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DETERMINATION OF THE MOVEMENT SPEED OF SEED ON THE DISTRIBUTOR OF COULTER FOR THE SUBSOIL-SPREADING METHOD OF SOWING

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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 openerfor 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.

The value of the length of the slope is selected based on the range and uniformity of the distribution of the seed and is 60 mm. The combined distributor can distribute seeds of grain crops at a width of 95-100 mm. When conducting two-factor experiments, it was established that the best distribution index of seeds has a combined distributor made in the form of a two-way curvilinear prism. The design of the coulter for subsoil and spreading of seed of grain crops with a combined seed distributor is developed. During the previous experiments and the search multivariate experiment, the linear regression equations were specified and the most significant factors influencing the optimization parameter were determined.

Theoretical dependence for determination of constructive parameters of the distributor are received as follows: speed of convergence from the curved generatix from the diameter of the circle diameter of the circle generatix of brachistichrone; distance of the seed distribution (parametric form) from the constructive parameters of the with surface at an angle (length of the surface at an angle and angle of its installation to the horizon), usage of which allows to determinate optimal parameters of the determinator and surface for the supporting of seed sawing on the operating width of the coulter with necessary distance and equability.

Speed of the seed movement from the curved generatix of coulter depends on the diameter of the circle generatix of brachistichrone and coordinate of the seed hitting on the curved surface.

***Key words**: speed, sowing, distributor, generator, equitability.*
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Introduction

The substantial difference between raw seeders and seeders for subsoil-spreading method of sowing – is the sunflower construction, specifically its distribution unit. Seeder coulters for subsoil spreading method of sowing are commonly made as cultivator steel with different operating width *(Vasylenko P.M., 1960; Heege H. J. 1993*).

Seed distributor is one of the main elements of the coulter, which have an effects on the equitability of technical material on the field area and increasing of the sowed border area. Different forms of removers and constructions of the distribute units of coulters for subsoil spreading method of sowing are caused by increasing of the equitability of seeds on the field area.

Explorers (*Hevko, 2014; Sysolin, and Sysolina , 2014)* proved advantages of distributors with curved generator when seeds slowly change direction of their movement with minimal wastes of the motional energy on the working area and where they are compiled to the under coulter space and is sowed on the furrow sole.

To search top performance of the movement speed in the point of convergence, the curve shall fulfil conditions of the most quick movement of elements during certain interval.

Exploration by A.A. Kirov is devoted to the theoretical and experimental researches of seed movement on the curved generator. He examines brachistichrone as combination of a straight section and a circle of a constant radius **r**, and explores seed movement on the curve generator as movement of seeds on such a circle.

Materials and methods

Taking into account that process of seed distributor during subsoil spreading method of sowing is selective, as it's determined by the large number of factors that cannot be included, so this process must be dealt with according to the laws of probability (*Romanyshyn, and Zayets, 2006; Hevko, and Pavelchuk, 2016; Lisovyi, et. at., 2016)*. In this regard different types of technological schemes of the coulter distributor units are proposed for further study.

Results of the research and discussion

Received formula od the speed of convergence (1) on the on the curve area of generator V with forecast accuracy can be used for calculation of trajectory and speed of seed movement after convergence from the on the on the curve area of distributor (Romanyshyn, 2006; Zayets, 2006):

$$V = \sqrt{e^{-\pi \cdot f}\left(V_0 \cdot \cos^2 \gamma_0 - \frac{6 \cdot g \cdot r \cdot f}{1+4 \cdot f}\right) + 2 \cdot g \cdot r \cdot \frac{1-2 \cdot f^2}{1+4 \cdot f^2}} \ , \qquad (1)$$

Vo – speed of seed movement to the curve area of generator, m/s;

γ_0 - angle between vertical axis and basic direction of speed Vo;

g - acceleration of gravity, m/s.

But in fact radius of brachistichrone curvature changes accordant to the determined theorem. Difference between actual radius of brachistichrone and radius of the circle causes difference between speed of movement from the curve generatix and estimated generatix. As speed of seed movement after convergence from the curved area of distributor determinates reserve of kinetic energy, which can lead to range of seed distribution in undercoulter area, so in its consideration of this matter such an exploration is very important and necessary stage of theoretical study (Zayets, 2014).

