APPLICATION OF THE THEORY OF DIMENSIONAL ANALYSIS AND SIMILARITY IN MODELING GRAIN AND SEED SEPARATION PROCESSES

D.A. Volyk
Research Assistant, Institute of Mechanics and Automation of Agricultural Production. National Academy of Agrarian Sciences of Ukraine
S.P. Stepanenko
Doctor of Engineering, Senior Research Officer, Institute of Mechanics and Automation of Agricultural Production. National Academy of Agrarian Sciences of Ukraine
B.I. Kotov
Doctor of Engineering, professor, *Podillia State University*
R.A. Kalinichenko
Ph.D., professor, Separated Subdivision NULESU «Nizhyn Agrotechnical Institute»

Technical progress in the grain and seed processing industry mainly involves the intensification of separation processes and the creation of machine complexes and auxiliary equipment [1-3, 5-7]. Attention is paid to manufacturing quality [2, 7-9], external design [4-6], and elements of automation [5-9]. Work is also being done to improve working conditions and environmental ecology, such as reducing air pollution in the service area and minimizing noise levels [5-7].

The trend towards the creation of combined grain and seed cleaning machines [1-6] has been established, which contain autonomous units of air-screen separation devices, trieurs, scalpers, screening sections, and more. Fractionation by air flow and screen [2-4, 8, 9] is used to improve the efficiency of the machines.

In calculating additional resistances R_D that arise during the separation process, the fractionation can be done using the known expression [1-4]:

$$R_D = \gamma_D \frac{\rho \cdot \vartheta^2}{2} \quad (1)$$

where: γ_D is the coefficient of additional resistance during the movement of the grain environment;

$$\gamma_D = \gamma_p \cdot \lambda + \gamma_m = \gamma_m \cdot [1 + k \cdot \lambda] \quad (2)$$

$$k = \frac{\gamma_p}{\gamma_m} \quad (3)$$

where: γ_p, γ_m are the coefficients of additional resistance during the movement of the air flow and material, respectively;

λ is the concentration of the flow.

The physical phenomena observed in the processes of grain and seed separation and fractionation are quite complicated to understand, but these processes can be significantly simplified by using the method of dimensional analysis and similarity. By establishing the existence of a functional relationship for the coefficient of additional resistance during the movement of the grain environment between the pressure losses with the aspiration channel diameter *D,* the diameter of the material grains *d*, the angle of inclination of the smooth screen α, the amplitude of the smooth screen oscillations *r*, the air and material grain densities ρ_p and ρ_m, the air flow and material grain velocities V_p and V_m, and the flow concentration λ, as well as the kinematic viscosity of the air ν, the gravitational acceleration *g*, the friction coefficient of the grain material on the smooth screen f_m, using the π-theorem, a generalized criterion equation was derived for the resistance coefficient during grain medium movement:

$$\gamma_D = f\left[\frac{r}{D};\frac{D}{d};\frac{\rho_m}{\rho_p};Re;Re_m;Fr;\lambda;\alpha;f_m\right] \tag{4}$$

$$Re = \frac{V_p \cdot D}{\nu};\ Re_V = \frac{V_V \cdot d}{\nu};\ Fr = \sqrt{\frac{V_p^2}{g \cdot D}}; \tag{5}$$

where: V_V is the material extraction velocity.

During the investigation of this equation, no dependence of γ_D on *Re* and *Fr* was found using experimental data, therefore further processing was carried out using a simpler expression.

$$\gamma_D = f\left[\frac{r}{D};\frac{D}{d};\frac{\rho_m}{\rho_p};Re_m;\lambda;\alpha;f_m\right] \tag{6}$$

Transitioning to the method of dimensional analysis, which is often used in calculations using the coefficient *k*, we determine:

$$k = f\left[\frac{r}{D};\frac{D}{d};\frac{\rho_m}{\rho_p};Re_m;\alpha;f_m\right] \tag{7}$$

Experiments were conducted on a laboratory setup to investigate this dependency. The material (soybeans, wheat, corn, sunflower) moved along an unperforated sieve, under which air was supplied through an aspiration channel with a diameter of D=100 mm and D=200 mm with $\frac{r}{D} = 0{,}1$, as well as D=100 mm with $\frac{r}{D} = 0{,}05$ and a change in α from 2 to 12^0.

Based on the fact that some dependencies for *k* that lie in a horizontal plane or change the angle of inclination of the sieve to the horizon are aligned in a logarithmic system, and some in a semi-logarithmic system, equation (7) can be presented in the form:

$$k = x \cdot \left[e^{x_1 \cdot \frac{r}{D}}\right] \cdot \left[\frac{D}{d}\right]^{x_2} \cdot \left[\frac{\rho_m}{\rho_p}\right]^{x_3} \cdot [f_m]^{x_4} \cdot \left[e^{\alpha \cdot x_5}\right] \cdot [Re_m]^{x_6} \tag{8}$$

Further processing of the experimental data was carried out using equation (8) by the method of least squares to obtain the constants $x_1, x_2, x_3, x_4, x_5, x_6$.

The general form of the conditional equations for processing is determined by taking the logarithm of the dependence (8), after which we obtain:

$$\ln k = \ln x + x_1 \cdot \frac{r}{D} + x_2 \cdot \ln\left[\frac{D}{d}\right] + x_3 \cdot \ln\left[\frac{\rho_m}{\rho_p}\right] + x_4 \cdot \ln[f_m] + x_5 \cdot \alpha + x_6 \cdot \ln[Re_m] \tag{9}$$

For aspiration channels with different geometric dimensions and cross-sectional shapes, as well as varying the geometric position of the outlet opening, 29 equations were compiled based on experimental data.

To determine the unknowns according to the Legendre principle (multiplying by coefficients at the sought unknowns), normal equations are derived from the conditional equations. The solution of this system of linear equations using the Gauss method [8, 9] was carried out in the applied software.

The values of coefficients obtained are: $x = 0{,}986$; $x_1 = 0{,}058$; $x_2 = 0{,}535$; $x_3 = -0{,}019$; $x_4 = -0{,}238$; $x_5 = 0{,}331$; $x_6 = -0{,}257$.

Abstracting from the values of *x*, we obtain a computational generalized criterion equation for the processes of separating grain and seeds with different geometric parameters that vary the position, both of the aspiration channel and the kinematic parameters of the technical means:

$$k = Z \cdot e^{0{,}331 \cdot \alpha} \tag{10}$$

where:

$$Z = \left[e^{0{,}058 \cdot \frac{r}{D}}\right] \cdot \left[\frac{D}{d}\right]^{0{,}535} \cdot \left[\frac{\rho_m}{\rho_p}\right]^{-0{,}019} \cdot [f_m]^{-0{,}238} \cdot [Re_m]^{-0{,}257} \tag{11}$$

In case of changing the position of the air flow supply to the sieve (from vertical to horizontal or inclined), i.e. changing the angle of the air flow supply to the vertical, we will have:

$$k = Z \cdot e^{0{,}875 \cdot \beta} \tag{12}$$

where: β - is the angle of inclination of the air flow supply to the vertical.

The obtained equations can be recommended for practical use, as they are reliably confirmed by experiments within the range of process parameters:

$\frac{r}{D} = 0 \dots 0{,}5$; $d = 2{,}1 \dots 12$ мм; $Re_m = 1200 \dots 14000$; $D = 100 \dots 200$ мм; $\frac{\rho_m}{\rho_p} = 800 \dots 2000$; $Re = 8{,}5 \cdot 10^4 \dots 3{,}2 \cdot 10^5$.

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