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COUPLED PROBLEMS OF LOCALIZATION OF DUST AND GAS

O. A. AVERKOVA*, K. I. LOGACHEV*, I. N. LOGACHEV* AND A. E. CANAR*

* Belgorod State Technological University named after V.G. Shukhov
(BSTU named after V.G. Shukhov), 308012 Belgorod, Russia
e-mail: kilogachev@mail.ru, web page: http://www.bstu.ru

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Abstract. The paper outlines the developed mathematical models, computational algorithms forcalculation of dust and gas streams in the spectrum of action of local ventilation device of the closed type (aspiration shelter) from nodes overload of granular materials.

1 INTRODUCTION

The most reliable way of localization and capturing of dust and gas emissions in the production premises of industrial enterprises is the use of dedusting ventilation systems (aspiration), main element of which is local ventilation exhaust (LVE).Performance of dedusting ventilation system should reduce particulate air pollution to the level of maximum permissible concentration at a minimum flow of air entering in LVE.

The aim of this work is to develop methods for the calculation of the velocity field in the spectra of actions of LVE, which allowstaking into account: influence of the rotating elements of the technological equipment on the velocity distribution of airflow; vortex structures, spreading in the closed LVE - aspiration shelters; separated flows, generated at the entrance to the leaks of aspiration shelters and exhaust openings; distribution of dust aerosols in the obtained velocity field of airflows.

2 METHOD OF REDUCING VOLUME OF EJECTED AIR

A mathematical model of ejection of air in a circular perforated pipe was developed for determining the effect of the flow of granular material on the air environment and the effectiveness of exhaust cover, equipped with a bypass chamber.

It was considered axisymmetric particle flow in a circular pipe with cross-sectional area $\tilde{s}_t$, m^2 (Fig.1-2). A cylindrical bypass-chamber is provided around the tube (with cross-sectional area $\tilde{s}_b$, m^2), aerodynamically connected with a tube with perforated wall.

Because of overflowing of air from pipe to the bypass chamber, speed of ejected air in the pipe ($\tilde{u}$, m/s) and speed of the upward flow in the bypass chamber ($\tilde{\omega}$, m/s) are changing along the length of the channel.

To determine these velocities we used the equation of conservation of momentum of the air in a fixed volume $\tilde{V}\,(\mathrm{m}^3)$, bounded by the surface $\tilde{S}(\mathrm{m}^2): \int_{\tilde{S}} \tilde{\rho}\vec{\tilde{u}}\,\tilde{u}_n d\tilde{S} = \int_{\tilde{V}} \vec{\tilde{M}} d\tilde{V} + \int_{\tilde{S}} \vec{\tilde{p}}_n d\tilde{S}$,where $\tilde{u}_n$ -

projection of the vector the air velocity on the external $\vec{n}$ surface normal $\tilde{S}$, м/с; $\vec{\tilde{u}}$ - velocity vector of air, м/с; $\tilde{\rho}$ - density of air kg/m^3; $\vec{\tilde{M}}$ - vector of mass forces, N/m^3; $\vec{\tilde{p}}_n$ - vector of surface forces, applied to an elementary area $d\tilde{S}$ with an external normal $\vec{n}$, Pa.

Whence, neglecting small values of higher order, we have come to the basic equation of one-dimensional problems of dynamics of ejected air in the pipe in a dimensionless form:

$$dp + 4udu = \mathrm{Le}(v-u)\left|v-u\right| / v \cdot dx\,, \tag{1}$$

where $\mathrm{Le} = \psi\beta_k \tilde{l}\tilde{F}_{м} / \tilde{V}_{ч}$; $\beta_k = \tilde{G}_{ч} / (\tilde{\rho}_{ч}\tilde{v}_k\tilde{s}_t)$; $p = 2\tilde{p} / (\tilde{\rho}\tilde{v}_k^2)$; $u = \tilde{u}/\tilde{v}_k$; $v = \tilde{v}/\tilde{v}_k$; $x = \tilde{x}/\tilde{l}$; $\tilde{p}$ - static pressure in pipe, Pa (hereinafter we are talking about excessive static pressure); $\tilde{v}_k$ - velocity of particles at the end of pipe, m/s; $\tilde{l}$ - total length of pipe, m; dimensionless number Le («ejection parameter») is the ratio of maximum ejection pressure forces (at $\tilde{v} - \tilde{u} = \tilde{v}_k$) and dynamic pressure of the ejected air.

