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RESULTS OF TESTING A DISC PNEUMATIC SEED DRILL FOR FLAX

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ABSTRACT

Introduction. The creation of high-tech, resource-saving and reliable working bodies of combined sowing machines, that allows meeting the agrotechnical requirements for carrying out tillage and sowing of small seed crops, is the most important task of the agricultural industry.

Materials and methods. The solution of the task is based on the use of mathematical models of complex multi-level systems of the interaction of the main working bodies of the combined machine, as well as on conducting laboratory tests and field experiments of the objects under study. The novelty of the proposed theoretical equations emphasizes the relevance of the chosen subject.

Results. An in-depth analysis of the design features of mechanical, hydraulic, electromechanical, electro-pneumatic, and pneumatic sowing systems made it possible to identify insufficient study of this issue and outline ways to improve these sowing units. The main objectives of the research are the analysis of existing seed drills of combined sowing machines for flax and other small-seed crops, mathematical modeling of the object "seeds – seed drill – seed tube", theoretical substantiation of the design parameters and operating modes of the horizontal disc seed drills using air transport of the material, determination of quality characteristics of the work of a test body in laboratory and field conditions, as well as economic assessment when introducing the unit into the production.

Discussion. The developed design of the horizontal pneumatic seed drill for small-seed crops provides high-quality and resource-saving sowing. The established mathematical model of the seed drill is applicable to disc, vibration, friction and cellular dosing systems of agricultural machines. When agrotechnical requirements for sowing are fulfilled, the seed drill allows obtaining a significant increase in the yield of flax seeds and other small-seed crops.

Conclusions. The ways for the development of modern sowing and metering systems of combined machines and sowing drills for the cultivation of small-seed crops are substantiated by obtaining theoretical grounds of the interaction of the working bodies of a horizontal disc pneumatic seed drill for flax, taking into account

the technological and physicomechanical properties of seeds, as well as obtaining regression equations for plant spacing indicators and germination from the operating modes of the unit.

Key words: Sowing, test result, experiment result, sowing drill, pneumatic conveying, pneumatic system, dosing, small-seed crops, flax, seeds, horizontal disc, laboratory unit, economic assessment, sowing quality, experiment, spot seeding.

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1. INTRODUCTION

The theory of interaction of the mechanical seeders' working bodies with seed material was started by the eminent scientists V.P. Goryachkin, S.V. Letoshnev, V.A. Zheligovsky. M.N. Chatkin, K.P. Kazarov, N.P. Kryuchin, O.A. Sizov, N.P. Laryushin and others [1-7] developed the study of the design characteristics of mechanical and pneumatic seed drills in their works.

At first, the tasks of the research are to substantiate the use of a new working body – a horizontal air disc seed drill.

- To analyze the existing sowing systems of combined machines and seeders for sowing flax.
- To carry out mathematical modeling of the object "seeds – seed drill – seed tube".
- To theoretically substantiate the operating parameters of the design of a horizontal disc air seed drill.
- To establish the qualitative characteristics of the work of a prototype of the seed drill in the laboratory and field conditions.
- To make an economic assessment of the results of the implementation of a horizontal disc air seed drill in the production conditions.

The analysis of the design features of various types of seeders allowed classifying the working bodies of domestic and foreign researchers and developers. The main deviations from the established GOST requirements are the plant spacing, the deviation from the sowing centerline, the reliability of the sowing operation, etc.

Pneumatic systems using compressed air are the most used in modern combined machines and seeders. They provide the improved quality performance of sowing machines [8-17], considering the selection of optimal parameters of metering devices [18].

The classification features of modern pneumatic seed drills for small-seeded crops, including flax, are the design features of the working bodies (disc, drum, belt, etc.) and the operation mode of the sowing systems (using extreme pressure, vacuum, etc.) [19].

The analysis of the movement of seeds of small-seed crops, considering their technological and physicomechanical properties, made it possible to develop an algorithm for designing a seed drill without the identified shortcomings.

2. MATERIALS AND METHODS

Theoretical studies of the subject were carried out using system analysis and synthesis, taking into account the methods of classical mathematics and theoretical mechanics, verification of the compiled theoretical and regression models using general methods with Mathcad and Excel software, as well as the theory of experiment planning [20, 21]. The work is carried out within the framework of R&D "Development of adaptive technologies for the cultivation of linen flax on soddy-podzolic soils under the entry of fallow lands into operation, AAAA-A18-118083090015-8".

