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INNOVATIVE METHODS OF INCREASING THE EFFICIENCY OF SELECTING PLANTS

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In modern crop production, energy-saving technologies play a key role, being one of the most promising directions. This requires the introduction of new-generation agricultural machines that guarantee high-quality operations, in particular, the sowing of small-seeded crops. New constructions of agricultural machinery are developed with an emphasis on multi-functionality, energy efficiency and resource conservation.

Existing sowing machines often do not meet the requirements of universal seeders, which prompts the search for new solutions. One of such promising directions is the development of seeding technological processes, which are based on the formation of a uniform flow of seeds, using sowing devices of the new generation.

The development of the construction and technological scheme of the seeding device for the selection seeder and the substantiation of its parameters is an urgent and strategically important task for the modern agricultural sector.

In addition to this, it is important to consider the requirements for adapting new technologies to changing field conditions and climatic factors. The development of technologies that reduce seed losses, reduce energy costs and increase sowing accuracy is an integral part of this process. In addition, modern selection planters must integrate the latest automation systems that allow monitoring of sowing parameters in real time, which helps to reduce the human factor and improve the accuracy of operations.

The use of advanced materials and innovative designs improves the durability and performance of sowing devices. Lightweight materials reduce energy consumption, while modular constructions simplify maintenance and adaptability. Incorporating renewable energy sources, like solar-powered systems, further supports energy-efficient and eco-friendly agricultural practices.

Key words: *seeds, small-seeded crops, seeding device, classification, structural and technological scheme, analysis.*

Eq. 5. Fig. 5. Ref. 14.

1. Problem formulation

In modern crop production, energy-saving technologies play a key role, being one of the most promising directions. This requires the introduction of new-generation agricultural machines that guarantee high-quality operations, in particular the sowing of small-seeded crops such as sorghum, amaranth, rapeseed, mustard, flax and poppy.

Breeding planters are specialized agricultural machines designed for precise sowing of seeds during breeding research or cultivation of certain varieties of plants. They are used to conduct experiments with different types of crops in order to obtain new varieties or improve existing ones. The main feature of selective planters is their ability to provide a precise dose of seed to each well or row.

The key features of breeding planters include:

Sowing precision – These devices allow precise adjustment of seed depth and spacing, which is crucial for small-seeded crops like rapeseed, poppy, or flax.

Multifunctionality – Modern planters can perform multiple tasks simultaneously, such as applying fertilizers or soil preparation, streamlining the sowing process.

Versatility – The sowing mechanisms of selective seeders are adaptable to various seed types, accommodating crops with diverse physical and mechanical properties.

Resource efficiency – These machines ensure even seed distribution, reducing material waste and enhancing the overall efficiency of resource utilization.

2. Analysis of recent research and publications

The seeder is one of the most important working organs of the seeder. It serves to select a certain amount of seeds from the total mass and to form its output flow with given parameters [1]. Therefore, the advantages and disadvantages of seed drills, in relation to the quality of seed distribution in the row and in general on the sown field, are mainly determined by the operation of the sowing machines.

Until now, several classifications of sowing devices of general-purpose seeders and for small-seeded crops in particular have been published in the literature [2, 3]. However, many of the researchers do not fully reflect the features of the designs of seeding machines and do not agree with each other on the basis of classification, which introduces certain difficulties in the improvement and development of their structural and technological schemes.

Of the classifications of seeders for small-seeded crops developed so far, the classification proposed by [4] is of greatest interest. In this classification, the principle of operation of the devices and the constructive design of their seeding devices were taken as a feature, which gave it a more universal character with the possibility of covering both existing and newly created models. However, in this classification, there is no place for electromechanical sowing devices and automatic control systems for their work. Therefore, an updated classification of sowing devices is proposed, which is shown in fig. 1

