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Development of Mechatronic Systems for Targeted Division and Selection of Seed Material

One of the key stages in seed material processing is sorting, as seed mixtures typically contain impurities of various origins. These impurities include stems, leaves, mineral inclusions, weed seeds, and damaged seeds of the primary crop. Seed sorting, as a subtask of separation, relies on the physical differences between the components of the mixture. The main physical characteristics of seeds include size, shape, weight, color, density, and others. These properties determine the parameters of modern seed cleaning equipment, influencing its design and operational efficiency. Modern separation methods based on physical and mechanical properties have been reviewed, focusing on aerodynamic characteristics (pneumatic columns), size (screens of various shapes), density (pneumo-vibratory separators), elasticity, electrophysical properties (dielectric separators), and color (photo separators). Technological lines for the separation of small-seeded crops have been presented, taking these parameters into account. The designs of adaptive aerodynamic, vibratory screen, vibro-pneumatic separators, selective seed graders, and photoelectronic separators have been described in detail. These machines are equipped with sensors, electric motors, control units, and software, enabling enhanced productivity and separation quality. For instance, an adaptive aerodynamic separator ensures uniform airflow, promoting efficient mixture separation, while the vibro-pneumatic separator can automatically adjust the inclination of the working surface to optimize the process. The integration of adaptive mechatronic systems into primary seed production processes significantly improves seed quality, reduces energy consumption, and ensures the flexibility of technological lines. Research results confirm the effectiveness of the proposed designs, fostering the development of modern methods for seed material separation. Furthermore, the development and implementation of these advanced systems align with the increasing demand for high-quality seeds in agriculture. The use of adaptive mechatronic systems allows for real-time monitoring and adjustment of separation processes, minimizing human intervention and errors. This not only enhances the precision of sorting but also contributes to sustainable practices by reducing waste and energy usage. In conclusion, the evolution of seed sorting technologies underscores the importance of innovation in agricultural machinery. By leveraging cutting-edge technologies such as photoelectric sorting and pneumatic systems, the agricultural industry can meet the growing challenges of productivity, efficiency, and environmental responsibility. The adoption of these advanced systems promises to elevate the standards of seed processing, ensuring better yields and more sustainable farming practices worldwide.
seeds, separation, cleaning, sorting, automation, efficiency, quality

Problem setting. In Ukraine, there is a regulatory document DSTU 2240-93 'Seed of Agricultural Crops. Varietal and Sowing Quality' [1], which defines standards for varietal and sowing quality, methods of packaging, labeling, transportation, and other relevant requirements. According to this standard, seed material must be of good quality: large, clean, with high germination, free from disease pathogens and impurities [2].

Seeds of different agricultural crops are divided into three main categories: basic seed (BS), elite seed (ES), and reproductive seed (RS). Each category is characterized by specific quality indicators, including varietal purity, content of seeds of the main crop, the amount of seeds of other crops and weeds, germination, and maximum moisture content [3, 4].

Varietal purity is highest for BS (99.6–99.8%), slightly lower for ES (99.2–99.7%), and lowest for RS (92–98%). The content of seeds from other crops in the BS category is minimal (20–50 seeds/kg), while for RS this figure can reach 240 seeds/kg. The content of weed seeds is lowest for BS (8–50 seeds/kg) and highest for RS, reaching 1500 seeds/kg. Germination varies from 90% for BS, 85% for ES, to 70–80% for RS, depending on the crop. The maximum permissible moisture content of seeds is the same for all categories and crops, ranging from 9–13%.

Very high requirements are placed on seed material of small-seed crops, which can be achieved through detailed study of the physical-mechanical properties of the seed material of each crop and the correct selection of equipment for separation based on the results of the research.

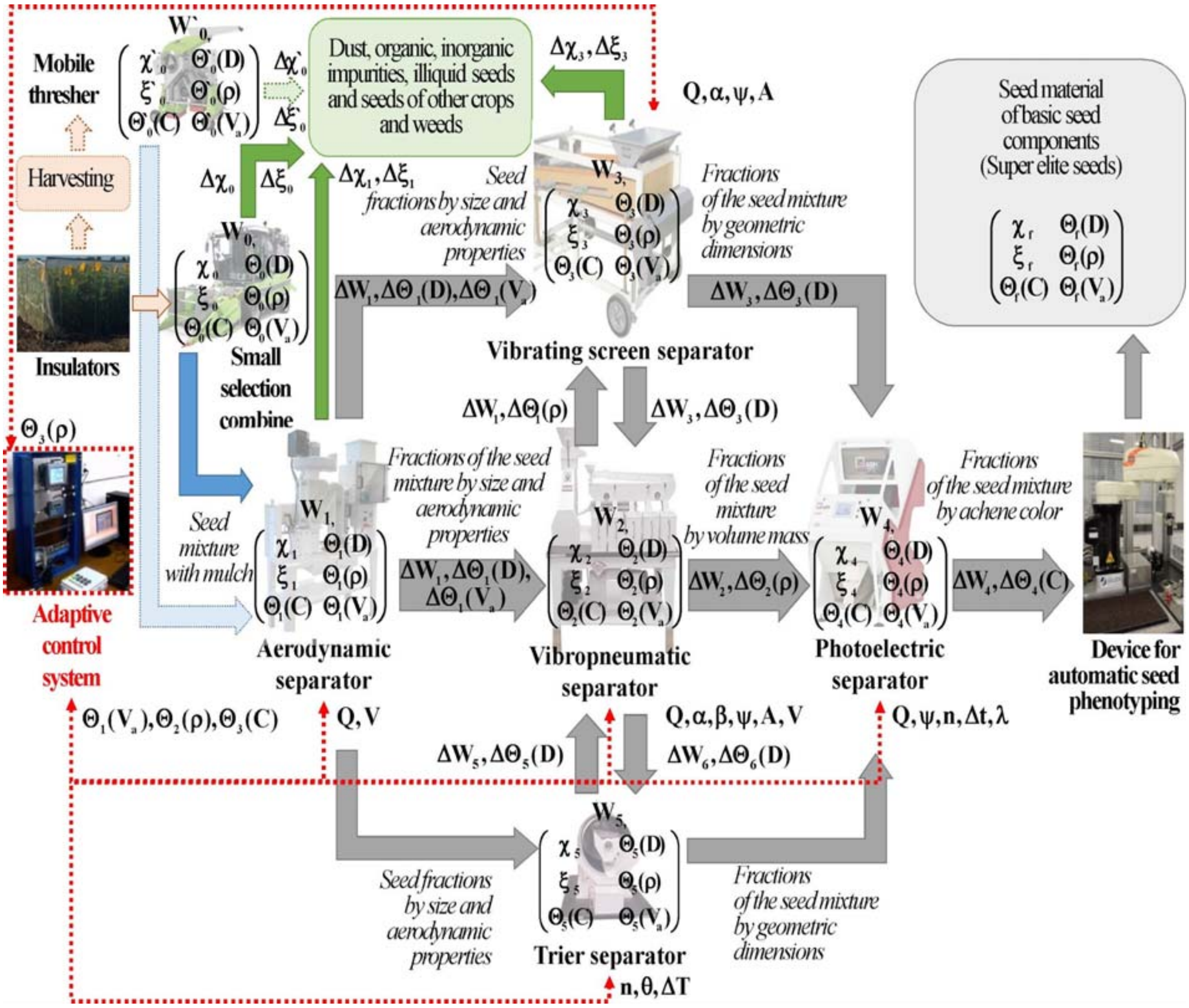
Analysis of the latest studies and publications. One of the main stages of the seed material processing process is the sorting stage, as the seed mixture contains various impurities: stems, leaves, mineral impurities, and others. Additionally, the seed material will contain low-quality seeds of other crops, broken and damaged seeds of the main crop, as well as weed seeds [5]. By processing the seed material through the removal of impurities and excess moisture, its quality is improved. The principle behind the operation of seed cleaning equipment is based on the physical differences in characteristics that can exist between the seeds of cultivated plants and other unwanted particles. Seed sorting can be viewed as a specific task within the separation process aimed at enhancing the quality of seed material.

