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DEVELOPMENT OF A NEW ROTARY FEEDER DESIGN AND BASED FLOW PARAMETERS FOR A SEED FEEDER DEVICE

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Abstract: In the article, the design of the fuzzy seed feeder device is developed. The flow characteristics are determined according to the geometric parameters of the proposed rotary feeder hopper. Graphs showing the interdependence of the numerical values of the obtained parameters were obtained.

Keywords: Feeder, hopper, rotary, spring, trapezoidal disc, rubber, fuzzy seed, flow, hardness, vertical pressure, horizontal pressure, friction, coefficient, shear force, angular velocity, linear velocity, power, efficiency.

Introduction. When designing the structure of the rotary feeder combined with the hopper, it is first of all necessary to determine the value of the load, which is caused by the amount of seed in the hopper, and affects the rotery feeder. To date, a number of empirical formulas are used to develop the structure of the seed rotary feeder [1-4]. In the obtained expressions, the product coming out of the hopper is characterized by a uniform distribution along the outlet surface where the continuous body and rotary feeder are connected. But in practice, the impact of the product in the hopper on the rotary feeder has different values on different surfaces [5,6].

The following factors affect the ratio between the loads acting on the seed feeder and the power driving the device [1]:

- ✓ the nature of the seed flow in the hopper;
- ✓ flowability of the seed;
- ✓ selected hopper shape;
- ✓ precise geometric dimensions of the hopper;
- ✓ friction between the seed and the hopper;
- ✓ feeder rotary and its geometric proportion;
- ✓ of the hopper.

The seed is most effective in the specified amount and reliable supply of seed in the specified amount can be achieved using a combination device of mass flow rotary feeder and hopper. The degree of seed filling of the seed distribution hopper, in turn, is an important factor affecting the feeding process.

Research by Reisner [7] showed that the initial load current in the supply device can be up to 2 ÷ 4 times greater than the load value in the nominal operation. However, studies [1, 2] have shown that the product current load can sometimes increase up to 4 to 8 times.

The dispersed body moving in the hopper mainly forms two types of flow: mass and funnel-shaped flow (Fig. 1). That is, mass flow of objects in the hopper toward the exit hole is characteristic. Mass flow requires that the hopper wall be vertical and sufficiently smooth. If the hopper is highly flat and undulating, then a funnel-shaped flow occurs.

The results of the experimental research show that the flow of seed occurs in the form of a funnel in the hopper, which is used in practice at the vegetable oil production enterprise [8, 9]. This, in turn, means that the constant movement of seed from the hopper to the rotary feeder is not ensured. As can be seen from Figure 1, we can observe that the seed stops in the stagnation zone as a result of the funnel-shaped flow. Today, cotton seed feeder devices are widely used hoppers of the form shown in Figure 2 below.

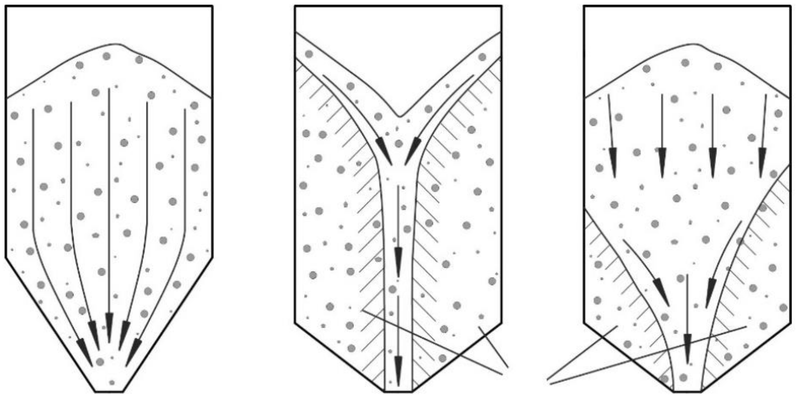


Figure 1. Mass flow (a) and funnel flow (b)

