Parameters and indicators of the longitudinal-transverse oscillation sieve

K Astanakulov

1Tashkent Institute of Irrigation and Agricultural Mechanization Engineers, Tashkent, Uzbekistan

komil_uzmei@mail.ru

Abstract. The work quality of the grain cleaning machines depends on work indicators of the sieve. Based on this, longitudinal-transverse oscillation sieve developed for grain cleaning machine. The developed sieve researched theoretically and experimentally. According to the researches, it was defined that the longitudinal oscillation of the grain-cleaning sieve \( n_f = 140 \text{ – } 175 \text{ rpm} \), the amplitude of the longitudinal oscillations \( A_l = 30 \text{ mm} \), the amplitude of the transverse oscillations \( A_t = 3 \text{ – } 5 \text{ mm} \), and the slope angle \( \alpha = 14^\circ \). In these operating parameters work indicators of the sieve consisted of the grain losses is not more than 0.5 % and cleaning efficiency is 99.6 %. It found that the quality indicators of the longitudinal-transverse oscillation sieve on the same loads are 1.2 – 2.3 times higher than the longitudinal oscillation sieve.

1. Introduction
Wheat is one of the main crops in Uzbekistan. During the cereal producing one of the main operations is harvesting, cleaning as well as storage, or recycling before using it as foodstuff. According to the limited norms of grain preparation, the content of other impurities in the grain must be no more than 5.0%, and by the baseline values not more than 1.0%. According to these requirements, the number of other impurities in the grain that harvested by combine is allowed up to 5.0%.

However, experimental observations have shown that in some cases, the amount of non-grain impurities in the grain harvested due to uneven ripening in the fields, excessive drying or moisture of the grain, high weeds, improper adjustment of combine work units and breakdown of milling machines [1, 2]. It has also been reported to increase up to 7–9 %. Therefore, post-grain harvesting measures indicate that other impurities need to be removed before storing or using the grain for consumption. Otherwise, in the component of the grain to become stalk pieces and other types of impurities causes to increase the rate of Fusarium and mycotoxins and other harmful microorganisms [3-7]. For this, the grain is sent through the initial cleaning, primary cleaning, secondary cleaning, and pre-milling stages [8 – 10].

There are several ways to clean the grain from unfamiliar compounds. Namely, the grain is cleaned with sieves, purified from airflow stream by light impurities, stalks, weed seeds, small troops, trimmings, weeds, black moth, and other diseases by water or fluid [11 - 21]. Also, rotary and optic cleaning devices were developed too for grain cleaning [9, 22, 23]. However, the most used devices a flat sieves.

A grain cleaning machine is designed and tested for small farms in Uzbekistan. This machine is simple and resource-saver and it has the parameters to clean the grain from the unthreshed ears. Also,
Unlike the well-known machines, a rolling rubbing device for placing the grain from unthreshed ears is considered in the design to segregate the grain from unthreshed ears of wheat separated during grains volume cleaning in the course of cleaning by masticating them with rollers that rotate against each other. On the basis of implemented research it is determined that the best mastication of unthreshed ears by least damage of grain is achieved at a rotation frequency of the first roller at 600 rpm, and the second roller within 800-1200 rpm and at the clearance between rollers of 2-3 mm. For the achievement of qualitative clearing of grain lots at a minimum loss of grain, it is necessary to choose the following intervals of parameters and the operation modes: frequency of sieve fluctuations is 100 - 150 rpm; the amplitude of oscillations sieve is 30 - 50 mm; an angle of slope sieve is 8 - 11 [24].

However, this machine has not been investigated and its parameters used for cleaning grain from other impurities after being harvested in a combine. Moreover, these and other grain-cleaning machines that have flat sieve have only a longitudinal oscillation since the grain size does not sufficiently separate the grain. This requires the improvement of the grain cleaning machines’ sieve unit.

