Studying The Movement Of Seeds Of Onion When Discharging From The Sowing Unit According To The Theoretical Method

Turdaliev Voxidjon Maxsudovich, Makhkamov Gulomjon Usmonjonovich, Komilov Sahob Rasuljonovich, Razoqov Alisher Yakubjonovich

Abstract : One of the most important issues of sowing small-seeded crops (in the example of onions) is considered. The method of sowing has a great influence on crop yields. The choice of planting method is due to the need for a more uniform distribution of plants over the field area in order to optimize the conditions for their development. Studying the movement of seeds during the sowing process is the most important task. Because, the object of sowing is the seeds. The article provides an analysis of previous work on the precision sowing of small seed crops. And also, the flight and the trajectory of the seeds from the ejection window to the bottom of the groove were studied theoretically. In the research, methods of higher mathematics, classical mechanics, and impact theory were used in which it was possible to obtain the necessary equation. Based on the numerical solution of the obtained equation, graphs are constructed that determine the trajectory of falling onion seeds when ejected from the sowing apparatus and the graphical dependence of the recovery coefficient on the height of the sowing apparatus. And also installed, the installation height of the metering unit

Keywords : Seeds, onions, movements, equations, speed, trajectory of a small-seeded crop, sowing apparatus, impact, fall, rebound, angle

1. INTRODUCTION

The main task of improving the processes and working bodies of agricultural machines is to increase crop yields [1, 2, 3]. Sowing seeds is the most important stage in the cultivation of crops. Sowing should provide the most favorable condition for seed germination and further development, which helps to increase field germination and crop yields. However, in the field it is difficult to provide piece crops and determine the seeding of small-seeded vegetables. Seeds with an average diameter of less than 3 mm, including most seeds of vegetables, flowers and canola, such as tomatoes, peppers, radishes, carrots and other seeds of vegetables, with flat and fleecy surfaces. Therefore, it is difficult to develop an accurate seeder for small seeded crops. In accordance with agricultural requirements, accurate sowing can provide the most rational distribution of seeds in the field [4]. Optimal plant development requires an optimal planting area for each individual plant. The accuracy of sowing seeds, a uniform distance between plants, the same depth of sowing and the best conditions for the growth and development of seeds can save a lot of seeds and ensure a stable crop and high crop yield [5, 6]. The work shows that the correct seeding rate per unit area is vital for productivity. In order to evaluate the desired seeding rate, the number of seeds dropped must be monitored in real time. A seed quantity sensor has been developed that allows small seeds to pass stably through a ray of light. The developed sensor can be used for accurate and reliable control of the number of seeds for the precise sowing of small seeds [7].

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In the literature, the influence of various factors on the uniformity of sowing is considered. It was found that a seed drop height of 8 mm invariably provides a better sowing structure than a drop height of 15 mm with an accurate vacuum seeder. They recommended that the metering device on the seeder be located as low as possible, and that the seeds fall freely to the bottom of the soil trench. They stated that the variability of the distance between the seeds with the help of a precision vacuum seeder increases with increasing forward speed. They found that a forward speed of 1 m / s provides a better sowing structure than 1.5 and 2.0 m/s for accurate sowing of melon and cucumber seeds [8].

2 RESEARCH METHODS.

According to the analysis of the study, the following can be attributed to the main factors influencing the uniformity of seed distribution:

- quality of dosing of seeds by the sowing apparatus;
- the stability of the flight time and the path of the seeds from the exhaust window to the bottom of the groove;
- redistribution of seeds after hitting the soil.

