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Investigation of equilibrium angles of winter rapeseed on an inclined plane of an electro frictional separator and optimization of their geometrical sizes

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Summary. The results of investigations of the equilibrium angle of the components of a seed mixture of winter rape on the surface of a moving tape of an electro frictional separator in an electric field of corona discharge are presented. Dependences of influence of the speed of the separator tape movement and the intensity of the electric field in its working zone on the angle of equilibrium of qualitative, acute and traumatized seeds of winter rape were obtained. The possibility of using the seed equilibrium angle as an index of its divisibility on an electro frictional separator based on a combination of physical-mechanical and biological properties has been confirmed. At the established angles of equilibrium, the geometric parameters of the inclined plane of the electro-frictional separator are optimized.

Key words: winter rape seed, electro frictional separator, seed properties, signs of divisibility, angle of equilibrium, separator duck, and geometric parameters

INTRODUCTION

There are many reasons for the appearance of poor-quality, biologically defective seeds in the crop production. Basically, they appear due to various kinds of damage due to unsatisfactory agro-climatic conditions of growing (frequent rainy and rather warm days), conditions of harvesting, drying, increase of passage of sowing material on the working surfaces of seed-cleaning machines in the process of post-harvest treatment, etc. [1, 19] . In this case, it is worth noting that both micro and macro traumatized seeds are undesirable. The most harmful is micro-damage in the seed embryo zone. Under such conditions, in the process of germination, the sprout loses its orientation, is swirling. Colonies of photo pathogenic fungi develop on damaged sites, which may cause the death of sprouts. Damage of the shell results in profound physiological changes in the seeds, loss of nutrients, and metabolic disorders, which weakens the growth of seedlings [9, 10, 13, 20]. Damage reduces the crop properties of the seed during its storage. In places of trauma, pathogenic microorganisms develop, resulting in a rise in the temperature of the seed mass, which leads to self-warming.

In this connection, in the process of post-harvest treatment of a seed mixture of winter rape, it is necessary to have an effective separation of the available low quality seed.

Seeds from all sorts of injuries are different from the qualitative shape of the surface and roughness. Because of this, their separation can be most effectively carried out on inclined planes, especially those in which an electric field of corona discharge is used as an additional working body. The sign of divisibility during separation on such separators are the angles of equilibrium of the components of the mixture.

After examining their significance, it is possible to find and optimize such technological and structural parameters of the electric separation on an inclined plane, in which the separation of various damaged seeds of the winter rape crop sowing material will be the most fully carried out.

Analysis of recent researches and publications. In order to establish the possibility of separating of winter rape seeds of low-quality, non-viable seeds on an electro frictional separator [5, 6, 13, 15] by electron scanning microscopy on a JEOL-T220A microscope, the state of the surface of individual ones was investigated. On the received results they can be conditionally divided into three types:

1) qualitative - filled, spherical forms;

2) feeble - wrinkled, irregular with incomplete endosperm;

3) damaged - from various kinds of cracks of the shell, destroyed by a shell or core.

In the conditions of primary seed production, there is a need for seed separation of the latter two types as unsuitable for sowing. For this purpose, the electro frictional separator is the best suited, using an electric field of corona discharge as an additional working body. It implements the possibility of separating the mixture by a combination of physical-mechanical and biological properties [2, 3, 4, 5, 7, 13, 14, 16].

The integral index of divisibility (a sign of divisibility), which binds the biological state of the seeds with the influence of all forces acting on them in the electric field on the moving inclined tape of the electro frictional separator, is the angle of their equilibrium α_p [7, 8, 9, 12,13]

Its mathematical expression is obtained from the condition of equality of forces acting on a seed on a mobile inclined plane:

$$f\cos\alpha \cdot G = G\sin\alpha \,, \qquad (1)$$

$$f = tg\alpha \,.$$

Where: f – coefficient of friction.

Taking into account (1) we can assume that, under ideal conditions, α_p is approximately equal to the angle of friction of the drift of the seed φ.