3. RESULTS

When using the developed mathematical models of the interaction of the horizontal disc pneumatic seed drill with the seeds (flax seeds) it is possible to use the phased automation of the design process of the elements of the sowing system, considering the specific conditions of the object.

During the research of the flowchart of the model "seeds – seed drill – seed tube", the technological process of sowing flax is divided into the following stages.

- Seeds sink into a seed disc cell.
- Seeds fall out in the seed tube.
- Movement (transportation) of seeds along the seed tube to the coulter group.

The kinematics of seed movement in a flat coordinate system allows determining the projections of velocities on the coordinate axes. The resulting equations of speed and acceleration allow composing differential equations of seed movement, considering the fact that external constraints can affect the seeds [22].

The result of one of the tasks – improving the quality component of the operation of sowing, based on the analysis of the scientific and patent literature – is the development of the design of a horizontal disc pneumatic seed drill. The intellectual property of the prototype is confirmed by the patent for utility model No.110589 and the patent for invention No.2575364 (Figure 1).

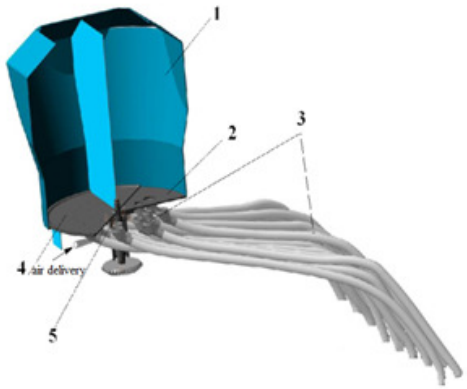

Figure 1 Horizontal pneumatic disc seed drill
1 – tank; 2 – bottom with seeding windows; 3 – seed tube; 4 – seed disc; 5 – drive

The horizontal disc pneumatic seed drill for sowing flax and other small-seed crops consists of a seed tank, a base with sowing windows, seed tubes, a sowing disc, a drive shaft, and air ducts for transporting the seed material.

The principle of operation of the seed drill is as follows. Prior to the work start, the tank is filled with the seeds. When the seed disc rotates, the seeds sink into the cells. At the coincidence of the cell axes with the seeding window, the seeds enter the seed tube and are picked up by the air flow. The seeds are transported to the coulters by seed tubes are bedded in the soil at an equal distance from each other in a row.

Laboratory studies were carried out in a laboratory unit for testing seed drills, developed on the basis ofTver State Agricultural Academy (Figure 2).

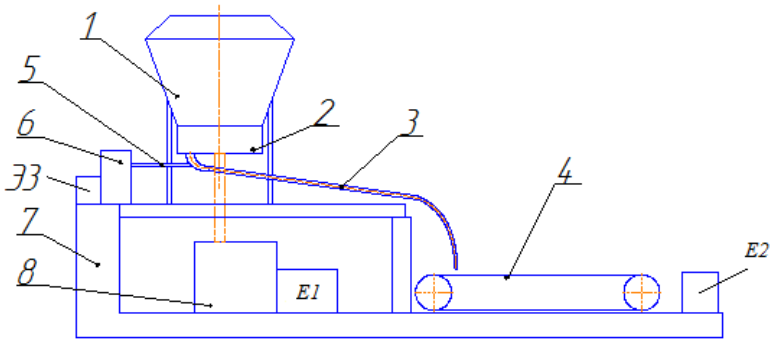

Figure 2 Laboratory unit for prototype testing
1 – tank; 2 – seed drill; 3 – seed tube; 4 – transporter; 5 – air duct; 6 – pneumatic unit; 7 – unit frame, 8 – gearbox; E1, E2, E3 – electric engines

The drive of the laboratory unit for testing a prototype is carried out by an electric motor. The tank is loaded with seeds of the selected crop. A seeding disc is pre-installed with the corresponding structural and geometrical parameters. The flap at the base of the tank opens the seed windows. At the work start of the laboratory unit, the seeds are transported to the unloading zone. At a coincidence of the cell axes and the sowing window, the seeds enter the seed tube, and, after passing through the upper cylinder, are transported by the air flow generated by the fan. Indicators of deviation from the seed centerline and the distance between the seeds in a row are recorded from the surface of the belt conveyor moving at a given angular velocity and fixed on it with a consistent material.

