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# Air Classification of Crushed Materials

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**Abstract.** Air classification is widely used in industry for fractionation of crushed materials. Simplicity and high efficiency at low energy costs are distinguished by air classifiers with an inclined louver grille. The relevance of the work is conditioned upon the fact that it conducted an experimental and theoretical study of these devices on a model material – quartzite, which retains its density regardless of size. Through an experimental and theoretical study on a model material, quartzite, this work aims to investigate air classifiers with an inclined louver grille and propose a mathematical model that can reduce the amount of preliminary work required for calculating industrial classifiers. In the process of mathematical modelling, two tasks were solved: calculating the velocity field of two-dimensional vortex-free air flows inside the classifier and the subsequent study of particle motion in these fields. To set the correct boundary conditions of the problem, a thermomagnetometry was made and experimental studies of air velocities at the defining points of the classifier were carried out. A model of the distribution of extracted particles along the height of the classifier is suggested. A comparison of theoretical calculations with experimental data at different speeds and consumption concentrations showed satisfactory agreement. This study provides valuable insights into the separation properties of air classifiers with an inclined louver grille, specifically on a model material, quartzite. By conducting both experimental and theoretical studies, the authors were able to develop a mathematical model that accurately predicts air classification indicators for various materials. The results of this study have significant prospects in the industry, as it can potentially reduce the time and cost required for conducting preliminary laboratory studies on small copies of devices for specific types of raw materials.

**Keywords:** consumption concentration; fractionation; current function; fractional extraction; classifiers

## 1. Introduction

In the process of processing and enrichment of minerals, problems arise, the solution of which is associated with the allocation of small classes from a large volume of crushed raw materials. The main method of classification is screening<sup>1)-7)</sup>, which is carried out by scattering crushed materials on sieves and sieves with calibrated holes. However, the separation of materials with a particle size of less than 1 mm is impractical to carry out on screens, since in this case their specific productivity is significantly reduced. It is more rational to separate such fine-grained dry materials by air classification<sup>8)-14)</sup>, where, under certain conditions, larger particles fall out of the air stream under the action of gravity or centrifugal forces, and small particles are carried out by the air flow into precipitation devices. By adjusting the speed and trajectory of the air

flow, it is possible to vary the size limit of the separated particles<sup>15)</sup>.

The existing air classifiers differ in design, separation efficiency, and have low energy costs. Among them, air classifiers with an inclined louver grille<sup>16)</sup> are of practical interest for their simplicity and high performance, the presence of which contributes to the loosening of the material and the destruction of particle aggregates at the inlet in the transverse air flow. The fine fraction is extracted and further separation occurs in an inclined air flow, where there are no areas of turbulence. This device demonstrated high separation rates in the works of V.B. Ponomarev during dry processing of stone crushing waste, metallurgical slags<sup>17)</sup> and fireclay powder<sup>18), 19)</sup>. In the latter, the influence of the tilt angles of the plates and the louver grating itself on the efficiency and separation boundary was studied.

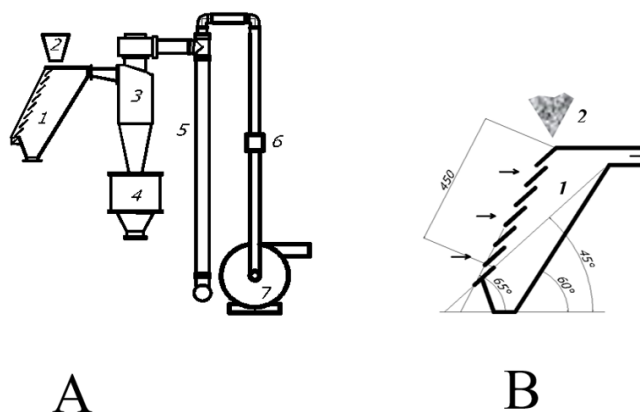
Traditionally, air classifiers are used in the non-metallic materials industry. Our interest is explained by the successful application of these devices in the technology of dry magnetic enrichment of iron-containing ores. If the magnetic separators are configured to work with large-lump ore, then the small class of concentrate is clogged with low-iron aggregates. To increase the total concentration of iron, the isolation of a fine product and its additional enrichment is required. This operation involved an air classifier with an inclined louver grille and new magnetic separators<sup>18-21)</sup>, designed to enrich small fractions.

