THEORETICAL STUDIES OF SORTING RICE SEEDS IN THE ELECTRIC FIELD

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Annotation. The article provides information about the device, the principle of operation of the developed dielectric device for sorting rice seeds, the results of determining the design parameters of bipolar electrodes and theoretical studies to substantiate the angle of separation of rice seeds from the surface of the working body and the magnitude of the applied voltage to bipolar electrodes, as well as the coordinates of the axis of the separation plane of the receiving hopper. The results of theoretical studies revealed that with a working body diameter of 350 mm and a frequency of its rotation of 50 min-1 for sorting rice seeds on a dielectric device, it is enough to apply a voltage of about 1500 V to the multipolar electrodes. At the same time, for a clear separation of rice seeds torn off from the working surface into the sowing and technical fraction, the coordinates of the axis of the dividing plane of the receiving hopper should be set from the axis of rotation of the working body at a distance: horizontally 165 mm and vertically 300 mm, with its height 150 mm.

Key words: rice seeds, dielectric device, sorting, bipolar electrodes, electric field, electric force.

Introduction

It is known that one of the possible ways to increase the yield of agricultural seeds, in particular, rice seeds, and, accordingly, to reduce the costs of their cultivation is pre-sowing preparation of high-quality seed. The quality of the seed can be improved in various ways, for example, by sorting. However, the existing sorting devices do not allow obtaining high-quality seed material that meets all agrotechnical requirements. Since, with the existing sorting devices, agricultural seeds are sorted only by one important physical and mechanical property, i.e. by weight and geometrical dimensions.

From literary sources it is known that in order to obtain high-quality, full-fledged, biologically homogeneous seed material with high laboratory field germination and potential yield, sorting of agricultural seeds must be performed according to all the most important physical and mechanical properties [1-5]. Sorting seeds in an electric field meets this requirement. Since, the electric field acts on seeds, taking into account their different quality, selectively, taking into account all the physical and mechanical properties. As a result, the seeds of agricultural crops in an electric field are sorted according to all the most important physical and mechanical properties, i.e. by mass, geometric dimensions, density, electrical resistance, dielectric constant, etc. [6-9]. In addition, the electric field has a positive stimulating effect on their field germination, post-emergence growth and development, and plant productivity [10-15].

Considering the above, as well as relying on the achievements of science and production, we propose to sort them in an electric field based on the dielectric principle to improve the sowing qualities of rice seeds [16-19].

Purpose of the study

Theoretical study of the possibility of sorting rice seeds on a dielectric device, substantiation of the angle of their separation and the value of the applied voltage to the opposite polarity electrodes and the coordinates of the axis of the separation plane of the receiving hopper.

Materials and research methods

The dielectric device for sorting rice seeds has been developed on the basis of a patent search and previously conducted scientific research in this direction. Theoretical studies of the technological process of sorting rice seeds on the surface of the working body of

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a dielectric device were carried out on the basis of the laws and rules of theoretical mechanics and electrical engineering.

Research results and their discussion

The study of the physical and mechanical properties of rice seeds showed that they are an elongated ellipsoid of revolution with length "a", width "b" and thickness "c" along the axes. In this regard, the sorting of rice seeds on a dielectric device must be done twice, first in thickness and then in width.

Based on this, the design parameters of the bipolar electrodes wound on the surface of the working bodies of the dielectric device must be determined from the average values of the thickness and width of rice seeds. The design parameters of the bipolar electrodes of the upper working body will be determined depending on the average value of the thickness, and the lower from the average value of the width of rice seeds.

Considering that there is an optimal ratio between the design parameters of the system of opposite-polar electrodes and the size of the seeds, at which the magnitude of the electric force reaches the highest value [20-23] and, based on the average thickness and width of rice seeds, the diameters of the opposite-polar electrodes of the upper of the working body we take de1 = 2.5 mm, and the lower de2 = 3.5 mm.

