Performance indicators of flat sieve with oblong holes located at an angle

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Abstract. Increase in the productivity of domestic grain cleaning machines produced by traditional methods has exhausted itself. Therefore, the country's agricultural enterprises of various forms of ownership need high-performance innovative grain cleaning machines for post-harvest grain processing. The article presents various methods and ways to improve the performance of grain cleaning machines. The results of studies are presented to determine the completeness of separation and the sieve capacity of grain cleaning machines with oblong holes located at an angle, when interacting with a long edge, which makes reciprocal oscillations. Theoretically, rational values of inclination angle of the sieve holes are determined equal to $\alpha' = 10\ldots 15^\circ$, which increases the probability of a particle passing into the sieve hole by 1.7 times. The results of the production inspection of the sieves of the proposed design showed that the capacity of the grain cleaning machine increased by 23%, and the quality of cleaning the grain mixture meets the agrotechnical requirements.

1 Introduction

Grain heap coming from combines consists of grain of harvested crop and various impurities. Their separation is performed on grain cleaning machines based on difference of physical and mechanical properties of grain material. The main task of post-harvest treatment is to obtain grain to the required conditions depending on the purpose. It is known that grain is divided into seed, forage and commodity (food). Their quality is regulated by the existing state standards.

The solution to this problem is achieved by cleaning, sorting and drying. It is known that the work of mass-produced domestic grain cleaning machines is mainly based on the reciprocation motion of the cleaning shoes. Improving the performance of such machines in traditional ways, in our opinion, has exhausted itself. It is necessary to continue the search for the development and creation of innovative technologies and technical means for post-harvest grain processing. The review and analysis of machines and aggregates for grain heap separation showed that there are various ways and ways to solve this important national economic problem. Some of these are described below.

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2 Material and methods

Grain cleaning machine is proposed, where the cleaning shoe makes circular movements. It has been found that the separation process improves at the inclination angle of the sieve holes edge $\beta = 45^\circ$, the frequency of vibrations of the sieve $n = 110 \text{ мин}^{-1}$, the amplitude of vibrations of the sieve $A = 0.09 \text{ m}$, the angle of transverse inclination of the sieve $\alpha_t = 1.5^\circ \pm 2.5^\circ$. With such parameters and operating modes, the grain orientation with respect to the screen holes changes several times faster than with reciprocating motion. At the same time, it was noted that the throughput capacity increases, and the quality of the grain mixture cleaning meets the agrotechnical requirements.

Works present the results of the study of the sieve operation of the grain cleaning machine, located in such a way that the direction of the long bridges of the sieve coincides with the direction of oscillations and perpendicular to the direction of the grain movement. As a result of the experiments, the most significant factors affecting the completeness of grain separation from the parameters of a flat sieve that makes transverse fluctuations were determined and substantiated: the value of the specific load (G) - $0.335... 0.838 \text{ kg/(м}^2\times \text{ c)}$; angle of longitudinal inclination of sieve (a) - $10... 16^\circ$; amplitude of sieve oscillations (R) - $(7.25... 9.25) \times 10^{-3} \text{ m}$; sieve frequency (n) - $450... 550 \text{ мин}^{-1}$.

3 Results and Discussion

In this article, the study of the influence arrangement of oblong holes of a flat sieve at an angle on the parameters of the technological process of separation of the grain mixture is presented. A fragment of such a sieve is shown in Figure 1.

![Fig. 1. Fragment of the investigated sieve (the arrow indicates the direction of sieve oscillations).](image-url)
It is well known that the main parameters of the separation process of grain mixture by a sieve grain cleaning machine are the completeness of separation and productivity.

Additional indicators characterizing the sieve workflow are: the resulting speed of grain material movement down the sieve, the thickness of the grain layer, the distribution of grain across the sieve width, the utilization factor of the sieve length and others.

A review and analysis of work in this area shows that most researchers consider the separation process at the cleaning shoe as “black box” system with the transformation of input (primary) values into output (final). Therefore, according to our data, mathematical models have not yet been developed that allow theoretically investigating the effect of particle movements on the completeness of separation. That is why in theoretical studies, usually this characteristic of the sieve is taken as a given, fixed value.

Average velocity $V_{msd}$ the relative movement of the particle down the sieve was determined by the formula:

$$V_{msd} = \frac{2 \cdot \pi \cdot (x_d - x_u)}{\omega}$$

(1)

Where $x_d$ - movement of the particle down the $x$ axis; $x_u$ - movement of the particle up the screen; $\omega$ - angular frequency.

Dependency graph $V_{msd} = f(\alpha')$ is shown in Figure 2.

![Fig. 2. Dependence of average rate change $V_{msd}$ relative movement of grain down the sieve.](image)

It is known that there is a close relationship that the productivity is directly proportional to the rate of movement of the grain material on the sieve, the dependence shown in Figure 2 confirms the validity of the rational range choice, the variation of inclination angle of the oblong holes of the sieve ($0 \leq \alpha' \leq 20^\circ$).

As a qualitative indicator of work, we assume the coefficient use of the $\eta$ sieve length used in the work, which shows how many times the grain path along the sieve is greater than the length of the sieve itself.

If during one period of the sieve oscillation the particle moves along it for the distance $x_d - x_u$, and the grain path along the sieve, taking into account lateral movements, $\sqrt{x_d^2 + y_R^2} + \sqrt{x_u^2 + y_L^2}$ will be the coefficient use of the sieve length for our case with inclined holes will be equal to:
Where $y_R$ - movement of the particle to the right along the $y$ axis; $y_L$ - movement of the particle to the left on the sieve.

