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STUDIES ABOUT THE INFLUENCED OF THE SURFACE STATE ON A BEHAVIOR OF SOLID PARTICLES FINDED INTO AN AIR FLOW

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Abstract: *An important factor in the aerodynamic sorting process represents the surface state of solid particle. In this work the results of studies concerning the influence of the surface state of solid particle over behaviour of particle in ascendancy vertical air flow, respectively the value of the floating speed of solid particle are presented.*
The experimental determinations proved that the turbulence intensity of the air flow obtained "behind" of the solid particle is direct proportional with the value of the air flow speed and with the value of friction coefficient of the respective particle.
Key words: *friction coefficient, perimeter, the floating speed of particle, turbulence intensity.*

1. INTRODUCTION

The choosing of the sorting method and sorting equipment is made taking into consideration the characteristic after which the particle mixture may be differentiate [4, 6, 10].

When the components of the mixture of solid particles are distinguished after their behavior in air flow, the sorting process can be realized after the aerodynamic properties, which are characterized mainly by the floating speed. This can be determinate analytically (for ideal particles, spherical, isotropic and which have a stable position in air flow) and experimental (with help of a special equipment) [3, 7]

The floating speed of solid particles is influenced by different factors: the density of the particle, shape of the particle, the dimensions of the particle and the surface state of the particle [2, 9]

The researches made to set off the influence of the surface state (the friction coefficient) on the floating speed of the particle are very poor, presenting just the value of these, without correlating these factors [5, 8].

2. THE EXPERIMENTAL PART

To determine the floating speeds of different types of the particles it was used a laboratory installation (fig. 1). Air flow is produced by the axial fan 1. On the aspiration pipeline of the fan is connected the sedimentation room 2, sealed on the inferior side by the seeds box 3. In the extension of the sedimentation room is the vertical channel 4 built with glass walls for the visualization of the particles. The upset jump room of fan is connected to a compartment which contains a filter element 5 from cloth, which has the role to retain the fine particles of dust which, possibly, were aspirated together with the work particles. The flow capacity is measured with help of tow rotameters 6 positioned behind the filter element 5, and by closing the evacuation connections 7 it is realized the adjustment of air quantity which flows through the installation (large adjustment and fine adjustment). For the determination of the floating speed of a particle the air flow capacity from installation is regulated until the particle is in a stable position in the channel with the glass walls. The value of the air flow capacity is read with the help of two rotameters 6 and knowing the section of the glass pipeline, the floating speed of the solid particle can be found out [1].

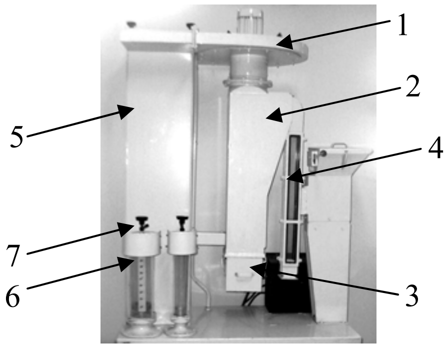


Fig.1. *The scheme of equipment for determination of the floating speed of the particles: 1 - axial - radial fan; 2 - sedimentation room; 3 - box of seeds; 4 – vertical air channel; 5 - filter elements; 6 - rotameter; 7 - nozzle for air evacuation from installation*

The surface state of the solid particles is characterized by the friction coefficient. The values of friction coefficient μ_f were determined indirectly, by computation, using the relation presented the in specialty literature [10]:

$$\mu_f = tg\varphi \quad , \tag{1}$$

where φ is the friction angle between the particle and material on which the particle moves (friction)(fig. 2) [10], in which:

- G weight of the particle;
- N reaction force;
- m mass of particle;
- φ friction angle.

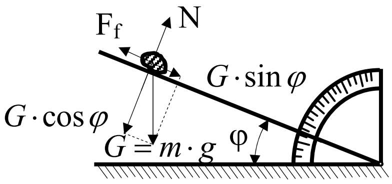


Fig. 2. *The scheme of the device for determination the friction angle φ*

In laboratory the determination of friction angle (for sliding and for rolling) it was realized on a metallic plate, having a plane surface and a roughness R_a = 3, 2 μm.