Using the expression [10], we determine the interelectrode distance of the oppositely polarized electrodes wound on the surface of the upper and lower electrodes of the working body

$$\delta_1 = 2\left[(r_т + r_{эв})\sin\frac{\theta}{2} - r_{эв}\right] = 2\left[(1{,}125 + 1{,}25)\sin 67^\circ - 1{,}25\right] = 1{,}8$$

$$\delta_2 = 2\left[(r_ш + r_{эк})\sin\frac{\theta}{2} - r_{эк}\right] = 2\left[(1{,}275 + 1{,}75)\sin 67^\circ - 1{,}75\right] = 2{,}06 мм,$$

Where

δ1, δ2 is the interelectrode distance of the oppositely polarized electrodes of the upper and lower working body, mm;

гт, гш - average radius of thickness and width of rice seeds, mm;

гэв, гэ is the average radius of different-sided electrodes wound surfaces of the upper and lower working body, mm;

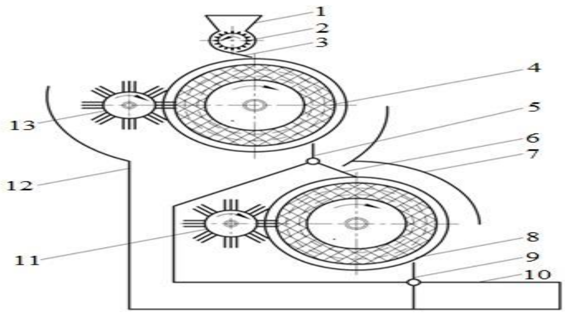
Ɵ / 2 - angle between vertical and electrical force, degree.

According to the data obtained, the interelectrode distance in the upper working body is assumed to be δ1 = 1.85 mm, and in the lower one, δ2 = 2.0 mm.

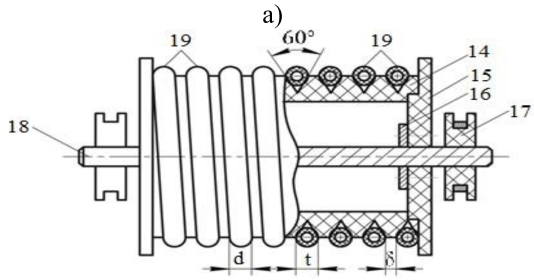
Thus, to ensure the greatest electric force of pressing rice seeds to the surface of the working body of the dielectric device and, accordingly, to increase the efficiency of their sorting, with the diameter of the oppositely polar electrodes of the upper and lower working body equal to 2.5 mm and 3.5 mm their interelectrode distance should be equal to 1.85 and 2.0 mm.

Based on the conducted patent searches, analysis of the design of the developed dielectric sorting devices, previously carried out research work on sorting agricultural seeds in an electric field and the results of determining the structural parameters of heteropolar electrodes, we have developed a dielectric device for sorting rice seeds ...

Figure 1 shows a schematic diagram and a working body of a dielectric device for sorting rice seeds.



a)



b)

Figure 1.

Schematic diagram (a) and working body (b) dielectric rice seed sorting device:
1 – loading hopper; 2 – feeder; 3 and 6 pitched board; 4 and 8 - working bodies; 5 and 9 - dividing planes; 7 and 12 - protective covers; 4 and 10 - receiving bunkers; 11 and 13 - removable brushes; 14 – polyethylene pipe; 15 – side discs; 16 – flanges; 4 and 17 - current collectors; 18 – shaft; 19 – bipolar electrodes

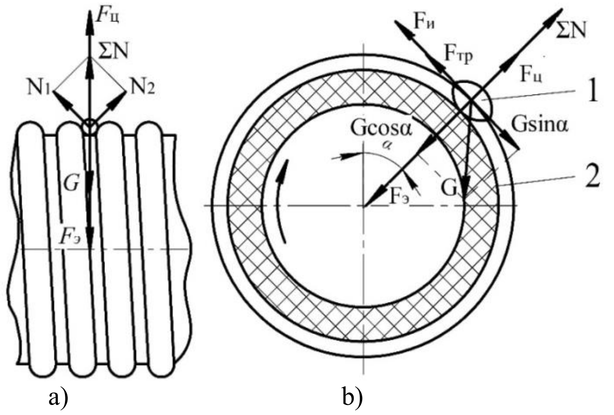
The working bodies of the dielectric device are made of polyethylene pipe 14, and grooves are cut on the surface of the upper working body in the form of a two-thread screw with a depression angle "γ", width "t1" and a distance between them "δ1" and wound on them bipolar electrodes with a diameter "d1" corresponding to the thickness of rice seeds "c", and grooves are cut on the surface of the lower working body in the form of a two-thread screw with an anglescrap of the depression "γ", width "t2" and the distance between them "δ2" and on them are wound oppositely polar electrodes with a diameter "d2" corresponding to their width "b". Polyethylene pipes with the help of side discs 15 made of dielectric material and iron flanges 16 are fixed on the shaft 18. Bipolar electrodes 19 are connected to a high-voltage power source through current collectors 17 [24-28].

