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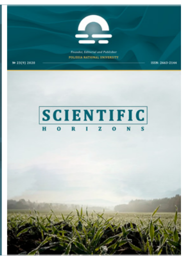

Optimisation of the design parameters of the control module of the air generator of an aerodynamic separator

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Abstract. The production of high-quality seed material and food grain required the use of efficient separation technologies. Aerodynamic separation was widely implemented in various designs of equipment intended for removing light impurities from the initial grain mass and dividing it into fractions that were uniform in their properties. The use of a differential airflow provided a relatively high 60-70% efficiency of grain cleaning from impurities. The study was aimed at investigating the efficiency of aerodynamic separation in order to identify ways to improve the quality indicators of the technological process of cleaning and calibrating the initial grain mass. Experimental investigations indicated that the airflow in the cross-section of the air channel of the SAD-4 model aerodynamic separator was non-uniform. Specifically, the airflow velocity in the lower third of the channel cross-section was 48-52% lower than in the upper and middle zones, between which the airflow non-uniformity amounted to only 7-9%. It was established that the intensity of the separation regimes affected the quality of the fractional composition. Under maximum operating settings, owing to the non-uniform distribution of airflow along the vertical plane, the heterogeneity of the fractional composition increased to 61%. The scientific problem of increasing the homogeneity level of the fractional composition of cleaned grain was proposed to be solved by modelling the airflow in the pneumatic channel of the aerodynamic separator in accordance with the operating settings. A design of an air generator with a mechanism

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for equalising airflow velocity in the cross-section of the separation channel was proposed. The investigations showed that when the operating settings were changed from "1" to "7", the airflow intensity in the lower third of the channel cross-section varied from 1.9 to 12.6 m/s, which was 37-49% higher than in the serial separator. Under maximum separation regimes, the uneven distribution of the components of the initial grain mixture between fractions decreased to 25-29%. A functional relationship was established between the intensity and uniformity of the airflow in the separation channel and the homogeneity of the fractional composition of the cleaned grain

Keywords: airflow regime; relative velocity; fraction yield; terminal velocity; airflow control

INTRODUCTION

The justification and theoretical prerequisites for the influence of airflow on the efficiency of separating the components of the initial grain mixture attracted the interest of scientists and researchers in many countries. Ukrainian researchers B. Kotov *et al.* (2022) carried out studies of the separation of grain material in a pneumatic channel and determined the rational form and parameters of material feed. Based on the results of these investigations, mathematical relationships were established that made it possible to determine the rational parameters of pneumogravitational and pneumo-inertial separators. However, understanding the velocity parameters of material feed into the air channel was not sufficient for a complete understanding of the process of dividing the initial grain mixture into several fractions. The performed studies were limited to establishing rational trajectories of motion of particles in a two-phase medium, and therefore only two fractions were obtained.

Researchers I. Dudarev *et al.* (2020) demonstrated the expediency of using the different aerodynamic properties of the components of a grain mixture for its division into uniform fractions in an airflow. In their studies, the prospect of using a combined method of gravitational separation was emphasised, since the process took place without energy consumption. However, despite the positive results of these investigations, in the opinion of the present authors it was not possible to obtain a well-cleaned material without the use of an additional artificial airflow. The scientific problem of increasing the productivity of aerodynamic separation by preliminary stratification of grain mixtures was addressed by V. Koshulko and I. Kudriavtsev (2024). The effectiveness of preliminary stratification in the process of removing light impurities was theoretically substantiated and experimentally confirmed. A mathematical model for determining the initial position of the feed material and for justifying the design of the air channel was proposed. The conducted research did not take into account the process of calibrating the initial grain mass into several fractions, which limited the application of the proposed solution.

The investigations of inertial fractionation by S. Stepanenko *et al.* (2023) demonstrated a significant increase in the efficiency of dividing grain material into fractions. The use of variable airflows that correlated with the aerodynamic properties of the components was proposed in order to intensify the division of grain material into fractions. This approach made it possible to develop solutions that contributed to improving the efficiency of the control of aerodynamic separation. In subsequent studies, S. Stepanenko *et al.* (2025a) proposed the use of a combined centrifugal–pneumatic gravitational separator for removing impurities from a grain mixture. According to the results of experimental investigations, quantitative indicators of division into two fractions were obtained, with the outlet ratio ranging from 39% to 61%. However, the proposed solutions did not make it possible to ensure the implementation of a grain calibration process, since the main attention was paid to the physical and mechanical properties of the grain and light inclusions.

