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NUMERICAL SIMULATION OF THE WASTE SEPARATION PROCESS OF SUNFLOWER SEED MIXTURE IN THE PNEUMATIC SEPARATING CHANNEL OF THE AERODYNAMIC SEPARATOR

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Sorting of grain and waste is a multifaceted, complex scientific and technical problem, which, depending on the task, has various solutions. Various methods of aerodynamic separation are used in many scientific works. Regarding the sorting of impurities and waste, it should be noted that the sorting of garbage, waste and by-products of some agricultural crops does not yet have an effective solution from the side of agricultural engineering.

The analysis of technological lines of cleaning and separation of seed material in the screening and fanning department of the oil extraction plant revealed the following shortcomings. The lines are not complex, which leads to the formation of a large amount of waste that can be used in the production of food and feed products, mineral fertilizers, fuel, etc. There is no equipment for extracting grain/oil impurities from garbage and waste, and for sorting them with rationally agreed mode parameters based on software. Increasing the productivity of lines is carried out by increasing the number of equipment, which reduces the coefficient of its use and requires additional power.

In order to solve these shortcomings, it is necessary to develop an aerodynamic separator that will improve the quality of the waste treatment of the sunflower seed mixture.

As a result of the first stage of numerical modeling of the process of separation of the components of the sunflower seed mixture waste in the pneumatic separating channel, the trajectories of the movement of its components were obtained. Processing of the simulation results in the Wolfram Cloud software package made it possible to calculate the second-order regression equation of the dependence of the horizontal flight distance of the components (sunflower husks and small particles) on the effective diameter, the speed of the supply of components and the speed of the air flow. Taking into account the accepted conditions for the efficiency of the separation process, the cross-section of the pneumatic separation channel is determined - a square with a side of 220 mm

As a result of the second stage of numerical modeling of the process of interaction between the waste streams of the seed mixture and air in the pneumatic separating channel, their visualization was obtained for various combinations of factors. Using the Wolfram Cloud software package, the second-order regression equation of the dependence of the content of sunflower kernels in the area of the kernel collector, the productivity of the separation process and the volume flow of air (the productivity of the air flow generator) on the height of the waste layer of the supplied sunflower seed mixture and the speed of the air flow was calculated. Taking into account the accepted conditions for the efficiency of the separation process, the rational design and technological parameters of the pneumatic separating channel of the aerodynamic separator are substantiated.

Keywords: *seed, mixture, components, aerodynamic separator, column, air flow, parameters, speed, efficiency, modeling.*

Eq. 14. Fig. 5. Table 4. Ref. 19.

1. Problem formulation

The principles of sustainable development and rational use of resources formed the basis of the concept of "circular economy", or "closed cycle economy" as a new economic model based on reduction, reuse and recycling of energy, transition from fossil fuels to the use of renewable energy sources, recovery of resources, recycling of secondary raw materials [1].

The Ministry of Economic Development and Trade of Ukraine prepared the National Report "Sustainable Development Goals: Ukraine" [2], which defines the basic indicators for achieving the Sustainable Development

Goals. Goal 12 of the National Report "Responsible consumption and production" notes the need to create legal and institutional prerequisites for the formation of a green economy in Ukraine, which will significantly reduce the dependence of economic growth on the use of natural resources and energy. At the same time, the concept of circular economy should serve as a basis for rethinking the role of waste as resources. Among the measures within the framework of "Goal 12", it is envisaged, in particular, to ensure the sustainable use of chemicals based on innovative technologies and productions, as well as to reduce the volume of waste generation and increase the volume of its processing and reuse based on innovative technologies and productions.

Seed waste and garbage is a promising raw material for processing, because it contains 30-50% grain/oil admixture suitable for further use [3]. It is expedient to obtain this valuable raw material only by mechanical sorting of waste on specially developed machines [4]. The existing technical support for sorting to remove oil/grain admixture does not provide the necessary technological efficiency. Therefore, the search for constructive solutions for the creation of machines for fine cleaning of grain mass is an urgent task for agricultural engineering.

