MATHEMATICAL MODELING AND STUDY OF THE GRAIN CLEANING MACHINE SIEVE FRAME OPERATION
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МАТЕМАТИЧЕСКОЕ МОДЕЛИРОВАНИЕ И ИССЛЕДОВАНИЕ РАБОТЫ РЕШЕТНОГО СТАНА ЗЕРНООЧИСТИТЕЛЬНОЙ МАШИНЫ

Ildar Badretdinov *), *Salavat* Mudarisov, *Ramil* Lukmanov, *Radik* Ibragimov, *Valeri* Permyakov, *Marat* Tuktarov

Federal State Budgetary Educational Establishment of Higher Education "Bashkir State Agrarian University", Ufa / Russia
Tel: 7(347)2283213; E-mail: badretdinovil@rambler.ru

ABSTRACT

The purpose of this work is a mathematical description of sieve frame structural and technological parameters necessary for the implementation of the technological process model of a grain cleaning machine operation. The paper presents the results of the study of the grain cleaning machine sieve frame operation. A kinematic study of a flat swivel multi-link mechanism of the grain cleaning machine sieve frame was made. The method of determining the coordinates of the sieve frame nodal points was developed to calculate their speed. Structural and technological parameters of the mechanism were also studied.

АННОТАЦИЯ

Цель данной работы − математическое описание структурных и технологических параметров решетного стана, необходимых для реализации модели технологического процесса работы зерноочистительной машины. В статье представлены результаты исследования работы решетного стана зерноочистительной машины. Проведено кинематическое исследование плоского шарнирного многозвенного механизма решетного стана зерноочистительной машины, для которого известны все геометрические размеры и закон движения ведущего звена. Приведена методика определения координат узловых точек решетного стана для расчета скорости их движения, а также исследование конструктивно-технологических параметров механизма.

INTRODUCTION

Today, grain cleaning machines with a sieve cleaning system are dominant means of removing impurities from food and seed grain (*Dorokhov et al., 2018; Ma et al., 2018; Okunola et al., 2018; Vasylkovskyi et al., 2019)*. Design of grain cleaning machines with such a working body is rather simple, easy to use, the most universal and popular in agricultural production (*Ma et al., 2018; Okunola et al., 2018; Popov et al., 2015; Shevtsov and Beznosov, 2014; Vasylkovskyi et al., 2019*). The separation of grain heap on sieves occurs according to geometric parameters, i.e. according to seed thickness and width. Thickness is the smallest geometric size of a single seed (of an ellipsoid shape), and the width is the average grain size (*Steponavičius et al., 2008; Vasylkovskyi et al., 2019*). Grain material is split by width on sieves with round holes: grains, the width of which is less than the diameter of the sieve holes, pass through them (passage), and large grains are thrown out from the sieve (descent). By thickness, grain material is split on the sieve with oblong holes. Sieve frames are usually sprung (with flexible springs). The springs make oscillatory motion provided by crank gear. Sieve frame oscillation frequency varies from 420 to 500 min^{-1}, oscillations amplitude A = 7.5...15 mm, canting angle is equal to 5...8 degrees (*Okunola et al., 2018; Popov et al., 2015; Shevtsov and Beznosov, 2014; Singh et al., 2017*). The sieves are mainly installed as follows: first sieves for large impurities separation are installed, and then sieves for small impurities separation are placed (i.e. for feeble and crushed grain). To increase productivity sieves are arranged by parallel tiers. Grain crops have an ellipsoidal shape (*Fominykh, 2006; Kornev, 2015; Kundu and Gupta, 2014; Voicu et al., 2008*).

Most of crop production area of the Russian Federation is used for small grains and pulse crops (about 60%). The most common crops are wheat, barley, rye and oats. According to statistical data of the Ministry of Agriculture of the Russian Federation the record bulk yield of wheat during the last three years was in 2017 and made 85 Mt (the weight of wheat after cleaning).

To improve the efficiency of grain separation process carried out using sieve frames, it is necessary to know the laws of sieve frame drive system operation, as well as structural and technological parameters of the links of a sieve mechanism. Service properties of sieve system grain cleaning machines do not fully meet the increasing requirements of modern agricultural production. Imperfect design results in vibration and bad separation of grain heap (*Popov et al., 2015; Singh et al., 2017; Steponavičius et al., 2008*). Vibration in its turn negatively affects the design of the grain cleaning machine and destroys its driving gear. There are many difficulties during the technological process of grain sieving connected with a wide range of cultures, various geometrical sizes and physical and mechanical parameters of seeds, on which the sieve selection depends. The interaction process of separated materials' components with the working bodies of the machine is also rather complicated.