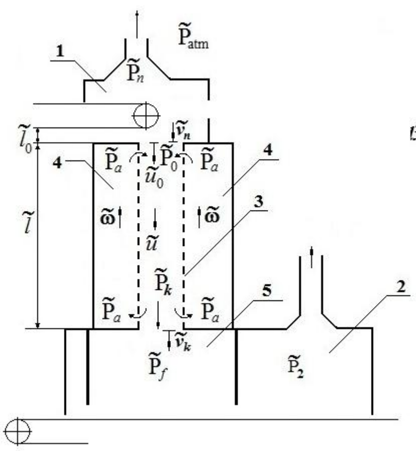

Figure 1: The scheme of aspiration of handling node, equipped by upper (1) and lower (2) aspirated shelters, a perforated chute (3) with the bypass chamber (4) and form camera (5) in the lower shelter

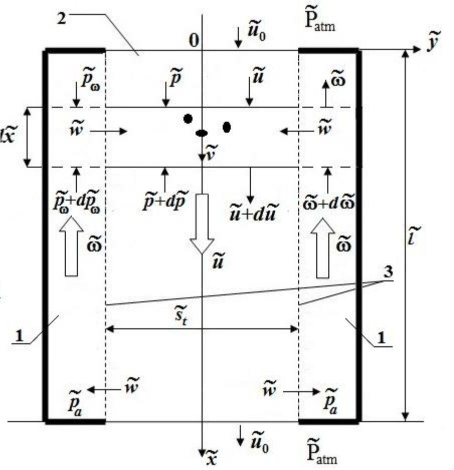

Figure 2: An exemplary scheme of perforated chute with the bypass chamber: 1 – bypass chamber; 2 – a pipe;3 – perforated walls of chute

Similarly, we obtained an equation of dynamic of rising air in the bypass channel with cross-sectional area $\tilde{s}_b$ (in the absence of aerodynamic resistance forces of channel walls):

$$dp_{\omega} + 4\omega d\omega = 0;\quad p_{\omega} = 2\tilde{p}_{\omega} / (\tilde{\rho}\tilde{v}_k^2);\quad \omega = \tilde{\omega}/\tilde{v}_k\,, \tag{2}$$

where p_{ω} - dimensionless static pressure in transverse cross sections of the bypass channel.

After a number of transformations, we have a system of differential equations:

$$du/dx = E\cdot\gamma\sqrt{\left|\vartriangle p\right|};\qquad dp/dx = -4uE\gamma\sqrt{\left|\vartriangle p\right|} + \mathrm{Le}(v-u)\left|v-u\right|/v\,,$$

where parameters are calculated by formulas $\vartriangle p = p_{\omega} - p = p_a - 2\left((u-u_0)/r\right)^2 - p$; $E = \hat{S}_t / \sqrt{\zeta_0} = \tilde{\Pi}\tilde{l}\varepsilon / (\tilde{s}_t\sqrt{\zeta_0})$; $v = \sqrt{(1-n^2)x + n^2}$; $n = \tilde{v}_0/\tilde{v}_k$; γ – mark of pressure difference $(p_{\omega} - p)$;

$\tilde{v}_0$ - flow rate of particles at the inlet of the pipe; $\hat{S}_t$ - the ratio of the total area of perforation holes in the walls of tube to its cross-sectional area; $\tilde{\Pi}$ - perimeter of pipe; ε - degree of perforation of the walls of the pipe ($\varepsilon = 0$ in the absence of perforation, $\varepsilon = 1$ in the absence of the pipe walls); ζ_0 - coefficient of local resistance (c.l.r.) of perforation hole.

We use the following boundary conditions:

$$u(0) = u_0; \quad p(0) = -\zeta_n u_0^2; \qquad (3) \qquad\qquad u(1) = u_0; \quad p(1) = \zeta_k u_0^2, \qquad (4)$$

where $\zeta_{n,}$ ζ_k - coefficients of local resistance to movement of air at the inlet of pipe and outlet of pipe. Some difficulties arise in connection with the fact that the desired data are exactly the velocity of the air at the entrance to the pipe (at the outlet of pipe) - u_0 and overpressure at the beginning (at the end) of the bypass channel - p_a.

Therefore, the solution of the boundary value problem is solved by the method of random search:specifying of u_0, is solved the Augustin-Louis Cauchy problem with initial conditions (3), wherein a predetermined value of p_a from the condition $p(1) > p_a > p(0)$, $p_a \approx (\zeta_k - \zeta_n)u_0^2/2$ and then verifies the condition (4). To facilitate the search of values u_0 and p_a you can use the bisection method (method of half division).

The increase in the number of ejection Le, as in the case of flow in a pipe with impermeable walls, promotes growth of u_0. The asymptotic of the growth (fig.3) and decline in ejection are notable in compare with the flux of particles in the non-perforated pipe ($u_0 < u_2$ - dash-dotted curve) in the investigated range of numbers Le.

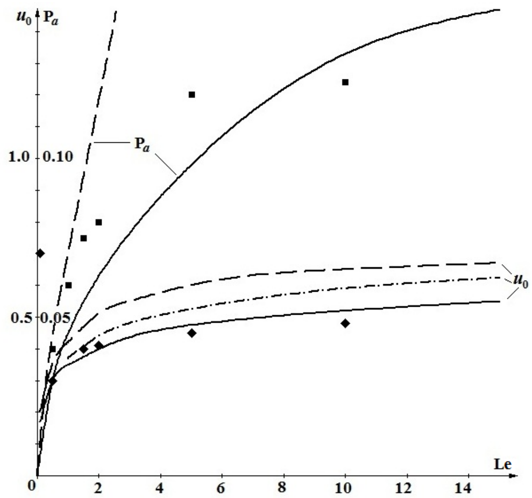

Figure 3: Dependence of ejected air velocity u_0 and pressure in the bypass chamber p_a from the number of Le (at $E = 1$; $r = 1$; $n = 0.4319$; $\zeta_n = 0.5$; $\zeta_k = 1$; $\zeta_0 = 1.5$) ;solid curves are constructed according to the formulas of the linearized problem; dashed line - at maximum forces $k = 1$, $\mathrm{Le}(v-u)$; dash-dotted line is for the case of pipes with impermeable walls ($E = 0$); rhombuses ◆ - for u_0 and squares ▪ - for p_a according to the results of the numerical solution of «exact» equation

