Researches of pneumatic sowing machine with peripheral cells location and inertial superfluous seeds extraction

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Abstract. In the article we provide the new design of pneumatic sowing machine with peripheral cells on the seed disk and a passive device for removing extra seeds with inertia method for precise seeding of cultivated crops. A series of studies was proposed for sugar beet seeds sowing device, we defined the influence of dilution in a vacuum chamber of sowing device and angular velocity cell seed disk on the cells filling factor. The design of the new pneumatic sowing machine can significantly reduce the vacuum in the system having increased the angular speed in cell seed disk to the values of seeding device travelling speed, thus provide a constant point of seeds drop from the seed disc at the same trajectory of their flight to the furrows and the qualitative cells filling. To determine the rational parameters and modes of sowing device we used method of multifactor experiment planning. We determined the main levels and intervals of varying factors for sugar beet sowing along with determining the filling factor of cell seed disk. With application of package Statistica 6.0. for parameter optimization - cell seed disk filling factor was constructed response surface and line of even output.

Key words: pneumatic seeding machine/device, seed disc, experiment, cells filling factor, dilution, cells angular speed

INTRODUCTION

Modern Ukraine - a country with high potential for the agricultural sector in the growing row crops, implementation of which is impossible without the introduction of new technologies and providing high-performance manufacturers of agricultural machinery. Selection of equipment for agricultural production in the initial phase, namely drills for precise seeding - is the primary condition for future good harvest.

Modern pneumatic sowing drill devices of high precision, despite a long history of their creation and improvement, have several disadvantages, the main ones are: insufficient dosing capacity caused by limited seed angular velocity of the disk ($V_k \leq 0{,}5$ m / s) and the presence of uncontrolled redistribution random intervals between the seeds in the furrow, because of the high relative speed of the seed in contact with the latter during the drills movement with nominal speeds (V_c = 1,5 ... 2,5 m/s). Eliminating these deficiencies is achieved by increasing the angular velocity of the sowing disk and its harmonization with the drills travelling speed. [1-5].

THE ANALYSIS OF RECENT RESEARCHES AND PUBLICATIONS

However, in the construction of modern pneumatic sowing machines to solve this problem is technologically impossible, since this affects the formation of one seed flow at an early stage of its formation.

The quality of seeds dosage to furrows depends primarily on the uniformity of seeds location on sowing disc. Therefore, the approach to choosing forms of the disc mouths is crucial initial condition of uniform dosage [6, 7].

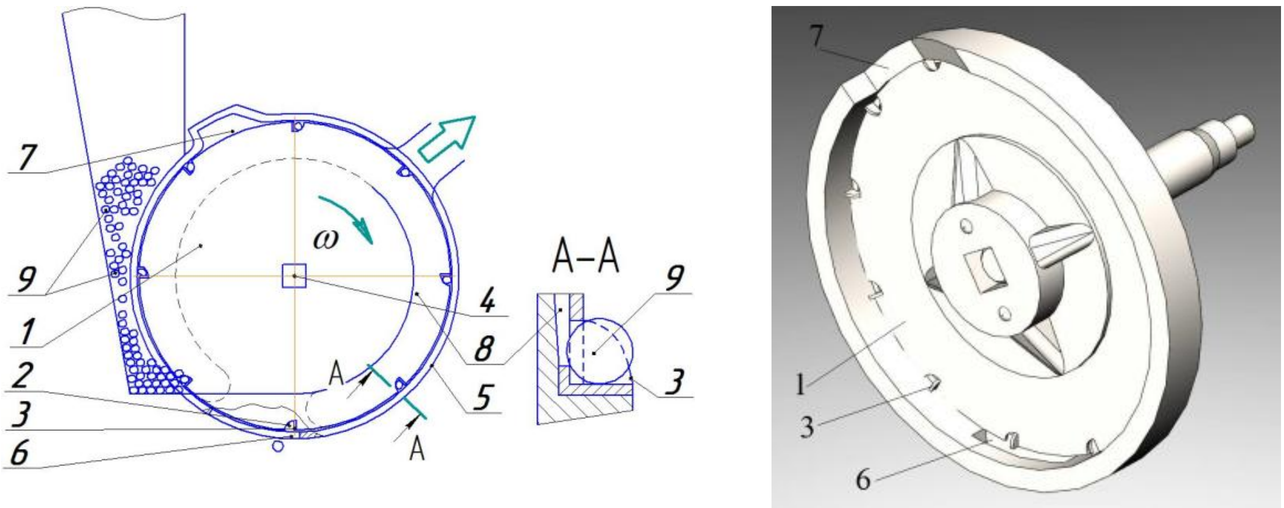
In order to improve accuracy at seeding process, at the Department of Agricultural Engineering of Kirovograd National Technical University we developed a prototype of a new section for accurate pneumatic sowing of cultivated crops seeds (Fig. 1) [1-4].