Another difficulty of the grain sieving process is insufficient development of its theoretical framework as well as of the justification methods of machines parameters and their operating modes (*Fominykh, 2006; Giyevskiy et al., 2018; Kornev, 2015; Singh et al., 2017; Tarasenko et al., 2012; Vasylkovskyi et al., 2019*). In this regard, there is a need to improve both the theory of separation and the design of grain cleaning machines' sieve frames (*Dorokhov et al., 2018; Fominykh, 2006; Kornev, 2015; Mudarisov and Badretdinov, 2008; Steponavičius et al., 2008; Tarasenko et al., 2012*).

The purpose of this study is to develop a mathematical model of the functioning of kinematic mechanism of the grain cleaning machine sieve frame, to determine the coordinates of the sieve mechanism node points, as well as the links velocity and acceleration, to establish a scientific rational for the kinematic parameters of a sieve frame and a grain heap to implement a mathematical model for the technological process of the grain cleaning machine sieve frame operation taking into account its structural and technological parameters.

MATERIALS AND METHODS

The Froude number is one of the most important functional parameters for estimating grain material movement on the sieve surface. It reflects the ratio of forces acting on a single seed lying on the sieve, the sieve oscillations amplitude and gravity (*Savinyh et al., 2018; Steponavičius et al., 2008*).

Let us consider a design model used to determine the coordinates of the sieve frame nodal points of the grain cleaning machine ZVS-20 (The constructive parameters of the mechanism, m: $OA = OA_1 = 0.01$, $AB = 0.45$, $A_1B_1 = 0.5$, $O_1B = O_2C = O_3B_1 = O_4C_1 = 0.355$, $BC = 1.758$, $B_1C_1 = 1.764$) necessary to calculate their speed and inertia forces acting on grain heat components on the sieve (Figure 1).
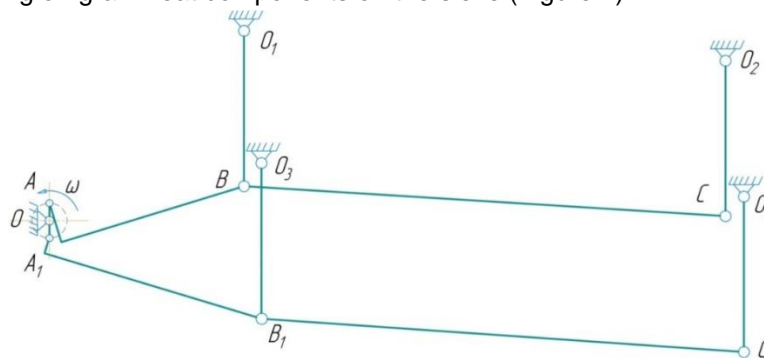

Fig. 1 - Design model of the grain cleaning machine sieve frame

Let h_k and l_k be the coordinates of anchor poles O_k, $k = 1, 2, 3, 4$. Right-handed Cartesian coordinate system will be taken as the reference frame. The origin of the coordinate system is located in the sieve frame drive shaft marked as point O. We plot the sieve frame nodal points to compose the equations of geometric relations, trajectories of which are known: A, B, C, A_1, B_1, C_1. These points move round radii circles OA, O_1B, O_2C, OA_1, O_3B_1, O_4C_1 OA, O1B, O2C, OA1, O3B1, and O4C1 respectively. Point A simultaneously belongs to the crank OA and to the connecting rod AB. The crank OA of radius r ($r = OA = OA_1$) makes a rotational motion and accordingly the motion law of point A is known. Point A at time t, depending on the rotation angle value of the driving link $\varphi(t)$ has coordinates:

$$x_A = r \cdot \cos \omega_0 t, \qquad\qquad y_A = r \cdot \sin \omega_0 t \qquad\qquad (1)$$

The motion law of the driving link of the mechanism:

$$\varphi(t) = \omega_0 t,$$

Point B belongs simultaneously to the connecting rod AB and the crank O_1B. Point C belongs to the connecting rod BS and to the crank O_2C. Three independent parameters are necessary to describe plane motion of the sieve frame nodal points. They are: the x, y coordinates of the point and the rotation angle φ around this pole. The position of a planar figure in its plane at any given time can be completely determined by the time functions. It is called the equations of the planar figure motion:

$$x_A = x_A(t), \qquad y_A = y_A(t), \qquad \varphi = \varphi(t) \tag{2}$$

The position of a planar figure (sieve frame) in its plane is determined by the position of its two points. As base points in the equations of geometric relations we take points B and C (Figures 2, 3).
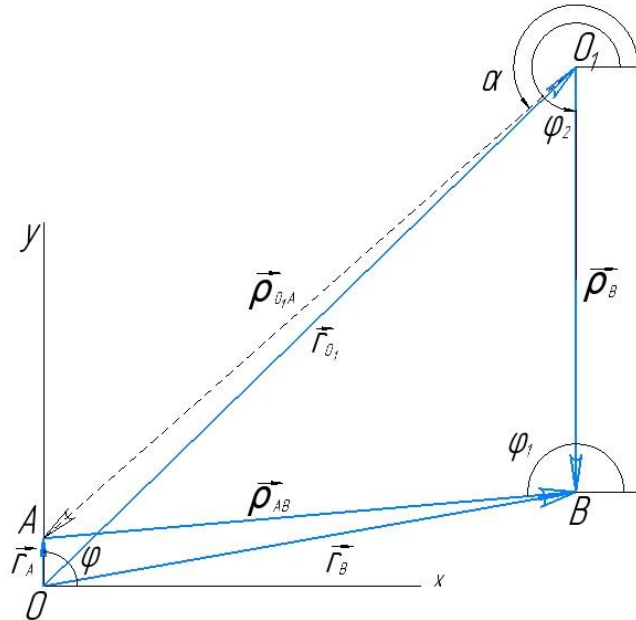

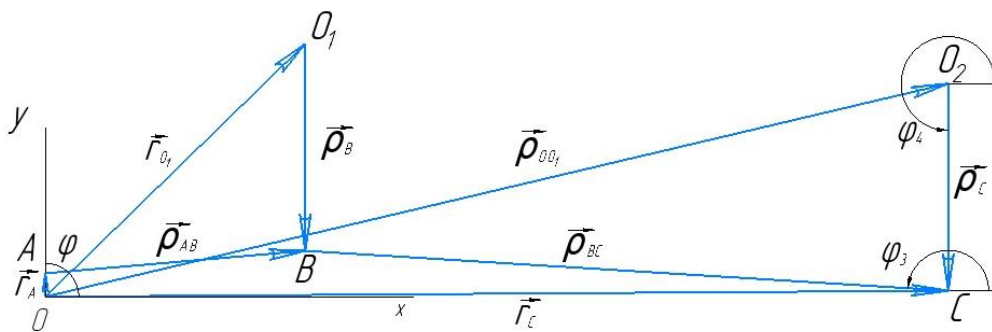**Fig. 2 - Vector paths for finding point B**

Fig. 3 - Vector paths for finding point C

We project vectors on the coordinate axes Ox and Oy to obtain the equations of geometric relations of the links of the sieve mechanism.

$$
\begin{aligned}
OA\cos(\varphi) + AB\cos(\varphi_1) &= l_1 + O_1B\cos(\varphi_2) \\
OA\sin(\varphi) + AB\sin(\varphi_1) &= h_1 + O_1B\sin(\varphi_2) \\
l_1 + O_1B\cos(\varphi_2) + BC\cos(\varphi_3) &= l_2 + O_2C\cos(\varphi_4) \\
h_1 + O_1B\sin(\varphi_2) + BC\sin(\varphi_3) &= h_2 + O_2C\sin(\varphi_4)
\end{aligned}
\tag{3}
$$

To obtain the equation of geometric relations in a coordinate form we transfer the summands with unknown functions to one side:

$$
\begin{aligned}
AB\cos(\varphi_1) - O_1B\cos(\varphi_2) &= l_1 - OA\cos(\varphi), \\
AB\sin(\varphi_1) - O_1B\sin(\varphi_2) &= h_1 - OA\sin(\varphi)
\end{aligned}
\tag{4}
$$

In equations (3) the given function is the law of a driving link $\varphi(t)$.

The calculated functions of time are: $\varphi_1(t)$, $\varphi_2(t)$, $\varphi_3(t)$, $\varphi_4(t)$.

We solve the system of nonlinear equations (3) using the analytical method, and thus obtain expressions for the required functions in parametric form.

