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Substantiation Of Seed Disc Construction For Sowing Seeds.

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ABSTRACT

Showing the necessity to change mechanical seeders design for seeders when sowing seeds of melons and vegetables, including the most common GAMMA seeder. The conditions for seed entering into the mesh of the sowing disk, the length of the mesh, and the parameters of the input and output chamfers are theoretically justified.

Keywords: seeds, seeder, sowing disks, disk mesh, mesh parameters.

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INTRODUCTION

Due to their biological diversity, the seeds of vegetable crops (including melons) are characterized by an extended period of germination, different growth force and reaction to unfavorable growing conditions. As a result, plants develop unevenly, which leads to a decrease in yield.

With intensive use of land, the size and quality of the crop of vegetable crops directly depend on the optimal density of plant standing: both increased and sparse density leads to a decrease in yield. Therefore, at the present stage of development of vegetable growing and melon growing, the quality of sowing is given special importance.

For sowing melons, can recommend a seeder with a mechanical sowing device GAMMA (Figure 1).

Figure 1: General view of the GAMMA seeder for the cultivation of tilled crops with a mechanical seeder

This seeder consists of six sowing units 1, a traction apparatus 2, gears and distributions, two-disc markers 3, support wheels 4 and frame 5.

Each sowing section consists of a seed can, a sowing device, a vomer, a rolling wheel, drive mechanisms for the sowing apparatus, and a parallelogram suspension to the mainframe

Depending on the width of the rows, the number of sections may vary. At the same time, the working width of the machine also changes, equal to the product of the number of sections by the width of the rows. So, for example, 6, 4, 3 and 2 sections are installed on the GAMMA seeder for seeding with 70, 105, 140 and 210 cm rows. The width of the seeder picking at these rows is 4.2 m. When sowing with 60, 90, 120 and 180 cm inter-row spacing and the same number of sections, the seeding width of the seeder is 3.6 m.

During the work of the seed drill with nesting, the sowing disks of the apparatuses located on the bottom of the seed cans rotate and the seeds fill the disc cells. The cells are located on the periphery of the disks, and one cell receives one grain. Superfluous and incorrectly laid seeds are cleaned by reflectors. From the disc cells, the seeds fall to the opening in the bottom of the apparatus and are ejected into the opener body (Figure 2).

Depending on the type of sown seeds, a seeding disk with a certain number and diameter of holes is selected. The coulter is a two-disk seeder with a copying wheel, which sets the depth of seeding. Consequently, a certain role in the quality of sowing seeds, especially melons, belongs to the design of the sowing disk sowing disk, which necessitates their further improvement.

Considering that the quality of seed sowing is mainly related to the shape and parameters of the disc sowing discs, our studies mainly used methods of theoretical justification of the conditions of seed capture, their entry into the mesh and the force interaction between the seed and the mesh edge, and between adjacent seeds. The classical laws of mechanics and dynamics of bulk materials are used [1, 5].

Figure 2: Double disc coulter with replacing a wheel

MATERIALS AND METHODS

The quality of sowing of seeds of vegetable and melon crops depends to a large extent on the dimensional characteristics of the cell of the sowing disk. To determine the size of the cells filled with seeds, consider the scheme of the movement of one seed as a particle on the disk before entering the mesh (Figure 3).

