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JUSTIFICATION OF THE PARAMETERS
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JUSTIFICATION OF THE PARAMETERS OF A VIBRATORY FEEDER OF AN AERODYNAMIC SEPARATOR FOR SEED MIXTURES

The issue of improving the efficiency of feeding seed mixture waste into the separation channel of an aerodynamic separator using a vibratory feeder is considered. The need to ensure uniform and stable material feeding, taking into account the feeder capacity and the height of the formed material layer at its outlet, is substantiated. The influence of the frequency and amplitude of oscillations of the vibratory feeder on these technological parameters was investigated. The frequency and amplitude of oscillations were taken as the controlled experimental factors, while the evaluation criteria were the capacity of the vibratory feeder and the height of the seed mixture waste layer (using sunflower as an example) at its outlet. Experimental studies were conducted according to a full factorial design for two factors at three variation levels with three replications.

Based on the experimental results, mathematical models describing the dependence of the vibratory feeder capacity and the height of the formed material layer on the frequency and amplitude of oscillations were obtained. A significant interrelated effect of the investigated operating parameters on feeder capacity was established. It was determined that the height of the seed mixture waste layer is primarily dependent on the amplitude of oscillations, with its effect being distinctly nonlinear.

Technological constraints were established, according to which the height of the material layer at the outlet of the vibratory feeder should not exceed 0.036 m, while its capacity should be within the range of 50–150 kg/h. Based on a combined analysis of the obtained mathematical relationships, a rational oscillation amplitude of $A_v \approx 1.5$ mm was substantiated. The possibility of regulating the vibratory feeder capacity at this amplitude by varying the oscillation frequency was established. The proposed approach provides a basis for automated control of the material feeding intensity into the separation channel using a MikroD3 microprocessor controller.

Keywords: vibratory feeder, aerodynamic separator, seeds, seed mixture, waste, separation, oscillation frequency, oscillation amplitude, capacity, layer height.

Introduction. Improving the processes of cleaning and separation of seed mixtures is one of the pressing tasks in enhancing the efficiency of technologies for post-harvest processing and processing of agricultural raw materials. The quality of the separation process largely determines the possibility of further rational use of the obtained fractions, reduction of process losses, and improvement of the efficiency of processing enterprises. Of particular importance is the improvement of technical means that ensure not only the direct separation of mixture components but also

the creation of optimal conditions for a stable separation process.

The relevance of this problem is particularly pronounced in the processing of oilseed crops, which are an important type of oil-bearing raw material. During their cleaning and technological processing, waste is generated along with the main product, which may include seed particles, hulls, plant-derived fragments, and other components. Such material is characterized by considerable heterogeneity in terms of geometric parameters, mass, density, shape, surface condition, and aerodynamic properties. Differences in the



physical and mechanical characteristics of individual components create conditions for their separation but, at the same time, complicate the organization of stable material feeding into the working zone of separators.

Improving the completeness of separation of such mixtures is important not only technologically but also from a resource-saving perspective. Effective fractionation of waste makes it possible to recover components potentially suitable for further use and reduce the amount of material that is irreversibly removed from the technological process. Therefore, improving separation processes should be considered as one of the directions for increasing the comprehensive utilization of raw materials and reducing losses during their processing.

One of the promising methods for separating heterogeneous seed mixtures is aerodynamic separation, the principle of which is based on differences in the behavior of particles in an air stream. The efficiency of this process depends not only on the velocity characteristics of the air stream and the physical and mechanical properties of the mixture components but also on the conditions under which they enter the separation channel. To ensure stable separation, it is necessary to create a uniform material flow in which particles enter the working zone of the separator with minimal fluctuations in flow rate and without the formation of local accumulations.

Uneven feeding of the seed mixture can lead to periodic overloading of individual sections of the separation channel, changes in the conditions of airflow around the particles, and deterioration of their separation according to aerodynamic properties. If the layer thickness is excessive, particles may shield one another, resulting in unequal interaction with the air stream. Therefore, the efficiency of aerodynamic separation is largely determined by the quality of preliminary material flow formation.