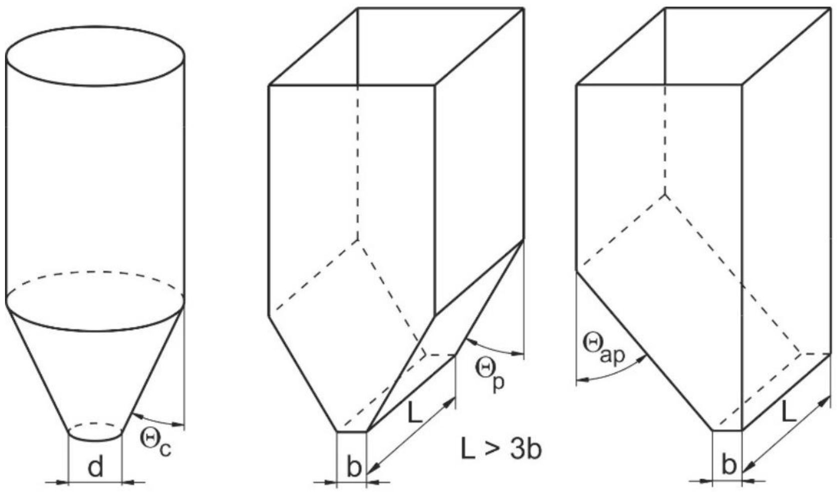
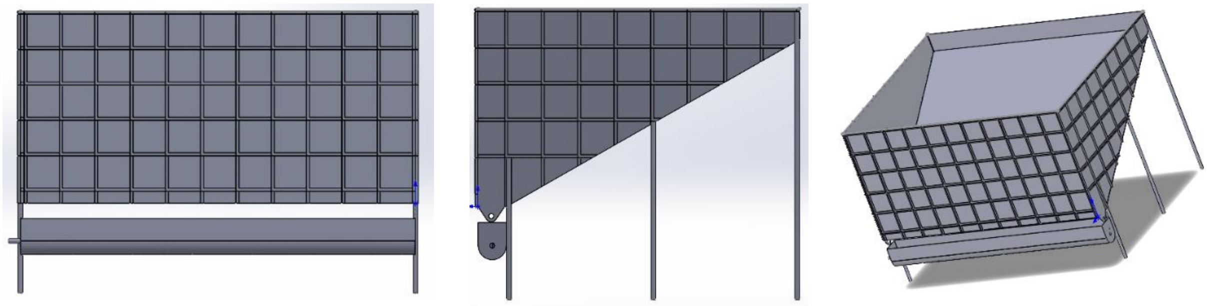


Figure 2. Hoppers main constructive forms.

Work in release take went studies as a result there is to provide device worker in the environment long lifetime observation done increased [8, 9]. The seed hopper inside arched layer harvest is being distributed seed of the amount high difference with he changed to go as a result technological of the system the work product low to be was determined. This while own in turn energy a waste and efficiency indicators to decrease take came. The seed from the hopper to himself typical exit flow, one series main characteristic to factors dependent will be [10-12].

Nonmangantolate in the enterprise being used the seed to provide of the device hopper constructive scheme in Figure 3 given .



a *b* *c*

Figure 3. Cotton seed to provide device hopper . a - profile projection , b - frontal projection , c - three o' - sized scheme

Development of an efficient design of the rotary feeder. A resource-efficient construction of the rotary feeder was developed based on the determination of the specific physical and mechanical properties of cotton varieties grown on a large scale today, as well as on the basis of a deep analysis of the existing hopper structure and the supply process. The main goal of the structural change is to achieve high productivity by ensuring the continuity of the seed flow inside the hopper.

The design of the proposed fuzzy cottonseed feeder shown in Figure 4. Rotary feeder shaft 1, trapezoidal disc 2 and quarter-section rotary parts 3 fixed to it by welding, plates 4 located on the surface of the rotary, rubber stoppers closing the gaps between the rotary parts 3, and trapezoidal rods the spring connecting the centers of gravity consists of 6.

The structure moves in the following order: the movement from the shaft 1 is transmitted through the trapezoidal disc 2 to the plates 4 located on the surface of the rotary 3. The seed layer at the hopper exit hole is cut to a certain thickness by rotary planks 4 and transferred to the next stage by rotary motion. This process is repeated on each of the planks 4 located around the rotary 3. The resistance force resulting from the cutting of the seed layer, in turn, acts on the plate 4, turning it in the opposite direction to the rotation. In turn, the quarter shape of the rotary 3 also deforms the trapezoidal disk 2 by a small amount, opposite to the direction of rotation relative to the shaft 1. This, in turn, causes the springs attached to the trapezoidal disks 2 to stretch one by a small amount, and compress the other one. The energy collected due to the stiffness of the spring 6, in turn, ensures that the planks 4 located on the rotary piece 3 vibrate in a small amount.