Studies of vortex flows by V. Adamchuk *et al.* (2021) made it possible to identify ways of increasing the intensity of the process of cleaning grain mass from impurities and of improving the productivity of centrifugal separators. Based on the results of these investigations, initial conditions were established for the division of particles of a grain mixture in three directions of motion depending on their physical and mechanical properties. The obtained solutions were characteristic only of systems in which calibration of the feed material was not envisaged. However, the proposed developments could be used to describe the behaviour of particles in an airflow in the presence of centrifugal influences. In the studies of D. Li *et al.* (2024), theoretical aspects of the separation of grain mixtures using the aerodynamic principle of division were presented. In the course of investigating an inclined airflow, the resistance of the grain layer to air passage, seed buoyancy, operating airflow velocities and overall airflow velocity were taken into account. The obtained data formed the basis for the development of a new type of aerodynamic separator, SCA-5, for cleaning and sorting seed mixtures. The work was aimed at describing the advantages of the proposed design solutions of the separator, which could be used in the design of new equipment.

Significant attention was also paid to scientific research on the separation of a grain mixture into components in a vertical channel. Scientists V. Bulgakov *et al.* (2020a) proposed their own separator design using sail-type elements that generated oscillatory motion and thereby increased the efficiency of dividing the feed material into fractions. The expediency of using flow vibrations was emphasised in the work of L. Knaub (2020), which was focused on a differential approach to particles of different shapes, including the derivation of a vibrational Reynolds criterion. An important aspect of increasing separation efficiency was the reduction of energy consumption.

The substantial volume of scientific research on the separation of grain mass components in an airflow indicated serious prospects and the relevance of the problem. The search for improved solutions for cleaning grain from impurities with simultaneous calibration required both theoretical and experimental investigations. Primarily, such an approach was useful for serial equipment, the improvement of which had to be based on operational experience and an adequate scientific assessment of performance indicators. Therefore, the aim of the study was to identify directions for increasing the efficiency of the aerodynamic separator of the SAD-4 model and to substantiate the design and technological parameters of an airflow modulator in the separation channel.

MATERIALS AND METHODS

The efficiency index of the separation process was defined as the degree of separation of a given component of the grain mixture, η, which was calculated as the ratio of the amount of the separated component to the total amount of the same component in the initial grain mass (Zhou *et al.,* 2024):

$$\eta = \frac{P_k}{P_0}, \tag{1}$$

where P_k – the amount of one component separated from the grain mixture,%; P_0 – the maximum determined amount of the same component in the initial grain mixture,%.

Reference values of critical velocity obtained from studies of particle motion in a vertical airflow (Bazaluk *et al.,* 2022) were used for the calculations. This approach was adopted as the baseline condition for the subsequent analysis of the separation process in the inclined channel of the aerodynamic separator. The object of the study was the SAD-4 model aerodynamic separator, in which the grain mixture was divided into fractions in an inclined airflow combining the action of the aerodynamic air pressure force and gravity. To describe the motion of an individual grain or another component of the grain mass in the airflow, the equilibrium equation was used (Nanka *et al.,* 2019):

$$mg = \frac{1}{2} k \rho S_m (\upsilon - u)^2, \tag{2}$$

where g – the acceleration due to gravity, m/s^2; mmm was the mass of the particle, kg; m –the midship cross-sectional area of the particle in the airflow, m^2; u –the grain velocity, m/s; υ – the airflow velocity, m/s; k – the aerodynamic drag coefficient; ρ – the density of the medium under the given conditions, kg/m^3.

On the basis of Eq. (2), the relative velocity of particle motion ($\upsilon\upsilon$ – u)was considered as a function of its midship cross-sectional area and the specified airflow velocities. Theoretical analysis was carried out for wheat, assuming a thousand-kernel mass of 40 g, which corresponded to typical values for varietal seed material. For three characteristic airflow velocities (6, 8 and 12 m/s), the dependences of the relative velocity on the midship cross-sectional area of the grain were plotted (Fig. 1). The resulting curves were used to select the range of operating airflow velocities and the separator setting regimes during laboratory tests.

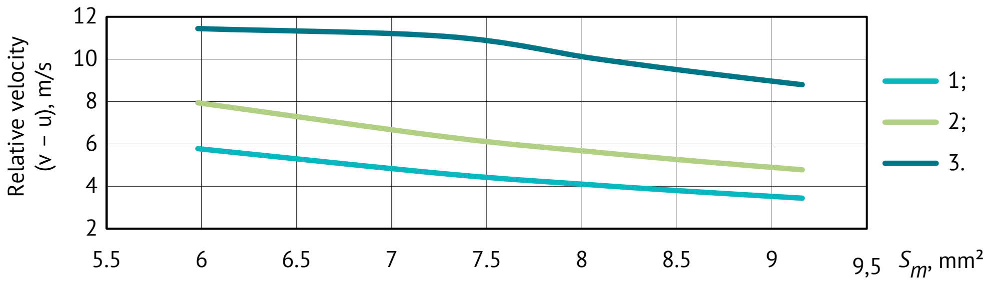

***Figure 1**. Dependence of the relative velocity of a wheat kernel on its midship cross-sectional area at different airflow velocitie*