Let us pay attention to the fact that the absence of vorticity regions in this apparatus significantly simplifies the mathematical description of air flows in the volume of the apparatus and the behavior of particles during separation. The purpose of the work is to conduct an experimental and theoretical study of air classifiers with an inclined louver grille on a model material, quartzite, and to suggest a mathematical model that can significantly reduce the preliminary work required for calculating industrial classifiers. The prospects of this study include the improvement of air classification processes through the experimental and theoretical study of air classifiers with an inclined louver grille on a model material,

quartzite. The research questions posed in this work include the determination of separation properties of a laboratory classifier with an inclined louver grate under various flow concentrations and inlet air velocities, as well as the development of a model for the distribution of extracted particles along the height of the classifier. Additionally, the study aimed to reduce the stage of preliminary work required for the calculation of industrial classifiers through the suggested mathematical modeling approach.

## 2. Materials and Methods

When studying the process of air classification as a model material, it is necessary to choose a substance that has the same chemical composition of particles and density, regardless of their size. For this purpose, quartzite with a density of  $2.65 \text{ g/cm}^3$  was used. A laboratory fractionation unit for crushed materials is shown in Figure 1A. The manufactured air classifier with an inclined lattice (1) is geometrically similar to those described in<sup>16)</sup> and is shown in Figure 1B. The width of each input channel was 50mm. The thickness of the blinds is 0.5 mm, the distance between the blinds plates is normal – 25mm.



**Figure 1.** Diagram of a laboratory fractionation plant for crushed materials (A) and the design of an air classifier (B) with an inclined louver grille

*Note: 1 – pneumatic classifier; 2 – material feeder; 3 – air cyclone; 4 – collection of fine particles; 5 – bag filter; 6 – flow meter; 7 – high pressure fan.*

The device works as follows. The raw material is fed by the feeder (2) to the upper plate of the blinds. The air flow is created by a high-pressure fan (7). A large class rolls down the inclined planes of the blinds, and a small product is carried away by the air flow into the classifier (1). A large part of this product falls to the bottom of the classifier, and the rest is deposited in a cyclone (3) and the dust-like is captured by a bag filter (5).

The granulometric composition of the materials was determined by sieve analysis using the available set of sieves with holes of the size: 0.063; 0.125; 0.250; 0.5; 1; 2; 4mm.

The study of air flow velocities was carried out by the

thermoanemometric method<sup>22)-24)</sup> of measurement, the principle of operation of which is based on the temperature dependence of the electrical resistance of a heated conductor placed in the flow. The sensing element is a sensor heated by an electric current. As a rule, these are platinum, nickel or tungsten filaments 5-10 microns thick<sup>22)</sup>.

Unfortunately, we did not have such materials in stock. Therefore, a tantalum wire with a thickness of 100 microns was used as a sensor, whose temperature coefficient of resistance is  $0.0038\text{K}^{-1}$ . The ratio of the filament length to its diameter is approximately 450. Therefore, the influence of the heat sink through the ends of the wire can be neglected<sup>22)</sup>. The simplest direct current

measurement scheme was implemented. In this case, a constant current is maintained, heating the wire, and the change in electrical resistance caused by its cooling is measured<sup>25)</sup>.

Preliminary studies of the sensor characteristics in a uniform air flow in the speed range of 0-7 m/s at various incandescent currents were carried out. We stopped at the filament current – 700mA. At constant current and low air flow rates, the resistance of the thread changes relatively quickly to a speed of 0.4-0.5 m / s, and with its further increase, this dependence becomes gentler with a gradual exit to the plateau. The work was limited to the range of air velocities: 0.4-0.8 m/s. At lower speeds, the sensor readings are more affected by random changes in air flow and other instabilities. To reduce the measurement error, the numerical averaging operation was applied by 50-80 measurements. For this purpose, a voltmeter connected to a computer was made based on a microcontroller and a 16-bit ADS1115 ADC with an internal reference voltage.

Based on a preliminary experiment, a calibration curve of the relative change in the thread voltage from the air flow velocity was constructed, which allowed determining the flow velocities in the classifier. To observe the movement of the material in the volume of the classifier, its side walls were made of transparent plastic. This allowed, in particular, visually establishing that vortices are not formed in the classifier volume. The electrically non-conductive side walls of the classifier made it possible to produce a thermoanemometric sensor, in which the thin side holders of the thread were in close contact with the side walls of the classifier<sup>26)</sup>. There were limiters on the holders, which ensured the same installation of the sensor relative to the geometry of the windows.