Field experiments (Figure 3) of the developed and manufactured prototype were carried out in accordance with standard techniques and the requirements of the state industry standards for seeders. The response of the field experiment was the plant spacing (the distance between the seeds in a row) and the field germination of flax.

Figure 3 Carrying out the field testing of a disc pneumatic seed drill

Theoretical studies and mathematical dependences for a horizontal pneumatic seed drill allow determining its optimal parameters and modes of operation: the diameter of the seed disc – 600 mm, the diameter of the cells of the seed disc – 8 mm.

The 3D model of the seeding disc is shown in Figure 4.

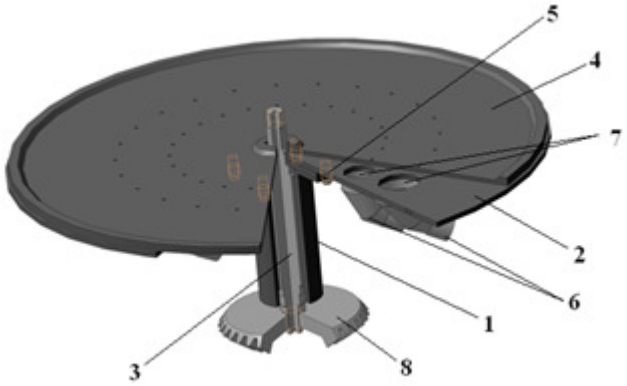

Figure 4 Seeding disc
1 – tank case; 2 – tank bottom; 3 – shaft; 4 – seed disc; 5 – flap; 6 – seed tube; 7 – seed windows; 8 – bevel gear

When researching a horizontal disc pneumatic seed drill for flax, it is also mentioned its use in the educational process at the agricultural machinery department, the technological and transport machinery and complexes department of the Tver State Agricultural Academy for preparing students of major 35.03.04 Agronomy and 35.03.06 Agroengineering, graduate students in major 05.20.01 – Technologies and Means of Mechanization of Agriculture, as well as in design bureaus for the creation of agricultural machines. The prototype is used at the enterprises of the Tver region for the cultivation of feed crops.

4. DISCUSSION

The analysis of scientific, technical and patent-licensed sources made it possible to evaluate the high prospects for the introduction of a horizontal pneumatic disc seed drill into production. The use of the modular (combined) design principle allows improving the quality indicators of sowing and eliminating shortcomings in meeting the agrotechnical requirements for sowing small-seed crops.

A methodical approach to conducting experimental studies allowed us to statistically process the data of regression equations and establish three-dimensional graphical dependences of the response indicators of the flax-sowing.

The regression equations are tested by Cochran's criterion for reproducibility, Fisher's criterion for adequacy, and Student's criterion for the significance of the main coefficients [23]:

$$y = 11{,}68 + 0{,}88x_3 + 7{,}79x_1^2 + 7{,}88x_2^2 + 7{,}59x_3^2, \quad (1)$$

where x_1 – the diameter of the cells of the seeding disc d, mm; x_2 – the frequency of rotation of the seeding disc n, min^{-1}; x_3 – belt speed V, m/s.

Figure 5 shows a graph of the plant spacing (the distance between the seeds in a row) and the studied factors (the diameter of the cells of the sowing disc and the belt speed). As a result of the analysis of the obtained response surface, the optimum range of values of the studied factors was determined.

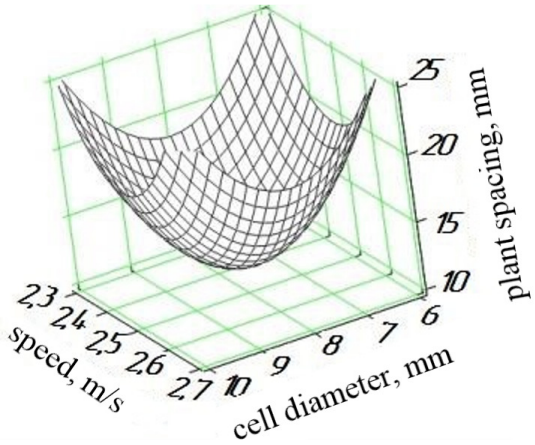

Figure 5 Dependence of the plant spacing (distance between the seeds in a row) on the belt speed and the diameter of the cells at a disc rotation frequency of 65 min^{-1}

Figure 6 shows the dependence of the seed crushing ratio on the frequency of rotation of the sowing disc.