The result of sorting the seed material is influenced by various individual physical properties of the seeds [6]. Physical characteristics include: size, length, weight, shape, color, etc. [7]. Without examining the physical characteristics of different types of seeds, it is impossible to further adjust modern seed cleaning machines [8, 9], improve and develop new types of machines [10, 11]. Published reviews of characteristics [12, 13] have allowed the formation of a modern technological line for the separation processes of small-seed crop materials, taking into account their physical-mechanical characteristics (Fig. 1). This area of research continues to develop.

All seed material separation methods can be categorized based on the physical-mechanical properties of the seeds: by aerodynamic properties (using pneumatic columns and other air channels) [14, 15, 16]; by size characteristics (width and thickness on screens with round and rectangular holes, length on triers) [17, 18, 19]; by density or bulk weight (using pneumatic tables, pneumatic vibratory separators) [20, 21]; by elasticity (on impact sorting tables) [22]; by electrophysical properties (in dielectric separators, separators in a corona discharge field); and by color (using photo separators) [23].

Setting objectives. The aim of the research is to enhance the efficiency of technical and technological support in primary seed production by justifying adaptive mechatronic systems for the precise division and selection of seed material from agricultural crops.

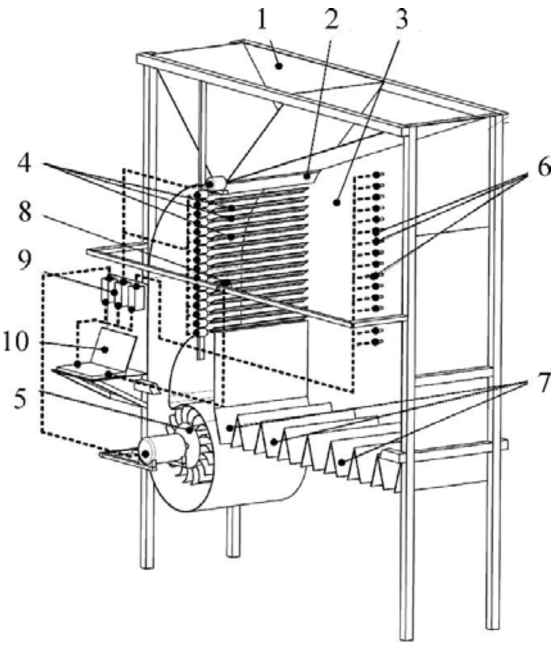
Presentation of the main material. The adaptive aerodynamic separator (Fig. 2) consists of a frame, a hopper with a flap, a separation chamber with a vertically arranged cascade of flaps, and a centrifugal fan. The fan is driven by an asynchronous electric motor. The separator is also equipped with fraction and dust collectors. Additionally, it is provided with stepper motors. The shafts of these motors are connected to the hopper flap and the cascade of vertically arranged flaps. Inside the separation chamber, air flow speed sensors are placed. A camera is installed in front of the transparent front wall of the separation chamber. A control unit is provided for managing the flaps. This unit is connected by electrical wires to the stepper motors. The asynchronous electric motor is connected to a frequency converter via electrical wires.