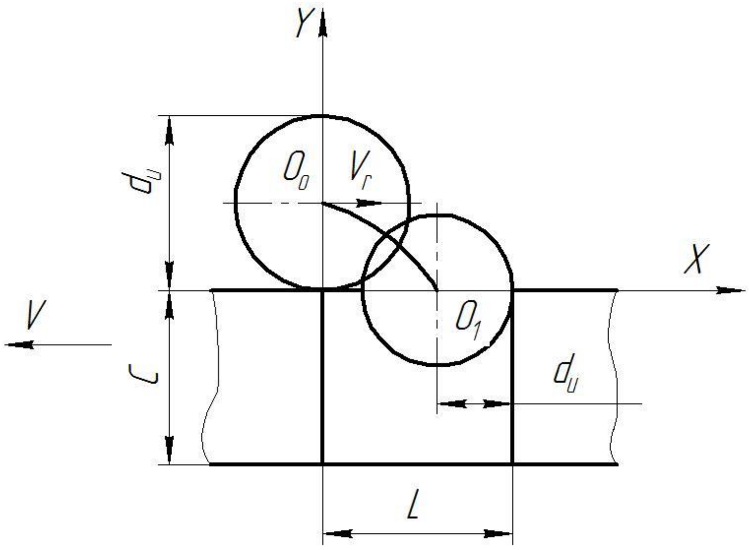

Figure 3: Scheme of motion of a particle on the disk before entering into mesh

Before entering the cell, the particle moves horizontally with a relative velocity V_r, which is less than the velocity of the disk V. When the leading edge of the cell passes under the centers O_0 of the particle, the particle begins a complex motion: uniformly horizontal and uniformly accelerated vertically under the action of gravity.

The motion of a particle, in this case, can be described by a system of equations:

$$\begin{cases} X = V_r \cdot t \\ Y = \dfrac{d_u}{2} - \dfrac{g \cdot t^2}{2} \end{cases} \quad (1)$$

The process of sinking the particle into the mesh of the disk occurs in a manner analogous to that of the body through the opening of the sieve. It is known that in flat sieves the spherical body occupies a stable position in the moving hole if its center of gravity is not higher than the upper plane of the sieve [1].

In the case under consideration, the particle will take a stable position in the disk, if during the flight t it descends by an amount $dY / 2$ earlier than moves horizontally *(X)* by the value $(L - \xi \cdot d_Y)$ [2]. Then expression (1) takes the form:

$$\begin{cases} L - \xi \cdot d_Y = V_r \cdot t \\ \dfrac{d_u}{2} = \dfrac{g \cdot t^2}{2} \end{cases} . \quad (2)$$

Define the length of the mesh from equation (2)

$$L = V_r \sqrt{\frac{d_u}{g}} + \xi \cdot d_Y , \quad (3)$$

V_r -relative velocity of particle motion along the disk, m/s;

ξ - coefficient characterizing the position of the center of gravity of the particle;

d_u - conditional particle diameter, m.

According to the dependence (3), the length of the disc cell is a variable, depending mainly on the relative velocity of particles along the disk and their dimensions: even a small increase in the rotational speed of the disk leads to a deterioration in the occupancy of the cells by particles [3]. Exceeding the same length of cells from the optimal value breaks the frequency of the supply of mice by one particle, and the cases of feeding two or more particles per mesh increase.

Consequently, it is necessary to justify the shape of the working element of the disk so that the gripping ability of the cell within certain limits of the change in the rotation speed of the disk is preserved. For this purpose, a shallow, somewhat elongated input chamfer in the form of a flat inclined pre-depression path is formed above the front wall of the cell. Due to this, the distance between the center of gravity of the particle and the surface of the disk is less than the front edge of the cell, rather than without a chamfer, and some velocity of vertical movement of the particle appears in the cell. Because of this, it takes less time to lower the center of gravity of the particle in the mesh, and the particle will take a stable position in it before touching its trailing edge.

Thus, the lower the center of gravity of the particle is relative to the surface of the disk and the higher the velocity of its movement in the vertical direction, the better the capturing capacity of the cells.

RESULTS AND DISCUSSION

The trajectory of the displacement of the center of gravity of a particle with the velocity of free fall is described by a parabolic dependence. The chamber must be spaced from the trajectory of the motion of the center of gravity of the particle at a distance of its radius [4]. When working in the given speed mode of the sowing disk, the cell with a chamfer of the similar profile can theoretically be considered as increased by the length of the chamber, but, on the other hand, such a cell with a maximum facet can capture more than one particle and contribute either to a pinch of the upper particle between the reflector and the lower particle, followed by damage to one of them, or by feeding two particles simultaneously into the vomer.

To avoid this phenomenon, it is necessary to reduce the depth of the cell and its length, shifting the profile of the maximum chamfer to the side of the cell. The displacement of the profile must be continued until the upper particle, relying on the lower particle and on the profile of the chamber, is not deepened to such an extent that it will certainly be scraped off the cell by the reflector of excess seeds without damaging one of them. Therefore, it is necessary to determine the maximum possible immersion in the cell of the second particle, simultaneously leaning on the lower particle and the profile of the chamfer from the condition of not pinching the top.