2. Analysis of recent research and publications

Sorting of grain and waste is a multifaceted, complex scientific and technical problem, which, depending on the task, has various solutions. This problem was dealt with by Ukrainian scientists: O.I. Zagorodniy and O.V. Bogomolov [5], O.V. Kozachenko and M.V. Bakum [6], E.B. Aliyev [7], B.I. Kotov. and Stepanenko S.P. [8] and others. Various methods of aerodynamic separation are used in their works. Regarding the sorting of impurities and waste, it should be noted that the sorting of garbage, waste and by-products of some agricultural crops does not yet have an effective solution from the side of agroengineering.

The analysis of the technological lines of cleaning and separation of seed material in the screening and fan section of the oil extraction plant [9–11] made it possible to identify the following shortcomings:

– the lines are not complex, that is, they generate a large amount of waste, which, due to its biochemical and technological properties, is a valuable raw material for further use in the manufacture of food and feed products, as well as for the production of a number of separate types of products, such as mineral fertilizers, fuel, etc.

– the technological lines do not include equipment for removing grain/oily impurities from the warehouse, equipment for sorting garbage and grain waste with rationally coordinated operating parameters due to the use of software based on algorithms that determine the technological process of sorting the seed mixture according to a set of signs of divisibility with higher productivity and quality.

– increasing the productivity of the lines was provided by multiplying the number of low-performance equipment, which requires an increase in the installed capacity and a decrease in the utilization ratio of the equipment.

In order to solve the presented shortcomings, it is necessary to develop such an aerodynamic separator, which will improve the quality of the waste treatment of the sunflower seed mixture.

3. The purpose of the article

Carry out numerical modeling of the process of separation of sunflower seed mixture waste in the pneumatic separation channel of the developed aerodynamic separator and justify its rational design and technological parameters.

4. Results of the researches

Numerical modeling of the process of separation of sunflower seed mixture waste in the pneumatic separation channel of the developed aerodynamic separator was carried out in the Simcenter Star-CCM+ software package [12, 13].

Polyhedral cell generator and surface mesh generator were used as mesh models. The basic grid cell size is set to 0.02 m.

The ideal gas model, the separated gas flow model, the Lagrangian multiphase, the Hertz-Mindlin multiphase interaction model, and the rolling resistance model were used as physical models. The particle model is set according to the actual shape of the object using the coordinate method.

Simulation in Simcenter Star-CCM+ uses a standard turbulence model k-ε, the convergence accuracy is equal to 10^{-4}. When setting the boundary conditions in all simulations, the inlet and outlet pressure velocities are assumed to be the inlet and outlet air flow. The motion of the gas phase is solved by the standard turbulence model k-ε. Standard wall functions of Simcenter Star-CCM+ [14] are used as wall processing methods.

Three Lagrangian phases were created using the discrete element method (DEM): sunflower kernel, husk and small particles. Physical and mechanical properties of DEM particles and their interaction are given in table. 1 [15–18].

Дthe following air properties were used for modeling: molar mass – 28,8 g/mol dynamic viscosity – $1,86 \cdot 10^{-5}$ Pass. The reference magnitude of the simulation is the gravity vector, which has the following coordinates (0.0; 0.0; -9.81) m/s^2.

The simulation was carried out by a non-stationary implicit method with a step of 0.001 s. At the same time, 5 iterations took place at each step. For moving DEM particles, the Courant number was 0.05–0.35.

Table 1

Average values of the physical and mechanical properties of the components of the seed mixture waste

Property	Sunflower kernel	Husk	Small particles
Effective diameter, mm	5–25	5–25	5–25
Actual density, kg/m^3	990±30	510±50	200±70
Young's modulus, MPa	1,07±0,11	1,23±0,15	0,52±0,10
Coefficient of friction at rest against the wall (AISI 201)	0,39±0,15	0,32±0,12	0,25±0,04
Poisson's ratio	0,28±0,04	0,32±0,06	0,22±0,05
The coefficient of friction between particles at rest	0,42±0,06	0,48±0,07	0,38±0,07
Recovery factor	0,44±0,10	0,35±0,12	0,36±0,10
Rolling resistance coefficient	0,36±0,02	0,33±0,03	0,37±0,09

The first stage of simulation of the process of separation of sunflower seed mixture waste in the pneumatic separation channel was carried out according to the scheme presented in fig. 1.