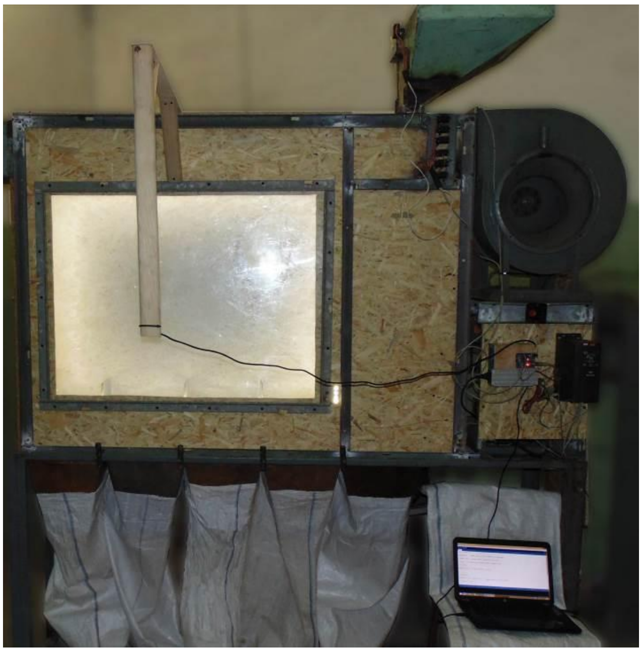


Q – seed feed rate, kg/h; V – air speed, m/s; α, β – angles of inclination of the surface (screen), °; ψ – frequency of surface oscillations (screen), s^{-1}; A – amplitude of surface oscillations (screen), m; n – drum rotation frequency, rpm; Δt – time delay for nozzle activation, ms; λ – photodetector sensitivity, %; θ – tray inclination angle, °; ΔT – rotation duration, s; W – seed mixture moisture content, %; χ – content of organic and inorganic impurities, %; ξ – degree of seed material damage, %; $\Theta(V_a)$ – fractional composition by aerodynamic properties V_a, %; Θ(D) – fractional composition by geometric size D, %; Θ(ρ) – fractional composition by bulk density ρ, %; Θ(C) – fractional composition by seed color C – RGB or C – HSV, %

Figure 1 – Modern technological line for the processes of seed material separation of agricultural crops
Source: developed by the authors

Based on the obtained data from numerical modeling, it was determined that by using an automated cascade of flaps, it is possible to achieve the equalization of the air flow speed (±0.2–0.4 m/s) in the separation chamber of the aerodynamic separator, which can include any flow generator. However, this results in a loss of nominal speed by 5–15%. The increase in speed can be achieved by increasing the air flow generator's performance (e.g., by increasing the fan blade rotation frequency), which leads to an increase in energy consumption by 5–15%. However, considering the priority of quality in the technological process of separation in the aerodynamic separator, these losses can be neglected.





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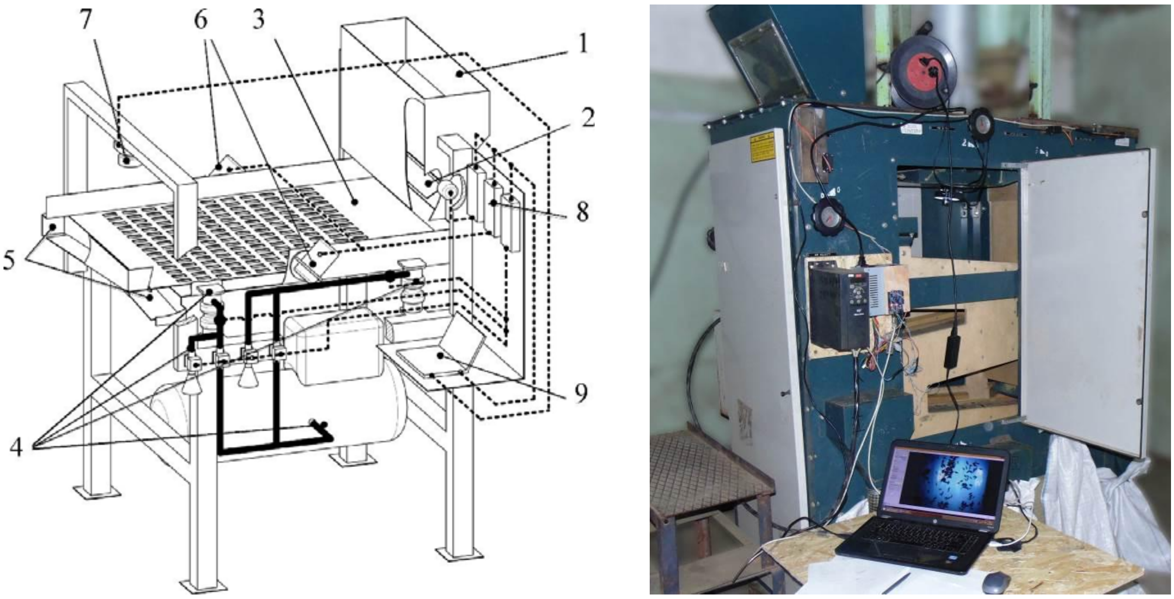
1 – hopper; 2 – flap with stepper motor; 3 – separation chamber; 4 – cascade of flaps;
5 – centrifugal fan with electric drive; 6 – airflow speed sensors; 7 – fraction collectors;
8 – camera; 9 – control units; 10 – personal computer

Figure 2 – Structural-technological diagram (a) and overall view (b) of the experimental sample of the adaptive aerodynamic separator

Source: developed by the authors

The adaptive vibratory screen separator (Fig. 3) consists of a base, a body, a screen frame, a receiving device, a hopper, a flap, a discharge window for seed flow and passage, and two electric vibrators. According to the invention, the separator is additionally equipped with two front and two rear pneumatic cushions. These pneumatic cushions are installed on the base and support the body. The separator has a stepper motor, the rotor shaft of which is connected to the flap. It also includes front high and atmospheric pressure electrovalves and a front electronic pressure sensor. These are connected to the two front pneumatic cushions via pipelines. Rear high and atmospheric pressure electrovalves and a rear electronic pressure sensor are connected to the two rear pneumatic cushions via pipelines. An air receiver and compressor are sequentially connected to the front and rear high-pressure electrovalves. Two air filters are connected to the front and rear atmospheric pressure electrovalves. A camera is installed above the end of the screen frame in the area without holes. The control unit for the stepper motor is connected to the stepper motor via electrical wires. The control unit for the motors is connected to the two electric vibrators. The control unit for the pneumatic cushions is connected to the front and rear high and atmospheric pressure electrovalves, as well as to the front and rear electronic pressure sensors. The separator is equipped with a personal computer with software. The software is based on the algorithm for performing technological processes of separation, cleaning, and sorting of grain or seed mixtures by geometric size. The computer is connected to the camera, control units for the stepper motor, motors, and pneumatic cushions via electrical wires.



