Impact of the precleaner pneumatic duct on the grain dresser performance

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Abstract. There is a wide variety of seed cleaners capable of functioning in seed treatment mode as part of the grain dresser. The most promising is the modernization of existing seed cleaning units, since it is possible to use their construction part, which will significantly reduce the cost of upgrading the production line for obtaining the seed material in the post-harvest processing. The goal during the equipping is to create an optimal set of grain dressers that allow getting seed material in one pass through the unit, minimizing micro and macro damage, which in turn affect future productivity. The goal of the research was to assess the impact of the precleaner pneumatic duct on the operation of the entire cleaning department.

1. Introduction
At the present time, the problem of obtaining high-quality seed material is becoming more and more urgent, which is not possible without the use of post-harvest processing. The mechanization of this process is carried out mainly for grain dressers having various sets of machines, which are able to function in various modes and arrangements. Currently, most of these aggregates require repair and modernization and are far beyond the service life. At the same time, the construction part allows bringing it into working condition with minimal expenses, which cannot be said about the technological department. The question arises when solving the modernization problem, such as what kind of machines the aggregates need to be equipped with and how do these machines affect the performance of grain dressers. In this regard, understanding the impact of each machine on the technological process will allow equipping the grain dressers with an optimal set of machines.

The necessity for testing the solutions by testing existing grain dressers, which operate in various modes and include a different set of machines, was created. This necessity is based on a number of works on analyzing the functioning of aggregates operating according to various layouts [1-3] and on the works characterizing the degree of influence of a particular technological operation on the entire system as a whole [4-7]. It is also based on modern methods and principles for constructing systems of private technological operations [8], modern mathematical models [9-10] and methods for modeling technological processes occurring in the grain dressers [11-12].

2. Materials and methods
In order to test the hypotheses, a universal grain dresser located at the trashing floor of the Mayorsky farm, Oryol district, Rostov region, was taken as the base (Figure 1). It can function in primary and seed treatment modes.
The functional diagram of the aggregates’ grain dressing department (Figure 2) includes the following machines: MPO-50 with an aspiration system and without a skeletal device, an air-sieve seed cleaning machine VRM-6, a BTZ-700 indented cylinder, a gravity table, NPK-50 (N1) cup elevator and NPK-25 (N2, N3, N4).

The aggregate (Figure 2) is capable of operating in two modes. During the precleaning of the grain material, it enters the MPO-50 machine from the dump pit, then it is delivered to the VRM-6. During seed cleaning, the grain material enters the MPO-50 machine, then it is delivered to the VRM-6, the indented cylinder and the gravity separator. In order to make comparison, the tests were conducted in the case when the grain material in the seed cleaning mode entered directly into the VRM-6 machine bypassing the pneumatic duct of the MPO-50 machine.

Figure 1. Universal grain dressing aggregate.

Figure 2. Functional diagram of a universal grain dressing aggregate.

Large, light, small waste enters the hopper of weed impurities, grain impurities enter the fodder hopper, refined grain enters the refined grain hopper, and seeds enter the seed hopper.
Adjusting the sieves in the VRM-6 sieve machine as follows to ensure the quality of the peeled seed for seed purposes: 1st sieve’s screen aperture is 1.7 mm; 2nd - 2.0 mm; 3rd - 3.6 mm.

Tests of the stationary grain dressing aggregate were carried out in order to determine the technological performance indicators of the aggregate according to a sequential scheme. An additional air separator with a forced air flow was used in the MPO-50 grain preliminary cleaning machine if comparing to the prototypes (for example, the ZAV-40 aggregate). The MPO-50 fulfills the agrotechnical requirements for cleaning seed material.

Assessing the seed cleaning performance of the grain dressing aggregate prototype was carried out after their rational adjustment and stabilization of operating modes. Sampling of grain and weed fractions was carried out in accordance with the requirements of Russian State Standard GOST 12036-85.