An even greater effect of minimizing u_0 is observed when increasing the degree of perforation and there is asymptotic - when $E \geq 2.5$ the decrease of u_0 practically stops.

The decrease volumes (speed u_0) of ejected air due to its recirculation in the bypass channel is higher, the greater the number of Le and less than n.

The decrease in ejection is even more noticeable with increasing aerodynamic resistance at the exit and entrance of air into the perforated tube. This fact confirms the significant role on the volume of recirculated air in the conventional (non-perforated) bypass channel pressurization of the top shelter and the presence of the buffer capacity (form-chamber) in the lower cover, which create a greater vacuum at the top of the pipe and an afflux - at the bottom. This creates conditions for a more intense overflow of air through the perforation holes. Volumes of ejected air can be reduced by 1.3-1.5 times by increasing ζ_k to 8-32 and 1.45-1.55 times with increasing of ζ_n to 4-16 (if $\mathrm{Le} \geq 10; \quad r = 2; \quad E = 2.5$).

3 REDUCTION OF THE VOLUME OF AIR ENTERING THROUGH LEAKAGES

Initially, we considered a potential separation of airflow at the entrance to flat slot, in front of which there are two screens, perpendicular to its axis and investigated separated flow in the slit-like intake channel extending beyond the flat wall, in the spectrum of action of which there is an impervious screen. Then, using the theory of functions of a complex variable was able to solve the more general problem of separated flow in a horizontal channel, the inlet section of which protrudes from the vertical wall at a distance S (Fig. 4).

The flow is limited by impenetrable screen, remote at a distance G from the inlet section of flat channel with height 2B, and divided at the distance M by vertical shield (screen with a central hole in height of 2R) into two regions. An impenetrable screen in this case allows simplifying the task of determining the constants of the integral of the Christoffel-Schwarz, in particular to estimate the magnitude of increments at the infinite point A.

The function of Zhukovsky in this case has the form: $\omega = \frac{1}{2}\ln\frac{\sqrt{t}+\sqrt{b}}{\sqrt{t}-\sqrt{b}} + \frac{1}{2}\ln\frac{\sqrt{t}+\sqrt{p}}{\sqrt{t}-\sqrt{p}}$, and for complex potential, we obtained an expression: $w = \frac{h-m}{1-m}\cdot\frac{q}{\pi}\cdot\ln\left(\frac{t-m}{m}\right) + \frac{1-h}{1-m}\cdot\frac{q}{\pi}\cdot\ln(t-1)$.

A connection of points of auxiliary plane t and points of the physical region defined by the formula:

$$z = i + (1-k)\frac{\delta_\infty}{\pi}\cdot A + k\frac{\delta_\infty}{\pi}\cdot B \text{, where } A = \int_0^t e^{\omega}\frac{dt}{t-m}; \; B = \int_0^t e^{\omega}\frac{dt}{t-1}.$$

Shield with a central aperture divides intake torch into two parts, wherein, despite low consumption of closest to cut-off part of hole, its velocity is higher than the other parts, which increases the inertial preload of jet to axis of the channel and, as a consequence, reduces the thickness of the jet δ_∞.

On the value of δ_∞ is influenced as location of shield M, as magnitude of the hole R. Influence of value δ_∞ on the coefficient resistance of input environment ζ in aspirating hole is determined by the formula of Idelchik I.E .: $\zeta = \left(1/(\delta_\infty)^m - 1\right)^2$, where $m = 1$ for slit intake canal and $m = 2$ for round pipe.

