THEORETICAL GROUNDING OF SEEDS VALVE OPENER SETTINGS FOR SUBSOIL-SPREADING SOWING METHOD
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ТЕОРЕТИЧНЕ ОБҐРУНТУВАННЯ ПАРАМЕТРІВ РОЗПОДІЛЬНИКА НАСІННЯ СОШНИКА ДЛЯ ПІДҐРУНТОВО-РОЗКИДНОГО СПОСОБУ СІВБИ

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ABSTRACT
In the article, we examine the determination of the distributor optimal shape and the seeds distribution process by combined distributor in the form of a curved prism. Based on calculations we found out that seeds distribution uniform for bandwidth depends on the distributor shape that is sown with the opener for cereals continuous sowing. Formulas for determining the seed speed on the distributor surface were recorded, depending on changes of structurally technological parameters including generating circle prism diameter. It was recorded the mathematical model of the coordinates and the seed trajectory and the range flight seed of ideal forms. Uniformity of seeds distribution for opener widths will be characterized by the seeds flow speed on the distributor sloping plot of guiding and coordinates falling on the distributor surface. The effect of the distributor sloping plot length on seeds uniformity distribution was researched, the obtained dependences of the flight distance determining on the seeds distributor sloping plot length and seeds uprising speed through which the optimal lengths of sloping plot was selected. The paper presents the main results of theoretical studies and recommendations for this type of passive distributors use in opener for subsoil-spreading crops sowing method.

РЕЗЮМЕ
В статті розглядається визначення оптимальної форми розподільника та процес розподілу насіння комбінованим розподільником у виді криволінійної призми. На основі розрахунків встановлено, що від форми розподільника залежить рівномірність розподілу насіння за шириною смуги, яка засівається сошником для суцільної сівби зернових колосових культур. Записано формули для визначення швидкості руху насінини по поверхні розподільника, в залежності від зміни констукційно-технологічних параметрів, зокрема, діаметру твірного кола призми. Записано математичну модель визначення координат і траєкторії руху посівного матеріалу та дальності польоту насінини ідеальної форми. Рівномірність розподілу насіння за шириною захвату сошника буде характеризуватися швидкістю надходження насіння на похилу ділянку розподільника з направляча та координатами потрапляння на поверхню розподільника. Досліджено вплив довжини похилої ділянки розподільника на рівномірність розподілу насіння, отримані залежності визначення дальності польоту насіння від довжини похилої ділянки розподільника і швидкості його сходу, по яких обране оптимальне значення довжини похилої ділянки. В роботі представлені основні результати теоретичних досліджень та рекомендації щодо використання даного типу пасивних розподільників в сошниках для підґрунтово-розкидної сівби зернових культур.

INTRODUCTION
Appreciable difference between the current seeding machine for ground slightly spreading method of sowing is the construction of seeding machines, in particular their distribution adjustment (*Hevko B. M. et. al., 2014; Sysolin P. V. and Sysolina I. P., 2014).* Seeding machines for ground slightly spreading method of sowing mostly are in form of cultivator share with different sweeping distance. Seed spreader is one of the main seeding machine elements, which influence at equability of spreader of technologic material on the field surface and increase of the width of sowing line. Different forms of the bafflers and seeding machine spreader adjustments constructions for ground slightly spreading sowing method caused by seeds increasing on the field area equability (*Romanyshyn O. Y. and Zayets M. L., 2006; Hevko B. M. and Pavelchuk Yu. F., 2016; Lisovyi I. O. et. at., 2016)*.

Advantages of the spreaders with non-rectilinear shape performance on the working surface the seed of which change direction of its moving with minimal kinetic energy wastes and moves to the seeding machine area and saw on the furrow bottom – were proved by analysts *(Vasylenko P.M., 1960; Heege H. J. 1993*). Such a design of the opener allows to reduce its effect on the seed, that is, the micro- and macrocracks formation (*Derevianko D. A., 2015*).