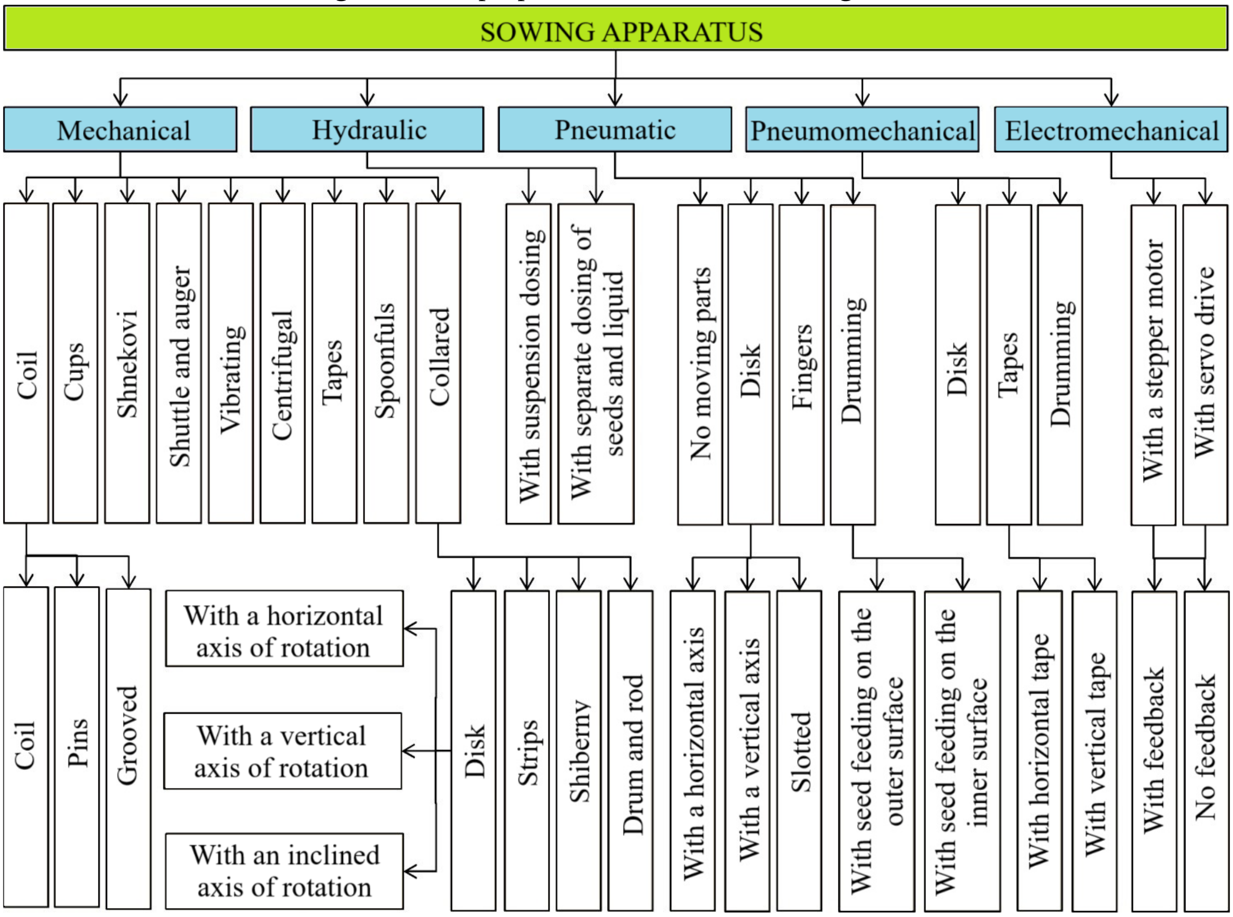

Fig. 1. Classification of Seeding Mechanisms for Small-Seeded Crop Planters

According to the principle of action (capture of seeds), sowing devices of modern seeders for small-seeded crops can be divided into mechanical, pneumatic, pneumomechanical, hydraulic and electromechanical.

Mechanical devices can be divided into coil, cup, screw, vibrating, centrifugal, spoon, cellular and belt devices based on the design and principle of operation of the main working body, which selects seeds of their total weight and creates a seed flow [5].

Mechanical devices are characterized by sufficiently high reliability and ease of maintenance.

