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JUSTIFICATION OF THE DIMENSIONS OF THE SLIDE-LIKE ELECTRIC FRICTION SEPARATOR SURFACE FOR SEPARATION OF WINTER PAPESEED

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Abstract.

The article presents the results of the development of the theoretical determination of the optimum dimensions of the surface of the electric friction slide-like separator for the parting of difficult-to-separate impurities or poor-quality (fragile, with different degrees of shell damage) seeds from the seed mixture.

On the basis of a theoretical analysis of possible cases of the movement of particles of seed mixtures along a moving inclined surface with an electric field superimposed on it, it was established that the determining parameters that affect the path traveled by the seeds up or down the separator web, are the seeds, the angle of inclination of the plane α, the movement velocity V_e, the radius r, the mass m of the seed and the value of the electric force F_e, as a result of the impact of the applied electric field. It is thanks to the additional impact of the electric force that it becomes possible to significantly reduce the distance of low-quality seeds rolling along the surface and increase the path they travel along with the surface in the direction of its movement.

The obtained analytical dependences make it possible to determine the minimum distance from the edge of the surface to the line of seed supply to it. For technological reasons, these distances should be increased due to the fact that they may come into contact with seeds that roll down, and due to the presence of rounded areas at the ends of the operating area of the surface, formed by the location of drive and tension rollers of a certain diameter.

As a result of the research, it was established that in order to carry out the technological process of rapeseed separation with the intention to separate low-quality (weak and of different damage degress) seeds, the working length of the surface of the electric friction slide-like separator should be 0.6 m.

Keywords: electric friction separator, surface length, winter rapeseed, separation.

FORMULATION OF THE PROBLEM.

Post-harvest treatment of winter rapeseed can be carried out in several stages, depending on the purity of the crop and the requirements that are placed on the final product. It may include primary, secondary, and additional cleaning, if necessary. The first two stages are carried out using machines with grid, trier and air operating units. The third stage is performed when the seed mixture should be separated from the hard-to-separate additives or low-quality (fragile, with varying degrees of damage of the shell) seeds. This process is carried out on special separation machines of various designs (Yermak *et. al* 2012, Shvets 2012).

A separate type of such machines are electric friction slide-like separators, in which an electric field is used as the main or additional operating unit length (Batsurovska 2021, Zakharov 2017, Inozemtsev *et. al 2010*, Kovalyshyn *et. al 2011*, Matviichuk *et. al* 2020, Nishchenko *et. al* 2008, Paraniuk *et. al* 2007, Shvets 2012). The sign of separability, according to which the grain mixture is parted in these machines, is the equilibrium angle (Kovalyshyn *et. al 2015*, Kovalyshyn *et. al 2017*). It depends on the set of physicomechanical and electrical properties of the components' particles of the separated mixtures.

The implementation of such separators in technological processes of seed processing is hampered by the lack of recommendations regarding the geometric dimensions of their operating unit (moving surface). In order to choose them correctly, it is necessary to perform a theoretical analysis of the movement of seeds along the above mentioned surface and develop recommendations for calculating the of that same surface necessary to ensure a high-quality separation process.

THE ANALYSIS OF RECENT STUDIES AND PUBLICATIONS.

The movement of seed mixture particles on a moving inclined plane has been studied by a number of researchers. All of them came down to determining their absolute velocities V_a, which is the sum of two components: the escape V_e, which is determined by the direction and magnitude of the movement velocity of the plane itself, and the relative V_r (Vasylenko 1960, Nishchenko *et. al* 2008).

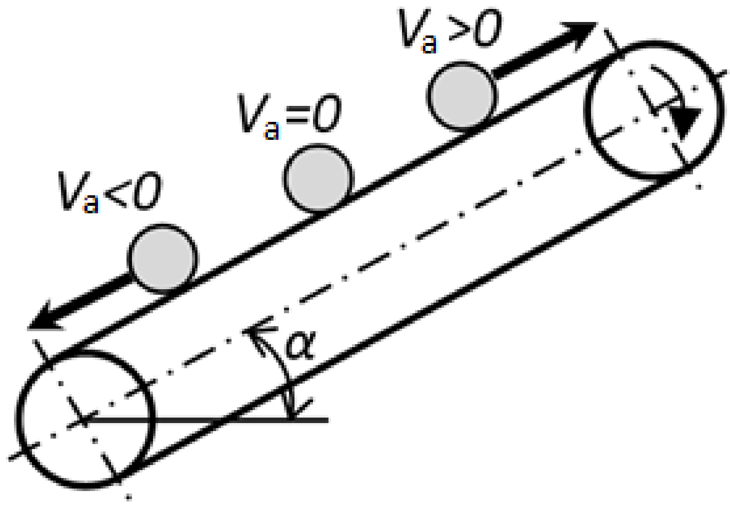

Figure 1. Possible options for the movement of seeds

In the process of separation, the absolute speed of the seed can acquire one of three values, namely (Fig. 1):

1) $V_a > 0$; $V_e > V_r$ (the particle moves up the plane);
2) $V_a < 0$; $V_e < V_r$ (the particle moves down the plane).
3) $V_a = 0$; $V_e = V_r$ (the particle is in equilibrium with respect to the stationary coordinate system).

