RESULTS OF NUMERICAL MODELING OF THE PROCESS OF HARVESTING THE SEEDS OF FLAX BY A HARVESTER OF THE STRIPPING TYPE

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Harvesting is the main technological operation in the production of agricultural crops. Modern technologies imply a transition from the classic harvesting of cereals and other crops using a combine harvester to the most promising technology of plant stripping at the root. The effectiveness of such an approach means bringing down the energy consumption during harvesting process by reducing the load on the threshing-separating systems of combine harvesters, improving the quality indicators for harvesting, better performance, etc. [1, 2].

Designing effective technical means for harvesting crops, including flax, using a stripping method implies complex interactions and nonlinear relationships between the environment and devices' working bodies. That predetermines the complexity of mathematical modelling of the optimization and control processes.
Significant impact on the quality of the harvester’s technological process is exerted by the formation of an air flow by a beat-reflector and stripping rotor, which varies in direction and magnitude. The proper formation of an air flow and the separation of pile in the region of a harvester of the stripping type could become a prerequisite for improving its efficiency in the technology of harvesting agricultural crops.

Given the significant effect exerted on the process of stripping by an air flow that forms in the region of a harvester, it is a relevant task to undertake a research aimed at the further improvement and design of technical equipment with high efficiency indicators. This can be achieved by substantiating the rational structural-technological parameters of stripping devices.

2. Literature review and problem statement

The current state of development of technical equipment for the harvesting of agricultural crops implies using a method of stripping the plants at the root. Given the scientific justification for the specified field of mechanical engineering, there are examples testifying to the efficiency of using products by leading manufacturers of single- and two-rotor designs of harvesters [4–6]. Specifically, single-rotor stripping harvesters that are available in the market of harvesting machinery are made by the British company Shellbourne Reynolds [5] and the Russian company ОАО Пензмаш [6]. The two-rotor harvester Слavyanka is manufactured by the enterprise Ukr. Agro-service (Ukraine) [4].

The studies reported in [7–10] found that the significant effect on the quality indicators for the process of harvesting agricultural crops using a method of stripping is exerted by the structural-operational parameters of harvesters, as well as the parameters of related processes. The related processes, first of all, include the formation of an air flow in the region of a harvester at rotation of the rotor-reflector and the stripping rotor. Work [7] established that the magnitude of losses of grain at harvesting is affected by the position and frequency rotation of a stripping rotor, the translational speed of a machine, and the air flow velocity. In this case, the authors found that the air flow velocity at the inlet should be not less than 5 m/s and should reduce at the outlet in the region of an integrated auger. The authors established that the gap between a rotor and a casing of the device must be in the range from 0.09 to 0.11 m. It should be noted that the authors’ recommended values for this indicator, based on the results obtained in [8], helped determine the distance between a rotor and a casing in the front part, which at radius of the stripping rotor of 0.35 m amounts to 0.14 m. In this case, according to the results of the study, they concluded about the feasibility of applying a suction air flow formed by a harvester’s stripping rotor, thereby positively affecting quality of the process. The expediency of taking into consideration and formation of an air flow, which predetermines the ability to control the process has been proven in papers [9, 10]. According to authors of [9], enhancing the effectiveness of harvester operation necessitates ensuring the establishment of a motion mode of a pile’s components considering their sail capacity. The work argues that it is an appropriate mode when the value for average speed of an unstripped pile’s components would exceed the speed of grain. In this case, it was demonstrated by the mathematical model of the process of stripping agricultural crops, built in [9], that the air flow velocity, formed by a rotor, is included in the equation of grain motion along a stripping tooth and a transporting channel.

To account for the influence of air flow velocity on the movement of grain, one must know its numerical value, as well as a direction, as was studied in [10]. The authors found that the process of transporting a stripped pile is accompanied by its partial segregation. One of the reasons of this phenomenon may be a process of layering of an air flow, detected in [11]. It is unclear how the authors accounted for the dimensional characteristics of the distance between a rotor and a casing of the device at the inlet to the channel and at the outlet.

In addition, the influence of the examined parameters on the shape formation of a harvester’s casing was not substantiated, as well as the agreement between the current research results and results reported in earlier studies.

