DESCRIPTION OF THE PARAMETERS OF ELECTRIC SEPARATOR OF RAPE SEED MIXTURES

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Summary. The article deals with the results of theoretical and experimental researches on rape seed separation by the electric separator. The optimum parameters of the separating process are defined.

Key words: rape seed, electric separator, movement trajectory, factors

THE SETTING OF THE PROBLEM

One of the tasks of seed mixture separation is its division on the individual fractions. The most valuable seeds among these fractions are those possessing the highest sowing and harvest properties. To define them from the general amount it is necessary to use such separators which would separate not owing to physical-mechanical properties but to the biological qualities.

Electric separators are the machines which are capable to account for the biological seed quality in the process of separation, where the electric field of crown charge is the main or additional operating element [1,7,9,12,13]. The separation of seed mixtures is prformed according to physical-mechanical and electric properties of seeds.

Numerous researches on both the theoretical and practical aspect allowed to investigate a wide range of different types of electric seed separators [1,7,13]. All of them aim at the refining seed mixtures from inefficiently removed admixtures.

The prominent place is devoted to electric-frictional separators [7,9,12,13], the operating element of which is the curve friction plane. They are very prospective in the technological line in the preparation of rape seed [9,14].

The lack of the results of the researches on the process of rape seed mixtures electric separation causes great problems in their application. To solve this problem it was necessary to conduct certain investigations in order to define the influence of the basic regulation parameters of the separation process on the quality of the received sowing material and according to this analysis to determine the qualitative indices of their optimal parameters.

THE PRELIMINARY RESEARCH ANALYSIS

The rough surface inclined at the angle α towards the horizon forming angle β with the line of the biggest incline moves concessively on its surface with the constant speed $\vec{V}_f$ (Fig. 1).
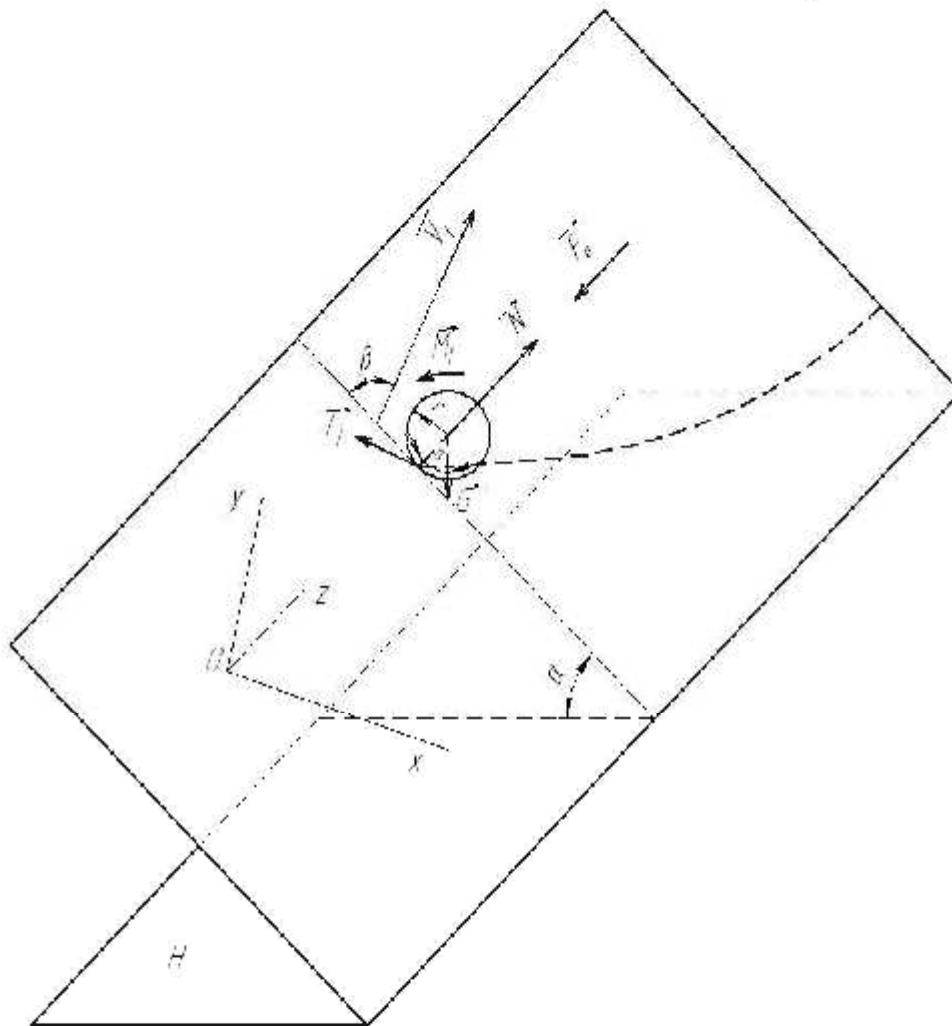