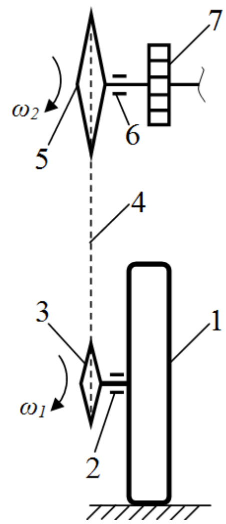
In studies, much attention is paid to the justification of the pinch angle and the place of the ejector, since the crushing of seeds depends on these parameters, speed and direction of flight. In the cells of a mechanical sowing device, the seeds are placed freely and they can be ejected without an ejector. There is a significant difference in the trajectories and flight speeds of seeds ejected by the ejector and released freely. According to the analysis of studies, it is possible to proceed with free unloading of the cells, in which the negative influence of the ejector on the flight path of the seeds is eliminated and their crushing is reduced. Based on the above, we studied theoretically the flight and the path of the seeds from the discharge window to the bottom of the groove. Onion seeds at the exit from the sowing apparatus has an initial speed of v0. Because, the movement is transmitted from the support wheel using a chain drive to the metering unit. In this case, we take the initial speed v0 of onion seeds equal to the linear speed of the sowing apparatus. We begin the study to determine the linear speed of the sowing apparatus.

3 RESULTS.

According to the scheme in figure 1, we determine the angular velocity of the support wheel

$$\omega_1 = \frac{v_a}{R} \quad (1)$$

where va - seeder speed, m/s; R - radius of the support wheel, m



1-wheel support, 2, 6-bearing, 3-wheel sprocket; 4-flail; 5-driven sprocket; 7-disc meter

Fig. 1. *The scheme of the drive sowing apparatus*

It is known that the angular velocity of a link is the same at all points of the link [9, 10]. Therefore, we will take the angular velocity of the drive sprockets equal to the angular velocity of the support wheel. In this case, the angular velocities of the driven sprocket and sowing apparatus are determined as follows

$$\omega_2 = \frac{\omega_1}{u} \quad (2)$$

where ω1 - angular velocity of the leading sprocket, rad/s; u - gear ratio of the chain transmission.

Determine the linear speed of the metering unit

$$v_2 = \omega_2 R_2 \quad (3)$$

where ω2 - angular velocity of the sowing apparatus, rad/s; R2 - radius of the sowing apparatus, m

The movement of onion seeds was investigated as follows (Figure 2.).

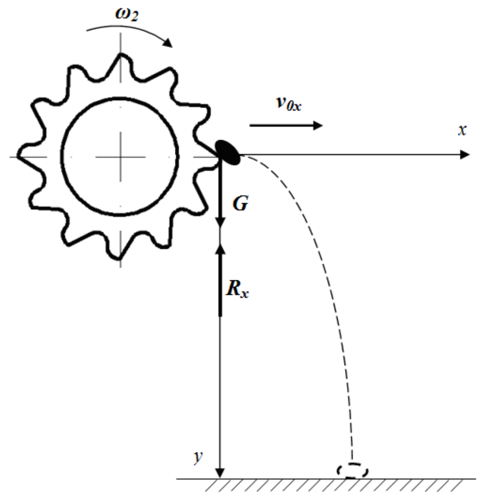


Fig. 2. *The scheme for determining the trajectories of onion seeds during the release*

If we take into account air resistance when studying the movement of onion seeds, according to Figure 3, we write the equation for the movement of seeds

$$m\ddot{x} = -R_x \quad (4)$$

$$m\ddot{y} = G - R_x \quad (5)$$

where m - mass of onion seeds, kg; Rx - air resistance force, N; G - gravity, N.

The forces of gravity and air resistance are defined as follows [11, 12]

$$G = mg \quad (6)$$

$$R_x = \frac{1}{2}\mu\varsigma S v^2 \quad (7)$$

where g - gravitational acceleration, m/s2; μ - drag coefficient depending on the shape of the body; ς - density of air, kg/m3; S - midellar surface of onion seeds, m2; v - speed of onion seeds, m/s.

Considering (6) and (7), we write the system of equations (4) and (5) as follows

$$m\ddot{x} = -\frac{1}{2}\mu\varsigma S v^2 \quad (8)$$

$$m\ddot{y} = mg - \frac{1}{2}\mu\varsigma S v^2 \quad (9)$$

or

$$m\ddot{x} = -\frac{1}{2}\mu\varsigma S \dot{x}^2 \quad (10)$$

$$m\ddot{y} = mg - \frac{1}{2}\mu\varsigma S \dot{y}^2 \quad (11)$$

Determine the movement of onion seeds along the x axis using equation (10). Given that $\dot{x} = v_x(t)$, we write the equation (10)

