Improving the efficiency of air-grid grain-separators for cleaning sunflower seeds

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Abstract. One of the possible ways to improve the performance of the air-sieve grain-cleaning machines of the MVU-1500 type is to modernize the feeding device of the sieve system of the lower sieve boot due to its design features, namely the shape of the surface and its coating, which will improve the quality of separation of the sunflower seed heap in the pneumatic channel for the final air suction. The optimal design parameters of the divider, at which their rational values are achieved, are: the divider length located at the lower sieve boot 613mm; the friction coefficient of the divider surface \( f = 0.065 \), corresponding to the fluoroplastic-4 material; the divider inclination angle \( 34.06 \) degrees. With these optimal values of the divider design parameters, sunflower seeds are obtained of high quality, meeting the agrotechnical requirements of OST 70.10.2-82, with its rational productivity, which is \( W = 1.68 \) t/h compared to the series-produced one \( W = 1.4 \) t/h depending on the composition of the heap of seeds.

1. Introduction

Post-harvest sunflower seeds treatment is the final operation which allows identifying injured inferior seeds, the content of which in a seed heap leads to the microorganism growth, which leads to a decrease in their quality [1].

The author conducted experimental studies to determine the quality of the main crop seeds before and after their secondary cleaning (Figure 1), which contain the following components: whole seeds, organic impurity (fragments of calathides and stems), broken and hulled seeds [2,3].

Various types of serial grain-cleaning machines are used to isolate these impurities from a sunflower seed heap, one of which is air-sieve machines [4-8], for example, of the MVU-1500 type, in the designs of which the flat screens in sieve boots are used as working bodies and are multi-operated [9-12].

The drawback of most grain-cleaning machines of the MVU-1500 type is the low quality of separation of the sunflower seed heap, due to the passage of a continuous flow of a seed heap in the pneumatic channel of the final air suction, which leads to the vertical airflow lack of blowing it out.

Therefore, the questions on the generalization of existing scientific research and design work aimed at improving the quality of separation of sunflower seed heap in a pneumatic channel of final air suction, which will improve the productivity of the series-produced grain-cleaning machines such as air-sieve, are becoming increasingly relevant.
2. Materials and methods

The improved air-sieve grain-cleaning machine of the MVU-1500 type, according to the RF Patent № 2681493 (Figure 2a), consists of an upper sieve boot 1, a lower sieve boot 2, a general sedimentation chamber connected to an air blower (not shown), a pneumatic channel 3 for preliminary air suction, a pneumatic channel 4 for final air suction, a feeder roller 5, a valve 6, a screw 7 for removing heavy impurities, a screw 8 for removing light impurities, a damper 9 for fine adjustment of the pneumatic channel for preliminary air suction, a damper 10 for fine adjustment of the pneumatic channel for final air suction, a damper 11 for an air supply rough adjustment, an exhaust pipe 12, a spout 13. At the end of the lower sieve boot, under the opening of the vertical pneumatic channel for the final air suction, the dividers 14 (Figure 2b) are installed in a number of not less than three, the inner surface of which has a coating with a low friction coefficient, for example, of fluoroplastic, located at an angle of 40-45° in the horizontal plane. With a minimum of three, the dividers have been installed because the width of the pneumatic channel for the final air suction is approximately 1500 mm and, based on structural considerations and metal consumption, we obtain a divider length of 500 mm. The dividers 14 (Figure 2c) are made in the form of combs, the teeth 15 of which have the shape of a truncated cone, the upper top of which is 1/3 of the lower base. Based on design considerations, with a divider length of 500 mm, we obtain the number of teeth is four, each of which is 125 mm. Moreover, the angle in the top of the cone is 20-30°, and the lower base of the cone has holes for its attachment to the lower sieve boot 2. The divider teeth 14 have oppositely directed welts 16 on the sides, the height of which is 1/4 of the width of the pneumatic channel 4 for the final air suction, and the top of the cone of the divider 14 has a width equal to 5-6 sizes of the seed width. The width of the divider top of the cone is 5-6 sizes of the seed width, because when the average width of the seed is 7 mm, we obtain the size of this top – 42 mm, that is about 5 to 6 sunflower seeds can be placed in the top of the cone.

The technological process of the improved air-sieve grain-cleaning machine of MVU-1500 type when cleaning sunflower seeds is as follows.

The seed material is fed into the receiving chamber, where it evenly spreads across the gap between the valve 6 and the feed roller 5. Further along the inclined slopes, the material is sent to the upper sieve boot 1 for a sieve cleaning (Figure 2a).

On the way after the feed roller 5, the seed material is blown by air stream of the pneumatic channel 3 of the preliminary air suction, where light impurities are separated: chaff, bits of the leaves, seed shells, dust.
These impurities are removed from the sedimentation chamber of the machine by the auger 8 for removing light impurities. Air containing dust is sent for further cleaning through the exhaust pipe 12 of the machine.

After cleaning at the upper sieve boot 1 from large and small impurities, the seeds are sent along the slopes to the lower sieve boot 2 for further cleanup. The mass of seeds is divided in two equal parts, one of which is sent to the upper deck of the sieves, the other one is sent to the bottom deck.