The values of the absolute velocity of the seed V_a and the escape velocity V_e of the separation belt will determine the path that the components of the mixture will take along it up or down from the line of their placement on the belt. In the works (Nishchenko *et. al* 2008, Nishchenko *et. al* 2009, Shvets 2015, Shvets 2012), differential equations were obtained – they regarded planar motion of a seed (in the shape of a ball) along an incline in an electric plane. According to them, the main factors that affect the parameters of seed movement are the angle of inclination of the plane α, the movement velocity V_e, the radius *r* and mass *m* of the seed and the value of the electric force F_e, the source of later being corona discharge electric field superimposed on the plane.

There are works (Batsurovska 2021, Kovalyshyn *et. al 2015*, Paraniuk *et. al* 2007, Shvets 2011, Kovalyshyn *et. al 2017*) devoted to the study of the effect of electric force on the trajectory of seed movement. Thus, in (Kovalyshyn *et. al 2015*) it was established that the maximum difference in the equilibrium angles of the components of the winter rapeseed mixture is achieved at values of the electric force F_e = 1,76…2 $\cdot 10^{-6}$ H. It is known from (Kovalyshyn *et. al 2010*, Kovalyshyn *et. al 2017*) that the trajectories of seed movement will be determined by the necessary geometric parameters of the separation plane.

THE OBJECTIVE

The aim of the research is to substantiate the geometric parameters of the belt of the slide-like electric friction separator for separating winter rapeseeds; the goal is to separate low-quality (fragile, with the damage of varying degrees) seeds by means of a theoretical analysis of the movement of the seeds along a moving friction plane in an electric field.

PRESENTING THE MAIN BODY

In the process of separation, the seeds are put onto the moving separation plane, which is inclined to a certain level in relation to the horizon. Once on it, the force of the weight of the seed *G*, the normal reaction of the plane *N*, the frictional force F_f, and the action force of the electric field applied to the plane F_e will start to impact the seed (Fig. 2).

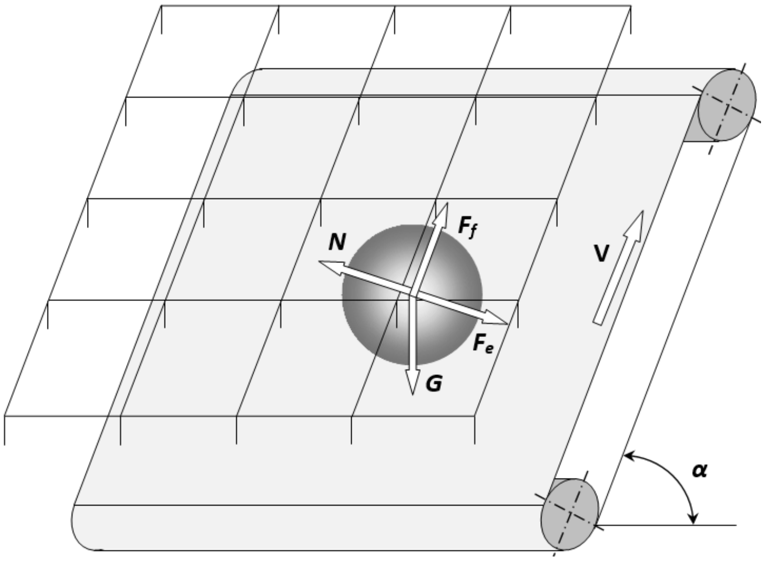

Figure 2. Diagram of the forces acting on the seed on an inclined plane in an electric field

In this case, the seed mixture particle is modeled as a sphere with radius *r*.

If at the moment of the introduction on the separation plane, the movement velocity of the seed will be lower than the movement velocity of this plane ($V_s<V_p$), then the seed will move down it. The inequality in this case holds:

$$f\cos\alpha\cdot G-G\sin\alpha<0. \quad (1)$$

where *f* is the coefficient of friction of the seed against the plane.