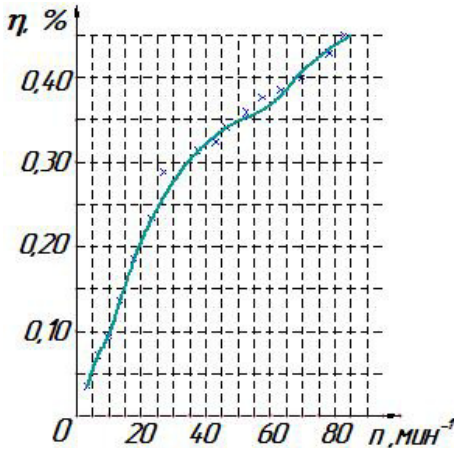

Figure 6 Dependence of seed crushing ratio on the frequency of rotation of the sowing disc

The highest quality sowing (the plant spacing is 11 ... 15 mm) is ensured at a rotation speed of the sowing disc of 65 min^{-1}; the diameter of the cells of the seeding disc of 8 mm and at a speed of 2.5 m/s. With the above-mentioned performance indicators, the percentage of seed damage by the seed drill is less than 1% (0.36).

During the field experiment, the response was estimated by the speed of the tractor with the seeder and the pressure in the pneumatic system of the drill.

The regression equation for the results of a field experiment is as follows:

$$y = 1{,}63 - 0{,}719x_1 + 1{,}1x_1^2 + 1{,}1x_2^2, \quad (2)$$

where x_1 – the pressure in the pneumatic system q, MPa; x_2 – the speed of the tractor V, km/h.

Figure 7 shows a graph of the plant spacing (the distance between the seeds in a row) from these factors.

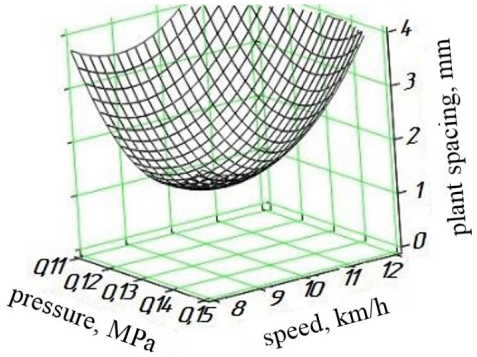

Figure 7 Dependence of plant spacing (distance between seeds in a row) from pressure and speed of movement

Figure 8 shows a graph of germination versus tractor speed and pressure in the pneumatic system.

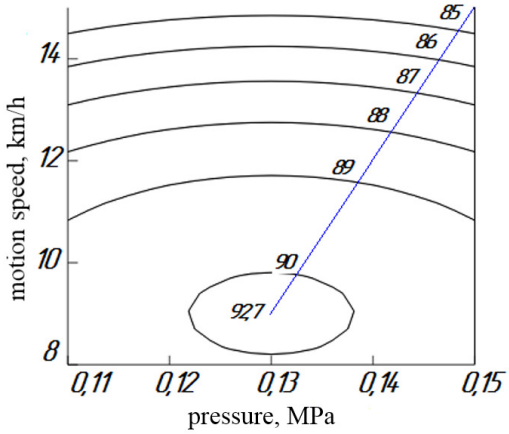

Figure 8. The dependence of field germination (%) on the speed and pressure in the pneumatic system

The established quality indicators of the drill's work, considering the agrotechnical requirements for sowing, are the speed of the tractor with the seeder – 9 km/h, the pressure in the pneumatic system of the seeder – 0.13 MPa.

Production tests on the basis of agricultural enterprises of the Tver region showed that the use of the described drill-based construction allows increasing the yield of flax to 23.5% (straw by 3.3 Cwt/ha, seeds by 0.55 Cwt/ha in comparison with the control variant). The plant spacing was, on average, 1.4 cm; deviation from the centerline, on average, 0.6 cm; field germination 86%. At the control variant – SZL-3.6 seeder – 1.9 cm; 2.1 cm and 78%, respectively.

5. CONCLUSIONS

The economic assessment of the introduction of the seed drill design into the production conditions was carried out in accordance with standard methods and state standard No23728-23730-88 (Agricultural machinery. Methods of economic evaluation). The feasibility study confirmed the positive aspects of the application of the horizontal pneumatic disc seed drill. The annual economic effect from its use was 2,534.5 rubles per one hectare of sowing. The payback period for investment costs is one season.

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