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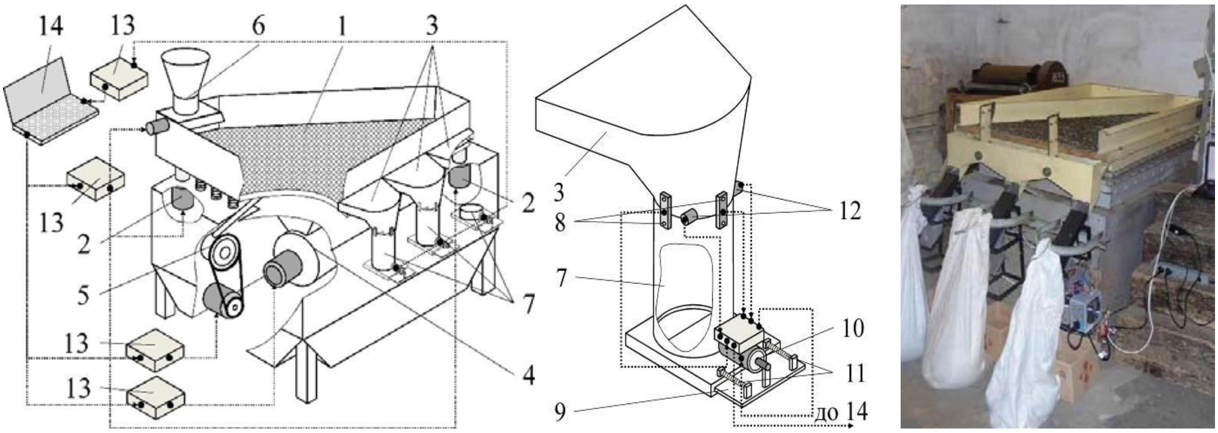
1 – hopper; 2 – flap with stepper motor; 3 – screen; 4 – system for adjusting the screen inclination angle;
5 – discharge windows for seed flow and passage; 6 – electric vibrators; 7 – camera;
8 – control units; 9 – personal computer

Figure 3 – Structural-technological diagram (a) and overall view (b) of the experimental sample of the adaptive vibratory screen separator
Source: developed by the authors

Based on the obtained theoretical and experimental dependencies, an adaptive vibratory screen separator was developed based on the Cimbria Unigrain calibration machine, with a performance of 189±13 kg/h and separation quality (total seed concentration) of 3.4±1.3%.

The adaptive vibropneumatic separator (Fig. 4) with an air-permeable deck, discharge windows, flaps, fan, crank-rocker mechanism, and electric drive. According to the invention, the separator is equipped with a seed feed unit, volumetric mass measurement units for the seeds, which are connected to each discharge window via strain gauge sensors; control units for the electric motors driving the fan and crank-rocker mechanism for the vibration of the air-permeable deck. The separator is equipped with a control unit for the stepper motors driving the adjustment of the longitudinal and transverse tilt of the deck and the flap of the seed feed unit, measurement control units, a general measurement unit, and a personal computer. The invention ensures increased productivity, improved quality, and reduced labor intensity in performing the separation technological processes.

Based on the obtained theoretical and experimental dependencies, an adaptive vibropneumatic separator was developed based on the PVS-type pneumatic vibrostage, with a productivity of 131±6 kg/h and separation quality (distribution coefficient) of 95.5±1.5%. The calibration of the volumetric mass measurement unit of the adaptive vibropneumatic separator was developed and conducted.



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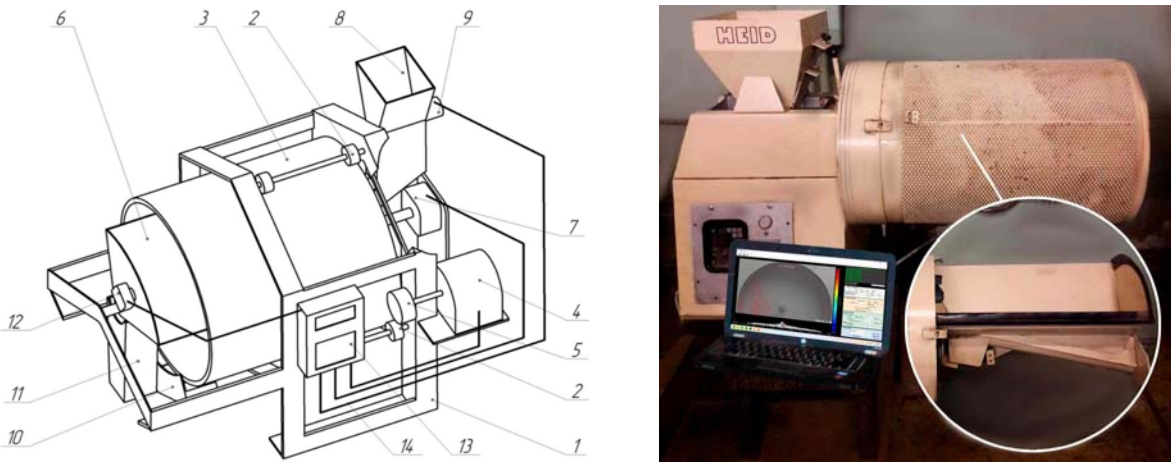
1 – deck; 2 – system for adjusting the tilt angles of the deck; 3 – discharge windows; 4 – fan with electric drive; 5 – crank-rocker mechanism with electric drive; 6 – seed feed unit; 7 – volumetric mass measurement unit; 8 – strain gauge sensors; 9 – flap; 10 – pushing electromagnet (solenoid); 11 – tension springs; 12 – infrared diode and photodetector; 13 – control units; 14 – personal computer

Figure 4 – Structural-technological diagram (a) and overall view (b) of the experimental sample of the adaptive vibropneumatic separator

Source: developed by the authors

The adaptive seed selection trier (Fig. 5) includes a frame, support rollers, a cylindrical drum with cells, a motor-reducer, a drive roller, a tray, a hopper-feeder, a collector for larger seeds, and a collector for smaller seeds. The invention is characterized by the fact that the trier is additionally equipped with a stepper motor, the shaft of which is fixed to the tray. A flap with a stepper motor is installed in the hopper-feeder. A camera, whose lens is directed toward the center of the drum with cells, is mounted on the front part of the tray. The control unit is connected via electrical wires to the motor-reducer, stepper motor, flap stepper motor, and camera.