At the same time, tantalum wire with a thickness of 100 microns, fixed on these holders by contact welding, was located in the center of the channel entrance window from one side wall to the other and parallel to the louver plates. This geometry of the sensor introduced minimal distortion into the air flow due to the small thickness of the tantalum wire, the cross section of which is 250 times smaller than the window area. Let's pay attention to the fact that when the input velocity of the air flow is mentioned below, it will mean its value in the narrowest part of the window between the plates. Here, the width of each window is 50 mm, the height is 25 mm. The number of windows is 6.

### 3. Results and Discussion

The study of the separation properties of an air classifier with an inclined louver grate was carried out on crushed quartzite of one granulometric composition, given below:

Table 1. Granulometric composition of the initial quartzite

Sieve size, mm	Private remainder r
4	14%

3	10%
1	12%
0.5	18%
0.25	15%
0.125	14%
0.063	8%
0	9%

After each experiment, all separation products were collected, the mixture was classified. As necessary, fractions missing for the initial granulometric composition were added. Before the subsequent experiment, the mixture was thoroughly mixed.

The classification process is characterised by the degree of fractional extraction into a large separation product  $\Phi_K(x_i)$  or into a small class  $\Phi_M(x_i)$ , which is a fraction of particles of a narrow class of fineness  $x_i$  extracted into a large or small purge. They are interconnected by the equation<sup>16)</sup>:

$$\Phi_K(x_i) + \Phi_M(x_i) = 1. \quad (1)$$

Conditioned upon the fact that in experiments on the air classification unit (Figure 1A), it is difficult to completely extract the dust-like fraction from the bag filter, the fractional and mass compositions of the source material were first determined in the experiment and after its classification of a large class, to which the material deposited at the bottom of the classifier was added. The degree of fractional extraction into a large class  $\Phi_K(x_i)$  was determined as the ratio of the weights of fractions  $x_i$  in a large separation class and the initial product. Then, by the ratio (1), the degree of fractional extraction into a small class was calculated. Usually<sup>16)</sup> this value is attributed to the particle size equal to their average value on the sieve.

Notably, the experimental data contain various errors related, for example, to sieve analysis, particle collection, a limited number of measurements, a small set of sieves, and others. As a rule, for their partial elimination and convenience of description, experimental values are approximated by theoretical distributions that pass through the experimental array and in some way average it. Various analytical dependences are known<sup>16)</sup>, with the help of which it is possible to approximate the degree of fractional extraction into a fine product  $\Phi_M(x_i)$ . In this paper, the well-proven Plitt approximation was used<sup>16)</sup>:

$$\Phi_M(x) = \frac{1}{1 + \left(\frac{x}{x_{50}}\right)^p}. \quad (2)$$

where the Ehler-Mayer criterion can be used to

calculate the separation efficiency indicator  $p^{16)}$ :

$$p = \frac{\ln\left(\frac{1}{9}\right)}{\ln\left(\frac{x_{75}}{x_{25}}\right)}. \quad (3)$$

Here  $x_{25}$ ,  $x_{50}$ ,  $x_{75}$  are the average sizes of narrow fractions of particles carried into the fine product by 25%, 50%, 75%, respectively. The parameter  $p$  characterises the sharpness of separation. Thus, the results of pneumatic separation of powders can be described using experimental values  $x_{25}$ ,  $x_{50}$ ,  $x_{75}$  or  $x_{50}$  and the parameter  $p$  (3). Below are the results of the air separation of quartzite powders on a laboratory classifier with an inclined louver grille. The air flow velocity was calculated from the air flow rate, i.e. the flow meter indicator 6 (Figure 1), and the total cross-sectional area of the input channels 75 s.m<sup>2</sup>. The results in Table 1 are given for air flow rates of 2 m/s; 2.5 m/s; 3 m/s and various consumption concentrations of  $\mu$  (kg/m<sup>3</sup>) of powder mass per unit volume of air.

Table 2. Parameters of the degree of fractional extraction into the fine product of the classifier

Air flow velocity, m/s	2	2.5	3	3	3	3
Consumption concentration $\mu$ , kg/m <sup>3</sup>	0.6	0.5	0.4	2.4		
	6**	2	4		4.3	6.3
$x_{50}$ mm	0.1	0.1	0.2	0.1	0.1	0.1
	29	67	27	78	58	47
$p$	3.2	3.2	3.1	2.7	3.3	4.7
	2	1	5	3	0	3

Above are the results of an experimental study of the separation of crushed quartzite on a laboratory air classifier with an inclined louver grille. Theoretical consideration of these results is carried out by the method of mathematical modelling. The approach is based on solving two problems. The first is to find the velocity field of the air flow inside the classifier at the specified geometric dimensions, and the second is the subsequent study of the movement of particles in these fields<sup>7)</sup>.