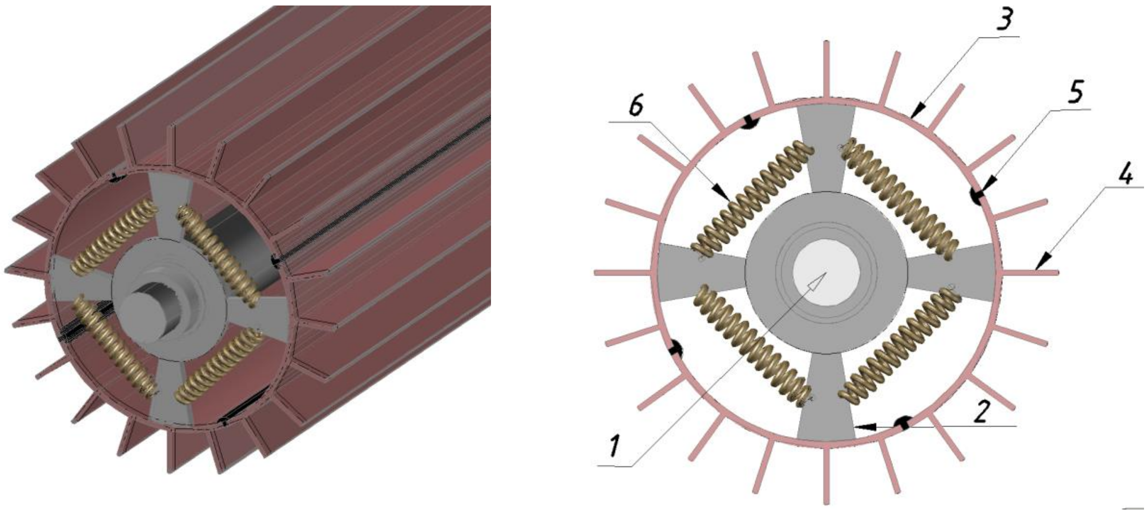


Figure 4. The scheme of the rotary for the supply of fuzzy cottonseed.

As a result of this, there is a vibration of the fuzzy cottonseed layer that is in contact. This increases the efficiency of filling the gaps between rotary 3 and plank 4 with seed. The slits between the rotaries 3 caused by the deformations of the springs 6 are permanently closed by means of rubber 5 glued to them. This, in turn, allows for increased seed supply productivity and uninterrupted system operation.

Determine the possibility of seed transmission of the rotary feeder. The design of the rotary feeder has an important functional impact on the technological system. The fuzzy cottonseed sample under experimental research has an average moisture content of 9.6 %. Based on the flow property tests, this moisture content corresponded to the condition where the cohesive strength of the seed grains was approximately maximum. The critical outlet dimensions required for mass flow were calculated based on the theories of Jenike [2] and Enstad [13, 14] and were much larger in practical results. That's why the construction of the proposed provision was developed to allow additional vibration of the rotary. According to the conducted research and the opinion of engineers with high working experience, in most cases, the condition of seed sticking around the exit hole of the hopper is often observed. Figure 5 shows the directions of pressure forces occurring at the internal points of the hopper filled with seed.

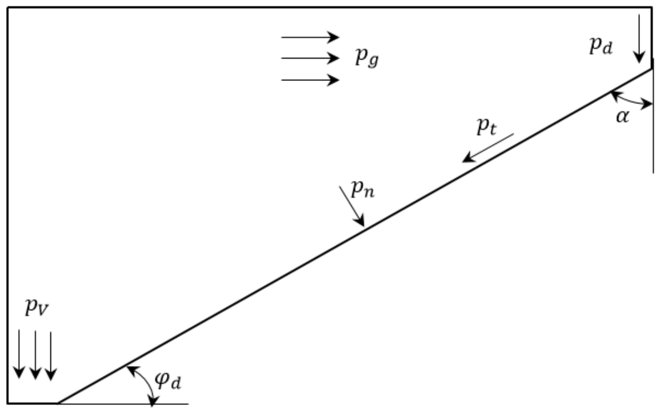


Figure 5. The directions of influence of the pressure occurring at the internal points of the hopper. p_V –vertical pressure occurring at the outlet p_n –of the hopper , normal pressure acting on the wall of the hopper, p_g –horizontal pressure.

The pressure acting on the walls of the hopper p_d is determined by the following expression:

$$p_d = p_V \cdot K, \quad (1)$$

where K – the coefficient of the ratio of normal and vertical pressure in the hopper, $\frac{p_n}{p_V}$; p_V –vertical pressure.

In determining the value of ϕ the ratio of normal and vertical pressure in the hopper K is equal to the internal friction angle of the fuzzy cottonseed and is equivalent to the equilibrium angle of the fuzzy cottonseed. The value of the coefficient of internal friction was obtained in accordance with our experimental studies $\phi = 46°30'$. The K value of is determined by the following expression:

$$K = \frac{1-sin\phi}{1+sin\phi} = tan^2\left(\frac{\pi}{2} - \frac{\phi}{2}\right), \quad (2)$$

Then, for the case we are studying, K= 0.16.