To reach maximal speed of moving in point of convergence of curve line, the curve line must be capable of the terms requiring of the quickest moving of elements during certain interval. Such a curve line accordant to the determination is called brachistochrone (*Zayets M. L. and Zhyvega M. M., 2015)*.

Zayets M. L. *(Zayets M.L. et. al., 2014*) devoted his work to the theoretical and experimental researches of the seed moving on the curve lines. He examines the brachistochrone as compatibility of rectilinear area and circle of the permanent radius r, and moving of seeds on the curve as a moving of seeds on this circle.

MATERIAL AND METHODS

Using the method of machines, work items and processes mathematical modelling, using computational differential equations, conversion and graphical definition on the basis of mechanics laws let us consider seed moving on a sloping surface (sloping area) of the combined distributor (fig. 1). At time t_0 seed comes down from the curvilinear areas of the combined distributor and starts moving with an initial velocity V (V_0) at an angle β_0. Gravity and friction acts on a seed as the direction of movement will occur along some curve.

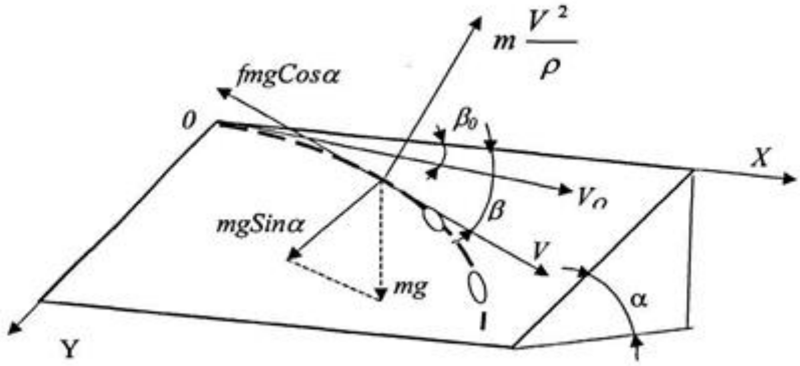

Fig. 1 – Forces calculation model, acting on the seed during its moving on the distributor sloping plot

Let us complete differential equations of the seed moving in projections on the normal line and tangent line to the trajectory. These equations are as follows (*Romanyshyn O. Y. and Zayets M. L., 2006*):

$$m\frac{dV}{dt} = mg \times \sin\alpha - fmg \times \cos\alpha, \tag{1}$$

$$m\frac{m^2}{\rho} = mg \times \sin a \times \cos\beta \tag{2}$$

Where:

V – speed of the seed moving on the inclined surface at the moment t, [m/s];

α – the angle of the horizontal curve section, [rad];

β – the angle between moving elements at the moment *t* and OX Cartesian axes, [rad];

ρ – curve radius of the movement pattern on the curve section at the moment, [m]

f – seed moving coefficient on the steel.

Kindly note, that:

$$\rho = \frac{dS}{d\beta} = \frac{V \cdot dt}{d\beta} \tag{3}$$

where, $\frac{dS}{d\beta}$ – increasing of distance, [m].

If we mention ρ in equation (2) and determine dt, we obtain:

$$dt = \frac{V \cdot d\beta}{g \cdot \sin\alpha \cdot \cos\beta} \quad (4)$$

Substitute the value dt in the equation (1), we obtain as follows:

$$\frac{dV}{V \cdot d\beta} mg \cdot \sin\alpha \cdot \cos\beta = mg \cdot \sin\alpha \cdot \sin\beta - fmg \cdot \cos\alpha \quad (5)$$

Using mathematical calculations, we obtain:

$$\frac{dV}{V} = tg\beta \cdot d\beta - f \cdot ctg\alpha \frac{1}{\cos\beta} \cdot d\beta \quad (6)$$

The difference equation obtained is the equation with articulate modulars.

The general solution to the equation is as follows:

$$V = \frac{C}{\cos\beta} \cdot \left(\frac{1 - tg\frac{\beta}{2}}{1 + tg\frac{\beta}{2}} \right)^{f \cdot ctg\alpha} \quad (7)$$

where C – permanent data.