It is possible to improve efficiency of a harvester of the stripping type by introducing an additional beat-reflector to its design [12]. Such an approach has made it possible to reduce the loss of grain by up to 0.85…1.0%. The authors found that the shape of the casing’s front wall depends on the radius of the rotor, the position of its lower edge, and the angle of falling onto this surface. In this case, the motion of grain along the inner surface of the casing, for which they derived its curvature and which ensures a reduction in the magnitude of losses, was considered without accounting for the influence of an air flow formed in the region of a harvester. To enhance quality indicators in the operation of a two-rotor stripping device, [13] reported obtaining the optimal parameters for a beat-reflector. These parameters are: the diameter of a beat-reflector d = 0.38 m and the frequency of its rotation ω = 86.9 s⁻¹. That has made it possible to reduce the loss of grain at harvesting from 3.3% to 1.6%. In this case, the author failed to take into consideration, when modeling the process, the impact of an air flow formed in the region of a stripping harvester.

Thus, there is reason to believe that the lack of detailed research into the influence of an air flow in the region of a harvester of the stripping type on quality of the process of harvesting plants using a method of their stripping necessitates our study in this field.

3. The aim and objectives of the study

The aim of this study is to substantiate theoretically the structural-technological parameters for a harvester of the stripping type that is used to harvest flax. That would make it possible to build more effective technical tools for harvesting using a method of stripping plants at the root.

To accomplish the aim, the following tasks have been set:

– to determine the speed mode of an air flow in the region of a harvester of the stripping type and to substantiate the geometric shape of its casing, the size and position of an air grid;

– to explore the process of pile displacement in the region of a harvester of the stripping type with a curvilinear shape of the casing and to substantiate its structural-technological parameters.

4. Results of numerical simulation of the processes that occur in the region of a harvester of the stripping type

4.1. Substantiation of structural parameters for a harvester

Determining a speed mode of air displacement in the region of a harvester of the stripping type would make it
possible in the future to substantiate the geometrical shape of a harvester’s casing, the size and position of an air grid depending on operational parameters of the stripping rotor and beat-reflector.

To obtain a vector field of velocities in the region of a harvester of the stripping type, we shall consider the process of air movement for a flat problem of numerical simulation in the \(XOY\) coordinates. The estimated scheme of a harvester of the stripping type is shown in Fig. 1.

We calculated the air flow regimes in the region of a harvester of the stripping type under the following boundary conditions:

1. The boundaries represent the rigid walls that are not permeable to air flow. In this case, air velocity at their surface equals 0 m/s.
2. The region of boundary I is transparent with the predefined constant atmospheric pressure.
3. The regions of boundaries II–IV can be transparent with the predefined constant atmospheric pressure, or rigid walls, depending on the examined variant of a numerical experiment.

The beat-reflector rotates counterclockwise at frequency \(n_1\), the stripping rotor – at rotation frequency \(n_2\) (Fig. 1).

The air flow was investigated using the software suite STAR-CCM+, which is implemented based on a finite element method [14, 15]. In this case, we applied the adaptive regular computational grids with a variable size of the cell. The base size of a cell was adopted to be 0.001 m. The model of a grid chosen was the generator of polyhedral cells, and the generator of a surface grid. Results from numerical modeling of the flow of a real gas by van der Waals (air) greatly depend on the chosen model of turbulence, the choice of a computations grid, the number of its nodes, as well as the computing algorithm. That predetermined the verification aimed at ensuring the convergence of the results obtained. We have chosen the following physical models for numerical simulation: the \(k-\epsilon\) conjugated flow turbulence model, the field of gravity force, the model of real gas by van der Waals, the Navier-Stokes equation averaged for Reynolds [16, 17].

To model numerically the process of air displacement in the region of a harvester of the stripping type, we selected the structural-technological parameters for a standard two-rotor harvester [18]. The following structural-technological parameters were chosen to be the factors in numerical modeling: the beat-reflector’s rotation frequency \(n_1\), the rotation frequency of stripping rotor \(n_2\), and the position of a transparent zone of boundaries \(L\). The limits of variation for the examined factors are given in Table 1.