The main feature of the new sowing device is the presence of the original seed disc 1 with peripheral cells 2, where on its inner surface are placed blades 3 to force capture a seed in the chamber and its further transportation to the dumping area.

Seed disc 1 with cells 2 attached to the drive shaft 4 and inserted in a cylindrical cavity of the housing unit 5.

When rotating, the seed disc 1, the cells 2 with the blades 3 get into the seed layer, where under the forces of gravity and pressure of the grain, a seed is independently embedded in the cell seed disk. A capture of a seed is being done by the blade 3 at the first contact with a layer of seeds; the other seeds are pushing only one that is already in contact with a blade to cell 2, where we observe its secure grip and suction using airflow and reliable maintenance. Next the captured seed is moving with the disc.

The form of cell seed disk (Fig. 2) is performed with the expansion in the radial direction toward the stationary cylindrical surface of the frame, which closes their volume and creates a fixed outer wall from the filling to seeding zones. In the area of sowing on the surface of the cylindrical frame we made a seeding window 6, which opens the cell drives in this area and provides free seeds drop to furrows with help of the gravity and centrifugal forces.



a b

Fig. 1. The proposed pneumatic seeding machine: 1 – seed disc; 2 – cell; 3 – blade; 4 – drive shaft; 5 –the frame; 6 – seeding window; 7 – passive device for removing extra seeds; 8 – vacuum chamber; 9 – seeds a - the scheme; b – a three-dimensional model.

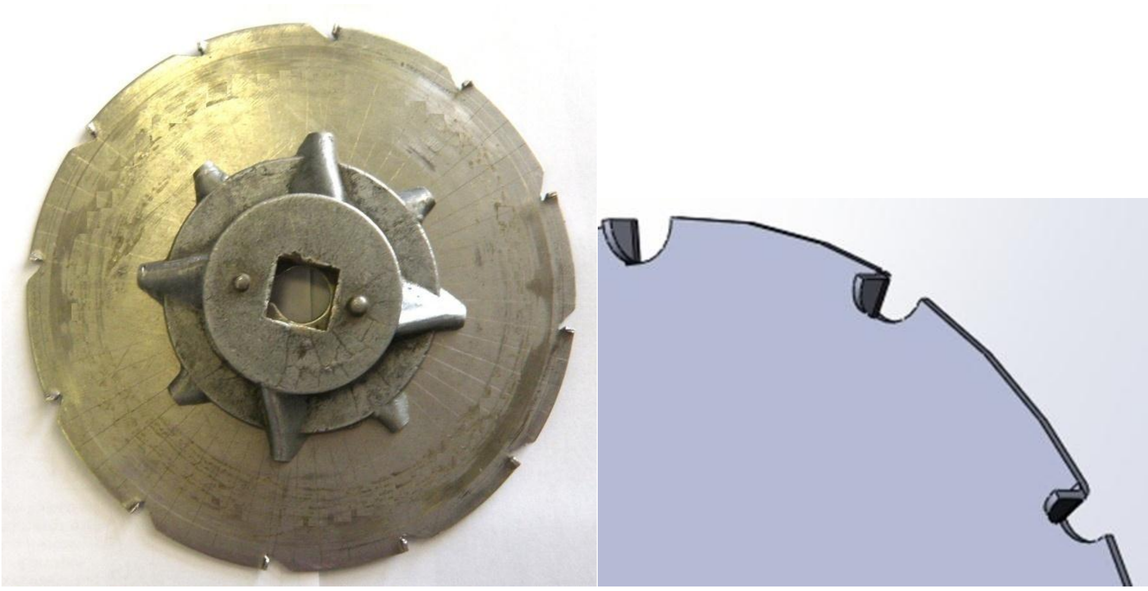


Fig. 2. General view and scheme of the sowing disc with a peripheral cells location.