In the air classifier, based on its design (Figure 1B), there are no areas of turbulence formed by geometric features, i.e. there is a vortex-free gas movement. The air velocity in the classifier is relatively high, so at any given moment a local equilibrium has time to be established. This means that the partial derivatives of the time parameters in the equations of continuity and motion can be neglected and the gas motion can be considered as steady<sup>27), 28)</sup>. The continuity equation characterises the immutability of the mass flow rate of gas in any section of the channel at steady flow:

$$\frac{\partial(\rho V_x)}{\partial x} + \frac{\partial(\rho V_y)}{\partial y} = 0, \quad (4)$$

where:  $V$  – air flow velocity,  $\rho$  – air density.

The condition of absence of vortices should be added to equation (4)<sup>22)</sup>:

$$\frac{\partial(V_y)}{\partial x} - \frac{\partial(V_x)}{\partial y} = 0. \quad (5)$$

We will solve the problems in terms of the current function  $\Psi(x, y)$ , which determines the trajectory of the gas “particles” and represents the fraction of mass flow introduced by the ratios<sup>27)</sup>:

$$\frac{\partial y}{\partial t} = v_y = -\frac{1}{\rho} \frac{\partial \Psi}{\partial x} - \text{gas velocity in the Y direction;}$$

$$\frac{\partial x}{\partial t} = v_x = \frac{1}{\rho} \frac{\partial \Psi}{\partial y} - \text{gas velocity in the X direction}$$

(6)

With such a replacement, equation (4) is satisfied automatically, and from (6) we obtain an equation for finding the current function  $\Psi(x, y)$ :

$$\frac{\partial}{\partial x} \left( \frac{1}{\rho} \frac{\partial \Psi}{\partial x} \right) + \frac{\partial}{\partial z} \left( \frac{1}{\rho} \frac{\partial \Psi}{\partial z} \right) = 0. \quad (7)$$

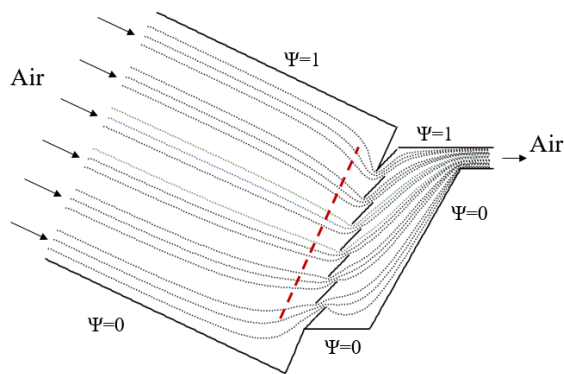
The air flow in the classifier is formed by a high-pressure fan (discharge 2.5-3kPa). The main resistance is created by a bag filter and a cyclone. At the output of the classifier, the discharge is significantly less than 1 kPa. The density of the air depends on the pressure and temperature. The temperature is constant, and the pressure change is less than 1%. Therefore, the air density in the classifier can be considered constant, equal to atmospheric.

In the present problem, the boundary conditions on the blinds are ambiguous. They have a decisive influence on the final result and therefore requires a separate experimental study of air flows at the entrance to the device. When the fan was turned on, the thread of the thermoanemometer sensor was sequentially placed in the middle of each window. When the sensor was located in the upper window, the air velocity of 0.5 m/s was set by adjusting the fan speed, and with this setting, measurements were carried out in the remaining windows. The research led to a rather unexpected result with an accuracy of up to several percent of the air velocity in the middle of each window were equal to each other. Therefore, we will assume that the air flow through the lattice windows is also the same.<sup>13)</sup>

To set the boundary conditions of the problem, we

consider that when the fan is turned on, a certain discharge is created in front of the louver grille, where the external air rushes. A flow is created, the front of which is directed towards the lattice. Let's take the following two-dimensional model. We will assume that the external air moves to the grate through a channel perpendicular to it, and the width of which is larger than the dimensions of the inclined grate. With an infinite channel width, such a model describes the real situation in a two-dimensional representation. However, to calculate it, it should be limited. We assume that it is larger than the size of the lattice by the value of 3-4 distances between the edges of neighboring lattice plates. We assume that at a distance from the grid equal to the width of the channel, the flow is uniform, i.e. there are no air flows in the perpendicular direction at the inlet.<sup>14)</sup>

The current function, according to (7), is determined up to a constant multiplier, i.e. the topography of air flows does not depend on the input air velocity. It can be assumed that within the scope of the classifier, its values do not exceed 1. The boundary conditions of equation (7) for calculating the function  $\Psi$  are shown in Figure 2.



