Experimental Study of a Pneumatic Separator

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Abstract. The article provides information on the relevance of grain cleaning in modern agricultural production. A model of a new pneumatic centrifugal grain separator is proposed. Experiments have been carried out to determine the quantitative and qualitative indicators of the separator's operation. The dependences of the completeness of separation and grain losses on the supply and the resulting air velocity have been obtained. The analysis of the obtained dependencies is carried out and recommendations are given on the use of the separator and its rational modes for preliminary, primary and secondary cleaning of grain.

1. Introduction

Agriculture in the north of the Omsk region is going through far from the best times. The equipment of Agricultural Production Cooperatives (APC) and Peasant Farm Economies (PFE) grows old and wears out, breaks down. The material and technical base is clearly outdated and does not meet the modern requirements of a market economy. This is especially true of the base of the grain-flow economy [1].

Many units and complexes supplied to collective and state farms in the 60s and 70s of the last century (mainly ZAV-10, ZAV-20, KZS-10, KZS-20) are outdated morally and materially. The machines with which they were originally equipped fail due to wear and tear, rust due to a leaky roof [2]. All this entails a deterioration in the quality of both food grain and seed [3]. Currently, there are projects for the modernization of outdated units and complexes, mainly related to equipping with new machines, replacing the roof and walls. However, this modernization is often costly for farms [4].

In the last few turns, APCs and PFEs, which have replaced collective and state farms, give up part of the sown area. Accordingly, grain cleaning and drying equipment, designed for large sown areas in terms of productivity, is now clearly in excess. If in the past grain-drying complexes (GDC) worked in 2-3 shifts, now they work during daylight hours [5]. Right now the time is ripe for the creation of fundamentally new machines for cleaning grain. These are gravity separators, pneumatic grain separators such as SAD, Almaz and others. Magnetic, dielectric and other types of grain cleaning are developing. With the use of modern grain cleaning technologies, circles, string sieves and other novelties of the past are forgotten [6].

2. Main part

We have proposed a new design of a vortex pneumatic grain separator figure 1. The separator works as follows: grain with impurities is fed from the feeding hopper 2 to the splitting cone 3. It has screw blades to unwind the grain flow and enter it into the blowing chamber at an initial speed. Upon entering the
latter, the grains are separated according to the critical hover rate and volumetric weight. The heaviest fraction, consisting of the seeds of the main crop, falls into the receiver of fractions 5. The fodder impurities are carried by a large amount and enter the receiver of fractions 6. Further of all fractions, light impurities fly off, falling into the receiver 7. Dusty air comes out through the outlet channel 8. A suction fan (not shown in the diagram) can be installed in the outlet channel.

This separator has the following adjustments:
1. Air flow rate. This quantity has two mutually perpendicular components: tangent and normal. The first seeks to spin the grain-air mixture, the second – to throw particles from the center of rotation under the action of centrifugal force. The speed is controlled by the fan impeller speed by varying the DC voltage supplied to the DC motor. The value of the air flow velocity is measured at a distance of 100 mm from the cylindrical surface at the point where the turbulent phenomenon disappears, depending on the number and shape of the blades. The air velocity is measured in radial and tangential directions using a Pitot-Prandtl tube with an accuracy of 0.5 m/s. For the experiments, the resulting velocity was calculated, obtained as the geometric sum of the tangent and normal velocities. The experiment was carried out on the values of the resulting velocity, fixed for the values: 4.5±0.25 m/s; 6.0±0.25 m/s; 7.5±0.25 m/s; 9.0±0.25 m/s; 10.5±0.25 m/s [7].
2. The load of the grain mass on the separator is regulated by the feed mechanism by opening the metering flap. Fixed load values are: 60 ± 2.5 kg/h, 90 ± 2.5 kg/h, 120 ± 2.5 kg/h, 150 ± 2.5 kg/h, 180

Figure 1. Diagram of a centrifugal pneumatic grain separator: 1 – separator body; 2 – dosing hopper; 3 – dissecting cone; 4 – fan impeller; 5 – receiver for heavy fraction (refined grain); 6 – receiver of fodder fraction; 7 – receiver for light impurities; 8 – outlet duct for dusty air;

– refined grain; – fodder impurities; – light impurities; – dusty air.
± 2.5 kg/h. The load is measured by determining the mass of the issued grain mixture during the experiment (30 seconds) and recalculated per hour of operation of the installation.