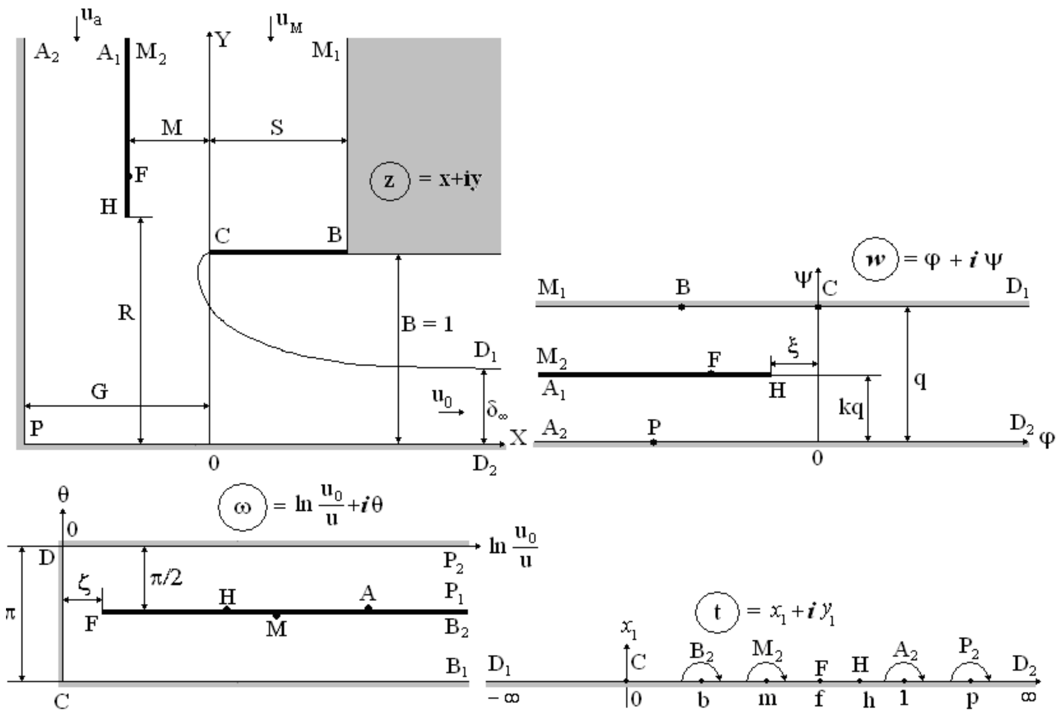

Figure 4: To the definition of an orthogonal grid and velocity field of suction channel of protruding torch with screen

As research has shown, the change in relative thickness of the jet $\bar{\delta} = \delta_\infty(1)/\delta_\infty(\infty)$ and the relative coefficient of resistance $\bar{\zeta} = \zeta(1)/\zeta(\infty)$ (here $\zeta(1) = \zeta|_{R=1}$; $\zeta(\infty) = \zeta|_{R\to\infty}$) have clearly defined extrema while removing the shield at $M \approx 0.75$ not only at a considerable distance of blank wall, but also with a noticeable approximation of this wall to this aspiration hole. Thus, value $\bar{\delta}$ has a minimum, and $\bar{\zeta}$ - the maximum.

The use methods of theory of functions of a complex variable and Zhukovsky`s method allows accurately determine parameters of flow separation, but does not give the opportunity to explore the flow in plane multiply connected regions containing screens of finite length as well as the flows near the round suction channels.

Therefore, there was a need to develop a method in which these disadvantages have been eliminated.

We considered multiply connected flow region (fig.5 a) at the entrance into a flat (or round) intake channel, in the spectrum of action of which there is thin screen (a circular disc with a central opening), at its circulation flow around. Flow separation occurs and forms a free current line from a sharp edge *C*.

A numerical procedure was developed to determine its position, velocity of flow at any given point and the coefficient of local resistance (c.l.r.) at the entrance to the inlet hole

Discrete mathematical model for a plane problem is constructed as follows (fig.5 b). Let us denote: N is number of attached vortices, the same number will be the control points. A vortex lying on the sharp edge of visor C is considered to be free. Attached vortices were located at the points of fracture boundaries. Between the attached vortices were located control points.

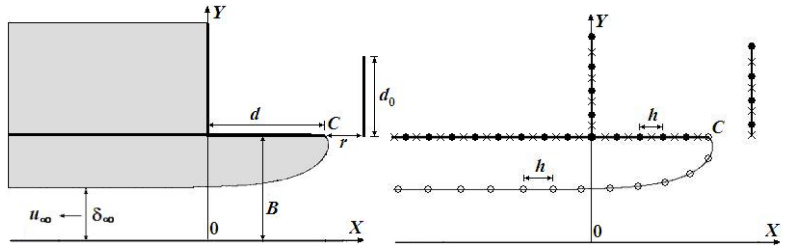

Figure 5:The statement of the problem::a) physical region of flow; b) discretization of the boundary of area (● −attached vortices, ○ −free vortices, × −control points)

Point of $\xi^k(\xi_1,\xi_2)$ − is point location of k-th attached vortex; $x^p(x_1,x_2)$ − p-th control point. To ensure impermeability of axis OX we reflect symmetrically with respect to it all the vortices; circulations of symmetric vortices should be opposed.Compliance with this condition is automatically leads to a condition of non-circulatory flow. It was assumed that desired free line of vortices circulation is constant and equal to γ. The total impact of all jets on a control point x^p in the direction of the outward normal is expressed by the equation:

$$v_n(x)=\sum_{q=1}^{N}\left(G\left(x,\xi^q\right)-G\left(x,\xi^{q+N}\right)\right)\Gamma\left(\xi^q\right)+\gamma\sum_{k=1}^{N_S}\left(G\left(x,\zeta^k\right)-G\left(x,\zeta^{k+N_S}\right)\right), \quad (5)$$

where ζ^k –point location of the free vortex. Function $G(x,\xi)=\left((x_1-\xi_1)n_2-(x_2-\xi_2)n_1\right)/\left(2\pi\left((x_1-\xi_1)^2+(x_2-\xi_2)^2\right)\right)$ expresses by itself the velocity caused at the point $x(x_1,x_2)$ along a predetermined direction $\vec{n}=\{n_1,n_2\}$ of a single vortex, located at the point $\xi(\xi_1,\xi_2)$. Since $v_n\left(x^p\right)=0$ in all control points,i. e. condition of impermeability is performed, at change of $p=1,2,\ldots,N$ the expression (5) is transformed into a system of linear algebraic equations for determining the unknown circulations $\Gamma\left(\xi^q\right)$ of attached vortices.