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1 – frame; 2 – support rollers; 3 – drum with cells; 4 – motor-reducer; 5 – drive roller; 6 – tray; 7 – stepper motor; 8 – hopper-doser; 9 – flap with stepper motor; 10 – larger seed collector; 11 – smaller seed collector; 12 – photocamera; 13 – control unit; 14 – electric wires

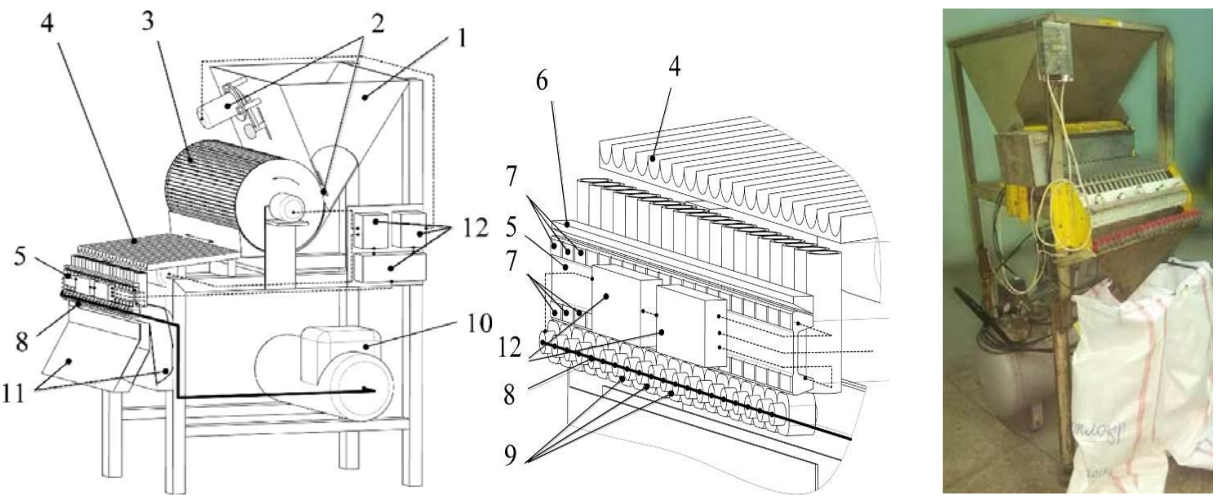
Figure 5 – Structural-technological diagram (a) and general view (b) of the experimental sample of the mechatronic system for the selection-seed treater

Source: developed by the authors

For testing the developed design of the seed selection trier, the K3538 trier (Cimbria Heid GmbH) was improved. The application of the developed mechatronic control system for the K3538 seed selection trier allows performing the technological process of separating mustard seed mixture by the length of its components with a productivity of 123.5 ± 6.3 kg/h, impurity content in the tray seed mixture of 0.82 ± 0.17%, content of main crop seed in the cylindrical seed mixture of 16.85 ± 2.69%, and power of 0.93 ± 0.23 kW.

The photoelectronic separator (Fig. 6) includes a frame, a material feeding unit with a hopper and a flap, a seed registration unit with nozzles, an illuminator, registering photoreceptors, and an information processing unit, a seed output unit with gas nozzles, a relay block, an air receiver, and a compressor, and collectors for liquid and non-liquid seeds. The material feeding unit is additionally equipped with a stepper motor, the shaft of which is connected to the flap via a crankshaft mechanism, and a control unit for the stepper motor.

Based on the obtained dependencies, the photoelectronic separator has been improved, with a productivity of 38±3 kg/h and a separation quality (total seed concentration) of 1.2±0.1%.



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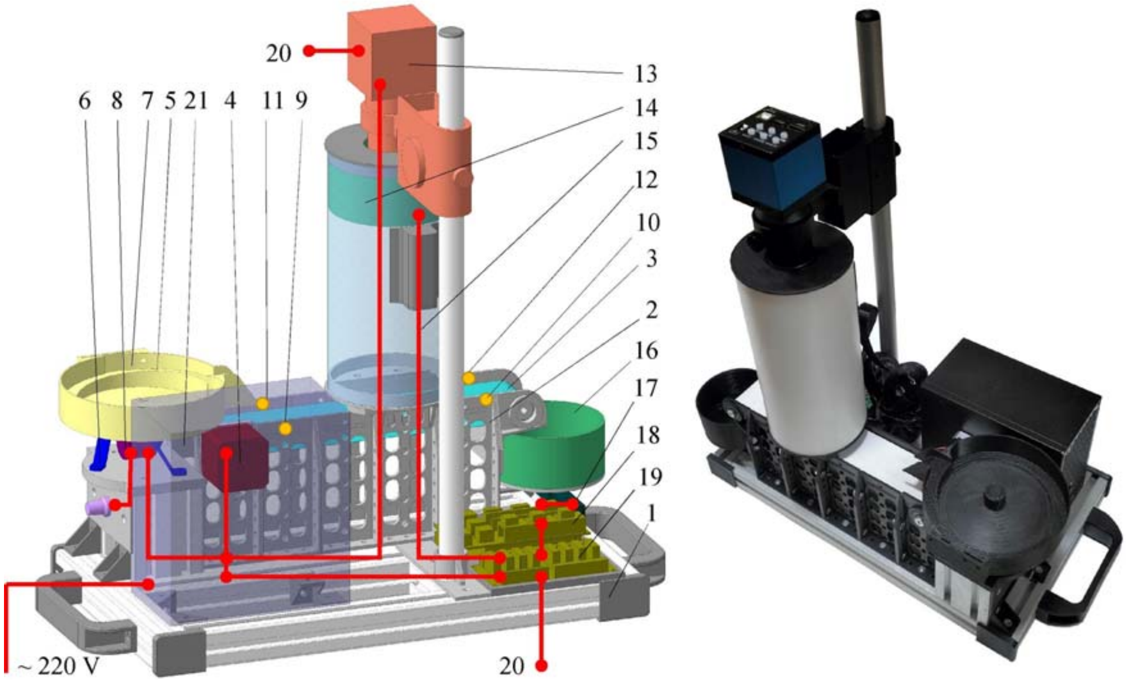
1 – hopper; 2 – flap with stepper motor; 3 – drum with radial blades and electric drive; 4 – vibrating tray with vibrator motor; 5 – seed registration block; 6 – illuminator; 7 – recording and control photoreceptors; 8 – seed output block; 9 – gas nozzles; 10 – compressor with air receiver; 11 – collectors for liquid and non-liquid seeds; 12 – control units