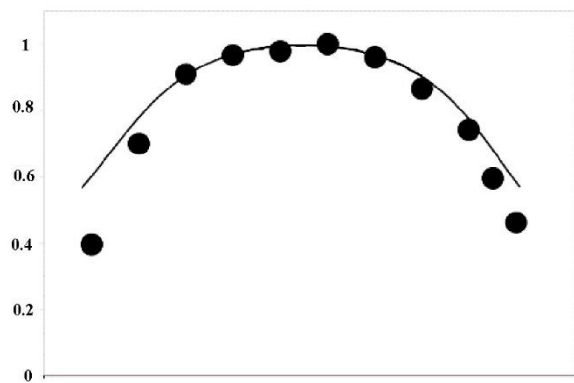
**Figure 2.** Air flow calculation model and calculated air flow trajectories (dotted curves) in the classifier

A solid curve shows the boundaries of air movement. On the left and right boundaries,  $\Psi$  changes linearly from 0 to 1. The red dotted line shows the line along which the speed of the incoming air flow was measured. They are determined in accordance with the fact that the constancy of  $\Psi$  along a certain line, according to (6), means that there is no air flow in a perpendicular direction. This condition is satisfied by the boundaries of the input channel and the surface of the classifier. In addition, it is satisfied on the surface of the blinds. Previously, it was found that the air flows passing through the windows are the same. Therefore,  $\Psi$  on the surface of the blinds take the values: 0, 1/6, 2/6, 3/6, 4/6, 5/6, 1. At the entrance to the system and the exit, the air flow velocity is perpendicular to the boundary and is the same at each point. Therefore,  $\Psi$  changes linearly along the border.

Figure 2 shows the calculated air flows at the inlet and in the volume of the classifiers. It follows from it that vortices may occur on the upper plates of the lattice, but

only at the entrance. However, they were not observed in experiments. Visually, the shape of the flow is clearly visible with increased loads of pulverized particles. If vortices are formed at the entrance, then they quickly disappear between the plates. Their development at the inlet contributes to the additional mixing of the flow and thereby improves classification<sup>29)</sup>.

Additional experimental studies of air flows were carried out. The local air velocity at the classifier inlet was measured using the thermoanemometer described above. To conduct the experiment, the side walls of the classifier were extended towards the incoming flow by narrow plates. The sensor rested on the edges of these plates and slid along them. At the same time, the thread moved along a straight line parallel to the classifier input grid and spaced from the louver plates at a distance of approximately 68-70mm from the edge of the plates. This line is schematically marked with a red dotted line in Figure 2 in front of the inclined grid. In Figure 3, the measured values of the relative velocity of the air flow along this straight line are shown with dots. The maximum speed is taken as a unit.



**Figure 3.** Comparison of experimentally measured (points) air flow velocities with calculated (curve) above the inclined classifier grid

The solid curve shows the theoretical values. There is a good correspondence of the data presented, but the experimental dependence changes steeply at the edges. From the calculation shown in Figure 3, it can be seen that at the edges of the lattice, air flows pass relatively long paths along the entrance window. These calculations are performed for a two-dimensional model. In the three-dimensional model, there are air flows in the direction perpendicular to the drawing, shortening the lateral long two-dimensional paths. The discrepancy between the theoretical and experimental curves at the edges is partly due to this effect. Nevertheless, the accuracy of the calculations can be considered acceptable.