It is known that the angle of pinching of a particle must be greater than or equal to the total frictional angles of its o upper and lower surfaces [5].

$$\alpha \geq \varphi_1 + \varphi_2 \quad (4)$$

φ_1 – angle of friction of the upper seed on the reflector;

φ_2 - angle of friction of the upper seed on the lower seed.

Consider the scheme of pinching a particle by a reflector and another (lower) particle (Figure 4).

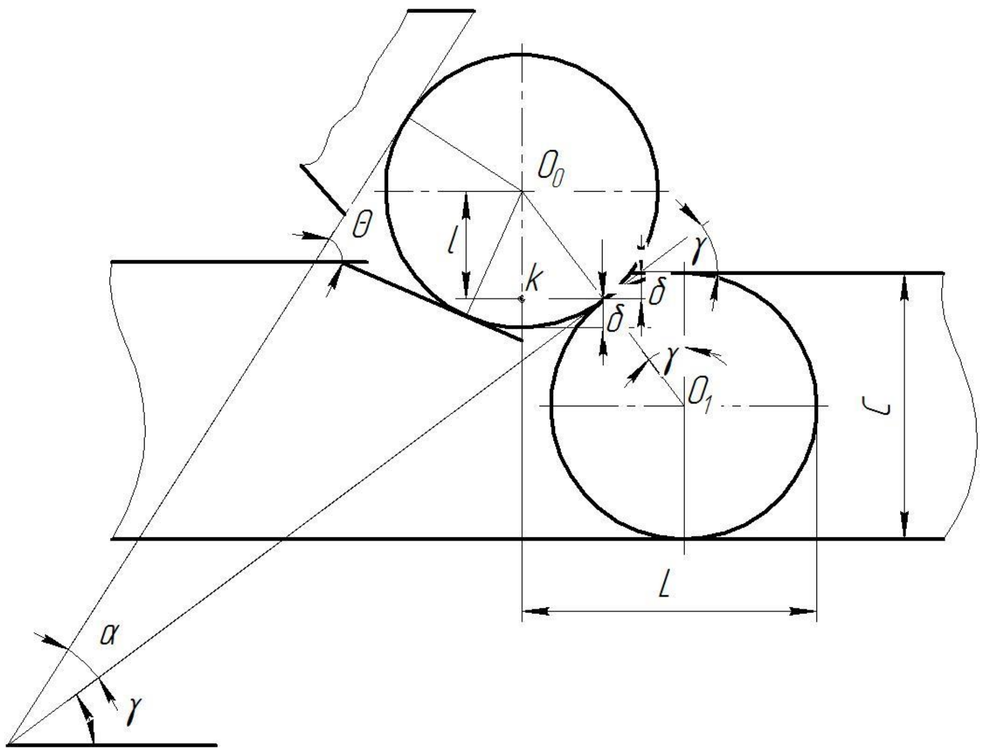

Figure 4: Scheme of pinching a particle by a reflector and another lower particle

Denote the maximum permissible value of the immersion of the upper particle in the cell $2 \cdot \delta$ and determine its value, referring to Figure 4:

$$\delta = \frac{d_u}{2} - l \quad , \quad (5)$$

l- distance *(O₀ K)* from the center of mass of the upper particle to the projection to the vertical axis of the point of contact with the lower particle.

The distance *l* is determined from a right triangle

$$l = \frac{d_u}{2} \cdot \cos\gamma \quad (6)$$

Therefore

$$\delta = \frac{d_u}{2}(1 - \cos\gamma) \quad (7)$$

γ-the angle between the tangent passing through the point of contact between the upper and lower seeds and the surface of the disk, deg.

Given that $\gamma = \theta - \alpha$ we obtain:

$$\delta = \frac{d_u}{2}\left[1 - \cos(\theta - \alpha)\right] \quad (8)$$

θ- angle between the plane of the reflector and the surface of the disk, deg.