Large and small impurities as wastes are removed from the machine along the inclined spouts 13. The cleaned material, from the upper and bottom decks of the lower boot sieves 1 and 2, respectively, is delivered to the teeth 15 of the divider 14 (Figure 2c), on the inner surface of which the material flow slides, accelerates, and acquires increased input velocity. At the same time, the entire flow of material is stratified into separate jets, making it easily accessible for blowing it with a vertical air flow. Next, the material divided into separate jets enters the pneumatic channel 4 for the final air suction. At this time, heavy and clean sunflower seeds fall to the outlet and are removed from the machine, and light and inferior seeds are delivered by an upward airflow to the upper part of the pneumatic channel 4 for the final air suction, where they are precipitated and removed by the screws 7 and 8.

Based on a preliminary study of the object of research (an improved air-sieve grain-cleaning machine of the MVU-1500 type), optimization parameters are determined and a priori information is analyzed. A priori factors ranging is presented in table 1, taking into account the theoretical researches.

![Figure 2](image-url)

**Figure 2.** The air-sieve grain-cleaning machine MVU-1500: a – general view; b – divider disposition – view A; c – general view of the divider

The following materials have been selected for the divider surface: kapron (polyamide), teflon, and fluoroplastic-4, which correspond to the values of the friction coefficient.

The productivity (ys) of an air-sieve grain-cleaning machine of the MVU-1500 type has been selected as an optimization criterion.

The listed researched factors affect productivity, and are controlled.
Table 1. Factors affecting the quality of separation of a sunflower seed heap by the improved air-sieve grain-cleaning machine according to the RF Patent № 2681493, their conventional signs (symbols) and planned levels of variation

| Factors                        | Symbols | Level of variation | Variation step |
|-------------------------------|---------|-------------------|----------------|
|                               | Coded designation | Natural designation | -1 | 0 | +1 |
| Divider length, mm            | x1      | ℓ                 | 300 | 500 | 700 | 200 |
| Divider surface friction coefficient | x2  | f                 | 0.04 | 0.07 | 0.10 | 0.03 |
| Divider inclination angle, deg. | x3  | β                 | 30 | 40 | 50 | 10 |

3. Results and discussion
A two-dimensional section of the response surface is characterized by an indicator [13] of the performance of an air-sieve grain-cleaning machine of the MVU-1500 type depending on the selected factors (table 1). After the experiment, an obtained regression equation describes the performance of an air-sieve grain-cleaning machine of the MVU-1500 type when cleaning a sunflower seed heap of the “Lakomka” variety, which has the following form:

\[ y_s = 1.64 + 0.30x_1 + 0.05x_2 + 0.14x_3 + 0.117x_1x_2 + 0.325x_1x_3 + 0.15x_2x_3 - 0.076x_1^2 + 0.079x_2^2 + 0.254x_3^2. \] (1)

The analysis of the model (1) shows an increase in the optimization criterion [13] (the productivity of an air-sieve grain-cleaning machine of the MVU-1500 type) in the case when the divider length and the friction coefficient of its surface, the divider length and its inclination angle, as well as the friction coefficient of its surface and its inclination angle, are simultaneously at the upper levels.

Substituting the obtained results of the coded values in the equation (1), we determine the rational performance of the air-sieve grain-cleaning machine of the MVU-1500 type when cleaning a sunflower seed heap, which is \( y_s = 1.68 \text{ t/h}. \)

To analyze the equation (1), a canonical transformation has been conducted:
- the divider length (X1) and the friction coefficient (X2) of its surface:
  \[ Y - 1.68 = -0.076X_1^2 + 0.149X_2^2, \] (2)
- the divider length (X1) and its inclination angle (X3):
  \[ Y - 1.68 = -0.076X_1^2 + 0.184X_3^2, \] (3)
- the friction coefficient (X2) of the divider surface and its inclination angle (X3):
  \[ Y - 1.68 = 0.149X_2^2 + 0.184X_3^2. \] (4)

The canonical regression coefficients included in the expressions (2) and (3) have different signs, then the response surfaces are of the minimax type, and (4) have the same signs and the center of the figure is near the center of the experiment, then the response surfaces will be of a minimum type [13].

To determine the design parameters of the values of the factors in the natural form, we use the well-known expression, which is given in the paper [14]:

\[ X_1 = 0.56 \cdot 200 + 500 = 613.02 \text{mm}; \]
\[ X_2 = -0.17 \cdot 0.03 + 0.07 = 0.065; \]
\[ X_3 = -0.59 \cdot 10 + 40 = 34.06 \text{grad}. \]
Accepting the following values of the design parameters of factors in the natural form for the feeding device in the form of a divider:
- its length, located at the lower sieve boot - 613 mm;
- friction coefficient of its surface - 0.065;
- its inclination angle is 34.06 degrees.

4. Conclusion
One of the possible ways to improve the performance of the air-sieve grain-cleaning machines of the MVU-1500 type is to modernize the feeding device of the sieve system of the lower sieve boot due to its design features, namely the shape of the surface and its coating, which will improve the quality of separation of the sunflower seed heap in the pneumatic channel for the final air suction.

The optimal design parameters of the divider, at which their rational values are achieved, are:
- x1 – the divider length located at the lower sieve boot ℓ = 613 mm;
- x2 – the friction coefficient of the divider surface f = 0.065, corresponding to the fluoroplastic-4 material;
- x3 – the divider inclination angle α = 34.06 degrees.

With these optimal values of the divider design parameters, sunflower seeds are obtained of high quality, meeting the agrotechnical requirements of OST 70.10.2-82, with its rational productivity, which is W = 1.68 t/h compared to the series-produced one (W = 1.4 t/h) depending on the composition of the heap of seeds.

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