![Fig. 1. Estimated scheme of a harvester of the stripping type](image)

**Table 1**

| Interval of factor variations | Factors’ levels of variation | Factors |
|-----------------------------|-------------------------------|---------|
| Upper level (+)             | Rotation frequency of beat-reflector \(n_1\), rpm | 800 |
| Lower level (–)             | Rotation frequency of stripping rotor \(n_2\), rpm | 400 |
| Basic level (0)             | Position of transparent zone of boundary \(L\), m | 600 |

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| Basic level (0)              | Position of transparent zone of boundary \(L\), m | 600 |

Numerical modeling was carried out based on the full factorial experiment with a total number of experiments \(3^2 = 27\). The modeling results were used to obtain the visualization of air flow velocity distribution in the region of a harvester of the stripping type (Fig. 2).

For each variant of the numerical experiment, we calculated the maximum air velocity using the software suite Wolfram Mathematica, and approximated the data obtained, the result of which is the established dependence on the examined factors in an encoded form:

\[
V_{\text{max}} = 21.1293 + 0.677778x_1 - 0.0177778x_1^2 + 1.72333x_2 + 0.1375x_1x_2 + 6.42111x_3 - 0.2125x_1x_2 - 1.8025x_1^2 + 0.84556x_2^2 + 0.000425x_3 + 0.0000450625x_3^2 + 0.000021389x_3^3 + 0.0000303056x_3^4 + 0.0363264x_3^5 + 0.0177778x_3^6. \quad (1)
\]

The statistical treatment of the resulting equation (1) is summarized in Table 2; analyzing the results makes it possible to reduce nonessential coefficients in equation (1) and record it in the following form:

\[
V_{\text{max}} = 21.1293 + 1.72333x_1 + 1.21222x_2^2 + 6.42111x_3 - 0.2125x_1x_2 - 1.8025x_1^2 + 0.84556x_2^2 \quad (2)
\]

Following the transformation of equation (2) into the decoded form, we obtain:

\[
V_{\text{max}} = -2.53657 + 2.55L - 0.0007125n_1 + 0.0000303056n_1^2 + 0.0363264n_2 - 0.042550625n_1n_2 - 0.000425Ln_2 - 0.0000450625n_1n_2 + 0.000021389n_2^2. \quad (3)
\]

By registering, in turn, the factors of experiments at a certain level, we built the graphic interpretations of dependence (3), shown in Fig. 3.

Fig. 3 shows that increasing the rotation frequency of a rotor-reflector \(n_1\) and stripping rotor \(n_2\) increases the maximum air velocity in the region of a harvester \(V_{\text{max}}\) governed by a parabolic law. In turn, the position of a transparent zone of boundaries \(L\) almost does not affect the value for a maximum air velocity \(V_{\text{max}}\), and, according to Fig. 2, characterizes its direction only.
According to Fig. 2, air velocity changes, depending on the operational parameters for a stripping rotor and a beat-reflector, from 0 to 30 m/s.

Based on studies into the aerodynamic properties of a flax pile’s components, the speed of their deposition exceeds 2 m/s.

Thus, the air velocity from 0 to 2 m/s does not affect the movement of the components. Imposing the velocity of an air flow in the region of a harvester of the stripping type in the range from 0 m/s to 2 m/s makes it possible to observe its boundary region where one registers the speed of 0 m/s (Fig. 4).

Approximating the boundary zone of a zero-air velocity in the region of a harvester of the stripping type in the form of a semicircle with radius \( R_h = 0.53 \) m and a center \( y_h = x_h = 0.28 \) m and \( x_h = x_c = 0.64 \) m, we obtain the shape for a harvester’s casing.

Using the software suite STAR-CCM+, we mapped the distribution of velocities of the formed air flow in the region of a harvester of the stripping type with the obtained shape of a casing that is shown in Fig. 5.
4.2. Substantiation of operational parameters for a harvester

To investigate the process of displacing components of a stripped pile in the region of a harvester of the stripping type with a curvilinear shape of its casing and in order to substantiate its structural-technological parameters, we performed numerical simulation using the software suite STAR-CCM+. The following physical models were employed: the $k-\varepsilon$ model of conjugate turbulence flow, the field of gravity force, the van der Waals model of real gas, the Navier-Stokes equation averaged for Reynolds; a Lagrangian multiphase model, and a discrete element model.

