Dielectric separation

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Abstract. This article describes the dielectric sorting methods, the pros and cons of existing dielectric sorting machines. At the cotton ginning plants of the Republic of Uzbekistan, the widely introduced KSM-1-15 sizing and sorting machine is used to sort bare cotton seeds. Its disadvantage is that during prolonged operation, the holes of the perforated vibrating gratings become clogged with seeds, and the calibration process deteriorates. With this sorting, both small seeds with a very low and high specific gravity, and a part of seeds with a high weight of 1000 seeds, but a relatively low specific gravity, go into marriage. Some of the seeds are damaged. The sowing fraction of seeds with the same size retains a pronounced heterogeneity in terms of nutrient supply and maturity. Therefore, methods and devices are needed that are capable of separating seeds according to the combination of physic-mechanical and chemical-biological properties of seeds. These requirements are met by the dielectric method of sorting seeds in an electric field.

1 Introduction

The most effective in sorting cotton seeds is the dielectric calibration and sorting machine DKSM-1-2 with a working body in the form of a squirrel cage. A distinctive feature of this working body is that in the process of pre-sowing preparation of bare cotton seeds, two operations are combined in it: seed calibration by thickness and width with sorting by weight and density (Figure 1).

In DKSM-1-2, the separated mixture from the loading device enters the surface of the rotating working body in the seed calibration zone A, i.e., in the zone where the seeds are separated according to geometric dimensions. In this zone, seeds having geometric dimensions smaller than the interelectrode gap, passing through it, fall into the outlet tray 6 for small seeds, located inside the working body and are removed from the device.

Larger seeds, i.e., seeds remaining on the surface of the working body, in the separation zone B due to the action of an inhomogeneous electric field created by rod electrodes of alternating polarity, are polarized and, under the action of electric forces, are attracted to the indicated electrodes.

Due to the different quality of seeds, the magnitude of these forces acting on each individual seed will be different. Quality seeds will be the first to break away from the surface of the rotating working body and fall into the quality seed receiver (in fraction I). Sluggish,

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defective seeds will be more strongly attracted to the electrodes of the working body and, moving in place with them due to its rotation, will find themselves in the cleaning zone C, where the electrodes are disconnected from the high voltage source. Seeds previously attracted to the electrodes are detached from them and fall into fraction II or are pushed out by the cleaning roller 9 from the surface of the working body into the receiver of low-quality seeds.

This machine allows you to calibrate with high accuracy in size and separate by weight and density the seeds of agricultural crops that have a round shape (peas, beets, radishes).

However, seeds having an elongated shape, falling on the surface of the working body into the interelectrode gap with their pointed end, wedged into this gap. Because of this, during the separation process, the interelectrode gaps of the working body are completely filled with seeds and the calibration and separation process practically disappears, which is a disadvantage of the known dielectric separator.

In addition, in the specified machine, the process of seed separation depends on their orientation relative to spaced rod electrodes; part of the seeds, falling from the loading device onto the surface of the rotating working body, knocks down and disturbs the stable position of others. All this worsens the quality of the process of separation into sowing fractions due to the ingress of defective seeds into it.

2 Materials and methods

In order to improve the accuracy of seed calibration by size and separation by quality, a dielectric calibration and sorting machine with a unified working body was manufactured at the Department of Electrical Engineering, Electromechanics and Electrotechnology of the Andijan Machine-Building Institute.
This goal is achieved by the fact that in a dielectric sizing and sorting machine, including a loading hopper, a working body located under it, made in the form of a "squirrel cage" of rod electrodes of alternating polarity installed on the support disks of the working body, receivers of separation products, electrodes of the same polarity installed with the possibility of rotation around its axis in the zones of calibration and cleaning of seeds.

This solution makes it possible to increase the accuracy of seed calibration by size and separation by quality due to the rotation of the electrodes of the same polarity of the working body around its axis.

