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THEORETICAL PREREQUISITES FOR SORTING PAPPUSES BY IMPROVED TRIBOELECTRIC DEVICE

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The article provides a brief analysis of the proposed methods for sorting raw cotton pappuses in an electric field and theoretical assumptions about the possibility of sorting them in an improved triboelectric device. The results of theoretical studies showed that raw cotton pappuses, depending on their mass and, accordingly, fiber quality, detach from the surface of the rotating loaded working body at different rotation angles. The latter allows, by correctly establishing the coordinate axis of the location of the separating surfaces, to sort the pappuses into different fractions depending on the quality indicators of their fibers and obtain seeds of guaranteed quality from pappuses with high fiber quality.

In this case, for sorting raw cotton flakes by fiber quality into different fractions, it is sufficient to create an induced electric field strength on the surface of the rotating charged working element within $5 \cdot 10^5$ V/m. An increase or decrease in the magnitude of the voltage from this value leads to a decrease in the efficiency of sorting raw cotton pappuses on an improved triboelectric device.

Keywords

sorting, raw cotton pappuses, improved triboelectric device, applied electric field, electric power, voltage.

Introduction. As is known, high-quality, biologically homogeneous, and full-value cotton seeds with high laboratory-field germination and potential yield are the key to a future harvest. In this regard, the search for ways to improve the sowing qualities of cotton seeds is relevant.

Research by scientists has established that there is a close linear correlation between the fiber quality of raw cotton pappuses and the sowing qualities of cotton seeds [1,2]. Since the higher the quality of cotton fiber, the higher the sowing qualities of the seeds, and vice versa, the lower the quality of cotton fiber, the lower

the quality of cotton seeds. Therefore, by sorting raw cotton bolls by the quality of their fibers, it is possible to obtain seeds of cotton of guaranteed quality.

Considering the above, it is proposed to sort raw cotton by the quality of its fibers into pre-separated flakes on a triboelectric device, the electric field of which arises due to the friction of two dielectric bodies of rotation, i.e., a dielectric drum and a winding brush [3, 4]. Pre-separated pappuses, falling on the surface of the rotating charged dielectric drum, polarize and, under the action of the resulting electrical force, are attracted to it by various electrical forces depending on the quality indicators of the fibers and, detaching from it at different angles of rotation, fall into the corresponding fractions of the receiving hopper.

The disadvantage of this device is that the working part is made of a dielectric material by heating to form a cylindrical drum, which leads to a change in its physical and mechanical properties.

It is also proposed to sort raw cotton by the quality of its fibers to pre-selected pappuses on a dielectric device, an electric field arising between different polar electrodes woven onto the surface of the working part in the form of a two-start screw [5, 6, 7, 8]. Pre-separated pappuses, falling on the surface of different polar electrodes, polarize and, under the action of the resulting electrical force, attract to the working part with different electrical forces depending on the quality indicators of the fibers and, detaching from its surface at different angles of rotation, fall into the corresponding fractions of the receiving hopper.

The disadvantage of these devices is that, firstly, they do not allow for high-quality sorting of raw cotton fly into various fractions, and secondly, they are fire-hazardous, as when a spark occurs between different polar electrodes, the pappuses fibers ignite.

Based on the analysis of the proposed devices for sorting raw cotton pappuses in an electric field and relying on scientific achievements, as well as the experience of manufacturers, we have put forward a working hypothesis to improve the triboelectric device for sorting raw cotton by the quality of its fibers, pre-separated pappuses into various fractions [9, 10]. The essence of the working hypothesis lies in the fact that on the surface of the working body made of polyethylene pipe in a vertical plane, helical grooves with a width of " δ " close to the average geometric dimensions of the pappuses and a depression angle of " γ " which is less than the angle of friction of their fibers with the surface of the polyethylene material, are cut. When performing the working part in this way, the slivers, falling on the surface of the working part, are rationally placed in helical grooves, which leads to an increase in the area of their contact and the angle of friction of the fibers with the surface of the polyethylene pipe. The latter allows to increase the electrical force of

pressing the pappuses against the surface of the working part and increase the accuracy of their sorting into different fractions according to fiber quality indicators.

Purpose of the research. Theoretical justification of the possibility of sorting raw cotton pappuses by fiber quality into various fractions on the surface of a rotating charged working element of an improved triboelectric device.