$$mv_x' = -\frac{1}{2}\mu\varsigma S v_x{}^2 \quad (12)$$

Dividing the two sides of equation (12) by the mass of the onion, we obtain the following

$$\frac{dv_x}{{v_x}^2} = -\frac{\mu\varsigma S}{2m} dt \quad (13)$$

To determine the speed of onion seeds along the x axis, we integrate equation (13) once

$$-\frac{1}{v} = -\frac{\mu\varsigma S}{2m} t + C_1 \quad (14)$$

For t=0, x=0 and $\dot{x}(0) = v_{0x}$.
Then

$$C_1 = \frac{1}{v_0}$$

And also, equation (14) forms the following form

$$\frac{1}{v} = \frac{\mu\varsigma S v_{0x} t + 2m}{2mv_{0x}} \quad (15)$$

From equation (15) we find v

$$v_x = \dot{x}(t) = \frac{2mv_{0x}}{\mu\varsigma S v_{0x} t + 2m} \quad (16)$$

To determine the movement of onion seeds along the x axis, we integrate equation (16) once and get

$$x = \frac{2mv_{0x}}{\mu\varsigma S v_{0x}} \ln(\mu\varsigma S v_{0x} t + 2m) + C_2 \quad (17)$$

For t=0, x=0. There fore

$$C_2 = -\frac{2m}{\mu\varsigma S} \ln(2m) \quad (18)$$

Given equation (18), we can write equation (17) as follows

$$x = \frac{2m}{\mu\varsigma S} \ln(\mu\varsigma S v_{0x} t + 2m) - \frac{2m}{\mu\varsigma S} \ln(2m) \quad (19)$$

Given that, $\ln(x + \Delta x) - \ln(x) = \ln\frac{x + \Delta x}{x}$, we write equations (19) as follows

$$x = \frac{2m}{\mu\varsigma S} \ln\left(\frac{\mu\varsigma S v_{x0} t}{2m} + 1\right) \quad (20)$$

We determine the movement of onion seeds along the Y axis using equation (11). To simplify the equation, divide the two sides by the mass m of onion seeds. In this case, we obtain

$$\ddot{y} = g - \frac{1}{2m} \mu\varsigma S \dot{y}^2 \quad (21)$$

Given that, $\dot{y} = v_y(t)$, and also for convenience, the solution to the problem we add a note that $\frac{\mu\varsigma S}{2m} = A^2$. Moreover, equation (21) takes this form

$$v_y' = \frac{dv_y}{dt} = g - A^2 v_y^2 \quad (22)$$

From equation (22) we define dt

$$dt = \frac{dv_y}{g - A^2 v_y^2} \quad (23)$$

From here

$$\int \frac{dv_y}{g - (Av_y)^2} = t + \ln C_3 \quad (24)$$

Given that, $\int \frac{dx}{a^2 - x^2} = \frac{1}{2a} \ln\frac{a + x}{a - x}$, we write equation (24) as follows

$$\frac{1}{2A\sqrt{g}} \ln\frac{\sqrt{g} + Av_y}{\sqrt{g} - Av_y} = t + \ln C_3 \quad (25)$$

$$\ln\frac{\sqrt{g} + Av_y}{\sqrt{g} - Av_y} = 2At\sqrt{g} + \ln C_3 \quad (26)$$

$$\frac{\sqrt{g} + Av_y}{\sqrt{g} - Av_y} = C_3 e^{2At\sqrt{g}} \quad (27)$$

$$\sqrt{g} + Av_y = C_3\sqrt{g} e^{2At\sqrt{g}} - C_3 Av_y e^{2At\sqrt{g}} \quad (28)$$

$$Av_y(1 + C_3 e^{2At\sqrt{g}}) = C_3\sqrt{g} e^{2At\sqrt{g}} - \sqrt{g} \quad (29)$$

$$v_y = \frac{\sqrt{g}}{A} \cdot \frac{C_3 e^{2At\sqrt{g}} - 1}{C_3 e^{2At\sqrt{g}} + 1} \quad (30)$$

or

$$v_y = \frac{\sqrt{g}}{A} \cdot \frac{e^{2At\sqrt{g}} - C_3}{e^{2At\sqrt{g}} + C_3} \quad (31)$$