This is explained by the fact that the rotation of the electrodes around its axis in the calibration zone also leads to the rotation of the seeds in the interelectrode gap and, thereby, eliminates their jamming. In addition, the rotation of the electrodes also leads to the orientation of the elongated seeds with their major axis along the electrodes. This improves the seed calibration process.

And when the electrodes of the same polarity rotate in the seed cleaning zone, i.e. in the area above the last receiver of separation products for low-quality seeds, the need for a cleaning ejector brush disappears, because the rotation of the electrodes causes the seed to rotate, detach from the electrodes and enter the receiver poor quality seeds.

Thus, the rotation of the electrodes of the same polarity around its axis will completely clear the interelectrode spaces of the working body from wedged seeds.

Figure 2 shows a dielectric sizing and sorting machine with a unified working body in section, side view (a), rear view - (b).

The proposed device works as follows.

Seeds from the hopper 1 enter the calibration zone of the working body 2, in which electrodes of the same polarity from all electrodes of alternating polarity 3, through one equipped with gears 4 at the ends, mounted on support disks 6, a ring gear 5, receivers of separation products 7.

The proposed device works as follows.

Seeds from the hopper 1 enter the calibration zone of the working body 2, in which electrodes of the same polarity from all electrodes of alternating polarity 3 are equipped with gears 4. These gears come into contact with a rigidly fixed ring gear 5, covering the calibration and cleaning zone.

When the working body rotates at a speed of $\omega$, the electrodes of the same polarity (electrodes equipped with gears 4 at the end) also rotate around their axis, since their gears are engaged with the ring gear 5. Rotation of the electrodes around its axis in the calibration zone leads to rotation of the seeds in the interelectrode gap and thereby eliminates their jamming.
In addition, the rotation of the electrodes also leads to the orientation of the elongated seeds with its major axis along the rod electrodes.

All seeds having a thickness and width less than the interelectrode gap (small seeds) pass through this gap under the action of their weight and fall into fraction I of the small seed receiver 7 located inside the working body 2 and are removed from the device.

Larger seeds enter the separation zone, where there is no rotational movement of the electrodes around its axis, since the ring gear 6 does not cover this zone, i.e., the electrode gears in this zone disengage from the ring gear. In this zone, the seeds, being at rest relative to the electrodes of the working body, are attracted to the surface of the working body due to the action of the voltage $U$ of the inhomogeneous electric field.

Large high-quality seeds (dense, heavy) will be the first to come off the surface of the rotating working body 2 and fall into fraction II of the separation products receiver 7.

Low-quality seeds (loose, light) are stronger than high-quality ones and are held by the electric field and therefore will move to the seed cleaning zone, where the electrodes of one of the polarities begin to rotate around their axis, since the gear of these electrodes engages with the ring gear 6, rotation electrodes of one of the polarities in this zone leads to the rotation of the seeds, which reduces the electrical pressing force. With a decrease in the electric force, the seeds, breaking away from the electrodes, under the influence of their own weight, fall into the fraction of low-quality seeds III of the receiver of separation products 7, i.e. the need for a cleaning brush (or ejector roller) is eliminated.

To study the separation process of bare cotton seeds, a working body (Figure 3a) and a laboratory stand (Figure 3b) were developed and manufactured. The stand allows for independent start-up and operation of the loading device and the working body, high voltage supply to the electrode system, smooth change in the rotational speed of the working body, protection of circuits from short circuits and overloads, as well as control of power supply to electrical circuits [1] article BM and AS on the development of an electronic circuit).

It consists of a load-bearing structure (frame) 1, a loading device 2, a working body 3, separation product receivers 4, an electric drive of the working body 5 and a device control station 6. The loading device includes a hopper 7, inside which a tedder 8 is installed to prevent roof hopper and rubber feed roller 10.

### 3 Results and discussion

The capacity of the laboratory dielectric calibration and sorting plant is 240 kg/h, power consumption is 180 W, supply voltage is 220 V, the length of the working body is 350 mm, the diameter of the working body (drum) is 320 mm, the speed range is 10 ... 80 rpm, the width is 530 mm, height 1290 mm, installation length 510 mm.