The use of a vibratory feeder is a promising technical solution for preparing a seed mixture for aerodynamic separation. Its application makes it possible to combine material conveying and metered feeding operations, as well as to create the necessary conditions for forming the material flow before it enters the separation channel. The operating principle of such a feeder consists in the directed movement of bulk material along a working surface subjected to oscillatory motion with specified parameters. Under the influence of oscillations, particles move along the working surface, while their motion is determined by the interaction of inertial, gravitational, frictional, and support reaction forces. Depending on the oscillation mode, the particle velocity, material feeding intensity, and distribution pattern over the feeder surface change. This provides an opportunity to control the technological process by regulating the parameters of the vibrational excitation.

The main operating parameters determining the performance of a vibratory feeder include oscillation frequency and amplitude. Their variation directly affects

the kinematic characteristics of material movement and, consequently, the feeder capacity and parameters of the formed material flow. In this regard, not only the absolute value of each parameter but also the nature of their interaction is important. The same capacity can potentially be achieved with different combinations of frequency and amplitude; however, the conditions for forming the material layer may differ.

In the proposed design, the combined vibratory feeder is intended for controlled feeding of seed mixture waste into the separation channel, followed by its entrainment by the air stream. The feeder design should ensure continuous material movement and the formation of a stable flow before its introduction into the aerodynamic separation zone. To generate the required oscillation mode, an electromagnetic vibration exciter with adjustable amplitude is provided. The oscillation frequency is set using a microprocessor-based control system, which enables targeted adjustment of the feeder operating modes and investigation of their influence on the technological parameters of the process.

The possibility of independently adjusting the oscillation parameters is an important prerequisite for adapting the feeder to the characteristics of the material and the required separator capacity. At the same time, increasing the intensity of vibrational excitation does not always result in a proportional improvement in technological performance. At certain combinations of frequency and amplitude, excessive material flow into the separation channel may occur, leading to an increase in layer thickness and deterioration of the conditions for interaction between individual particles and the air stream.

Conversely, insufficient oscillation intensity may reduce the rate of material movement along the working surface, cause instability in material feeding, and limit the overall capacity of the separator. Therefore, when selecting the feeder operating mode, it is inappropriate to focus exclusively on maximizing its capacity. At least two interrelated technological criteria should be considered simultaneously: feeding capacity and the thickness of the seed mixture layer at the feeder outlet. Consequently, substantiating the rational relationship between the parameters of vibrational excitation and the technological performance of the process is an important prerequisite for ensuring the specified feeder capacity and stable operation of the aerodynamic separator.

Review of recent research and publications. Vibratory feeders have been widely used in technological processes involving the conveying, orientation, dosing, and controlled feeding of bulk materials in various industries [1–6]. Their use is particularly appropriate in technological lines where continuous and uniform material flow to the next working element or processing zone is required. Compared with conventional conveying devices, vibratory feeders are characterized by a relatively simple design, the ability to adjust operating modes,



and the capability to provide controlled movement of bulk materials without the use of complex mechanical drive systems.

The operating principle of vibratory feeders is based on transmitting oscillatory motion to a working surface, as a result of which material particles undergo directed movement. The nature of this movement is determined by a combination of the structural and operating parameters of the equipment, as well as the physical and mechanical properties of the material. The main controllable parameters include the frequency and amplitude of oscillations of the working element. Their variation affects particle velocity, material feeding intensity, its distribution over the working surface, and, consequently, the feeder capacity.

One of the main advantages of vibratory feeders is the ability to regulate the intensity of material conveying and dosing by changing the operating parameters of the working element oscillations. This makes it possible to adapt the equipment operation to the properties of a particular bulk material and the technological requirements of the subsequent operation. This capability is particularly important when processing heterogeneous mixtures whose components may differ significantly in size, shape, density, mass, and other physical and mechanical characteristics.

The theoretical principles underlying the calculation and design of vibratory machines are based on the laws governing the oscillatory motion of their working elements and the establishment of relationships between vibration parameters and technological characteristics of the process [7]. At the same time, the efficiency of bulk material movement is determined not by an individual parameter but by their combined effect. Changing the oscillation frequency at a constant amplitude or, conversely, changing the amplitude at a constant frequency can significantly alter the nature of particle interaction with the working surface and with one another. As a result, the material movement velocity, flow density, and its distribution across the width and length of the working element change.

Chandravanshi and Mukhopadhyay analyzed the dynamic characteristics of a vibratory feeder and established the influence of its operating parameters on the velocity of particle movement along the vibrating surface. The results obtained by the authors demonstrated that the parameters of the oscillatory process significantly affect the kinematic characteristics of bulk material flow [8]. This confirms the need for a well-founded selection of vibration modes depending on the required equipment capacity and the properties of the material being conveyed.