Materials and methods of research. Theoretical studies of the possibility of sorting raw cotton pappuses by fiber quality on the surface of a rotating loaded working element of an improved triboelectric device were carried out using the laws and rules of theoretical mechanics and electrical engineering based on mathematical analysis. Based on the results of theoretical studies, a graph of the change in the angle of detachment of pappuses from the surface of the working body depending on their mass at different values of the applied electric field strength was constructed, and by analyzing the curved dependencies, a conclusion was made about the possibility of sorting flyers by fiber quality indicators into different fractions on an improved triboelectric device.

Results of the study and their discussion. To implement the proposed working hypothesis, a technological scheme and working body of an improved triboelectric device were developed. Figure 1 shows the technological scheme and working body of the improved triboelectric device for sorting raw cotton pappuses.

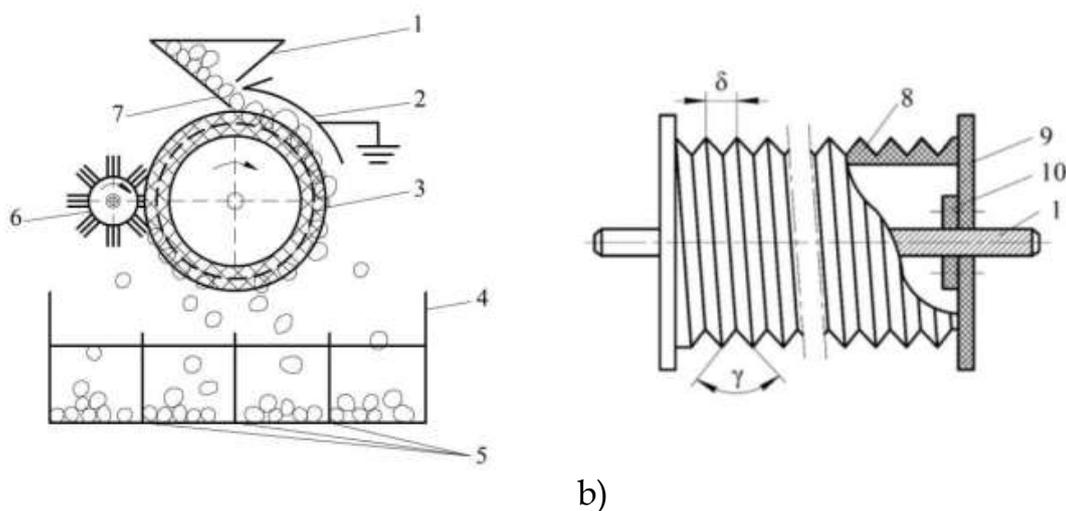


Fig. 1. Technological scheme (a) and working body (b) of the improved triboelectric device:

- 1 - loading hopper; 2 - grounded electrode; 3 - working body;
- 4-receiving hopper; 5-separating planes; 6-mounting brush;
- 7 - inclined board; 8-polyethylene pipe; 9-side discs; 10 - flange; 11-Shaft

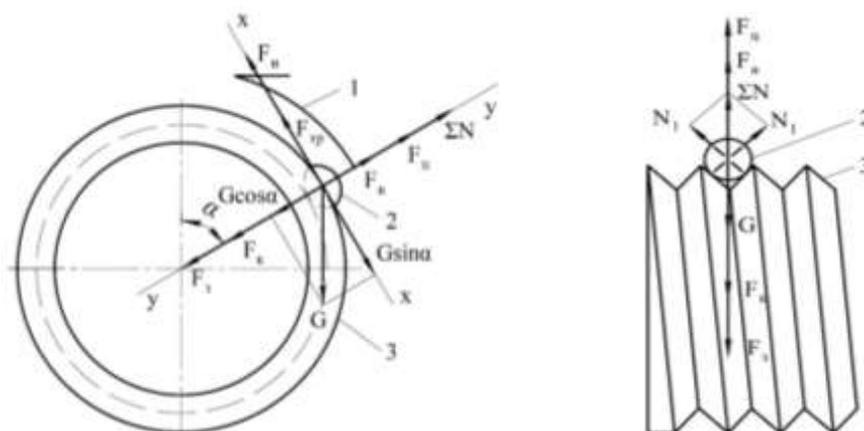
The improved triboelectric device consists of a loading hopper 1, a grounded electrode 2, a working body 3, a receiving hopper 4, separating planes 5, an ironing brush 6, and a rolling board 7.