***Note:** 1 – 6 m/s; 2 – 8 m/s; 3 – 12 m/s*

***Source:** developed by the authors*

An additional stage of the study consisted in determining the spatial distribution of airflow velocity in the aspiration channel of the serial SAD-4 aerodynamic separator. Measurements were carried out using a set of measuring equipment manufactured by Testo (Germany), which provided registration of instantaneous airflow velocity values at specified points. The cross-section of the air channel was conventionally divided into three vertical zones – upper, middle and lower. In each zone, three measurement points were set in the horizontal direction, positioned at equal distances from one another in order to ensure uniform coverage of the cross-sectional area.

The operating mode of the fan was defined by the position of the air supply lever, which was changed stepwise from setting “1” to setting “7”. For each lever position, the airflow velocity was recorded at all nine measurement points. For each vertical zone (upper, middle, lower), the mean velocity value was calculated as the arithmetic mean of the three horizontal measurements. The mean airflow velocities by zone, depending on the lever position, were presented in the form of graphs that reflected the pattern of variation in airflow intensity in the working plane of the channel. In this way, initial data were obtained for the subsequent quantitative assessment of the uniformity of airflow velocity distribution in the channel cross-section.

Laboratory investigations of the grain separation process were conducted using wheat grain as a model material. Before the experimental part, the test weight of the initial grain mass was determined according to a standard method. Ten samples of grain were taken from the working batch, and the test weight was measured for each; thereafter, the mean value was calculated and used as a reference characteristic of the initial mixture. This procedure made it possible to characterise the initial state of the grain mass fed to separation and subsequently to compare the test weight values of individual fractions with the initial value.

Further experiments were performed on the serial SAD-4 aerodynamic separator under operating modes typical of practical use. The feed rate of the grain mass into the separation zone was set by the position of the material feed lever (in particular, settings “1” and “2” were used), and the airflow intensity was set by the position of the lever controlling the fan capacity (in particular, settings “3” and “4”). For each combination of operating parameters, a steady-state mode of separator operation was ensured, after which the fractions were collected from all outlet spouts.

For each of the five fractions obtained at the outlet of the aerodynamic separator, the test weight and mass yield were determined. Sampling for the test weight analysis was performed from each fraction by quartering, which ensured the representativeness of the samples. Each test mode was carried out with three repetitions. For each repetition, the grain test weight within the fraction and the relative mass yield of this fraction with respect to the total mass of the initial mixture were determined. Subsequent data processing was performed by calculating the mean values of the indicators over the repetitions and constructing distribution charts of test weight and mass yield for each fraction under the investigated modes.

The combination of theoretical calculations, measurements of airflow velocity in the channel cross-section and laboratory tests with determination of test weight and mass yield of the obtained fractions was used as a single methodological basis for the further assessment of the performance of the serial air generator of the SAD-4 aerodynamic separator and for comparison with the improved design solutions.

RESULTS AND DISCUSSION

According to the constructed theoretical dependences, it was established that, with an increase in the midship cross-sectional area of a wheat kernel at a constant thousand-kernel mass of 40 g, the relative velocity of its motion in the airflow decreased for all investigated airflow velocities (6, 8 and 12 m/s). This indicated an increase in the aerodynamic resistance to motion as the projection of the geometric dimensions of the grain in the flow plane increased. At higher airflow velocities ($\upsilon = 12$ m/s), an increase in the midship cross-sectional area *Sm* from 6.5 to 7.5 mm^2 no longer led to a significant change in relative velocity, which pointed to the feasibility of applying more intensive airflow regimes to ensure stable separation of grains with similar geometric parameters. The obtained theoretical curves in fact defined the range of operating velocities within which the efficiency of the serial and the improved jet generators was subsequently evaluated.

Analysis of the experimental curves of airflow velocity distribution over the height of the air channel of the serial SAD-4 separator (Fig. 2) showed an approximately linear increase in velocity in all three zones (upper, middle and lower) as the position of the fan capacity lever was changed from “1” to “7”. At the same time, a pronounced non-uniformity of the velocity field in the vertical plane was revealed. Regardless of the lever position, the airflow velocity in the lower third of the channel was 48-52% lower than in the upper and middle zones. The difference between the upper and middle zones, by contrast, was small and amounted to only 7-9% at intermediate regimes (settings “3”, “4” and “5”), while at minimum and maximum settings (“1”, “2”, “6” and “7”) the velocities in these zones practically coincided. This pattern of airflow intensity distribution indicated that the components of the grain mass entering the lower zone of the channel were exposed to a substantially weaker airflow than the particles in the middle and upper zones, which potentially reduced the quality of separation and the homogeneity of the fractional composition.

