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JUSTIFICATION FOR THE MOVEMENT OF GRANULATED MASS ALONG THE MATRIX CHANNEL OF A GRANULAR FEED PRODUCTION DEVICE

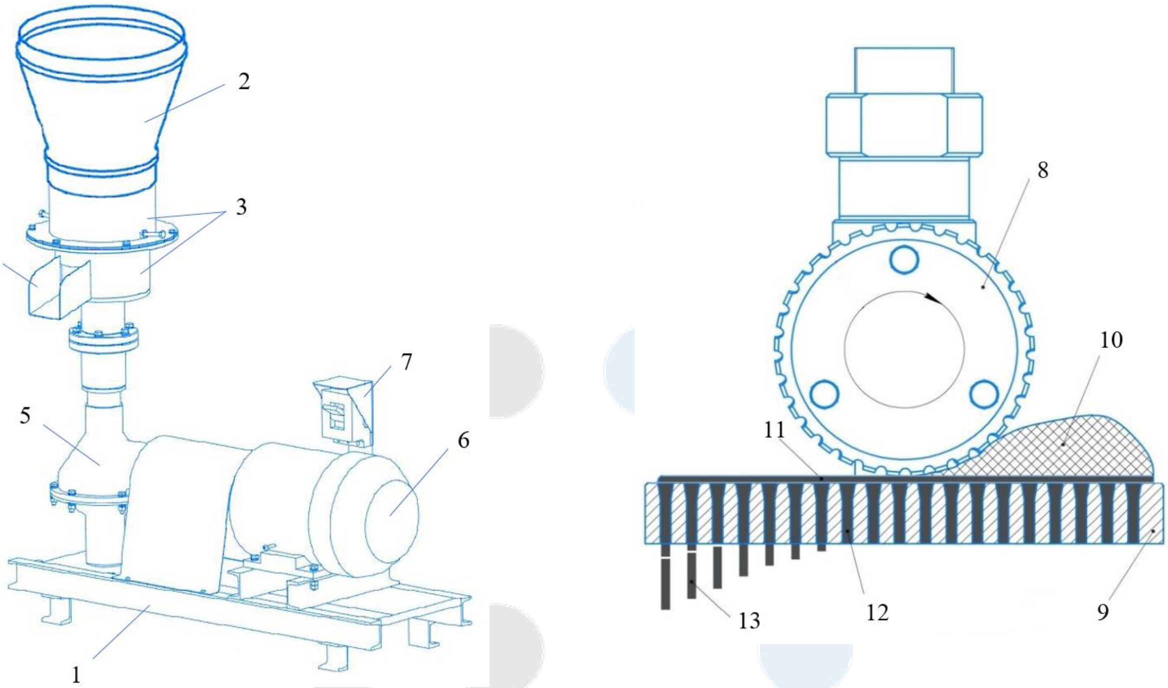
M.M. Ergashev[1], B.SH. G‘aybullayev, V.G‘.Nasrullaev
Scientific-Research Institute of Agricultural Mechanization (SRIAM)

Abstract: The article highlights that the granulating device consists of a frame, a loading hopper, a working chamber, a tray, a gearbox, an electric motor, and a control panel, and presents the results of research to substantiate the movement of the granulated mass along the matrix channel of the granulated feed preparation device. It is noted that the fraction of friction pressure for the forming material is directly proportional to the length of the channel and inversely proportional to its diameter, and the difference between the sealing pressure and the total friction force serves as an indicator of the material's movement intensity along the channel.

Keywords: granulated feed preparation device, sealing roller, matrix, length of the matrix channel, friction force, pressure of the sealing roller on the material layer, friction coefficient, lateral pressure coefficient, pressure on the lateral surface of the material.

Introduction. Today, as the population of our republic grows, the demand for food and meat products is increasing. Therefore, in our country, as in all branches of agriculture, great attention is paid to the development of livestock farms. Furthermore, there is a high demand in our Republic for the development of a universal device for grinding coarse and grain feed, as well as resource-saving devices for preparing granular compound feed for small livestock farms. In addition, in Uzbekistan, attention is paid to the creation of small farms specializing in animal husbandry and the development of energy-saving equipment that performs several technological processes in accordance with agrotechnical requirements to obtain high yields.