Since t=0, y=0 and $\dot{y}(0) = v_{y_0} = 0$, then $C_3 = 1$. Therefore, equation (31) takes the form

$$v_y = \frac{\sqrt{g}}{A} \cdot \frac{e^{2At\sqrt{g}} - 1}{e^{2At\sqrt{g}} + 1} \quad (32)$$

To solve the problem, multiply the right side of equation (32) by $e^{-At\sqrt{g}}$. Then

$$v_y = \frac{\sqrt{g}}{A} \cdot \frac{e^{At\sqrt{g}} - e^{-At\sqrt{g}}}{e^{At\sqrt{g}} + e^{-At\sqrt{g}}} \tag{33}$$

Given the hyperbolic function, that $shx = \frac{e^x - e^{-x}}{2}$, $chx = \frac{e^x + e^{-x}}{2}$ and $thx = \frac{shx}{chx} = \frac{e^x - e^{-x}}{e^x + e^{-x}}$ [13, 14, 15]. Determine the speed

$$v_y = \dot{y}(t) = \frac{\sqrt{g}}{A} \cdot th(At\sqrt{g}) \tag{34}$$

To determine the movement of onion seeds along the y axis, we integrate equation (33) once and get

$$y(t) = \frac{\sqrt{g}}{A} \int th(At\sqrt{g})dt + C_4 \tag{35}$$

or

$$y(t) = \frac{\sqrt{g}}{A} \int \frac{sh(At\sqrt{g})}{ch(At\sqrt{g})}dt + C_4 \tag{36}$$

Given that $(shx)' = chx$. We write equation (36) as follows

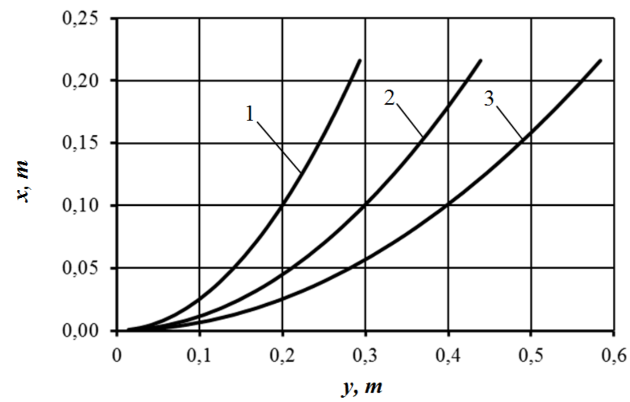
$$y(t) = \frac{\sqrt{g}}{A} \frac{1}{A\sqrt{g}} \int \frac{dch(At\sqrt{g})}{ch(At\sqrt{g})} + C_4 = \frac{1}{A^2} \ln ch(At\sqrt{g}) + C_4 \tag{37}$$

For t=0, y=0 and $ch(A0\sqrt{g}) = \frac{e^0 + e^0}{2} = 1$. Then $C_4 = 0$ and equation (37) takes the following form

$$y = \frac{2m}{\mu \varsigma S} \ln ch\left(\sqrt{\frac{\mu \varsigma S\, g}{2m}}t\right) \tag{38}$$

To determine the movement of onion seeds along the x and y axes, we will solve equations (20) and (38) numerically in the MathCAD program. The solution was carried out with the following numerical values of the parameters: m=0.0035 kg; v0x=(1.4; 2.1; 2.8) m/s; μ=0.25 (temperature of the circle at 10-150C); ς=1.25 kg/m3; S=0,0006 m2; g=9.8 m/s2; tϵ [0; 21] s.

Based on the numerical solution of Eqs. (20) and (38), the trajectories of onion seeds on the corresponding axes were obtained (see figure 3). From the obtained graphs it can be seen that the flight path of the seeds will change according to the law of the parabola and with an increase in the initial speeds of the seeds, the value of x and y increases in a non-linear pattern. This is because the initial seed speed directly affects the flight of seeds.