On the other hand, another inequality holds for such a case when $tg\alpha>f(\alpha_{min}>arctgf)$. This inequality is the evidence to the angle of inclination of the plane α to the horizon being greater than the angle of friction of the seed $\varphi_m=arctgf$.

After some time has passed, the velocity of the seed rolling along the plane becomes equal to the movement velocity of this plane. This time can be found from the expression:

$$t_1=\frac{V_n\cdot m}{3{,}5f(G\cos\alpha)-G\sin\alpha}. \quad (2)$$

where *m* is the seed mass.

The distance travelled by the seed at this point of time will equal to:

$$S_1=f(F_e+G\cos\alpha)-G\sin\alpha)\frac{t_1^2}{m}. \quad (3)$$

The dependences of the distance S_1 on the angle of inclination of the plane are shown in Fig. 3.

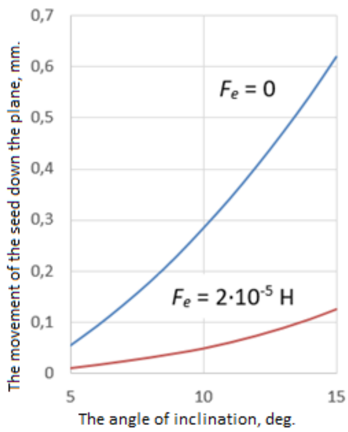

Figure 3. Dependencies of seed movement down an inclined plane on the angle of its inclination and the magnitude of the applied electric force

The seed can move up together with a plane in case of additional impact being applied on it. The condition of such a movement will look like this:

$$f\left(F_e + G\cos\alpha\right) - G\sin\alpha > 0. \tag{4}$$

Out of this condition, the value of the electric force, which will ensure its implementation, will equal to:

$$F_e > G\cos\alpha\left(\frac{tg\alpha}{f} - 1\right). \tag{5}$$

At the moment when the velocity of the seed equals to the velocity of the plane, it will begin to move up with it. However, due to the constant rolling of the seed, a state may arise when $F_f < fN$. This will cause it to move up over a period of time:

$$t_2 = \frac{V_{c1}}{g\sin\alpha}. \tag{6}$$

and will travel the distance

$$S_2 = V_{c1} \cdot t_2 - \frac{5}{7} g\sin\alpha \frac{t_2^2}{2}. \tag{7}$$

where $V_{c1} = \frac{(f(F_e + G\cos\alpha) - G\sin\alpha)}{3{,}5f(F_e + G\cos\alpha) - G\sin\alpha}$ - variable with time of the movement speed of the center of mass of the seed that has a shape of the sphere.

In order for the movement of the seed along with the plane not to stop, the condition must be fulfilled:

$$\frac{2}{7} G\sin\alpha < f(G\cos\alpha + F_e). \tag{8}$$

By putting the appropriate parameters of the separation process and the characteristics of the rape seeds into (7), the theoretical dependences of the movement of the seeds together with the plane on the angle of its inclination and the magnitude of the applied electric force were obtained (Fig. 4)

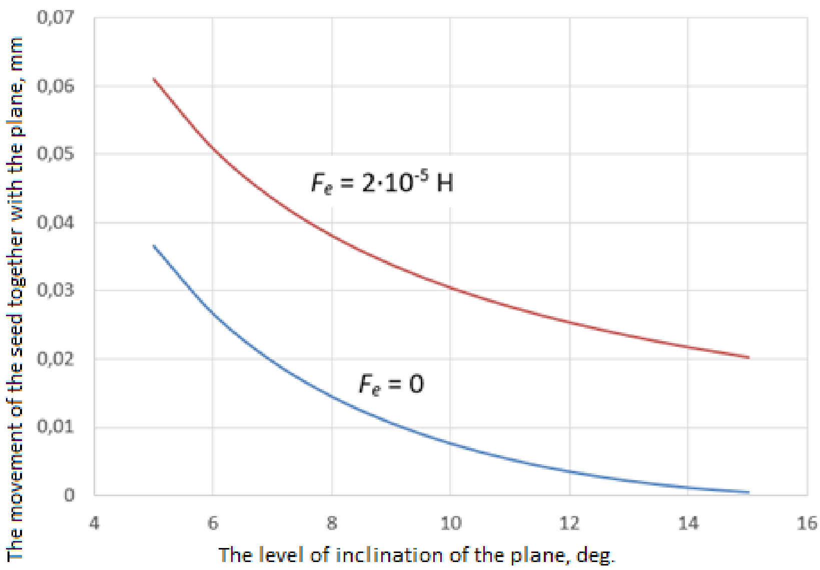

Figure 4. Dependencies of the movement of seeds up the belt on the angle of its inclination and the magnitude of the applied electric force

Analyzing the obtained results, it can be stated that applying an electric field to the separation plane significantly increases the distance travelled by the seed together with the plane in the direction of its movement (by 40% at $\alpha = 5°$ and by 98% at $\alpha = 15°$).