Simulation of feeding the material was carried out in the zone of a stripping comb of the rotor. The initial orientation of all pile’s components in space is random, and the initial motion speed of a stripped pile’s components equaled 0 m/s. Based on data from our review of the scientific literature and earlier laboratory studies, we accepted the following physical-mechanical properties of a stripped pile’s components whose values are given in Table 3.

| Properties                  | Seed Boxes | Seed Boxes with seed | Box husk | Stem segments |
|-----------------------------|------------|----------------------|----------|--------------|
| Volumetric mass, kg/m$^3$   | 710        | 90                   | 60       | 30           |
| Young modulus of elasticity, MPa | 0.2       | 0.3                  | 0.1      | 0.1          |
| Poisson ratio               | 0.5        | 0.8                  | 0.6      | 0.5          |
| Mass share in a pile, %     | 40         | 10                   | 40       | 10           |

The estimation scheme of a harvester of the stripping type with a curvilinear shape of its casing is shown in Fig. 6. Region I is transparent for all pile components (seeds, boxes, stems, and segments of the stem). Region II can be penetrated only by box husks, which is predetermined by the presence of an air grid with a diameter of round holes of 1.5 mm.
The numerical modeling factors were the following structural-technological parameters: the rotation frequency of a beat-reflector $n_1$, the rotation frequency of a stripping rotor $n_2$, the position of a transparent zone of boundaries $L$, and its width $B$ (variation range is given in Table 4).

The numerical modeling was conducted based on a full factorial experiment with a total number of experiments of $3^4 = 81$.

### Table 4

| Levels of variation for factors of numerical modeling | Rotation frequency of beat-reflector $n_1$, rpm ($x_1$) | Rotation frequency of stripping rotor $n_2$, rpm ($x_2$) | Position of transparent zone of boundary $L$, m ($x_3$) | Width of transparent zone of boundaries $B$, m ($x_4$) |
|------------------------------------------------------|--------------------------------------------------------|-------------------------------------------------------|-------------------------------------------------------|-------------------------------------------------------|
| Upper level (+)                                      | 800                                                    | 800                                                   | 0.35                                                  | 0.45                                                  |
| Basic level (0)                                      | 600                                                    | 600                                                   | 0.60                                                  | 0.30                                                  |
| Lower level (−)                                      | 400                                                    | 400                                                   | 0.85                                                  | 0.15                                                  |
| Interval of factor variation                         | 200                                                    | 200                                                   | 0.25                                                  | 0.15                                                  |

The criteria for estimating the process of pile separation in a harvester are: the mass fraction of the yield of husk and segments of the stem $\Delta_h$, the mass fraction of the yield of seeds and boxes with seeds bolls $\Delta_s$. We calculated the indicators based on formulae:

$$\delta_h = 100(1 - \frac{m_h}{m_{hs}}), \quad (4)$$

$$\delta_s = 100(1 - \frac{m_s}{m_{hs}}), \quad (5)$$

where $m_h$ is the mass of husks and segments of the stem in the region of a harvester, kg; $m_s$ is the mass of seeds and boxes of seeds in the region of a harvester, kg; $m_{hs}$ is the mass of a pile, kg.

The result of modeling is the visualization of distribution of a pile's components in the region of a harvester of the stripping type (Fig. 7).

For each variant of a numerical experiment, we calculated the mass share of the yield of husk and segments of the stem from the region of a harvester $\Delta_h$. By using the software suite Wolfram Mathematica, we approximated the data obtained and established the dependence on experimental factors in an encoded form:

$$\delta_h = 33.8704 + 0.687037x_1 + 0.605556x_1^2 - 2.87407x_1^3 - 0.236111x_1x_2 - 1.16667x_2^2 + 3.87222x_2 + 0.216667x_2x_3 + 0.108333x_3x_4 - 0.172222x_4^3 + 5.40926x_4 - 0.125x_4x_2 - 0.811111x_3x_4 + 0.0194444x_3x_4 + 0.15x_4^2. \quad (6)$$

The statistical treatment of the resulting equation (6) is given in Table 5; analyzing the data makes it possible to reduce nonessential coefficients in equation (6) and represent it in an encoded form:

$$\delta_h = 9.47596 + 50.784B + 6.666667B^2 + 14.8956L - 2.75536L - 0.01253988n_1 - 0.00416667Bn_1 + 0.00433333Ln_1 + 0.0000151389n_1^2 + 0.0309824n_1 - 0.027037Bn_1 + 0.00216667Ln_1 - 5.90278 \times 10^{-6} n_1n_2 - 0.0000291667n_2^2. \quad (7)$$

**Fig. 7.** Visualization of the distribution of a pile’s components in the region of a harvester of the stripping type at the following parameter values:

- $a - n_1 = n_2 = 800$ rpm, $L = 0.85$ m, $B = 0.45$ m;
- $b - n_1 = 800$, $n_2 = 400$ rpm, $L = 0.85$ m, $B = 0.30$ m;
- $c - n_1 = n_2 = 400$ rpm, $L = 0.85$ m, $B = 0.15$ m;
- $d - n_1 = n_2 = 600$ rpm, $L = 0.85$ m, $B = 0.30$ m
Table 5 gives the same notation as Table 2.