It was chosen particles with the same density, respectively ρ = 1200 kg/m^3; the same equivalent diameter, respectively d_e = 3 mm; for which it was determined and established:

- the friction coefficient;
- the perimeter of the particle;
- the floating speed;
- the intensity of the turbulence.

These determinations were realized five times and below are presented the average values, in order to obtain the relations of dependency between the following two factors: the floating speed and the friction coefficient.

3. EXPERIMENTAL RESULTS.

After the experimental determinations the following variations of the floating speed of the solid particles were obtained function of the solid particle mass (fig. 3). The values were measured with help of laboratory equipment which is presented in figure 1.

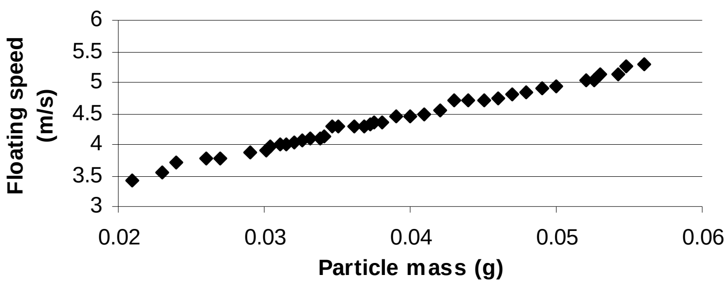


Fig. 3. *The variation of the floating speed function of the solid particle mass*

For the same particles was determined, experimentally, the variations of friction coefficient μ_f depending on the particle mass (fig. 4).

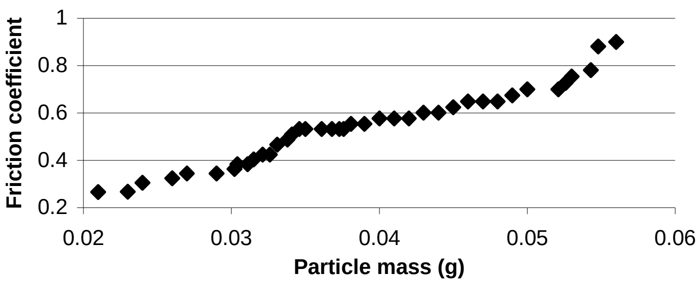


Fig. 4. *The variation of friction coefficient function of the particle mass*

Both in the case of solid particles movement into an air flow and in the case of solid particles movement on a plane, their motion is influenced by the friction force, respectively by the surface state of particle.

To differentiate two particles from their surface state (roughness) point of view we consider that they are differentiated by the total size of surface. The rough particle has an unfolded total surface bigger than smooth particle. By eliminating is analyzed just the difference between the circumferences (the perimeters) of the particles (a coarse particle has a bigger perimeter than a smooth particle).

For the determination of perimeter of a solid particle we used the Solidworks software, respectively the function Measure, to measure the perimeter of solid particle. Further, for the studied particles, the variations of the speed floating and the friction coefficient depending on the perimeter of solid particle are presented (fig. 5 and fig. 6).

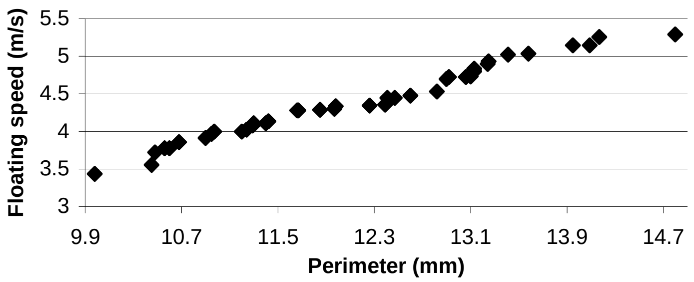


Fig. 5. *The variation of floating speed function of the perimeter of solid particle*