Figure 6 – Structural-technological diagram (a) and general view (b) of the experimental sample of the improved photoelectric separator

Source: developed by the authors

A belt device for automatic seed phenotyping (Fig. 7) has been developed, which is additionally equipped with a seed feeding unit installed before the belt conveyor. The unit consists of a bowl with a helical track, which is secured to a vibrating surface using a screw, with a vibrator motor fixed underneath. Three spring plates are mounted on the frame, angled at 45° relative to the horizontal plane in the direction of lifting the helical track. The vibrator motor is connected to a width-pulse modulator via electrical wires, and the modulator is connected to the control unit. After the belt conveyor, a mass measurement unit is installed, consisting of a strain gauge connected to the control unit via electrical wires. One end of the strain gauge is fixed to the frame, while the other is attached to a plate on which a bushing is mounted. The device is also equipped with a battery located in the power supply unit. It maintains the accuracy of individual seed geometric measurements, determines their shape and color, and ensures low labor intensity and high technological efficiency in implementing the seed phenotyping procedure as breeding material based on its morphological and marker traits. Experimental verification results showed that the productivity of the matrix device is 1 kg/hour, while the belt conveyor device achieves 5 kg/hour.



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1 – frame; 2 – belt conveyor; 3 – belt; 4 – electric motor; 5 – seed feeding tray; 6 – shock absorbers; 7 – flap; 8 – vibrator motor; 9, 10 – infrared LEDs; 11, 12 – photodetectors; 13 – camera; 14 – RGB LEDs; 15 – lightproof tube; 16 – receiving tray; 17 – strain gauge; 18 – amplifier; 19 – control unit; 20 – personal computer; 21 – power supply

Figure 7 – Structural and technological diagram (a) and overall view (b) of the device for automatic seed phenotyping

Source: developed by the authors

Conclusions. The study focuses on enhancing the efficiency of technical and technological support for the precision separation of sunflower seed material. It establishes the mechanical and technological principles for creating automated control systems to optimize the structural and operational parameters of equipment used in the seed separation process.

A precision technological scheme for the separation process line has been developed to meet the requirements for cleaning and separating seed mixtures, ensuring a high varietal purity of sunflower seed material (98.0–99.9%). This scheme incorporates automation of technical equipment.

To further enhance the efficiency of sunflower breeding and seed production, an automatic seed phenotyping device has been integrated into the technological line. This device accelerates the breeding process, optimizes the design of crossing programs through bioinformatics-based data analysis, and improves seed sorting efficiency.

List of references

1. ДСТУ 2240-93. Насіння сільськогосподарських культур. Сортові та посівні якості. Технічні умови. Київ: Держстандарт України. 1993. 74 с.

2. Кириченко В.В. Основи управління продукційним процесом польових культур. Харків. 2016. 711 с.
3. Шевченко І.А., Лях В.О., Поляков О.І., Сорока А.І., Ведмедєва К.В., Журавель В.М., Махно Ю.О., Товстановська Т.Г., Буділка Г.І. Льон олійний, гірчиця. Стратегія виробництва олійної сировини в Україні (малопоширені культури). Інститут олійних культур Національної академії аграрних наук України. Запоріжжя: СТАТУС. 2017. 44 с.
4. Шевченко І.А., Поляков О.І., Ведмедєва К.В., Комарова І.Б. Рижій, сафлор, кунжут. Стратегія виробництва олійної сировини в Україні (малопоширені культури). Інститут олійних культур Національної академії аграрних наук України. Запоріжжя: СТАТУС. 2017. 40 с.
5. Brandenburg N. The principles and practice of seed cleaning: separation with equipment that senses dimension, shape, density, and terminal velocity of seeds. Seed science and technology. 1977. 5. P. 173–186.
6. Jayas D., Cenkowski S. Grain property values and their measurement. Handbook of Industrial Drying. 2006. P. 575–603. DOI: 10.1201/9781420017618.ch24
7. Riahi E., Ramaswamy H. Structure and composition of cereal grains and legumes. Handbook of Postharvest Technology. 2003. P. 17–40. DOI: 10.1201/9780203911310.pt1
8. Sablani S.S., Ramaswamy H.S. Physicial and thermal properties of cereal grains. Handbook of Postharvest Technology. 2003. P. 17–40. DOI: 10.1201/9780203911310.ch2
9. Öztürk T., Esen B. Physical and mechanical properties of barley. Agricultura tropica et subtropica. 2008. 41. P. 117–121.
10. Tavakoli M., Tavakoli H., Rajabipour A., Ahmadi H., Gharib-Zahedi S.M.T. Moisture-dependent physical properties of barley grains. International Journal of Agricultural and Biological Engineering. 2009. P. 84–91. DOI: 10.3965/j.issn.1934-6344.2009.04.084-091
11. Sologubik C., Campañone L., Pagano A., Gely M. Effect of moisture content on some physical properties of barley. Industrial Crops and Products. 2013. P. 762–767. DOI: 10.1016/j.indcrop.2012.08.019.
12. Karaj S., Müller J. Determination of physical, mechanical and chemical properties of seeds and kernels of Jatropha Curcas L. Industrial Crops and Products. 2010. P. 129–138. DOI: 10.1016/j.indcrop.2010.04.001
13. Чурсінов Ю.О., Луценко М.В., Кудрявцев І.М. Техніко-економічне обґрунтування доцільності сортування відходів зернових та олійних культур. Наука технології інновації. 2022. 2(22). С. 61–67. DOI: 10.35668/2520-6524-2022-2-08
14. Алієв Е.Б., Бабин І.А. Сокол С.П. Чисельне моделювання процесу аеродинамічної сепарації дрібнозернистого сипкого матеріалу. Техніка, енергетика, транспорт АПК. 2023. 1(120). С. 5–13. DOI: 10.37128/2520-6168-2023-1-1
15. Степаненко С.П., Котов Б.І., Мельник В.А., Волик Д.А. Моделювання процесу переміщення зернового матеріалу в робочій зоні сепаратора. Науковий вісник ТДАТУ. 2024. 14 (1). С. 1–15. DOI: 10.32782/2220-8674-2024-24-1-3
16. Мельник В.А., Попадюк І.С., Волик Д.А., Степаненко С.П. Дослідження розвитку технологій та технічних засобів для пневмовідцентрового розділення зернових матеріалів. Праці Таврійського державного агротехнологічного університету імені Дмитра Моторного. 2024. 24(1). С. 75-88. DOI: 10.32782/2078-0877-2024-24-1-5
17. Naumenko M., Sokol S., Filipenko D., Guridova V., Kharytonov M. Numeric model of the grain mixture flow in a cylindrical sieve which revolves around the inclined axis. INMATEH – Agricultural Engineering. 2018. 56(3). P. 67–74.
18. Kharchenko S., Samborski S., Paśnik J., Kharchenko F. The natural oscillations of perforated sifting surfaces with epicycloidal holes. Advances in Science and Technology Research Journal. 2025. 19(1). 256–268. DOI: 10.12913/22998624/195463
19. Kharchenko S., Samborski S., Kharchenko F., Korzec-Strzałka I., Andrii S. Dynamics of Loose Materials and Oscillations of Cylin-drical Perforated Sifting Surfaces with Volumetric Riffles. Advances in Science and Technology Research Journal. 2024. 18(8), P. 238–255. DOI: 10.12913/22998624/194114
20. Aliiev E., Gavrilchenko A., Tesliuk H., Tolstenko A., Koshul'ko V. Improvement of the sunflower seed separation process efficiency on the vibrating surface. Acta Periodica Technologica, APTEFF. 2019. 50. P. 12–22. DOI: 10.2298/APT1950012A
21. Bredykhin V., Gurskyi P., Alfyorov O., Bredykhina K., Pak A. Improving the Mechanical-Mathematical Model of Grain Mass Separation in a Fluidized Bed. European Journal of Enterprise Technologies. 2021. 3(1 (111).P. 79–86. DOI: 10.15587/1729-4061.2021.232017