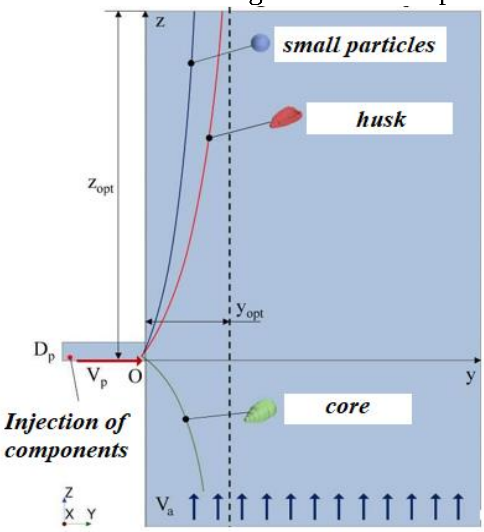

Fig. 1. Scheme of modeling the movement of waste components of the sunflower seed mixture in the pneumatic separation channel

We assume that the waste components of the seed mixture are injected singly at one point every 10 s. At the same time, their effective diameter D_p (coded – x_1) is a research factor and varies in the range of 0.005–0.025 m. Further, under the action of a formalized belt conveyor, the components are fed to the pneumatic separating channel at a speed V_p (coded – x_2), which varies in the range of 0.05–0.25 m/s. The air flow is uniform at the entrance to the pneumoseparating channel, its speed V_a (coded – x_3) varies in the range of 1–5 m/s. The research was conducted according to the full factorial design for three factors at three levels.

Due to the different aerodynamic characteristics of the waste components of the sunflower seed mixture, the sunflower seed core moves downwards, while the husks and small particles rise upwards. In this way, the separation process takes place in the pneumoseparating channel.

The quantitative criterion for evaluating the process is its productivity q, which is directly proportional to the feed rate of the components of the sunflower mixture V_p and should strive for the maximum value:

$$q \sim V_p \rightarrow \max. \quad (1)$$

The energy criterion is the energy consumption of the air flow generator E, which is directly proportional to the square of the air flow speed V_a and the area of the pneumoseparating channel and should tend to the minimum value. Assuming that the cross section of the pneumoseparating channel is a square with a side y_{opt} we have:

$$E \sim V_a^2 \cdot y_{opt}^2 \rightarrow \min. \quad (2)$$

A condition for high-quality separation of sunflower seed mixture waste is the maximization of the vertical speed of the sunflower husk V_{hz} and small particles V_{dz} in the direction Oz and minimization of the vertical velocity of the sunflower kernel V_{kz} in the direction -Oz. This condition ensures the smallest horizontal flight distance of the components (sunflower husks and small particles) y_{opt} (Fig. 2), that is:

$$y_{opt} \to \min. \tag{3}$$

To study the influence of the supply of waste seed mixture and the fractional content of its components on the quality of the separation process, the second stage of modeling the interaction of the flow of waste seed mixture and air was carried out. The simulation scheme is shown in Fig. 2.

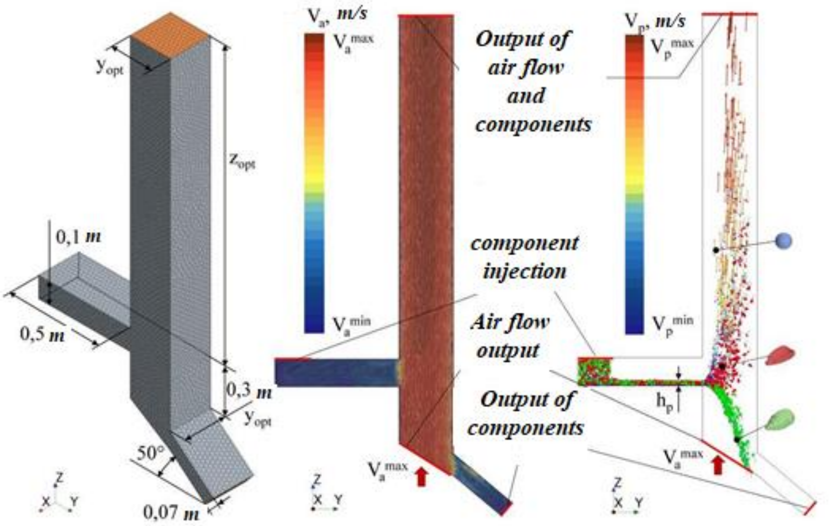

Fig. 2. Modeling scheme of waste separation of sunflower seed mixture in a pneumatic separation channel

It is assumed that the seed mixture was previously calibrated on sieves and the effective diameter of the components is within 0.009 m to 0.013 m.