Substituting into the equation 8 the value of the angle α from expression 4, we obtain

$$\delta = \frac{d_u}{2}\left[1 - \cos(\theta - \varphi_1 - \varphi_2)\right] \quad (9)$$

By adopting the chamfer depth value $h_f = 2\delta$, we obtain

$$h_f = d_u\left[1 - \cos(\theta - \varphi_1 - \varphi_2)\right] \quad 10)$$

Let us further define, at this depth of immersion, the length of the input chamfer, taking into account the movement of the seed into the mesh along the parabola. During the time *t* of particle movement from the beginning of the chamfer to the leading edge of the cell (Figure 5), it will move:

- in the vertical direction *Y:*

$$h_f = \frac{g \cdot t^2}{2} \quad (11)$$

- in the horizontal direction *X:*

$$V_r \cdot t = l_f + \frac{d_u}{2} \cdot \cos\left(arctg \frac{V_r}{V_0} \right) \quad (12)$$

l_f - length of the entrance chamfer, m;
V_0 - velocity of vertical movement of a particle in a mesh, m/s.

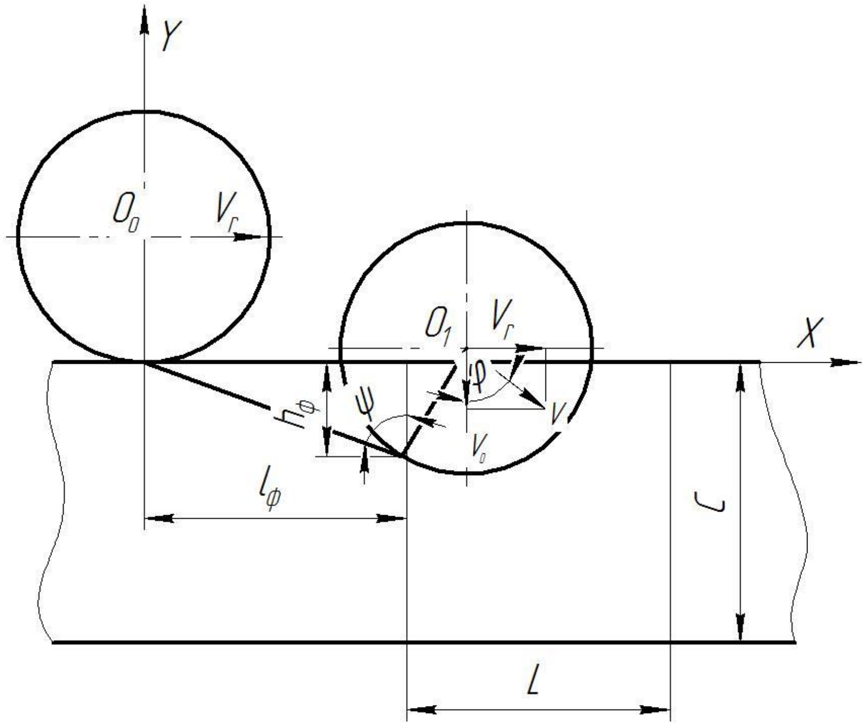

Figure 5: Scheme of the motion of the particle along the input face of the sowing disk cell

Moreover, the quantity V_0 can be defined as

$$V_0 = \sqrt{\frac{h_f \cdot g}{2}} \quad (13)$$

From equation (11) we obtain that

$$t = \sqrt{\frac{2 \cdot h_f}{g}} \quad (14)$$

and from equation (13) with allowance for (14) we have that

$$l_f = V_r \cdot \sqrt{\frac{2 \cdot h_f}{g}} - \frac{d_u}{2} \cdot \cos\left(arctg \frac{V_r}{V_0} \right) \quad (15)$$

The velocity of the vertical movement of the particle into the mesh of the disk:

$$V_0 = \sqrt{\frac{h_f \cdot g}{2}} \quad (16)$$

To determine the relative velocity of a particle's motion along a disk V_r, Let us consider the forces acting on the particle by mass *m* (Figure 6):

G - force of gravity, *N*;
F_1 - the force of gravity, the force of horizontal pressure on the particle, created by the vertical force of the overlying layers, *N*;
F_2 - the friction force of the particle against the wall of the sowing apparatus, *N*;
F_3 - frictional force of the particle o overlying layers, *N*;
F_4 - particle friction force on the side of the seed layer, *N*;
- force of horizontal pressure on the particle, created by the centrifugal force of inertia, *N*;
- force of horizontal pressure on a particle created by the Coriolis force of inertia, *N*;
P_{cf} - compressive force acting on the side of the overlying layers and directed to the line for packing the particles, *N*;
R_w - force of reaction of the can wall, *N*;
- reaction force of a disk, *N*.