The results of laboratory tests to determine the test weight of grain for the five fractions obtained on the serial SAD-4 separator under different operating modes (Fig. 3) confirmed the influence of airflow non-uniformity on the quality of fractionation. Under the mode with the grain feed lever set to “1” and the fan capacity lever set to “3”, the maximum test weight of the initial mixture was 764 g/L and the mean value was 746.5 g/L. In the second fraction, kernels with a test weight of 725 and 733 g/L were recorded, whereas the maximum test weight for this fraction reached 776 g/L. In the third fraction, by contrast, samples with a test weight of

731 g/L were registered, which exceeded some of the values characteristic of the second fraction. At higher separation modes, a similar pattern was observed: in the fourth fraction, a test weight of 761 g/L was recorded, which exceeded the value of 759 g/L in the second fraction. Thus, a noticeable internal heterogeneity in test weight was observed within each fraction, and overlapping ranges of values were observed between fractions, indicating mixing of the components of adjacent fractions.

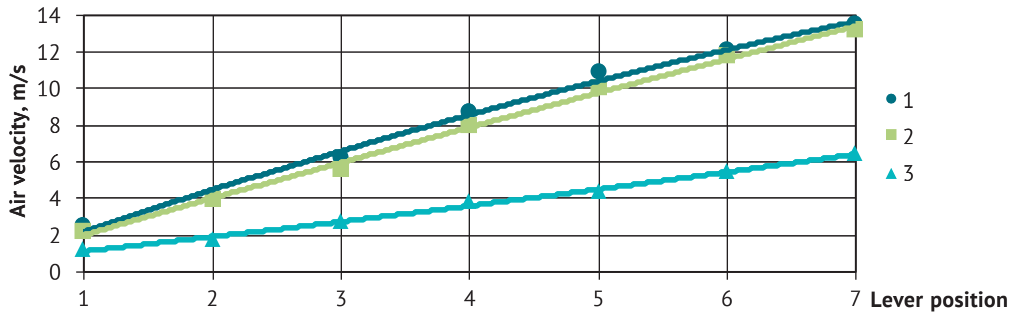

***Figure 2**. Results of the investigation of airflow velocity in three zones of the vertical plane of the air channel of the SAD-4 separator*

***Note:** 1 – upper zone; 2 – middle zone; 3 – lower zone*

***Source:** developed by the authors*

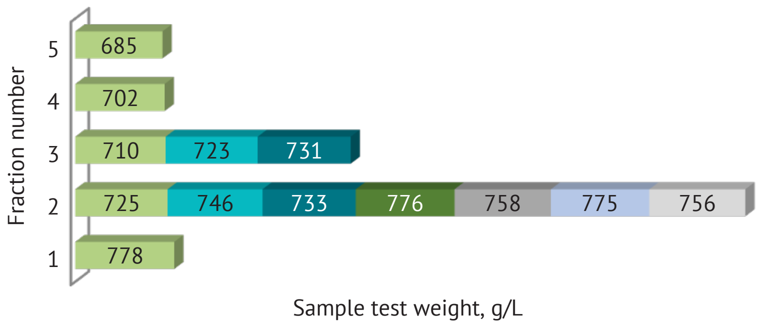

***Figure 3**. Results of the investigation of test weight samples for each fraction under the operating mode with the grain feed lever set to "1" and the fan airflow lever set to "3"*

***Source:** developed by the authors*

An additional quantitative indicator of this heterogeneity was the mass distribution of the grain mass between the fractions. It was established that, under the operating mode with the material feed lever set to "1" and the fan capacity lever set to "3", 61% of the total mass of the initial mixture was directed into the second fraction, whereas the shares of the other fractions were substantially smaller. Under the mode with the grain feed lever set to "2" and the fan capacity lever set to "4", the mass yield in the fourth fraction increased and the difference between the third and fourth fractions decreased slightly; however, it was still not possible to eliminate the overlap in test weight completely. The combination of these data confirmed that the non-uniformity of the airflow in the channel of the serial SAD-4 directly affected both the distribution of components between fractions and the internal homogeneity of each fraction.

The theoretical and experimental results obtained for the serial SAD-4 aerodynamic separator showed that the non-uniform distribution of airflow velocity in the vertical plane of the channel caused overlapping ranges of test weight between adjacent fractions and a non-uniform mass distribution of the feed material. For seed material, this implied a risk of forming fractions with different germination energy and heterogeneous sowing qualities. In view of this, it was proposed to improve the jet generator of the SAD-4 by supplementing it with elements that made it possible to model the airflow in the lower zone of the air channel (Fig. 4).

