Modelling of force action on ellipsoid-shape seed in pneumo-electric separator channel

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Abstract. The behavior of seed in pneumo-electric separator channel is revealed. The characteristic of the active forces on ellipsoid-shape seed is demonstrated. Due to a differential equations you can find the coordinates of seed mixtures particles' motion to determine the conditions under which we get maximum effect.

Key words: ellipsoid-shape seeds, pneumo-electric channel, modelling.

FORMULATION OF THE PROBLEM

The increase in gross yield of seeds of crops is impossible without a sufficient number of high-quality seed mass [1], by its sowing qualities, quantitative content of weeds' impurities, which are difficult to separate, would be able to meet the existing standards [2]. We can possibly achieve this by improving postharvest processing technologies and facilities. This is especially true for small seeded crops (vegetables, industrial, fodder grasses, etc.). We meet significant difficulties of objective nature to bring it to the required sowing condition [3,4]. For this reason there is a need to conduct additional cleaning that is performed on special seed purificatory machines.

Among them, an important place is given to pneumatic separators where seed purification is carried out by their aerodynamic peculiarities of components.

REVIEW OF RECENT PUBLICATIONS

Separation of seed mass by aerodynamic peculiarities of their components is a sufficiently widespread method [10,11,13]. It is based on particles' differences in resisting airflow. This resistance depends on several factors and is not the same for some of them [12]. Therefore, the particles move in the air stream with different speeds and on different paths [9].

Nowadays, in theoretical terms the issues of separation of seed mixtures by their aerodynamic peculiarities in pneumatic separators are sufficiently covered [5,6,7]. A number of authors have devoted their researches identifying the critical speed of floating and soaring ratios of components of seed mixtures [5], calculations of air flow [10] and justification of ventilator parameters for their construction [7], the definition of structural forms and geometric dimensions of pneumatic channels etc. [10].

Some of them studied the force of interaction of seed mixtures with air flow [6], its influence on the path of the movement and the possibility of their separation by aerodynamic peculiarities.

This interaction takes into account the cumulative effect of gravity and force of air flow on the particles. However, in condition of improving the designs of pneumatic separators using,as additional working body, the electric field in their separating channels, the particles will be influenced by an additional electrical force. In this case there is a need to study the interaction of power that will be taken at the same time as the action of gravitational and electrical forces.

STATEMENT OF THE PROBLEM

To increase the efficiency of separation of hard-to-separate seed mixtures in air flows is possible if we concentrate an additional force action and this force would be different for biologically viable seed of crops and for non-viable (without embryo) or weed seeds. To implement such power effect on components of seed mixtures could be possible in a separator channel with uniform electric field.

In this case there is a need to study the combined action of forces on a particle of seed mixture in the channel.

THE MAIN STUFF

In order to consider the behavior of particles of the seed mixture in pneumo-electric separator channel we should understand and characterize the forces which effect them. As a rule in such separators seed mixtures which have the shape of an ellipsoid are separated. With this in mind, we will consider the impact of forces on a seed of this shape. It can be described, using the data presented in Fig. 1.

The seed is impacted by the resultant of three power factors:

1) resultant force of gravity G, which is directed vertically downward and attached to the center of mass of the particle:

$$G = mg, \quad (1)$$

where: m - mass of seed; g – gravity of Earth.

2) resultant electrostatic force Fe, which is directed horizontally and attached to the axis of symmetry of the ellipsoid particles at point O2:

$$F_e = E\,q, \quad (2)$$

where: E - electric field intensity; q - charge of a particle.

3) resultant forces F_a caused by the action of air flow on the particle:

$$F_a = KV_aA_m, \quad (3)$$

where: V_a – speed of the air stream; A_m – midship section area; K - coefficient of resistance of the circumference.

Resultant force F_a is directed vertically upward and applied at the geometric center of the ellipsoid O.

Let us consider some cases of the actions of these forces on a particle of seed mixture.

1. The force of the airflow F_a is equal to force of gravity G.

Then the resultant of three forces is equal to $R = F_e$ and will pass through the center of masses C, in the condition:

$$\sum_{\hat{e}=1}^{\ddot{\imath}} M_e(F_{\ddot{\imath}}) = 0\,. \quad (4)$$

Expand the condition (4):

$$F_{\ddot{\imath}} \cdot Y_c \cdot \cos\varphi - F_e \cdot L \cdot \sin\varphi = 0\,. \quad (5)$$

Since $F_a = G$, then using (5) we determine the angle φ:

$$tg\,\varphi = \frac{G \cdot Y_c}{F_e \cdot L}\,. \quad (6)$$

In this case, from (3) we can find the speed of air flow:

$$V_a = \frac{G}{K \cdot A_m}\,, \quad (7)$$

where: A_m - midship area of the particle.

If we want to determine the force of airflow by these conditions we need to calculate the midship area A_m of a seed mixture particle - a projection of a seed area on a plane which is perpendicular to the direction of air flow in the channel of pneumo-electric separator. It should be also kept in mind that seed has the shape of an ellipsoid of revolution with semiaxes a and b (Figure 2).