However, these devices have a number of disadvantages: low ability of uniform sowing of seeds, lack of automation of the sowing process, lack of possibility of quick change of the batch of seeds during sowing of selection plots, possibility of seed injury.

Hydraulic sowing devices are mainly intended for dotted and nest sowing of germinated seeds of small-seeded crops. These devices are based on the principle of volume dosing of a suspension consisting of a liquid and seeds evenly distributed in it. Water or gel is usually used as a working fluid. Dosing devices, as a rule, are piston pumps or valve systems that provide portioned supply of suspension through pipelines directly into the soil or furrows, open coulters. The rate of sowing seeds is established by changing their content in the suspension of the volume of the served portion. The quality of the work of these devices is determined by the uniformity of the distribution of seeds in the liquid [6, 7].

The advantages of these sowing machines are primarily the possibility of adding growth stimulants and microfertilizers together with the liquid, which has a positive effect on the further growth and development of plants. Disadvantages of devices of this type are: low uniformity of seeding, lack of possibility to quickly change the batch of seeds during sowing in selection areas, difficulty in maintenance due to a large number of hydraulic channels and nozzles.

Pneumatic seeding devices can be divided into disc, drum, finger (rod) and devices without moving parts, which work both on the vacuum principle and on the principle of pumping air into the seed chamber according to the design of the sowing devices. In both cases, the seeds are pressed against the holes (cells) of the seeding devices by an air jet, held and transported by it to the place of discharge. Dropping seeds is usually carried out by stopping the air supply (shielding) or by mechanical droppers [8].

Pneumomechanical sowing machines are divided into disc, drum and belt based on their design. In this case, the group of pneumomechanical devices includes sowing devices, in which pneumatics serve to improve the capture and removal of seeds from the total mass. Further transportation and provision of uniform supply of seeds in these devices is carried out by special mechanical devices [9].

The advantages of pneumatic and pneumomechanical sowing devices are high accuracy of sowing for large seeds (> 5 mm) and low complexity during maintenance. Also, these sowing machines can be equipped with sensors for monitoring the position of the seed in the hole, which allows you to automatically transfer the working body to another position in the event of the absence of seeds. This helps to increase the accuracy of sowing. The disadvantages of these devices are insufficient sowing accuracy for small seeds (< 5 mm), the need to control the tightness of the system and clean it from contamination.

Electromechanical sowing devices differ from mechanical ones by the presence of an electric drive of the working bodies. Both stepper motors and servo drives can be used. The use of a control system with electric drives and various speed and position sensors allows the sowing process to be carried out with sufficiently high accuracy even for small-seeded crops. At the same time, it is possible to change seed varieties directly during sowing in different areas. The disadvantages of electromechanical sowing devices are the complexity of technical maintenance, the high level of knowledge of service personnel and the need to form a database of variety samples before the sowing process [10-12].

Based on the above, it can be stated that it is electromechanical seeding devices that are most appropriate to use during selective sowing of small-seeded crops.

3. The purpose and objectives of the research

The purpose of the research is a comprehensive analysis of the operation of modern electromechanical seeding devices and the determination of ways to improve them to ensure accurate sowing of small-seeded crops on selection plots.

4. Research results

A comprehensive analysis of the operation of modern electromechanical sowing devices was carried out in accordance with the SOU of the National Academy of Sciences 73.1-001:2011 "Organization and conduct of scientific research works" DSTU 3575-97 "Patent research. Basic provisions and procedure of conduct" and generally accepted methods of information search.

The conducted analysis showed that the most common selection planters in Ukraine are planters with electromechanical seeding devices "Maple" (Fig. 2), which are designed for accurate row sowing of small-seeded crops in the areas of preliminary and production competitive variety testing, as well as for conducting agrotechnical experiments. The seeder is equipped with a reliable electromechanical drive and a rotary seed distributor. The seed distributor has a smooth adjustment of the rotation frequency for the best distribution of seed material of different sizes on the coulters [13].

a b

Fig. 2. General view of the "Klen-4.2" (a) and "Klen-1.5" (b) selective seeders [14]

The "Maple" seeding system is a complex (Fig. 3), which consists of: a power switch, a control panel, a dispenser motor, a seed distributor motor, a speed sensor, dispenser sensors, and a remote signal to the tractor driver's cabin.

