Advances in Social Science, Education and Humanities Research, volume 393
The Fifth Technological Order: Prospects for the Development and Modernization of the Russian Agro-Industrial Sector (TFTS 2019)

# Investigational Study of Grain Separator Operation with Cylindrical Shaker Screen of Improved Orienting Ability

Vladimir Koval
*Department of Agronomy and Agricultural Engineering*
*Tara branch of the Omsk State Agrarian University named after P.A. Stolypin*
Tara, Russia
ORCID: 0000-0001-6667-0187

Maxim Begunov
*Department of Agronomy and Agricultural Engineering*
*Tara branch of the Omsk State Agrarian University named after P.A. Stolypin*
Tara, Russia
ma.begunov@omgau.org

Alexey Chernyakov
*Department of Agronomy and Agricultural Engineering*
*Tara branch of the Omsk State Agrarian University named after P.A. Stolypin*
Tara, Russia
av.chernyakov@omgau.org

Alexander Yatsunov
*Department of Agronomy and Agricultural Engineering*
*Tara branch of the Omsk State Agrarian University named after P.A. Stolypin*
Tara, Russia
an.yatsunov@omgau.org

***Abstract*— The article is devoted to the process study of grain separation on a double-sieved separator with cylindrical shaker screens with improved orienting activity using the planned experiment. Grain cleaning is a matter of pressing concern for agricultural production, because with the increased weed infestation, the load on the machines of grain post-harvesting has increased. This article presents the elements of the planned experiment processing. The regression equation adequate at the 5% significance level is obtained. The dependences of the qualitative characteristics of the sieve boot - the completeness of the separation from the variable parameters: the specific load on the working elements, the angle of inclination of the sieve holes and the oscillation frequency of the working elements are constructed. The interpretation of the processes occurring during the grain material movement on the perforated area is given. Rational design and operational parameters of the separator intensifying the separation process are determined. Conclusions on the study results are formulated.**

***Keywords—grain purifier, separation, sieves, grain heap.***

## I. Introduction

Grain-cleaning and sorting equipment has gone a long way of formation from unconnected machines on the asphalt area to complexes for cleaning and drying of grain material [1].

Many scientists have toiled in the vineyards of theoretical bases creation of grain separation and the design of new separators nodes. [2].

A tremendous amount of experimental research was carried out in laboratories of different scales in order to create modern machines and their working elements.

In modern agriculture, along with the solved problems of bringing the process of grain cleaning to the industrial level, there are not fully worked out issues, in particular-with primary and, especially – secondary cleaning. [3].

In seed growing, there is a shortage of grain-cleaners, while a number of scientists note that their share is about 12% of the required amount [4]. This leads to the conclusion that the grain-cleaners operate with significant overloads in excess of the standard, which affects the quality of the grain material. The working element in many grain-cleaners is a flat perforated screen [5]. Broadly, the separating power of grain-cleaners is limited by the performance of the sieve boot. In the course of the years of formation of grain-cleaners the set of ways and receptions of increase of qualitative and quantitative indicators of grain-cleaners with flat-sieved working elements was brought forward. One of the promising ways to increase the quantitative and qualitative indicators of grain-cleaners is the use of shaker screens with improved orienting ability [6]. This technical solution allows to combine the advantages of both flat-sieved separators and machines, the working elements of which make oscillating movements, and the location of the holes at an angle further allows to intensify the separation process [7]. This drive configuration and sieve position is used because of the unexplored operation.

This article is devoted to experimental studies of the separator operation with swinging working elements with improved orienting ability [8].

research methodology

The orientation of the oblong holes on the separator working elements is shown in figure 1.

The single seed has an oblong shape and, thus, is oriented along the long sides of the rectangular holes of the sieve, which has a positive impact on the probability of passing the small fraction [9].

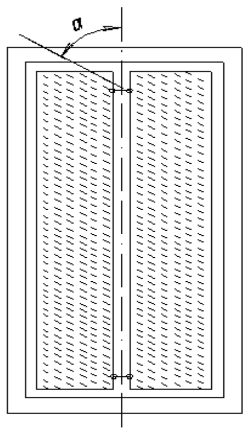


Fig. 1. Orientation of oblong holes on the separator working elements (top view): α – angle of inclination of rectangular sieve holes.

According to the results of the previously conducted screening experiment, it was determined that the separation process at this plant is influenced by the parameters: load per unit area on the sieve (G); the angle of inclination of the sieve holes (α) and the speed of the transmission shaft (n). The result of the experiment, which was carried out by the movement method along the gradient, was determined by the limits of change of the above parameters.