Van Nguyen and Golikov investigated the patterns of particle movement in a vibratory feeder and considered possibilities for optimizing its operating modes. The results of these studies confirm the feasibility of a comprehensive approach to selecting the frequency and amplitude of oscillations when designing

and operating vibratory feeding devices [9]. Thus, their operational efficiency largely depends on the coordination of operating parameters with each other and their correspondence to the characteristics of the material.

The use of vibratory feeders in technological lines for cleaning and separating grain and seed materials is of particular interest. In this case, the feeder performs not only a conveying or dosing function but also prepares the material flow for subsequent technological treatment. The uniformity of feeding determines the stability of loading the separator working element and, consequently, the efficiency of separating the initial mixture into individual fractions.

This is particularly important for aerodynamic separation, in which the components of a seed mixture are separated as a result of their interaction with an air stream. The motion conditions of an individual particle in the separation channel are determined not only by its physical, mechanical, and aerodynamic properties but also by the manner in which the material enters the air stream. Uneven feeding or excessive local accumulation of material can impair separation conditions because individual particles will interact with the air stream under different initial conditions.

Therefore, when a vibratory feeder is used as part of an aerodynamic separator, an important technological parameter, alongside capacity, is the material layer thickness at the feeder outlet. Formation of a layer of specified thickness contributes to more uniform introduction of the seed mixture into the separation channel and the creation of stable conditions for its interaction with the air stream. Accordingly, the feeder operating parameters should ensure not maximum capacity as such, but a feeding intensity at which capacity is consistent with the permissible material layer thickness.

For seed mixtures, this issue is of additional importance due to the heterogeneity of the material in terms of its physical and mechanical characteristics. Waste generated during seed cleaning and processing may contain components that differ in geometric dimensions, mass, density, and aerodynamic properties. Under such conditions, stable flow formation before the material enters the separation channel is one of the prerequisites for effective subsequent separation of the mixture.

Analysis of existing studies indicates that researchers have primarily focused on establishing the laws governing the movement of bulk materials along vibrating working surfaces, investigating the dynamic characteristics of equipment, and determining the capacity of vibratory conveying and feeding systems. At the same time, the use of such equipment directly as part of an aerodynamic separator imposes additional requirements on the technological parameters of the material feeding process. In this case, it is important to simultaneously ensure the required feeder capacity and form a uniform seed mixture layer of a specified thickness before it enters the separation channel.

The frequency and amplitude of oscillations may exert an interrelated influence on these technological parameters. Increasing the intensity of vibrational excitation can contribute to an increase in material movement velocity and feeder capacity; however, under certain operating modes, it may alter the conditions for forming the mixture layer at the outlet. Conversely, insufficient oscillation intensity may result in reduced capacity and unstable material feeding. Therefore, determining a rational range of operating parameters requires their comprehensive experimental investigation.

Thus, establishing the patterns of the combined influence of oscillation frequency and amplitude on the technological performance of a vibratory feeder, particularly its capacity and the thickness of the formed seed mixture layer, remains a relevant and insufficiently studied issue. Experimental substantiation of rational feeder operating parameters, taking into account the technological requirements of aerodynamic separation, will make it possible to ensure stable material feeding and create the necessary conditions for its effective separation in the separation channel.

Aim and Objectives of the Study. The aim of the study was to experimentally determine the patterns of influence of the oscillation frequency and amplitude of a vibratory feeder on its capacity and the height of the formed layer of seed mixture waste (using sunflower as an example), as well as to substantiate rational operating parameters to ensure uniform and stable material feeding into the separation channel of an aerodynamic separator.

At the first stage of the study, the structural and functional characteristics of the combined vibratory feeder (Fig. 1), designed to form a moving flow of seed mixture waste and subsequently provide its controlled feeding into the aerodynamic separation zone, were investigated. In its upper part, the vibratory feeder is

connected to the loading device by means of an elastic gasket, which provides the necessary mobility of the working element during oscillations.