To determine the movement of the links of the sieve frame mechanism we write down the equations for point *B*:

$$AB\cos(\varphi_1) - O_1B\cos(\varphi_2) = l_1 - OA\cos(\varphi) = -O_1A\cos\alpha$$
$$AB\sin(\varphi_1) - O_1B\sin(\varphi_2) = h_1 - OA\sin(\varphi) = -O_1A\sin\alpha. \qquad (5)$$

where $O_1A\ cos\alpha$ and $O_1A\ sin\alpha$ is a projection of the vector p_{O1A} onto a coordinate axis.

$$O_1A = \sqrt{(O_1A\cos\alpha)^2 + (O_1A\sin\alpha)^2} = \sqrt{OO_1{}^2 + OA^2 - 2\cdot OA\cdot OO_1\cos(\varphi - \beta)} \quad (6)$$

$$OO_1 = \sqrt{h_1^2 + l_1^2}, \qquad \beta = arctg\left(\frac{h_1}{l_1}\right) \text{ module and direction of the vector } r_{O1}$$

$$ABcos\,(\varphi_1) = O_1B\cos(\varphi_2) - O_1A\cos\alpha,$$
$$ABsin\,(\varphi_1) = O_1B\sin(\varphi_2) - O_1A\sin\alpha. \qquad (7)$$

We square both sides of the equation and sum the first with the second, using trigonometric formulas, we get:

$$AB^2 = O_1B^2 + O_1A^2 - 2\cdot O_1B\cdot O_1A\cdot cos(\varphi_2 - \alpha)$$
$$\varphi_2 = \alpha + arccos\left(\frac{O_1B^2 + O_1A^2 - AB^2}{2\cdot O_1B\cdot O_1A}\right) \qquad (8)$$

We rewrite equation (4) to find the angular coordinate φ_1:

$$O_1B\cos(\varphi_2) = ABcos\,(\varphi_1) + O_1A\cos\alpha,$$
$$O_1B\sin(\varphi_2) = ABsin\,(\varphi_1) + O_1A\sin\alpha.$$
$$O_1B^2 = AB^2 + O_1A^2 + 2\cdot AB\cdot O_1A\cdot cos(\varphi_2 - \alpha),$$

The final form of the angular coordinate φ_1 is:

$$\varphi_1 = \alpha + arccos\left(\frac{O_1B^2 - O_1A^2 - AB^2}{2\cdot AB\cdot O_1A}\right) \qquad (9)$$

Since the links of the sieve mechanism are suspended in parallel, the angular coordinate $\varphi_2 = \varphi_4$.
The remaining unknown values of the equation system (3) are found on the same model.

$$l_1 + O_1B\cos(\varphi_2) + BC\cos(\varphi_3) = l_2 + O_2C\cos(\varphi_4)$$
$$h_1 + O_1B\sin(\varphi_2) + BC\sin(\varphi_3) = h_2 + O_2C\sin(\varphi_4)$$
$$\varphi_3 = -arccos\left(\frac{l_2 - l_1 + O_2C\cos(\varphi_4) - O_1B\cos(\varphi_2)}{BC}\right) \qquad (10)$$

We differentiate with respect to time the equations of geometric connections (3) to determine the angular velocities of the links of the sieve frame mechanism.

$$
\begin{array}{ccccc}
-AB\cdot\sin(\varphi_1)\omega_1 & O_1B\cdot\sin(\varphi_2)\omega_2 & 0 & 0 & = OA\cdot\sin(\varphi)\omega_0, \\
AB\cdot\cos(\varphi_1)\omega_1 & -O_1B\cdot\cos(\varphi_2)\omega_2 & 0 & 0 & = -OA\cdot\cos(\varphi)\omega_0, \\
0 & -O_1B\cdot\sin(\varphi_2)\omega_2 & -BC\cdot\sin(\varphi_3)\omega_3 & O_2C\cdot\sin(\varphi_4)\omega_4 = & 0, \\
0 & O_1B\cdot\cos(\varphi_2)\omega_2 & BC\cdot\cos(\varphi_3)\omega_3 & -O_2C\cdot\cos(\varphi_4)\omega_4 = & 0.
\end{array}
\qquad (11)
$$

The system of equations (8) is represented in matrix form:

$$A\cdot X_\omega = B, \qquad (12)$$

where *A* is the matrix of coefficients of the left parts of the equations; X_ω is the vector of unknown angular velocities of the links; *B* is the vector of the right parts of the equations.

$$A = \begin{pmatrix}
-AB\cdot\sin(\varphi_1) & O_1B\cdot\sin(\varphi_2) & 0 & 0 \\
AB\cdot\cos(\varphi_1) & -O_1B\cdot\cos(\varphi_2) & 0 & 0 \\
0 & -O_1B\cdot\sin(\varphi_2) & -BC\cdot\sin(\varphi_3) & O_2C\cdot\sin(\varphi_4) \\
0 & O_1B\cdot\cos(\varphi_2) & BC\cdot\cos(\varphi_3) & -O_2C\cdot\cos(\varphi_4)
\end{pmatrix}$$

$$X_\omega = \begin{bmatrix} \omega_1 \\ \omega_2 \\ \omega_3 \\ \omega_4 \end{bmatrix}, \qquad B = \begin{bmatrix} OA\cdot\sin(\varphi)\omega_0 \\ -OA\cdot\cos(\varphi)\omega_0 \\ 0 \\ 0 \end{bmatrix}$$

The solution of the equations (9) has the following form:

$$X_\omega = A^{-1}\cdot B \qquad (13)$$

To determine the angular accelerations of the links of the sieve frame mechanism we will differentiate with respect to time equation (8) and obtain a system of equations in matrix form:

$$A \cdot X_a = C \tag{14}$$

where *C* is the vector of the right parts of the equations.