Based on the above, and based on the analysis of scientific and technical literature and conducted research, a granulation device design has been developed that allows for the preparation of granulated feed of a specified size and density while ensuring high quality indicators, consisting of a frame 1, a loading hopper 2, a working chamber 3, a chute 4, a gearbox 5, an electric motor 6, and a control panel 7 (Fig. 1). A rotating sealing roller 8 and a matrix 9 are placed inside the working chamber.



1 - frame; 2-loading hopper; 3-working chamber; 4 - tray; 5 - gearbox; 6 - electric motor; 7-control panel; 8-compaction roller; 9 - matrix; 10 - feed mixture; 11-compacted feed mixture; 12-matrix channel filled with compacted feed mixture; 13 – granule

Figure 1. Design diagram and technological process of the device for preparing granulated feed

The operation of the device proceeds as follows. When it is connected to the network, the electric motor 6 and the gearbox 5, as well as subsequent drives, set the roller 8 in motion. At the same time, the required feed mixture is loaded into loading hopper 1. The roller 8 located inside the working chamber is compacted in the channels opened in the matrix 9 due to rotation around the central axis and around its own axis. The feed mixture is compacted into a cylinder in the matrix channel and cut into uniform sizes using special knives. Feed cut to the same size is taken out through tray 4 [1, 2].

By increasing or decreasing the number of knives, it is possible to change the size of the feed being pressed into a cylindrical shape. In addition, by changing the number of revolutions of roller 8, the productivity of the device can be changed.

Materials and Methods. Pressure is applied along the vertical axis to the material located in the matrix channel by the sealing roller. The movement of the material along the channel is hindered by friction forces arising on its lateral surface. As the applied pressure increases, the stresses in the material also increase, which in turn leads to the radial deformation of the material, where an additional increase in lateral pressure and friction force is observed on the lateral surface of the material. That is, the force acting on the material in the inlet section of the channel is balanced by the resultant of the force in the outlet section of the channel and the friction forces distributed along the lateral surface of the material being formed. Material displacement begins only when the axial force is greater than the sum of the friction forces of the material against the surface of the matrix channel. The sealing roller acts cyclically on the matrix channel. Upon the end of the roller's contact with the channel, the axial pressure becomes zero. The material located in the channel tends to increase in size in the axial and diametrical directions under the influence of residual internal stresses. However, the diametrical increase in dimensions is prevented by the channel walls, while axial elongation is prevented by the forces of friction against the lateral surface of the material.

To determine the pressure change along the length of the matrix channel, let us consider the equilibrium conditions of the elementary material layer located in the cylindrical hole of the device matrix, where the channel with length l is divided into two parts with lengths l1 and l2 (Fig. 2).