Let's explore movement of single seed on the brachistichrone which is the distributor generatix (pic.1).

Part of seeds material reaches the curved surface with basic speed Vo. Weight, friction, centrifugal force and normal pressure make an influence on the seeds during movement on the curve surface.

Cheming forces for normal line and tangent line, we will write a system of differential equations *(Vasylenko, 1960)*:

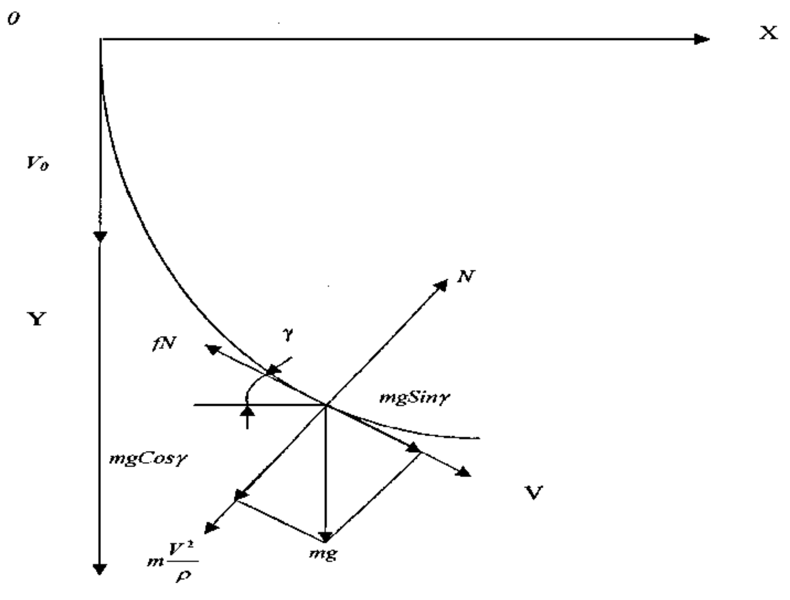
$$m \cdot \frac{dV}{dt} = m \cdot g \cdot \sin \gamma - f \cdot N$$
$$N = m \cdot \frac{V^2}{\rho(\varphi)} + m \cdot g \cdot \cos \gamma \qquad ; \qquad (2)$$

where: m-mass of seeds, kg;

V – speed of seeds, m/s;

N – normal pressure, H;

γ – angle of arrival, radian;



Picture 1 – Scheme of forces acting on the material point during movement on the brachistichrone

t- time of movement, s;

ρ(φ)- radius of the brachistichrone curvature, depending on the rotation angle of the circle generatrix (φ)

Known, that brachistichrone is created by circle, going straight without sliding. So for every point radius of the brachistichrone curve is equal to the circle bisecant AC (pic. 2.).With that one end of the bisecant chord belongs to a straight line along which the circle rolls.

We'll connect points A and C with the circle center O. So an isosceles triangle AOC is as follows:

$$\triangleleft OCA = \frac{\varphi}{2} \ ; \qquad (3)$$

where, φ – is rotation angle of circle after movement during time t.

The right-angled triangle OBC determines the following:

$$BC = OC \cdot \cos\frac{\varphi}{2} = \frac{d}{2} \cdot \cos\frac{\varphi}{2} \ ; \qquad (4)$$

where d- is a diameter of the circle generatrix, m

So, radius of brachistichrone curvature AC is as follows:

$$\rho(\varphi) = d \cdot \cos\frac{\varphi}{2} \ ; \qquad (5)$$

We'll move AC parallel to itself up to crossing with brachistichrone (A'C) and draw a horizon line A'C and tangent 1 through the corossing point A:

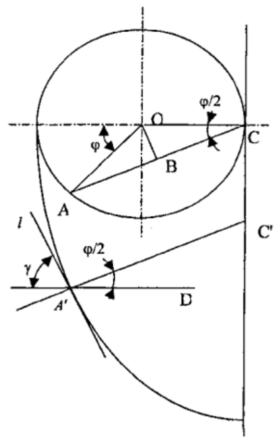
$$\gamma = \frac{\pi}{2} - \frac{\varphi}{2} \qquad (6)$$

We'll take into account that some circle turners on the angle φ during time t:

$$dt = \frac{d\varphi}{V}\rho(\varphi) = \frac{d\varphi}{V}\cdot d\cdot\cos\frac{\varphi}{2};$$

We'll enter values (4), (5) and (6) in system of equations (2), and then receive:

$$V\cdot\frac{dV}{d\varphi} + f\cdot V^2 = g\cdot d\cdot\cos^2\frac{\varphi}{2} - g\cdot d\cdot\frac{\sin\varphi}{2}; \qquad (7)$$



Picture 2 – Scheme for determination of radius of the brachistichrone curvature

Received differential equation is the Bernoulli's equation.