By registering, in turn, the experimental factors at a certain level, we built graphical interpretations of dependence (7) that are shown in Fig. 8.

### Table 5

| Coefficient | $s_i$ | $t_{a,b_i}$ |
|-------------|-------|-------------|
| $a_{00}$    | 0.853337 | 39.5989 |
| $a_{10}$    | 0.34919 | 1.96752 |
| $a_{20}$    | 0.34919 | -8.23069 |
| $a_{30}$    | 0.34919 | 11.0892 |
| $a_{40}$    | 0.34919 | 13.4909 |
| $a_{12}$    | 0.427668 | -0.552089 |
| $a_{13}$    | 0.427668 | 0.506623 |
| $a_{14}$    | 0.427668 | -0.292282 |
| $a_{23}$    | 0.427668 | 0.253311 |
| $a_{24}$    | 0.427668 | -1.80659 |
| $a_{34}$    | 0.427668 | 0.0454662 |
| $a_{11}$    | 0.604815 | 1.00123 |
| $a_{22}$    | 0.604815 | -1.92897 |
| $a_{33}$    | 0.604815 | -0.284752 |
| $a_{44}$    | 0.604815 | 0.24801 |

For each variant of the numerical experiment, we calculated the mass share of the yield of seeds and boxes with seeds from the region of a harvester $\Delta h$. By using the software suite Wolfram Mathematica, we approximated the data obtained, the result being the established dependence on experimental factors in an encoded form:

$$\delta_i = 4.09892 - 1.23483x_1 + 0.755854x_1^2 - 4.39665x_1 + 0.167115x_1^2 + 5.40082x_1^3 + 5x_1 + 0.06388x_1^3x_1^4 + 0.0655556x_1^3x_1^4 + 0.037037x_1^3 + 0.275627x_1 - 0.752957x_1^x_1 - 0.836738x_1x_1 - 0.0138889x_1x_1 + 0.212664x_1^2. \quad (8)$$

The statistical treatment of the resulting equation (8) is given in Table 6.

Analysis of data from Table 6 makes it possible to reduce the nonessential factors in equation (8) and represent it in a decoded form:

$$\delta_i = 68.4187 + 3.36314B - 5.40444L + 5.39259L_2 - 0.0213202n_1 - 0.0250986Bn_1 + 0.0000188964n_1^2 - 0.178318n_1 - 0.0278913Bn_2 + 0.000137252n_2^2. \quad (9)$$

Table 6 gives the same notation as Table 2.

### Table 6

| Coefficient | $s_i$ | $t_{a,b_i}$ |
|-------------|-------|-------------|
| $a_{00}$    | 0.600928 | 6.82099 |
| $a_{10}$    | 0.245328 | -5.03337 |
| $a_{20}$    | 0.245328 | -17.9215 |
| $a_{30}$    | 0.245328 | 1.08698 |
| $a_{40}$    | 0.245328 | 1.1235 |
| $a_{12}$    | 0.300464 | 0.556188 |
| $a_{13}$    | 0.300464 | 0.212634 |
| $a_{14}$    | 0.300464 | -2.50598 |
| $a_{23}$    | 0.300464 | 0.018499 |
| $a_{24}$    | 0.300464 | -2.78482 |
| $a_{34}$    | 0.300464 | -0.0462248 |
| $a_{11}$    | 0.424921 | 1.77881 |
| $a_{22}$    | 0.424921 | 12.9203 |
| $a_{33}$    | 0.424921 | 0.793177 |
| $a_{44}$    | 0.424921 | 0.50048 |

By registering, in turn, the experimental factors at a certain level, we built graphical interpretations of dependence (9) that are shown in Fig. 9.

