Studying the design and operational parameters of the sieve module of the grain cleaning machine

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Abstract. The purpose of the study is to improve the efficiency of sieve cleaning by justifying the kinematic mode of operation and a rational scheme for the distribution of sieves in mills, depending on their purpose. Raw combine heaps of winter wheat of the “Alay Zarya” variety and barley of the “Priazovsky 9” variety were used as grain material. The conducted research allows us to justify the angles of inclination of the ear sieves, which should be located in the upper tier with an angle of inclination to the horizon of 7° and be equipped with lattice cloths with round holes (a diameter of 7.5 or 8.0 mm). The frequency of oscillation of the sieve mill must be selected in the range of 340–370 min⁻¹, which provides the maximum completeness of the selection of feed fractions by sorting sieves. In one tier in length, preference should be given to the placement of three lattice cloths.

1. Introduction

The increase in grain production in Russia highlights needs to improve the system of post-harvest processing, which includes two main areas: cleaning grain for commercial purposes and cleaning grain to obtain seed material, sorting or dividing it into fractions in various ways [1–5]. Production lines are currently mainly used to produce commercial grain and seeds [6]. The basis of such production lines are universal double-aspiration air-sieve machines which can be used both for cleaning grain for commercial purposes and for preparing seeds when changing the operating mode [4, 7].

Two-aspiration grain cleaning machines include two aspirations. The first one performs cleaning of grain from light impurities, and the second aspiration selects from the pile of puny, biologically incomplete and crushed grain, which is one of the main parts of the feed fraction [4, 5].

The separation of fine grain into the feed fraction is the task of sieve cleaning. The quality of separation of the heap into fractions depends on the operation of the aspiration system of machines and sieve cleaning, especially the main sorting sieves [2, 7–9].

The selection of the feed fraction by size and the size of the feed fraction on sieves depends to a large extent on the schemes of their placement in the sieve mill and the kinematic mode of operation [7, 9].

2. Materials and methods

Experimental studies were conducted in the laboratory of the Department of agricultural machinery, tractors and automobiles. As grain material, raw combine heaps of winter wheat of the “Alay Zarya”
variety and barley of the “Priazovsky 9” variety were used. The study was carried out on an experimental installation, the scheme of which is shown in figure 1.

Figure 1. The scheme of the experimental installation: 1 – front and rear suspension; 2 – drive mechanism of the mill; 3 – tray for output of refined grain; 4 – tray for output of feed fraction; 5 – rack; 6 – sorting sieve; 7 – spike sieve; 8 – divider; 9 – sieve mill; 10 – loading device; 11 – two-respiratory pneumatic system; 12 – frame

The installation includes: a frame 12, a two-air pneumatic system serviced by a single air flow 11, a loading device 10, a sieve mill 9 with a tier of ear sieves 7, and three tiers of sorting sieves 6. The sieve mill 9 contains a grain divider 8 for dividing the grain heap into equal parts between tiers of sorting sieves. The mill is divided into two parts and its upper part is attached to the lower part pivotally for the possibility of changing the angle of inclination using the stand 5. For the separate output of the formed fractions, the mill contains trays for the output of the refined grain 3 and trays for the output of the feed fraction 4 separately from each variety sieve. The mill is suspended on the frame by means of front and rear suspensions 1 of different lengths, which allows one to adjust the angle of its inclination in relation to the horizon. The reciprocating movement of the mill is reported by the drive mechanism of the mill 2. In the upper part of the mill, 7 grid panels with round holes of 7.0 mm are installed, the maximum length of which is 1.94 m on the installation. In the lower part of the mill, there are sorting sieves 6 with webs with oblong holes of 2.6 mm, the maximum length of which is 2.91 m in one tier. Sorting sieves on the experimental plant were placed in one, two or three tiers.

The installation provided the possibility to change the tilt angle of grains sieves in the range from 5º to 12º by changing the length of the strut 5 mill, feed grain on the material by a metering valve and the oscillation frequency. The oscillation frequency of the grid mill was changed by changing the rotation frequency of the electric motor of the mill drive in the range from 250 to 400 min⁻¹ using the frequency Converter STA-A2.

The oscillation frequency of the sieve mill was measured using a mechanical tachometer PM10-R. The angle of inclination of the sieves was measured with a BOSCH GLM 100 C Professional laser rangefinder. The divider 8 for dividing the grain pile into equal parts at two and three tiers was made in accordance with the technical solution under patent No. 2708970 RU (Figure 2).

The grain material divider contains a housing consisting of side walls 1, a back wall 4 with a receiver 2, and a front wall 5. Between the front 5 and back 4 walls, vertical partitions 3 are placed at the same distance, forming different sections 9 that are open from above and from below with the walls. The quantity of sections 9 multiple of the number of tiers of sorting sieves in the lower part of the sieve mill. In the front wall 5 of each section 9, windows 8 are made at three levels in height, and the interval in height of the windows 8 corresponds to the distance in height of the installation of sorting sieves 7 in the lower part of the mill. Each window 8 of the sections 9 at the base contains a
partition, made in the form of a pitched tray 6 and extending to the back wall 4 of the section 9. On the front side, the partitions extend beyond the front wall of the 4 sections, which ensures that they overlap on the corresponding tier of sieves in the lower part of the mill. On the side walls 1, crowns 7 are fixed on the outside to install the grain divider along the guide rails of the grating mill.

Figure 2. Divider diagram: 1 – side walls; 2 – receiver; 3 – vertical partitions; 4 – rear walls; 5 – front walls; 6 – pitched trays that serve as the bottom; 7 – brackets; 8 – window; 9 – different sections

The characteristics of the initial pile were determined using laboratory RL-1 sieving with a set of sieves with oblong and round holes. The average thickness of wheat and barley grains, was 2.46 mm and 2.72 mm, respectively; the weight of 1000 seeds was 33.2 g and 40.5 g, and the average square deviation of the thickness was 0.83 mm and 0.82 mm.