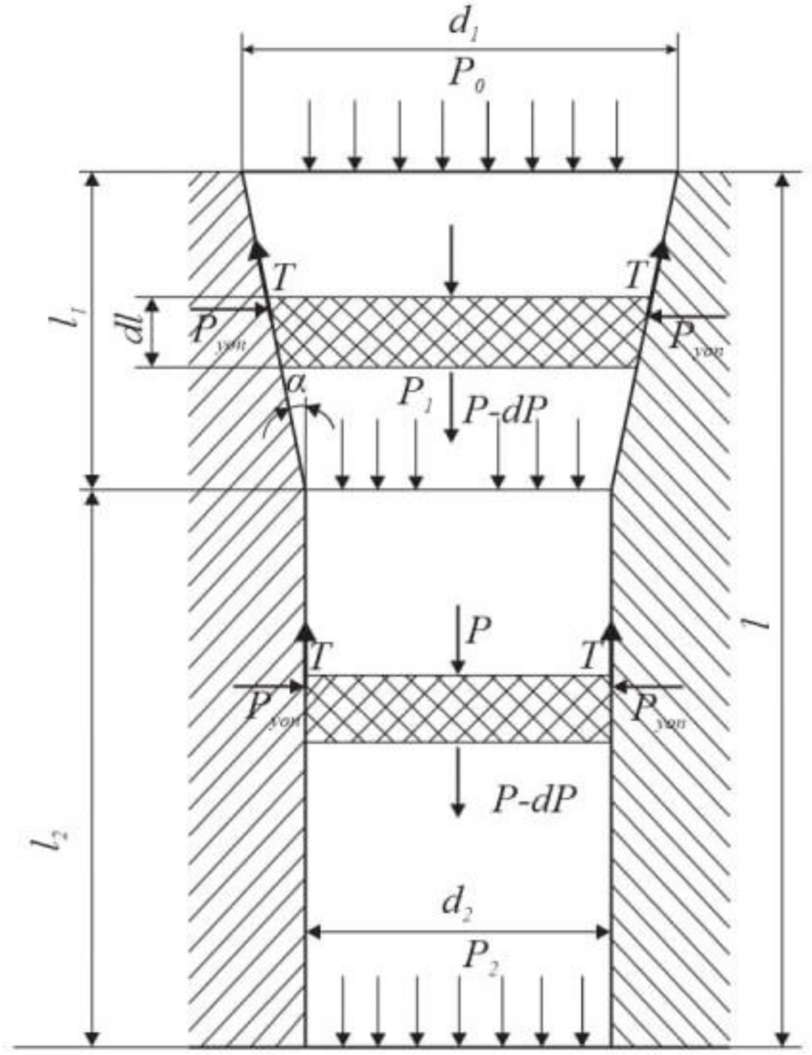


Figure 1. Diagram of forces acting on the material in the matrix channel

Results and Discussion. The friction force and the pressure force of the material on the lateral surface are determined by the following expressions [3, 4].

$$T = \pi \cdot d \cdot P \cdot f \cdot \xi \cdot dl\,, \tag{1}$$

$$P_{yon} = P \cdot \xi\,, \tag{2}$$

where *T* is the friction force N; *d* is the particle diameter, m; *P* is the pressure of the sealing roller on the material layer; Pa; *f* – external friction coefficient ξ – lateral pressure coefficient; P_{yon} is the pressure on the lateral surface of the material, Pa.

The product of the lateral pressure coefficient and the friction coefficient practically does not change along the length of the channel, i.e., we assume it to be a constant value.

For a material element of length dl, let us write the equilibrium conditions for all acting forces in the first section of length l_1. The direction of motion of the material mass is taken as the positive direction of the action of the specific pressure force of compaction. Taking this into account, the equilibrium condition for the first section takes the following form:

$$-\frac{\pi \cdot d_2^2}{4} dP = \pi \cdot \left(d_1 - 2l_1 \cdot \sin\alpha\right) \cdot f \cdot P \cdot \xi \cdot dl \cdot \cos\alpha, \quad (3)$$

where 2α is the conicity angle of the first section, °; d_1 is the channel diameter in the first section, m.

From this

$$-\frac{dP}{P} = \frac{4f \cdot \xi \cdot \cos\alpha}{d_1 - 2l_1 \cdot \sin\alpha} dl \quad (4)$$

By integrating the left side of this equation from P_0 to P_1, and the right side from 0 to l_1, we obtain:

$$P_1 = P_0 \cdot \exp\left(2f \cdot \xi \cdot ctg\alpha \cdot \ln\left(1 - 2\sin\alpha \frac{l_2}{d_1}\right)\right), \quad (5)$$

bunda P_0, P_1, - mos ravishda kirishdagi, birinchi uchastkadan chiqishdagi bosimlar, Pa.

For the second part of the channel

$$-\frac{\pi \cdot d_2^2}{4} dP = \pi \cdot d_1 \cdot P \cdot f \cdot \xi \cdot dl, \quad (6)$$

After the transformation, we get the following

$$-\frac{dP}{P} = \frac{4}{d_1} \cdot f \cdot \xi \cdot dl \quad (7)$$

By integrating the left side of the equation from P_1 to P_2 and the right side from 0 to l_2, we obtain:

$$P_2 = P_1 \cdot \exp\left(-\frac{4}{d_2} \cdot f \cdot \xi \cdot l_2\right) \quad (8)$$

where P_2 is the pressure at the outlet of the second section, Pa. d_2 is the channel diameter in the second section, m.