The working body 3 is made of polyethylene pipe 8 and on its surface in a vertical plane, helical grooves of width " δ " are cut, close to the average geometric dimensions of the pappuses and the depression angle " γ ," which is less than the friction angle of their fibers with the surface of the polyethylene material, and with the help of side discs 9, made of dielectric material and iron flanges 10, are fixed to shaft 11.

The operating principle of the improved triboelectric device is as follows.

Pappuses of raw cotton from loading hopper 1 through sliding board 7 fall on the surface of the rotating loaded working body 3. Falling on the surface of the rotating charged working body 3, the blades of raw cotton are rationally placed in helical grooves and, under the action of the applied electric field, are polarized. As a result of the generation of electric force, they are attracted to the surface of the rotating loaded working body 3. In addition to electric force, mirror reflection force, centrifugal force, gravity force, inertia force, reaction force, and friction force also act on particles. Depending on the ratio of the acting forces and, accordingly, the physical and mechanical properties, the flakes detach from the surface of the working body 3 at different angles of rotation and enter the corresponding fractions of the receiving hopper 4. The pappuses that stick to the surface of the working part are removed using a brushing brush 7 and enter the last fractions of the receiving hopper 4.

Figure 2 shows a diagram of the forces acting on the pappuses when hitting the surface of a rotating charged working element of an improved triboelectric device.



a) b)

Fig. 2. Diagram of forces acting on flyers:

1 - grounded electrode; 2 - pappuse; 3 - working body

From Figure 2, it follows that the following forces act on the pappuses that hit the surface of the working part of the improved triboelectric device:

1. Electric field strength F_k , arising under the action of an induced electric field [11, 12]

$$F_k = E \cdot Q = \frac{\varepsilon_0 E^2 AB \Phi_3}{4} \left(1 + 2 \frac{\varepsilon_{\pi} - 1}{\varepsilon_{\pi} + 2} \right), \quad (1)$$

where E - voltage of the induced electric field, V/m;

Q - battery gain of pappuses, Cl;

$\varepsilon_0 = 8.85 \cdot 10^{-12}$ F/m - dielectric constant;

A, B - respectively, the large and small axes of the pappuses, m;

Φ_3 - coefficient taking into account the shape of the pappuses [13];

ε_{π} - relative dielectric permeability of the pappuses.

2. Mirror reflection force F_3 , arising under the interaction of a charged pappuses with a charged working element [14, 15]

$$F_3 = \frac{Q^2}{r_{\text{эKB}}^2} = \frac{\varepsilon_0 E^2 AB \Phi_3}{16\pi} \left(1 + 2 \frac{\varepsilon_{\pi} - 1}{\varepsilon_{\pi} + 2} \right) \quad (2)$$

where $r_{\text{эKB}} = (1/2)\sqrt{AB\Phi_3}$ is the equivalent radius of the pappuses with a suitable surface, m.

3. The straightening force of the pappuses fibers F_b , arising under the action of an induced electric field [15]

$$F_b = \frac{\pi d^2}{4} (\varepsilon_{\pi} - 1) n_k \varepsilon_0 E^2, \quad (3)$$

where d - fiber diameter of the pappuses, m;

n_k - the number of pappuses fibers in contact with the surface of the charged working body, pcs.

4. Centrifugal force F_u

$$F_u = \frac{mV_{\pi}^2}{R}, \quad (4)$$

where m - pappuses mass, kg;

V_{π} - linear pappuses speed, m/s;

R - distance from the drum rotation axis to the center of gravity of the pappuses, m.

5. Weight G

$$G = mg \quad (5)$$

where g - acceleration of free fall, m/s².

6. Inertial force F_{II}

$$F_{II} = \frac{mdV_{II}}{dt} \quad (6)$$

7. Summary reaction force of the working body ΣN to the pappuses.

8. Friction force F_{TP}

$$F_{TP} = f\Sigma N, \quad (7)$$

where f - coefficient of friction of the pappuses against the surface of the working part during movement.

genii.