Arbitrary constant shall be determined from the permanent terms $\beta = \beta_0 V = V_{cx}$:

$$C = \frac{V_{cx}}{\cos\beta_0} \cdot \left(\frac{1 + tg\frac{\beta_0}{2}}{1 - tg\frac{\beta_0}{2}} \right)^{f \cdot ctg\alpha} \quad (8)$$

RESULTS

As a result of theoretical research, we got the differential equation for determining structural and technological parameters of the combined distributor:

- speed descent of the curvilinear generatrix;
- the range distribution of seeds;
- the design parameters of the sloping area (length of the sloping area and installation angle to the horizon) the use of which allows to determine the optimal parameters of the distributor and the sloping sections.

Substitute the value C in equation (7) and after calculation we get defining formula for determining the seed speed on the curve section:

$$V = \frac{V_{cx}}{\cos\beta_0 \cdot \cos\beta} \cdot \left[\left(\frac{1 + tg\frac{\beta_0}{2}}{1 - tg\frac{\beta_0}{2}} \right) \cdot \left(\frac{1 - tg\frac{\beta}{2}}{1 + tg\frac{\beta}{2}} \right) \right]^{f \cdot ctg\alpha} \quad (9)$$

Movement pattern of the speed in the curve section shall be determined as follows:

$$dx = V \cdot \cos\beta \cdot dt, dy = V \cdot \sin\beta \cdot dt \quad (10)$$

Or according to the following equation: (4):

$$dx = \frac{V^2 \cdot d\beta}{g \cdot \sin\alpha}$$
$$dy = \frac{V^2 \cdot tg\beta \cdot d\beta}{g \cdot \sin\alpha} \quad (11)$$

The general consensus of the simultaneous equations (11) is as follows:

$$C_1=-\frac{2V_{cx}^2}{g\cdot\sin\alpha\cdot\cos^2\beta_0}\cdot\left(\frac{1+tg\frac{\beta_0}{2}}{1-tg\frac{\beta_0}{2}}\right)^{2\cdot f\cdot ctg\alpha}\cdot\left(\frac{1}{2\cdot f\cdot ctg\alpha-1}\cdot\left(\frac{1+tg\frac{\beta_0}{2}}{1-tg\frac{\beta_0}{2}}\right)^{2\cdot f\cdot ctg\alpha-1}+\frac{1}{2\cdot f\cdot ctg\alpha+1}\cdot\left(\frac{1-tg\frac{\beta_0}{2}}{1+tg\frac{\beta_0}{2}}\right)^{2\cdot f\cdot ctg\alpha+1}\right)$$
$$C_2=-\frac{V_{cx}^2}{g\cdot\sin\alpha\cdot\cos^2\beta_0}\cdot\left(\frac{1+tg\frac{\beta_0}{2}}{1-tg\frac{\beta_0}{2}}\right)^{2\cdot f\cdot ctg\alpha}\cdot\left(\frac{1}{2\cdot f\cdot ctg\alpha-2}\cdot\left(\frac{1-tg\frac{\beta_0}{2}}{1-tg\frac{\beta_0}{2}}\right)^{2\cdot f\cdot ctg\alpha-2}-\frac{1}{2\cdot f\cdot ctg\alpha-2}\cdot\left(\frac{1-tg\frac{\beta_0}{2}}{1+tg\frac{\beta_0}{2}}\right)^{2\cdot f\cdot ctg\alpha+2}\right) \quad (12)$$

where C_1 and C_2 – are the variables.