General solution of the equation:

$$V^2 = g\cdot d\cdot\left[\frac{\cos^2\frac{\varphi}{2}}{f} + \frac{2\cdot f\cdot\sin\varphi-\cos\varphi}{2\cdot f\cdot\left(4\cdot f^2+1\right)} - \frac{2\cdot f\cdot\sin\varphi-\cos\varphi}{4\cdot f^2+1}\right] + e^{-2\cdot f\varphi}\cdot C; \qquad (8)$$

where C- constant integration

Constant integration shall be determinated accordant to the basic conditions: of generatrix of brachistichrone circle that matches with point of hitting of seeds on the curvature generatrix of distributor;

$$\varphi = \varphi_0 - \varphi_1, \quad V = V_0.$$

$$C = e^{2\cdot f\cdot\varphi_1}\cdot\left(V^2{}_0 - g\cdot d\left[\frac{\cos^2\frac{\varphi_1}{2}}{f} + \frac{2\cdot f\cdot\sin\varphi_1-\cos\varphi_1}{2\cdot f\cdot\left(4\cdot f^2+1\right)} - \frac{2\cdot f\cdot\sin\varphi_1-\cos\varphi_1}{4\cdot f^2+1}\right]\right); \qquad (9)$$

Taking into account that $\varphi_0=\pi$, we can note the following:

$$\varphi = \pi - \varphi_1; \qquad (10)$$

Substitute the value of arbitrary constant C (mathematical expression 9) and value of angle φ (mathematical expression 10) in equation (8), we'll receive formula for determination of speed convergence of seeds from the on the on the curve generatix of distributor:

$$V_{cx} = \sqrt{g\cdot d\cdot\left[\frac{\cos^2\frac{\pi-\varphi_1}{2}}{f} + \frac{2\cdot f\cdot\sin\varphi_1+\cos\varphi_1}{2\cdot f\cdot\left(4\cdot f^2+1\right)} - \frac{2\cdot f\cdot\sin\varphi_1+\cos\varphi_1}{4\cdot f^2+1}\right] + e^{2\cdot f\left(2\cdot\varphi_1-\pi\right)}\left(V^2{}_0 - g\cdot d\cdot\left[\frac{\cos^2\frac{\pi-\varphi_1}{2}}{f} + \frac{2\cdot f\cdot\sin\varphi_1-\cos\varphi_1}{2\cdot f\cdot\left(4\cdot f^2+1\right)} - \frac{2\cdot f\cdot\sin\varphi_1-\cos\varphi_1}{4\cdot f^2+1}\right]\right)}; \qquad (11)$$

During installation of the distributor at an angle to the horizon, (mathematical expression 11) will be as follows:

$$V_{cx} = \sqrt{g\cdot\cos\alpha\cdot d\cdot\left[\frac{\cos^2\frac{\pi-\varphi_1}{2}}{f} + \frac{2\cdot f\cdot\sin\varphi_1+\cos\varphi_1}{2\cdot f\cdot\left(4\cdot f^2+1\right)} - \frac{2\cdot f\cdot\sin\varphi_1+\cos\varphi_1}{4\cdot f^2+1}\right] + e^{2\cdot f\left(2\cdot\varphi_1-\pi\right)}\left(V^2{}_0 - g\cdot\cos\alpha\cdot d\cdot\left[\frac{\cos^2\frac{\pi-\varphi_1}{2}}{f} + \frac{2\cdot f\cdot\sin\varphi_1-\cos\varphi_1}{2\cdot f\cdot\left(4\cdot f^2+1\right)} - \frac{2\cdot f\cdot\sin\varphi_1-\cos\varphi_1}{4\cdot f^2+1}\right]\right)}; \qquad 12)$$

Angle φ_1 is determinated as follows:

$$\varphi_1 = \arccos\left(1 - \frac{2 \cdot a}{d}\right); \quad (13)$$

where a – is a distance from the axis of distributor to the point of seed hitting, m (pic.3).