From Figure 2, it is evident that the electric forces F_{κ} and F_3 attract the flyers to the surface of the working body, the straightening force of the fibers F_B and the centrifugal force F_{II} pushes them away from it, the force of gravity G in the upper half-cylinder presses the pappuses to the surface of the working body, and in the lower half-cylinder pushes them away from it. In this regard, from the ratio of the acting forces, depending on the physical and mechanical properties of the pappuses, it is possible to determine the angles of their detachment from the surface of the rotating charged working element of the improved triboelectric device.

From the diagram of the acting forces, it follows that the detachment of the flywheels from the surface of the rotating charged working body occurs under the condition $\Sigma N=0$, i.e., under the condition

$$F_{\kappa} + F_3 - F_B + G \cos a - F_{II} = 0, \quad (8)$$

where a - angle of rotation of the pappuses on the surface of the working part, o.

Substituting the values of forces F_{κ} , F_3 , F_B , G and F_{II} into expression (8) and making some transformations, we obtain the following expression for determining

the angle of detachment of raw cotton blades from the surface of the rotating charged working element

$$\alpha = \arccos \left[\frac{V_n^2}{gR} - \frac{\varepsilon_0 E^2 AB \Phi_3 L}{mg} \right], \quad (9)$$

where $\varepsilon_0 E^2 AB \Phi_3 L = F_k + F_3 - F_B$ - the total electrical force acting on pappuses, N.

$$\text{Here } L = \frac{1}{4} \left(1 + 2 \frac{\varepsilon_n - 1}{\varepsilon_n + 2} \right) + \frac{1}{16\pi} \left(1 + 2 \frac{\varepsilon_n - 1}{\varepsilon_n + 2} \right)^2 - \frac{\pi d^2}{4AB\Phi_3} (\varepsilon_n - 1) n_k.$$

From expression (9) it follows that at the constancy of the design parameters and operating mode of the improved triboelectric device, the breaking point of the raw cotton blades depends on the square of the magnitude of the applied electric field voltage (E) and the physical and mechanical properties (A ; B ; Φ_3 ; ε_n ; d ; n_k ; m) of the pappuses themselves. In this case, by changing the magnitude of the applied electric field strength, it is possible to change the angle of detachment of the flakes from the surface of the rotating charged working element within a wide range, i.e., the applied electric field strength can serve as the main regulating factor when sorting raw cotton flakes by the quality indicators of their fibers on an improved triboelectric device.

Using formula (9), we perform a calculation to determine the angle of detachment of particles of different masses from the surface of the rotating charged working body of the improved triboelectric device at the following parameter values: $V_n = V_6 = 1,26$ M/c; $g = 9,81$ M/c²; $R = 0,2$ M; $\varepsilon_0 = 8,85 \cdot 10^{-12}$ Ф/М; $E = 4 \cdot 10^5$; $5 \cdot 10^5$ и $6 \cdot 10^5$ В/М; $A = 32,42 \cdot 10^{-3}$ М; $B = 24,62 \cdot 10^{-3}$ М; $\Phi_3 = 1,17$; $L = 0,65$; $\varepsilon_n = 7,0$; $m = 100, 120, 140, 160, 180, 200$ и $220 \cdot 10^{-6}$ mg. Figure 3 shows the curves of changes in the angle of detachment of raw cotton flyers from the surface of the working body depending on their mass at different values of the applied electric field strength.

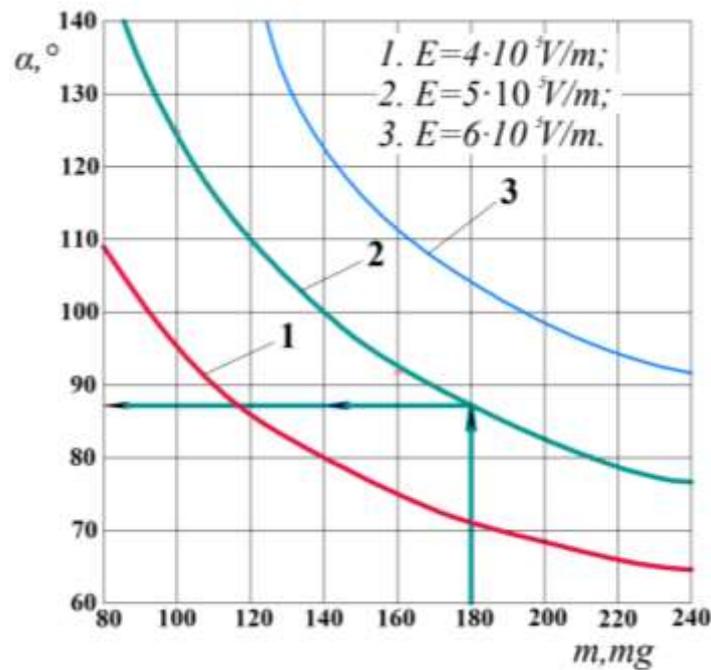


Figure 3. Curves of changes in the angle of detachment (α) of flywheels from the surface of the working body depending on their mass (m) at different values of electric field strength (E)