Calculated dependencies of the $\eta$ from the value of longitudinal and transverse movements of the particle are obtained, which are presented in Figure 3.

\[ \eta = \frac{\sqrt{x_D^2 + y_R^2} + \sqrt{x_U^2 + y_L^2}}{x_D - x_U} \]  \hspace{1cm} (2)

Fig. 3. Dependence of the use factor of the sieve length, from the angle of the oblong holes.

It follows (Figure 3.), that with an increase of inclination angle of the sieve holes and the angle of transverse inclination of the sieve leads to an increase in the coefficient use of the sieve length, which suggests positive influence of these factors on the process of separation of the grain mixture.

Entering cleaning shoe, particles of grain heap are randomly located on it. Moreover, two situations are possible. First, when the grain enters the hole area, then at a certain position of the particle relative to the hole, it can pass through the hole. This situation is analyzed quite deeply in the works.

The second situation is when the grain falls the jumper. In this case, when the sieve oscillates, the relative movement of the grain will be carried out parallel to the longitudinal faces of the holes and, if the center of gravity of the grain is located on jumper area, it cannot enter the hole zone. Thus, particles located on the jumpers do not participate in the separation process. Their entry into the zone of holes is possible as a result of an accidental process of interaction with other particles or in the case of a special sieve design, for example, with jumpers having cross section in the form of a triangle or circle.

Therefore, in order for the particle to pass through the hole of the sieve, it is necessary that it be in hole zone and positioned relatively to the hole faces in a certain manner. Considering these events as independent, the probability of the particle passing through the holes sieve will be equal to:

\[ P = P_\gamma \cdot P_\beta \]  \hspace{1cm} (3)
Where $P$ - probability of the particle passing through the sieve hole; $P_0$ - probability of "through" location of the particle on the hole faces; $P_\beta$ - probability of particle interaction with the hole faces due to the trajectory of particle movement on jumper.

To determine the position of the particle, at which its passage through the sieve hole is not difficult, we will use the design scheme (Figure 4). In this case, we consider a grain in the form of an ellipsoid oval, in which the large axis is equal to the length of the grain $a$, and the small axis is equal to the thickness of the grain $b$, the central section is an oval of arcs of conjugate radii $R_1$ and $R_2$. The magnitude of the radii $R_1$ and $R_2$ at the given dimensions of the large and small axis of the oval can be calculated or determined graphically. The center of gravity of the grain coincides with its geometric center $0$.

![Design diagram of the relative position of the grain and the sieve hole.](image)

For the accepted conditions, the limit position of the grain relatively to the sieve hole according to the condition of its passage through the hole will be such that the center of gravity of the grain will be located on one longitudinal face of the hole, and the second longitudinal face of the hole will be tangent to the curve forming an ellipsoid oval. The angle between the hole face and the long axis of the particle is denoted as $\gamma$.

Expressing the sides of the triangle $OBO$ through the dimensions of the hole and the grain, we get:

$$\sin \gamma = \frac{2 \cdot (h_0 - R_2)}{a - 2 \cdot R_2},$$

(4)

Where $\gamma$ - the limit angle at which the grain can pass into the sieve hole; $a$ - the size of the long axis of the particle; $h_0$ - hole width; $R_2$ - the small radius of curvature at the top of the particle.

The obtained ratio determines the maximum angle $\gamma$ between the longitudinal axis of the grain and the hole face of the sieve according to the condition of passage. Therefore, the passage of the grain into the hole is possible only if:
0 ≤ γ ≤ ± \arcsin \frac{2 \cdot (h_0 - R_2)}{a - 2 \cdot R_2}. \quad (5)

At angles \( \gamma_R \) greater than those determined by (5), theoretically the separation capacity of the sieve will tend to zero at any direction of movement of the particle.

For the grain with sizes \( a = 5.2 \text{ mm}, b = 2.1 \text{ mm} \) and surface curvature radii \( R_1 = 2.5 \text{ mm} \) and \( R_2 = 0.7 \text{ mm} \), as well as a sieve with hole sizes 2.2×20 mm and jumper width 2.5 mm according to formula (4), the limit angle \( \gamma_R \) at which the grain can pass into the sieve hole is calculated:

\[
\gamma_R = \arcsin \frac{2(2.2 - 0.7)}{5.2 - 2 \cdot 0.7} = 52°
\]

The method proposed by V. F. Evtyagin was used to theoretically determine the productivity of the Q sieve, according to which, with a known value of the coefficient use of sieve length \( \eta \), dependence was used in the form of the following formula:

\[
K' = \frac{L_E \cdot (1 - \varepsilon)}{\varepsilon \cdot a \cdot G}
\]

(6)

Where \( K' \) - a coefficient depending on the design and kinematic mode of the sieve, as well as on the value of the specific load; \( L_E \) - the length of the sieve in the experimental study; \( \varepsilon \) - completeness of separation; \( a \) - the relative content of the pass-through fraction in the starting grain material; \( G \) - specific load per unit width of the sieve per unit time.

Taking into account the ratio of the average speed at the reference experimental and studied theoretical mode, we determine the performance of the sieve for the selected mode.

4 Conclusion

The results of calculations of the theoretical capacity of the sieve at the specified value of separation completeness \( \varepsilon = 0.8 \) are shown in Figure 5.

\[\text{Fig. 5. Dependence of theoretical performance } Q \text{ of screen with inclined holes in the function of longitudinal } \alpha' \text{ and transverse } \alpha R \text{ inclination angles.}\]

The obtained dependencies \( Q = f(\alpha', \alpha_R) \) show that the rational values of inclination angle of the sieve holes are \( \alpha' = 10...15° \), which contributes to an increase in the probability
of the particle passing into the sieve hole by 1.7 times. And the angle of transverse inclination of the sieve has a positive effect on productivity, but its value should be limited by the conditions of grain shifting to one side of the sieve.

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