If the electric force of F_e operates on the seed, condition (1) will look like:

$$\frac{F_e}{G}\sin\varphi_T = \sin(\alpha - \varphi_T). \quad (2)$$

Here from, the expression of the angle of equilibrium of the seed in an electric field on an inclined plane:

$$\alpha_p = \varphi_T + \arcsin\left(\frac{F_e \sin\varphi_T}{G}\right). \quad (3)$$

Since the value of the electrical force of F_e depends to a large extent on the shape of the seed, its surface, the presence of damage, cracks, etc., it can be argued that the equilibrium angle is an integral indicator that takes into account the forces acting on the seed, its physical, mechanical and biological properties.

The condition of the outer surface of the components of the seed mixture will affect their movement along the tape of the electro-frictional separator. In the case of electric separation, low-quality seeds, having got into the inter electrode space of the separator; will receive a larger charge, resulting in a stronger attraction to the surface of the conductive tape [4, 7, 9, 10, 11, 13, 15, 16, 17]. Ultimately, this results in an increase in the difference between the angles of equilibrium of the components of the mixture and their coordinates from the separation plane and ensuring that the conditions for their effective separation are met.

Since the components of the rape seed mixture should have different values of the angle of equilibrium on the inclined moving separation plane, then setting the value of the angle of inclination within the $\alpha_{pmin} < \alpha < \alpha_{pmax}$, it is possible to achieve a result when the difference in their coordinates is the maximum. However, for this purpose it is necessary to provide optimum geometrical parameters (width and length) of the separating plane of the electro-frictional separator.

The purpose of the work was to improve the quality of winter rape seed production due to the study of the main feature of the divisibility of its components - the equilibrium angles on the separation electro frictional plane and their influence on the main parameters of electric separation.

MAIN RESULTS OF THE RESEARCH

Determination of the equilibrium angles of the components of a seed mixture of winter rape, which were qualitative, feeble and damaged seeds, were carried out on an experimental installation (Fig. 1).

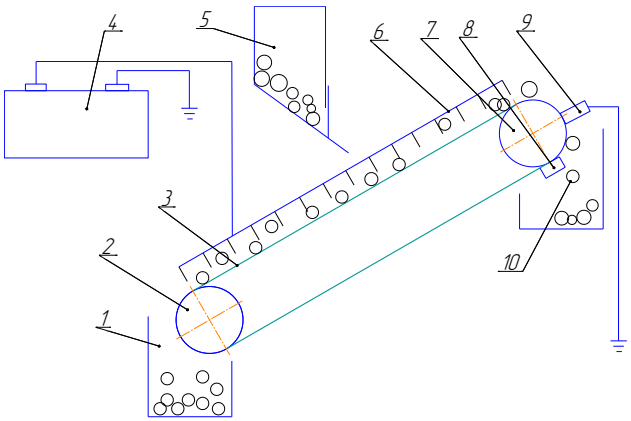


Fig. 1. Technological scheme of experimental installation: 1 - conditioned seed receiver; 2 - driven roller; 3 - separation tape; 4 - a source of high voltage; 5 - bunker-feeder; 6 - crowning electrode; 7 - driving roller. 8 - cleansing brush; 9 - protective earthing; 10 - receiver of waste

These angles of equilibrium were determined for different values of the regulated electro separation parameters-the intensity of the electric field in the working area of the separator *E (kV / cm)* and the velocity of the tape *Vt (m / s).* The value of the speed of the tape of the separator *Vt* varied from 0.03 m / s to 0.15 m / s, and the intensity of the electric field *E* varied from 0.7 to 3 kV / cm.

The method of conducting the research was as follows.

For each case, at the given values of the named parameters, the lowest angle of inclination $\alpha_н$ was found which ensured the removal of all the seeds of the sample up the tape, and the largest angle $\alpha_в$, by which all the seeds rolled down it. The difference between these angles was the magnitude of the variation of the distribution of this sample. Dividing it into a number of class's n_i, they received a class interval:

$$i_\alpha = \frac{\alpha_B - \alpha_H}{n_i}. \quad (4)$$

This interval was rounded up to an integer. We determined n_i for each component. For all experiments we took one meaning of i_α with the condition that the number of classes n_i was not less than 5.