Since, according to the previous simulation, the rational values of the speed of the formalized belt conveyor were determined $V_{p\text{-}opt}$ and its width y_{opt}, then the supply is determined by the height of the waste layer of the seed mixture h_p:

$$q \sim V_{p-opt} y_{opt} h_p, \tag{4}$$

Therefore, the height of the waste layer of the sunflower seed mixture was chosen as a research factor h_p (coded – x_4) within 0,01–0,03 m and air flow speed V_a (coded –x_3). Numerical simulations were carried out using a full-factor design for two factors at five levels.

The content of sunflower kernels in the area of the kernel collector was chosen as the criterion for evaluating the quality of separation $\eta_{k\text{-}k}$, which should be maximum.

As a result of the first stage of numerical modeling of the process of separation of sunflower seed mixture waste in the pneumatic separating channel, the trajectories of its components were obtained.

For different variants of the numerical experiment, at different values of the factors, different flight trajectories of the waste components of the sunflower seed mixture are observed. Determine for each combination of factors the value of the flight distance of the components (sunflower husks and small particles) y_{opt}.

Using the Wolfram Cloud software package [19], we will calculate the regression equation of the second order of dependence y_{opt} from research factors in coded form:

$$y_{opt} = 0,286222 + 0,0136111\, x_1 + 0,0498333\, x_1^2 + 0,0834444\, x_2 - \\ - 0,0000833333\, x_1 x_2 + 0,006\, x_2^2 - 0,0756111\, x_3 + 0,0400833\, x_1 x_3 - \\ - 0,0615\, x_2 x_3 + 0,0818333\, x_3^2. \tag{5}$$

The calculated statistical indicators are shown in the table. 2. Regression coefficients for which the calculated Student coefficient is less than the table value are highlighted in gray $t_{0,05}(27) = 2,05$. These regression coefficients will be neglected in the future as statistically insignificant.

After decoding and removing insignificant regression coefficients, we have (Fig. 3):

$$y_{opt} = 0,639806 - 51,8917\, D_p + 1993,33\, D_p^2 - 0,154514\, V_a + \\ + 4,00833\, D_p V_a + 0,0204583\, V_a^2 + 1,75694\, V_p - 0,3075\, V_a V_p. \tag{5}$$

According to fig. 3 increasing the effective diameter of the components D_p at certain values of air flow speed V_a leads to a decrease in the horizontal distance y_{opt}. This is explained by an increase in the mass of the components and, accordingly, a decrease in their flight range. Increasing the speed of supplying components V_p logically leads to an increase in distance y_{opt}. In turn, for the speed of the air flow V_a at certain values of the speed of supply of components V_p a certain optimum is observed, which can be explained by a change in the movement vector of the components of the mixture in space.

Table 2

Statistical indicators of the regression equation (5)

	Estimate	Standard Error	t–Statistic	P–Value
a_{00}	0,286222	0,0250114	11,4437	$2{,}07281\cdot10^{-9}$
a_{10}	0,0136111	0,011578	1,1756	0,255958
a_{20}	0,0834444	0,011578	7,20714	$1{,}46642\cdot10^{-6}$
a_{30}	-0,0756111	0,011578	-6,53057	$5{,}13676\cdot10^{-6}$
a_{12}	-0,0000833333	0,0141801	-0,00587677	0,995379
a_{13}	0,0400833	0,0141801	2,82673	0,0116317
a_{23}	-0,0615	0,0141801	-4,33706	0,000447816
a_{11}	0,0498333	0,0200537	2,48499	0,0236631
a_{22}	0,006	0,0200537	0,299196	0,768417
a_{33}	0,0818333	0,0200537	4,0807	0,000778548

