Theoretical background to the definition of resolution of seed mixes in vibro electric bowl separator

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Summary. It is proved that to achieve a highquality seed that has no impurities and substandard weeds (various damaged, shrunken) and biologically inferior (no germs) seeds of receipt is impossible without secondary postharvest treatment, and in many cases, additional cleaning.

This can be achieved using the separator with working units, which would provide a selective effect on the power components of the separated mixtures. One of these is proposed as a vibro electric bowl separator, which implements the combined effect on the particles of seed mixtures by vibrations, electric field and gravitational forces.

Theoretical studies of the impact of installed power adjustable parameters that affect the angle of separation of particles from the surface of the cylindrical bowl vibro electric separator makes the main feature of divisibility. They were the parameters of the electric field oscillating motion of the bowl, its size and speed. In order to achieve the greatest effect of separation of the components of seed mixtures becomes possible by optimization of these parameters that would provide the greatest difference of angles of the separating working surface.

Key words: seed mixture, vibro electric bowl separator, vibrating oscillation, the electric field separation, divisibility feature, the angle of breakaway from the separating surface.

FORMULATION OF THE PROBLEM

The structure of sowing acreage in Ukraine a significant percentage is given to small seeded crops (vegetable, technical, forage grasses, oil, etc.). Their yield is largely determined by the quality of seed. Only seeds with high sowing and fruitful qualities without weed impurities and substandard (damaged, shrunken) and biologically inferior (without germ) particles are able to provide high productivity of these crops. Obtaining such material is not possible without the second post-harvest handling, and in many cases further purification. However the available seed purifying machines are not always effective in terms of quality cleaning. Promising areas of improvement and development of new researches is the design of such working units, which would provide a selective power effect on the divided components of mixtures. To achieve this is possible by obtaining the cumulative effect on the particles of seed mixtures by vibrations, electric field power, and gravitational forces and so on. But separation under such conditions, especially in cylindrical working bodies has not been

studied well enough and needs some further theoretical and experimental studies.

ANALYSIS OF KEY STUDIES AND PUBLICATIONS

The issue of separation of seed mixtures on the surface of the bowl is undertaken in the works of many scientists. Some of them studied the separation of seed mixtures in external cylindrical surfaces [14; 16; 17]. They obtained the equations of motion of a particle on the surface of the bowl, the conditions of its descending and analytically determined the angle of separation, which is the main feature of its divisibility on coupling cylindrical planes [1; 2; 7; 20]. Its value depends strongly on the components of separated mixture force determined by a combination of gravitational and centrifugal forces [3; 9; 13]. These forces, in turn, depend on structural and technological parameters of bowl separator [4; 11; 14; 16; 17].

In order to intensify the process of separation of seed mixtures on the friction surfaces we use the power of action of different nature. This significantly increases the efficiency of separation, especially hard-to-divide mixes through the imposition of high voltage electric field on them [6, 12, 15, 18, 19]. Under these conditions the particles apart gravitational forces will be influenced by electrical power.

Other researchers propose to extend the functionality of separators, giving their working bodies oscillating movement. Under such conditions, the power to effect a particle of seed mixture is the sum of gravitational, electric power and inertia. This option is implemented in separators which use in their working body a moving in an electric field oscillating inclined plane [5; 8; 10].

Regarding bowl separators, the ongoing studies [4; 8; 16; 17] justify the expediency imposition on their working surfaces and electric field. They theoretically justify the basic technological and design parameters of electric separation on rotating in electric field cylindrical surfaces [12; 15; 18].

Regarding quite a positive impact on separation efficiency of hard-to-divide mixtures we provide a friction inclined plane with an applied electric field an oscillating movement, which makes it possible to predict a similar effect of separation in a bowl vibro electric separator. To confirm this it is necessary to investigate the trajectory of movement and conditions of the particles' breakaway of a separator's surface.

THE MAIN STUFF PRESENTATION

As the object of research aimed to determine the resolution of seed mixtures in a vibro electric cylindrical separator we selected a bowl radius *R* rotating around a horizontal axis of symmetry at a constant angular velocity ω and performs oscillatory motion in a plane which is inclined to the vertical with angle α (Fig. 1). Movement of the seed particles therein mixture, which we accept as a material point of mass *m* is carried out under the action of combined forces - gravity, electrical and inertia.



