Determination of Separator Constructive Parameters

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Abstract. The article describes the two swinging sieves separator with increased guide activity. The kinetics of two sieves oscillatory mechanism is examined on the basis of the deterministic approach to the process study. In the course of theoretical research, a theoretical model was obtained, which defines the sieve movement. This model allows to calculate the kinematics of both separator sieves and its design parameters.

Introduction

Post-harvest grain processing is the final stage in its production. The post-harvest processing and grain storage accounts for more than one-third of the costs associated with its production [1]. Timely post-harvest grain processing, harvested by combine harvesters contributes to high harvesting rates, prevents grain spoilage and its quality. One of the final stages and the most crucial part of it is the secondary treatment. Since the 50s of the last century, the seed grain share is 20...25% of its total volume [2]. The seeds of the most stringent requirements of GOST on purity, germination and other indicators.

At present, due to the increased contamination of the fields occupied with crops, grain-cleaning machinery load has increased. The seeds are passed through grain cleaning machines several times to bring the grain to the sowing conditions, while processing costs and grain injury are increasing [3]. And this, in turn, leads to an increase in the prime cost of the final sales unit and a decrease in the machine productivity.

One of the most common separating elements, both for primary and secondary grain cleaning, are punch sieves [4, 5]. Of these, the most applicable are sieves with rectangular openings that separate the seeds by thickness. These sieves have much higher specific productivity values than sieves with round holes. The authors of many works come to the conclusion that cylindrical sieves are the most productive, and swinging sieves injure grains less than others. The most loaded sieves in seed cleaning machines are considered to be sowing and sorting, on which small and frail spines are separated. To increase the productivity of these, and others, is solved by those who are standing in the camp, in two ways. The first way is an extra strong one, connected with an increase in the battery size, the power and other similar aspects. The second way is a promoted one, includes a study for achieving the highest level of competitiveness possible through the mobilization of important factors influencing the quantitative and qualitative machine quality. The realization of the second way is kept due to the fact that there is not enough study of grain separation process on the sieve.

Analyzing various separator designs for cleaning grain material, we can conclude that today some of the most promising are machines capable of combining the advantages of both flat-sieve and machines with a curved sieve surface.

Such a combination of advantages is possible with the use of a grain cleaning machine with two cylindrical swinging sieves with elongated holes located at an angle $\alpha$ to the movement of the grain material.

This machine will allow you to increase the penetration degree through the net by improving the grain management through the holes.
Theoretical investigations of the grain cleaning process were carried out on the sieves with rectangular openings located at the angle to the longitudinal sieve axis.

We have developed a separator with swinging working organs which openings have a straightforward shape and are arranged under a specific angle $\alpha$ to seed movement.

Such a configuration allows to increase screening sieve ability by location improving of grains regarding the holes [7].

2. Object and research methods
The kinematic mechanism design of sieves suspension and its drive was made for a laboratory sample (Fig. 1).

Figure 1 - Laboratory sample diagram of a machine for the grain separation with oscillating tools:
1 - electric drive; 2 - frame; 3 - sieve cleaners; 4 - jumpers; 5 - sieve pendants; 6 - mounting sieve suspensions; 7 - connecting rod; 8 - crank; 9 - sieve; $\alpha$ – inclination hole angle regarding the sieve.

Grain cleaning separator, contains a frame 2, on which with the sieve hangers help 5 concave sieves 9, cross-sectioned in a cross-section, are mounted, made in the form of a cylindrical surface. To the sieve 9 pivotally attached jumper 4, connecting the sieve. The mountings of the sieve hangers 6 lie in the same plane and are shifted regarding each other, yoke, and they have a longitudinal inclination to the horizon. Under the sieves 9 brushes 3 are installed.

In the movement of the sieve 9 are driven from the motor-reducer 1 by means of the crank 8 and the connecting rod 7, are connected to each other by a hinge. The movement from the first sieve to the second is transmitted through the jumper 4. The sieve 9 oscillates about its axis.

Grain cleaning separator works as follows: the source material received at the beginning of the first and second sieves, under the action of oscillatory motion begins to move across the sieves, and due to the mill and holes inclination - along the sieve above, freely falling on the sieve below. Having reached the extreme point, the movement of the sieves is repeated in the opposite direction. Due to the fact that the axles of fastening the suspensions of sieves are displaced regarding each other in opposite directions, during the movement, the sieves move in the horizontal plane between themselves. This makes it necessary for them to connect with the help of the first pin 4, which allows to move between the sieves and also connects them [8]. The cleaning of the holes will be done from the entrances of the discovered grain by means of brushes, which are placed in the upper mill part.

The advantages of such a separator are the structure simplicity, in which the particle moves under the influence of a number of forces: inertia, centrifugal and gravitational. Moving a particle from the sieve to the sieve and back promotes intensive mixing, and therefore actively prevents the separation of the divided mass, and allows the weevils in the upper layer to get to the sieve. The grain pile moves with
a thin layer, and due to the arrangement of the longitudinal holes at an angle, the grain material is more intensively oriented on the sieve, which shortens the residence time of the small fraction on the sieve.