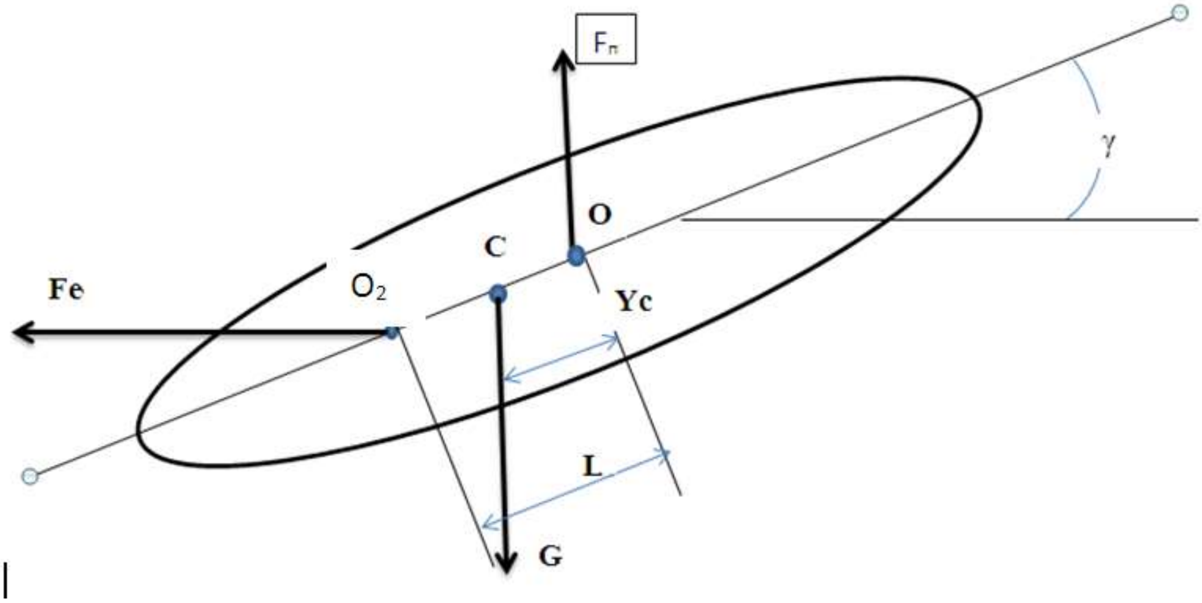

Fig. 1. Forces' effect on a particle of a seed mixture in pneumo-electric channel

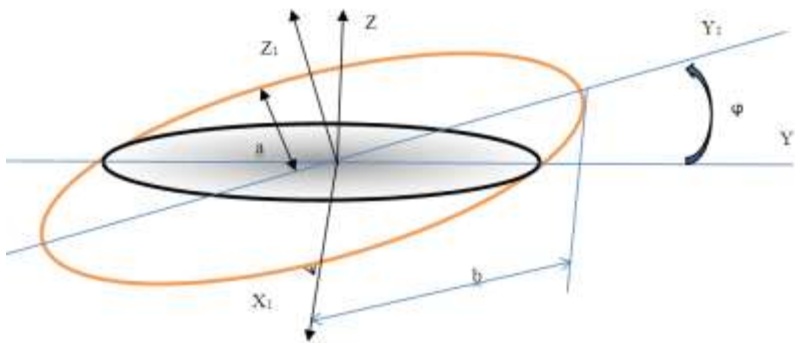

Fig. 2. Figure to determine a midship section of an ellipsoid-shaped particles

Then the equation of the surface of the ellipsoid in canonical form looks like:

$$\frac{X_1^2}{a^2}+\frac{Y_1^2}{b^2}+\frac{Z_1^2}{c^2}=1\,. \qquad (8)$$

If the coordinate system is rotated by an angle φ around the axis OX, the relationship between the coordinates of points in the old and new coordinate systems will be expressed by the formulas:

$$Y_1 = y\cdot\cos\varphi + z\cdot\sin\varphi\,,$$
$$Z_1 = z\cdot\cos\varphi + y\cdot\sin\varphi\,. \qquad (9)$$

Substituting (9) into (8), we obtain the equation of the surface of the ellipsoid in turned coordinate system:

$$\frac{X^2}{a^2}+\frac{(y\cdot\cos\varphi+z\cdot\sin\varphi)^2}{b^2}+\frac{(z\cdot\cos\varphi+y\cdot\sin\varphi)^2}{a^2}=1 \qquad (10)$$

Taking into account that $z = 0$, we obtain the equation of the ellipse:

$$\frac{X^2}{a^2}+y^2\left(\frac{\cos^2\varphi}{b^2}+\frac{\sin^2\varphi}{a^2}\right)=1\,, \qquad (11)$$

with semiaxes a and $b=\dfrac{ab}{\sqrt{a^2\cos^2\varphi+b^2\sin^2\varphi}}$.