The experimental design was based on the jet generator of the SAD-4 aerodynamic separator. Movable plates and a control mechanism were installed in the lower third of the jet generator. The degree of opening of the movable plates was calculated on the basis of the well-known continuity condition for the flow of a continuous medium (Zhou *et al.,* 2024), under the requirement of achieving the necessary velocity regimes. The calculated values yielded parameters that made it possible to define three variable positions of the movable plates over the entire range of positions of the fan capacity lever (Table 1).

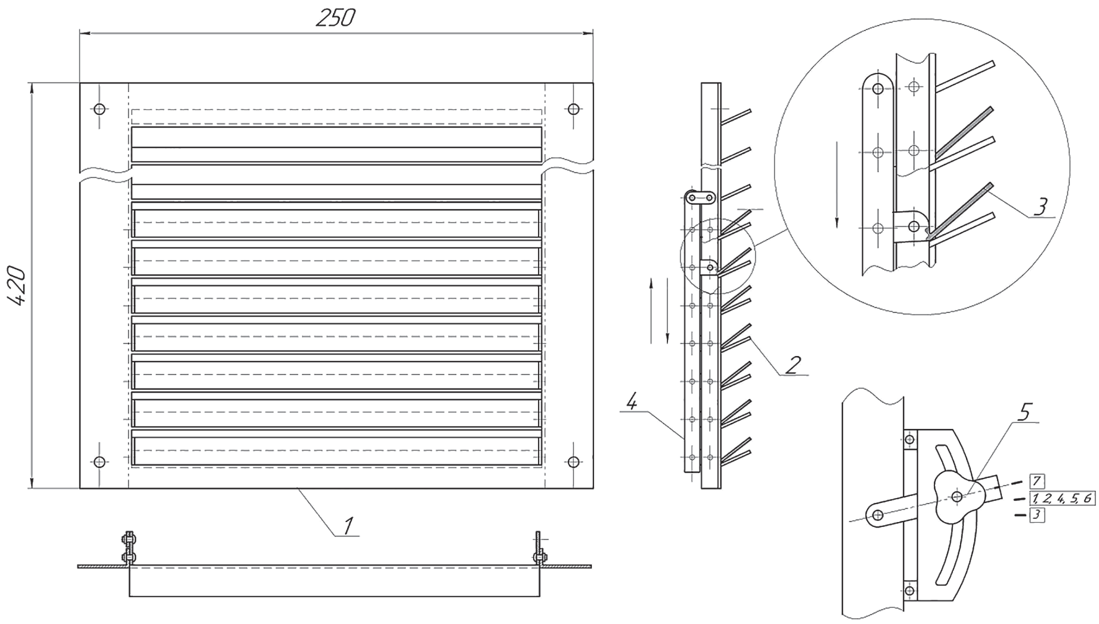

***Figure 4**. Experimental design of the jet generator*

***Note:** 1 – jet generator; 2 – fixed plate; 3 – movable plate; 4 – connecting bar; 5 – mechanism for controlling the movable plates adapted to the fan capacity*

***Source:** developed by the authors*

***Table 1**. Calculated and design parameters*

Lower zone	Distance between plates (mm) according to the position of the fan capacity lever						
	1	2	3	4	5	6	7
Calculated parameter	9.8	10.0	10.85	10.36	9.78	9.65	9.17
Design parameter	10	10	11	10	10	10	9

***Source:** developed by the authors*

The obtained design parameters were used in the experimental prototype for laboratory investigations. Accordingly, the opening of the movable plates in the lower zone had three fixed positions: the upper position corresponded to the fan capacity lever set to "7"; the middle position corresponded to the fan capacity lever set to "1", "2", "4", "5" and "6"; and the lower position corresponded to the fan capacity lever set to "3" and had a maximum opening of 11 mm. Studies of the operating regimes of the aerodynamic separator with the improved jet generator design indicated a more uniform airflow velocity in the vertical plane of the air channel (Fig. 5).