By solving the system of equations (1)–(3) together with (5) in the Wolfram Cloud software package, we obtain a rational equation that connects research factors with each other:

$$0{,}420403 - 51{,}8917\,D_p + 1993{,}33\,D_p^2 - 0{,}154514\,V_a + \\ + 4{,}00833\,D_p V_a + 0{,}0204583\,V_a^2 + 1{,}75694\,V_p - 0{,}3075\,V_a V_p = 0. \quad (6)$$

With y_{opt} = 0,2195 m. Then for further calculations we take the cross-section of the pneumatic separating channel - a square with a side of 220 mm.

For components whose effective diameter is within 0.009–0.013 m, the speed of the formalized belt conveyor is $V_{p\text{-}opt}$ = 0,069–0,077 m. We take the average value of 0.073 m.

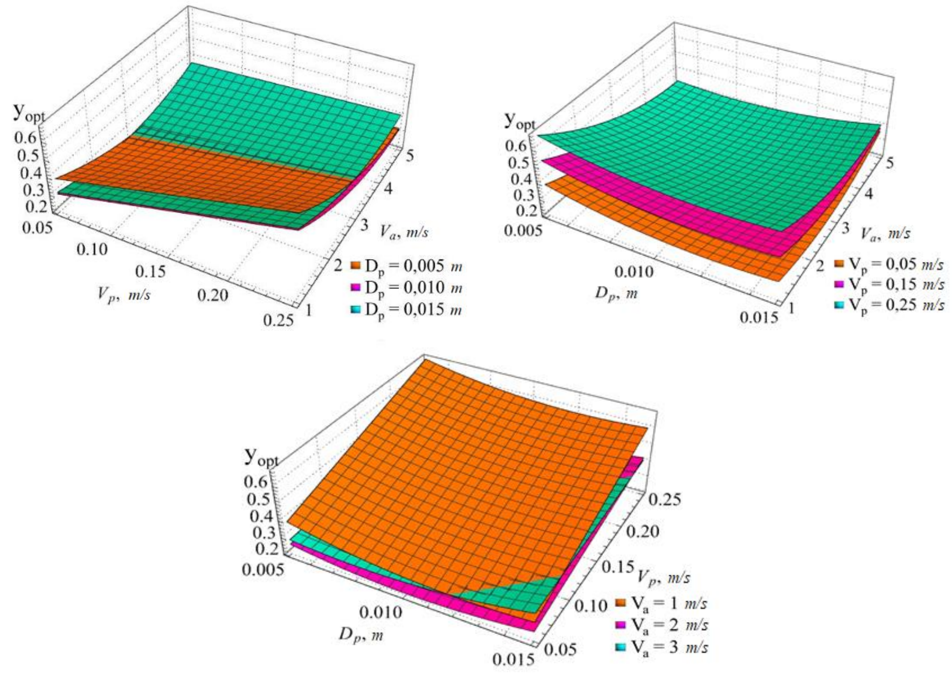

Fig. 3 Dependence of the horizontal flight distance of the components (sunflower husks and small particles) y_{opt} from the effective diameter D_p, component feed rates V_p and air flow speeds V_a

As a result of the second stage of numerical modeling of the interaction of the flow of seed mixture waste and air in the pneumatic separation channel, their visualization was obtained for various combinations of factors, which are presented in fig. 4.

Fig. 4 shows the distribution of the components of the seed mixture waste in the pneumatic separation channel and the vector field of their velocities.

The value of the productivity of the separation process q, volume flow rates of the air flow $Q_a$and the content of sunflower kernels in the area of the kernel collector $\eta_{k\text{-}k}$ for each experiment.