According to the above-mentioned views, the sieve of the cleaning machine was chosen as an object of the research. As an aim and tasks of the research, development longitudinal-transverse oscillation sieves as well as defining its parameters and indicators by theoretical and experimental researches were appointed.

2. Methods

The experiments were carried out on Krasnodar-99 wheat grains. Prior to experiments, the moisture and size-mass classifications of grain and its other impurities were determined on the basis of the State Standard 20915-2011 - Testing of agricultural tractors and machines. Procedure for the determination of test conditions.

An experimental sample of the grain cleaning machine with a longitudinal-transverse oscillation sieve was prepared for experiments (Fig. 1).

For defining indicators State Standard 33735-2016 - Agricultural machinery Grain-cleaning machines. Test methods and Uzbek State Standard 880: 2004 - Wheat requirements for state purchases and deliveries were used as standard methodological guidelines. Laboratory means used for analyzing and measure were shown in Figure 2.

Grain cleaning and loss are largely dependent on the type and size of the holes. For this reason, different types of sieves were compared in the machine's upper and lower sieves to select the appropriate type of grain cleaning unit. In the experiments, long rectangular shapes and with rounded holes 4 mm, 5 mm and 6 mm, 5x20 mm were used to remove large impurities in the grain mixture, also with a long rectangular 2x18 mm round holes with a diameter of 2 mm and 3 mm holes were studied for separation of small other impurities in the grain mixture. Grain cleanliness and losses were considered as criteria for assessing the performance of the sieve of the experimental machine. The grain that went from the machine's sieve gathered and the grain losses were determined by their proportion to the total sample.
3. Results and Discussion

The slope angle of the sieve is determined by the unmoving condition of the grain mixture that is on its surface when it stays at without moving. For this, the slope angle of the sieve $\alpha_s$ should be less than minimal friction angle $\phi_{min}$ of the grain

$$\alpha_s < \phi_{min} \quad (1)$$

As the image progresses smoothly along the longitudinal plane, the rollers that are placed next to it are moved horizontally as a result of movement along the direction. This movement is accelerated by the passage of grains and separation from other forces due to the direction of the forces affecting the grain on the surface of the vortex (For long-term and transverse oscillatory movements.) Determine the forces acting on the grain mixture acting on the gravity surface. The gravity $G=mg$, the inertia $J=m\omega^2r\cos\omega t$, the normal reaction $N=mg\cos\alpha_s$ and the frictional $F_{fr}=f(N=mg\cos\alpha_s - J\sin\alpha_s)$ forces influence along X-axis to grain mixture that moving on the surface of the sieve (Fig. 3).

![Figure 3. Scheme of forces influencing on grain at a sieve](image)

In this case, the condition of a longitudinal movement of grain will be as in the following:

$$g \sin \alpha_s + \omega^2 r \cos \omega t \cos \alpha_s > f_{g_s} \left( g \cos \alpha_s - \omega^2 r \cos \omega t \sin \alpha_s \right), \quad (2)$$

where $\omega$ is the angular velocity of the sieve crank, $r$ is the radius of the crank, $m$; $t$ is the moving time, s. $f_{g_s}$ is the friction coefficient of the grain.

The friction coefficient depends on grain moisture [25]. During the researches, we receive friction coefficient $f_{g} = 0.5 - 0.55$ at 15 – 18 % grain moisture.

The equation has a solution in case if $t=(0; t_1)$ then it will be $2r>A_s$.

Then the longitudinal movement of grain $A_l$ will be as in the following:
Transverse movement of grain:

\[
A_t = \frac{2g(f_g \cos \alpha_s - \sin \alpha_s)}{\omega^2(\cos \alpha_s + f_g \sin \alpha_s)}
\]  

(3)

Transverse movement of grain:

\[
A_t = \chi A_s \sin \omega t
\]  

(4)

where \(A_t\) is the longitudinal amplitude of the sieve oscillations, m; \(\chi\) is the coefficient, considering difference between the amplitude of the grain and sieve oscillations, \(\chi = 0.8\)–0.9.

