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Identification of parameters of pneumatic and mechanical seeding device under the influence of vacuum

Kateryna Vasylkovska[1*], Oleksii Vasylkovskyi[1], Serhii Leshchenko[1], Mykola Sviren[1] and Mykola Moroz[2]

[1]*Central Ukrainian National Technical University (CUNTU), Kropyvnytskyi 25030, Ukraine*
[2]*Kremenchuk Mykhailo Ostrohradskyi National University, Kremenchuk 39600, Ukraine*
[*]*Corresponding author:* vasilkovskakv@ukr.net

Abstract

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Modern pneumatic and mechanical seeding devices of tilled seed drills provide effective one-seed dosing, but due to a significant difference between the fly-out velocity from the disk (up to 0.5 m/s) and the seed drill velocity (up to 2.5 m/s), there is a redistribution of the calculable intervals between seeds in the furrow. The solution of this task is to create the appropriate conditions for ensuring high velocity of the seed disk rotation. The construction of a new pneumatic and mechanical seeding device for precision seeding of tilled crops with peripheral location of cells on a seed disk and a passive device for removing unnecessary seeds in a centrifugal method is suggested.

The analysis of the design of the seeding device allows asserting that it is possible to catch, remove and drop the seeds even without the formation of rarefication in the vacuum chamber. Removal of unnecessary seeds is carried out by means of manufacturing in the body of the device a passive device with a cavity, to which, under the action of centrifugal forces, unnecessary seeds fall and go back to the filling zone. In order not to remove the main seed along with the unnecessary seeds when the rotation velocity of the seed disc approaches the velocity of the seeding device, additional force should be applied that would keep the main seed in the cell, that is, the force of suction.

Thus, the presence of suction force will increase the size of the cavity (the angle which determines its size) to 0.26...0.32 rad at the angular velocities of the disk, respectively, 25...30 rad/s. That will guarantee the removal of unnecessary seeds, because their movement along the blade in this case, exceeds half its diameter.

Keywords: seeding disk; seed; blade; cavity position angle; removal of unnecessary seeds

Introduction

The search for means of accurate dosing of the seed material from the hopper to the furrowhas always been relevant. Seeding devices have undergone a long and difficult way, especially seeding machines for precision single-seed sowing.

Modern pneumatic and mechanical seeding devices of tilled seed drills provide effective single-seed dosing, but due to the significant difference in fly-out velocities fromthe disk (up to 0.5 m/s) and the seed drill velocity (up to 2.5 m/s), there is a redistribution of the calculable intervals between seeds in the furrow(Amosov, 2007; France et al., 1984; Boyko et al., 2003; Mursec et al., 2007; Sysolin et al., 2001; Sysolin et al., 2004; Voytyuk et al., 2005).

The approximationof rotational velocity of the disk seed cell to the travelvelocity of the seed drill allows balancing the velocities' parallelogram while seeds are flying out of the disk. Thus, the accuracy of seed placement in the furrow will depend only on the accuracy of seed location on the seed disk.

Material and Methods

The solution of this task is to create the appropriate conditions for ensuring high rotation velocities of the seed disk.

The design of a unique pneumatic and mechanical device (Petrenko et al., 2011; Petrenko et al., 2013) (Figure 1) was developed at the Department of Agricultural Engineering of Central Ukrainian National Technical University. The seed disk 1 has cells 2 which are formed by sectoral cut-outs of the disk and blades 3. Externally, the cells are covered by the device casing 5.

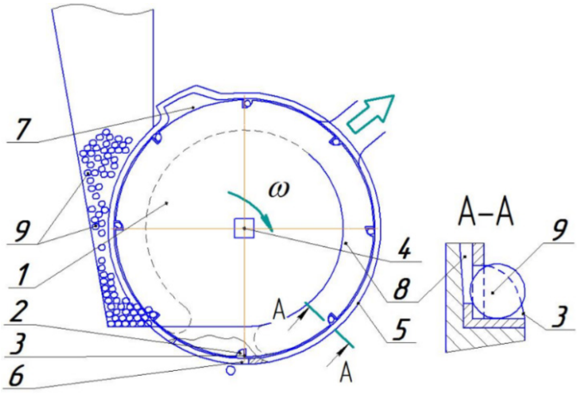


Fig. 1. The model of the pneumatic and mechanical seeding device

1 – seed disk; 2 – cell; 3 – blade; 4 – driving shaft;5 – casing; 6 – seeding outlet;7 – inactive appliance for removing extra seeds;8 – vacuum chamber; 9 – seeds

The process of the seeding device operation is as follows. When the disk is rotating, the blades catch a seed and automatically place it in a cell. The vacuum created in the system keeps the seed from transverse tangential and radial displacement. In addition, the blades prevent the trapped particles to fall out in the tangential direction, and the casing prevents falling out in the radial direction. In this way, the particles move to the pocket 7 where the excess „twin“ seeds are removed.