22. Nykyforov A., Antoshchenkov R., Halych I., Kis V., Polyansky P., Koshulko V., Kilimnik I. Construction of a regression model for assessing the efficiency of separation of light-weight seeds on vibratory machines involving measures to reduce the harmful influence of the aerodynamic factor. Eastern-European Journal of Enterprise Technologies. 2022. 2(1 (116)).P. 24–34. DOI: 10.15587/1729-4061.2022.253657
23. Shevchenko I.A., Aliev E.B. Research on the photoelectronic separator seed supply block for oil crops. INMATEH – Agricultural Engineering. 2018. 54 (1). P. 129–138.

References

1. DSTU 2240-93. (1993). *Nasinnya sil's'kohospodars'kykh kul'tur. Sortovi ta posivni yakosti. Tekhnichni umovy [Seeds of agricultural crops. Varietal and sowing qualities. Technical conditions]*. Kyiv: Derzhstandart of Ukraine. 74 p. [in Ukrainian].
2. Kyrychenko, V.V. (2016). *Osnovy upravlinnya produktsiynym protsesom pol'ovykh kul'tur [Fundamentals of field crop production process management]*. Kharkiv. 711 p. [in Ukrainian].
3. Shevchenko, I.A., Lyakh, V.O., Polyakov, O.I., Soroka, A.I., Vedmedeva K.V., Zhuravel, V.M., Makhno Yu.O., Tovstanovskaya T.G., Budilka G.I. (2017). *L'on oliynyy, hirchytsya. Stratehiya vyrobnytstva oliynoyi syrovyny v Ukrayini (maloposhyreni kul'tury) [Flaxseed, mustard. Strategy for the production of oilseeds in Ukraine (uncommon crops)]*. Institute of Oilseeds of the National Academy of Agrarian Sciences of Ukraine. Zaporizhzhia: STATUS. 44 p. [in Ukrainian].
4. Shevchenko, I.A., Polyakov, O.I., Vedmedeva K.V., Komarova I.B. (2017). Red, safflower, sesame. *Ryzhiy, saflor, kunzhut. Stratehiya vyrobnytstva oliynoyi syrovyny v Ukrayini (maloposhyreni kul'tury). [Strategy for the production of oilseeds in Ukraine (uncommon crops)].* Institute of Oilseeds of the National Academy of Agrarian Sciences of Ukraine. Zaporizhia: STATUS. 40 p. [in Ukrainian].
5. Brandenburg, N. (1977). *The principles and practice of seed cleaning: separation with equipment that senses dimension, shape, density, and terminal velocity of seeds*. Seed science and technology, 5. 173–186.
6. Jayas, D., Cenkowski, S. (2006). *Grain property values and their measurement*. Handbook of Industrial Drying. 575–603. DOI: 10.1201/9781420017618.ch24
7. Riahi, E., Ramaswamy, H. (2003). *Structure and composition of cereal grains and legumes*. Handbook of Postharvest Technology. 17–40. DOI: 10.1201/9780203911310.pt1
8. Sablani, S.S., Ramaswamy, H.S. (2003). *Physicial and thermal properties of cereal grains.* Handbook of Postharvest Technology. 17–40. DOI: 10.1201/9780203911310.ch2.
9. Öztürk, T., Esen, B. (2008). *Physical and mechanical properties of barley.* Agricultura tropica et subtropica, 41. 117–121.
10. Tavakoli, M., Tavakoli, H., Rajabipour, A., Ahmadi, H., Gharib-Zahedi, S.M.T. (2009). *Moisture-dependent physical properties of barley grains*. International Journal of Agricultural and Biological Engineering. 84–91. DOI: 10.3965/j.issn.1934-6344.2009.04.084-091
11. Sologubik, C., Campañone, L., Pagano, A., Gely, M. (2013). *Effect of moisture content on some physical properties of barley*. Industrial Crops and Products. 762–767. DOI: 10.1016/j.indcrop.2012.08.019
12. Karaj, S., Müller, J. (2010). *Determination of physical, mechanical and chemical properties of seeds and kernels of Jatropha Curcas L.* Industrial Crops and Products. 129–138. DOI: 10.1016/j.indcrop.2010.04.001
13. Chursinov, Yu.O., Lutsenko, M.V., Kudryavtsev, I.M. (2022). *Tekhniko-ekonomichne obgruntuvannya dotsil'nosti sortuvannya vidkhodiv zernovykh ta oliynykh kul'tur [Feasibility study of the feasibility of sorting grain and oilseed waste]*. Science of Technology Innovation, 2(22). 61–67. DOI: 10.35668/2520-6524-2022-2-08 [in Ukrainian].
14. Aliiev, E.B., Babin, I.A., Sokol, S.P. (2023). *Chysel'ne modelyuvannya protsesu aerodynamichnoyi separatsiyi dribnozernystoho sypkoho materialu [Numerical modeling of the process of aerodynamic separation of fine-grained bulk material].* Engineering, Energy, Transport of the Agricultural Complex. 1(120). 5–13. DOI: 10.37128/2520-6168-2023-1-1 [in Ukrainian].
15. Stepanenko, S.P., Kotov, B.I., Melnyk, V.A., Volyk, D.A. (2024). *Modelyuvannya protsesu peremishchennya zernovoho materialu v robochiy zoni separatora [Modeling the process of grain material movement in the working zone of the separator].* Scientific Bulletin of the TSATU, 14 (1): 1–15. DOI: 10.32782/2220-8674-2024-24-1-3 [in Ukrainian].
16. Melnyk, V.A., Popadiuk, I.S., Volyk, D.A., Stepanenko, S.P. (2024). *Doslidzhennya rozvytku tekhnolohiy ta tekhnichnykh zasobiv dlya pnevmovidtsentrovoho rozdilennya zernovykh materialiv [Research on the development of technologies and technical means for pneumatic centrifugal*