Vertical pressure that occurs in a hopper p_V filled with seed based on the expression proposed by Walker, Walters, Shinohar and Jenike [10, 15-17], we write the value as follows:

$$P_V = \frac{\rho_h \cdot g \cdot A}{\mu \cdot K \cdot C} \cdot \left(1 - \frac{1}{e^{\frac{K \cdot \mu \cdot C \cdot h}{A}}}\right), \quad (3)$$

where is ρ_h –the bulk density of the fuzzy cottonseed, g –the free fall acceleration, A –the cross-sectional area of the hopper, μ –the coefficient of friction of the fuzzy cottonseed on the hopper wall ($tan\varphi_d$), C –the perimeter of the hopper outlet, and h –the height of the hopper.

Based on the numerical solution, we determine the value of the vertical pressure occurring at the outlet hole of the hopper in accordance with the types of seeds. In this case, we obtain the average indicators of the parameters representing the physical and mechanical properties of the investigated seed varieties:

bulk density of fuzzy cottonseed $\rho_h = 469{,}6\,\frac{kg}{m^3}$;

vertical cross-sectional surface of the hopper $A = 5{,}6m \cdot 5m = 28m^2$;

coefficient of friction of fuzzy cottonseed on the hopper wall $\mu = 0{,}3154$;
the perimeter of the hopper outlet $C = 12m$;
hopper height $h = 5m$.
Then the value of the pressure at the outlet of the hopper is as follows:

$$p_V = \frac{469{,}6\frac{kg}{m^3}\cdot 9.81\frac{m}{sek^2}\cdot 28m^2}{0{,}3154\cdot 0{,}16\cdot 12m}\cdot\left(1-\frac{1}{e^{\frac{0{,}16\cdot 0{,}3154\cdot 12m\cdot 5m}{28m^2}}}\right) = 47{,}336kPa.$$

Based on the numerical solution of the obtained expression (3), the dependence graph representing the change of the vertical pressure at the outlet hole of the hopper at different values of the level of fuzzy cottonseed inside the hopper : $h = 1; 2; 3; 4; 5\ m$, $A = 20 \div 35m^2$ the intermediate change of the surface of the vertical section of the hopper is presented in Fig. 6.