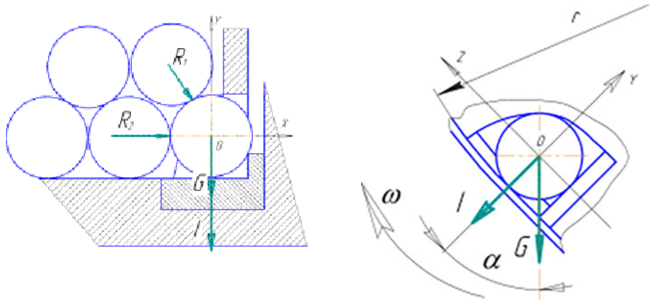
The suggested device has a significant advantage over the classical ones, since it ensures the forced seizure of the seeds with blades and the constructive elements to be kept in cells. Let us consider the operation of the device in the worst conditions with the absence of vacuum.

The analysis of the suggested design of the seeding device (Petrenko et al., 2011; Petrenko et al., 2013: Vasylkovska, 2018) allows us asserting that seeds can be caught, removed and dropped even without the use of vacuum in the vacuum chamber.

Results and Discussion

The analysis of the design of the proposed seeding device (Petrenko M. et al., 2011; Petrenko M. et al., 2013) allows asserting that it is possible to catch, remove and drop the seeds even without the formation of rare fication in the vacuum chamber.

Obviously, the seeds will be definitely caught due to the presence of peripherally located cells with blades and pressure *R* from the seed mass on the caught seed (Figure 2).



***a*)** ***b*)**

Fig. 2. Forces affecting a seed in the process of catching:
***a* – layout of forces in projection XOY;**
***b* – layout of forces in projection XOZ**

Having one-seed filling of the cells and ensuring the fulfilment of condition (1), the particle will move along the inner surface of the casing to the zone of dropping into the furrow.

$$K = \frac{\omega 2.r}{g}, \tag{1}$$

where ω is the angle velocity of the disk, [rad/s];

r is the distance of the particle's mass centre relative to the disk rotation point, [m];

g is the free fall acceleration, [m/s^2].

Natural removal of unnecessary seeds can be accomplished by manufacturing a passive device with a cavity in the casing of the device. Under the action of centrifugal forces, unnecessary seeds move to the cavity and go back to the filling zone (Figure 3).

Obviously, during the rotation of the disk at the angle ε, the main seed has to move radially at the distance less than half its own diameter, in order not to get along with the "extra" particles to the cavity:

$$L < \frac{d}{2}, \tag{2}$$

where *d* is the diameter of the seed, m.

To ensure the falling of excess seeds, the centrifugal force must exceed the force of gravity of the seed. When the rotation velocity of the seed disk is approximated to the seed drill velocity, it is possible that the main seed can be removed along with the extra seed. It is necessary to use additional force that would keep the main seed in the cell, which is the suction force P (Vasylkovska et al., 2018).

Since the particle does not completely cover the sucking hole of the peripherally located cell, and the permissible movement of the particle into the cavity is not significant $\leq 0.5d$, then the suction force P can be considered to be a constant value (Figure 3).

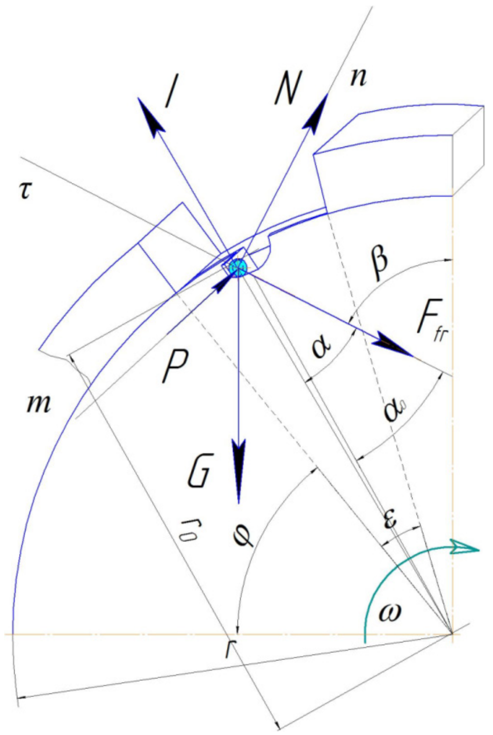


Fig. 3. Forces affecting a seed when it is transported to the dropping zone

The equation of the particle motion in the field of the operating forces will be written as:

$$m \cdot S'' = -f \cdot (m \cdot g \cdot \sin\beta + P - m \cdot \omega^2 \cdot r \cdot \sin\alpha) - m \cdot g \cdot \cos\alpha + m \cdot \omega^2 \cdot r \cdot \cos\alpha \tag{3}$$

where G is gravity force, $G = m \cdot g$, N;
P is suction force, kPa;
I is centrifugal force, $I = m \cdot \omega^2 \cdot r$, N;
F_{fr} is friction force, $F_{fr} = f \cdot N = f \cdot (-m \cdot \omega^2 \cdot r \cdot \sin\alpha + m \cdot g \cdot \sin\beta)$, N;
N is the force of normal response, N;
f is the coefficient of friction on the casing material;
m is the mass of a seed, kg;
β is the angle of blade adjustment vertically, $\beta = \frac{\pi}{2} - \varphi + \alpha_0 + \omega t$;
φ is the angle of the cavity location;
α_0 is the angle that determines the position of the blade.