As follows from the curved dependencies, with a change in the mass of the flakes, the angle of their separation from the surface of the working part changes. For example, if the angle of detachment of a 100 mg pappuses is 125°, then the angle of detachment of a 160 and 220 mg pappuses is 93°10' and 79°37' respectively (Fig. 3, curve 2), i.e., with an increase in the mass of the pappuses, the angle of their detachment from the surface of the working part of the improved triboelectric device decreases. This is explained by the fact that with an increase in the mass of the flakes, the quality indicators of the fibers increase and their deformation under the influence of an electric field decreases. As a result, the contact area of the flywheels with the surface of the charged working body decreases, which, in turn, leads to a decrease in the electrical force of their contact with it. In this regard, flakes of different masses and, accordingly, fibers of different quality are attracted to the surface of the working body by electrical force of varying magnitude and detach from it at different angles of rotation. The latter allows, by correctly establishing the coordinate axis of the separating planes, to sort raw cotton bolls into various fractions depending on the quality indicators of their fibers and obtain guaranteed sowing material from bolls with high-quality fibers.

From Figure 3, it is also evident that with a change in the magnitude of the induced electric field strength, the angle of detachment of the flyers of the same mass changes. For example, if at the magnitude of the induced electric field

strength $4 \cdot 10^5$ V/m, the angle of rupture of 160 mg mass beads is 75° (Fig. 3, curve 1), then at the magnitude of the electric field strength $5 \cdot 10^5$ and $6 \cdot 10^5$ V/m it is $93^\circ 10'$ and $115^\circ 48'$ respectively (Fig. 3, curves 2 and 3). That is, with an increase in the magnitude of the applied electric field strength, the angle of detachment of particles of the same mass increases. This is explained by the fact that with an increase in the electric field strength, the electric force of adhesion of particles to the surface of the working part and, accordingly, the angles of their detachment from its surface increase. In this regard, with a change in the magnitude of the applied electric field strength, it is possible to change the angles of detachment of the flyers from the surface of the working part of the improved triboelectric device within a wide range.

Analysis of the curve dependencies from Figure 3 shows that if we consider flakes with a mass of less than 180 mg and fiber of lower quality, then to sort flakes with high-quality fiber from low quality, it is sufficient to create an induced electric field strength on the surface of the rotating charged working body within the range of $5 \cdot 10^5$ V/m. An increase or decrease in the magnitude of the electric field strength from this value leads to a decrease in the efficiency of sorting raw cotton flakes by the quality of their fibers into various fractions on an improved triboelectric device.

CONCLUSION

The proposed electrical methods do not allow for precise and qualitative sorting of raw cotton into various fractions based on the quality indicators of their fibers, and some of them are fire-hazardous. Improvement of the triboelectric device allows sorting raw cotton particles accurately and qualitatively according to the quality indicators of their fibers into various fractions, thanks to the rational placement of the working part on the helical grooves. In this case, the voltage of the induced electric field can serve as the main regulating factor when sorting raw cotton flakes by the quality of their fibers on an improved triboelectric device.

Blades, rationally placed on the surfaces of the working body of the improved triboelectric device, depending on their mass and, accordingly, the quality indicators of their fibers, detach from it at different angles of rotation, which allows, by correctly establishing the coordinate axis of the distribution planes, to sort them into different fractions and obtain guaranteed sowing material from blades with high-quality fibers.

In this case, for sorting raw cotton flakes by their fiber quality into different fractions, it is sufficient to create an induced electric field strength on the surface of the rotating charged working element within $5 \cdot 10^5$ V/m. An increase or decrease in the voltage value from this value leads to a decrease in the efficiency of sorting raw cotton bolls on an improved triboelectric device.

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