Solution of the equations (11) allows us to determine the angular acceleration of the links of the sieve frame mechanism. It has the following form:

$$X_a = A^{-1} \cdot C \tag{15}$$

$$C = \begin{pmatrix} OA\cos(\varphi)\omega_0^2 + AB\cos(\varphi_1)\omega_1^2 - O_1B\cos(\varphi_2)\omega_2^2 \\ OA\sin(\varphi)\omega_0^2 + AB\sin(\varphi_1)\omega_1^2 - O_1B\sin(\varphi_2)\omega_2^2 \\ -O_1B\cos(\varphi_2)\omega_2^2 - BC\cos(\varphi_3)\omega_3^2 + O_2C\cos(\varphi_4)\omega_4^2 \\ -O_1B\sin(\varphi_2)\omega_2^2 - BC\sin(\varphi_3)\omega_3^2 + O_2C\sin(\varphi_4)\omega_4^2 \end{pmatrix}$$

We determine velocities and accelerations of the nodal points of the sieve frame mechanism using Figures 2, 3, and taking into account that the vector modules are constant and their derivatives with time can be determined using Euler formula:

$$\dot{\overline{r}} = \overline{\omega} \times \overline{r} \tag{16}$$

We find the velocities of the nodal points of the sieve frame mechanism:

$$\overline{v_A} = \overline{\omega_0} \times \overline{r_A}, \qquad \overline{v_B} = \overline{\omega_2} \times \overline{\rho_B}, \qquad \overline{v_C} = \overline{\omega_4} \times \overline{\rho_C}. \tag{17}$$

Having differentiated with respect to time expression (14), we find the acceleration of these points:

$$\overline{a_A} = \overline{\omega_0} \times (\overline{\omega_0} \times \overline{r_A}), \qquad \overline{a_B} = \overline{\varepsilon_2} \times \overline{\rho_B} + \overline{\omega_2} \times (\overline{\omega_2} \times \overline{\rho_B}),$$
$$\overline{a_C} = \overline{\varepsilon_4} \times \overline{\rho_C} + \overline{\omega_4} \times (\overline{\omega_4} \times \overline{\rho_C}). \tag{18}$$

Equations (8-10, 13, 15, 17, 18) are a mathematical model of a kinematic mechanism of the grain cleaning machine scalping frame. This model allows determining the coordinates of the nodal points, their speed and acceleration. A similar method is used to determine the coordinates of the nodal points, their speed and acceleration for the lower sieve, which works in the opposite direction of the upper sieve. (*Badretdinov et al., 2017; Bertiaev, 2005*).

RESULTS

Included in Tables 1, 2 are basic physical and mechanical properties and statistical analysis of geometric parameters of grain heap before cleaning. To analyse the physical and mechanical properties of the grain material, certain fresh crop samples harvested at a normal amount of moisture were taken. Geometric parameters were measured using a micrometre MK 0-25, the inherent error of the device being ±0.01 mm. The amount of sampling of the grain heap components was 100 pieces. The mass of a single seed-beetle was determined using electronic jewellery scale A 03 with accuracy class of ±0.001 g.

Table 1

Statistical analysis of geometric parameters of grain heap ("Vatan" wheat variety)

Parameter	Minimal	Maximal	Average value, X	Dispersion, σ^2	Squared error distance, σ	Variation, v
Grain heap (before cleaning)						
Length *l*, mm	1.11	28.1	10.77	39.8	6.31	58.59
Thickness *a*, mm	0.30	9.5	2.11	1.80	1.34	63.57
Width *в*, mm	1.40	5.7	3.53	1.02	1.01	28.64
Equivalent diameter, d_e, mm	0.72	5.41	2.59	-	-	-

Table 2

Statistical analysis of the mass of a single seed beetle ("Salavat Iulaev" wheat variety)

Parameter	Minimal	Maximal	Average value, X	Dispersion, σ^2	Squared error distance, σ	Variation, v	Standard error of the mean
Weight [g]	0.012	0.08	0.036	0.0001	0.0105	29.32	0.0011

Experimental studies of the grain heap show (Tables 1, 2) that grain heap is inhomogeneous and has a wide range of both physical and mechanical and geometric parameters (*Casandroiu et al., 2009; Ermolev, 2010; Fominykh, 2006; Saitov et al., 2016*).