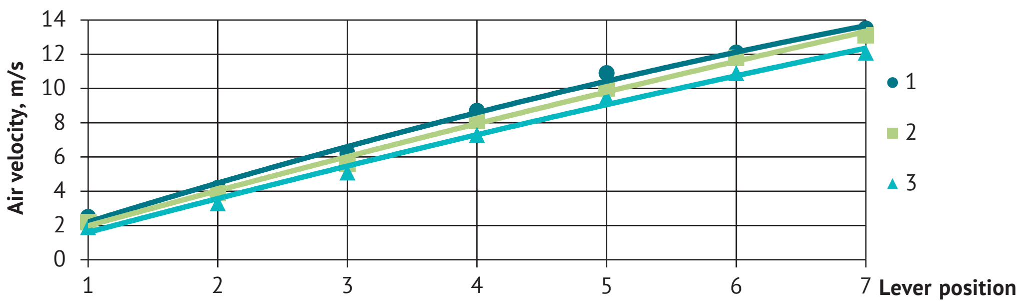

***Figure 5**. Distribution of airflow velocity in the vertical plane for each zone of the air channel when investigating the improved jet generator*

***Note:** 1 – upper zone; 2 – middle zone; 3 – lower zone*

***Source:** developed by the authors*

Compared with the data in Figure 2, the airflow velocity in the lower zone of the air channel became very close to the values in the upper and middle zones. The investigations of the improved air generator indicated an increase in airflow velocity at different setting modes of the aerodynamic separator. Thus, in comparison with the serial jet generator, when the fan capacity lever was set to "1", the airflow velocity in the working plane increased by 0.7 m/s; at setting "2" – by 1.5 m/s; at setting "3" – by 2.4 m/s; at setting "4" – by 3.5 m/s; at setting "5" – by 5.1 m/s; at setting "6" – by 5.4 m/s; and at setting "7" – by 5.7 m/s. Minor deviations of airflow velocity within 0.3-0.5 m/s between the zones of the working plane made it possible to model the ballistic trajectory of the movement of the grain mass components. This approach prevented good-quality grain from entering the fourth fraction and contributed to increasing the homogeneity of the outlet fractions up to 70%, with potential for further improvement.

The key characteristic of the aerodynamic separation of the components of the initial grain mass was the value of the critical velocity. For wheat grain, the critical velocity was 8.9-11.5 m/s, which was unattainable in the lower zone of the serial jet generator. Laboratory investigations of the improved jet generator revealed an increase in the mean airflow velocity in the cross-section of the separation channel (Fig. 6).

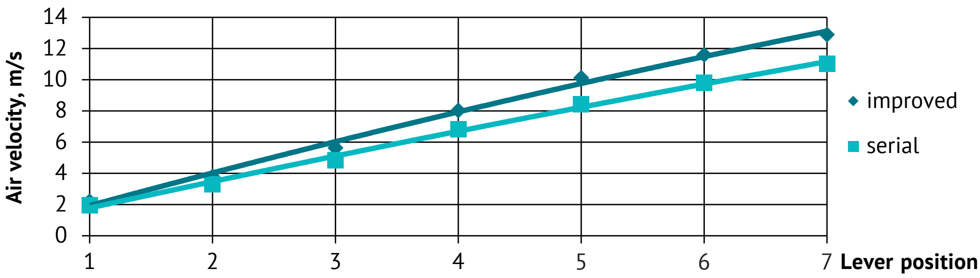

***Figure 6**. Mean airflow velocity in the vertical plane of the air channel of the serial and improved aerodynamic separators*

***Source:** developed by the authors*

The improved SAD-4 aerodynamic separator exhibited higher mean airflow velocity in the separation channel at any position of the fan capacity control lever. Thus, when the fan capacity lever was set to position "1", the mean airflow velocity in the working plane increased by 11.7%; at position "2" – by 15.1%; at position "3" – by 16.5%; at position "4" – by 17.6%; at position "5" – by 20.2%; at position "6" – by 18.4%; and at position "7" – by 17.3%. The maximum mean airflow velocity exceeded 13 m/s, which was fully sufficient for calibrating wheat grain mass and the grain mass of other crops. The introduced improvements ensured a uniform air pressure field in the vertical plane of the pneumatic separation channel under different operating settings of the aerodynamic separator. Thus, comparison of the serial and the improved designs of the jet generator showed that equalising the velocity field in the lower third of the channel made it possible to substantially increase the homogeneity of the fractional composition and to bring the operating regimes closer to the critical velocities required for high-quality calibration of the grain mass.

The discussion of the obtained results made it possible to relate them to current theoretical and engineering approaches to aerodynamic separation of grain mixtures and, at the same time, to delineate the niche occupied by the proposed improvement of the jet generator. In the theoretical model of particle motion in an aspiration channel proposed by V. Bulgakov *et al.* (2020b), the trajectory of a grain was described by the balance of gravity and aerodynamic drag forces in a flow with a certain distributed velocity, while the velocity field was effectively considered uniform within the calculation domain. A similar approach could be observed in the analytical assessment of pneumatic separation quality under multilayer feeding performed by A.V. Nesterenko *et al.* (2017), where separation quality was related to feed parameters and the mean characteristics of the airflow. The experimental data obtained in the present study, showing a 48-52% difference between the air velocities in the lower and upper–middle zones of the channel of the serial separator, indicated that practical implementation of theoretical regimes was possible only under conditions of deliberate shaping of the vertical velocity profile; otherwise, even correctly selected critical velocities did not ensure stable calibration by test weight over the entire height of the channel.