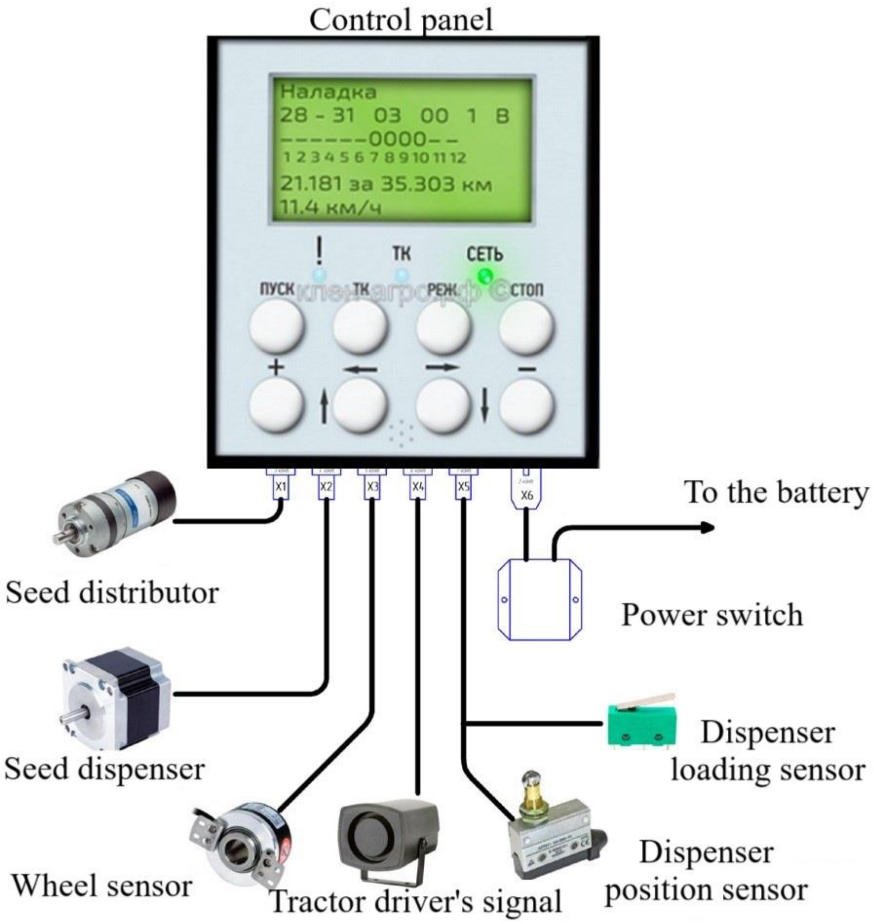

Fig. 3. Scheme of the "Klen" seeding system [14]

The system is powered by a power wire with terminals for connecting to the battery. Setting the parameters of the site and the parameters of the seeder is done quickly, centrally from the control panel. Monitoring of the operation of the sowing system is electronic (light and sound signaling of a malfunction on the control panel). Accounting of sown plots is electronic (indication on the control panel) [14].

The control panel is the main node of the system with which the planter operator interacts. It has a display, three light indicators, six navigation buttons and a separate signal button (on the right side of the case). Controls the electrical structural elements of the seeder according to the selected operating mode.

The dispenser motor is a stepper motor that rotates the dispenser. Located behind the device itself.

The motor-reducer of the spreader - drives the seed distribution device to the coulters, equipped with a collector electric motor. Its efficiency is determined by the remote control based on the current consumed. The seed distribution device itself (spreader) is located under the surface of the dispenser and is connected to the coulters by flexible seed ducts.

Wheel sensor – the optical sensor is located in the hub of the support wheel (on the left in the direction of movement of the seeder). It is used to measure the speed of movement and determine the distance traveled. It is connected to the remote control through an extension adapter.

The dispenser position sensor is a mechanical limit switch that activates when the outlet opening of the dispenser is blocked (initial position). Has mechanical adjustment. The dispenser stops when the sensor contacts open.