On the working body, the distance between the rod electrodes mounted around the circumference on the support disks made of organic glass is 4 cm. This provides the greatest electrical force of attraction of the seeds to the surface of the working body and the best calibration of their sizes when the diameter of the rod electrodes is 6 mm. High voltage is supplied to the system of electrodes of the working body through current-collecting tips from gas-light transformers of the TG-1020 type [2,3] BM and ASh article on the development of an electronic circuit).
The procedure for conducting experimental studies is as follows. The damper 9 (Figure 3 b) is installed according to the scale specially marked on the hopper at the required mark. Voltage is applied to the control panel and the motor circuit is turned on, which drives the working body. During testing, the working bodies can be changed. The voltage on the working body and the frequency of rotation of the working body are set. Then the feed roller motor and the stopwatch are turned on. Immediately after leaving the working body of the last seed, the stopwatch and the entire installation are turned off. Seeds divided into fractions are selected and weighed on technical scales of the VLTK-2000 type.

Laboratory and field studies of the seed separation process.

In order to determine the effectiveness of the developed dielectric calibration and sorting device with a unified working body DSCMVE in comparison with the existing machines DKSM-1-2 and KSM 1-15, laboratory and field experiments were carried out. The peculiarity of the experiments was that the object of the study was not only seeds differentiated from the seed mixture, but also seedlings, as well as cotton plants formed from seeds.

The source material for the research was zoned bare cotton seeds of the Andijan-36 breeding variety. The fourth part of these seeds was taken as a control, and the remaining ¾ was intended for separation on machines KSM-1-15, DKSM-1-2 and DKSMVE. For the convenience of the subsequent presentation, the control seeds and plants are called the seeds and plants of the first variant; options in which the seeds were selected on the separators

Fig. 3. The working body (a) and the scheme of the laboratory stand (b) for studying the process of electro separation of seeds.
KSM-1-15, DKSM-1-2 and DKSMVE, respectively, the second, third and fourth. The scheme of seed preparation is shown in Figure 4.

The studies were carried out both in field and laboratory conditions in accordance with the scheme shown in Figure 5.

**Fig. 4.** The scheme of seed preparation for research.

**Fig. 5.** Research scheme.

Laboratory studies included a morphometric analysis of seed radiographs, an assessment of their sowing qualities, a biometric analysis of ten-day-old seedlings, and a technological assessment of cotton fiber. The studies were carried out in accordance with the methods described in the works [3, 4] The methodology for conducting morphometric analysis is as follows. Each seed was assigned a number, and then the seed was weighed on an analytical
balance, after which it was mounted on radiolucent paper with glue. Then fluoroscopy was performed. The resulting radiographs were analyzed using a television image analyzer. The latter measured the length (J), width (X), area (S), and perimeter (L) of the entire seed image. The length and area of only the upper part were also measured. Then the design parameters were determined: the shape complexity index \((L^2/4\pi S)\), elongation \((J/X)\) and others.

In the case of poor-quality embryo S of the seed, air cavities are formed inside the peel. On x-ray, these cavities are fixed as light areas inside a black outline. The area of the black image of the embryo S is reduced by the area of light areas, and the perimeter L is increased by the perimeter of the image of the embryo adjacent to the air. It has been experimentally established that in seeds with an underdeveloped embryo, the shape complexity index \((L^2/4\pi S)\) has values of more than 1.6. The shape complexity coefficient for the seeds of the sowing fraction KSM-1-15 turned out to be 8.6. This indicates an underdeveloped embryo. For seeds of the sowing fraction DKSM-1-2 and DKSMVE, the complexity index is equal to 1.6 and 1.2, respectively. This indicates a higher quality of the seeds of the DKSMVE sowing fraction compared to the seeds of the DKSM-1-2 sowing fraction.

The assessment of sowing qualities of seeds was carried out according to the traditional method [5, 6, 7].