Fig. 1. Scheme of forces acting on rape seed of the globe-shaped form situated on the moving friction plane and located under free incline angle in the electromagnetic field

Movable coordinate $Oxyz$ is tied with the plane. Moreover, the axis Ox is directed downwards across the line of the biggest decline and the axis Oz is perpendicular to the plane. Axes of immovable system of account $O_1x_1y_1z_1$ are parallel to the corresponding axes of the movable system of account.

Let us consider the relative movement of seeds with mass m_1, in the shape of homogeneous sphere and radius R_1, on the plane. At the starting moment $t=0$ the centre of the seed mass has

the relative velocity $\vec{V_0}$ an it forms the angle θ_0 with the axis Ox. During movement the speed is subjected to the influence of the system of forces (the force of weight $\vec{G} = m \cdot \vec{g}$; the normal reaction $\vec{N}$; the force of sliding friction $\vec{F_f}$; the movement of rolling friction forces M_f; the additional electrostatic force $\vec{F_e}$ which is perpendicular to the plane).

Differential equation of movement of the ball's mass centre in the natural form and differential equation of rotary movement around the mass centre may be expressed in the following way:

$$m\frac{dV}{dt} = mg\sin\alpha\cos\theta - F_f,$$

$$m\frac{V^2}{\rho} = mg\sin\alpha\cos\theta ,$$

$$0 = N - mg\cos\alpha - F_e$$

(1)

$$J\frac{d\omega}{dt} = F_f \cdot R - M_f,$$

where: V is the relative velocity of the ball's mass centre;

θ is the angle between the vector of velocity $\vec{V}$ and the axis Ox;

$J = 0,4mR^2$ is the axial moment of the ball's inertion concerning the central axis.

The moment of rolling friction is determined by,

$$M_f = \delta \cdot N = \delta(mg\cos\alpha + F_e),$$

(2)

where: δ is the coefficient of rolling friction.

Taking into consideration the fact that the ball rolls without sliding, one must keep to the following conditions:

$$\omega = \frac{V}{R}; \qquad\qquad F_f < fN = f(mg\cos\alpha + F_e).$$

(3)

The force of sliding friction is determined with the help of the following formula:

$$F_f = \frac{1}{1,4} \cdot \left(0,4\sin\alpha\cos\theta + \frac{\delta}{R}(mg\cos\alpha + F_e) \right).$$

(4)

When the additional force $F_e = 0$ the condition (3) will be kept at all values of the angle θ with:

$$tg\alpha < 3,5 \cdot \left(f - \frac{\delta}{R} \right).$$

(5)

Otherwise the conditions can be achieved by the application of additional force F_e:

$$F_e > \frac{mg}{f - \frac{\delta}{R}}\left(\frac{2}{7}\sin\alpha - \left(f - \frac{\delta}{R} \right)\cos\alpha \right).$$

(6)

Considering the fact that inequality (3) is obtained, we exclude the value of the force of friction F_f from the equation (1). As a result, we arrive at the system of differential equations:

$$\begin{cases} 1,4 \cdot m \dfrac{dV}{dt} = mg \sin\alpha \sin\theta - \dfrac{\delta}{R} \cdot (mg \cos\alpha + F_e), \\[3mm] m \dfrac{V^2}{\rho} = mg \sin\alpha \cos\theta . \end{cases} \qquad (7)$$

Taking into consideration that the curvature of the curve is determined by the formula:

$$\frac{1}{\rho} = -\frac{d\theta}{dS} \qquad \text{and} \qquad V = \frac{dS}{dt}, \qquad (8)$$

dS is an elementary arc of the trajectory of relative movement of the ball's mass centre.