The source of mechanical oscillations of the working element is an electromagnetic vibration exciter. Under the action of the oscillations generated by it, the material acquires directed motion along the working surface of the vibratory feeder toward the separation channel. At the feeder outlet, the formed seed mixture flow enters the working zone of the separator, where the particles are entrained by the air stream and subsequently separated according to their aerodynamic properties.

The equipment design allows the vibratory feeder to be disconnected from the loading device, which simplifies its maintenance and cleaning, together with the separation channel, of residual material. To provide access to the internal working elements, an inspection hatch with locking latches is provided on the front of the separator. This design solution enables prompt inspection, cleaning, and maintenance of the equipment working zone.

The electromagnetic vibration exciter (Fig. 1, a) is structurally designed as an electromagnetic system with adjustable oscillation amplitude. The required amplitude value is set according to the specified operating mode before starting the separator. Changing this parameter makes it possible to regulate the intensity of vibrational excitation of the material and, consequently, the nature of its movement along the feeder working surface.

To improve operational reliability and safety, the vibration exciter is equipped with a thermal relay designed to monitor its thermal condition. If the permissible temperature is exceeded or an overload occurs, the system automatically switches off the vibration exciter, preventing overheating and possible equipment damage.

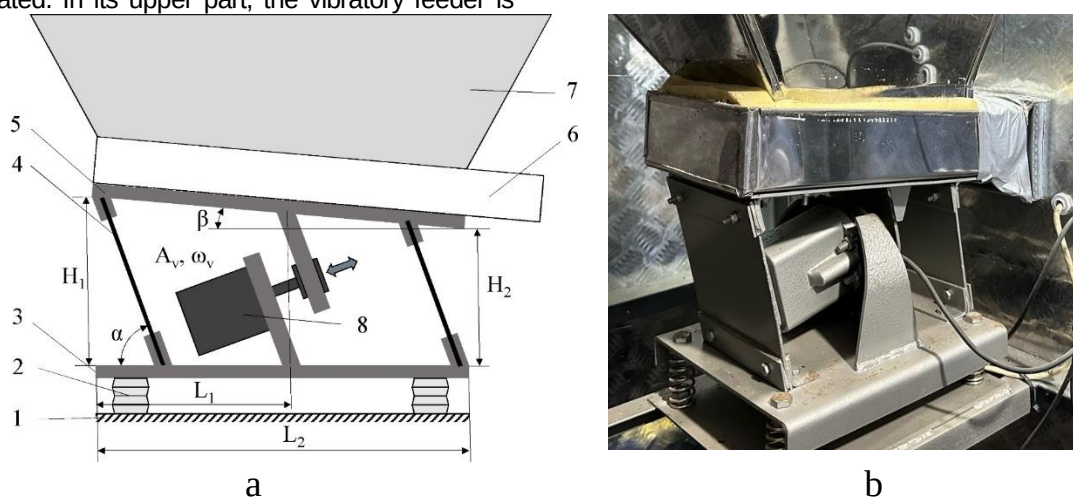


Fig. 1. Vibratory feeder of a column-type aerodynamic separator: a – schematic diagram; b – general view; 1 – base; 2 – springs; 3 – lower frame; 4 – spring element (plate); 5 – upper frame; 6 – tray; 7 – hopper; 8 – electromagnetic vibration exciter.

Since the determination and optimization of the structural parameters of the vibratory feeder were not included in the objectives of this study, their values were adopted based on calculations performed according to established methods [7–9]. As a result, the following structural parameters of the vibratory feeder were established: $H_1 = 185$ mm; $H_2 = 150$ mm; $L_1 = 200$ mm; $L_2 = 300$ mm; $\alpha = 78^\circ$; $\beta = 15^\circ$. The adopted geometric characteristics remained unchanged throughout all experimental studies, which made it possible to focus on

determining the influence of vibration operating parameters on the technological performance of the feeder.

The operating modes of the vibratory feeder were controlled using a MikroD3 microprocessor controller according to the electrical circuit shown in Fig. 2. The use of the controller provided the possibility of regulating and maintaining the specified operating parameters of the vibration exciter during the experiments.