Variation coefficient v in respect to thickness is 63.57%, and 28.64% in respect to width. This greatly complicates the process of a proper sieve selection. The mass of a single grain is taken into account when determining the inertial force, judging by the coefficient of variation $v = 29.32\%$ varying in a wide range.

Conditions for moving the components of the grain heap downward the oscillating sieve frame. If the components of the grain material move downward the sieve, inertial force, acting on the individual seeds, will be directed downwards, the force of friction on the sieve will be directed upwards along the sieve surface, the force of gravity - downward, and the normal sieve reaction - upward and perpendicular to the sieve surface. By the direction of the forces acting on the grain heap components, the nature of their movement trajectory by the oscillating sieve surface can be defined. The mode of movement of the grain components by the sieve is selected in the following way: the time of the heap component particles contact with the sieve should be maximum, which ensures more efficient separation. At the same time, to improve the performance of the grain cleaning machine, the speed of the grain material movement by the sieve should also be maximum. Apparently, these requirements contradict each other. Thus, optimization problem should be solved.

One of the most important functional parameters of a layer on the surface of the sieve is the Froude number expressing the ratio of the forces acting on a particle lying on the sieve, oscillation amplitude of the sieve and gravity. This number can be expressed as follows

$$F_r = \frac{r\omega^2}{g}, \tag{19}$$

where r is the radius of the crank (r = 0.01 m); ω is the angular velocity of the crank drive shaft (ω = 425...475 min^{-1}); g is the acceleration of free fall, m/s^2.

Visualization of trajectories of speed and acceleration movement of the links, which were received according to the results of modeling and calculation performed with the use of Mathcad program, is presented in Figures 4, 5.
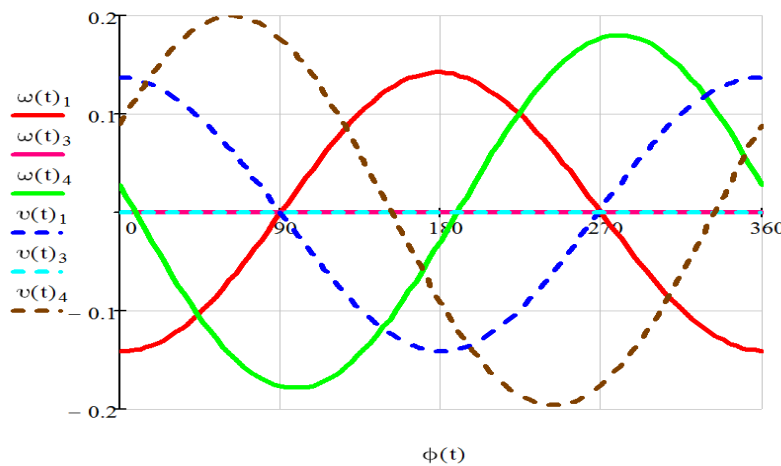

Fig. 4 - Graph of changes in speed (rad/s) of the links of the grain cleaning machine sieve frame
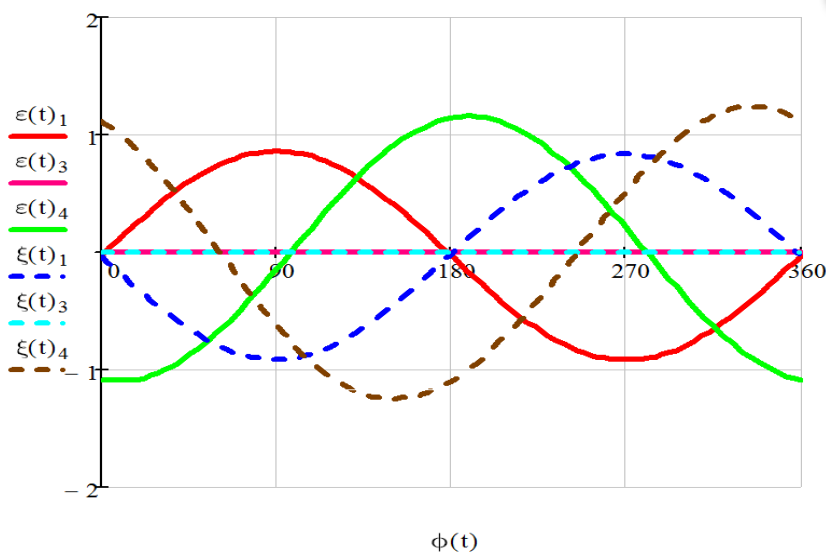

Fig. 5 - Graph of changes in the acceleration (rad/s^2) of the links of the grain cleaning machine sieve frame

In Figure 4 acceleration of the scalping frame links are marked by unbroken lines. Acceleration of the bottom frame links are marked by dotted lines. As one can see, they work in inversed manner. There are also small deviations: the speed of the bottom sieve frame link is slightly higher than the speed of the scalping frame link. Due to that, the technological operation process is accompanied by vibration.