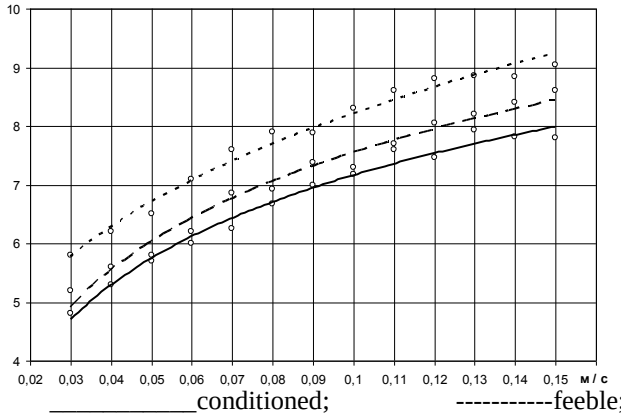
By stabilizing in each experiment the significance of the parameters (factors) that characterize the above mentioned individual cases of conducting research, first we set the angle $\alpha_н + i_\alpha$ and released the seeds on the tape. The seeds that got into the lower receiving hopper had the equilibrium angle, which equaled:

$$\alpha_P = \alpha_H + \frac{i_\alpha}{2}. \quad (5)$$

The seeds that appeared in the upper receiver were again released on a moving tape, at an angle of inclination equal to $\alpha_н + 2i_\alpha$, repeating everything as in the previous experiment.

In the last experiment of this series, seeds were taken that had a maximum angle of equilibrium.

According to the results of the research, we obtained graphic dependences of the equilibrium angles of the components of the rapeseed mixture from the regulated parameters of electric separation-the intensity of the electric field in the working zone of the separator E (kV / cm) and the velocity of the tape Vp (m / s).

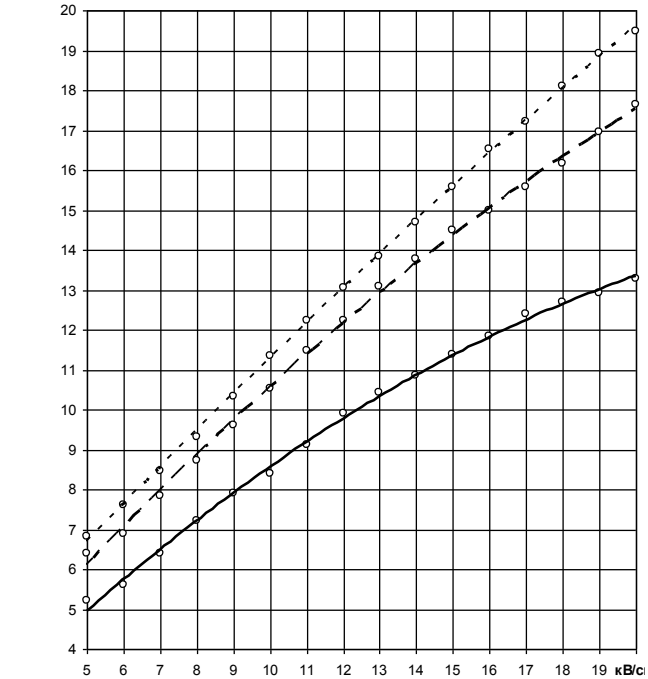


_____conditioned; ----------feeble; ……. damaged

Fig. 2. Dependences of the variation of the angle of equilibrium on the winter rape on the speed of the tape of the separator Vp

The results of the research show that increasing the speed of the tape of the separator Vp increases the angle of equilibrium of the seeds of the rape α_p.

The voltage of the electric field E has a significant effect on the value of the angle of equilibrium, since the value of the additional electric force F_e, which is applied perpendicular to the plane of motion of the separator tape, directly depends on it. As the tensile strength increases, the angle of equilibrium of the studied seed increases too. (Fig. 3).



_____conditioned; ----------feeble; ……. damaged.

Fig. 3. Dependence of changes in the angle of equilibrium on winter rape from the intensity of the electric field E

Having analyzed the fig. 2 and 3, it should be noted that the feeble and damaged seeds, in comparison with the qualitative ones, have a greater significance of the angle of equilibrium. In the absence of an electric field action, the difference in the angles of equilibrium of the components of the seed mixture did not exceed 3 degrees. An overlay on the plane of an additional electric force leads to an increase in the difference in the angles of the equilibrium of the qualitative and damaged seed. For E = 3 sq./cm this difference is 7 degrees. The reason for this is the fact that the feeble and damaged seeds receive a larger charge and, with the increase in the electric force, they are pressed down to the plane more strongly. It is for these reasons that the values of their angles of equilibrium, in comparison with the angles of equilibrium of quality seeds, are greater.