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The grain heap to be cleaned consisted of the main crop – Wheat Rosinka, zoned for the north of the Omsk region and a mixture of weeds: wild oat – 2.4%, wheatgrass seeds – 2.8%, fresh intake – 0.9%, Kostyor Bezosty – 0.5%, chaff – 0.5%, failure – 1.5%. The initial heap was taken in the form of samples from the bunkers of the Yenisei-954 combine harvesters and was the harvest of 2020. The evaluation of the composition of the grain heap was carried out by the gravimetric method carried out on an electronic balance with an accuracy of 0.5 g [8].

The completeness of the separation of trash impurities (completeness of separation) and the loss of the main crop were taken as optimization criteria. The first criterion was assessed by the amount of trash impurities released by the separator in relation to all trash impurities present in the original heap. The second criterion was assessed by the mass of grain of the main crop that got into waste together with light impurities. Separation completeness and losses are measured as a percentage. Depending on the values of these quantities, preliminary, primary and secondary grain cleaning, as well as grain cleaning machines, are distinguished [9].

The experiments were carried out according to the classical experiment by the method of enumerating factors with one fixed. Each experiment was carried out in four repetitions. Each repetition of the experiment was carried out in the following sequence: thoroughly mixed grain was poured into the hopper in the amount necessary for the experiment, the fan was turned on, the required air flow rate was set according to the supply voltage and through the Pitot-Prandtl tube, and the supply of the initial grain material was turned on in accordance with the plan of experiments. ... At the same time, the stopwatch was activated for 30 seconds. After the expiration of the experiment, the grain supply was turned off, and then the fan. At the end of the experiment, the grain material fractions were weighed and disassembled manually. The arithmetic mean of the separation completeness and losses of the main culture was calculated, as well as the standard deviation [10].

Based on the results of the experiment, we build the dependences of the completeness of grain separation on the feed and the resulting speed (figure 2) and grain losses on the feed and the resulting speed (figure 3).

![Figure 2](image_url)  
Figure 2. Dependence of the completeness of grain separation on the feed and the resulting speed.
3. Conclusion
The following conclusions can be drawn from the results of experimental studies:

1. The dependence of the separation completeness on the grain supply at all values of the resulting air flow velocity is inversely proportional, which does not contradict common sense and the results of experiments of other scientists.

2. The dependence of the completeness of separation on the resulting air flow rate is directly proportional. With an increase in the latter, a greater amount of impurities are blown out of the grain heap, which is also logical.

3. Loss of grain is almost equally dependent on the grain feed and the resulting speed. At low grain feeds, its losses are higher, which is explained by the large removal of impurities and, along with them, the seeds of the main crop. In the receiver of light impurities, more shriveled seeds of the main crop get into the receiver, which is also confirmed by visual observation. With an increase in feed, the amount of impurities separated on the separator per unit of time also increases.

4. With an increase in the resultant air velocity, grain losses increase, since the critical velocity of puny caryopses is lower than that of full-fledged ones, and the air flow easily raises them too.

Further, we will determine which grain cleaning corresponds to a greater extent to the tested separator. To do this, refer to the table describing cleaning and grain cleaning machines (table 1).

| Cleaning, sorting of grain and seeds | Completeness of separation, % | Loss of main crop, % |
|-------------------------------------|-------------------------------|---------------------|
| Preliminary                         | 50                            | 0.05                |
| Primary                             | 60                            | 1.5                 |
| Secondary and special               | 80                            | 1.0                 |

When comparing the results of the experimental study with the tabular ones, the following was obtained:
1. It is more profitable to carry out preliminary grain cleaning at grain feeds equal to 150 and 180 kg/h at air speeds of 4.5 ... 6.0 m/s. In these cases, light and coarse impurities are separated, and the separation completeness exceeds 50%. Grain losses do not exceed the established 0.05%.

2. It is more profitable to carry out the primary cleaning of grain at grain feeds equal to 120 ... 180 kg/h at air speeds of 4.5 ... 9.0 m/s. With an increase in grain feed, the rational speed increases proportionally.

3. Secondary cleaning of grain is more profitable to carry out at grain feeds equal to 60 ... 120 kg/h at air speeds of 4.5 ... 7.5 m/s. With an increase in grain feed, the rational speed also increases proportionally.

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