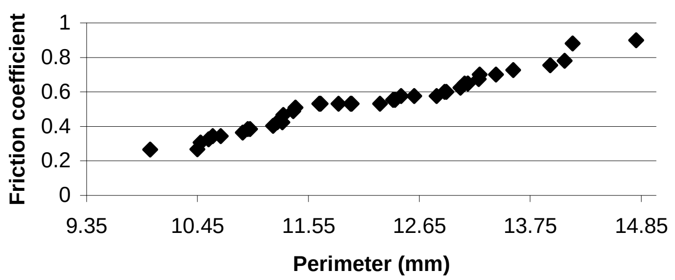


Fig. 6. *The variation of friction coefficient function of the perimeter of solid particle*

In a process of aerodynamic sorting, the particle behaves differently in air flow because of friction which appears between their surfaces and air flow. Because, practically the intensity of the air flow turbulence obtained in the behind of solid particle it can not be measured, the simulation program FLUENT was utilized. In figure 7 is presented, with help of FLUENT program, the distribution of the flow lines (turbulence) around of solid particle with the smooth surface and around of particle with the rough surface for an air flow with speed equal with value of the floating speed of respective particles. It was considered that the smooth particle has the perimeter 1, in this case the coarse particle, presented in the figure 6, have the perimeter bigger by 1,69, respectively 3,2 times (it was measured with help of the function Measure from Solidworks software).

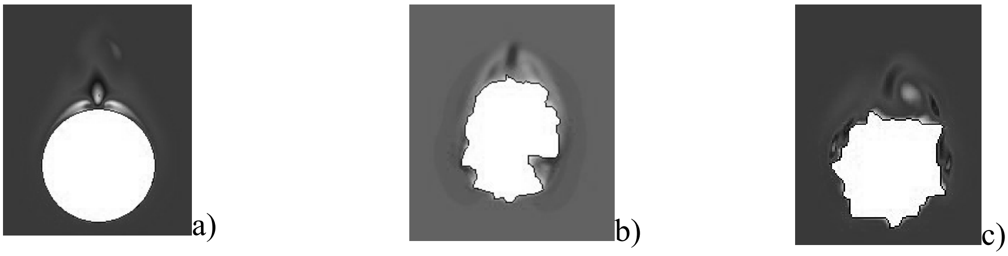


Fig. 7. *Form of the air flow turbulence for different particles:*

a) Particle with the smooth surface (the perimeter 1); b) particle with the rough surface (the perimeter 1,69); c) particle with the rough surface (the perimeter 3,2)

Taking into account the values of the turbulence intensity of the air flow, in figure 8 is presented the variation of this factor depending on the friction coefficient of the solid particle.

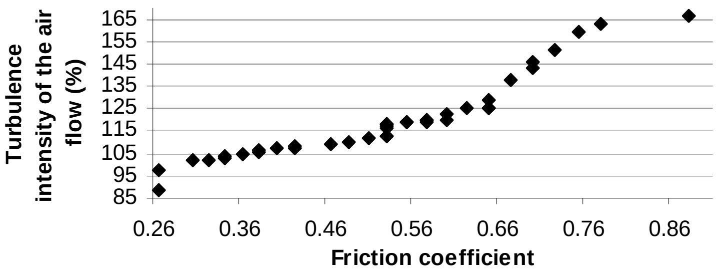


Fig. 8. *The variation of turbulence intensity of the air flow depending on the friction coefficient*

The variation of the turbulence of the air flow depending on floating speed of the solid particles is presented in the figure 9.