The dispenser loading sensor is a mechanical limit switch that activates when the loading handle is pressed (and the cone is lowered). When you press the handle, the chain closes. It is an optional element of the system, in case of failure it is duplicated by the "+" button on the remote control.

The tractor driver's signal is a remote high-volume sound emitter. It is turned on by the button located on the right side of the remote control. It is used to send a signal to the tractor driver by the planter operator (for example, about the need to start moving or stop).

The power switch is a circuit breaker located at the power input to the system. It serves to protect the tractor system and equipment from overcurrent in the event of a short circuit or damage to the wiring. Also acts as a mechanical power switch. Structurally, it is a block with two cables: one is connected to the control panel, the other to the tractor battery.

The presented system is automated, but needs the following improvement:

– it is necessary to improve the working body of the sowing device to ensure the accuracy of sowing small-seeded crops at the level of 99.9%;

– to sow areas of pre-basic seed production, it is necessary to ensure automatic loading of seeds of various varieties to the seeding machine;

– the sowing system in the areas of pre-basic seed production needs to be improved, taking into account GPS-tracking;

– elements of the sowing system should be block-type for easy replacement in case of their failure.

To solve these problems, a seeding apparatus of a selection seeder for small-seeded crops was developed, the structural and technological scheme of which is presented in fig. 4. The seeding device contains frame 1, which is fixed on the frame of the selection planter. One container 2 is installed on frame 1, where cassettes 3 with seeds are placed. Cassettes 3 consist of a housing 4, a retractable case 5 and an RFID tag 6. On the back side of the container 2, the container actuator 7 is installed on the frame 1. On the front side of the container 2, the case actuator 8 and the data reading module 9 are installed on the frame 1. From two sides strain gauges 10 are rigidly attached to the frame 1 under the case actuator 8. A container 11 is attached to the strain gauges 10. A cylindrical dispenser 12 with triangular cutouts is placed in the container 11. A shaft 13 with a valve 14 is installed parallel to the dispenser 12. The shaft 13 is connected to the shaft of the stepper motor 15, which is rigidly fixed from the outside of the container 11. The distributor 17 is fixed to the frame 1 with the help of brackets 16. The nozzles of the seed pipe 18 are rigidly fixed to the distributor 17 from below. Corrugated seed tubes (not shown in the figure) are attached to the nozzles of the seed tube 18.

The container actuator 7, case actuator 8, data reading module 9, strain gauges 10, stepper motor 15 are connected to the control unit 20 by means of electric wires 19. The control unit 20 is connected to the rotation sensor 21, which is placed on the seeder wheel, by means of electric wires 19. The control unit 20 is connected by means of electrical wires 19 to the signal of the tractor driver 22, which is placed in the tractor cabin. The control unit 20 is connected by means of electrical wires 19 to the GPS communication module 23, which is placed on the seeder. The control unit 20 is connected by means of electrical wires 19 to the power source 24, which can be the battery (12 V) of the tractor.

