheta}{dt} = G \cdot \sin\alpha - k \cdot N \\ \dfrac{m \cdot \vartheta_\varphi^2}{r_0} = N \cdot \cos\beta \\ G \cdot \cos\alpha = N \cdot \sin\beta \end{cases} \quad (11)$$

The velocity of cotton seeds in screw motion $\vartheta_{\varphi} = \vartheta \cdot \cos\alpha$ And the weight of the seed $G = m \cdot g$ is equal to.

We determine the expression for the dependence of the deviation angle of the seed in screw motion from equation (11) on its mass, velocity, and transmission angles.

$$tg\beta = \frac{m \cdot g \cdot r_0 \cdot \cos\alpha}{m \cdot \vartheta^2 \cos^2\alpha} = \frac{r_0 \cdot g}{\vartheta^2 \cdot \cos\alpha} \qquad (12)$$

From the equation of motion of cotton seeds along the OZ axis, namely $z = a \cdot \varphi + f(r)$ from the expression

$$tg\beta = \frac{1}{f'(r_0) \cdot \cos\alpha} \qquad (13)$$

In that case, expression (12) is transformed into the following form.

$$\vartheta = \sqrt{g \cdot r_0 \cdot f'(r_0)} \qquad (14)$$

By assuming that the velocity of cotton seeds in helical motion remains constant upon impact with the mesh surface, we derive the following equation.

$$m \cdot \vartheta_0 \cdot r_0 \cdot \cos\alpha = m \cdot \vartheta \cdot r_0 \cdot \cos\alpha \quad \Rightarrow \vartheta_0 = \vartheta = const$$

In that case, the following expression from equation (11) will be valid.

$$G \cdot \sin\alpha = k \cdot N \qquad (15)$$

$$\frac{m \cdot \vartheta_{\varphi}^2}{r_0} = N \cdot \cos\beta \qquad (16)$$

(15) and (16) Using the expressions for the dependence of the normal pressure force on the screw surface on the seed mass and the helical deviation angle, analyses were carried out using the Maple software. An increase in normal pressure force leads to the clogging of various impurities in the mesh surface, which reduces the efficiency of cotton seed sorting.

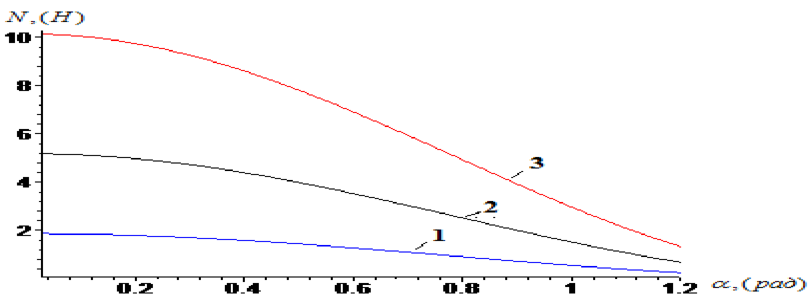


Figure 10. Graph of the relationship between the pressure force on cotton seeds on the screw surface and the coverage angle at different values of the screw's linear speed.
$\vartheta_1 = 8$ м/с $\vartheta_2 = 6$ м/с $\vartheta_3 = 4$ м/с

Conclusion

It can be concluded that increasing productivity requires considering the relationship between bulk density and screw speed. To ensure uniform seed transfer in the screw conveyor, it is essential to maintain an adequate speed. Additionally, the possibility of further improving the screw conveyor design has been identified.

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