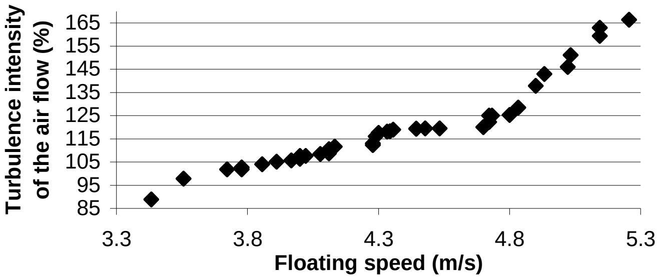


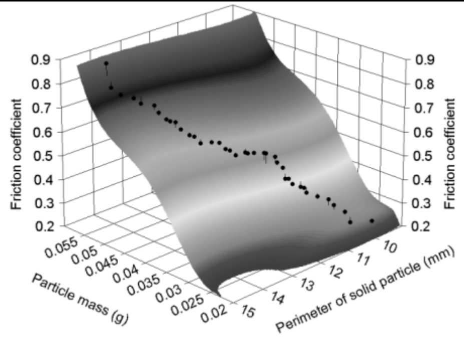
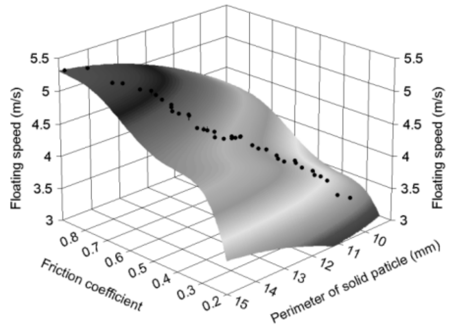
Fig. 9. *The variation of turbulence intensity of the air flow depending on the floating speed*

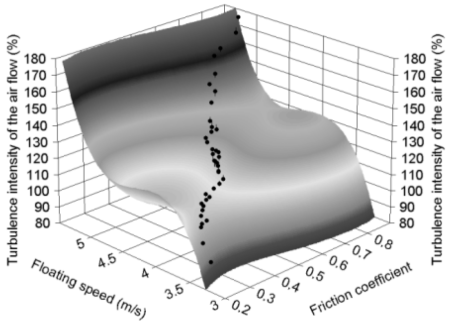
4. MATHEMATICAL MODELATION

As in any process, in this case it was looked up to obtain an equivalent mathematical model of process.

Starting from the values obtained on experimental way, with the help of the generating linear and nonlinear equation software, TableCurve 3D, it was determined the equation of the frictional coefficient variation of the solid particles depending on the particle mass and on its perimeter (see table 1.a), as well as the correlation between floating speed, the friction coefficient and the perimeter of solid particle (see table 1.b). The dependency between turbulence intensity of the air flow around each particle, the friction coefficient and floating speed was also determined (see table 1.c).

Table 1. Mathematical models

 a)	$\mu_f = 7114{,}8214 + 10533{,}385 \cdot \ln m_p + 0217{,}3155 \cdot \left(\ln m_p\right)^2 + 1830{,}0012 \cdot \left(\ln m_p\right)^3 + 268{,}57755 \cdot \left(\ln m_p\right)^4 + 15{,}723033 \cdot \left(\ln m_p\right)^5 + 1{,}6189338 \cdot P_e - 0{,}13762953 \cdot P_e^2 + 0{,}003764544 \cdot P_e^3$, (2)
 b)	$v_p = -12{,}505204 + 107{,}94986 \cdot \mu_f - 393{,}75147 \cdot \mu_f^2 + 690{,}2027 \cdot \mu_f^3 - 574{,}92575 \cdot \mu_f^4 + 183{,}1513 \cdot \mu_f^5 + 0{,}68336123 \cdot P_e - 0{,}021122558 \cdot P_e^2$, (m/s) (3)

 c)	$$I_t = -3755{,}5261 - 820{,}35344 \cdot \mu_f + 1788{,}6542 \cdot \mu_f^2 - 1304{,}8774 \cdot \mu_f^3 + 221{,}5177 \cdot \mu_f^4 + 2817{,}1036 \cdot v_p - 662{,}17222 \cdot v_p^2 + 51{,}687849 \cdot v_p^3, \ (\%) \quad (4)$$

The corresponding mathematical equation was made the next notations:

- m_p - mass of the solid particle, g;
- P_e - perimeter of solid particle, mm.
- I_t - the turbulence intensity of the air flow.

The correlation coefficients of the equations (2), (3) and (4), generated with the program Table Curve 3D, are: 0,985, 0,99 and 0,989.

5. CONCLUSION

Analyzing the experimental data it was established that both the floating speed and the friction coefficient vary directly proportional with mass of solid particle.

With Solidworks software it could be measured the perimeter of solid particles, and it is observed that both floating speed of the solid particle and the friction coefficient are influenced directly by this.

Both the current lines and the turbulence intensity of the air flow are influenced by the perimeter of the particle.

Both speed of the air flow, in this case represented through floating speed of the solid particle, and friction coefficient of the solid particle influences significantly the distribution of the current lines, respectively the turbulence intensity of the air flow.

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