3. Results and discussion
The results of experimental studies on the influence of the angle of inclination of the ear sieve and the frequency of mill oscillation on the loss of full-fledged grain from the sieve are presented graphically in figure 3.

Figure 3. Losses of grain heap from ear sieves (P) depending on the frequency of vibrations of the sieve mill (n) at different angles of their installation to the horizon: a – wheat; b – barley.

As can be seen from figure 3A, with increasing frequency of oscillation of the sieve mill, grain losses from the ear sieves increase regardless of the angle of inclination. When the angle of inclination is not more than 7°, grain losses do not exceed the permissible [P]=0.5% even at a frequency of 400
min$^{-1}$ and the working length of the ear sieve is 0.6 m. Increasing the angle of inclination to 9° increases the speed of moving the heap along the ear sieve, but grain losses remain less than acceptable. A different character of the change in the grain yield from the ear sieves on the pile of wheat is observed at the angle of inclination of 12°.

When the oscillation frequency increases from 250 to 300 min$^{-1}$, grain loss does not exceed the allowable value. In the future, when the frequency of fluctuations from 310 to 400 min$^{-1}$, the grain yield increases sharply and makes up from 0.8 to 2.0 %, which exceeds the agricultural testing. This allows us to conclude that the angle of inclination should not exceed 12°, and the frequency of vibrations of the mill should be from 250 to 280 min$^{-1}$.

The results of the research on the justification of the frequency of oscillation of the sieve mill and the angles of inclination of the ear sieves during barley cleaning are presented in figure 3b.

Their analysis shows that the loss of grain from ear sieves during the cleaning of barley at a higher rate with an increase in the frequency of vibrations of the sieve mill than during the cleaning of wheat. Only when the sieve angle is 5°, the loss of full grain does not exceed the permissible [P]=0.5% at all frequencies. Even at the angle of inclination of 7°, the grains become larger than the permissible ones at the frequency of oscillations above 340 min$^{-1}$. With increasing the angle of installation of the ear sieves to the horizon up to 9°, the losses do not exceed the permissible values only at frequencies of 250-280 min$^{-1}$, and at the angle of inclination of the sieves 12° – only at the frequency of 250 min$^{-1}$.

Thus, the conducted research allows us to state that when cleaning barley on a sieve mill, it is rational to install ear sieves at an angle of inclination to the horizon of no more than 7°, and the frequency of vibrations of the sieve mill should not exceed 340 min$^{-1}$.

For the final selection of the rational oscillation frequency of the sieve mill, an assessment of its influence on the operation of sorting sieves was carried out. One can evaluate the work of sorting sieves only by the completeness of the feed fraction selection. The lower tier of the sieve mill included three consecutive sorting sieves with an angle of inclination of 9° and the output of each fraction in a separate collection. Changing the completeness of the selection by sorting grids is shown in figure 4.

When cleaning wheat, as can be seen from the graphic dependence, the maximum efficiency of the feed fraction allocation falls on the frequency of oscillations of the sieve mill 340 min$^{-1}$. For sorting barley into fractions, the rational frequency range is higher and ranges from 280 to 370 min$^{-1}$. Thus, the results of the research allow us to conclude that it is not advisable to increase the frequency of oscillations above 340 min$^{-1}$.

The results of the studies on the effect of feed on the efficiency of separation of feed fractions by an air-grid separator are shown in figure 5.

As can be seen from the presented data, when installing a single sorting solution, the maximum completeness of the feed fraction allocation at a specific feed of 0.5 t/(h·dm) does not exceed 50 %,
which does not even meet the agrotechnical requirements for pre-cleaning. Installing a second sorting sieve in length allows meeting the agrotechnical requirements for cleaning grain for commercial purposes with a specific feed of more than 2.0 t/(h·dm).

![Figure 5](image_url) **Figure 5.** The effect of the specific feed of the heap (Q) on the completeness of the feed fraction (ε) allocation at different lengths of sorting sieves (L)

Preparation of seed material with a specific feed of less than 0.5 t/(h·dm) is only possible if a third sorting sieve is installed in the length of the tier. The diagram shown in figure 6 shows experimental data that characterize the change in the completeness of the separation into fractions for different schemes of sorting sieves.

![Figure 6](image_url) **Figure 6.** Influence of the number of tiers of sorting sieves (n1) on the completeness of the separation of the feed fraction by the separator (ε)

As can be seen from the above diagrams, a single-tier arrangement of sorting sieves for the feedings under consideration cannot provide the fullness of the feed fractions in size required for seeds. Adding another tier of sorting sieves to the sieve mill with their length in the tier of at least two guarantees the preparation of commercial grain with the completeness of separation into fractions of 0.67...0.73 with an acceptable specific feed from 0.5 to 2.0 t/(h·dm). The three-tier arrangement of sorting sieves for specific feedings up to 1.5 t/(h·dm) ensures the fullness of separation into fractions required for seeds, even when two sorting sieves are installed on each tier in length.

4. Conclusion
The conducted studies allow us to justify the angle of inclination of the ear sieves, which should be located in the upper tier with an angle of inclination to the horizon of 7° and be equipped with lattice cloths with round holes with a diameter of 7.5 or 8.0 mm. When using a machine for seed preparation, one tier of ear sieves is sufficient. The frequency of oscillation of the sieve mill must be selected in the range of 340...370 min⁻¹, which provides the maximum completeness of the selection of feed fractions by sorting sieves installed in three tiers and equipped with grid cloths with oblong holes for separating...
grain into fractions by thickness. In one tier in length, preference should be given to the placement of three lattice cloths.

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