In order to remove extra seeds from cell seed disk, next to it at the top of the cylindrical surface of the body, above the filling zone we made a passive device 7, which is a special cavity in which disengaging extra seeds are separated from the disk, and then fall (drop) in the filling zone of the working chamber.

The proposed improvement of the design of the pneumatic disc sowing device eliminates its major shortcomings, improves reliability and increases the process of cells seed disc filling as well as the efficiency of superfluous seeds removal and reliability of the cells exemption in the sowing area. This ensures a constant point of sowing seeds drop from the disk and the same trajectory of their fall to the furrows, which positively affects the uniformity of distribution and intervals between seeds in the furrow. This generally enhances the disk angular velocity and increases the productivity of the machine.

THE MAIN RESULTS OF THE RESEARCH

A series of preliminary and exploratory studies have shown [8-12], that the process of cells filling takes place at the time of seed layer entry into the cell of the working chamber.

This feature of the device as the availability of optimal conditions for seed orientation of the lower layer of seeds moving accordingly to the relative number of cells significantly improves their filling in a wide range of angular velocities and a small dilution in a vacuum chamber and does not require a large area of filling

Before the implementation of experimental studies we conducted randomization of experiments to level the influence of the factors that are not controlled, and to ensure their objectivity when choosing the object.

In order to determine the rational parameters and modes of the sowing device we used a method of multifactor experiment planning.

The purpose of the series of experiments has been the implementation of matrix 2^2 plan of Box-Hunter, in the result of which we determined the influence of the dilution effect in a vacuum chamber (ΔP) and the angular velocity of cell seed (V_a) on the quality of their filling.

Experiment planning of matrix presented in Table 1.

Table 1. Experiment planning matrix 2^2

№ of experiment	*ΔP*, kPa	V_a, m/s
	x_1	x_2
1	-1	-1
2	+1	-1
3	-1	+1
4	+1	+1

The seed sowing machine handy ability is easy to assess by the rate of filling cells, which is equal to the amount actually sown seed over time to the number of cells of the seed disk that have been gone the drop point over the same period.

The optimal distribution of seeds in a row can be achieved by filling the cells with no spaces. That is why as an optimization criterion we adopted the filling factor of cell seed disk.

The main level and intervals of varying factors for sowing sugar beet were determined by the filling factor of the cell seed disk (Table 2).

Table 2. Levels of factors in sugar beet seed sowing device of peripherally located cells to the seed disk

Factor	Natural denotations	Code denotations	Interval of varying	Levels of variation					
				natural			code		
				top	null	bottom	top	null	bottom
1	2	3	4	5	6	7	8	9	10
Dilution in vacuum chamber, *kPa*	*ΔP*	x_1	±0,2	0,5	0,3	0,1	+1	0	-1
Peripheral speed of cells, *m/s*	V_a	x_2	±0,5	2,5	2,0	1,5	+1	0	-1

In the first stage of experimental studies we used a disk with peripheral cells, whose number *z* is equal to 12 pieces.

Dilution in a vacuum chamber selected on the basis of studies [8-12], and considering the theoretical studies [6, 13, 14], according to which ΔR = 0.1; 0.5 kPa and in addition ΔR = 0.3 kPa.

The peripheral speed of cells V_p m / s was selected based on the recommendations of research, experiment results search [8-12], and the results of theoretical research according to which V_p = 1.5; 2.5 m / s and an additional V_p = 2 m / s [6, 13, 14].