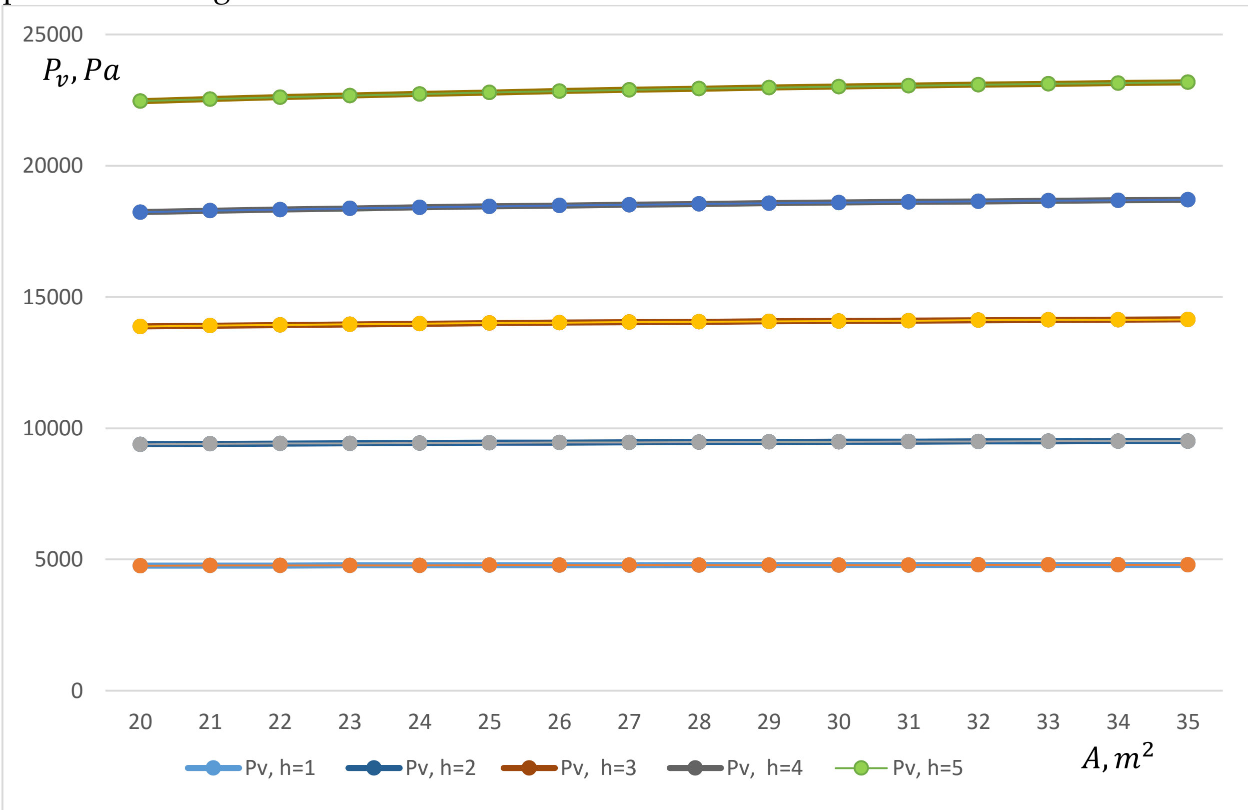


Figure 6. Dependence of the change in the value of the vertical pressure on the surface of the exit hole.

From the graph we can see thatt the value of h the vertical pressure P_v varies by a very small value even at different values of the vertical cross-sectional area of the hopper $A = 20 \div 35m^2$. For example:

$h = 5,\ A = 20m^2,\ P_v = 22{,}462\ kPa;$

$h = 5,\ A = 28m^2,\ P_v = 22{,}939kPa;$

$h = 5,\ A = 35m^2,\ P_v = 23{,}183\ kPa.$

We can see the change of the vertical pressure value at the outlet of the hopper with the increase of the seed level in the hopper through the connection graph presented in Figure 7.

Figure 8 shows the relationship between the value of the vertical pressure in the hole of the hopper P_v and the coefficient of friction of the fuzzy cottonseed on the hopper wall, μ representing the ratio of normal and vertical pressure occurring in the hopper, at different values K. We can see from the graph that an increase in the coefficient of friction between the fuzzy cottonseed and the hopper wall leads to a decrease in the pressure at the hopper outlet. As a result, the rate of seed flow decreases and negatively affects the provisioning process. We can see that the value $K = 0{,}16$ of the coefficient of friction between the hopper and the fuzzy cottonseed under study $\mu = 0{,}3154$is the value of the vertical pressure at the outlet of the hopper 22,96 kPa.

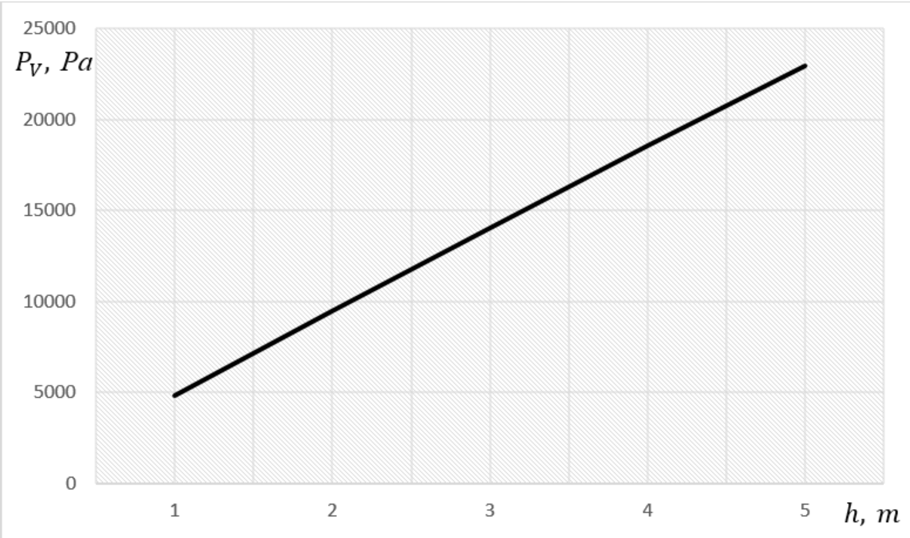


Figure 7. The graph of the dependence of the amount of seed in the hopper on the vertical pressure at the exit hole