The task of this study was to identify the most rational parameters of the sieve, allowing increasing its orienting activity, and, as a consequence, quantitative and qualitative indicators.

Many rain scientists use $\varepsilon$, «equation (1) » as the main criterion of optimization [10]:

$$\varepsilon = \frac{P}{P_0 \cdot a} \tag{1}$$

where P – the amount in volume or weight terms of the pass fraction secreted by the separator;

$P_0$ – total quantity of grain delivered to the separator during the experiment, kg, кг;

*a* – the relative content of the feed fraction in the grain material.

Each experiment was repeated four times, based on the accepted reliability of the results (0.95) and the experiment errors (2σ) (σ - standard deviation value).

In order to describe the regularities of the completeness of separation on a grain-clearner with cylindrical swinging sieves of improved orienting activity, a planned experiment was carried out, for which a symmetric orthogonal composite four-level plan was selected. The task of the experiment is to identify the influence of three factors on the completeness of the separation and obtain a process model of the form (2):

$$y = b_0 + \sum_{1 \le i \le k} b_i x_i + \sum_{1 \le i \le j \le k} b_{ij} x_i x_j + \sum_{1 \le i \le k} b_{ii} x_i^2 \tag{2}$$

In accordance with the experiment plan, each factor value varied on five levels, including star points. First, experiments were carried out in the core of the plan at the levels: +1 and -1, then the regression equation was built on the coefficients obtained as a result of the experiment. This equation was tested for adequacy by Fisher's criterion at 5% and 1% levels. If it was not adequate, additional experiments were carried out in the center of the plan (point 0; 0; 0) and in the star points shown in table 1.

TABLE I. FACTORS CODING

| FACTOR | load per unit area on the sieve G, kg/(m²·h) | The rotation frequency of the transmission shaft n, min⁻¹ | Angle of inclination of the holes α, degrees |
|---|---|---|---|
| A coded identification | $X_1$ | $X_2$ | $X_3$ |
| Basic level | 2100 | 110 | 30 |
| Variability interval | 500 | 20 | 15 |
| Upper level | 2600 | 130 | 45 |
| Lower level | 1600 | 90 | 15 |
| Star point +α | 2715 | 134,6 | 48,45 |
| Star point -α | 1485 | 85,4 | 11,55 |

As a result of the experiment according to the above plan, a number of numerical values were obtained, subject to subsequent statistical processing [10].

The regression equation was obtained, which was adequate at the 5% significance level, since ($F^{calculated}$ = 1,28 <$F^{table}$ = 1,83).

One of the coefficients of the regression equation ($x_{12}$) was not statistically insignificant, as indicated by the test for significance according to Student's criterion

Regression equation in a coded form:

$$\begin{aligned} y = 0{,}699394 - 0{,}13724x_1 + 0{,}0029x_2 + \\ 0{,}00183x_3 + 0{,}002594x_1x_3 + 0{,}002594x_2x_3 + \\ 0{,}041277x_1^2 - 0{,}0298x_2^2 - 0{,}02642x_3^2 \end{aligned} \tag{3}$$

The following conclusions may be drawn from the obtained equation:

- the largest in modulus coefficient is in front of the parameter $x_1$ – load per unit area on the sieve. Consequently, it has a greater effect on the separation completeness. The negative sign in front of it indicates that with increasing of $x_1$ the las decreases. It does not conflict with common sense;

- positive signs in front of mixed factors $x_{13}$ and $x_{23}$ say, that they are proportional to the completeness of the equation;

- a positive sign before the coefficient $x^2{}_1$, tells about the concavity of the characteristics of the separation completeness of from the grain supply to the sieve. This confirms the exponential nature of this characteristic, determined repeatedly by other scientists;

- negative signs before the coefficients $x_{22}$ and $x_{33}$ tells about on the convexity of their forms and confirm the presence of rational regimes in the range of their variation.

During the experiment the following observations were made:

At constant amplitude of sieves vibrations providing cleaning of their surfaces by brushes, the frequency of oscillations influences the mode of movement of s grain mass: at low frequencies grain material reaches opposite edges of sieves. At relatively high frequencies, the grain is mainly at the junction of two sieves, not reaching the edges. In this case, not the entire surface of the sieve works as expected in advance. When designing two-sieved separators, it is necessary to take into account the speed acquired by the grains when rolling on a perforated surface. It is necessary to conduct experiments to determine the distance of the passage of particles on cylindrical sieves, as well as the time spent on this passage. Since the oscillation frequency of sieves is small, it should also be taken into account in relative motion. During the experiment, it was also noticed that the cleaning brushes installed passively at the bottom of the sieve also affect the grain movement mode. According to the rules of adjustment of grain-cleaners, they are installed in such way that the bristles rise above the working surface of the sieve by 1 mm [11]. Our brushes have been installed in accordance with these rules. When rolling the grains, they are oriented relative to the holes, and the brushes work as disorientators.