Table 3

Statistical indicators of the regression equation (7)

	Estimate	Standard Error	t–Statistic	P–Value
a_{00}	0,924629	0,0014689	629,468	$1{,}67618\cdot10^{-42}$
a_{40}	-0,0524	0,00105773	-49,54	$1{,}48098\cdot10^{-21}$
a_{30}	0,0604	0,00105773	57,1033	$1{,}01302\cdot10^{-22}$
a_{43}	-0,012	0,00149586	-8,02215	$1{,}60849\cdot10^{-7}$
a_{44}	-0,0245714	0,00178789	-13,7432	$2{,}53874\cdot10^{-11}$
a_{33}	-0,0382857	0,00178789	-21,4139	$9{,}16773\cdot10^{-15}$

Using the Wolfram Cloud software package, we will calculate the regression equation of the second order of dependence $\eta_{k\text{-}k}$ from research factors in coded form:

$$\eta_{k\text{-}k} = 0{,}924629 - 0{,}0524\, x_4 - 0{,}0245714\, x_4^2 + 0{,}0604\, x_3 - 0{,}012\, x_4 x_3 - 0{,}0382857\, x_3^2. \quad (7)$$

The calculated statistical indicators are shown in the table. 3. Regression coefficients for which the calculated Student's coefficient is less than the table value are highlighted in gray $t_{0,05}(25) = 2{,}06$. These regression coefficients will be neglected in the future as statistically insignificant.

After decoding and removing insignificant regression coefficients, we have (Fig. 5):

$$\eta_{k\text{-}k} = 0{,}7184 + 6{,}38857\, h_p - 245{,}714\, h_p^2 + 0{,}0996286\, V_a - 0{,}6\, h_p V_a - 0{,}00957143\, V_a^2. \quad (8)$$

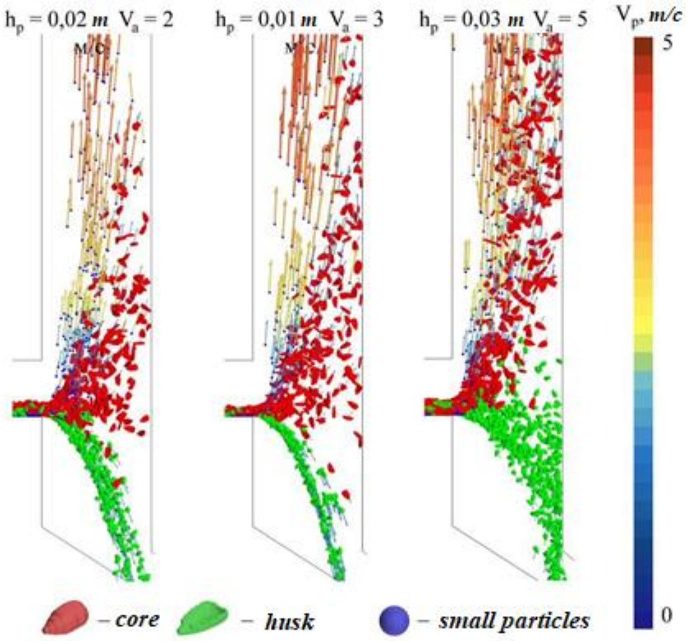

Fig. 4. Distribution of seed mixture waste components in the pneumatic separation channel

According to fig. 5 increasing the height of the waste layer of the sunflower seed mixture that is served, h_p leads to a decrease in the content of sunflower kernels in the area of the kernel collector $\eta_{k\text{-}k}$. This is explained by the fact that a large number of components that collide and prevent each other from moving under the influence of the air flow are supplied to the area of the pneumoseparating channel. In addition, the accumulation of waste components of the seed mixture leads to a decrease in the speed of the air flow. In turn, an increase in the speed of the air flow V_a allows to improve the quality of separation, thereby increasing the content of sunflower kernels in the area of the kernel collector $\eta_{k\text{-}k}$.

Using the Wolfram Cloud software package, we will calculate the second-order regression equation of the dependence of the performance of the separation process q and the volume flow of air (the performance of the air flow generator) Q_a from research factors in coded form:

$$q = 136{,}279 + 69{,}608\, x_4 + 0{,}24\, x_4^2 + 0{,}072\, x_3 - 0{,}452\, x_4 x_3 - 0{,}022857\, x_3^2, \quad (9)$$

$$Q_a = 514{,}331 + 1{,}84\, x_4 - 2{,}8\cdot10^{-13}\, x_4^2 + 349{,}6\, x_3 - 1{,}16\, x_4 x_3 - 0{,}3428\, x_3^2. \quad (10)$$