When selecting the kinematic mode of the sieve, the velocity of grains on its surface should not exceed the specified limited velocity. Otherwise, the grain will not be able to pass through the holes and may break out. The maximum velocity of the grain on the sieve surface calculated as follows.

The condition of grain passing through the sieve hole

\[
X \leq S_c \quad \text{and} \quad Y \geq H_c
\]  

(5)

where \(S_c\) and \(H_c\) is the coordinates of marginal condition grain on axis \(X\) and \(Y\), m.

The marginal velocity of grain

\[
V_{marg} \leq \left[ \frac{D_h}{2} - \frac{l_s}{2} \frac{b_g}{2} \frac{tg \alpha_s - A_o \cos \gamma_o}{\cos \alpha_s} \right] \left( \frac{g}{b_g / \cos \alpha_s + 2A_o (\sin \gamma_o + \cos \gamma_o \cos \alpha_s)} \right)
\]  

(6)

where \(D_h\) is the diameter of the sieve hole, mm; \(A_o\) is the sieve oscillations amplitude, mm; \(\gamma_o\) is the angle of changing the clearance edge when the sieve fluctuates, degrees.

If we consider that in this formula \(D_h = 6\) mm; \(l_s = 5.8\) mm; \(b_g = 3.0\) mm; \(A_o = 10\) mm; \(\alpha_s = 14^0\); \(\gamma_o = 75^0\); \(g = 9.8 \text{ m/s}^2\) that marginal velocity of grain on the sieve surfaces must be \(V_{marg} \leq 0.0042\) m/s.

Based on the theoretical research, the grain cleaning machine was theoretically grounded in the longitudinal oscillation of the grain through the holes and separating it from the alien forces. Experimental studies also performed to study the separation of grains from other forces in the longitudinal oscillations. In experiments investigating the effects of different holed sieves on grain cleaning and loss, the slope angle of the sieve is set to 10\(^0\), the frequency of oscillations is 150 rpm, and the amplitude of the oscillations is 20 mm.

The results of the experiments influence the quality of the paintings and the performance of the shapes in the holes of different shapes and sizes. At first, comparing of sieves rounded holes with diameter 4 mm, 5 mm and 6 mm, and elongated rectangular shapes 5x20 mm, to distinguish all unthreshed ears, stalks, and other compounds from the grain mixture.

The quality separation of the compounds was at 4 mm in diameter was defined. Thus, the highest cleanliness consisted of 99.8\% (Table 1). This indicator was 98.6\% when the diameter of the sieve hole was 5 mm, and the round holes were slightly lower, at 82.3\%, with a 6 mm diameter. In the separation of large other impurities in the grain mixture, the elongated rectangular diameter of 5x20 mm was also tested, where the separation of large impurities was very low and was 76.1\%. This is due to the increased likelihood of large additives joining the grains as they grow in size.

The collapsed joints investigated not only the separation quality of the compounds but also their extinction. Grain losses were observed only for high sieve holes with a diameter of 4 mm, which was 6.4\%. This is since grains larger than 4 mm in thickness are removed from the mold by joining large compounds without being labeled.

| Types of sieve hole | Separating completeness of mixtures (%) | Grain losses (%) |
|--------------------|---------------------------------------|-----------------|
|                    |                                       |                 |

Table 1. Influence the type of sieve hole to work quality
When selecting for cleaning grain from small additives, long rectangular shape of hole 2x18 mm with round holes 2 mm and 3 mm in diameter used. Comparison of these compounds showed that 95.2, 97.3, and 96.1 % respectively, of the extraction, compounds less than the grain size. As it turns out, grains have achieved almost similar results in the separation of grain from fewer impurities. However, grain loss was 0.3% in round-holed diameter with a diameter of 2 mm, which was 4.9% higher than a round hole diameter of 3 mm. In the rectangular shapes of the hole with 2x18 mm sized, the grain loss was 2.4%. This is 8 times higher than that of a round-holed sieve with a diameter of 2 mm, and 2 times lower with a diameter of 3 mm. From a comparison of the above results, an upper sieve that round-holed diameter with a diameter of 5 mm and a lower sieve hole diameter of 2 mm was selected for the grain of the grain cleaner.