With respect to the orientation of the grains with oblong holes, the following conclusion can be drawn: orientation occurs, and moreover, with the quiet nature of the material movement throughout the sieves, which is observed at low frequencies.

The coefficients were converted to natural sizes in order to get quantitive evaluation of the regression equation. As a result of translation the following expression is received:

$$\varepsilon = 0{,}459 - 0{,}00318\cdot G + 0{,}01895\cdot\alpha + 0{,}01288\cdot n + 0{,}0000001297\cdot G\cdot n + 0{,}00000371\cdot\alpha\cdot n + 0.0000004136\cdot G^2 - 0.0000243\alpha^2 - 0{,}00006605\cdot n^2 \quad (4)$$

In order to get a more complete analysis of the experimental results, the dependence of the completeness of the separation on the variables-factors is presented in (Fig. 2...4).

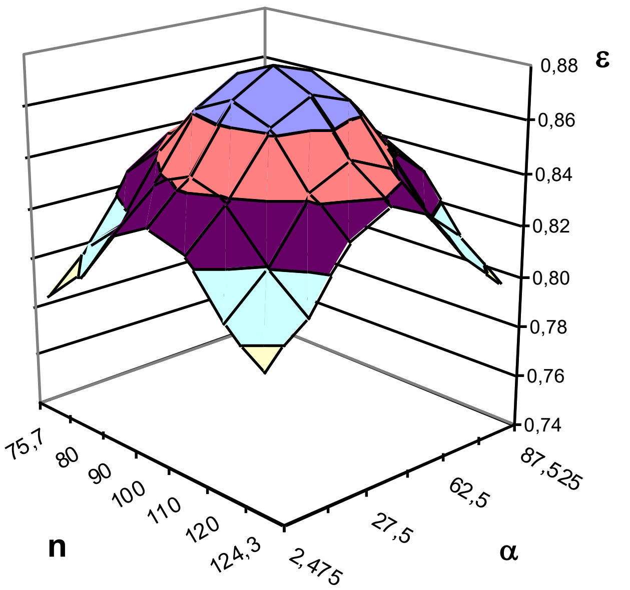


Fig. 2. Dependence of separation completeness on angles of inclination of holes α and a rotation frequency of a transmission shaft n. G = 1000 kg/m²·h.

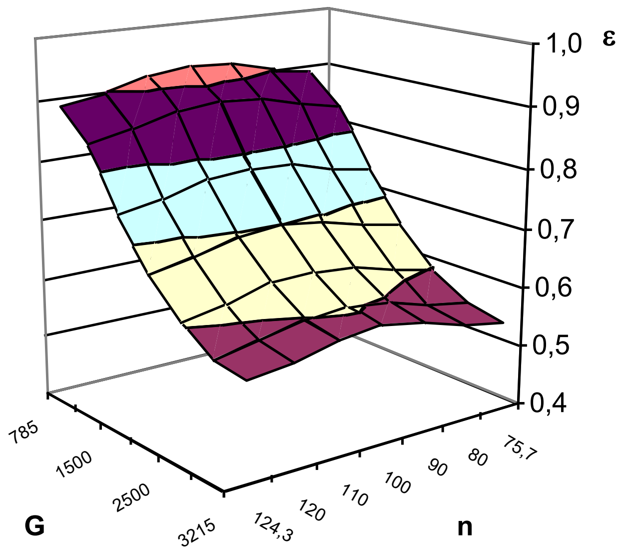


Fig. 3. Dependence of separation completeness on angles of inclination of holes α and load per unit area on the sieve G. n = 100 min⁻¹.