The second approximation for the free streamline is constructed using the Runge-Kutta method for the numerical solution of systems of ordinary differential equations $dx/dt=v_x$; $dy/dt=v_y$.

Line current begins to build with sharp edges C. As soon as the distance between the point (x,y) and sharp edge becomes h, then a free vortex comes in this point, i.e. it will be the second approximation for this point free line current. Then again, the current line is built, while again the distance between the point (x,y) and the previous position of the free vortex will be h.A free vortex is placed at this point and so on.

After determining of the second approximation for the free streamline is required to re-solve the system of equations (5) and to determine the circulation of attached vortices. Then, the third approximation of free streamline is being built and etc. This iterative process continues until the distance between the subsequent position of N_S-th free vortex and the previous one will be no more than a given accuracy ε. Discrete mathematical model is constructed in a similar manner for the axisymmetric problem.

The infinitely thin vortex rings were used as discrete features, without self-induction. The system of equations for determining the unknown intensities of attached vortex rings will take the form:

$$\sum_{q=1}^{N} G\left(x^p,\xi^q\right)\Gamma\left(\xi^q\right) = -\gamma \sum_{k=1}^{N_S} G\left(x^p,\zeta^k\right), \tag{6}$$

and speed is determined by the formula:

$$v_n(x) = \sum_{q=1}^{N} G\left(x\ ,\xi^q\right)\Gamma\left(\xi^q\right) + \gamma \sum_{k=1}^{N_S} G\left(x^p,\zeta^k\right), \tag{7}$$

where $G(x,\xi) = \dfrac{(A_1 b + A_2 a)}{b}\cdot\dfrac{4}{(a-b)\sqrt{a+b}}E(t) - \dfrac{A_2}{b}\cdot\dfrac{4}{\sqrt{a+b}}F(t)$ при $b \neq 0,\ A_1 = \dfrac{\xi_2{}^2 n_1}{4\pi}$, $2x_2\xi_2 = b > 0$,

$t = 2b/(a+b)$, $G(x,\xi) = \dfrac{\xi_2^2 n_1}{2a\sqrt{a}}$ при $b = 0,\ a = (x_1-\xi_1)^2 + \xi_2{}^2 + x_2{}^2 > 0$, $E(t) = \int\limits_0^{\pi/2}\sqrt{1-t^2\sin^2\theta}\,d\theta$;

$F(t) = \int\limits_0^{\pi/2}\dfrac{d\theta}{\sqrt{1-t^2\sin^2\theta}}$, $F(t) = \sum\limits_{i=0}^{4} c_i(1-t)^i + \sum\limits_{i=0}^{4} d_i(1-t)^i \ln\dfrac{1}{1-t}$,

$E(t) = 1 + \sum\limits_{i=1}^{4} c_i(1-t)^i + \sum\limits_{i=1}^{4} d_i(1-t)^i \ln\dfrac{1}{1-t}$, c_i, d_i formula are taken from the tables of special functions.

We considered various modes of flow around of vertical screen that is contained in the spectrum of the inlet channel. The circulation around the screen was the closest to the experimental data with the condition of finiteness of the speed on the lower edge. (Fig.6).

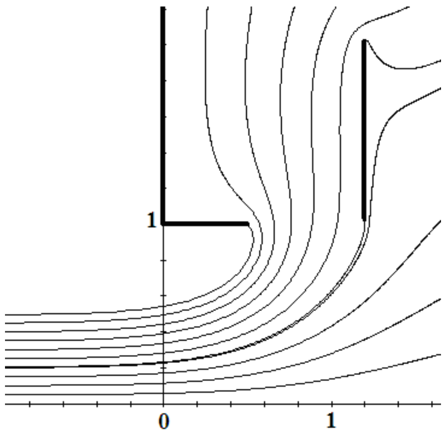

Figure 6: Line current at circulation flow around screen (δ_∞ = 0.4957; r = 0.7)

For a fixed value of length d_0 of the vertical screen and the change of distance r there is a minimum value of δ_∞. In particular, the value of δ_∞ for the plane problem for different values of d_0 has a minimum in the range $0{,}55 < r < 0{,}75$, and for axisymmetric one – $0{,}3 < r < 0{,}3$.. With a significant increase of d_0 for a plane problem, extremum occurs when $r = 0{,}75$, that corresponds with calculations according to the method of N. E. Zhukovsky at $d_0 \to \infty$.

Numerical experiments have shown that increasing the length of the profile of more than one caliber does not give significant practical effect.