The analysis of Figure 5 is similar to the graph of changes in speed of the sieve frame mechanism links. There are also small deviations: the acceleration of the bottom sieve frame link is slightly higher than the acceleration of the scalping frame link. That can be a possible cause of vibration.

Figure 6 shows a kinematic diagram of the sieve frame mechanism and a scaled illustration of speed and acceleration vectors at nodal points. When the scalping frame moves to the right, the bottom frame moves to the left. This is proved by the calculation results and shown by vectors directions.
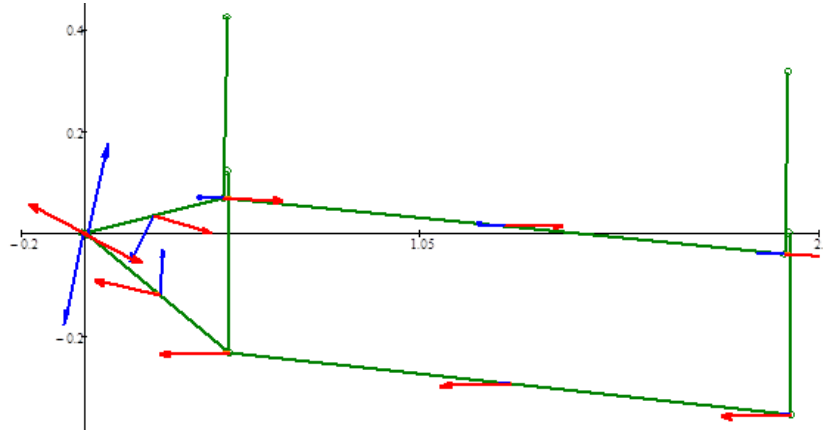

Fig. 6 - Plotting of a sieve frame mechanism, speed and acceleration vectors

Figure 7 shows that speed vectors are perpendicular to the crank and directed down the mechanism rotation. Acceleration vectors are directed down the crank.
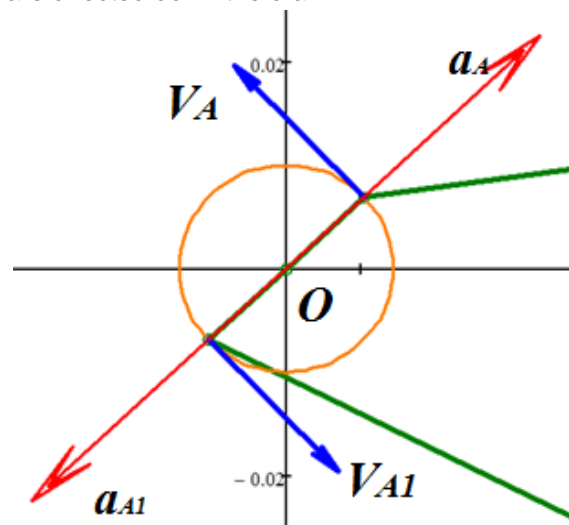

Fig. 7 - Visualization of the sieve frame crank (drive) trajectory, speed and acceleration vectors

Figures 8 and 9 show the plans of speeds and accelerations, respectively, at arbitrary values of the angle of rotation of the crank drive. Depending on the time, you can build such plans of speeds and accelerations for any position (angle of rotation) of the crank. The velocity (acceleration) diagram is a diagram which in real time captures vectors representing a module and a direction of motion of multiple links in the mechanism. The velocity diagram has the following properties: the segment connecting the tips of the velocity vectors of any two points of the body, perpendicular to the line connecting corresponding points of the body; the lengths of segments connecting the ends of the velocity vectors of body points, the proportional length of the segments connecting corresponding points.