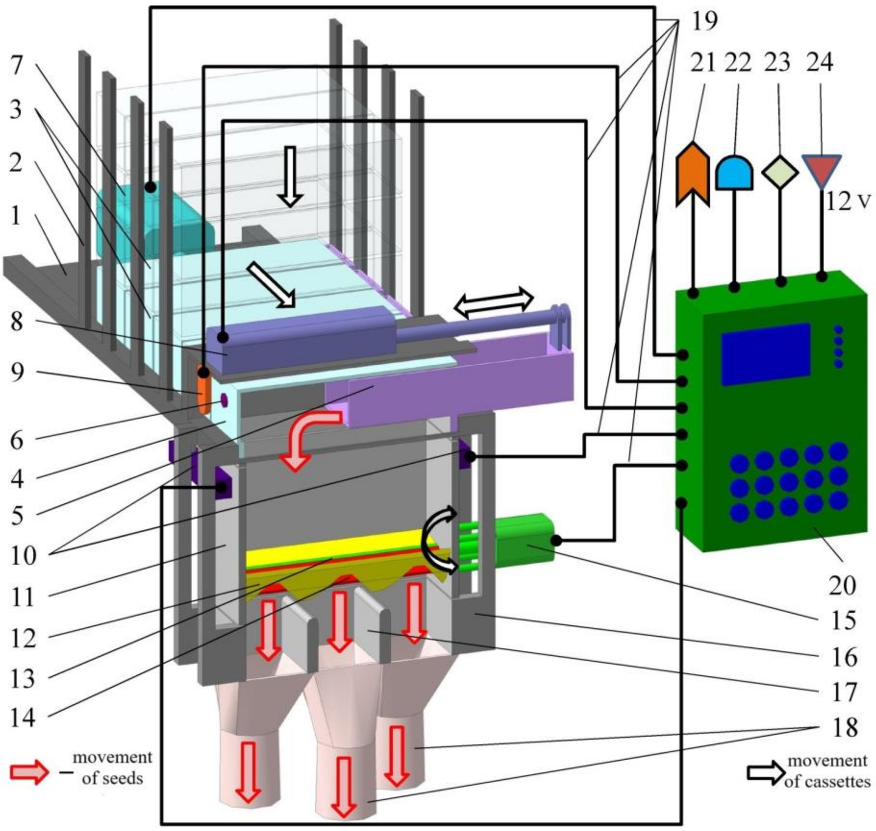

Fig. 4. Constructive and technological scheme of the seeding mechanism for a selective seeder of small-seed crops

The seeding device of the selection seeder of small-seeded crops works as follows. Before starting sowing according to the corresponding plan, the breeder fills the cassettes 3 with seeds of small-seeded cultures of the required variety samples by moving the retractable case 5 from the housing 4. After loading the seeds, using the programmer, the breeder records the number of the variety sample in the RFID tag 6. Next, the breeder installs the formed cassettes 3 with seeds in the container 2 and uploads to the control unit 20 via a personal computer or phone a file with a sowing plan. The file contains data on the size of the plots, their location, placement of variety samples on them, sowing density and morphological parameters of the seeds (average geometric size, weight of 1000 seeds and laboratory germination).

After the preparatory operations, the breeder turns on the control unit 20, which reads the received information from the file with the sowing plan and transmits the signal to the signal of the tractor driver 22 by means of electrical wires 19. The tractor driver begins to control the movement of the tractor. Information from the module

The GPS communication 23 and the speed sensor 21 are transmitted by means of electrical wires 19 to the control unit 20, where the coordinates of the seeder and the speed of the tractor are determined. By comparing the received data with the sowing plan, the control unit 20 starts the sowing process.

The control unit 20 by means of electrical wires 19 transmits a signal to the container actuator 7, which is actuated and moves the lower row of cassettes 3 from the container 2 along the frame 1 to the place where the data reading module 9 is installed. The data reading module 9 reads information about the sorting sample from RFID-tags 6 and transmits it to the control unit 20. The control unit 20 for the specified variety sample sets the sowing parameters according to the loaded sowing plan. Next, the control unit 20 transmits a signal by means of electrical wires 19 to the actuator of the case 8, which opens the retractable case 5 from the housing 4, which leads to the discharge of seeds into the container 11. After that, the actuator of the case 8 closes the retractable case 5.

Strain gauges 10 measure the mass of unloaded seeds and transmit this information to the control unit 20, which compares it with the loaded data of the morphological parameters of the seeds. Based on the decision made regarding the seeding rate, the control unit 20 by means of electrical wires 19 turns on the stepper motor 15, which starts rotating the shaft 13 and, accordingly, the valve 14 to a certain angle periodically in both directions of rotation. The frequency of rotation and the amplitude of the angle of rotation depends on the established rate of sowing and the morphological parameters of the seeds. In the open state, the valve 14 and the dispenser 12 form an opening through which the seeds get to the distributor 17, and then to the nozzle of the seed pipe 18 and the corrugated seed pipe. From the corrugated seed tube, the seed enters the coulter and further into the soil.