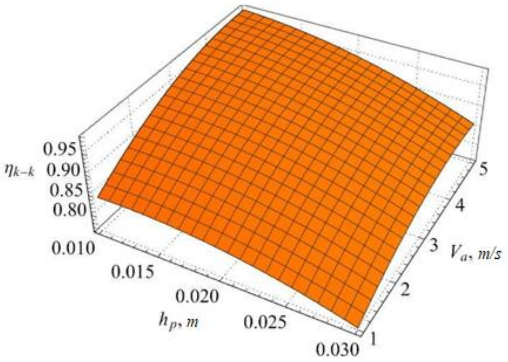

Fig. 5, Dependence of the content of sunflower kernels in the area of the kernel collector $\eta_{k\text{-}k}$ from the height of the waste layer of the supplied sunflower seed mixture, h_p and air flow speeds V_a

The calculated statistical indicators are shown in the table. 4. Regression coefficients for which the calculated Student's coefficient is less than the table value are highlighted in gray $t_{0,05}(25) = 2{,}06$. These regression coefficients will be neglected in the future as statistically insignificant.

Table 4

Statistical indicators of the regression equation (9)–(10)

	Estimate	Standard Error	t–Statistic	P–Value	Estimate	Standard Error	t–Statistic	P–Value
	(9)				(10)			
a_{00}	136,279	0,326024	418,004	$4{,}0\cdot10^{-39}$	514,331	1,4477	355,2	$8{,}7\cdot10^{-38}$
a_{40}	69,608	0,234764	296,502	$2{,}7\cdot10^{-36}$	1,84	1,042	1,764	0,0936
a_{30}	0,072	0,234764	0,306691	0,76241	349,6	1,042	335,34	$2{,}6\cdot10^{-37}$
a_{43}	-0,452	0,332007	-1,36142	0,18930	-1,16	1,4743	-0,7868	0,4411
a_{44}	0,24	0,396824	0,604803	0,55246	$-2{,}8\cdot10^{-13}$	1,7621	$-1{,}5\cdot10^{-13}$	1
a_{33}	-0,0228	0,396824	-0,05760	0,95466	-0,3428	1,7621	-0,1945	0,8477

After decoding and removing insignificant regression coefficients, we have:

$$q = -2{,}93657 + 6960{,}8\, h_p, \tag{11}$$

$$Q_a = -10{,}0686 + 174{,}8\, V_a. \tag{12}$$

Solving the system of equations:

$$\begin{cases} \eta_{k-k} \to \max, \\ q \to \max, \\ Q_a \to \min. \end{cases} \tag{13}$$

After ranking the criteria and reducing them to a single generalizing criterion, we will transform the system (13) into the following form:

$$K_2 = \frac{\eta_{k-k} - \min(\eta_{k-k})}{\max(\eta_{k-k}) - \min(\eta_{k-k})} \frac{q - \min(q)}{\max(q) - \min(q)} \frac{\max(Q_a) - Q_a}{\max(Q_a) - \min(Q_a)} \to \max. \tag{14}$$

Solving (14) together with (8), (11) and (12) in the Wolfram Cloud software package, we obtain rational values of research factors: $h_p = 0{,}018$ m, $V_a = 3{,}42$ m/s. With $\eta_{k\text{-}k} = 0{,}94$, $q = 122{,}9$ kg/h, $Q_a = 588$ m^3/h.

5. Conclusions

As a result of the first stage of numerical modeling of the process of separation of the components of the sunflower seed mixture waste in the pneumatic separating channel, the trajectories of the movement of its components were obtained. Processing of the simulation results in the Wolfram Cloud software package made it possible to calculate the regression equation of the second order of the dependence of the horizontal flight distance of the components (sunflower husks and small particles) y_{opt} from the effective diameter D_p, component feed rates V_p and air flow speeds V_a. Given the minimization condition y_{opt} and V_a for components whose effective diameter is within 0,009–0,013 m, the resulting speed of the formalized belt conveyor is $V_{p\text{-}opt} = 0{,}073$ m and the flight distance of the components (sunflower husks and small particles) $y_{opt} = 0{,}2195$ m. The cross-section of the pneumoseparating channel is adopted - a square with a side of 220 mm.