4 APPLICATION OF SWIRLED AIRFLOWS

In this paragraph is being developed a method of modeling dusty flows in the spectrum of action of LVE from rotating cylindrical parts and offered a new direction to reduce the dust discharge from aspirated shelters due to the use of the properties of swirling flows. Initially we developed a method of computer simulation based on the method of boundary integral equations with plane jets simulating rotating cylinders.

There were simulated dusty flows near open LVE, which shows the necessity of taking into account the rotation of the cylinders, which have a significant effect on the velocity field of the airflows and the value of the maximum diameter $d_{\max}$ of dust particles captured by LVE.

It decreases by 3-4 times. Thus, the accuracy of the model significantly influences on correct choice of an efficient dust collecting apparatus. It is shown that significant energy-saving effect and increase the effectiveness of LVE can be achieved by installing a mechanical screen.

In local exhausts of closed type - aspiration shelters can also be used rotating cylinders to reduce their energy consumption.

Using the developed computer program, we determined the value of $d_{\max}$ finely dispersed aerosols of different physical properties, that being carried into aspiration network with the aim to develop constructive proposals for designing of aspiration shelters with the functions of dust precipitation chamber.

Computational experiments have shown that reduction of 140-200 μm of the maximum diameter of dust particles can be achieved due to equipping of aspiration shelters with screening visors, rotating cylinders and exhaust-cylinder, conducing due to the airflow induced by their rotation of precipitation of dust particles on the bottom of cover. To study the processes of vortex is developed a mathematical model of vortex flows inside the shelter, in which may be located rotating cylinders, its computer implementation.

We considered the region with the boundary of S, in which is set the normal component of the velocity.

In the area may be located the rotors and exhaust-cylinders with known linear speeds $v_k, k = 1, 2, \ldots, M$. To simulate the boundary S is used a simple layer: continuously distributed fictitious sources with intensities $q(\xi)$. To account the influence of the airflow, initiated by rotation of a cylinder of radius of R_k, locate in their centers c_k plane vortices with known quantities of circulations $\Gamma_k = 2\pi R_k v_\kappa$.

At the time of $t = m \cdot \Delta t$ the system for determining the unknown circulation of attached vortices and intensities of sources (runoffs) will have the form:

$$\begin{cases} -0,5q(x^p)+\sum\limits_{\substack{k=N+1,\\ k\neq p}}^{N+W} q(\xi^k)\int\limits_{\Delta S^k} F_2(x^p,\xi^k)dS(\xi^k)+\sum\limits_{k=1}^{N} G(x^p,\xi^k)\Gamma(\xi^k)+\Lambda= \\ =v_n(x^p)-2\pi\sum\limits_{k=1}^{M} R_k v_{ki} G(x^p,c_k)-\sum\limits_{\tau=1}^{m}\sum\limits_{l=1}^{L} G(x^p,\zeta^{l\tau})\gamma^{l\tau}, \quad \sum\limits_{k=1}^{N}\Gamma(\xi^k)+\sum\limits_{\tau=1}^{m}\sum\limits_{l=1}^{L}\gamma^{l\tau}=0, \end{cases}$$

where function of $F_2(x,\xi)=\dfrac{1}{2\pi}\dfrac{(x_1-\xi_1)n_1+(x_2-\xi_2)n_2}{(x_1-\xi_1)^2+(x_2-\xi_2)^2}$ expresses by itself an impact on the point $x(x_1,x_2)$ a single source located at the point $\xi(\xi_1,\xi_2)$ along the unit vector $\vec{n}=\{n_1,n_2\}$; $v_n(x^p)$ - speed in the direction of the external normal to the boundary of the region in the p-th control point at $p=1,2,\ldots,N$ orthe middle of the p-th segment at $p=N+1,N+2,\ldots,N+W$; Λ - regularizing variable of I. K.Lifanova; $\gamma^{l\tau}$ - circulation of free vortex descended from the l-th sharp edge at time $t = \tau\cdot\Delta t$; W - number of boundary elements with a simple layer; N - number of attached vortices.

The speed is determined from the expression:

$$v_n(x)=\sum_{k=N+1}^{N+W} q(\xi^k)\int\limits_{\Delta S^k} F_2(x,\xi^k)dS(\xi^k)+\sum_{k=1}^{N} G(x,\xi^k)\Gamma(\xi^k)+2\pi\sum_{k=1}^{M} R_k v_k G(x,c_k)+\sum_{\tau=1}^{m}\sum_{l=1}^{L} G(x^p,\zeta^{l\tau})\gamma^{l\tau}$$

The trajectory of the dust particle is constructed based on the integration of the equation of its movement:

$$\frac{1}{6}\rho_p\pi d_e^3 v_p'(t)=-\psi\left|\vec{v}_p-\vec{v}_a\right|\left(\vec{v}_p-\vec{v}_a\right)\rho_a\chi S_m/2+\frac{1}{6}\rho_p\pi d_e^3\vec{g},$$

where $\vec{v}_a$ – air speed; ρ_a – air density; $\vec{v}_p$ – particle velocity; ρ_p – density of the particle; d_e– equivalent diameter of the particles; $\vec{g}$ – acceleration of gravity; $S_m=\pi d_e^2/4$ – the square of middle section of the particle; χ– coefficient of dynamic form; ψ–the coefficient of air resistance, calculated by the formulas of Stokes, Klyachko, Adam.