Fig.1. Power performance on a particle of a seed mixture on the cylindrical surface vibro electric separator: N – normal reaction; F_e – electrical power; G – the force of gravity; T – friction

For the mathematical description of the behavior of particles on the surface of the bowl, we introduce a coordinate system due to which they are moving.

As a beginning of a fixed coordinate system we choose a point O, around which the oscillatory motion occurs. The coordinate system $x_1O_1y_1$ is moving forward according to the law of the vibrational motion of a given function:

$$OO_1 = \alpha \sin(pt) \tag{1}$$

where: α – oscillatory amplitude; *p* – angular frequency of oscillatory movement.

Other mobile coordinate system $n\mu\tau$ connected with the moving material point (axis μ_{τ} directed along the main normal, and μ_{τ} – at a tangent to the trajectory of the relative motion of the point).

According to Newton's second law an equality can be written:

$$m\vec{a} = \vec{N} + \vec{F}_e + \vec{G} + \vec{T} , \qquad (2)$$

where \vec{a} – the vector of absolute acceleration relative to the fixed frame of reference.

The material point is in a complex motion. It moves with the bowl, which carries a plane-parallel motion and can move relative to it (moving relatively to bowl is set by arc coordinate s(t)).

When moving, the point of absolute acceleration vector can be represented as a geometric portable power \vec{a}_{port} , of relative \vec{a}_{rel} and Coriolis acceleration \vec{a}_{cor} :

$$\vec{a} = \vec{a}_{port} + \vec{a}_{rel} + \vec{a}_{cor};$$

$$\vec{a}_{port} = \omega^2 R\vec{n} - ap \sin pt(\cos \alpha \vec{i} = \sin \alpha \vec{j});$$

$$\vec{a}_{rel} = \frac{V_{rel}^2}{R}\vec{n} + \frac{dV_{rel}}{dt}\vec{\tau};$$

$$\vec{a}_{cor} = 2\omega V_{rel}\vec{n} ,$$
(3)

where: $\vec{\tau}, \vec{j}, \vec{n}, \vec{\tau}$ – the unit vectors directed along respective axes; $V_{rel} = \frac{ds}{dt}$ – relative speed point.

The positions of the moving point on the bowl determines the angle φ , positive readout is conducted from the axis counterclockwise. This moving point can be calculated by the formula:

$$\varphi = \varphi_0 + \omega t + \frac{s}{R} \tag{4}$$

where: t – alternating time, $0 \le t \le t_{\kappa}$; φ_0 – initial value of angle φ .

Let us project the vector equation (2) on the axes μn and $\mu \tau$ taking into account the expressions (3) and directions of forces acting on the point:

$$m(\omega^{2}R - ap^{2}\sin pt(\cos\alpha\cos180^{\circ} + \varphi) + \sin\alpha\cos(90 + \varphi)) + \frac{V_{rel}^{2}}{R^{2}} + 2\omega V_{rel}) = mg\cos\varphi + F_{e} - N,$$
(5)
$$m(\frac{dV_{rel}}{dt} - ap^{2}\sin pt(\cos\alpha(90 + \varphi) + \sin\alpha\cos\varphi) = mg\sin\varphi - T.$$

From the first equation (5) we determine the normal reaction N:

$$N = mg\cos\varphi + F_e = m(\omega^2 R + ap^2\sin\rho t\cos(\varphi - \alpha)) - \frac{m}{R}(\frac{ds}{dt})^2 - 2m\omega\frac{ds}{dt}.$$
(6)

On the basis of the second equation (5) we obtain the differential equation of the relative motion of a point, relative to the cylindrical surface:

$$\frac{d^2s}{dt^2} = \sin\varphi - a\rho^2 \sin pt(\varphi - \alpha) - \frac{T}{m}.$$
(7)

(10)

If the relative speed point is nonzero $\left(V_{rel} = \frac{dS}{dt} \neq 0\right)$, then under the law Coulomb the friction reaches its maximum and equals to:

$$T = -fNsign(\frac{ds}{dt}), \qquad (8)$$

where: f – coefficient of friction;

and function $sign(x) = \begin{cases} 1: x > 0\\ 0: x = 0\\ -1: x < 0 \end{cases}$.