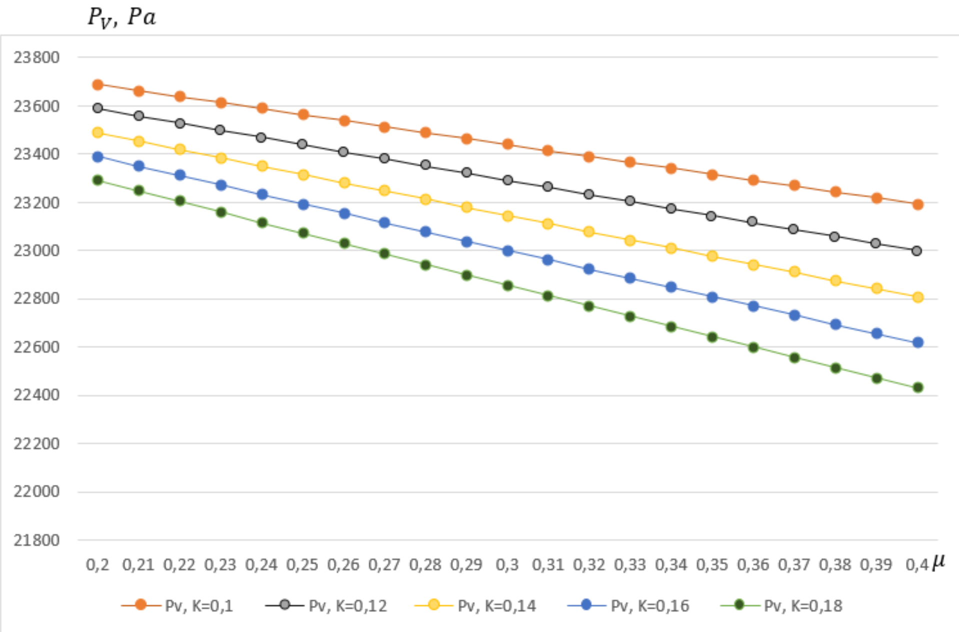


Figure 8. Graphs of the dependence of the coefficient of friction between the hopper and the fuzzy cottonseed on the change of the vertical pressure at the outlet hole of the hopper at different values of K.

From the value of the vertical pressure determined in the expression (3), the pressure acting on the hopper wall P_d can be determined by the following expression [1]:

$$p_d = K \cdot p_V.$$

Based on numerical solutions, the value of the pressure acting on the wall of the studied hopper $p_d = K \cdot p_V = 0{,}16 \cdot 22{,}96 kPa = 3.67\ kPa$is.

Taking into account the vertical pressure at the specified hopper outlet, we determine the load acting on the rotary feeder by the following expression:

$$Q_y = p_V lb, \qquad (4)$$

where hopper outlet length, $l = 5{,}6m$, b –outlet width $b = 0{,}4m$.

the expression (4), we can see the effect of the change in the value of the vertical pressure at the hopper outlet on the value of the load acting on the rotary feeder through the relationship graph shown in Figure 9:

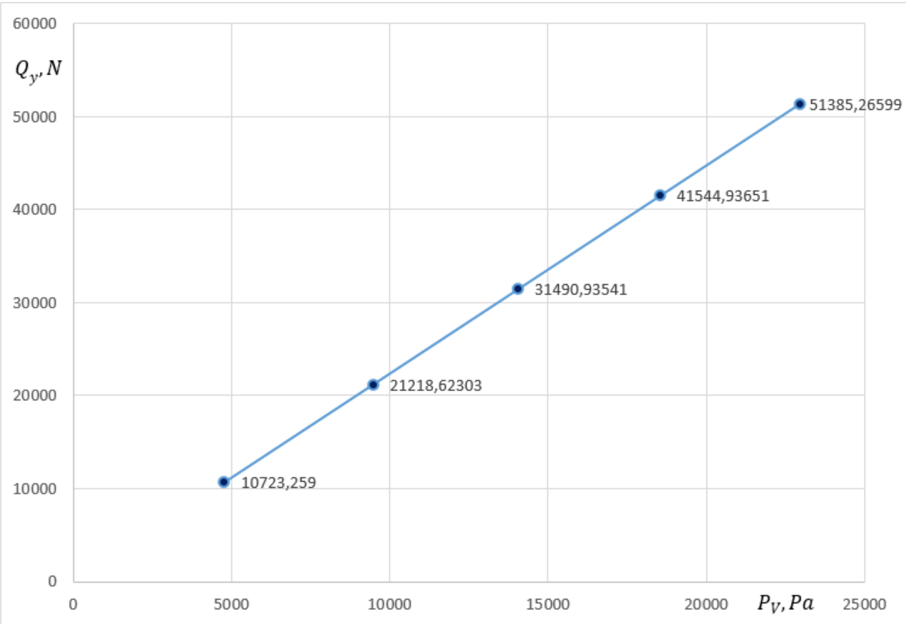


Figure 9. Graph of the dependence of the vertical pressure value occurring at the hopper exit hole on the loading of the rotary feeder at different values of the seed level in the hopper.