With the help of developed set of numerical algorithms, computer program was identified patterns of behavior of dust aerosols, arising during overloads of granular materials in aspiration shelter of standard design, depending on the availability of non-stationary vortex structures in the flow domain.

A set of particles of different sizes came in area of shelter from supply opening. We can enter dispersed composition and concentration of dust and performed simulation of its movement until their complete precipitation or capturing. Total mass of particles and concentration in the aspirated air have been determined, that were caught in the extraction, equal to the ratio of this mass to the volume of air in which they were held. The particle disperse structure in the suction pipe was determined by counting particles of different fractions, captured by suction.

As an example, it was implemented modeling of movement of dust particles (Fig. 7) in an aspiration shelter of node overload clinker on conveyor. It was considered the movement of 30,000 dust particles with a density of 3050 kg/м^3 with dynamic coefficient shape of 1.8 (sharp-grained particles).

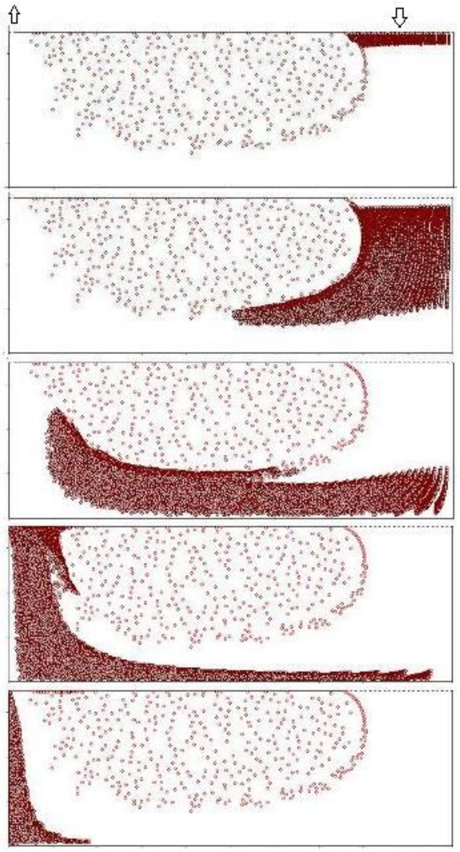

Figure7: Movement of dust cloud of 30,000 particles of various fractions in aspiration shelter node overload of clinker conveyor

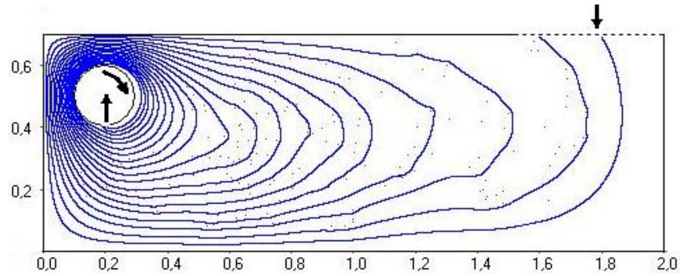

Figure 8: Swirledairfield

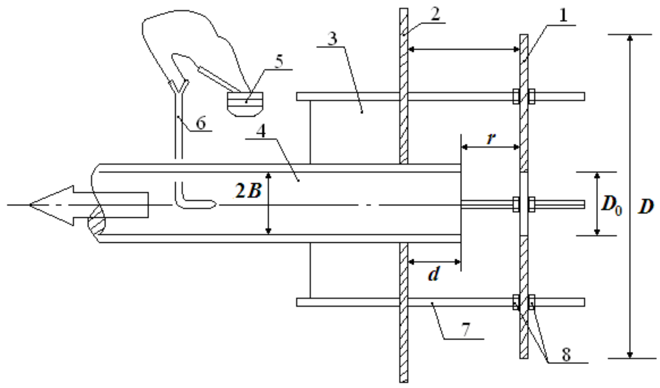

Figure 9: Scheme of experimental setup for determining resistance at the entrance of air into the screened round hole: 1 –screen with a central hole; 2 –shield; 3 –directing triangular prism; 4 –pipe; 5 –micromanometer with inclined tube; 6 –pneumometric tube of Pitot-Prandtl; 7 –steel rods-studs; 8 – screw-nuts for fixing screen

Replacement of exhaust hole on rotating cylinder-suction significantly changes the aerodynamics inside the shelter (fig.8).

Numerical experiments have shown that concentration of dust in intake air can be reduced from maximum permissible up to zero. It depends on speed of rotation of exhaust-cylinder. It is obvious that it should be the most removed from loading chute and conveyor belt. The direction of rotation should contribute to deposition of dust.

5 COMPARISON WITH THE EXPERIMENT

We have developed an experimental device, which is illustrated in fig.9, for study the flow separation at the entrance to the round aspiration channels. Comparison of calculated and obtained experimental values of coefficient of local resistance ζ (fig.10) demonstrates their satisfactory matching. The overestimation of calculated values of ζ, not more than 15%, and it is observed for small values of *r*.