Previously, the kinematics of the lever mechanism as applied to the two-grid separator scheme have already been studied [9] on a crank mechanism with a beam, identifying it with a hinged four-link mechanism (Fig.2)

![Figure 2 - Scheme of the crank mechanism with the rocker arm.](image)

The functional dependence of the angle \( \delta \) of the deflection of the rocker from the angle \( \alpha \), if the initial link is AB: where \( a, b, c, d \) are the lengths of the AB, AD, CD and BC links, respectively;

\[
\delta = \arctg \left( \frac{b \cdot \sin \gamma}{c - b \cdot \cos \gamma} \right) + \delta_i,
\]

\[
\cos \gamma = \arctg \left( \frac{b^2 + c^2 - a^2 - d^2}{2b \cdot c} + \frac{a \cdot d}{b \cdot c} \cos \alpha_h, \right)
\]

Angular velocity of the rocker arm:

\[
\omega_h = \omega_1 \cdot \frac{a}{c} \cdot \frac{\sin \beta}{\sin \gamma},
\]

where:

\[
\beta = 360^\circ - (\alpha_h + \gamma + \delta),
\]

Angular rocker acceleration:

\[
\varepsilon_3 = -\omega_1^2 \cdot \frac{a \cdot d}{b \cdot c} \cdot \cos \beta \cdot \sin \delta \cdot \frac{a}{c} \cdot \sin \alpha_h \cdot \sin \beta \cdot \cot \gamma \cdot \frac{1}{\sin^2 \gamma},
\]

A four-link hinge mechanism was considered (Fig. 3):
Figure 3 - Scheme of the hinged four-link mechanism.

The change dependence in the angles $\gamma$ and $\psi_2$ will be as follows:

$$\gamma = 90 - \delta,$$

(5)

Considering that the angles corresponding to the neutral position are equal $\gamma = \psi_2$, then their arbitrarily small angular displacements are also equal $\Delta\gamma = \Delta\psi_2$, so we get

$$\psi_2 = \gamma - 2\Delta\psi_2,$$

(6)

where $\Delta\gamma, \Delta\psi_2$ – small angles changes $\gamma, \psi_2$.

Taking into consideration $\Delta\psi_2 = \omega\Delta t$ and equation (7) we get

$$\psi_2 = 90 - \arctg \frac{b}{c - b \cdot \arctg \left( \frac{b^2 + c^2 - a^2 - d^2}{2b \cdot c} + \frac{a \cdot d \cdot \cos \alpha_h}{b \cdot c} \right)} + \delta_1,$$

(7)

The speeds and accelerations of both sieves are the same, since the sizes of their suspensions are the same and the sieves are rigidly interconnected by a jumper that transmits an oscillatory motion from the first to the second.

To find the motion parameters of the first and second cylindrical swinging screens, we use the technique used in the theory of mechanisms and machines [10]. In it, structural, kinematic and kinetostatic research is studied in a graphanalytic way for certain positions of the links of the mechanism of angular velocity, peripheral velocity, acceleration and angular acceleration, as well as the force effect at certain points.

The kinematic scheme of the proposed technical solution (Fig. 1) for simplicity was divided into three parts: a crank and a connecting rod with rocker arms and two hinged four-link mechanisms (a sieve mill) (Fig. 4).
The sieve mill orientation in space can be determined as follows:

- assigned the sieve angle in the horizontal plane $\beta$;
- the angle between the sieve hanger mounts (lines $M_{11}M_{12}$, $M_{11}M_{13}$, $M_{21}M_{22}$, $M_{21}M_{23}$) from the axis of symmetry ($\eta$);
- assigned sieve mill deflection angle ($\theta$), then the angle change of the sieve symmetry axis from the vertical axis ($\frac{\theta}{2}$);
- the angles of deflection of the sieve suspensions are calculated (lines $M_{11}M_{13}$, $M_{21}M_{22}$, $M_{21}M_{23}$) from vertical plane:
  - Angle of deflection for left-sided drives:
    \[ l = \frac{\theta - \eta}{2}, \]  
  - deflection angle for right-sided drives:
    \[ p = \frac{\theta + \eta}{2}, \]  
- the radius $r_1$ is calculated for different values of the arms (upper - $h_v$ and lower - $h_n$):
  \[ r_1 = \sqrt{r^2 - (h_v - h_n)^2}, \]  

Next, the deviation angle value is calculated relative to the vertical position when the deviation $\beta=0$:

\[ f_i = \frac{h_n - h_v}{r_1}, \]  

- coordinates values are determined $M_{11}, M_{12}, M_{13}, M_{21}, M_{22}, M_{23}$.

Expressions to determine the value of the coordinates of points $M_{11}, M_{12}, M_{13}, M_{21}, M_{22}, M_{23}$ will take the following form:

The point $M_{11}$:

\[
\begin{align*}
x_{11} &= m; \\
y_{11} &= h_v \cdot \cos(\beta); \\
z_{11} &= -h_v \cdot \sin(\beta); 
\end{align*}
\]  

The coordinates of the points $M_{12}, M_{13}$ are calculated depending on the coordinates of the point $M_{11}$. 