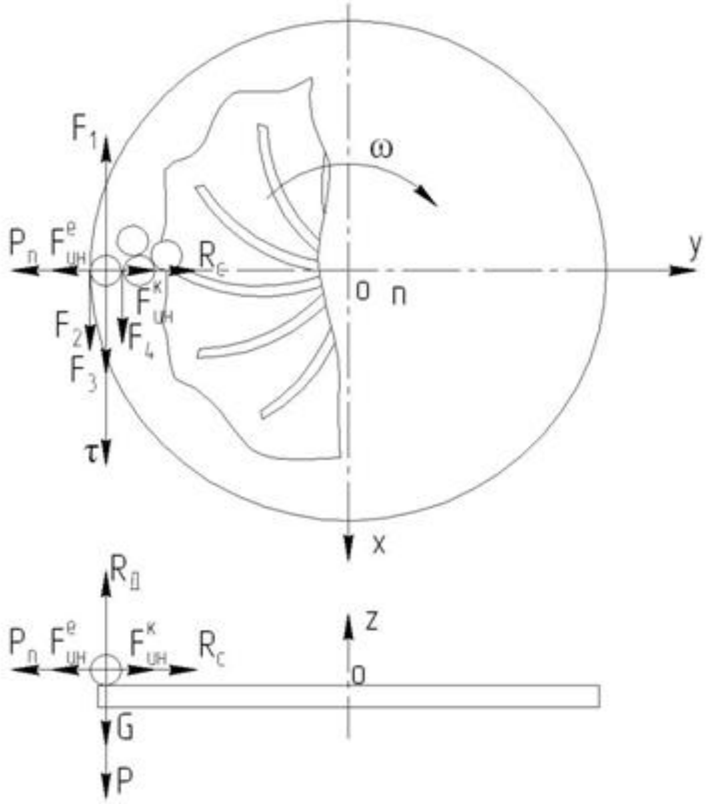

Figure 6: The scheme of forces acting on the particle, located on the sowing disk and moving in the mass of particles

According to the design scheme, we will compose the equations of equilibrium of forces in the coordinate axes *τ* and *n*:

$$\begin{cases} m_r^{\tau} = F_2 + F_3 + F_4 + F_1 \\ m_r^{n} = R_w + F_{if}^{k} - F_{if}^{e} - P_n \end{cases} \tag{17}$$

The resulting vertical *P* and horizontal P_n components determine the compressive force P_{cf} acting on the side of the overlying layers and directed to the line of packing of the particles.

Strength values F_1, F_2, F_3, F_4. and the dependence for determining the relative velocity of seed movement over the disk is set forth in [6], according to which

$$V_r = \frac{\omega}{2} \cdot \left(R - \frac{d_u}{2} \right) - \frac{g \cdot f_1}{2 \cdot \omega \cdot f_2} + \frac{\pi \cdot \gamma \cdot g \cdot d_u^3 \cdot cos\beta}{m \cdot \omega \cdot f_2} \left(\left(f_2 + f_3 \right) \cdot tg\beta + f_3 - f_1 \right)$$

According to the received data, it is possible to determine the optimal dimensions of the input chamfer and it is possible to build its profile.

However, in the process of filling the disc cells, partial immersion in the filled cell of the upper seed can occur not only at the front wall of the cell but also at the posterior wall of the cell. In this case, the upper seed may be trapped between the trailing edge of the cell wall and the reflector.

When sliding along the disc and filled cells, the edge of the reflector's tooth should move the seeds protruding from the cells relative to the disk in the direction opposite to its rotation without damaging the latter. To do this, short, low output chamfers are made on their back walls.