After the current function  $\Psi(x, y)$  and the velocity fields according to (63) have been calculated, it is possible to begin solving the problem of particle motion with a diameter  $D$  and density  $\rho_m$  in the air flow. The velocity field  $V_x(x, y)$  and  $V_y(x, y)$  normalised by the velocity

of the air flow entering the classifier. The trajectory of motion is determined by the solution of the equation of motion. In this case, we have a system of second-order differential equations:

$$\begin{cases} \frac{d^2X}{dt^2} = \frac{1}{m}F_x \\ \frac{d^2Y}{dt^2} = \frac{1}{m}F_y - g \end{cases}, \quad (8)$$

here  $X$  and  $Y$  are the coordinates of the particle,  $m$  is the mass of the particle,  $g = 9.81 \text{ m/s}^2$  is the acceleration of gravity,  $F_x$ ,  $F_y$  is the projection of the force of aerodynamic air pressure, which is determined by the relative velocity of the particle flow around the air flow,  $U \text{ m/s}^{16)}$ :

$$F_c = \lambda \rho \frac{\pi d^2}{4} \frac{U^2}{2}, \quad (9)$$

where  $\lambda$  is the coefficient of aerodynamic or hydraulic resistance,  $d$  is the diameter of the material particle,  $m$ ;  $\rho$  – air density,  $\text{kg/m}^3$ . We believe that the particle has a spherical shape.

$$U = \sqrt{(V_x - W_x)^2 + (V_y - W_y)^2}, \quad (10)$$

where  $W_x, W_y$  are the projections of the flow velocity vector,  $\text{m/s}$ ; and  $V_x, V_y$  are the projections of the particle velocity vector on the coordinate axes,  $\text{m/s}$ . The  $\xi$  drag coefficient depends on the Reynolds number:

$$Re = \frac{U \cdot D \cdot \rho_B}{\nu}, \quad (11)$$

where  $D$  is the diameter of the particle,  $\rho_B = 1.29 \text{ kg/m}^3$  – the density of the air,  $\nu = 0.000018 \text{ Pa} \cdot \text{s}$  – the viscosity of the air. The coefficient is  $\xi$  determined by experimental data. To determine the coefficient  $\xi$ , you can use the formula G. A. Adamova<sup>16)</sup>:

$$\lambda = \frac{24}{Re} \left[ 1 + 0.065 Re^{2/3} \right]^{3/2}, \quad (12)$$

with an error of  $\Delta \xi = 1.7\%$  for  $Re$  from 0 to 200.000. The classifying properties of the apparatus were calculated as follows. We assume that the material is fed by a feeder and rolls off the top plate and gets into the channel. Some of the small particles in the fall are captured by air and extracted by the classifier channel. Others, following a distorted trajectory, fall onto the lower plate and begin to roll down the inclined plane, reaching the edge of the plate, and again fall into the airflow of the next channel located below<sup>30), 31)</sup>.

Therefore, when studying the trajectories of particle

motion, we assume that the particles begin to move in the air flow from the edge of the upper plate and have a certain set of initial velocities directed along the upper plate of the channel in the direction of rolling. It was also assumed that the particles were evenly distributed in the velocity range from 0 to the maximum, which was defined as the velocity of particles rolling down without friction from the upper point of the louver plate.

For the calculation, a set of 6 speeds of this interval was taken at regular intervals. It was assumed that initially the particles had the same velocity, rolling down the upper plate of the blinds. If, as a result of its movement in the classifier, a particle enters the exit window, it is considered that it has been selected into a fine product. Otherwise, the particle gets into a large product. The louvered grille has 6 entrance windows<sup>32)</sup>.

In a working classifier, some of the particles reach the back wall and move along it under the action of an air flow, which was visually observed in the experiment. The particles are located in the near-surface transition region. With laminar, i.e. vortex-free air movement, as is customary in the work, the velocity on the surface is zero, and at the opposite edge of the transition region reaches volumetric velocity. In the transition region, this air flow velocity is less than the calculated one by a certain amount. In the calculations carried out, the entire area of the numerical solution is divided into cells. Therefore, in the cells near the surface, it was reduced by the surface influence factor. In addition, it was considered that when a particle interacts with the surface of the rear wall, an inelastic shock occurs, in which the velocity component perpendicular to the surface changes its direction to the opposite with a partial loss of its magnitude<sup>33)</sup>.

We will consider the classifier as a set of channels that begin with the entrance windows of the blinds. It has the same-sized entrance windows. The driving force is the dynamic pressure of the air flow. The extracted particle is accelerated by the air flow. The increase in energy is due to the work of the force of high-speed air pressure. As a result, there is a loss of pressure, which is the energy expenditure of the air flow to change the kinetic and potential energy of the particle<sup>34)</sup>.