1-vox=1,4 m/s; 2- vox=2,1 m/s; 3- vox=2,8 m/s

Fig. 3*. The trajectory of the fall of onion seeds when ejected from the sowing apparatus*

It can be noted that the initial speed of the seeds is 1.4 m/s, then the flight of the onion along the x axis will be up to 3 cm, with the y axis 2.1 cm. So, at the initial speed of 2.8 m/s, the flight of the onion along the axis x will be up to 6 cm, with an axis of 2.1 cm. It can be noted that onion seeds from the moment the seed disk falls out of the cell to the moment of contact with the bottom of the furrow is in a state of free fall. The rate of fall of seeds v at the time of impact on the bottom of the furrow according to research is defined as follows, in Figure 4.

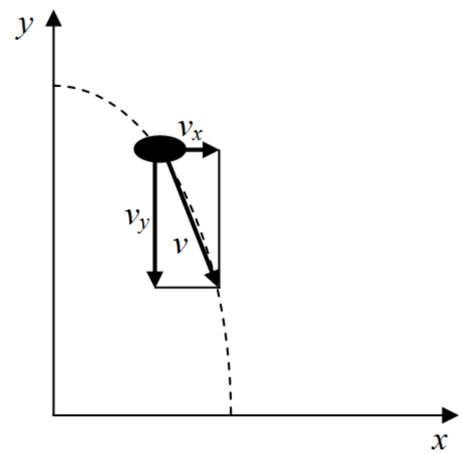


Fig. 4*. Scheme for determining the rate of fall of seeds*

From figure 4 we determine the rate of fall of seeds v

$$v = \sqrt{v_x^2 + v_y^2} \tag{40}$$

Given equation (16) and (34), we can write equation (40) as follows

$$v = \sqrt{\frac{4(mv_{0x})^2}{(\mu\zeta S v_{0x}t)^2 + 2m\mu\zeta S v_{0x}t + 4m^2} + \frac{2mg}{\mu\zeta S} th\left(\sqrt{\frac{\mu\zeta Sg}{2m}}t\right)} \tag{41}$$

Consider the collision of onion seeds with soil as shown in Figure 5.

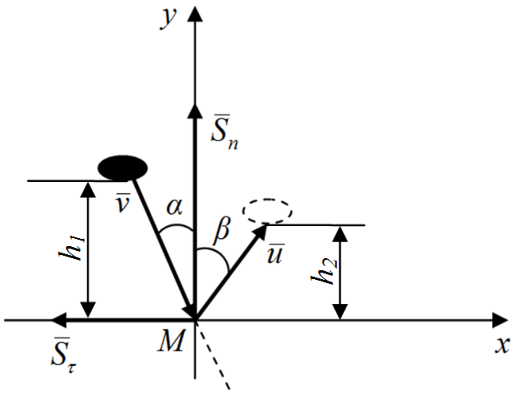


***Fig. 5**. Scheme for studying the collision of onion seeds with soil*

According to shock theory, it is known that the recovery coefficient is calculated by the formula [16]

$$k = \frac{u}{v} = \sqrt{\frac{h_2}{h_1}}, \tag{42}$$

where h1 - height of the fall of onion seeds, m; h2 - height of the rebound of onion seeds after impact, m.

From the expressions (1) we find the height of the sowing apparatus

$$h_1 = \frac{h_2}{k^2} \tag{43}$$

For a numerical solution, expression (43), taking into account that the depth of onion seed placement is within 1.5–2 cm, we accept the conditions that the seed bounce height should not exceed 1.5 cm, and also the recovery coefficient within k=0.44 ± 0.11. Based on the numerical solution of expression (43), a graphical dependence of the recovery coefficient on the height of the metering unit is constructed. The graph shows that the seeds remained in the bottom of the furrow during sowing, the installation height of the sowing apparatus should not exceed 17 cm (Figure 6).