To study the performance characteristics of the sieve of grain cleaning machine, the experiments were compared with the oscillation frequency of the sieve \( n_f = 140 \) rpm, sieve longitudinal oscillation amplitude \( A_l = 30 \) mm, slope angle \( \alpha_s = 14^\circ \) the grain cleaning efficiency was 99.3 % during the experiments and the losses were 0.7 % (Table 2). In the same parameters and operating modes, but with a transverse oscillation of \( A_t = 5 \) mm, the grain’s cleanliness increased partially to 99.5 %, and its losses decreased to more than twice to 0.3 %.

### Table 2. Work quality indicators of the sieve of grain cleaning machine

| Names of indicators | Amount of indicators                  |                     |
|---------------------|---------------------------------------|---------------------|
|                     | longitudinal oscillation sieve        | longitudinal-      |
|                     |                                       | transverse         |
|                     |                                       | oscillation sieve  |
| Grain cleanliness \( C_g \) (%) | 99.3                                 | 99.5                |
| Grain losses \( L_g \) (%)      | 0.7                                  | 0.3                 |

The two types of sieves tested at different oscillation frequencies to better study the performance. In experiments, the frequency of oscillations increased from 100 rpm to 175 rpm, while the grain cleanliness in the longitudinal oscillations increased from 98.8 % to 99.5 %, while the frequency of oscillations increased from 175 rpm to 200 rpm and decreased to 99.4 % (Fig. 4). When the frequency of the oscillation increased from 175 rpm to 200 rpm, grain cleanliness decreased because of passing the major impurities with together grain through the hole of the sieve.
In the longitudinal-transverse oscillation sieve, when the frequency of oscillations increased from 100 rpm to 175 rpm, grain cleanliness increased from 99.2 % to 99.6 %, and the frequency of oscillations increased from 175 rpm to 200 rpm this indicator did not change. In general, grain cleanliness was higher in longitudinal-transverse oscillation sieve than in longitudinal oscillation sieve at all frequencies.

The grain losses were defined too at these oscillations frequency of the sieve. It was the same for the two types of a sieve at the frequencies of 100 rpm and 125 rpm it consisted of 0.2 and 0.3 % respectively. When the oscillations frequency increased from 150 rpm to 200 rpm it was observed the significant difference between this indicator of two types of the sieves (Fig. 4).

In particular, at 150 rpm, the grain loss was 0.7 % in the longitudinal oscillations and 0.3% in the longitudinal-transverse oscillations. This indicator increased at sieve with longitudinal oscillations at frequency 175 rpm and 200 rpm reaching 1.3 and 2.7 %, however, the grain losses in the sieve with longitudinal-transverse oscillations were slightly lower, at 0.5 and 0.9 % in these frequencies.

According to the previous experiments, the quality indicators of longitudinal-transverse oscillation sieve on the same loads are 1.2 – 2.3 times higher than the longitudinal oscillation sieve. This is the basis for the development of grain cleaning machines with high work efficiency.

4. Conclusions

According to the researches, it was defined that the work quality indicators of the longitudinal-transverse oscillation sieve on the same loads are 1.2–2.3 times higher than those of longitudinal oscillation sieve. It is recommended that the oscillations frequency of the longitudinal-transverse sieve become $n_p=140-175$, longitudinal oscillations amplitude $A_l=30$ mm, transverse oscillations amplitude $A_t=5$ mm and slope angle $\alpha_s=14^\circ$. In these operating parameters of the sieve, it was achieved that the grain losses are not more than 0.5 % and the cleaning efficiency is 99.6 %.

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