Having reached the edge of the site (according to the data from the GPS communication module 23) or the end of the seeds in the container 11 (according to the data from the strain gauges 10), the control unit 20 transmits the corresponding signal by means of electrical wires 19 to the signal of the tractor driver 22. After that, the actuator of the container 7 pushes cassettes 3. The cassette without seeds is pushed out of frame 1, and the next one is installed in its place and the process is repeated.

During operation according to the seeding plan and the data received from the speed sensor 21 and the module

GPS communication 23, the control unit 20 transmits the appropriate signal by means of electrical wires 19 to the signal of the tractor driver 22, indicating the need to continue the journey, stops and turns.

The use of the proposed seeding device allows you to fully automate the process of seeding areas of pre-basic seed production almost without the participation of a breeder, ensuring high accuracy of seeding.

Further studies provide for the substantiation of the design parameters of the dispenser and operating parameters (speed, periodicity and amplitude of rotation) of the stepper motor of the seeding device, depending on the morphological properties of the seeds of small-seeded crops and the rate of their sowing.

Based on the research results, it can be concluded that when designing and calculating machines for sowing seed material of oil crops, the average size indicators of seeds can be used as initial data.

The first stage of theoretical research involves developing a model of random packing of small-seed crops in the seed hopper of a selective seeder and substantiating the geometric parameters of its dispenser.

The geometric shape of the seeds of small-seed crops (such as rapeseed, mustard, camelina, millet, etc.) will be approximated as spheres with an effective diameter D.

$$f\left(D, D_{\mu}, \sigma_{D}\right)=\frac{1}{\sigma_{D}\sqrt{2\pi}}\exp\left(-\frac{\left(D-D_{\mu}\right)^{2}}{2\sigma_{\mu}^{2}}\right), \qquad (1)$$

σD – the root mean square deviation for the effective seed diameter, m; $D\mu$ – the mean value for the effective seed diameter, m.

Assuming that the seed density is uniform and equal to ρ, the mass of 1000 seeds is determined by the formula:

$$m_{1000}=\frac{500}{3}\rho\pi D^{3}, \qquad (2)$$

where ρ – is the seed density, kg/m³.

The seed metering unit of the selection seeder has the shape of a rectangular parallelepiped with a height h, and its base is a square with a side length of - a.

The generation of random packing involves the sequential release of spherical seeds with a randomly chosen coordinate on the upper surface of the seed hopper of the selective seeder (Fig. 5), directed toward its bottom plane.

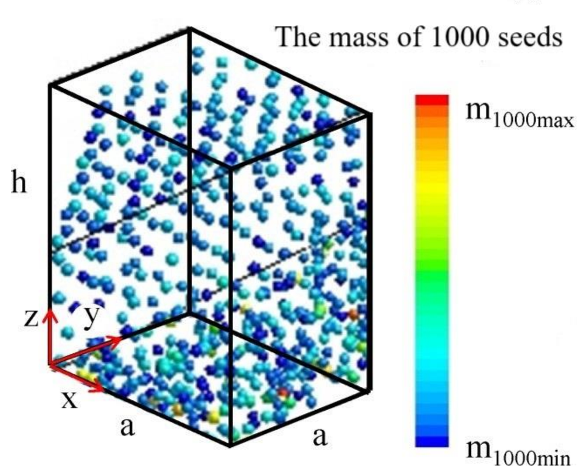

Fig. 5. Modeling the Filling of the Seed Metering Unit of a Selection Seeder with Spherical Seeds

The initial settling velocity is the same for all particles. For the random generation of seeds, we assume that the upper plane of the seed metering unit of the selection seeder is divided into $N_G = 4a^2/\pi D^2$ ells of equal size. In these cells, seeds are either generated (1) or not generated (0). The probability of seed generation in each cell is 0.5.

When the packed seeds come into contact, an interaction occurs that can be described as an elastic-damper contact. It is assumed that the seed can be affected by the following forces:

– the force caused by gravity (gravitational force):

$$\overline{F_g} = \frac{1}{6}\pi D^3 \rho \overline{g}, \qquad (3)$$

where – gravity vector, H.