$$x=-\frac{2\cdot V_{cx}^2}{g\cdot\sin\alpha\cdot\cos^2\beta_0}\cdot\left(\frac{1+tg\frac{\beta_0}{2}}{1-tg\frac{\beta_0}{2}}\right)^{2\cdot f\cdot ctg\alpha}\cdot\left(\frac{1}{2\cdot f\cdot ctg\alpha-1}\cdot\left(\frac{1-tg\frac{\beta}{2}}{1+tg\frac{\beta}{2}}\right)^{2\cdot f\cdot ctg\alpha-1}+\frac{1}{2\cdot f\cdot ctg\alpha+1}\cdot\left(\frac{1-tg\frac{\beta}{2}}{1+tg\frac{\beta}{2}}\right)^{2\cdot f\cdot ctg\alpha+1}\right)+C_1$$

Constant variables shall be determined according to the initial data:

If $\beta=\beta_0 ... x=0, y=0$:

$$y=-\frac{V_{cx}^2}{g\cdot\sin\alpha\cdot\cos^2\beta_0}\cdot\left(\frac{1+tg\frac{\beta_0}{2}}{1-tg\frac{\beta_0}{2}}\right)^{2\cdot f\cdot ctg\alpha}\cdot\left(\frac{1}{2\cdot f\cdot ctg\alpha-2}\cdot\left(\frac{1-tg\frac{\beta}{2}}{1-tg\frac{\beta}{2}}\right)^{2\cdot f\cdot ctg\alpha-2}-\frac{1}{2\cdot f\cdot ctg\alpha+2}\cdot\left(\frac{1-tg\frac{\beta}{2}}{1+tg\frac{\beta}{2}}\right)^{2\cdot f\cdot ctg\alpha+2}\right)+C_2$$

Analysis of equation (13), confirms that maximal X axis stroke (ranging of the seed spreader on the sowing width) shall be in case of coincidence of the speed direction at time zero with axis X $(\beta=0)$.

Data of the constant variables are determined from the following equations:

$$C_1=\frac{2\cdot V^2{}_{cx}}{g\cdot\sin\alpha}\cdot\left(\frac{1}{2\cdot f\cdot ctg\alpha-1}+\frac{1}{2\cdot f\cdot ctg\alpha+1}\right)$$
$$C_2=\frac{V^2{}_{cx}}{g\cdot\sin\alpha}\cdot\left(\frac{1}{2\cdot f\cdot ctg\alpha-2}-\frac{1}{2\cdot f\cdot ctg\alpha+2}\right) \quad (14)$$

When installing of the distributor with eccentricity, relative to the axis coordinate counting X seed wire we lead from point O (fig. 1) (the point of seed falling on a sloping plot) coordinate Y of the distributor axial line (fig. 2).

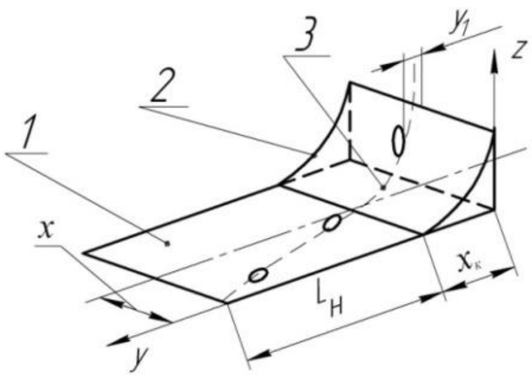

Fig. 2 – Scheme of the spreader with the curve section

1 – curve section, 2 – spreader, 3 – movement pattern of a seed

So, we can write the following:

$$\begin{aligned} x &= x(\beta) + C_1 + x_k \\ y &= y(\beta) + C_2 \pm y_1 \end{aligned} \quad (15)$$

where:

$x(\beta)$ and $y(\beta)$ – functions x and y depending on the parameter β (13);

C_1 and C_2 – data of constant variables (14);

x_k – projection of the curve moving line of the spreader on the curve section, [m];

y_1 – distance from the axis line of a spreader to the point of a seed impact on the curve section, [m] (Fig. 2).

During the sowing moving, under the inertial force, data of the seed movement pattern on the curve section differs from theoretical data and it will influence the line width, which the seeding machine sows.

This fact shall be mentioned and calculated due to the correction factor.