To analyse relation between speed of convergence and friction coefficient to a small extent within change f change of speed is 5,5… 5,9 %) and affect the speed of convergence.

The main factor which impact on speed of the convergence movement is diameter of the brachistichrone circle generatix. Optimal diameter of circle and, accordingly of geometrical dimensions of the distributor is determinated in case of sufficient speed of convergence on the on the curve area of distributor generatix.

To analyse depending of speed of movement from the coordinates of seed hitting on the curve surface we'll use depending (13) data **a = 0...0,02** and do math in accordance (12).

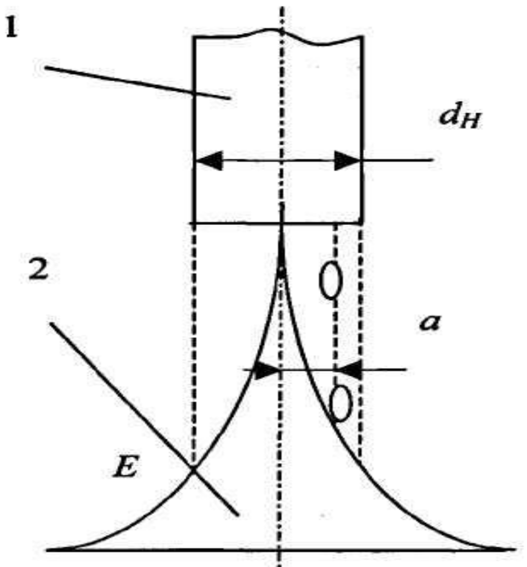
On the basis of calculation, we'll create graphic dependence of the speed movement from the coordinate of the seed convergence on the curve surface of the distributor V(a) (Pic. 5.).

Seeds hitting on the distributor in extreme point (E) of the projection bearing of seed (pic.3) have the top speed as these seeds will traverse less distance on the curve surface and wastes of kinetic energy of the force of friction will be less accordingly. In this case angle φ_1 is determinated as following:

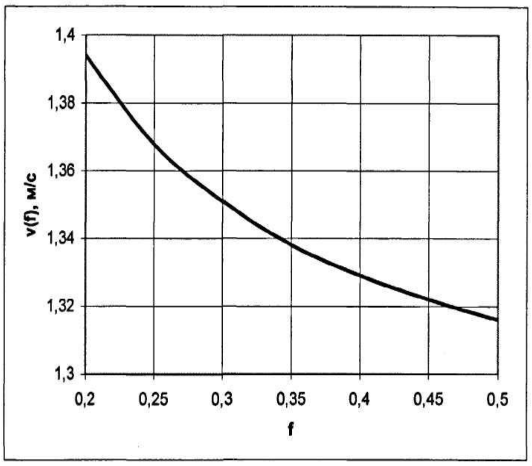
$$\varphi_1 = \arccos\left(1 - \frac{d_н}{d}\right); \quad (14)$$

where $d_н$ – is inner diameter of the guide pin, m:

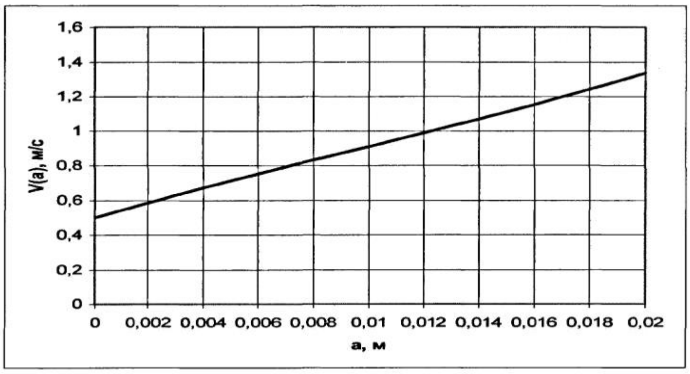
So, received correspondence data (12,13,14) allows to determinate speed of seed movement from the curved generatix in accordance with structural parameters (diameter of the generating circle, diameter of the crossing of reference guide or drill seed tube) of the distributor and coordinates of the seed hitting on the curved surface of distributor. To increase distance of the seed distribution on the line width, sowed by the coulter, the distributor with surface at an angle, which is its base, shall be used.