The obtained results make it possible to determine the minimum distance from the edge of the belt to the line of seed supply on it (Fig. 5).

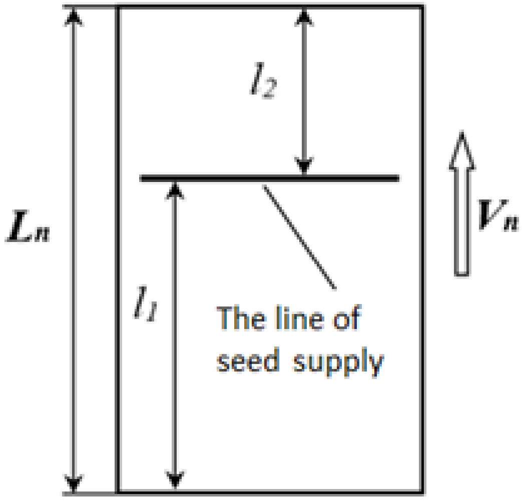

Figure 5. Scheme of positioning of the supply line on the belt of the electric friction separator

Therefore, according to (3) and fig. 3, the distance l_1 of the separator belt for separating rape seeds in the absence of an electric field should be between 0.4 and 0.6 m. Applying an electric force $F_e = 2 \cdot 10^{-6}$ N (Kovalyshyn *et. al 2015*) allows us to significantly reduce this distance ($l_1 \approx 0{,}1$ *m*). For the efficient operation of a slide-like electric friction separator, this indicator should be chosen slightly larger. The reason for this is that on the distance S_1 the seeds whose velocity has equaled the velocity of the belt moving up with it, may come into contact with the seeds that roll down. Therefore, we get the following:

$$l_1 = S_1 \cdot k_1 \tag{9}$$

where k_1= 1,1…1,3 is the coefficient of the distance increase l_1.

The length of the belt l_2 according to calculations (7) and according to fig. 4 during the separation of rapeseed should be l_2 = 0,03…0,04 m. This is a fairly small distance. However, due to the presence of a rounded section at the edge, caused by the location of the drive roller in the upper part, it should be increased by the radius *R*:

$$l_2 = S_2 + R \tag{10}$$

where *R* is the radius of the upper drive roller, m.

Taking into account (9) and (10), the recommended length of the belt of the electric friction slide-like separator can be determined as:

$$L_b = l_1 + l_2 = S_1 \cdot k_1 + S_2 + R\,. \tag{11}$$

By substituting the corresponding parameters in (11), we get:

$$L_b = 0{,}4 \cdot 1{,}2 + 0{,}04 + 0{,}08 = 0{,}6 \text{ m.}$$

Therefore, to carry out the technological process of rapeseed separation in order to separate low-quality (fragile and damaged to different degrees) seeds, the operating length of the belt of the electric friction slide-like separator should be 0.6 m.

CONCLUSION

As a result of the research, it was established that the movement of seeds along the separation belt of the electric friction separator is influenced by the angle of inclination, its movement velocity, and the magnitude of the electric force. The latter has the maximum effect on the trajectory of the movement of the seeds, as its impact leads to a reduction of the distance they take in the direction of the inclination of the belt and accelerates their acquisition of the parameters of the movement of the belt.

The dependencies obtained in the work make it possible to theoretically determine the required length of the belt of the slide-like electric friction separator. According to them, on a 0.6 m long belt, it will be possible to separate fragile and damaged to different degrees seeds from the seed mixture of winter rapeseed, the angles of equilibrium of which differ from the angles of equilibrium of seeds of a good quality.

REFERENCE

Batsurovska I.O. 2021. *Elektrotekhnolohii: navchalnyi posibnyk. Mykolaiv: MNAU.* P. 258

Vasylenko P. M. 1960. Teoryia dvyzhenyia chastyts po sherokhovatym poverkhnostiam selskokhoziaistvennych mashyn. *Kyev: UASKhN.* P. 284

Zakharov D.O. 2017. Elektrofizychni metody obrobky silskohospodarskoi produktsii. *Metodychni rekomendatsii. Navchalne vydannia. MNAU.* P. 39

Yermak V. P. Bohdanov Ye. V., Ilchenok A. A. 2012. Klasyfikatsiia zasobiv separatsii ta konstruktsii mashyn dlia vidboru nasinnia z vysokymy posivnymy vlastyvostiamy. *Zbirnyk naukovykh prats Luhanskoho natsionalnoho ahrarnoho universytetu* № 35. P. 127 – 132.