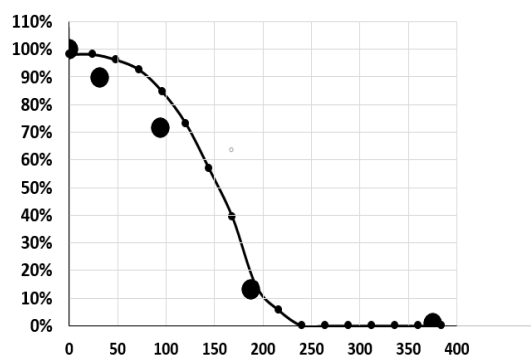
Let  $w$  be the fraction of the total mass of the extracted material that falls on the first, uppermost channel. In this case, the fraction of passing particles will be  $(1-w)$ . Since the total fraction of extracted particles is a small amount ~ 15-20% of the total flow, we will assume that the falling material flow in each window is approximately the same. Due to the fact that the classifier has the same-sized input windows, through which the air flow is also the same, the parameter  $w$  can be attributed to all channels. As a result, the extracted fraction of the material in the second channel will be  $w(1-w)$ , and those who passed through the third window will be  $(1-w)-w(1-w) = (1-w)^2$ . In the third window, the extracted fraction will be  $w(1-w)^2$ , and the past will be  $(1-w)^3$ . Respectively in the  $n$ th:  $w(1-w)^n$  and  $(1-w)^{n+1}$ .

The number of channels in the classifier is limited by

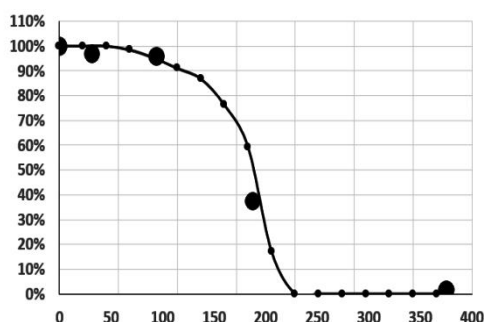
the value  $n$ . In accordance with accepted concepts, the total fraction of all extracted particles in  $n$  channels can be determined through the fraction of those that have passed the  $n$ th channel as  $1-(1-w)^{n+1}$ . Therefore, it is necessary to adjust the above-defined fractions of the extracted material  $w$  so that their total amount is equal to one. Then in each channel the proportion of extracted particles will change and will be:

$$w \frac{(1-w)^{i-1}}{1-(1-w)^{n+1}}. \quad (13)$$

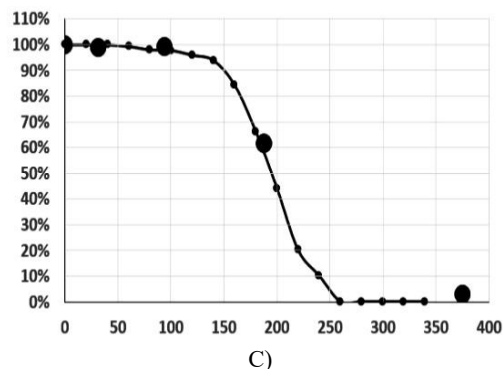
In Figure 4 below, experimental and theoretical values of the degree of fractional extraction into a fine product are compared when classifying quartzite for different air flow velocities and small values of the discharge concentration  $\mu$  ( $\text{kg}/\text{m}^3$ ). In the calculations, the influence of the rear wall of the classifier led to a decrease in the flow velocity in the transition region to 30% of the calculated value, and with inelastic reflection of the particle, 70% of the normally reflected velocity projection is lost. Theoretical curves were constructed by counting a relatively small number of trajectories. Therefore, they are not smooth curves.



A)

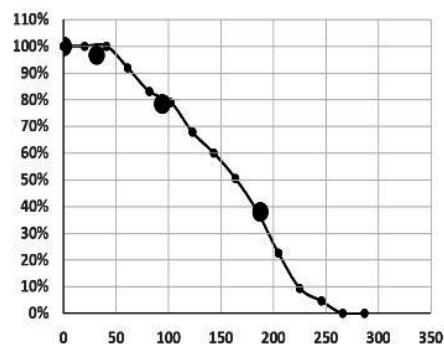


B)