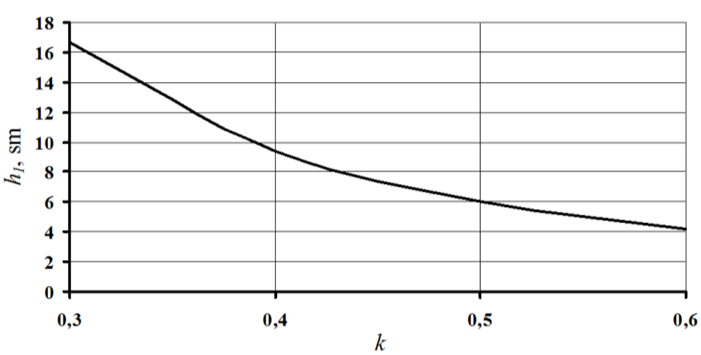


***Fig. 6**. Graphical dependence of the recovery coefficient on the height of the metering unit*

From the above, we consider the process of collision of seeds with soil. Define the momentum during impact in vector form as follows [17]

$$m(\bar{u} - \bar{v}) = \bar{S} \tag{44}$$

where m - mass of onion seeds, kg; u - speed of onion seeds after impact, m/s; v - speed of onion seeds before impact, m/s. Using figure 5 find the projection of equation (44) on the axis of the coordinate system

$$\begin{cases} m(u\sin\beta - v\sin\alpha) = -S_\tau \\ m(u\cos\beta + v\cos\alpha) = S_n \end{cases} \tag{45}$$

Given equations (42) and (45), we determine the recovery coefficient upon impact

$$k = -\frac{u\cos\beta}{-v\cos\alpha} \tag{46}$$

which implies equality

$$kv\cos\alpha = u\cos\beta \tag{47}$$

From the second equation of system (45), the normal component of the shock pulse is determined; it is equal to

$$S_n = mv(k+1)\cos\alpha \tag{48}$$

Based on the Routh hypothesis that the tangent and normal components of the shock pulse are related by the coefficient of sliding shock friction, similar to the coefficient of sliding friction in the case of finite forces. Then the Routh formula holds

$$S_\tau = f_d S_n \tag{49}$$

where Sτ - tangent component of the shock pulse, kgm/s; Sn - normal component of the shock pulse, kgm s; fd - coefficient of sliding shock friction.

Then the tangent component of the shock pulse will be equal to

$$S_\tau = f_d mv(k+1)\cos\alpha \tag{50}$$

Putting (50) in the first equation of system (45), we obtain

$$m(u\sin\beta - v\sin\alpha) = -f_d mv(k+1)\cos\alpha \tag{51}$$

Dividing the two sides of equation (51) by the mass m of onion seeds, we obtain the following

$$u\sin\beta = v(\sin\alpha - f_d(k+1)\cos\alpha) \tag{52}$$

To determine the speed of onion seeds after stinging, we form a system of equations

$$\begin{cases} u\cos\beta = kv\cos\alpha \\ u\sin\beta = v(\sin\alpha - f_d(k+1)\cos\alpha) \end{cases} \tag{53}$$

From the system of equations (53) it follows that

$$u^2(\cos^2\beta + \sin^2\beta) = v^2(k^2\cos^2\alpha + (\sin\alpha - f_d(k+1)\cos\alpha)^2) \tag{54}$$

Considering that cos2β+sin2β=1, from equation (54) we find u

$$u = v\sqrt{k^2\cos^2\alpha + (\sin\alpha - f_d(k+1)\cos\alpha)^2} \tag{55}$$

To determine the angle β, one more equality follows from the system of equations (53)

$$\frac{u\cos\beta}{u\sin\beta} = \frac{kv\cos\alpha}{v(\sin\alpha - f_d(k+1)\cos\alpha)} \tag{56}$$

Given that $\frac{\cos\beta}{\sin\beta} = ctg\beta$, we write equalities (56) as follows

$$ctg\beta = \frac{k\cos\alpha}{(\sin\alpha - f_d(k+1)\cos\alpha)} \tag{57}$$

or

$$\beta = arcctg\left(\frac{k\cos\alpha}{(\sin\alpha - f_d(k+1)\cos\alpha)}\right) \tag{58}$$