When testing the grain dressing aggregate in the seed cleaning mode, the initial seed material had the following composition: grain – 91.8%; straw impurities – 0.1%; big impurities – 0.76%; feeble grain – 3.4%; small weed impurities – 1.2%; crushed grain – 1.9%; weed seeds – 0.7%; organic impurities – 0.14%. Sampling and separating the weighing batch was carried out according to Russian State Standard GOST 12036-85. An assessment of grain microdamage after each machine was made when testing the unit.

3. Results
The resulting indicators of grain microdamage after passing through the machines are presented in table 1. The results of aggregate operation in seed cleaning mode are presented in Figure 3.

Table 1. The resulting indicators of grain microdamage after passing through the machines.

| Name of sampling location | Scheme No. 1 MPO+VMR-6+TB+PS | Scheme No. 2 VMR-6+TB+PS |
|---------------------------|-------------------------------|---------------------------|
| Dump pit (source grain material) | 41; 42; 44; 40; 43; 40; Average - 42 | 41; 42; 41; 43; 45. Average $\bar{m}_1$ = 42.4 |
| After MPO-50 machine | 42; 43; 40; 42; 44. Average $m_2$ = 42.2 |
| After VRM-6 machine | 58; 59; 56; 57; 59. Average = 57.8 |
| After indented cylinder | 61; 63; 62; 65; 62. Average = 62.6 |
| After gravity separator | 66; 67; 68; 66; 68. Average $m_3$ = 67 |

Dispersion $\sigma^2_1 = 2.8$

Dispersion $\sigma^2_2 = 2.2$

Dispersion $\sigma^2_3 = 1$

Dispersion $\sigma^2_4 = 1.7$

$F_p = 1.7$ => dispersions are homogeneous, $t_p = 0.272$ => the difference in the readings of microdamage to the grain material is not statistically significant.

Assessing the impact of the pneumatic duct in the MPO-50 machine on the growth of microdamages. In order to assess the statistical significance of the differences, the Student’s test was used. The dispersion homogeneity of the samples was determined using the F-test. In order to carry out the test, the average values of grain microdamage were determined for each weighing batch $k$ and their dispersion $\sigma^2_k$. 

$F_p = 1.7$ => dispersions are homogeneous, $t_p = 0.272$ => the difference in the readings of microdamage to the grain material is not statistically significant.
\begin{equation}
    m_k = \frac{\sum_{i=1}^{n_k} m_{ki}}{n_k};
\end{equation}

\begin{equation}
    \sigma_k^2 = \frac{\sum_{i=1}^{n_k} (m_{ki} - \bar{m}_k)^2}{n_k - 1}
\end{equation}

Numerical characteristics of random variables are given in table 1.

Assessing the calculated values of the F-test:

\begin{equation}
    F_p = \frac{\sigma_\delta^2}{\sigma_{\delta_k}^2}
\end{equation}

\begin{equation}
    F_p = \frac{2.8}{2.2} = 1.27
\end{equation}

For the test significance \( \alpha = 0.05 \) and the number of freedom degrees for the dispersion of the numerator and denominator \( K = 5 - 1 = 4 \), \( F_T = 6.39 \). Under the condition \( F_T > F_p \), the dispersions obtained as a result of the calculation with the probability error \( \alpha = 0.05 \) are homogeneous. Therefore, taking into account the normal distribution law of random variables \( m \), the statistical significance of the differences in the average values of the samples can be evaluated.

Assessment of the statistical significance of differences in the average values \( \bar{m}_k \) of the compared \( k \)-th samples using Student's t-test.