In recent studies devoted to numerical modelling of granular flows, the CFD–DEM approach has been used for a detailed description of particle–air interaction, the formation of recirculation zones and local velocity variations, which fundamentally differs from classical analytical models. The review by M.A. El-Emam *et al.* (2021) showed that even in relatively simple channels the velocity field was structurally non-uniform and was strongly modified by the presence of solid particles. The non-uniform distribution of velocity over the height of the pneumatic channel established in this article and its effect on the overlapping of test-weight ranges between fractions were, in fact, an experimental confirmation of the consequences highlighted in CFD-DEM studies. Against this background, the use of movable plates in the lower third of the jet generator could be regarded as a simple engineering mechanism for controlling the local velocity field, which was a functional analogue of changing boundary conditions in numerical modelling but did not require substantial complication of the design.

In a number of studies focused on the development of technical means for cleaning grain mixtures from light impurities, the main efficiency criterion was the degree of removal of foreign inclusions. In the study by C. Bracacescu *et al.* (2018), equipment for cleaning and sorting seed mixtures based on the aerodynamic principle was analysed, with attention concentrated on design schemes and regimes that ensured reliable separation of impurities. Similarly, in the work of P. Greyvensteyn *et al.* (2023), the design and testing of a pneumatic aspirator were considered, where the key indicators were grain cleanliness and the energy efficiency of the aspiration system. In contrast to these approaches, the results obtained for the improved aerodynamic separator demonstrated the possibility of combining the functions of cleaning and multifraction calibration: equalising the airflow velocity in the lower zone of the channel not only promoted stable removal of light impurities, but also reduced the overlap of fractions by test weight, which was critical for forming seed material with homogeneous sowing qualities.

Another group of studies focused on changing channel geometry and organising material feed. In the work of S. Kharchenko *et al.* (2021), modelling of aerodynamic separation of a pre-stratified grain mixture in a vertical channel showed that controlled placement of layers of different density at the inlet made it possible to improve separation quality without a substantial increase in energy consumption. In the study by E. Kolankowska *et al.* (2022), it was shown that a conical pneumatic separator for a mixture of buckwheat and wheat provided a smoother change in velocity along the particle trajectory, which had a positive effect both on separation quality and on indicators of sustainable agriculture. Compared with these solutions, improvement of the SAD-4 jet generator did not involve changing the global geometry of the channel or the feeding scheme; instead, local regulation of the cross-section in the lower part of the generator was used. The achieved increase in mean velocity to above 13 m/s and the reduction of differences between zones to 0.3-0.5 m/s made it possible to obtain an effect comparable to geometrically more complex designs, but with minimal intervention in the basic layout of the machine.

Further development of aerodynamic systems has often been associated with combining airflow and centrifugal forces. In the work of S. Stepanenko *et al.* (2025b), the motion of grain material in a combined centrifugal-pneumatic separator was modelled, where enhanced dynamic impacts on the particles made it possible to achieve high separation efficiency, but were accompanied by design complexity and increased energy consumption. Against this background, the improved jet generator, which provided a substantial improvement in the homogeneity of the fractional composition solely through optimisation of the velocity profile in a classical pneumatic channel, represented an alternative direction of modernisation – via fine tuning of the airflow regime rather than the introduction of additional force factors.

Thus, the comparative analysis showed that the results of the study were consistent with general trends in the development of the theory and practice of aerodynamic separation, but at the same time emphasised a specific aspect that remained in the background in most previous works – the influence of the vertical velocity profile on multifraction calibration. Whereas in existing publications the main tools for increasing efficiency were changes in channel geometry, feed organisation or combination with centrifugal fields, the present article demonstrated that even within a serial design, a technically feasible redistribution of airflow in the cross-section could significantly reduce fraction heterogeneity and bring operating regimes closer to the optimum without radical reconstruction of the equipment.

CONCLUSIONS

The components of the feed material for aerodynamic separation differed in their physical and mechanical properties and required different settings of airflow intensity in the working chamber of the separator. Smaller geometric dimensions of a wheat kernel demanded higher airflow velocity compared with kernels having a larger midship cross-sectional area at the same weight. The heavier the kernel, the higher the airflow velocity had to be under equivalent geometric parameters. Differential settings of airflow velocity were therefore dictated by the need to overcome the increasing force of weight. The midship cross-sectional area determined the importance of the position of a particle of the feed components relative to the airflow vector, which affected the energy consumption of the technological process of aerodynamic separation.