Considering that when the seed meets a fixed reflector, its relative velocity becomes zero, consider the interaction of a partially immersed seed in a filled cell and located between the reflector and the back wall of the cell (Figure 7). The forces on the upper seed at the points of tangency [6] are:

- frictional force about the chamfer of the disk, *N*;
- frictional force against the side wall of the can, *N*;
- frictional force on adjacent particles, *N*;
- frictional force against reflector surface, *N*;
-force reaction output chamfer, *N*;
-reflector pressure, *N*;
- compressive force of overlying layers, *N*;

and – vertical and horizontal components of the compressive force of the overlying layers, *N*;
- force of reaction of the can wall, *N*.

From the condition of equilibrium of the seed, which is at the moment of reflection in the output facet, we find:

axial projection of forces *X:* $\sum X = 0$:

$$N_2 - N_1 \cdot cos(\theta - \gamma') - F_1 \cdot sin(\theta - \gamma') - (F_2 + F_3) \cdot sin(\theta - \gamma') - \\ - P_N \cdot sin\theta + P \cdot cos\theta = 0 \quad (18)$$

axial projection of forces *Y:* $\sum Y = 0$:

$$N_1 \cdot sin(\theta - \gamma') - F_4 - F_1 \cdot cos(\theta - \gamma') - (F_2 + F_3) \cdot sin(\theta - \gamma') - \\ - P_N \cdot cos\theta - P \cdot sin\theta = 0 \quad (19)$$

moment of forces relative to the point O: $\sum M = 0$:

$$F_1 \cdot \frac{d_u}{2} - F_4 \cdot \frac{d_u}{4} = 0 \quad (20)$$

According to formula (19), the condition for reflection of a particle without damage is

$$F_1 \le \frac{N_1 \cdot sin(\theta-\gamma') - F_4 - (F_2+F_3)\cdot sin(\theta-\gamma') - P_N \cdot cos\theta - P\cdot sin\theta}{cos(\theta-\gamma')},$$

(21)

γ' - angle of incline of the output chamfer to the surface of the disk, deg.

From Fig. 7 we have that $F_1 = F_4$, then $N_1 \cdot f_1 = N_4 \cdot f_4$, $F_2 = P_N \cdot f_2$, and $F_3 = P_N \cdot f_3$. Then amount P_N find out from the equation (18):

$$P_N = \frac{N_1\left[\frac{f_1}{f_4} - cos(\theta-\gamma') - f_1 \cdot sin(\theta-\gamma')\right]}{(f_2+f_3)\cdot sin(\theta-\gamma') + sin\theta - ctg\beta\cdot cos\theta}, \quad (22)$$

Then obtain:

$$F_1 \le tg(\theta-\gamma') - \frac{f_1}{cos(\theta-\gamma')} -$$
$$-\frac{\left[\frac{f_1}{f_4} - cos(\theta-\gamma') - f_1 sin(\theta-\gamma')\right]\cdot\left[(f_2+f_3)cos(\theta-\gamma') + cos\theta - ctg\beta\cdot sin\theta\right]}{\left[(f_2+f_3)sin(\theta-\gamma') + sin\theta - ctg\beta\cdot cos\theta\right]\cdot cos(\theta-\gamma')},$$

(23)