Fig. 9 shows that increasing the rotation frequency $n_1$ and the width of a transparent zone of boundaries $B$ decreases the mass fraction of yield $\Delta s$. In turn, for rotation frequency $n_2$ and the position of a transparent zone of boundaries $L$ there is an optimum ($n_2=695$ rpm, $L=0.5$ m) at which the mass fraction of yield $\Delta s$ is minimal within the predefined range of factors.
It might seem obvious that such a mechanism of the influence of operational parameters for a stripping device on the formation of an air flow is a factor in controlling the shape formation of a harvester’s casing and the position of an air grid. Ensuring a decrease in the airflow velocity at the outlet from the channel is an a priori condition for the operation of stripping devices. In this case, the curvilinear shape of the casing is limited to a boundary zone, characterized by a zero value for airflow velocity (Fig. 4, 5).

Modeling the process of separation of a stripped pile in the region of a harvester with the derived shape of its casing implies taking into consideration the initial orientation, the motion velocity of a pile’s components, and their physical-mechanical properties (Table 3). It should be noted that the criterial estimate of the quality of a separation process depends on the level of variation for factors of numerical modeling (Table 4). These factors are: the mass yield of related components from a harvester Δa (husks, segments of the stem, etc.), as well as seeds and boxes of flax Δb.

The visualization of the distribution process of a pile’s components in the region of a harvester (Fig. 7) and the dependence of their mass share of yield (Fig. 8) on the experimental factors might act as a basis for solving a compromise problem. It implies minimizing the yield of related components of a pile and maximizing the yield of seeds.

Based on the research results, the following rational structural-technological parameters for a harvester with the obtained curvilinear shape of its casing have been defined: the rotation frequency of a beat-reflector n1 = 782 rpm, the rotation frequency of a stripping rotor n2 = 671 rpm, the position of a transparent zone of boundaries L = 0.82 m and its width B = 0.45 m.

Comparing the results from a body of research aimed at substantiating the rational parameters for harvester of the stripping type [8–10, 13] reveals the appropriateness of taking into consideration the influence of an air flow and the properties of a stripped pile’s components.

It is obvious that the feasibility of advancing the chosen field of research is predetermined by the need to develop and improve a set of methods aimed at solving tasks that arise when creating and implementing the combine-harvester-based technique for harvesting agricultural crops by stripping plants at the root.

6. Conclusions

1. The result of our numerical modeling of the aerodynamic processes in a harvester of the stripping type is the established distribution of air flow velocities in its region and the derived dependence of maximum air velocity Vmax on the rotation frequency of a beat-reflector n1 and a stripping rotor n2 and the position of a transparent zone of boundary L.

The result of our numerical modeling of the process of a pile separation in a harvester of the stripping type with a curvilinear shape of its casing taking into consideration the physical-mechanical properties of its components is the established dependences of the mass share of the yield of husks and segments of the stem from its region (a quality score for cleaning a pile from impurities) Δs and the share of yield of seeds and boxes with seeds (an indicator for seed losses) Δb on the rotation frequency of a beat-reflector n1 and a stripping rotor n2, the position of a transparent zone of boundary L and its width B.
That predetermines defining the rational shape of a harvester’s casing and the position of regions of a transparent boundary in order to ensure the high-quality progress of the technological process.

2. By solving a compromise problem, namely, minimizing the share of yield of related components \( \Delta_h \) and maximizing the share of yield of seeds and boxes with seeds \( \Delta_s \), we have defined the structural-technological parameters for a stripping harvester. These parameters are: the rotation frequency of a beat-reflector \( n_1 = 782 \text{ rpm} \), the rotation frequency of a stripping rotor \( n_2 = 671 \text{ rpm} \), the position of a transparent zone of boundaries \( L = 0.82 \text{ m} \) and its width \( B = 0.45 \text{ m} \).

References

1. Pogoreliy L. V., Koval’ S. N. Prognoz razvitiya tehnologiy i tekhniki dlya uborki zernovyh kul’tur na pervuyu chetvert’ XXI veka // Perspektivnye tehnologiy uborki zernovyh kul’tur, risa i semyan trav: sb. dok. mezhdunar. nauch.-tekhnich. konf. Melitopol’: TGATA, 2003. P. 17–21.