Due to (11), the expression for determining of midship section equals:

$$A_m=\pi\frac{a^2b}{\sqrt{a^2\cos\varphi+b^2\sin\varphi}}\,. \qquad (12)$$

Having expression (12) for determining midship area and taking into account (6), we can calculate the speed of air flow that meets the condition (3):

$$V_a=\frac{G}{\pi\cdot K\cdot a^2b}\sqrt{\frac{(a\cdot F_e\cdot L)^2+(b\cdot G\cdot Y_c)^2}{(F_e\cdot L)^2+(G\cdot Y_c)}}\,. \qquad (13)$$

When the power of the air flow F_a is less than seed gravity G:

$$G > K\cdot V_a\cdot A_m\,. \qquad (14)$$

This inequality is right for any φ, if:

$$V_a<\frac{G}{K\cdot\pi\cdot a\cdot b}\,. \qquad (15)$$

This seed will do plane-parallel movement con-sisting of the center of mass C and rotary motion around it (Fig. 3).

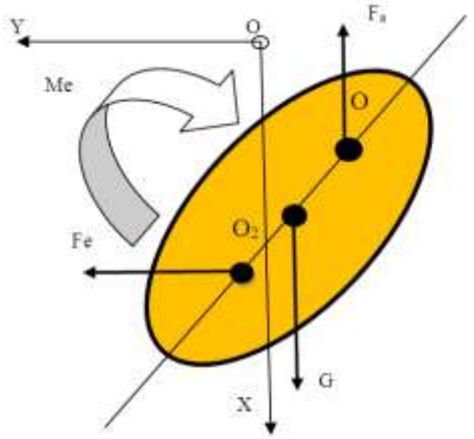

Fig. 3. Scheme of seed movement in pneumo-electric separator channel

In the projections on the axis XOY differential equations of motion will have the form:

$$m\frac{d^2x_c}{dt^2}=mg-K\left(V_a+\frac{dx}{dt}\right)A_1\,,$$
$$m\frac{d^2y_c}{dt^2}=F_e-K\frac{dy}{dt}A_2\,. \qquad (15)$$

$$\mathrm{I}\frac{d^2\varphi}{dt^2}=K\left(V_n+\frac{dx}{dt}\right)A_1\cdot Y_c\cdot\cos\varphi-$$
$$-F_e\cdot L\cdot\sin\varphi-2K\frac{d\varphi}{dt}\cdot a\int_0^b y^2\sqrt{1-\frac{y^2}{b^2}}dy\,, \qquad (16)$$

where: $A_1 = A_m$; $\mathcal{J}$ - moment of inertia of ellipsoid (seed) with respect to the axis of rotation:

$$A_2\,\frac{\pi a^2b}{\sqrt{a^2\sin^2\varphi+b^2\cos^2\varphi}}$$

$$\int_0^b y^2\sqrt{1-\frac{y^2}{b^2}}dy=b^3\frac{\pi}{16}\,. \qquad (17).$$

The system of differential equations must be integrated with the initial conditions:

$$t=0;\ X_c=0;\ Y_c=0;\ \varphi=0, \qquad (18)$$
$$\frac{dy}{dt}=0;\ \frac{dx_c}{dt}=0;\ \frac{dy_c}{dt}=0\,.$$

It can be solved by number of methods, including Runge Kutta's one.

Having solutions of equations (15), we can find the coordinates of a particle's motion of seed mixture as a function of time. In this case, to identify the conditions under which you can get the greatest effect of separation in pneumo-electric separator it is necessary to investigate the coordinate xc, which characterizes movement of a particle along the channel. The analysis of the equations shows us that the most significant effect on their value makes midship section area of the separating particles which undergoes the airflow. This area much depends on the electrical properties of seed particles, since the electric field is created between the plates of pneumo-electric channel and directs them along the force lines. Seeds of crops and weeds belong to separate biological species and their electrical properties are different. Because of this, they will interact differently with the electric field. Consequently, the components of seed mixtures will be guided in the channel at different angles, thus changing its midship area and will react differently on forces of air flow. With this we can come to the conclusion that there is a possibility to separate seeds of crops and weeds, especially of an ellipsoid shape, in the process of separation in a pneumo-electric separator.

We can find this possibility by modelling the force action on a particle of mixtures and find it by using such the parameters pneumoseparation under which coordinate *xc* for one component takes a positive value (going up), and for another - negative (fall down). Under these conditions, the separation will be the most effective.

CONCLUSIONS

1.We described the combined effect of forces on a seed of ellipsoid form in the pneumo-electric separator channel.

2. Differential equations of motion of an ellipsoid-shaped particle of seed mixture in the channel of a separator are presented. Their solutions allow you to find the coordinates of the separating particles' motion and evaluate the possibility of their separation.

3. After the analysis of the dependences we can conclude that the use of electric field in pneumo channels leads to different changes of the midship section of a crop seed and weeds due to differences in their electrical properties. This is the basic condition of the possibility of their effective separation in the proposed pneumo-electric separator.

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