– the total interaction force between the seeds and the wall can be calculated based on the Hertz-Mindlin contact model, which includes both elastic and damper components.

$$\overline{F_{contact}} = \overline{F_n} + \overline{F_t}, \qquad (4)$$

where $F_{contact}$ – force of interaction between the wall and seeds, H; $\overline{F_n}$ – normal force projection, H; $\overline{F_t}$ – tangential force projection, H.

The normal force projection is calculated by the equation:

$$\overline{F_n} = -K_n \overline{d_n} - N_n \overline{V_n}, \qquad (5)$$

where K_n – coefficient of normal stiffness of the elasticity component, kg/s^2.

The factors of numerical modeling are the average value of the effective seed diameter (0.001 m, 0.002 m, 0.003 m) and the coefficient of variation (0.1, 0.2, 0.3), which is calculated as the ratio of the standard deviation of the effective seed diameter to its average value. The modeling was carried out using a full-factorial experiment with two factors, resulting in a total of 9 experiments, each repeated five times.

5. Conclusions

Based on the analysis of existing sowing device designs, their classification was expanded to include the principle of operation and the structural features of the sowing mechanisms.

Patent and informational research revealed that electromechanical sowing devices are the most effective for selective sowing of small-seeded crops. These devices ensure high sowing accuracy and offer promising capabilities for switching between seed variety samples directly during sowing across different areas.

The analysis of the "Maple" seeding system highlighted key areas for improvement:

- enhancing the working component of the sowing device to achieve a sowing accuracy of 99.9% for small-seeded crops;
- implementing an automated seed-loading system for different varieties, specifically for pre-basic seed production areas;
- upgrading the sowing system with GPS tracking to optimize operations in pre-basic seed production areas;
- designing block-type components for easy replacement in case of malfunction.

To address these challenges, a design and technological scheme for the seeding device of a small-seeded selection seeder was developed. This innovation fully automates the sowing process in pre-basic seed production areas, requiring minimal breeder involvement while ensuring exceptional sowing precision.

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ІННОВАЦІЙНІ МЕТОДИ ПІДВИЩЕННЯ ЕФЕКТИВНОСТІ РОБОТИ СЕЛЕКЦІЙНИХ СІВАЛОК

У сучасному рослинництві енергозберігаючі технології відіграють ключову роль, будучи одним із найперспективніших напрямів. Це потребує впровадження сільськогосподарських машин нового покоління, які гарантують високу якість виконання операцій, зокрема сівби дрібнонасіннєвих культур. Нові конструкції сільськогосподарської техніки розробляються з акцентом на багатофункціональність, енергоефективність та ресурсозбереження.

Існуючі висівні апарати часто не відповідають вимогам універсальних сівалок, що спонукає до пошуку нових рішень. Одним із таких перспективних напрямків є розробка технологічних процесів сівби, які ґрунтуються на формуванні рівномірного потоку насіння, використовуючи висівні апарати нового покоління.

Розробка конструктивно-технологічної схеми висівного апарату для селекційної сівалки та обґрунтування його параметрів є актуальним і стратегічно важливим завданням для сучасного

агросектору.

На додаток до цього, важливо враховувати вимоги до адаптації нових технологій до змінних умов поля та кліматичних факторів. Розробка технологій, що знижують втрати насіння, скорочують енерговитрати та підвищують точність висіву, є невід'ємною частиною цього процесу. Крім того, сучасні селекційні сівалки мають інтегрувати новітні системи автоматизації, які дозволяють контролювати параметри сівби в режимі реального часу, що сприяє зменшенню людського фактору та покращенню точності операцій.

Використання передових матеріалів та інноваційних конструкцій підвищує довговічність і ефективність висівних пристроїв. Легкі матеріали зменшують споживання енергії, а модульні конструкції спрощують обслуговування та адаптацію. Включення відновлюваних джерел енергії, таких як системи, що працюють на сонячних батареях, ще більше сприяє енергоефективним і екологічно чистим методам сільського господарства.

Ключові слова: *насіння, дрібнонасінні культури, висівний апарат, класифікація, конструктивно-технологічна схема, аналіз.*

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