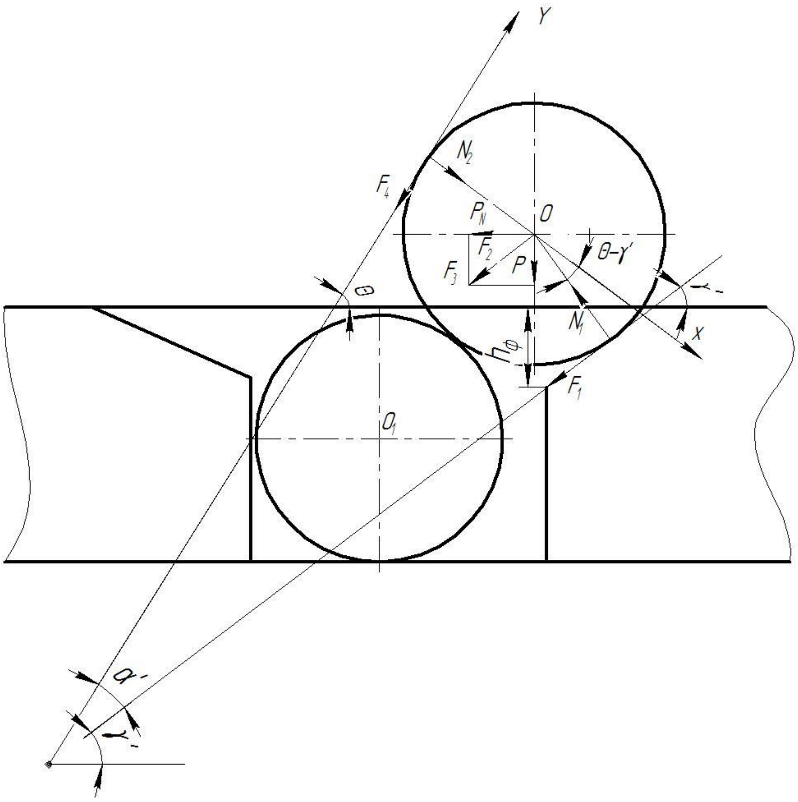

Figure 7: Scheme of the movement of the particle along the output face of the sowing disk

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CONCLUSIONS

Angle of output chamfer γ' ensures seed reflection without damage in accordance with equation 23, which is not analytically solved with respect to this angle. Its values are determined with the aid of a computer for fixed values of the coefficients of friction f_1, f_2, f_3, f_4 and angle β in accordance with the physical and mechanical properties of the seeds. As a result of calculations the values of the angle of inclination of the output chamfer γ' depending on the angle of inclination of the reflector θ within the limits of its change from 50 to 60°:

Table 1: Angle of inclination of the output chamfer γ' depending on the angle of inclination of the reflector θ within the limits of its change from 50 to 60°

θ, deg	50	52	54	56	58	60
γ', deg	12,8	12,7	12,6	12,8	13,1	13,6

Taking further the height of the output chamfer equal to the height of the entrance chamfer of the cell, and the value of the angle of incidence of the output chamfer, equal to 13 °, it is possible to construct the optimal profile of the outgoing chamfer [7].

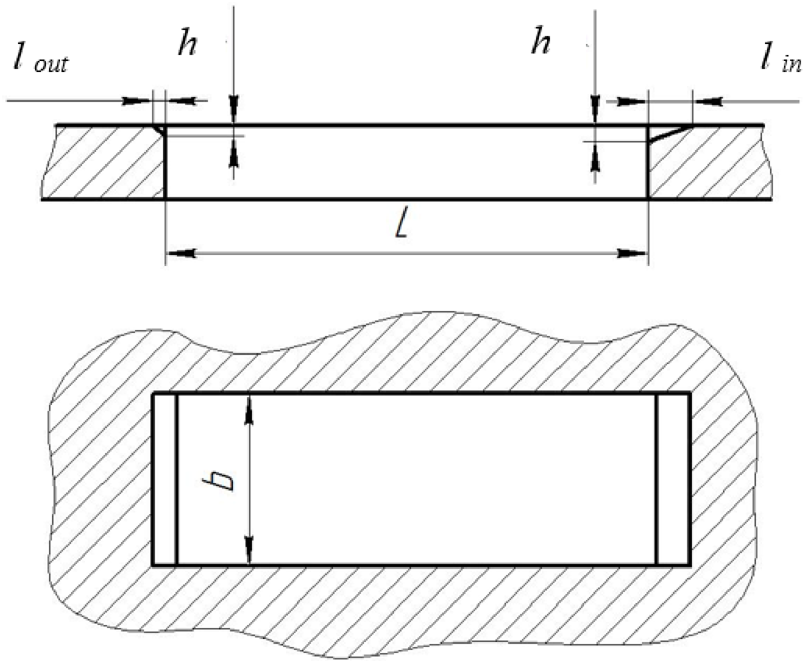

Figure 8: Scheme of the mesh the sowing disk with input and output chamfers for sowing the seeds of watermelons

Figure 8 shows a diagram of the cell of the sowing disk, for example, for sowing seeds of melons with optimal dimensions along the length, width, and depth of the mesh, designed taking into account the dependencies obtained.

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