As a result of the second stage of numerical modeling of the process of interaction between the waste streams of the seed mixture and air in the pneumatic separating channel, their visualization was obtained for various combinations of factors. Using the Wolfram Cloud software package, the regression equation of the second order of the dependence of the content of sunflower kernels in the area of the kernel collector was calculated $\eta_{k\text{-}k}$,of the productivity of the separation process q and volume flow of air (productivity of the air flow generator) Q_a from the height of the waste layer of the supplied sunflower seed mixture, h_p and air flow speeds V_a. Given the maximization condition $\eta_{k\text{-}k}$ and q at the minimum value Q_a received rational values of research factors: h_p = 0,018 m, V_a = 3,42 m/s. With $\eta_{k\text{-}k}$ = 0,94, q = 122,9 kg/h, Q_a = 588 m^3/h.

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ЧИСЕЛЬНЕ МОДЕЛЮВАННЯ ПРОЦЕСУ СЕПАРАЦІЇ ВІДХОДІВ НАСІННЄВОЇ СУМІШІ СОНЯШНИКУ В ПНЕВМОСЕПАРУЮЧОМУ КАНАЛІ АЕРОДИНАМІЧНОГО СЕПАРАТОРА

Сортування зерна та відходів – це різнопланова складна науково-технічна проблема, яка залежно від постановки завдання має різноманітні рішення. В багатьох наукових працях використовуються різноманітні способи аеродинамічної сепарації. Відносно сортування домішок та відходів слід зауважити, що сортування сміття, відходів та побічних продуктів деяких сільськогосподарських культур ще не мають ефективного вирішення з боку агроінженерії.

Аналіз технологічних ліній очищення та розділення насіннєвого матеріалу в шеретувально-віяльному відділенні олійноекстракційного заводу виявив наступні недоліки. Лінії не є комплексними, що призводить до утворення великої кількості відходів, які можуть бути використані у виробництві харчових та кормових продуктів, мінеральних добрив, палива тощо. Відсутнє обладнання для вилучення зернової/оліїстої домішки зі сміття та відходів, а також для їх сортування з раціонально узгодженими режимними параметрами на основі програмного забезпечення. Підвищення продуктивності ліній здійснюється за рахунок збільшення кількості обладнання, що знижує коефіцієнт його використання та потребує додаткової потужності.

Для вирішення цих недоліків необхідно розробити аеродинамічний сепаратор, який покращить якість очищення відходів насіннєвої суміші соняшника.

В результаті першого етапу чисельного моделювання процесу сепарації компонентів відходів насіннєвої суміші соняшнику в пневмосепаруючому каналі отримані траєкторії руху її компонентів. Обробка результатів моделювання в програмному пакеті Wolfram Cloud дозволила розрахувати рівняння регресії другого порядку залежності горизонтальної відстані польоту компонентів (лушпиння соняшника і дрібних частинок) від ефективного діаметра, швидкості подачі компонентів і швидкості повітряного потоку. З урахуванням прийнятих умов ефективності процесу сепарації визначено поперечний переріз пневмосепаруючого каналу – квадрат із стороною 220 мм.

В результаті другого етапу чисельного моделювання процесу взаємодії потоків відходів насіннєвої суміші і повітря в пневмосепаруючому каналі отримано їх візуалізацію для різних комбінацій факторів. З використанням програмного пакету Wolfram Cloud розраховано рівняння регресії другого порядку залежності вмісту ядер соняшника в області забірника ядер, продуктивності процесу сепарації і об'ємних витрат повітря (продуктивність генератора повітряного потоку) від висоти шару відходів насіннєвої суміші соняшника, що подається, і швидкості повітряного потоку. З урахуванням прийнятих умов ефективності процесу сепарації обґрунтовані раціональні конструктивно-технологічні параметри пневмосепаруючого каналу аеродинамічного сепаратора.

Ключові слова: *насіння, суміш, компоненти, аеродинамічний сепаратор, колона, потік повітря, параметри, швидкість, ефективність, моделювання.*

Ф. 14. Рис. 5. Табл. 4. Літ. 19.

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