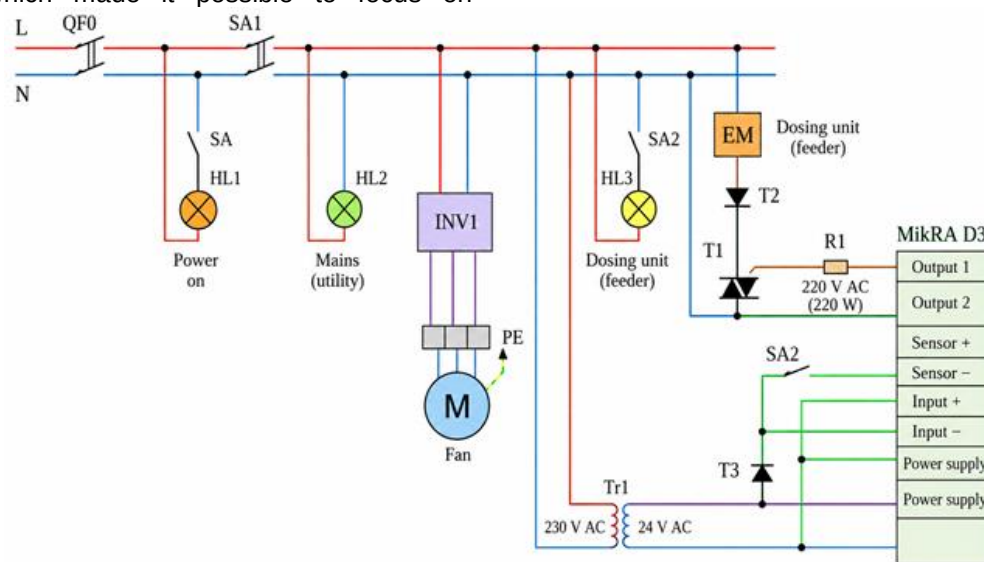


Fig. 2. Electrical circuit of a column-type aerodynamic separator

The oscillation frequency of the vibratory feeder ω_v and the oscillation amplitude A_v were selected as the controlled experimental factors. The oscillation frequency was varied using the MikroD3 microprocessor controller, while the required amplitude was set by changing the working length of the armature of the electromagnetic vibration exciter. The ranges and variation levels of the investigated factors are presented in Table 1.

The evaluation criteria for the efficiency of the vibratory feeder were its capacity q and the height of the sunflower seed mixture waste layer at the feeder outlet h_p . The capacity characterized the intensity of material feeding into the separation channel, while the height of the formed layer determined the conditions for subsequent interaction of the particles with the air stream. According to the results of preliminary theoretical studies, the limiting value of the layer height h_p should not exceed 0.036 m, which was adopted as

a technological constraint when determining rational operating modes of the vibratory feeder.

The experimental studies were conducted according to a full factorial design for two factors, each varied at three levels. Thus, the experimental design included nine combinations of operating modes. Each experiment was performed in triplicate, providing the possibility of statistical processing of the experimental data obtained and evaluation of the reproducibility of the results.

Based on the experimental results, the dependences of the vibratory feeder capacity q and material layer height h_p on the oscillation frequency ω_v and amplitude A_v were established. The obtained relationships were used to determine the range of rational operating parameter values that ensure the required feeder capacity while simultaneously satisfying the technological constraint $h_p \leq 0.036$ m.

Table 1

Variation levels of the factors in the experimental studies of the vibratory feeder

Variation level	Vibratory feeder oscillation frequency ω_v	Vibratory feeder oscillation amplitude A_v
Lower (–1)	20	0.001
Zero (0)	60	0.002
Upper (+1)	100	0.003
Interval (Δ)	40	0.001

Presentation of the Main Material. The results of the first stage of the experimental studies are presented in Table 2.

Table 2

Results of experimental studies of the vibratory feeder

№	x_{10}	x_{11}	ω_v , Hz	A_v , mm	q , kg/h				h_p , m			
					1	2	3	Average	1	2	3	Average
1	-1	-1	20	0.001	43.2	42.1	41.9	42.4	0.023	0.017	0.023	0.021
2	-1	0	20	0.002	59.2	57.1	58.6	58.3	0.035	0.024	0.028	0.029
3	-1	1	20	0.003	76	73.3	72.1	73.8	0.045	0.038	0.035	0.039
4	0	-1	60	0.001	79.1	76.8	76.9	77.6	0.029	0.024	0.024	0.026
5	0	0	60	0.002	133	127.2	125.3	128.5	0.042	0.026	0.038	0.035
6	0	1	60	0.003	185.5	175	177.1	179.2	0.053	0.035	0.057	0.048
7	1	-1	100	0.001	111.4	107	109.2	109.2	0.033	0.023	0.038	0.031
8	1	0	100	0.002	194.9	189.4	191.7	192	0.047	0.033	0.048	0.043
9	1	1	100	0.003	277.2	269	277.3	274.5	0.061	0.052	0.063	0.059