2. Sysolin P. V., Ivanenko I. Problemy i perspektivy vnedreniya v Ukraine tehnologii uborki zernovyh kolosovych kul’tur metodom ochesyvavshie koloskov // Tekhnika APK. 2008. Issue 5. P. 24–29.

3. Lezhenkin A. N., Kraschuk V. I., Kushnarev A. S. Tekhnologiya uborki zernovyh metodom ochesyvavshie koloskov // Tekhnika APK. 2008. Issue 5. P. 24–29.

4. Ochesyvayuschie zhatki «Slavyanka» // Ukr.Agro-servis. URL: http://ukragroserv.com.ua/каталог/очесывающая_жатка

5. The CVS range is suitable for harvesting Wheat, Durum, Barley, Oats, Flax and other small grain crops // Shelbourne Reynolds. URL: https://www.shelbourne.com/harvest/stripper-header/cvs/

6. Ochesyvayuschaya zhatka «OZON» // Penzmash. URL: http://penzmash.ru/root/1504-2/

7. Yuan J., Lan Y. Development of an Improved Cereal Stripping Harvester // Agricultural Engineering International: the CIGRE journal. Manuscript PM 07 009. 2007. Vol. IX. URL: http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.504.7187&rep=rep1&type=pdf

8. Mashkov A. M. Izuchenie vozduushnogo potoka odnobarebanannogo ochesyvayushcheho ustroystva MON-4-1 dlya obmolota zernovyh kul’tur na koronyu // Izvestiya sel’skokhozyaystvennyy nauki Tavridy. 2011. Issue 138. P. 153–160.

9. Bur’yanov A. I., Bur’yanov M. A. Modelirovanie protsessa ochesyvayushcheho ustroystva MON-4-1 // Sel’skokhozyaystvennoy nauki. 2014. Issue 4. P. 2–5.

10. Burianov M. A. Airstream formation in the feeder canal of a stripping device // Nauchnyi zhurnal KubGAU. 2014. Issue 96 (02). URL: http://ej.kubagro.ru/2014/02/pdf/51.pdf

11. Fustochenko A. Yu. Issledovanie vozduushnogo potoka, sozdavavemyho barabanom ochesyvayushchez zhatki // Sel’skokhozyaystven-nye mashiny i tehnologii. 2014. Issue 1. P. 23–25.

12. Shabanov N. P., Polegenko A. G. Constructive-technological parameters of a device for harvesting wheat threshing in the bud // Naukovi pratsi Pidvennoho filialu Natsionalnoho universitetu bioreursos i prirodokorystuvannia Ukrainy «Krymskyi ahrotehnolohichnyi universytet». 2013. Issue 156. P. 86–93.

13. Mashkov A. M. Ochesyvayuschie ustroystva i seriyanye zernoborochnye konobnayy // Trudy Krymskogo GAU. 2000. Issue 65. P. 222–227.

14. Modeling of mechanical and technological processes of the agricultural industry // Aliev E. B., Bandura V. M., Pryshliak V. M., Yaropud V. M., Trukhanska O. O. // INMATEH – Agricultural Engineering. 2018. Vol. 54. Issue 1. P. 95–104.

15. Research on sunflower seeds separation by airflow // Aliev E. B., Yaropud V. M., Dvin V. Yr., Pryshliak V. M., Pryshliak N. V., Ivlev V. V. // INMATEH – Agricultural Engineering. 2018. Vol. 56. Issue 3. P. 119–128.

16. Iguchi M., Ilegbusi O. J. Basic Transport Phenomena in Materials Engineering. Springer, 2014. 260 p. doi: https://doi.org/10.1007/978-4-431-54020-5

17. Bai C., Gosman A. D. Development of Methodology for Spray Impingement Simulation // SAE Technical Paper Series. 1995. doi: https://doi.org/10.4271/950283

18. Wallin S. Engineering turbulence modelling for CFD with a focus on explicit algebraic Reynolds stress models. Stockholm, 2000.

19. Shvartsman M. Е., Timchenko A. V. Uborka urozhay metodom obmolota renteniy na koronyu dvubarebanannoy zhatkoj ochesy- vayushcheho tipa «Slavyanka UAS» // Ukr.Agro-servis. URL: http://ukragroserv.com.ua/ru/статьи/уборка_урожая_методом_ обмолота_растений_на_корни_двухбарабанной_жаткой_очесывающего_типа_»славянка_уас»