separation of grain materials]. Proceedings of the Tavria State Agrotechnological University named after Dmitry Motorny, 24(1): 75-88. DOI: 10.32782/2078-0877-2024-24-1-5 [in Ukrainian].
17. Naumenko, M., Sokol, S., Filipenko, D., Guridova, V., Kharytonov, M. (2018). *Numeric model of the grain mixture flow in a cylindrical sieve which revolves around the inclined axis*. INMATEH – Agricultural Engineering, 56(3). 67–74. [in English].
18. Kharchenko, S., Samborski, S., Paśnik, J., Kharchenko, F. (2025). *The natural oscillations of perforated sifting surfaces with epicycloidal holes*. Advances in Science and Technology Research Journal, 19(1): 256–268. DOI: 10.12913/22998624/195463 [in English].
19. Kharchenko, S., Samborski, S., Kharchenko, F., Korzec-Strzałka, I., Andrii, S. (2024). *Dynamics of Loose Materials and Oscillations of Cylin-drical Perforated Sifting Surfaces with Volumetric Riffles.* Advances in Science and Technology Research Journal, 18(8): 238–255. DOI: 10.12913/22998624/194114 [in English].
20. Aliiev, E., Gavrilchenko, A., Tesliuk, H., Tolstenko, A., Koshul'ko, V. (2019). *Improvement of the sunflower seed separation process efficiency on the vibrating surface.* Acta Periodica Technologica, APTEFF, 50. 12–22. DOI: 10.2298/APT1950012A [in English].
21. Bredykhin, V., Gurskyi, P., Alfyorov, O., Bredykhina, K., Pak, A. (2021). *Improving the Mechanical-Mathematical Model of Grain Mass Separation in a Fluidized Bed.* European Journal of Enterprise Technologies, 3(1 (111): 79–86. DOI: 10.15587/1729-4061.2021.232017 [in English].
22. Nykyforov, A., Antoshchenkov, R., Halych, I., Kis, V., Polyansky, P., Koshulko, V., Kilimnik, I. (2022). *Construction of a regression model for assessing the efficiency of separation of light-weight seeds on vibratory machines involving measures to reduce the harmful influence of the aerodynamic factor*. Eastern-European Journal of Enterprise Technologies. 2(1 (116)). 24–34. DOI: 10.15587/1729-4061.2022.253657 [in English].
23. Shevchenko I.A., Aliev E.B. (2018). *Research on the photoelectronic separator seed supply block for oil crops*. INMATEH – Agricultural Engineering, 54 (1): 129–138. [in English].

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Розроблення мехатронних систем цільового поділу та відбору насіннєвого матеріалу

Одним із ключових етапів обробки насіннєвого матеріалу є сортування, адже насіннєва суміш містить домішки різного походження: стебла, листя, мінеральні включення, насіння бур'янів та пошкоджене насіння основної культури. Сортування насіння, як підзадача сепарації, базується на фізичних відмінностях між компонентами суміші. До основних фізичних характеристик насіння належать розмір, форма, вага, колір, щільність тощо. Ці властивості визначають параметри сучасного насіннєочисного обладнання, впливаючи на його конструкцію та ефективність.

Розглянуто сучасні методи сепарації за фізико-механічними властивостями, зокрема за аеродинамічними характеристиками (пневматичні колонки), розміром (решета різної форми), щільністю (пневмовібросепаратори), пружністю, електрофізичними властивостями (діелектричні сепаратори), кольором (фотосепаратори). Представлено технологічні лінії сепарації дрібнонасіннєвих культур, що враховують ці параметри. Описано конструкції адаптивного аеродинамічного, віброрешітного, вібропневматичного сепараторів, селекційно-насінницького трієра та фотоелектронного сепаратора. Вони оснащені датчиками, електродвигунами, блоками керування та програмним забезпеченням, що дозволяє підвищити продуктивність і якість сепарації.

Впровадження адаптивних мехатронних систем у процеси первинного насінництва дозволяє покращити якість насіння, зменшити енерговитрати та забезпечити гнучкість технологічних ліній. Результати досліджень підтверджують ефективність запропонованих конструкцій, сприяючи розвитку сучасних методів сепарації насіннєвого матеріалу.

насіння, сепарація, очищення, розділення, автоматизація, ефективність, якість

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