Laboratory investigations proved the non-uniform distribution of the airflow generated by the jet generator of the SAD-4 aerodynamic separator in the working separation plane. It was established that, in the vertical plane of the separation air channel, the airflow velocity in the lower third of the jet generator zone was 48-52% lower than in the middle and upper thirds. A small deviation of 7-9% in airflow velocity between the middle and upper zones of the jet generator in the air channel was observed when the fan capacity control lever was set to positions "3", "4" and "5", whereas at positions "1", "2", "6" and "7" the flow velocities were almost identical.

The considerable difference in airflow velocity in the lower zone adversely affected separation quality, particularly the homogeneity of the fractional composition. The presence of kernels with a test weight of 725 g/L in the second fraction was established, while the maximum test weight of this fraction reached 776 g/L, and the third fraction contained test-weight measurements that exceeded some values characteristic of the second fraction. At higher separation intensity, a measurement with a test weight of 761 g/L was detected in the fourth fraction, which exceeded the test weight of 759 g/L in the second fraction. It was found that, when the material feed lever was set to position "1" and the fan capacity lever to position "3", 61% of the entire initial grain mass entered the second fraction, and that, with increasing separation intensity, the mass yield in the fourth fraction increased while the non-uniformity between the third fraction decreased.

The improved design of the jet generator of the aerodynamic separator had flexible characteristics for adjusting airflow intensity in the lower third of the vertical plane of the separation air channel. The use of movable plates in the design provided three fixed positions corresponding to the positions of the fan capacity control lever. The results of laboratory investigations confirmed the effectiveness of the improved jet generator. An increase in airflow velocity in the lower zone of the vertical plane of the air channel by 0.7-5.7 m/s was established when the fan capacity control lever was moved between positions. Owing to the provided adjustment of the improved jet generator design, the mean airflow velocity in the working plane of the separation channel increased by 11.7-20.2% compared with the serial jet generator design. The proposed design implemented the concept of a ballistic trajectory of motion of the components of the initial grain mass due to a difference in airflow velocity of 0.3-0.5 m/s between the zones of the jet generator in the vertical plane of the air channel.

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CONFLICT OF INTEREST

None.

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Оптимізація конструкційних параметрів регулювального модуля повітряного генератора аеродинамічного сепаратора

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Анотація. Отримання якісного посівного матеріалу та продовольчого зерна потребує використання ефективних технологій сепарування. Аеродинамічне сепарування набуло широкого втілення у різних конструкціях обладнання яке призначене для відокремлення легких домішок від вихідної зернової маси та її поділу на однорідні за властивостями фракції. Використання диференційного повітряного потоку забезпечує досить високу 60-70 % ефективність очищення зерна від домішок. Робота була спрямована на дослідження ефективності аеродинамічного сепарування з метою встановлення шляхів покращення якісних показників технологічного процесу очищення та калібрування вихідної зернової маси. Експериментальні дослідження вказали на неоднорідність повітряного потоку у поперечній площині повітряного каналу аеродинамічного сепаратора моделі САД-4. Так, швидкість повітряного потоку у нижній третині площини каналу на 48-52 % менша ніж у верхній та середній площині, між якими неоднорідність потоку повітря становить незначні 7-9 %. Встановлено, що інтенсивність режимів сепарування впливає на якість фракційного складу. За умови максимальних режимних налаштувань за рахунок нерівномірності розподілу повітряного потоку у вертикальній площині неоднорідності фракційного складу збільшується до рівні 61 %. Було запропоновано вирішити наукову проблему збільшення рівня однорідності фракційного складу очищеного зерна шляхом моделювання повітряного потоку у пневматичному каналі аеродинамічного сепаратора відповідно до режимних налаштувань. Запропоновано конструкцію повітряного генератора з механізмом вирівнювання швидкості повітряного потоку у поперечній площині каналу сепарування. Дослідженнями встановлено, що при зміні режимних налаштувань від «1» до «7» інтенсивність повітряного потоку у нижній третині площини каналу змінюється від 1,9 до 12,6 м/с, що на 37-49 % більше ніж у серійного сепаратора. При максимальних режимах сепарування нерівномірність розподілу компонентів вихідної зернової суміші між фракціями знижується до 25-29 %. Встановлена функціональна залежність між інтенсивністю та рівномірністю повітряного потоку у каналі сепарування та однорідністю фракційного складу очищеного зерна

Ключові слова: повітряний режим; відносна швидкість; вихід фракції; швидкість витання; керування потоком повітря