Using the Wolfram Cloud software package, a second-order regression equation (1) describing the dependence of the vibratory feeder

$$q = 128.332 + 66.8666 x_{10} - 3.39 x_{10}^2 + 49.7166 x_{11} + 33.474 x_{10} x_{11} - 0.149 x_{11}^2, \quad (1)$$

where q is the vibratory feeder capacity, kg/h; x_{10} , x_{11} are the coded values of the vibration frequency ω_v and amplitude A_v of the vibratory feeder.

The calculated statistical parameters are presented in Table 3. The regression coefficients for which the calculated Student's t -value is lower than the tabulated value $t_{0.05}(9) = 2.26$ are highlighted in gray. These regression coefficients will subsequently be disregarded as statistically insignificant. The calculated Fisher criterion is $F =$

capacity on the experimental factors was obtained in coded form:

26822, which is greater than the tabulated value $F_t(6; 3; 0.05) = 8.94$. This means that the null hypothesis can be rejected and that the model has a statistically significant effect on the dependent criterion.

After decoding the variables and removing the statistically insignificant regression coefficients, the following equation is obtained (Fig. 3):

$$q = 21.374 - 495.832 A_v + 0.252916 \omega_v + 836.874 A_v \omega_v - 0.002124 \omega_v^2 \quad (2)$$

Table 3

Statistical parameters of regression equation (1)

a	Estimate	Standard Error	t-Statistic	P-Value
a_{00}	128.332	0.807852	158.859	$5.50026 \cdot 10^{-7}$
a_{100}	66.8666	0.442479	151.118	$6.38925 \cdot 10^{-7}$
a_{110}	49.7166	0.442479	112.35	$1.55425 \cdot 10^{-6}$
a_{1011}	33.474	0.541924	61.7707	$9.34785 \cdot 10^{-6}$
a_{1010}	-3.39	0.766396	-4.43635	0.0212888
a_{1111}	-0.149	0.766396	-0.195721	0.857334

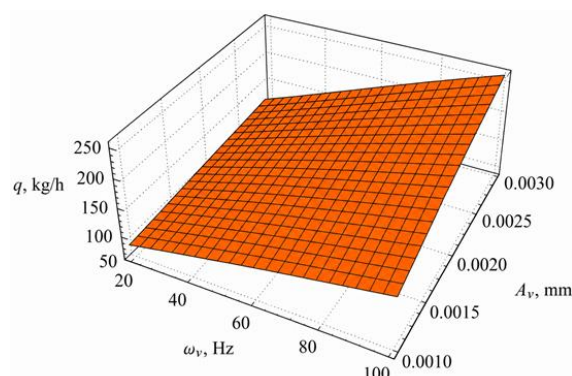


Fig. 3. Dependence of vibratory feeder capacity q on vibration frequency ω_v and amplitude A_v

The vibration amplitude A_v has a negative effect on capacity in the linear term; however, in combination with frequency, it makes a significant positive contribution through the term $836.874 A_v \omega_v$. This means that an isolated increase in amplitude reduces capacity, whereas simultaneous increasing of the frequency can compensate for this effect or even result in increased capacity. The term $-0.002124 \omega_v^2$ indicates that at excessively high frequencies, the capacity begins to decrease. Thus, achieving the required capacity requires appropriate selection of the vibration frequency and amplitude, avoiding excessively high frequencies and taking their interaction with amplitude into account.

Using the Wolfram Cloud software package, a second-order regression equation (3)

describing the dependence of the height of the sunflower seed mixture waste layer on the

experimental factors was obtained in coded form:

$$h_p = 0.0340555 + 0.00708332 x_{10} + 0.000716666 x_{102} + 0.0113832 x_{11} + 0.00224 x_{10} x_{11} + 0.00181666 x_{112}, \quad (3)$$

where h_p is the height of the sunflower seed mixture waste layer at the vibratory feeder outlet, m.