Or $\qquad \dfrac{d\theta}{dS} = -\dfrac{d\theta}{dt} \cdot \dfrac{1}{V}; \qquad\qquad \dfrac{dV}{dt} = \dfrac{dV}{d\theta} \cdot \dfrac{d\theta}{dt} .$

The equation (8) may be written in the following way:

$$\begin{cases} 1,4 \cdot \dfrac{dV}{d\theta} \cdot \dfrac{d\theta}{dt} = g \cos\theta - \delta \cdot g_1 \\[3mm] V \dfrac{d\theta}{dt} = g_1 \cdot \sin\theta . \end{cases} \qquad (9)$$

We mark:

$$g_1 = g \sin\alpha ; \qquad \delta = \frac{\delta}{g_1 \cdot R} \cdot \left(g \cos\alpha + \frac{F_e}{m} \right)$$

Having excluded $\dfrac{d\theta}{dt}$ from the equation (9) we get:

$$1,4 \cdot \frac{1}{V} \cdot \frac{dV\delta}{t\theta} = -\frac{\cos\theta}{\sin\theta} + \frac{\delta}{\sin\theta} . \qquad (10)$$

The equation (10) will help to get the equation determining the velocity of movements of the ball's mass centre at the spontaneous value of the angle θ ($0 < \theta \le \theta_0$):

$$V = V_0 \cdot \left(\frac{\sin\theta_0}{\sin\theta} \right)^{\frac{\delta}{1,4}} \cdot \left(\frac{tg\dfrac{\theta}{2}}{tg\dfrac{\theta_0}{2}} \right)^{\frac{\delta}{1,4}} . \qquad (11)$$

The second differential equation of the system (9) gives the opportunity to get the time (t) when the angle θ is changing from the primary value θ_0 to some values $\theta \le \theta_0$:

$$t = \frac{V_0}{g_1} \int\limits_{\theta}^{\theta_0} \left(\frac{\sin\theta_0}{\sin\theta} \right)^{\frac{\delta}{1,4}} \cdot \left(\frac{tg\dfrac{\theta}{2}}{tg\dfrac{\theta_0}{2}} \right)^{\frac{\delta}{1,4}} \cdot \frac{d\theta}{\sin\theta} . \qquad (12)$$

Projections of the relative velocity of the mass centre on the axis of the movable system of account are equal to:

$$V_x = V \cos\theta ; \qquad V_y = V \sin\theta . \qquad (13)$$

Considering $V_x = \dfrac{dx}{dt}$, $V_y = \dfrac{dy}{dt}$ one may get the differential equations for determining coordinates of the ball's mass centre at any moment:

$$\frac{dx}{dt} = V\cos\theta \; ; \qquad \frac{dy}{dt} = V\sin\theta \; . \tag{14}$$

From (9) we come to the conclusion that $dt = -\dfrac{V}{g_1} \cdot \dfrac{d\theta}{\sin\theta}$.

After insection of the expression for dt in (14) and prforming integration we get coordinates of the ball's mass centre at any moment:

$$x = x_0 + \frac{V_0^2}{g_1} \int_0^{\theta_1} \left(\frac{\sin\theta_0}{\sin\theta}\right)^{\frac{2}{1,4}} \cdot \left(\frac{tg\dfrac{\theta}{2}}{tg\dfrac{\theta_0}{2}}\right)^{\frac{2}{1,4}} \cdot \frac{\cos\theta\, d\theta}{\sin\theta} \; ,$$

$$y = y_0 + \frac{V_0^2}{g_1} \int_0^{\theta_1} \left(\frac{\sin\theta_0}{\sin\theta}\right)^{\frac{2}{1,4}} \cdot \left(\frac{tg\dfrac{\theta}{2}}{tg\dfrac{\theta_0}{2}}\right)^{\frac{2}{1,4}} \cdot d\theta \; , \tag{15}$$

$$z = R,$$

where: x_0, y_0 are the coordinates of the ball's mass centre at the starting moment.