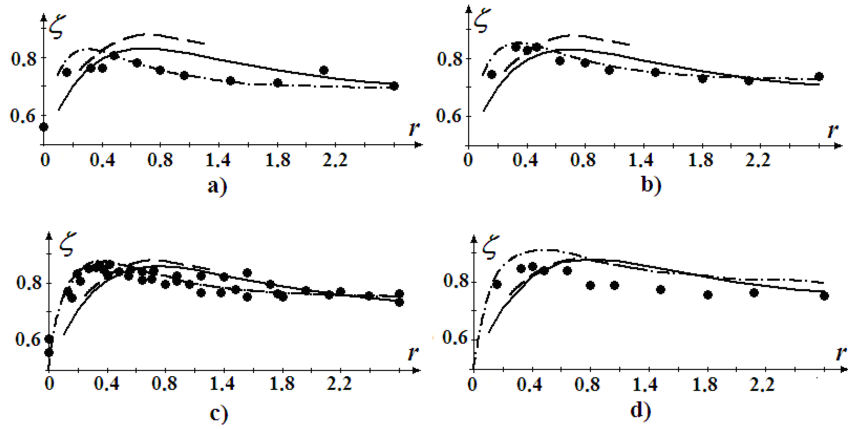

Figure 10: Comparison of calculated values of coefficient of local resistanceζ from a distance$r$ when $d_0 = 1.55$: a) d = 0.24; b) d = 0.48; c) d = 0.56; d) d = 1.2 (solid curve –calculations for a plane problem,dash-dotted curve –for axisymmetric one, dashed curve –method of N. E. Zhukovsky, circles – an experiment)

Value of ζ is the closest to experimental data, that has been found for the problem in axisymmetric formulation, which is naturally, because full-scale experiment was placed in the same formulation. Calculated and experimental extrema of coefficient of local resistance (fig. 10) are the same, which enables to conclude about the reliability of developed method of mathematical modeling and research results as for the plane problem (i.e. of separated flow at the inlet of rectangular aspiration aperture with an aspect ratio of not less than 1 to 10), as axisymmetric one.

6 CONCLUSIONS

1. For improving the efficiency of dedusting ventilation systems is necessary a package of measures for reducing:volume of ejected air, air consumption, entering through leaks and technological openings of aspirating shelters, dust discharge in aspiration network by using of properties of vortex, separate and recirculating flows.

2. A method of reducing the volume of ejected air during overloads of granular materials was developed. The effectiveness of creating a load device is analytically proved in the form of a vertical perforated pipe with a bypass chamber when loading granular materials. The process of recirculation of air in the system "boot perforated pipe - bypass camera" was investigated, determined the influence of their geometric and aerodynamic characteristics on volume of ejected air and performance of the aspiration system.

By calculation, it was shown that the performance of dedusting ventilation system might be reduced by at least 40% due to closed circulation of dusty flows without additional boosters of traction.

3. A non-contact method of reducing volume of air was developed, entering through leaks and technological openings of aspiration shelters for localization dust emissions, based on the effect of separation of airflow from sharp edges of mechanical screens.

We proposed and patented a method of controlling flow separation at the inlet to aspiration channels. We have developed mathematical models of separated flows at the entrance of round and slotted aspiration channels in the range of which can be arranged end-thin profiles.

We investigated different regimes of flow profiles, determined their geometrical dimensions and conditions, contributing to high aerodynamic resistance of aspiration channels.

We developed recommendations to reduce the volume of air entering through leaks of aspiration shelters. Calculated data experimentally are shown that airflow is possible to reduce by at least 20%, thereby increasing the efficiency of the aspiration system by reducing energy consumption.

4. A method for reducing dust discharge from aspiration shelters was developed, based on the use of swirling air currents, initiated by rotating exhaust-cylinders.

We proposed program-algorithmic support for research of processes dust discharge in aspiration network from localizing dust emission devices and investigated the dynamics of dust aerosols in aspirated flows, containing mechanical screens and rotating cylinders.

Based on computational experiments, we have investigated processes: influence of rotation cylindrical detail on airflow in the spectrum of absorption LVE open type and dynamics of dust particles in this flow; capturing of dust particles of different shape and density at changing ratio velocity of adsorption to speed of rotation of cylindrical part.

We identified regularities of the influence of thin impermeable screens, rotating exhausts-cylinders and cylinders on entrainment of dust in the aspiration network. It has been shown, that a significant reduction in dust discharge in aspiration network up to complete precipitation of dust on the conveyor belt can be achieved by using a rotating exhaust-cylinder.

5. Performed experimental research on installation of aspiration shelter with slotted leakages and stands for study of flow separation in the inlet to the intake of circular and slit-like shape channels, allowed to confirm the data obtained by analytical and computational experiment. We established qualitative and quantitative concurrence of the velocity field in the spectra of absorption and regularities of changes of the coefficient of local resistance to the entrance of the intake channels.

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