Figure 4 - Kinematic sieve scheme.
\[
\begin{align*}
x_{12} &= x_{11} - r \cdot \cos(\beta - f_1) \cdot \sin(l); \\
y_{12} &= y_{11} - r \cdot \sin(\beta - f_1); \\
z_{12} &= z_{11} - r \cdot \cos(\beta - f_1) \cdot \cos(l);
\end{align*}
\]

(13)

\[
\begin{align*}
x_{13} &= x_{11} - r \cdot \cos(\beta - f_1) \cdot \sin(p); \\
y_{13} &= y_{11} - r \cdot \sin(\beta - f_1); \\
z_{12} &= z_{11} - r \cdot \cos(\beta - f_1) \cdot \cos(p);
\end{align*}
\]

(14)

In the same way we determine the values of the coordinates of points M21, M22, M23.

Similarly, we obtain the coordinates of points M21, M22, M23.

3. Results of the study.

Based on the above, the equations of sieve mill motion are derived. Taking the value of the sieve inclination angle \(\beta\), the distance between the oscillation axes of the sieve suspensions (+m for the right and –m for the left), the sieve mill angle deflection regarding the symmetry axes +\(\frac{\pi}{k}\) for the right and \(-\frac{\pi}{k}\) for the left, where \(k\)- coefficient of deviation, you can define various kinematic parameters. Based on the obtained mathematical model, a simulation model was developed. This model allows you to change the design parameters, namely: the suspensions length parameters and the values of the sieves deflection angle.

![Figure 5 - Sieve drive diagram.](image)

The connecting rod and crank lengths, sieve suspensions and jumpers are calculated using a mathematical model.

For the implementation of the above, the coordinate values of the connecting rod fixation points to the lattice with its maximum and minimum deviations are calculated \((x_{\text{max}}, y_{\text{max}}, z_{\text{max}}), (x_{\text{min}}, y_{\text{min}}, z_{\text{min}})\).
Thus, the minimum and maximum values of the connecting rod fixation points to the lattice mill are determined regarding the crank rotation axis.

\[
\begin{align*}
x_{\text{max}} &= m - r \cdot \cos(\beta - f_i) \cdot \sin(-\frac{\theta}{2} + \frac{\eta}{2} + \frac{\pi}{k}); \\
y_{\text{max}} &= h_i \cdot \cos(\beta) - r \cdot \sin(\beta - f_i); \\
z_{\text{max}} &= -h_i \cdot \sin(\beta) - r \cdot \cos(\beta - f_i) \cdot \cos(-\frac{\theta}{2} + \frac{\eta}{2} + \frac{\pi}{k}); \\
x_{\text{max}} &= m - r \cdot \cos(\beta - f_i) \cdot \sin(\theta + \frac{\pi}{k}); \\
y_{\text{max}} &= h_i \cdot \cos(\beta) - r \cdot \sin(\beta - f_i); \\
z_{\text{max}} &= -h_i \cdot \sin(\beta) - r \cdot \cos(\beta - f_i) \cdot \cos(\theta + \frac{\pi}{k});
\end{align*}
\]

Thus, the minimum and maximum values of the connecting rod fixation points to the lattice mill are determined regarding the crank rotation axis.

\[
\begin{align*}
r_{\text{min}} &= \sqrt{(x_{\text{min}} - x_{\text{op}})^2 + (y_{\text{min}} - y_{\text{op}})^2 + (z_{\text{min}} - z_{\text{op}})^2}; \\
r_{\text{max}} &= \sqrt{(x_{\text{max}} - x_{\text{op}})^2 + (y_{\text{max}} - y_{\text{op}})^2 + (z_{\text{max}} - z_{\text{op}})^2};
\end{align*}
\]

crank length value:

\[
r_{\text{op}} = \frac{r_{\text{max}} - r_{\text{min}}}{2},
\]

rod length value:

\[
r_b = r_{\text{min}} + r_{\text{op}}.
\]

The distance between the crank rotation axis and the sieve suspension is determined by:

\[
r_m = \sqrt{(x_{13} - x_{\text{op}})^2 + (y_{13} - y_{\text{op}})^2 + (z_{13} - z_{\text{op}})^2},
\]

4. Conclusion.

The article substantiates the relevance of the grain post-harvest processing issue in modern agriculture, and, as a result, a grain separator model with a two-sieves design and installed sieve with increased orienting activity was proposed. This design allows you to carefully carry out the grain cleaning process without possible injury to it, however, using centrifugal forces. A simulation model of a two-sieves separator was obtained, which allows to calculate the coordinates of fixing the connecting rod points to the lattice mill with its maximum and minimum deviations, the crank length and the connecting rod length, the distance between the crank rotation axis and the sieve suspension. For the laboratory sample, the following values were obtained: crank length (150 mm), connecting rod (380 mm), and also sieve hangers lengths (350 mm) and jumpers (30 mm). In the case of an industrial scale separator development, these dimensions will be adjusted, but the mathematical dependencies used will remain the same.

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