The principle of operation of the device is as follows. When the device is connected to the network with the help of an electric motor and a gearbox, feeder 2, working bodies 4 and 8, as well as removable brushes 11 and 13 are set in rotary motion through chain drives. At this time, the sorted rice seeds from the loading hopper 1 with the help of a pitched board 2 are fed in an even layer to the surface of the upper working body 4. The seeds, falling on the surface of the upper working body 4, are placed in the interelectrode space of the bipolar electrodes 19, thickness "c" and are polarized due to the electric field caused between the bipolar electrodes and attracted to it under the action of the arising electric force. In addition to electric force, seeds are affected by centrifugal force, gravity, inertia, reaction and friction. Depending on the ratio of the acting forces, rice seeds differing in physical and mechanical properties are torn off the surface of the upper working body 4 at different angles of rotation. Good-quality seeds, earlier breaking away (in time) from the surface of the upper working body 4, fall on the surface of the lower working body 8, and not high-quality seeds, tearing off at large angles of rotation or being removed with a removable brush 11 fall into the technical fraction of the receiving hopper 10.

Rice seeds hitting the surface of the lower working body 8 are placed in the interelectrode space of the bipolar electrodes 19 with a thickness "b", and then the process of sorting is repeated. Sorted by thickness and width, as well as by other important physical and mechanical properties, rice seeds, breaking off from the surface of the lower working body 8, fall into the seed fraction of the loading hopper 10, and rice seeds that have come off at large angles of rotation, as well as adhered to its surface are removed using a removable brush 13 and fall into the technical fraction of the receiving hopper 10.

For a qualitative assessment of the technological process of sorting rice seeds on the surface of the working body of the dielectric device, it is necessary to carry out theoretical studies. Since theoretical studies of the technological process of sorting rice seeds make it possible to substantiate some design parameters and operating modes of a dielectric device [29-31].

Figure 2 shows a diagram of the forces acting on rice seeds when a dielectric device hits the surface of a rotating working body.



a) b)

Figure 2. Diagram of the forces acting on rice seeds:
1 – rice seeds; 2 – working body

From the presented diagram, it can be seen that the following forces act on the rice seeds that fall on the surface of the rotating working body of the dielectric device:

1. The electric field strength Fe, caused by the electric field, arising between oppositely polarized electrodes
11, 12]

$$F_э = \frac{2S_y U^2 \varepsilon_0 {\varepsilon_u}^2 (\varepsilon_y - 1)}{(2h_э \varepsilon_y + l_y \varepsilon_u)^2} \cos\frac{\theta}{2}, \qquad (1)$$

where Sc is the effective polarized part of the seed surface in contact shchaya with bipolar electrodes, m2;
U is the voltage value applied to the bipolar electrodes, V;
ε0 = 8, 85 · 10 F / m - dielectric constant;
εi and εc - dielectric constant of the insulation of electrodes and seeds;
he is the thickness of the electrode insulation, m;
lc - average length of power lines in the seed, m;
Ө - angle between vertical and electric forces, degree.
1. Centrifugal force:

$$F_ц = \frac{mV_c^2}{R}, \qquad (2)$$

Where: m is the mass of seeds, kg;
Vc — linear speed of seeds, m / s;
R is the distance from the axis of rotation of the working body to the center of gravity of the seeds, m.
G = mg; (3)
Where: g - gravitational acceleration m / s2;
3. Force of inertia:

$$F_и = \frac{mdV_c}{dt}, \qquad (4)$$

Reaction force -N.
4. Friction force:

$$Fтр = f\Sigma N, \qquad (5)$$

Where: f is the coefficient of friction of rice seeds on the surface of the working body at movement.

As follows from Figure 2, the force of the electric field Fe presses the seeds to the surface of the working body, and the centrifugal force pushes away from it, the force of gravity G in the first quarter of the working body presses the seeds to it, and in the second quarter pushes the seeds away from it. In this regard, depending on the ratio of the acting forces and, accordingly, the physical and mechanical properties of rice seeds, it is possible to substantiate the angles of their separation from the surface of the working body and the magnitude of the applied voltage to the oppositely polarized electrodes.

In order for rice seeds falling on the surface of a rotating working body of a dielectric device to be detached from it, according to Figure 2, the condition N = 0 must be satisfied, i.e. [32-33].

$$Fe – Fs = G \cos\alpha = 0, \qquad (6)$$

where α is the angle of rotation of rice seeds over the surface of the working body, degrees.

