Safflower seed cleaning machine and determining the rotational speed of its supplying roller

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Abstract. Farmers engaged in farming on arable lands are interested in growing safflower, which is harvested with grain combines in Uzbekistan. However, farmers face difficulties as they do not have a suitable machine to use when cleaning seeds. For this reason, a small-sized machine was created for farmers based on the amount of safflower they could grow. Number of rotations of the machine to transfer the sucking tube and the oscillating machine during operation is studied; according to theoretical calculations, it was found that the number of rotations of the supplying roller for the transfer of seed mixture corresponding to the working output of the machine 600 kg/h should be in the range of 140-230 rpm, while in experiments it was found that the number of rotations of the supplying roller should be equal to 200 rpm.

1. Introduction

Safflower is one of the valuable oilseed crops grown on arable land, from which oil is extracted, and stalks and seeds of processed oil are important nutrient for livestock [1-4]. Therefore, farmers in Uzbekistan are interested in growing it on arable lands. Safflower is more resistant to drought, and if the seeds germinate 3-4 times in the spring after germination, then it is possible to harvest it 1.0-1.2 t/ha [5, 6].

Safflower is harvested with grain combines, such as Keys-2366, Dominator-130, New Holland TS-5060, Vector-410 are used in Uzbekistan. Because, safflower is grown on arable lands, there are a lot of weeds (alhagi graecorum, atriplex pratovii sukhor, ferula, carduus coloratus, carthamus dianius, etc.) among crops. As a result, the content of foreign as mixtures in the seeds harvested in the combine reaches 8-13 per cent.

This indicates that the harvested seeds must be cleaned. According to the basic standards of storage or processing seed, the moisture content of the seed should not exceed 13 per cent, the amount of foreign admixtures should not exceed 2 per cent.
If the seeds are stored without cleaning, the admixtures in the seeds occupy a large portion of the useful volume of the warehouses, which makes the storage of the seeds more expensive. Due to mineral admixtures, fungal and mold microorganisms spread in the seeds, which heat up on their own [7, 8]. When uncleaned seeds are transferred to oil extraction devices during processing, a lot of dust is released and working conditions deteriorate. When seeds are heated before oil is extracted, foreign admixtures (weeds, leaves, etc.) can burn and cause a fire. When the seeds contain foreign admixtures, the quality of the oil obtained from them deteriorates the taste of the oil is spoiled. As a result of the absorption of some of the oil extracted from the seeds by foreign admixtures, the amount of oil obtained reduces. Mineral admixtures accelerate the digestion of oil extraction equipment; reduce the amount of protein in a proportion of the hull remains.

Therefore, one of the main tasks after harvesting safflower seeds is to clean it from other admixtures. Grain combines are used for harvesting in Uzbekistan, but due to the lack of grain-cleaning machines suitable for farmers to clean their seeds and this work is carried out by hand in the natural wind. This leads to the increase in heavy labor costs. Taking into considerations, research has been conducted to develop a machine that can be used to clean safflower seeds for farmers.

Initially, the available grain cleaning methods and machines were analyzed to create the most optimal design of the machine. The analysis of data on available grain cleaning methods has shown that grains can be cleaned in air streams, sieves, water, electric field, color, and other methods [9-15]. Air flow, sieve, air-sieve, electric drum and optical type grain cleaning machines used in the implementation of these grain cleaning methods have been developed and their construction has been studied. It was found out that the machines of grain cleaning machines are divided into flat-surface and cylindrical machines [16-21].

From these grain cleaning machines, it was found that air-pulverized grain cleaning machines are the most optimal design in terms of universality and high productivity. With the above in mind, an air-blown machine was developed for farmers to use in cleaning the safflower seeds (figure 1).

2. Methods

Design of the safflower seed cleaning machine and selection of the types of working parts were based on the analysis of design and technological work process of existing grain cleaning machines. Size and capacity of the machine were determined based on the amount of safflower to be cleaned on the farms (5-20 t).

Number of rotations of the machine supplying roller has been theoretically and empirically studied in relation to the work efficiency. Higher mathematical rules, mathematical analysis methods, and substitution methods were use in theoretical research. Experiments to study the performance of the supplying roller were carried out on Milyutin-114 one of the sorts of safflower.