Picture 3 - Sheme of seed supply on the distrubutor
1 - Reference guider, 2 – Distributor



Picture 4 - Theoretical dependence of the speed of seed convergence from the coefficient of friction



Picture 5 - Theoretical dependence of the speed of seed from the coefficient of seed hitting on the curved surface of the distributor

Conclusion. Theoretical studies of the process of seed distribution by the combined distributor allows to draw the following conclusions:

1. Distributor is one of methods of increasing the distance of the seed distribution on the width of sawing. Distributor is a combination of distributor with curved generatix as a brachistichrone, and curved surface generate circle which and is the basic of distributor.

2. Theoretical dependence for determination of constructive parameters of the distributor are received as follows:

speed of convergence from the curved generatix from the diameter of the circle diameter of the circle generatix of brachistichrone; distance of the seed distribution (parametric form) from the constructive parameters of the with surface at an angle (length of the surface at an angle and angle of its installation to the horizon), usage of which allows to determinate optimal parameters of the determinator and surface for the supporting of seed sawing on the operating width of the coulter with necessary distance and equability.

3. Speed of the seed movement from the curved generatix of coulter depends on the diameter of the circle generatix of brachistichrone and coordinate of the seed hitting on the curved surface.

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Обгрунтування швидкості руху насіння по розподільнику сошника для підгрунтово-розкидного способу сівби

У статті розглядається визначення оптимальної форми розподільника та процес розподілу насіння комбінованим розподільником у вигляді криволінійної призми. На підставі розрахунків встановлено, що рівномірність розподілу насіння залежить від форми розподільника, діаметра твірного кола кривої, координати потрапляння насінини на поверхню розподілу, і як результату швидкості її руху. Формули для визначення швидкості насіння на поверхні розподільника були записані залежно від зміни конструктивно- технологічних параметрів, включаючи змінний діаметр твірної призми кола. Була записана математична модель координат і траєкторії руху насіннєвого матеріалу та дальності польоту насінини. Рівномірність розподілу насіння по ширині захвату буде характеризуватися швидкістю потоку насіння на похилій ділянці розподільника та координат потрапляння на поверхню розподільника. Досліджено вплив довжини похилої ділянки розподільника на рівномірність розподілу насіння, отримані залежності, що визначають відстань польоту в залежності від довжини похилої ділянки розподільника та швидкість сходу насіння, за допомогою якої обираються оптимальні довжини похилої ділянки. Представлені основні результати теоретичних досліджень та рекомендації щодо використання цього типу пасивних розподільників сошників для підгрунтово-розкидного способу сівби.

Значення довжини схилу вибирається виходячи з діапазону та рівномірності розподілу насіння і становить 60 мм. Комбінований розподільник може розподіляти насіння зернових культур шириною 95-100 мм. При проведенні двофакторних експериментів було встановлено, що найкращий показник розподілу насіння має комбінований розподільник, виконаний у вигляді двосторонньої криволінійної призми. Розроблено конструкцію сошника для насіння зернових культур із комбінованим насіннєвим розподільником. Під час попередніх експериментів та багатоваріантного пошуку експерименту було визначено рівняння лінійної регресії та визначені найбільш значущі фактори, що впливають на параметр оп-

тимізації.

Теоретичну залежність для визначення конструктивних параметрів розподільника одержують таким чином: швидкість конвергенції з комбінованого розподільника залежить від діаметра твірного кола брахистохрони, та довжини похилої ділянки; відстань розподілу насіння (параметрична форма) від конструктивних параметрів поверхні встановленої під кутом до горизонту, використання якої дозволяє визначити оптимальні параметри розподільника. Швидкість руху насіння по розподільнику сошника залежить від діаметра твірного кола брахистохроги і координати потрапляння насіння на криволінійну поверхню.

Ключові слова: *швидкість, сівба, розподільник, твірна, рівномірність.*

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