Inozemtsev H.B., Paraniuk V.O., Kovalyshyn S.I., Shvets O.P., Mellnychuk V.I. 2010. Nasinnieochysna hirka. Patent na korysnu model № 50435 Biul. №11. P. 4

Kovalyshyn S., Shvets O., Salo Ya., Kuzma Ya-R. 2015. Vplyv dodatkovoi elektrychnoi syly na efektyvnist rozdilennia nasinnia ripaku na elektrofryktsiinomu separatori . *Visnyk LNAU "Ahroinzhenerni doslidzhennia"* №19, P. 45-51.

Kovalyshyn S. Y., Shvets O.P. 2011. Zastosuvannia elektrychnoho polia koronnoho rozriadu pid chas peredposivnoi obrobky nasinnia ozymoho ripaku. *Motrol: Motoryzacia I energetyca rolnictwa. Tom 13D. – Lublin: Ukrainski technologii*, P. 276 – 283

Matviichuk V.A., Rubanenko O.Ie., Stadniichuk I.P. 2020. Elektrotekhnolohii v APK*: navchalnyi posibnyk. Vinnytsia: TOV «Tvory».* 272 s.

Nishchenko I.O. Kovalyshyn S.I., Shvets O.P. 2008. Doslidzhennia protsesu separuvannia nasinnia ozymoho ripaku na rukhomii v elektrychnomu poli pokhylii ploshchyni. *Visnyk LNAU "Ahroinzhenerni doslidzhennia".* №12, T. 2., P. 225 – 230.

Nishchenko I. O., Shvets O. P. 2009. Doslidzhennia traiektorii rukhu chastynok nasinnievoi sumishi kuliastoi formy po rukhomii v elektrychnomu poli fryktsiinii ploshchyni. *Visnyk DDAU. Spetsialnyi vypusk* №2-09., P. 256-259.

Paraniuk V.O. Kovalyshyn S.I., Melnychuk V.I., Shvets O.P. 2007. Fizychni osnovy tekhnolohii separuvannia nasinnia silskohospodarskykh kultur. *Zb. nauk. pr. UkrNDIPVT im. L. Pohoriloho: Tekhniko-tekhnolohichni aspekty rozvytku ta vyprobuvannia novoi tekhniky i tekhnolohii dlia silskoho hospodarstva Ukrainy*. Vyp. 10 (24), K.1, P. 77 – 86.

Shvets O.P. 2013. Analiz rezultativ matematychnoho opysu rukhu nasinnia ripaku po separuvalnii ploshchyni elektrofryktsiinoho separatora. *Visnyk LNAU "Ahroinzhenerni doslidzhennia"* №17, P. 144-149.

Shvets O.P. 2010. Doslidzhennia ta vplyv kuta rivnovahy nasinnia ozymoho ripaku na traiektoriiu yoho rukhu po robochii poverkhni elektrofryktsiinoho separatora. *Zahalnoderzhavnyi mizhvidomchyi nauk.-tekhn. zb. Kirovohradsk. nats. tekhn. un-tu: Konstruiuvannia, vyrobnytstvo ta ekspluatatsiia silskohospodarskykh mashyn.* Vyp. 40, Ch.2, P. 235 – 241.

Shvets O.P. 2012. Obgruntuvannia parametriv ta rezhymiv roboty separatora nasinnia ozymoho ripaku: *dys. kand. tekhn. nauk: – Lviv,* 165 s.

Basiry M., Esehaghbeygi M. 2012. Cleaning and charging of seeds with an electrostatic separator. *Applied Engineering in Agriculture.* 28, 1. P. 143–147.

Kovalyshyn S. Shvets O., Grundas S., Tys J. 2013. Use of the electro-separation method for improvement of the utility value of winter rapeseeds. *Int. Agrophys.* 27., P. 419 – 424.

Kovalyshyn S. Shvets O., Holodnyak R. 2010. Description of parameters of electric separator of rape seed mixtures. *Teka. Commision of motorization and power industry in agriculture.* Volume X., P. 186 – 193.

Kovalyshyn S., Shvets O, Sosnowski S. 2017. The justification of the parameters of the dosage device for the electric frictional separator. *MOTROL. Commission of Motorization and Energetics in Agriculture* 19 (4), P. 69-72.

Kovalyshyn S. Shvets O. 2017. Investigation of equilibrium angles of winter rapeseed on an inclined plane of an electrofrictional separator and optimization of the irgeometrical sizes. *Teka. Commision ofmotorization andenergetics in agriculture* 17 (No.1.), P. 45-52.