$$h = 1 \div 5\ m$$

Taking into account expression (3), expression (4) can be written as follows:

$$Q_y = \frac{\rho_h \cdot g \cdot A}{\mu \cdot K \cdot C} \cdot \left(1 - \frac{1}{e^{\frac{K \cdot \mu \cdot C \cdot h}{A}}}\right) \cdot lb. \qquad (5)$$

the expression (5), we determine the numerical expression of the load value affecting the rotary feeder:

$$Q_y = 22{,}96 kPa \cdot 5{,}6m \cdot 0{,}4m = 51{,}43\ kN.$$

The value of the shearing force of the rotary feeder plates in the hopper exit opening of the fuzzy cottonseed layer is determined by the following expression:

$$F_k = \mu_E \cdot Q_y = \mu_E \cdot \frac{\rho_h \cdot g \cdot A}{\mu \cdot K \cdot C} \cdot \left(1 - \frac{1}{e^{\frac{K \cdot \mu \cdot C \cdot h}{A}}}\right) \cdot lb, \qquad (6)$$

where is μ_E −the equivalent friction coefficient proposed by Reisner [7] $\mu_E = 0{,}4$.

Then the numerical solution of expression (6) is as follows:

$$F_k = \mu_E \cdot Q_y = 0{,}4 \cdot 51{,}43\ kN = 20{,}57\ kN.$$

and the shear force cutting the seed layer at different values of the equivalent friction coefficient proposed by Reisner [7], presented in Figure 10.

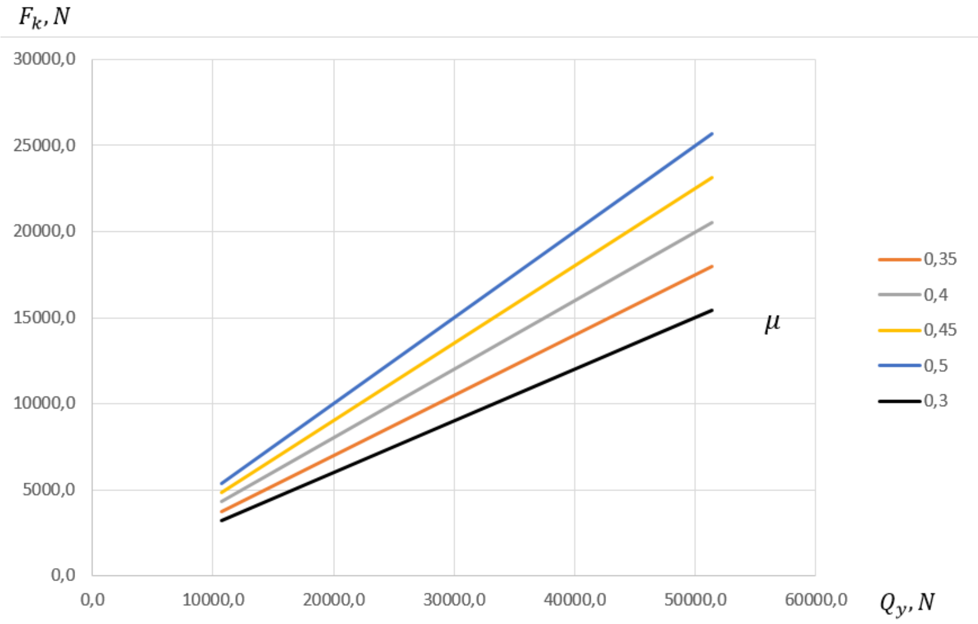


Figure 10. Graphs of the dependence of the value of the load acting on the rotary on the value of the cutting force at different values of the coefficient of friction in cutting the seed proposed by Reisner.

According to the value of the determined seed layer cutting force, it is recommended to determine the power required to move the rotary feeder by the following expression [8,9]:

$$P_f = F_k v_B, \qquad (7)$$

where is v_B −the linear velocity of the rotary feeder m/s.