The plan of speeds (accelerations) allows solving graphically the problems of determination of body points' speeds (accelerations), and is the most widespread graph-analytical method of research. In this case, the larger the selected scale, in which the vectors of velocities (accelerations) of body points are constructed, the more accurately the problem is solved.
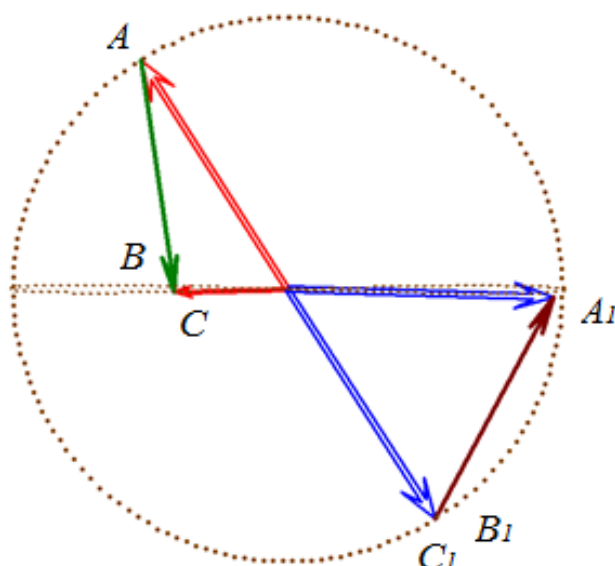
Fig. 8 - Plotting of velocity diagram at a selected value of the crank angle
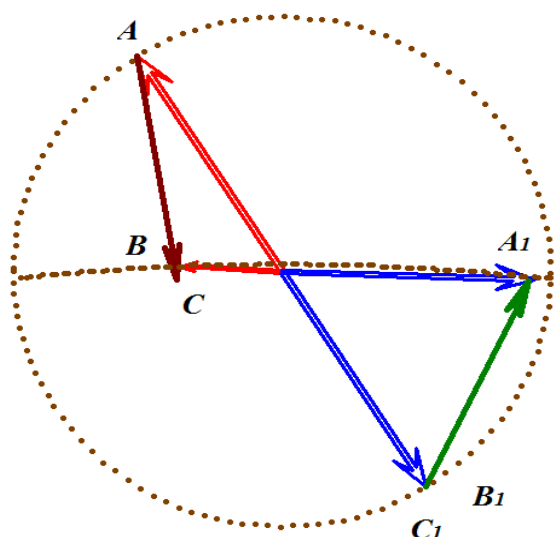

Fig. 9 - Plotting of the acceleration diagram at a selected value of the crank rotation angle

Experimental data got during the study of the grain heap components to be cleaned show the distribution of physical-mechanical and geometric parameters, which vary sufficiently over a wide range. This is proved by their variation coefficients (table 1 and 2). This primarily affects the sieving process, makes the correct selection of sieves difficult, reduces productivity, and affects grain cleaning efficiency.
Other scientists note the same in their studies (*Dorokhov et al., 2018; Ma et al., 2018; Okunola et al., 2018; Singh et al., 2017; Vasylkovskyi et al., 2019*). In addition to geometric parameters, separation efficiency is also affected by other properties (clogging, humidity) (*Kornev, 2015; Mudarisov et al., 2009, 2017; Okunola et al., 2018; Vasylkovskyi et al., 2019*).
Modeling and study of the sieve frame kinematic mechanism makes it possible to determine the coordinates of the nodal points, links speed and acceleration, as well as to identify and optimize the problem areas, choose the right design an**d** technological parameters.
Using this method after simulating and calculating the model of a real grain cleaning machine sieve frame on the example of ZVS-20, problem areas were identified, which is confirmed by vibration. These problems can be solved by changing the design parameters.
Using this modeling method makes it possible to improve the design and technological parameters of grain cleaning machines with a sieve cleaning system without significant effort and cost.

CONCLUSIONS

A mathematical model of the kinematic scheme of the grain cleaning machine sieve frame was developed. During the study, coordinates of the nodal points of the grain cleaning machine sieve frame were developed, their movement speed and acceleration plans were plotted. A mathematical model of the kinematic operation scheme of the grain cleaning machine sieve frame was designed. Froude number for a sieve frame Fr = 0,05 0,062... was determined. This value characterizes the ratio between inertial forces and gravity, in the field of which the components of a cleaned culture move. According to generally accepted classification, Fr < 1 means a quiet fluency. According to the results of modeling and calculation made on the example of the most common grain cleaning machine ZVS-20, its problem areas and imperfections of structural and technological parameters were identified. The proposed method of simulation of grain cleaning machines with a sieve cleaning system makes it possible to study the drive mechanism kinematics and the process of separation by flat oscillating working bodies, to analyse the contact degree of particles of grain heap components with the sieve, to identify problem areas and improve the design and technological parameters of the sieve frame of any grain cleaning machine. The model can be used many times, without requiring investment for its manufacturing and laboratory tests. Correct operation modes of the separation process can be chosen for different crops.

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