To determine the angle of incidence of onion seeds, we will take into account that it is equal to the angle between the paths of incidence of onion seeds with a vertical axis (Figure 7).
The determining coordinates of the falling onion seeds are denoted by the functions x=x(t) and y=y(t). From figure 7 α=90-γ or γ=90-α. From here

$$tg\gamma = tg(90-\alpha) = f'(x_0) \tag{59}$$

or

$$ctg\alpha = f'(x_0) \tag{60}$$

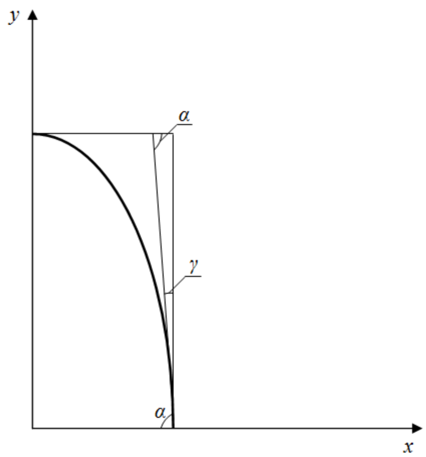


***Fig. 7**. Scheme for determining the angle of incidence of onion seeds*

By condition, the solution of trigonometric functions is as follows

$$f'(x_0) = \frac{y'(t_0)}{x'(t_0)} \tag{61}$$

If we take into account equations (16) and (34), then equation (61) forms the following form

$$f'(x_0) = ctg\alpha = \frac{\sqrt{2mg}\,th(\sqrt{\frac{\mu\varsigma Sg}{2m}}t)\left[\mu\varsigma S v_{x0} t + 2m\right]}{2mv_{x0}\sqrt{\mu\varsigma S}} \tag{62}$$

or

$$\alpha = arctg\left(\frac{2mv_{x0}\sqrt{\mu\varsigma S}}{\sqrt{2mg}\,th(\sqrt{\frac{\mu\varsigma Sg}{2m}}t)\left[\mu\varsigma S v_{x0} t + 2m\right]}\right) \tag{63}$$

To study the dependence of the angle α at the time of onion seed fall, equation (63) was numerically solved and graphical dependencies were constructed (Figure 8). From figure 8 shows that with an increase in the speed of the sowing unit, the limit of the change in the angle α increases.

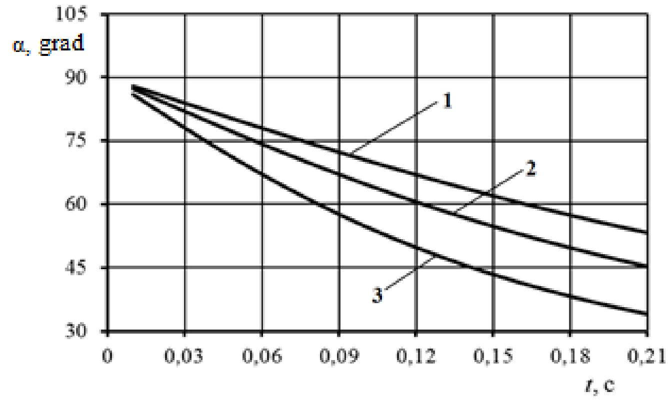


***Fig. 8**. Graphic dependences of the angle of incidence of onion seeds during the fall*

If we take into account the above and install the sowing device to a height of 17 cm from the soil, then the angle of incidence of onion seeds on the soil at a speed of v=5 km/h is 50 degrees, at a speed of v=7.5 km/h and 45 degrees at a speed of v=10 km/h 34 degrees. The numerical solution of equation (58) was performed for the following parameter values: fd=0.4; k=0.5; α=34 °, 45 °, 50 °. In this case, the angle β of the rebound of onion seeds will be equal, i.e. at α=50 ° β=53.6 °, at α=45 ° β=38.6 ° and at α=34 ° β=8.4 °. Research has shown that when the angle of incidence is between 51 ° and 89 °, it is more than the angle of rebound.

4 CONCLUSIONS.

As a result of this study, a differential equation was obtained to determine the movement of onion seeds. In the work, methods of higher mathematics are used, in which it is possible to obtain the necessary equation. Based on the numerical solution of the obtained equations, graphs are constructed that determine the trajectory of onion seeds on the corresponding x and y axes. The graphs show that the flight path of the seeds varies according to the law of the parabola. Based on the study, the collision of onion seeds with the soil revealed that for fixed values of k, α, the speed of onion seeds after the impact and the reflection angle β decrease with increasing impact coefficient of friction. From the results of this study, you can use it for designing the design of sowing apparatuses and fertilizer pipelines of seeders.

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