Substituting into expression (6) instead of the forces Fe, Fts and G their values and performing some transformations, we obtain the following expression for determining the angle of separation of rice seeds from the surface of the working body of the dielectric device:

$$\alpha = \arccos\left[\frac{fV_c^2}{gR} - \frac{2S_cU^2\varepsilon_0\varepsilon_u\left[\varepsilon_c - 1\right)}{mg(2h_э\varepsilon_c + l_c\varepsilon_c)^2}\cos\frac{\theta}{2}\right]. \quad (7)$$

From the last expression it follows that with the constancy of the design parameters and operating modes of the dielectric device, the angle of separation of rice seeds from the surface of the working body depends on the square of the applied voltage to the opposite polarity electrodes and the physical and mechanical properties of the seeds themselves.

In this case, with a change in the value of the applied voltage to the oppositely polarized electrodes, it is possible to change the angle of separation of rice seeds from the surface of the working body within wide limits, i.e. the value of the applied voltage to the bipolar electrodes can serve as the main regulating factor in the technological process of sorting rice seeds on a dielectric device.

Using expression (7), we make a calculation to determine the angle of separation of rice seeds from the surface of the working body with the following parameter values: Vc = Vb = 0.92 m / s; g = 9.81 m / s2; R = 0.178 m; Sc = 46.26 · 10-6 m2 and 75.86 · 10-6 m2; εi = 4.0; εc = 10; he = 0.675 · 10-3 m; lc = 2.05 · 10-3 and 3.26 · 10-3; m = 10; 20; thirty; 40 and 50 mg; U = 1000; 1500 and 2000 V.

Figure 3 shows a graph of the change in the angles of separation of rice seeds depending on their weight at various values of the applied voltage to the oppositely polarized electrodes.

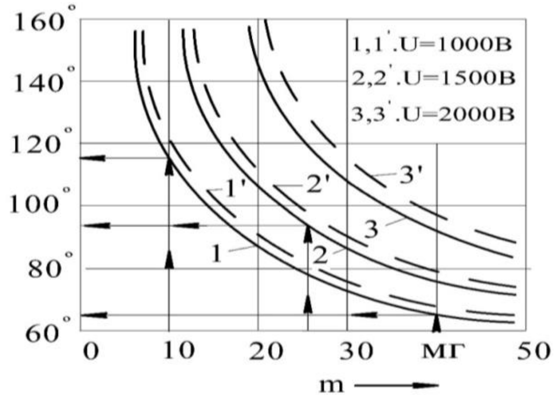


Figure 3.
Graph of changes in the angles of separation (α) of rice seeds depending on on their mass (m) at various values of the applied voltage (U)

As follows from Figure 3, at the same voltage, with a change in the mass of rice seeds, the angle of their separation from the surface of the working body of the dielectric device changes. For example, if at the magnitude of the applied voltage to the multipolar electrodes of 1000 V, rice seeds with a mass of 10 mg detach from the surface of the upper and lower working body at angles of rotation of 117º30′ and 120º, then rice seeds weighing 40 mg detach from them at angles of rotation of 65º33′ and 68º03 ′ (Figure 3, curves 1 and 11). Those. at constant values of the applied voltage, with an increase in the mass of rice seeds, the angle of their separation from the surface of the working body increases. In this case, with a change in the value of the applied voltage to the oppositely polarized electrodes, the angle of separation of seeds of the same mass changes. For example, if at the magnitude of the applied voltage to the bipolar electrodes within 1000 V, rice seeds weighing 25 mg are detached from the surface of the upper and lower working body at angles of rotation 75º20′ and 78º30′ (Figure 3, curves 1 and 11), then at to the value of the applied voltage within 2000 V, they are torn off at the angles of rotation 120º and 127º30′ (Figure 3, curve 3 and 31). Those. with an increase in the applied voltage to the multipolar electrodes, the angle of separation of rice seeds of the same mass from the surface of the working body of the dielectric device increases. The latter allows, by regulating the magnitude of the applied voltage to oppositely polar electrodes, to vary within wide limits the angle of separation of rice seeds from the surface of the working body of the dielectric device and qualitatively separate the source material into seed and technical fractions.