The statistical parameters were calculated and are presented in Table 4. The regression coefficients for which the calculated Student's t -value is lower than the tabulated value $t_{0.05}(9) = 2.26$ are highlighted in gray. Since these coefficients are statistically insignificant, they are not considered in the subsequent analysis. The

calculated Fisher criterion is $F = 28493$, which exceeds the tabulated value $F_{\alpha}(6; 3; 0.05) = 8.94$. This allows the null hypothesis to be rejected and confirms the statistically significant effect of the model on the dependent criterion.

After decoding the variables and removing the statistically insignificant regression coefficients, the following equation is obtained (Fig. 4):

$$h_p = 0.0162932 + 0.741666 A_v + 1816.66 A_v^2 + 0.0000108332 \omega_v + 0.05624 A_v \omega_v + 4.47916 \cdot 10^{-7} \omega_v^2. \quad (4)$$

Table 4

Statistical parameters of regression equation (4)

a	Estimate	Standard Error	t-Statistic	P-Value
a_{00}	0.0340555	0,000202351	168,297	$4,62568 \cdot 10^{-7}$
$a_{10\ 0}$	0.00708332	0,000110832	63,92	$8,44076 \cdot 10^{-6}$
$a_{11\ 0}$	0.0113832	0,000110832	102,706	$2,0347 \cdot 10^{-6}$
$a_{10\ 11}$	0.00224	0,000135741	16,5754	0,000477975
$a_{10\ 10}$	0.000716666	0,000191967	3,73324	0,0334996
$a_{11\ 11}$	0.00181666	0,000191967	9,46335	0,00250117

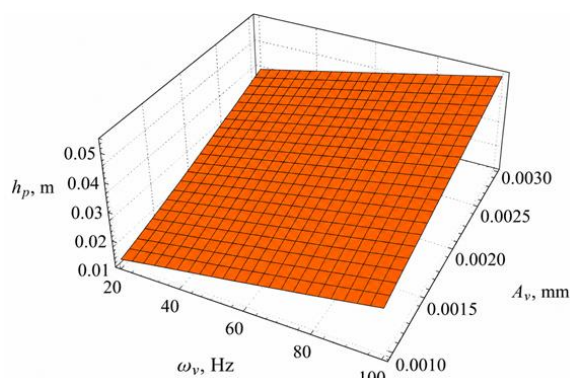


Fig. 4. Dependence of the height of the seed mixture waste layer at the vibratory feeder outlet h_p on vibration frequency ω_v and amplitude A_v

Analysis of the equation makes it possible to identify the main trends in the influence of the parameters. The linear term $0.741666 A_v$ indicates that the layer height h_p increases with increasing vibration amplitude. The quadratic term $1816.66 A_v^2$ indicates a significant nonlinear effect of amplitude, meaning that the layer height increases at an accelerating rate as A_v increases. The vibration frequency ω_v also affects the layer height, although its effect is considerably weaker: the linear

coefficient 0.0000108333 is very small, while the quadratic term $4.47916 \cdot 10^{-7} \omega_v^2$ indicates a slight accelerated increase with increasing frequency. A significant effect is exerted by the interaction between amplitude and frequency, described by the term $0.05624 A_v \omega_v$. This indicates that increasing the frequency at a fixed amplitude additionally contributes to an increase in the waste layer height. Thus, the height of the waste layer at the vibratory feeder outlet depends primarily on the vibration amplitude, with its effect being distinctly quadratic. Vibration frequency also affects h_p , but this effect is less significant compared with amplitude.

According to the numerical modeling results, the height of the sunflower seed mixture waste layer at the vibratory feeder outlet h_p should be less than 0.036 m, while the vibratory feeder capacity q should be within the range of 50 – 150 kg/h:

$$\begin{cases} h_p(\omega_v, A_v) \leq 0.036, \\ 50 \leq q(\omega_v, A_v) \leq 150. \end{cases} \quad (5)$$