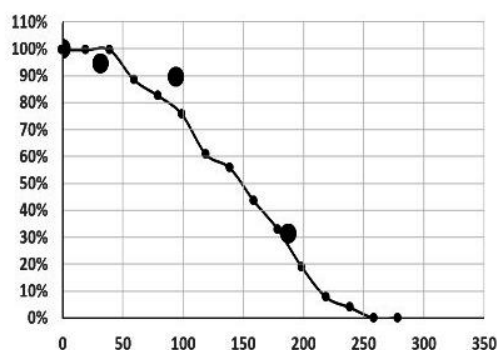


**Figure 4.** Comparison of experimental (dots) and theoretical values (solid line) of the degree of fractional extraction into a fine class when classifying quartzite for different air flow velocities: 2 m/s(A), 2.5 m/s (B), 3 m/s

In the experiment, the feeder was configured to supply a certain amount of material. Since the velocity of the air flow changed, the consumption concentration  $\mu$  ( $\text{kg}/\text{m}^3$ ) = 0.66(A); 0.52(B); 0.44(C) changed accordingly. The average dispersion for three sizes 31.5; 94; 187.5 microns was calculated from three series of experiments for each air velocity and was:  $\sigma=1.8\%$ (A);  $\sigma=1.7\%$ (B);  $\sigma=2\%$ (C). Consequently, the spread of the experimental value of the degree of fractional extraction into a small class corresponds approximately to the size of the point in the figure. The theoretical curves are calculated for the following parameters: A)  $w=0.3$ ;  $\xi=1$ ; B)  $w=0.52$ ;  $\xi=1$ ; C)  $w=0.6$ ;  $\xi=1$ . Figure 5 below shows data for different flow concentrations  $\mu$  at an air flow velocity of 3 m/s.

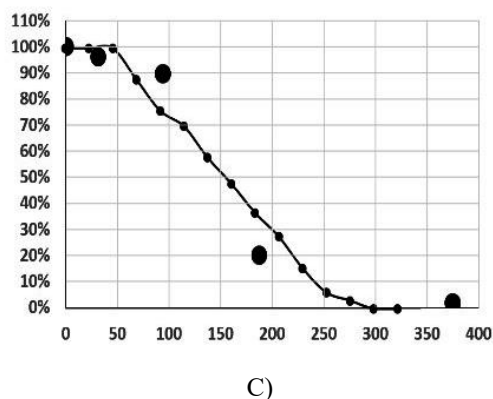


A)



B)





**Figure 5.** Comparison of experimental (dots) and theoretical values (solid line) of the degree of fractional extraction to a fine class when classifying quartzite for different flow concentrations at an air flow velocity  $v = 3$  m/s: A)  $\mu=2.4$ ,  $w=0.22$ ; B)  $\mu=4.3$ ,  $w=0.14$ ; C)  $\mu=6.3$ ,  $w=0.05$

The agreement is satisfactory, but the experimental function of the degree of extraction to a small class is characterized by a greater sharpness of separation at large values of the discharge concentration  $\mu$ . This probably finds its explanation<sup>35</sup>). The calculation considers only the redistribution of material between channels when the consumption concentration changes. But the increase in  $\mu$  has a greater effect on larger particles, because the channels begin to lock up, the air flow velocities decrease and this has a greater effect on the trajectories of larger particles, increasing the sharpness of separation. This mechanism was not considered in the calculations. It is enhanced by the fact that the locking of channels increases due to effects not considered here, namely, the pressure drops due to the frictional interaction of particles with each other at large  $\mu$  and their friction against the side walls of the classifier.

#### 4. Conclusions

This study presents an experimental and theoretical investigation of air classifiers with an inclined louver grille, which are widely used in industry for fractionation of crushed materials. The relevance of the work is due to the fact that it was conducted on a model material - quartzite, which retains its density regardless of size. The study has focused on the separation properties of a laboratory classifier with an inclined louver grate in the range of inlet air velocities and various flow concentrations.

The mathematical modelling has been used to calculate the velocity field of two-dimensional vortex-free air flows inside the classifier and to study the particle motion in these fields. The calculations have shown that in the upper channels of the classifier, the grain size of the extracted product shifts to the region of large particle sizes. This is conditioned upon the fact that when particles move from the lower channels, a significant part of the dynamic air

pressure is spent on increasing their potential energy. Additionally, a model of the distribution of extracted particles along the height of the classifier is suggested. The comparison of theoretical calculations with experimental data has shown satisfactory agreement, and the suggested mathematical modeling has the potential to significantly reduce the stage of preliminary work in the calculation of industrial classifiers.

The research presented in this paper enables the reduction of the preliminary work stage for an air classifier with an inclined louver grille, as well as the mathematical determination of air classification parameters for different materials.

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