– We may accept $x_0 = y_0 = 0$.

If at the starting moment the movable coordinate system coincides with the immovable one, the coordinates x_1, y_1, z_1 of the centre of the ball's mass in the immovable system may be determined with the help of the following formulas:

$$x_1 = V_n \cdot t \cos\left(\vec{V}_n \hat{} x_1\right) + x,$$

$$y_1 = V_n \cdot t \cos\left(\vec{V}_n \hat{} y_1\right) + y, \tag{16}$$

$$z_1 = R.$$

THE AIM AND THE TASK OF THE RESEARCH

The research is aimed at the examination of the impact of regulation parameters of the process of electric separation of rape seeds and determination of their optimal values.

EXPOSITION OF THE MAIN MATERIALS

The achieved mathematic equation and dependencies describe the movement of rape seeds of the spherical form of definite dimensions and mass on the movable frictional plane placed under spontaneous angle of decline in the electromagnetic field. Insetting the values of regulation param-

eters of the process of separation into the achieved equations we calculate theoretic dependence of velocity and trajectory of the movement of the particles of the rape seed mixture on the values of the entered regulation parameters, in particular the values of the decline angle of the separating plane, velocity of its movement and the tension of electric field in the working area of electric separator. By the regulation of the values of these parameters we may influence the trajectory of the movement of seeds mixture particles of the separating plane.

During the examination of the process of separation we determined the following values of regulated factors:

– tension of the electric field (E, kV/cm) – 0,71; 1,43; 2,14,
– angle of the separation plane slope (α, grade) – 5; 10; 15,
– velocity of the separation plane movement (V, m/s) – 0,06; 0,12; 0,18.

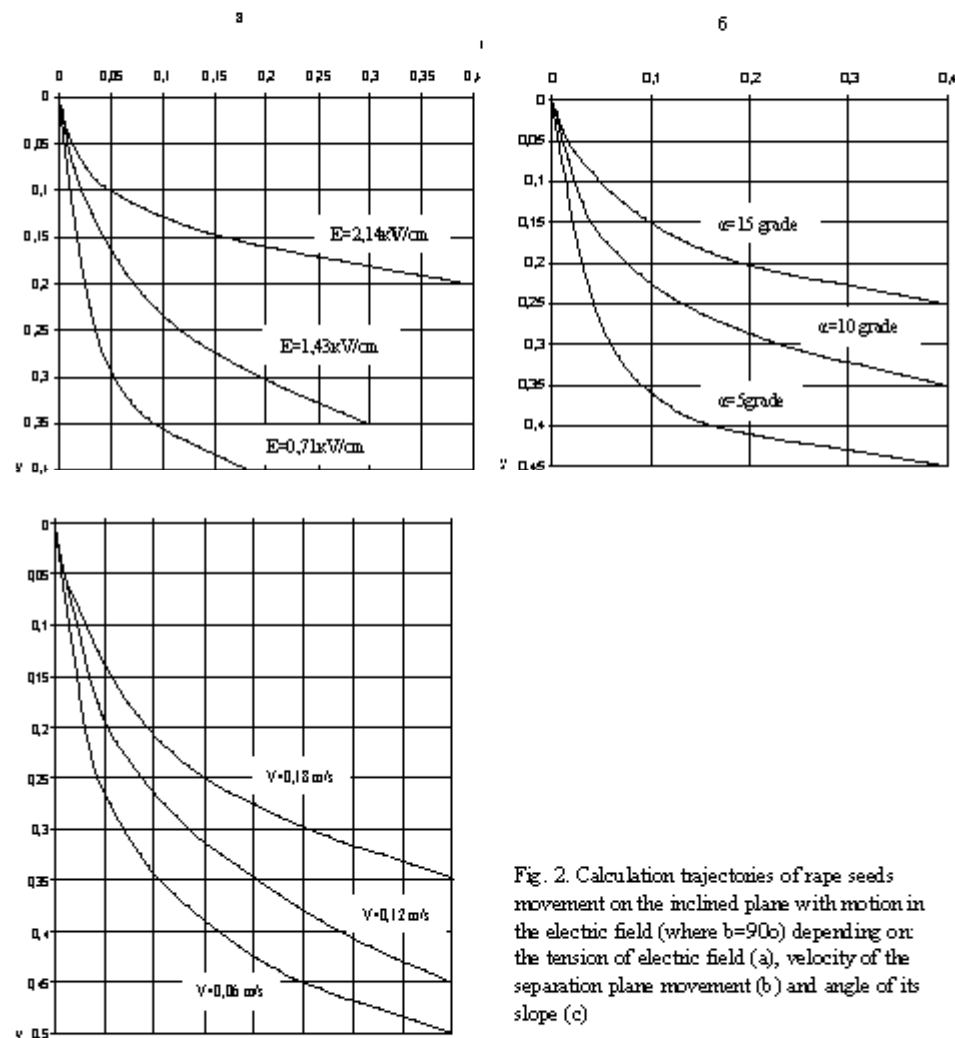The achieved calculating trajectories of rape seeds movement are suggested in Fig. 2.