The calculated value of the Student t-test:

\begin{equation}
    t_p = \frac{\bar{m}_1 - \bar{m}_2}{\sqrt{(n_1 - 1)\sigma_\delta^2 + (n_2 - 1)\sigma_{\delta_k}^2}} \sqrt{\frac{n_1n_2(n_1 + n_2 - 2)}{n_1 + n_2}}
\end{equation}

\begin{equation}
    t_p = \frac{42.4 - 42.2}{\sqrt{(5-1) \cdot 2.8 + (5-1) \cdot 2.2}} \sqrt{\frac{5 \cdot 5 \cdot (5+5-2)}{5+5}} = 0.2
\end{equation}

Table value of Student's t-test: for the number of freedom degrees \( K = n_1 + n_2 - 2 = 5 + 5 - 2 = 8 \) and significance level \( \alpha = 0.05 \), \( t_r = 2.306 \).

The calculation results are summarized in table 2.

If the \( t_r > t_p \), then null hypothesis is accepted and the average value \( \bar{m}_k \) is statistically not significantly greater than the average value \( \bar{m}_1 \) with a confidence probability of 0.95. Thus, the grain dressing in the pneumatic duct does not significantly affect microdamage of the grain material. Similarly, the statistical significance of differences in the indicators of microdamage after a gravity table was assessed. The results are presented in table 1.
4. Analyzing the results

In order to analyze the obtained test results presented in Figure 3, the limit of possible discrepancies of the sample average $\overline{d}_i$ and general average $\overline{d}$ purity of the seed material is determined.

For the freedom degrees number $k=(n-1)=(5-1)=4$ and the significance level $\alpha = 1 - \beta = 1 - 0.95 = 0.05$, the Student t-test value corresponding to a confidence probability of $0.95 - t=2.571$ was determined.

The absolute error of the sample average (compared with the general average) is determined using the following formula:
\[(\bar{A}_j - \bar{A}_d) = t \frac{s_d}{\sqrt{n-1}}\]

where \(s_d\) is the standard deviation of the purity values of the grain material.

The calculation results are summarized in table 2.

### Table 2. Absolute error calculation results.

| Material purity and repetition of experiment | With MPO Aggregate feed, kg/s | Without MPO Aggregate feed, kg/s |
|---------------------------------------------|-------------------------------|---------------------------------|
|                                             | 0.62                         | 0.12                           | 1.55 | 2.1 | 2.45 |
| Material purity and repetition of experiment |                               |                                | 1.99168 | 0.99049 | 0.99074 |
|                                             | 0.99160 | 0.99074 | 0.990319 | 0.989001 | 0.99164 |
| Material purity and repetition of experiment | 0.99155 | 0.99069 | 0.990289 | 0.989314 | 0.99165 |
|                                             | 0.99163 | 0.99050 | 0.990433 | 0.989026 | 0.99133 |
|                                             | 0.99165 | 0.99059 | 0.990343 | 0.989263 | 0.99179 |
|                                             | 0.99162 | 0.99060 | 0.990326 | 0.989026 | 0.99179 |
| Material purity and repetition of experiment | 0.99162 | 0.99060 | 0.990326 | 0.989026 | 0.99179 |
|                                             | 0.99162 | 0.99060 | 0.990326 | 0.989026 | 0.99179 |
| Material purity and repetition of experiment | 0.99162 | 0.99060 | 0.990326 | 0.989026 | 0.99179 |
|                                             | 0.99162 | 0.99060 | 0.990326 | 0.989026 | 0.99179 |
| Material purity and repetition of experiment | 0.99162 | 0.99060 | 0.990326 | 0.989026 | 0.99179 |
|                                             | 0.99162 | 0.99060 | 0.990326 | 0.989026 | 0.99179 |

5. Conclusions
An analysis of the results showed that the aggregate’s productivity, taking into account agricultural requirements (seed purity 99%), with the working pneumatic duct of the MPO-50 machine was 2.45 kg/s (8.82 t/h). It was 2.1 kg/s (7.56 t/h) without the pneumatic duct of the MPO-50 machine during cleaning. The presence of a pneumatic duct in the arrangement of the production line can significantly increase the performance of the grain dresser aggregate while observing agricultural requirements without a significant increase in micro and macro damage to grain.

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