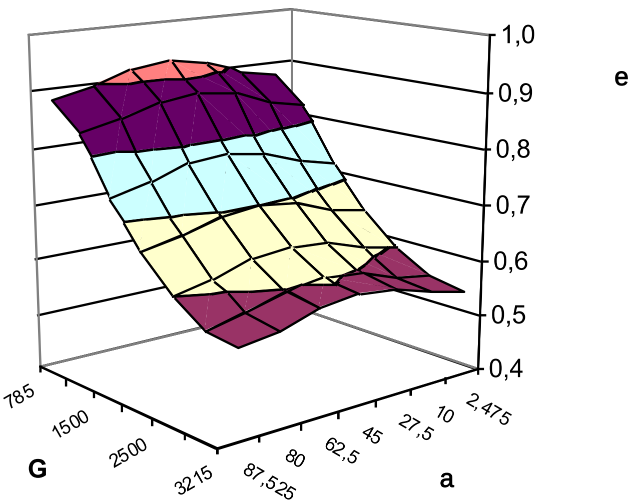


Fig. 4. Dependence of separation completeness from the load per unit area on the sieve G and a rotational speed of the transmission shaft n. α = 45° degrees.

## III. Conclusions

Analyzing the received regularities it is possible to draw the following conclusions:

*1)* The parameters adopted for the experiment have an effect on the grain separation completeness on the swinging sieves

*2)* It is obvious that the planned experiment is drawn up in a rational values range of variable factors, which can be seen from the graphs

*3)* "The angle of inclination of the sieve holes" parameter has a greater impact on the separation completeness than the transmission shaft speed. This is explained by the avalanche-like orientation process of particles by the edges of the sieve hole. The oscillations frequency is chosen for reasons of sufficiency of grain transit of both sieves and their balanced loading. Therefore, in these experiments, the variation range of the oscillation frequency is small.

*4)* Both of the above factors affect together to the process of grain separation on the sieve. A layer of single seeds located on the sieve, interacts with its holes. In this case, the mass of grain material located on the surface of the sieve is about half of its total mass.

*5)* When the load on the sieve increases and, accordingly, the number of grain layers on it, the orientation of the single seeds becomes less effective. Therefore, the process of grain cleaning passes better at higher frequencies.

## References


[1] G. Boumans, Grain Handling and Storage. Amsterdam, Oxford, New-York, Tokyo, 1985.

[2] A. Shevchenko, A. Bankrutenko, V. Koval, M. Begunov, and E. Demchuk, “Scarification of seeds as an increasing element of perennial legume grasses productivity,” Journal of Physics: Conference Series, Vol. 1059, 2018. [IX International Scientific Practical Conference: Innovative Technologies in Engineering, 2018] https://doi.org/10.1088/1742-6596/1059/1/012011

[3] R. Aguirre, A. Garay, “Continuous – flowing portable separator for cleaning and upgrading bean seeds and grains,” Ama, Agricultural Mechanization in Asia, Africa & Latin America, Vol. 30, No. 1, pp. 59-63, 1999.

[4] D. Choszcz, S. Konopka, K. Wierzbicki, “The determination of optimum parameters of various kinds of the sieve basket motion of winnowing machine on the cleaning process of mustard seeds,” Rocz. AR Poznaniu. Rol., No. 49, pp. 13-22, 1996.

[5] I. Shevtsov, “Sieve wire-welded construction with round bridges,” Agrarian Bulletin of the Urals, No. 2 (38), pp. 46-52, 2007. (in russ.)

[6] Patent for utility model 79012 of the Russian Federation MPK7 A 01 F 12/44, B 07 B 1/28, B 07 B 1/38; Application No. 2008109352/22 Claimed March 11, 2008; Publ. 20.12.2008, Inventions. Useful models, No. 35, 2008.

[7] A. Chernyakov, V. Koval, M. Begunov, and K. Pavlyuchenko, “The definition of constructive grain separator parameters,” Bulletin of the KrasGAU, No. 6 (129), pp. 65-70, 2017. (in russ.)

[8] V. Koval, A. Chernyakov, A. Shevchenko, M. Begunov, and E. Demchuk, “Determination of Separator Constructive Parameters,” IOP Conference Series: Materials Science and Engineering, Vol. 582, 012040, 2019. [X International Scientific and Practical Conference - Innovative Technologies in Engineering, May 2019] https://doi.org/10.1088/1757-899X/582/1/012040

[9] Yu. A. Medvedev, “Rotary Type Unit for Seed Cleaning,” Tekhnika i oborudovanie dlya sela (Machinery and equipment for the village), No. 6, pp. 32-33, 2017.

[10] F. Novik, Ya. Arsov, Optimization of metal technology processes by experimental design methods. Moscow: Sofia, 1980. (in russ.)

[11] P. Lapshin, N. Moskovchenko, “elf-cleaning plane sieve from the got stuck grains,” Mechanization and electrification of agriculture, No. 7, pp. 4-5, 2009. (in russ.)