Fig. 2. Calculation trajectories of rape seeds movement on the inclined plane with motion in the electric field (where b=90o) depending on: the tension of electric field (a), velocity of the separation plane movement (b) and angle of its slope (c)

The analysis of the achieved results proved that the increase of electric field tension in the working area of electric separator considerably influences the trajectory of seed, in particular, the coordinates of their separation plane exit. At the lower values of tension the seed exit takes place at the vertical side of the plane (Fig. 2a) which is characterized by the coordinate X. The increase of tension to the maximum value will cause the changes of coordinates of the descending seeds. In such case the seeds will go down from the vertical side of the plane characterized by the coordinate Y.

The angle of decline of the separation plane has an analogical influence (Fig. 2c). Its minimal value affects coordinates of the seeds which go down at the vertical side of the plane and its maximal value – at the cross side.

As far as the velocity of the movement of separation plane is concerned, the analysis of Fig. 2b proves that the seeds descending takes place at the vertical side (coordinate X) and depends on its value.

The achieved results give the opportunity to make the conclusion that the process of extraction will take place in the most effective way when the angle of decline of the separation plane $a = 10$ grades and the value of tension of electric field in the working area of electric separation E = 1,4 kV/cm. In addition, one may state that the admissible value of regulation factors will be within $a = 7\ldots12$ grades and E = 1,12\ldots1,75 kV/cm.

CONCLUSIONS

1. The achieved calculation trajectories give the opportunity to determine the effect of the basic regulation factors on the movement of rape seeds on the working surface of electric and friction separator and to define its constructive parameters.

2. The optimum values of the most influentional factors are determined by the results of implementation of the methods of multifactorial experiment. The angle of separating plane $a = 10$ grades. The tension of electric field in the working area of separator E is 1,4 kV/cm.

3. Determination of the optimal constructive and technological parameters of the electric separator will allow to increase the quality of pre-sowing treatment of rape seed and its sowing properties.

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OPIS PARAMETRÓW ELEKTRYCZNEGO SEPARATORA
DO MIESZANEK RZEPAKU

Streszczenie. Artykuł omawia wyniki badań teoretycznych i doświadczalnych nad rozdzielaniem nasion rzepaku przy pomocy separatora elektrycznego. Ustalono optymalne parametry procesu rozdziału.

Słowa kluczowe: nasiona rzepaku, separator elektryczny, trajektoria ruchu, czynniki