Figure 6 shows histograms showing the weight of 1000 seeds (a) and germination (b) (Figure 7) by options. The analysis of histograms shows that the seeds sorted on DKSMVE have the best indicators of seed quality.

![Fig. 6. Weight of 1000 seeds according to options.](image)

![Fig. 7. Seed germination by variants.](image)
Since traditional methods for assessing seed quality cannot fully assess and predict their further development, the assessment of seed quality was carried out using a biometric analysis of ten-day-old seedlings. Seed samples (30...100 pieces) are taken for analysis. Each of the seeds is weighed on an analytical balance and sown in quartz sand according to a random distribution scheme. As the germination proceeds, the dynamics of emergence of seedlings is recorded. 10 days after sowing the seeds, a biometric analysis of the seedlings is carried out according to the following indicators: the length and weight of the hypocotyl, the weight of the aerial part of the plant, and the weight of the cotyledons. Additionally, the appearance of the first true leaf is recorded. The measurements and registration of precisely these parameters of seedlings are due to the fact that they characterize the viability and rate of development of plants.

On Figures 8-9 presents the results of a biometric study of seedlings by options. The best indicators of the hypocotyl (Figure 8), aerial parts and cotyledons (Figure 9) were observed in the fourth variant.

The results of laboratory studies of seeds and seedlings were confirmed in field plot experiments. The experiments were carried out in accordance with the methodology developed in NPO Soyuzkhlopok. Accounting for the dynamics of the emergence of cotton seedlings showed (Figure 7) that seedlings from seeds prepared on a dielectric sizing and sorting machine with a unified working body DKSMVE turned out to be the fastest and most friendly compared to other options. For example, by the time of the last count in the fourth variant, the number of seedlings, equal to 90.2%, was 11% more than in the control, 9.8% more than in the second variant, and 1.5% more than in the variant with seedlings from the seeds of the sowing fraction DKSM-1-2.

On the plots of the third and fourth options, thinning was not required, in the plots of options No. 1 and No. 2, this operation was necessary.

It is known that the quality of seeds affects the growth and development of cotton plants in different phases of development. There were no significant differences in the number of true leaves, sympodial branches, and the height of the main stem. However, in terms of the number of fruit elements and boxes, all variants were inferior to the latter. A survey carried out shortly before the harvest season showed that in the fourth variant, the number of boxes, equal to 8.1, is the largest; for 0.4 pcs. bolls were inferior to plants of the third variant (DKSM-1-2); on plants of the first (control) and second (KSM-1-7) variants, there were 0.7 less bolls than in the fourth.

High-quality seeds provided not only early friendly shoots, faster growth and development of plants, the formation of more bolls, but also contributed to the acceleration of cotton maturation, ensuring optimal plant density (Figures 8-9).
Fig. 8. Average weight (a) and length (b) of the hypocotyl.

Fig. 9. Average weight of the aerial part (a) and cotyledons (b).
By the time of the last count, the amount of ripe cotton formed from the seeds of the sowing fraction of the DKSMVE machine was about 87%, which is 3.7% more than in the second and 6% more than in the control options.

On plants formed from seeds of the sowing fraction of DKSMVE, the average weight of raw cotton was the largest of all the considered options. This testifies not only to the good technological properties of the fiber, but also to the high quality of the seed progeny.

Cotton, grown from the seeds of the sowing fraction of the DKSMVE machine, provided the maximum yield compared to plants of other options.

4 Conclusions

Thus, laboratory and field studies have shown that of the considered separators, the most efficient separation of bare cotton seeds is carried out by a dielectric sizing and sorting machine with a unified working body DKSMVE. Compared to sorting at KSM-1-15, electroseparation at the latter provided an increase in the weight of 1000 seeds by 5 g, field germination by 6%, and yield by 3.5 q/ha. Therefore, the use of DKSMVE for the selection of high-quality cotton seeds is very promising and expedient.

The developed dielectric calibration and sorting machine with a unified working body DKSMVE can be used at variety testing stations, cotton factories and machine-building plants to set up new machines.

References