After plugging in the equation system (15) data points β_0, $x(\beta)$, $y(\beta)$, C_1 and C_2, note that the length of the curve section is datum by the line $L_н$, get the equation of seed moving on the curve section in the following parametric form:

$$x = K \cdot \left[-\frac{2V_{cx}^2}{g \cdot \sin\alpha \cdot \cos^2 \beta_0} \cdot \left(\frac{1}{2 \cdot f \cdot ctg\alpha - 1} \cdot \left(\frac{1 - tg\frac{\beta}{2}}{1 + tg\frac{\beta}{2}} \right)^{2 \cdot f \cdot ctg\alpha - 1} + \frac{1}{2 \cdot f \cdot ctg\alpha + 1} \cdot \left(\frac{1 - tg\frac{\beta}{2}}{1 + tg\frac{\beta}{2}} \right)^{2 \cdot f \cdot ctg\alpha + 1} \right) + \right. \\ \left. + \frac{2 \cdot V_{cx}^2}{g \cdot \sin\alpha} \cdot \left(\frac{1}{2 \cdot f \cdot ctg\alpha - 1} + \frac{1}{2 \cdot f \cdot ctg\alpha + 1} \right) + x_k \right] \quad (16)$$

$$L_H = -\frac{V_{cx}^2}{g \cdot \sin\alpha \cdot \cos^2 \beta_0} \cdot \left(\frac{1}{2 \cdot f \cdot ctg\alpha - 2} \cdot \left(\frac{1 - tg\frac{\beta}{2}}{1 + tg\frac{\beta}{2}} \right)^{2 \cdot f \cdot ctg\alpha - 2} - \frac{1}{2 \cdot f \cdot ctg\alpha + 2} \left(\frac{1 - tg\frac{\beta}{2}}{1 + tg\frac{\beta}{2}} \right)^{2 \cdot f \cdot ctg\alpha + 2} \right) + \\ + \frac{V_{cx}^2}{g \cdot \sin\alpha} \cdot \left(\frac{1}{2 \cdot f \cdot ctg\alpha - 2} - \frac{1}{2 \cdot f \cdot ctg\alpha + 2} \right) \pm y_1$$

where K – modifying factor, determined in an experimental way.

$$k = \frac{B_{еккс}}{2 \cdot x} \quad (17)$$

where $B_{експ}$ – observed width of line sowing by the seeding-machine.

According to the received system of equations the main parameters, which characterize propagation distance of seed, are the following: length of the curved section $L_н$ speed of seed movement from the curve sector of the spreader to the curve section V, angle of incidence of the curve section to the horizon α.

Analyzing the received equations, let's determine the minimal angle of incidence of the curve section in case of plugs deficiency on the curve section:

$$f \cdot ctg\alpha < 1 \quad (18)$$

or

$$f \cdot tg\alpha > 1 \quad (19)$$

Due to the value of traction coefficient 0.36...0.37 for spiked cereals, we determine that the minimal angle of incidence of the curve section is 19.8°...20.3°.

If length of the curve section is $L_н$, the speed moving of a seed is V_{cx} , the slope angle is α and due to the system of equations, we determine the seed distribution x , about a symmetric axis of the seeding machine. Using received equations (16), we determine that the line width, sewed by the seeding machine is nearly 95…100 mm while the length of the curve section is nearly 30...70 mm.

CONCLUSIONS

The following theoretical dependence for determining the constructive parameters of the compound spreader is obtained: moving speed from the curved line to the diameter of the brachistochrone circle line; propagation distance of seed (in parametric form) from the constructive parameters of the curve section (length of the curve section and angle of its adjustment to the horizon), usage of which allows to determine optimal parameters of the spreader and curve section to secure seed diffusion in the operating width of a seeding machine with necessary ranging and steadiness.

Length of the curved section selected according to the ranging and steadiness of the seed spreading shall be 60 mm. Compound spreader spreads crop seeds on the width 95-100 mm.

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