On the basis of the data obtained, it can be argued that the regulated parameters of the electric separation influence the angle of equilibrium of high quality, feeble and damaged seeds of winter rape in different ways. At separate values of these regulated parameters it is possible to obtain the maximum value of the difference between the values of the angles of equilibrium of the studied species of seeds, which is the main prerequisite for their effective separation.

In order to take the fullest account of the variability of components of the seed mixture of winter rape by the values of the angles of equilibrium on the inclined plane of the electro-friction separator, it is necessary to optimize its geometric parameters. This is possible by analyzing the movement of seeds on a given plane.

Having been put on the surface of the tape, seeds will start moving on it in some trajectories with different accelerations g_1:

$$g_1 = g \cdot \sin \alpha_p , \qquad (4)$$

where: g – acceleration of free fall, m / s^2; α_p – angle of equilibrium of seeds, deg.

By setting the angle θ (Fig. 4), as a function of the displacement of S of a seed, we can find the velocity of the motion of the center of its mass at an arbitrary value of this angle.

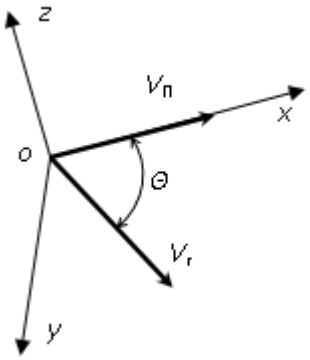


Fig. 4. Vectors of the velocities of the movement of seeds

The time *t*, during which the angle θ changes from the initial value θ_0 to some value $\theta \le \theta_0$ is determined by the formula (5):

$$t = \frac{V_0}{g_1}\int_{\theta}^{\theta_0}\left(\frac{\sin\theta_0}{\sin\theta}\right)^{1}\cdot\left(\frac{tg\frac{\theta}{2}}{tg\frac{\theta_0}{2}}\right)^{\frac{e}{1,4}}\cdot\frac{d\theta}{\sin\theta}\ . \qquad (5)$$

As it moves, the seed will be displaced along the curvilinear trajectory relative to its original position on the axes O_x and O_y.

During separation, during a certain period of time, the angle θ between the directions of the instantaneous relative speed of the seed V_r with the axis O_y will vary from 90 ° to 0 °. Given the interval h of the change of the angle θ, the equation of motion of the seed will look like:

$$V_1 = V_0\cdot\left(\frac{\sin\theta_0}{\sin\theta_h}\right)^{\frac{1}{1,4}}\cdot\left(\frac{tg\frac{\theta_h}{2}}{tg\frac{\theta_0}{2}}\right)^{\frac{e}{1,4}}\ . \qquad (6)$$

If the seeds of the rapeseed mixture have different values of the angles of equilibrium α_r, with $\alpha_{rq} < \alpha_{rf} < \alpha_{rd}$, then for the same time interval t they will pass different paths, since the value of the angle of equilibrium affects the seed acceleration value g_1. Thus, the time during which the angle θ varies from 90 ° to 0 ° according to (6) will be different:

$$t_n = \frac{\frac{V_1}{\sin\theta_h}}{g_{1n}}. \qquad (7)$$

In the case when it is necessary to select seeds from the seed mixture with the maximum value of the angle of equilibrium (cracked seeds), the angle of the greatest inclination of the separator tape should not exceed α_{rd}. In this case, at time t_1, the speed of their displacement along the axis O_h will reach zero, since $\cos 90^0 = 0$. The path that passes such a seed along the axis O_h will be equal to:

$$x_1 = \frac{V_1^2}{g_{11}} \qquad (8)$$

and on the O_y axis:

$$y_1 = \frac{x_1\cdot\cos\theta_h}{\sin\theta_h}\ . \qquad (9)$$

Further, such a seed will move only along the O_y axis together with the tape with the speed of V_p.