Taking into account the expression (6), we can write the expression (7) as follows:

$$P_f = \mu_E \cdot Q_y \cdot v_B = \mu_E \cdot \frac{\rho_h \cdot g \cdot A}{\mu \cdot K \cdot C} \cdot \left(1 - \frac{1}{e^{\frac{K \cdot \mu \cdot C \cdot h}{A}}}\right) \cdot lb \cdot v_B \qquad (8)$$

The frequency of rotation of the rotary $n_b = 2\frac{rew}{min}$ and considering that the diameter of the rotary is, the value of its linear velocity is: $d_b = 0{,}4m$

$$v_B = \omega_b \frac{d_b}{2} = \frac{\pi n_b}{30} \cdot \frac{d_b}{2} = \frac{\pi n_b d_b}{60} \qquad (9)$$

Numerical $v_B = 0{,}0419\frac{m}{s}$solution of the expression (9).

In accordance with the expression (7), the graph of the dependence of the rotary speed increase on the power consumption on the rotary shaft is shown below in Figure 2.21, *a*.

We can determine the torque on the rotary shaft by providing the power determined by the expression (8) by the ratio of the angular velocity of the rotary:

$$T_b = F_k \frac{d_b}{2} \text{ or },$$

$$T_b = \frac{P_f}{\omega_b} = \frac{30\mu_E \cdot \frac{\rho_h \cdot g \cdot A}{\mu \cdot K \cdot C} \cdot \left(1 - \frac{1}{e^{\frac{K \cdot \mu \cdot C \cdot h}{A}}}\right) \cdot lb \cdot v_B}{\pi n_b} \quad (10)$$

We can see from Figure 11 that the value of the screw torque changes with the decrease of the amount of seed in the hopper.

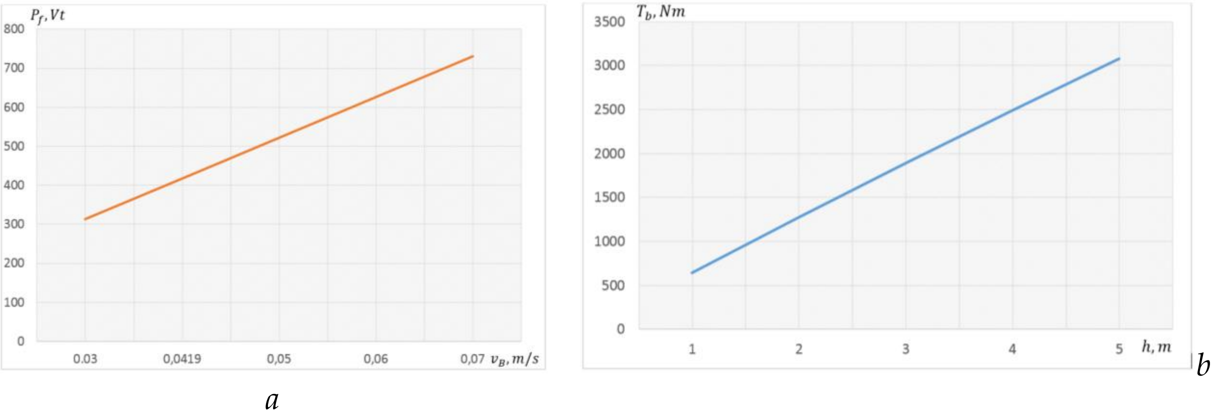


Figure 11. Graphs of the increase in the linear speed value of the rotary as a function of the power on the shaft (a) and the change of the seed level in the hopper as a function of the torque on the shaft.

It was proposed to determine the amount of seed flow from the rotary feeder to the screw conveyor by the following expression:

$$U_{ch} = \rho_h lbHv_B\eta_h \quad (11)$$

here H –is the thickness of the seed flow cut by the rotary plates, m, η_h –is the volumetric useful work coefficient of the seed transmission.

The volumetric useful work coefficient of seed transmission is determined by the following expression:

$$\eta_h = \frac{v_{vint}}{v_B} k_p, \quad (12)$$

where v_{vint} –the linear speed of the screw conveyor conveying the seed from the rotary feeder to the linter device k_p –is a coefficient that takes into account the filling of the plate gap due to the vibration of the proposed spring-loaded rotary.

Taking into account the expression (12), we can write the expression (11) as follows:

$$U_{ch} = \rho_h lbHv_{vint}k_p \quad (13)$$

If we determine the numerical solution $v_{vint} = v_B$ of the expression (13) and its values: $k_p = 0,56$

$$U_{ch} = 469,6\frac{kg}{m^3} \cdot 5,6m \cdot 0,4m \cdot 0,05m \cdot 0,0419\frac{m}{s} \cdot 0,56 \cdot 3600s = \frac{4443kg}{hour}.$$

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