Standards were used in the experiments such as GovST 33735-2016 “Agricultural machinery. Grain cleaning machines. Test Methods” & O’zDSt 880: 2004. “Wheat. Preparation and delivery requirements”. Before the experiments, moisture and size-mass classifications of other admixtures in the seed mixture were determined based on GovST 20915-2011 “Agricultural machinery. On basis of "Methods of determination of conditional testing".

As an evaluation criterion in determining the number of rotations of the supplying roller, its transmission of the seed mixture suitable for machine performance was taken. Number of rotations of the safflower seed machine was studied in the range of 125 rpm to 225 rpm and between 25 rpm. Experiments were performed in 6 repetitions to study number of rotations of each of supplying rollers. The results obtained in the experiments were analyzed on the basis of statistical methods, and their statistical values were averaged $M_{ave}$, standard deviation $\sigma$ and coefficient of variation $V$ were calculated [23].

3. Results and Discussions

Given that amount of safflower of the farmers to be cleaned was not very large, i.e around 5-20 tons, its working capacity was set at 600 kg / h, and the machine was designed to be small in size (Figure 1).
The working process of the seed cleaning machine is as follows (figure 1). The cleaned seed mixture is passed through the bunker 1, and it is supplied by measuring through the supplying roller 2 to sucking tube 3 of the air aspiration part. Using the air stream generated by the fan 4 in the sucking tube, light admixtures (dust, leaves, sawdust, etc.) contained in the seed mixture are separated and transferred to the dust sinking device 5. Extinguished light admixtures fall into a bag mounted on the bottom of the extinguisher. This avoids from the dust smokes around when machine is being operated. Large and small heavy admixtures move along the sloping bottom of the sucking tube and fall to the upper sieve 6. Large admixtures in the seed mixture are retained in this sieve. The seeds pass through the holes of the sieve and fall into the lower sieve 7, where the foreign mixtures is separated, while the cleaned seeds move along the surface of the sieve 7 and fall into clean seed container 9. The foreign admixtures separated by the upper and lower sieves fall into a separate container 8. The moving parts of the machine are driven by belt drives using an electric motor 10. The rollers are actuated by means of an oscillating device 12 and its connecting rod that moves the sieve 11.

It can be seen from the technological process of the machine that the foreign admixtures in the mass are separated in a combined way, i.e. first light mixtures in the air stream, then large and small admixtures in the sieves.

The seed mixture from the machine bunker is carried out by means of working parts that provide a specified amount of air to the sucking tube and sieves, which create an air flow. Based on the analysis of the structure and operation of the supply parts of seed cleaning machines, a supplying roller with a top surface was selected to ensure uniform transmission of seeds (Figure 2). During operation, performance of the supplying roller must be commensurate with performance of the sieve, otherwise sucking tube and sieve will not be able to separate other admixtures in safflower seeds. As the consequence, calculations were performed to determine number of rotations of the machine supplying roller.
Hourly productivity of a supplying roller can be determined as follows

\[ Q_r = 60 \cdot V_{r,a} \cdot n_r \cdot \rho_s \] \hspace{1cm} (1)

Here, \( V_{r,a} \) - the volume of the seed mixture falling into grooves of the supplying roller, m³;
\( n_r \) - number of rotations of the supplying roller, rpm;
\( \rho_s \) - density of seed mixture, kg/m³.

The size of seed falling into grooves of the supplying roller depends on capacity of the roller \( V_{c,a} \).

As the surface of the grooves of supplying roller is semi-cylindrical in shape, their capacity is as follows:

\[ V_{c,a} = \frac{\pi (r_a)^2 l_a}{2} \] \hspace{1cm} (2)

Here, \( r_a \) - radius of the grooves of supplying roller, m;
\( l_a \) - length of the grooves of supplying roller, m.

(2) we explain:

\[ V_{r,a} = \xi Z V_{c,a} = 0,5 \xi Z \pi (r_a)^2 l_a , \] \hspace{1cm} (3)

Here, \( \xi \) - coefficient of filling of grooves of supplying roller with seed mixture;
\( Z \) - number of grooves of supplying roller, pcs.

(3) substituting expression (1),

\[ Q_r = 30Z \xi \pi (r_a)^2 l_a n_r \rho_s \] \hspace{1cm} (4)

In (4) \( \rho_s, \xi, Z, r_a, l_a \) parameters are constant. In this case, adjustable parameter \( n_r \) is the number of rotations of the supplying roller, which can be used to change the rate of transmission of the seed mixture. Therefore, it is first necessary to determine the radius, length and number of the grooves of the supplying roller.