The feeble seed with the angle of equilibrium α_{rf} will pass, respectively, the path:

$$x_2 = \frac{V_2^2}{g_{12}} \quad \text{and} \quad y_2 = \frac{x_2\cdot\cos\theta_h}{\sin\theta_h},$$

and qualitative seeds with an angle of equilibrium α_{rq} is due

$$x_3 = \frac{V_n^2}{g_{13}} \quad \text{and} \quad y_3 = \frac{x_3\cdot\cos\theta_h}{\sin\theta_h}.$$

Possible trajectories of the movement of components of a seed mixture of rape on the working surface of the separator reflects the Fig. 5

Theoretically, the value of x_2 (Fig. 5) will characterize the required width of the separator tape from the point of feeding of the ascending mixture to its lower edge, that is, to the point of drop out of the seeds from the tape.

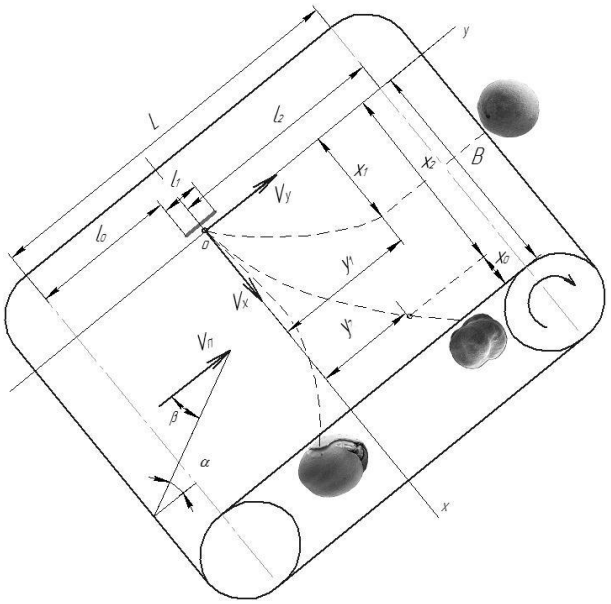


Fig. 5. Trajectory of the movement of rape seeds on the surface of the tape of friction separator

Taking into account that each fraction in the seed has some deviations from the mean value for it, the value of the equilibrium angle α_r, which may affect the quality of separation, will need to slightly increase the width of the tape, making it equal:

$$B = x_2 + x_0, \qquad (10)$$

where: x_0 = 0,1 ... 0,2 m.

Thus, seeds that have an equilibrium angle of $\alpha_r < \alpha_{rmax}$ for time t_1 must descend from the lateral edge of the tape. To do this, the condition must be fulfilled:

$$\vec{V}_n + \vec{V}_{II} \neq 0\ . \qquad (11)$$

Simultaneously with the downward movement of the seeds on the sloping plane of the separator, they will move along with the tape on the O_y axis with the speed of the V_P. The path they pass will be determined from equations (8) and (9).

As already mentioned earlier, cracked seeds with a maximum angle of equilibrium α_{rmax} at the end of time t_1 will move along the O_y axis with the velocity V_P of the tape. Therefore, the length of tape l_2 from the feeding point to the axis of the driving roller should be equal to or greater than y_1, that is:

$$l_2 \geq \frac{x_1\cdot\cos\theta_h}{\sin\theta_h}. \qquad (12)$$

Assuming the length of the feed line as l_1, and the distance from the edge of this line to the axis of the driven roller for l_0, we obtain the total length of the working line of the separator tape, that is, the distance between the axes of the rollers.

CONCLUSIONS

On the basis of the research conducted, the following conclusions can be drawn:

- the main feature of the separation of components of a seed mixture of winter rape on the separation plane of the electro-friction separator is the angle of their equilibrium;

- the values of the angle of equilibrium of winter rape seeds are influenced by regulated parameters - the

velocity of the moving plane and the strength of the electric field in the working zone of the separator, and the effect of the tension is much more significant;

- feeble and various kinds of damaged seeds are, in comparison with qualitative ones, greater values of the angle of equilibrium, which makes it possible to separate them on a sloping moving separating plane in the electric field;

- in case of choosing the optimal value of the velocity V_n and the intensity of the electric field E, it is possible to achieve the maximum difference in the values of the angles of equilibrium $\Delta\alpha_r$ for individual seeds, and at the same time to achieve the effective mode of operation of the separator;

- the angle of equilibrium α_r of the components of the seed mixture has a decisive influence on the optimal design parameters (dimensions) of the sewing plane of the electro-friction separator.

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