Taking into account equation (5), equation (8) for determining the pressure along the length of the channel takes the following form:

$$P_2 = P_0 \cdot \exp\left(2f \cdot \xi \cdot ctg\alpha \cdot \ln\left(1 - 2\sin\alpha \frac{l_2}{d_1}\right) - 4f \cdot \xi.\right. \quad (9)$$

Thus, the pressure acting on the forming material changes along the matrix channel according to an exponential law. As seen from the analysis of the given expression, it is advisable to reduce the channel length, friction coefficient, and lateral pressure coefficient to minimum values to reduce pressure losses when passing the material through the matrix channel. Furthermore, we can see that pressure losses increase as the channel diameter decreases.

A necessary condition for material movement along the matrix channel is that the pressure force acting on the material must be greater than the friction force, i.e., the pressure force must be greater than the friction force [5].

$$P_2\frac{\pi\cdot d_2^2}{4}+\left(P_0-P_1\right)\frac{\pi\cdot\left(d_1+d_2\right)^2}{16}>\pi\cdot d_2\cdot P_1\cdot\xi\cdot l_2+$$
$$+\pi\cdot\left(\frac{d_1+d_2}{2}\right)\cdot\left(P_1-P_2\right)\cdot\xi\cdot f\cdot l_1\cdot\cos\alpha \qquad (10)$$

after cuts and changes

$$l<\left(1-\exp\left(2\cdot f\cdot\xi\cdot ctg\alpha\cdot\ln\left(1-2\sin\alpha\frac{l_1}{d_1}\right)\right)\right)\frac{d_1+d_2}{8\cdot\xi\cdot f\cdot\cos\alpha}+\frac{d_2}{4\cdot\xi\cdot f} \qquad (11)$$

The obtained expression is a necessary condition for granulation and indicates the relationship between the geometric dimensions of the matrix channel and the properties of the granulating system. In this case, ξ is related to the magnitude of plastic strength. The product of the lateral pressure coefficient and the friction coefficient does not change along the length of the channel, i.e., it is a constant value. Based on the aforementioned assumptions, the total friction force acting on the lateral surface of the matrix channel can be determined using the following expression.

$$T=F\left(P_0-P_0\cdot e^{-\frac{L}{F}f\cdot\xi\cdot l}\right) \qquad (12)$$

$e^{-\frac{L}{F}f\cdot\xi\cdot l}$ expanding to the Maclaurin series and limiting to its first two terms, we have

$$T\approx P_0\cdot\xi\cdot f\cdot\pi\cdot d\cdot l, \qquad (13)$$

where the product $P_0\xi$ represents the lateral pressure per unit of channel lateral surface area; The product $P_0\xi f$ is the specific friction force; the quantity πdl characterizes the surface area of the matrix channel.

The fraction of pressure exerted by the formed material on the lateral surface of the channel can be determined by the ratio of the pressure exerted on friction to the total vertical pressure, i.e.,

$$\frac{P_0\cdot f\cdot\xi\cdot\pi\cdot d\cdot l}{\frac{\pi\cdot d^2}{4}P_0}=f\cdot\xi\frac{4l}{d} \qquad (14)$$

Consequently, for this forming material, the fraction of friction pressure is directly proportional to the length of the channel and inversely proportional to its diameter. The difference between the sealing pressure and the total friction force can serve as an indicator of the material's movement intensity along the channel. In this case, the following condition must be met:

$$P_0 \frac{\pi \cdot d^2}{4}\left(1-\frac{4f \cdot \xi \cdot l}{d}\right) > 0 \tag{15}$$

The greater the deviation of this value from zero, the faster the material moves in the channel.

The coefficient of friction of the forming material against the channel wall depends on the speed of the material's movement along the channel. Experiments show that the velocity of material movement along the end channels of the matrix is significantly higher, which is explained by the high rate of load application. Under these conditions, the formation of less effective viscosity leads to the release of a portion of the liquid phase. This liquid phase acts as a lubricant as the material moves along the matrix channel. Consequently, the friction coefficient in the peripheral channels decreases not only due to the high speed of movement but also due to the amount of liquid phase in the system, which plays a lubricating role.

Conclusion

1. For the forming material, the fraction of friction pressure is directly proportional to the length of the channel and inversely proportional to its diameter.
2. The difference between the sealing pressure and the total friction force serves as an indicator of the material's movement intensity along the channel.

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