In literature, it is stated that radius of the supplying roller is \( R_r \) in relation to radius of grooves of the supplying roller \( r_a \) and \( R_r = (3 \div 4) r_a \) the width of the groove \( b_a \) is approximately equal to the length of 3 grains \( l_y \) to \( b_a = 3l_y \) or greater than \( r_a = 1,5l_y \).

In that case:
If we take into account that maximum length of the safflower seed is 8.2 mm, then it becomes clear that radius of the groove should be $r_a = 1.5 \cdot 8.2 = 12.3$ mm, radius of the supplying roller should be $R_r = 6 \cdot 8.2 = 49.2$ mm. In order to prepare a supplying roller, we assume a radius of the groove is 12 mm and a radius of supplying roller is 50 mm.

Number of grooves in the supplying roller is $Z$:

$$Z = \frac{L_r}{d_a}, \quad (6)$$

Here, $L_r$ – length of the supplying roller circle, m.

It is known that length of the supplying roller circle is equal to:

$$L_r = 2\pi R_r, \quad (7)$$

(7) according to (6) is written as follows:

$$Z = \frac{2\pi R_r}{d_a}, \quad (8)$$

If we consider $R_r = 50$ mm, $d_a = 24.6$ mm, numbers of grooves of the supplying rollers should be $Z = 12.7$ pieces. To ensure symmetrical arrangement of grooves of the supplying rollers and presence of a wall of a certain thickness at the junction of adjacent rollers, we assume that $Z = 12$ pieces.

Considering number of grooves on surface of the supplying roller, we determine from expression (4) number of rotations of the groove $n_r$ as a parameter that can be adjusted during operation:

$$n_r = \frac{Q_r}{30Z\xi\pi r_a^2 l_a \rho_s}, \quad (9)$$

we can determine relationship from expression (9) between number of rotations, productivity and length of the supplying roller. In this case, we construct graphs of changes in number of rotations of the supplying roller depending on its productivity and length, taking into account that $\rho_s = 540$ kg/m$^3$, $\xi = 0.5-0.6$, $Z = 12$ pcs, $r_a = 12$ mm (figure 3).

As can be seen from graph, for transfer of seed mixture corresponding to required 600 kg/h working of sieve, it should be in range of number of rotations of sieve is 230 rpm when length of the supplying roller is 600 mm and 140 rpm rotations at 1000 mm or 140-230 rpm in the general case.
Figure 3. Depending on the number and length of supplying roller rotations change in machine performance
1–600 mm; 2–700 mm; 3–800 mm; 4–900 mm; 5–1000 mm.

In order to verify number of rotations of the safflower seed cleaning machine based on theoretical research and to determine optimal value, number of rotations was changed from 125 rpm to 225 rpm to 25 rpm. Results of the experiment showed that as rotations of supplying roller increase $n_r$, amount of seed $Q_r$ passing through sucking tube and sieve also increases (figure 4).

Figure 4. Number of supplying roller rotations effect on machine capacity
When the number of rotations of supplying roller was 175 rpm, amount of seed mixture passing through sucking tube and sieve of the machine was 528 kg/h, which was slightly higher, but expected performance was not achieved. When the number of rotations of the supplying roller was 200 rpm, working yield was 623 kg/h, and sufficient seed mixture was ensured on surface of the sieve in accordance with its seed permeability. When the number of rotations of the supplying rollers was increased to 225 rpm, amount of seed mixture passing into sucking tube and sieve of the machine was 716 kg/h, and seeds began to move throughout sieve surface by jumping and come out of sieve, it results in sharp increasing of the seed losses.

4. Conclusion
1. Taking into account the universality and high efficiency and efficiency of grain-cleaning machines, Uzbekistan has developed an air-cleaning machine for farmers, which is used to clean seeds of safflower.
2. Depending on number of rotations of the supplying roller, supply of the seed mixture from machine bunker to sucking tube and sieves, which generates an air flow is normalized.
3. Number of rotations of the machine supplying roller according to theoretical calculations, number of rotations of the supplying roller to transfer seed mixture for 600 kg/h of machine operation will be in the range of 140-230 rpm.
4. Based on theoretical studies, it was found that in experiments in which number of rotations of supplying roller was changed from 125 rpm to 225 rpm, number of rotations of the supplying roller was 200 rpm.

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