The analysis of the dependence curves in Figure 3 shows that if one considers rice seeds weighing less than 25 mg to be incomplete and unsuitable for sowing, then for a qualitative separation of the initial material into seed and technical fractions, it is enough to apply a voltage within 1500 V to the heteropolar electrodes (Figure 3, curves 2 and 21). An increase in the value of the applied voltage leads to pulling in high-quality seeds together with low-quality seeds into the technical fraction, and a decrease leads to an early separation of low-quality seeds from the surface of the working body and their entry into the sowing fraction.

As follows from Figure 3, for a clear separation of the separated rice seeds from the surface of the working body of the dielectric device into the sowing and technical fractions, it is necessary to correctly select the coordinates of the axis of the separation plane of the receiving hopper. This can be achieved by justifying the coordinates of the axis of the separation plane.

The coordinates of the axis of the location of the dividing plane of the receiving hopper can be justified using expression (7) and Figure 3, by constructing a fan of scattering of rice seeds of various weights detached from the surface of the working body. We construct a fan of scatter of loose rice seeds from the surface of the working body with its diameter 350 mm, rotation frequency 50 min-1 and the value of the applied voltage to the heteropolar electrodes of 1500 V for different masses, i.e. fifteen; 20; 25; thirty; 35; 40 and 45 mg.

Figure 4 shows a diagram of the scatter fan of rice seeds of various weights detached from the surface of the working body of the dielectric device.

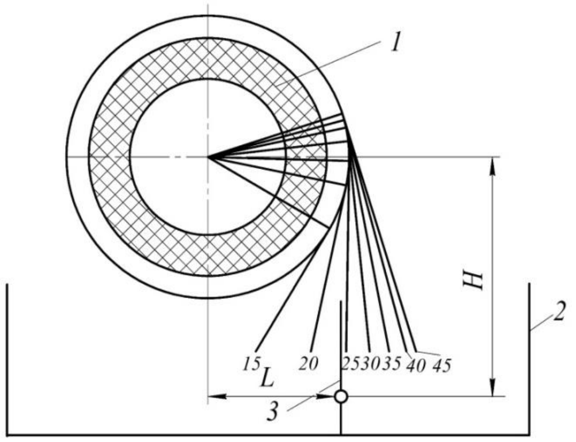


Figure 4.
Fan of scatter of loose rice seeds of different masses from the surface of the working body:
1 – working body; 2 – receiving hopper; 3 – dividing plane;

As follows from Figure 4, the fan of scattering of rice seeds of different mass separated from the surface of the working body differ from each other and fall into different parts of the receiving hopper. The latter allows, by correctly setting the coordinates of the axis of the dividing plane of the receiving hopper, to divide the rice seeds of various weights separated from the surface of the working body into sowing and technical fractions.

As noted above, if we consider rice seeds weighing less than 25 mg to be inferior and unsuitable for sowing, then for a clear separation of rice seeds torn off from the surface of the working body of the dielectric device into sowing and technical fractions, according to Figure 4, the coordinates of the axis of the separation plane of the receiving hopper must be installed from the axis of rotation of the working body at a distance: horizontally L = 165 mm, and vertically H = 300 mm. In this case, the height of the dividing plane should be within hr = 150 mm.

Theoretical studies have shown that for high-quality sorting of rice seeds into sowing and technical fractions with a working body diameter of 350 mm and a frequency of its rotation of 50 min-1, it is enough to apply a voltage of about 1500 V to the heteropolar electrodes. At the same time, a clear separation of the rice seeds separated from the surface of the working body of the dielectric device into the sowing and technical fraction is ensured when setting the coordinates of the axis of the separation plane of the receiving hopper from its axis of rotation at a distance: horizontally 165 mm, vertically 300 mm and at a height 150 mm.

Conclusions

The results of the theoretical studies made it possible to substantiate the angles of separation of rice seeds from the surface of the working body of the dielectric device and the magnitude of the applied voltage to the bipolar electrodes, as well as the location of the coordinate of the axis of the separation plane of the receiving hopper. It was found that for sorting rice seeds into sowing and technical fractions on a dielectric device with a working body diameter of 350 mm and a rotation frequency of 50 min-1, it is sufficient to apply a voltage of about 1500 V to the oppositely polar electrodes. At the same time, a clear separation of the rice seeds torn off from the surface of the working body of the dielectric device into the sowing and technical fraction is ensured by setting the position of the coordinate of the axis of the dividing plane of the receiving hopper from the axis of its rotation at a distance: horizontally 165 mm, vertically 300 mm and at its height 150 mm.

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