Or:

$$S'' = -f \cdot g \cdot \sin\beta + \frac{f \cdot P}{m} + f \cdot \omega^2 \cdot r \cdot \sin\alpha - g \cdot \cos\beta + \omega^2 \cdot r \cdot \cos\alpha, \tag{4}$$

where $r \cdot \cos\alpha = S + r_0 \cdot \cos\alpha_0$;
$r \cdot \sin\alpha = r_0 \cdot \sin\alpha_0$;
P, ω are invariables.

After solving the equation of formula (4) the displacement of the particle along the blade will be determined by the equation:

$$S = \frac{1}{2}\left(e^{\frac{\varphi t}{2}} - e^{-\frac{\varphi t}{2}}\right)^2 \cdot \left(r_0 \cdot (\cos\alpha_0 + f \cdot \sin\alpha_0) - \frac{f \cdot P}{m \cdot \omega^2}\right) + \frac{\sqrt{2} \cdot g}{4 \cdot \omega^2}[(\cos\alpha_1 + f\sin\alpha_1) \cdot e^{\omega t} + (\sin\alpha_1 - f\cos\alpha_1) \cdot e^{-\omega t} - \sqrt{2} \cdot (\sin(\omega t + \alpha - \varphi) - f \cdot \cos(\omega t + \alpha - \varphi))], \tag{5}$$

where $\alpha_1 = \alpha_0 - \varphi - \frac{\pi}{4}$.

The movement of the seed in the radial direction is within:

$$0 < L = S \cdot \cos\alpha_0 < \frac{d}{2} \tag{6}$$

To ensure the fulfilment of condition (6), a seed must move radially during the time for which the disk turns to the angle **ε**, which determines the size of the cavity:

$$t = \frac{\varepsilon}{\omega}, \tag{7}$$

where ε is the angle that determines the cavity size, rad;
ω is the angle velocity of the seed disk, rad/s;

Then, we have the following:

$$L = \left(\begin{array}{l} \frac{1}{2}\left(e^{\frac{\varphi t}{2}} - e^{-\frac{\varphi t}{2}}\right)^2 \cdot \left(r_0 \cdot (\cos\alpha_0 + f \cdot \sin\alpha_0) - \frac{f \cdot P}{m \cdot \omega^2}\right) + \\ + \frac{\sqrt{2} \cdot g}{4 \cdot \omega^2}[(\cos\alpha_1 + f\sin\alpha_1) \cdot e^{\omega t} + (\sin\alpha_1 - f\cos\alpha_1) \cdot e^{-\omega t} \\ - \sqrt{2} \cdot (\sin(\omega t + \alpha - \varphi) - f \cdot \cos(\omega t + \alpha - \varphi))], \end{array}\right) . \cos\alpha \tag{8}$$

The dependences of a moving particle along the blade on the rotation angle of the disk at different angular velocities are constructed (Figure 4).

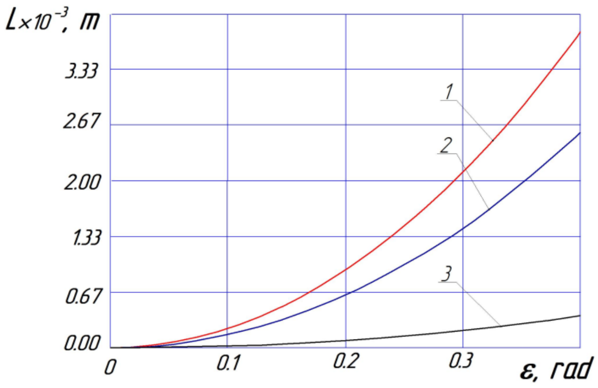


Fig. 4. Dependences of the movement of the particle along the blade on the rotation angle of the disk under the condition that vacuum is produced at angular velocities: 1 – 30 rad/s, 2 – 25 rad/s, 3 – 20 rad/s

As can be seen from the obtained dependence, the presence of suction force allows increasing the size of the cavity (the angle which determines its size) to 0.26...0.32 rad at the angular velocities of the disk, respectively, 25...30 rad/s. That will guarantee the removal of unnecessary seeds (twins), since their movementalong the blade in this case, exceeds half its diameter. And the main seed due to the presence of suction force is securely held in the cell and transported by the disk to the zone of dropping it into a furrow.

Conclusion

Therefore, the design of the seeding device ensures the seeds dosing to the furrow at the angular velocity of 25...30 rad/s, which is 11.25 rad/s higher than with the use of a seeding device without vacuum (Vasylkovska et al., 2018; Vasylkovska et al., 2019).

So, the presence of suction force will enable increasing the cavity size (the angle which determines its size) to 0.26 ... 0.32 rad at the angular velocities of the disk, respectively, 25...30 rad/s. It will guarantee the removal of unnecessary seeds (twins), because their movement along the blade in this case exceeds half its diameter. In addition, the amount of suction force, in comparison with serial seeding devices, is much lower. The main seed, due to the presence of suction force, is securely held in the cell and transported by the disk to the zone of dropping it into a furrow.

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