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is:

If for some period of time relative motion is absent

 $\left(\frac{ds}{dt}=0; \frac{d^2s}{dt^2}=0\right)$; when the formula (6) is somewhat simplified:

$$N = F_e + m(g\cos\varphi - \omega^2 R - ap^2\sin pt)\cos(\varphi - \alpha). \quad (9)$$

From equation (7) we can determine the friction force:

 $T = m(g\sin\varphi - ap^2\sin pt\sin(\varphi - \alpha)).$

 $\left|T\right| < f_{adh}N \quad , \tag{11}$

where: f_{adh} – coefficient of adhesion ($f_{adh} \ge f$).

Once inequality $|T| < f_{adh}N$ is executed, the relative motion of the point starts again and it will be needed to solve a system of equations (6) and (7).

Note that the electric force F_e is large enough, that

$$F_e > m(g + \omega^2 R + ap^2).$$
⁽¹²⁾

Under these conditions, the particle "sticks" to the bowl (N > 0) and do not break away from it at arbitrary values of the angle φ . Otherwise, in some moment of time $t = t_1$ a normal reaction becomes a negative value (N > 0) and a particle is separated from the surface of the bowl and further moves only by gravity. At this angle φ affects the electric force, which depends on the electric field and charge of the particle. Since particles components of separated mixtures belong to different species, their electrical properties are different. As a result, they possess different charges and different interacting with the electric field. The other adjustable parameters of the process vibro electric separation on cylindrical bowl is in rotation frequency ω and frequency of the vibrational motion p. Optimizing their values we can achieve a situation in which the angles of adhesion φ , which are the basic sign of divisibility in electric frictional bowl separator will be different for each component of separated mixture and they will be a defining condition of their effective separation.

CONCLUSIONS

1. One of the promising ways to improve the quality of seeds is to use cylindrical separators in which in order to improve the efficiency of separation of seed

mixtures an oscillating bowl movement is provided, and on its cylindrical surface an electric field of high voltage is imposed.

2. Theoretical studies of forces' action on a particle of the seed mixtures on the surface of vibro electric bowl we set adjustable parameters that affect the angle of its separation from the cylindrical surface φ , which is the main feature of divisibility. They are the parameters of the electric field of oscillating motion of the bowl, its size and frequency of rotation.

3. In order to obtain the greatest effect of the mixture components separation we need to optimize the parameters of vibro electric separation on the cylindrical surface that would provide the greatest difference of angles of adhesion φ of separation surface.

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ТЕОРЕТИЧЕСКИЕ ОСНОВЫ ОПРЕДЕЛЕНИЯ РОЗДЕЛЕНИЯ СЕМЕННЫХ СМЕСЕЙ В ВИБРО ЭЛЕКТРИЧЕСКОМ БАРАБАННОМ СЕПАРАТОРЕ

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Аннотация. Доказано, что для достижения семя высокого качества, который не имеет примесей и некачественные сорняки (различные поврежденные, усохшие) и биологически уступает (не микробы) семена получения невозможно без вторичной обработки послеуборочной, и во многих случаях, дополнительной очистки.

Это может быть достигнуто с помощью сепаратора с рабочими единицами, которые обеспечили бы селективное действие на силовых элементах отделенных смесей. Один из них предлагается в качестве вибро электрического сепаратора чаша, которая реализует совместное действие на частицы семян смесей вибрации, электрического поля и гравитационных сил.

Теоретические исследования влияния Установленная мощность регулируется параметрами, которые влияют на угол разделения частиц с поверхности цилиндрической чаши вибро электрического сепаратора делает основную особенность делимости. Они были параметры электрического поля колебательного движения чаши, ее размеров и скорости. Для достижения наибольшего эффекта разделения компонентов смеси семян становится возможным за счет оптимизации этих параметров, которые обеспечивают наибольшую разность углов рабочей поверхности разделительным.

Ключевые слова: смесь семян, вибро электрический сепаратор чаша, вибрируя колебаний, разделение электрического поля, функция делимость угол отрыва от поверхности раздела.