Solving system (5) together with equations (2) and (4) yields $A_v \approx 0.0015$ m, while the vibratory feeder capacity depends on its vibration frequency (Fig. 5):

$$q = 20.6313 + 1.50822 \omega_v - 0.002124 \omega_v^2. \quad (6)$$

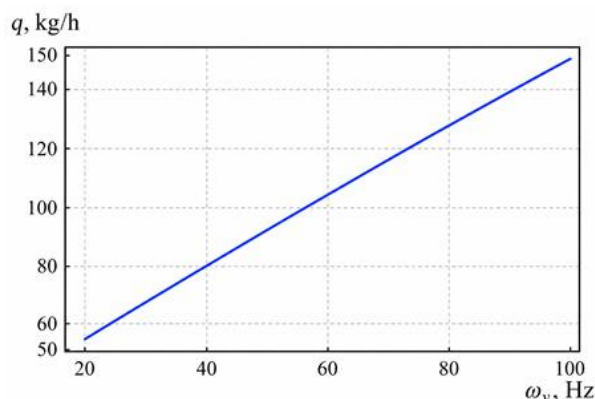


Fig. 5. Dependence of vibratory feeder capacity q on its vibration frequency ω_v

Equation (6) will be used to determine the vibratory feeder capacity by regulating the vibration frequency using the MikroD3 microprocessor controller.

Conclusions. The experimental studies established that the oscillation frequency and amplitude have a significant effect on the main technological performance indicators of the vibratory feeder, particularly its capacity and the height of the formed seed mixture layer. Based on the experimental data obtained, mathematical models describing the dependence of these parameters on the vibration operating conditions were developed.

It was established that the oscillation amplitude has the most significant effect on the height of the material layer, with this dependence being nonlinear. Taking into account the technological requirements for the operation of the aerodynamic separator, it was determined that the height of the seed mixture layer at the feeder outlet should not exceed 0.036 m, while its capacity should be within the range of 50–150 kg/h.

Based on the analysis of the obtained relationships, a rational oscillation amplitude of $A_v \approx 1.5$ mm was substantiated. At the established amplitude, it is advisable to regulate the capacity of the vibratory feeder by varying the oscillation frequency. This approach enables operational control of the intensity of seed mixture feeding into the separation channel and provides the basis for automating the material feeding process using a microprocessor controller.

The substantiated operating parameters can be used when configuring the control system of the vibratory feeder of the aerodynamic separator to ensure stable material feeding and improve the efficiency of the separation process.

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ОБҐРУНТУВАННЯ ПАРАМЕТРІВ ВІБРАЦІЙНОГО ЖИВИЛЬНИКА АЕРОДИНАМІЧНОГО СЕПАРАТОРА НАСІННЄВОЇ СУМІШІ

Розглянуто питання підвищення ефективності подачі відходів насіннєвої суміші до сепараційного каналу аеродинамічного сепаратора із застосуванням вібраційного



живильника. Обґрунтовано необхідність забезпечення рівномірної та стабільної подачі матеріалу з урахуванням продуктивності живильника та висоти сформованого шару на його виході. Досліджено вплив частоти та амплітуди коливань вібраційного живильника на зазначені технологічні показники. Як керовані фактори експерименту прийнято частоту та амплітуду коливань, а як критерії оцінювання – продуктивність вібраційного живильника та висоту шару відходів насінневої суміші (на прикладі соняшнику) на його виході. Експериментальні дослідження проведено за повним факторним планом для двох факторів на трьох рівнях варіювання з триразовою повторністю дослідів.

За результатами експериментальних досліджень отримано математичні моделі залежності продуктивності вібраційного живильника та висоти сформованого шару матеріалу від частоти й амплітуди коливань. Установлено суттєвий взаємопов'язаний вплив досліджуваних режимних параметрів на продуктивність живильника. Визначено, що висота шару відходів насінневої суміші

найбільшою мірою залежить від амплітуди коливань, причому її вплив має виражений нелінійний характер.

Установлено технологічні обмеження, відповідно до яких висота шару матеріалу на виході з вібраційного живильника не повинна перевищувати 0,036 м, а його продуктивність має перебувати в межах 50–150 кг/год. На основі сумісного аналізу отриманих математичних залежностей обґрунтовано раціональне значення амплітуди коливань $A_v \approx 1,5$ мм. Установлено можливість регулювання продуктивності вібраційного живильника за цього значення амплітуди шляхом зміни частоти коливань. Запропонований підхід створює передумови для автоматизованого керування інтенсивністю подачі матеріалу до сепараційного каналу з використанням мікропроцесорного контролера МікРА ДЗ.

Ключові слова: вібраційний живильник, аеродинамічний сепаратор, насіння, насіннева суміш, відходи, сепарування, частота коливань, амплітуда коливань, продуктивність, висота шару.

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