Angle of opening of the passive device for removing extra seeds in the experiments was ε = 25 ° [13, 14].

So, we obtained the results of the experiment implementation of planning matrix (Table 3).

Table 3. The results of the experiment implementation of planning matrix 2^2

№ of experiment	Factors		Criterion
	Dilution in vacuum chamber; *ΔP*, kPa	Peripheral speed of cells of seed disc; V_p, m/s	Cells filling factor; *K*, %
	x_1	x_2	y_2
1	0,1	1,5	83,4
2	0,5	1,5	128,6
3	0,1	2,5	59,1
4	0,5	2,5	114,6

In the design of the experimental set its design was made adjustable for each parameter and was based on theory and previous studies which have impact on the seeding [8, 9, 11-13].

For processing the experimental data we used package STATISTICA 6.0 [15-16]. As a result, we conducted a construction of statistical mathematical model for the coefficient seed filling cells disk K, (Y_1 = K).

Statistical evaluation of the results allows to conclude that the experiments are equally accurate as the estimated value of the Cochran's Q test G^P for optimization parameter Y when n = 4 and f_u = 2 makes G^P = 0,478 and is less than the tabular value G^P = 0,7679 [17-20] therefore we conclude that the process is playing.

Dispersion reproducibility (error experiment) is 0.183.

So, we obtained the regression equations:

$$Y_1 = 96,425 + 25,175x_1 - 9,575x_2 + 2,575x_1x_2 \quad (1)$$

We constructed a response surface and a line of level output for filling factor of cell seed disk K (Fig. 3).

The analysis of response surface and the line of level output for optimal values of filling cells K, can determine the rational values of the investigated factors, namely:

– the value of rational dilution in a vacuum chamber *x1 → ΔP*, should be in the range of 0.20 to 0.30 kPa;

– rational peripheral speed of cells of seed disk *x2* → V_p should be in the range from 2.0 to 2.5 m / s.

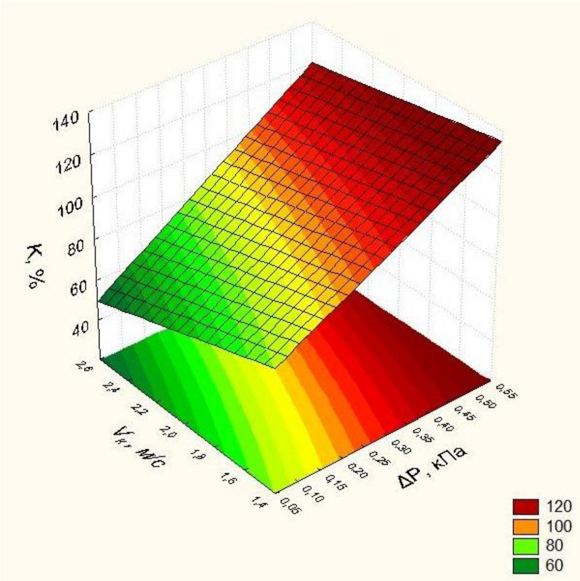


Fig. 3. The response surface and line of level output for cells filling factor of a seed disk.

The most influential factor in the process of filling cells seed disc of a research pneumatic sowing machine is the value of the dilution factor because in order to achieve a filling cell value K = 100% should be ΔP = 0,2 ... 0,3 kPa at the angular velocity of cells Va= 2.0 ... 2.5 m / s.

If we increase the value of dilution and reduct the angular velocity of cells we increase the filling factor due to worsening terms of dumping extra seeds.

CONCLUSIONS

The most influential factor in the process of filling cells seed disc of a research pneumatic sowing machine is the value of the dilution factor because in order to achieve a filling cell value K = 100% should be ΔP = 0,2 ... 0,3 kPa at the angular velocity of cells Va= 2.0 ... 2.5 m / s.

Thus, the design of the studied pneumatic device makes it possible to increase the angular velocity of the cells and reduce their number on the sowing disk, and greatly reduce the dilution in a vacuum chamber.

That is why the proposed seeding machine increases the technological efficiency of cultivated crops and reduces the energy costs.

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