Middle-East Journal of Scientific Research 17 (8): 1181-1186, 2013
ISSN 1990-9233
© IDOSI Publications, 2013
DOI: 10.5829/idosi.mejsr.2013.17.08.7094

About Dynamics of Clinker Dust in an Aspiration Hideout

Olga Alerksandrovna Averkova, Valentina Ivanovna Belyaeva,
Konstantin Ivanovich Logachev, Valery Anatolievich Uvarov and Arsen Enverovich Canar

Belgorod State Technological University named after V.G.Shoukhov, Russia,
Russia, 308012, Kostykova str., 46

Abstract: We have carried out research on simulation of the movement of clinker dust an aspiration hideout. Aerodynamic field inside the hideout is constructed based on discrete vortex where the movement was simulated of polyfractional dust cloud on the basis of integration of the equations of motion for each dust particle. We have been studied the influence on the dispersed composition and concentration of aspirating dust aerosols: the amount of dust particles entering into the cover, geometrical dimensions and velocities in the supply and exhaust ducts.

Key words: Methods of discrete vortices · Dusty aerosol · Disperse composition · Concentration

INTRODUCTION

A large amount of dust is produced and comes into the air when burning of cement clinker, which leads to a significant deterioration of working conditions. Dust, having similarity in composition to the feedstock is extracted from the cold end of the furnace. In the hot end of the furnace, on a refrigerator and especially in the gallery of clinker conveyors it frequently omitted clinker dust. Dust is black, has a high temperature, very abrasive. According to the design approach for dedusting unit of overload clinker conveyor, there is an aspiration cover and it designed to delete of aspiration air together with technological excess air out of the fridge, which is extremely inefficient, as it was mentioned in [1]. Therefore it is necessary to divide aspirating flux and excess air coming out of the fridge or by setting the bypass gas duct and additional technological gate or a separate device node of aspiration system [1], which is performed at a number of plants. But, unfortunately, the aspiration cover and as a whole system of the node aspiration is often executed "by eye", i.e. without appropriate calculations and rationale parameters.

For scientifically based choice of dedusting devices is necessary information concerning concentration and dispersed composition of dust in an aspirating air, which may be obtained by construction of the trajectories of single dust particle [2,3], multifractional complex [4,5] and the method of singular integral equations [2-10].

The purpose of this work is modeling of dynamics of the dust particles in an aspiration hideout node overload clinker conveyor for calculating the concentration and disperses of dust flux in the aspirating air. Cover scheme is shown in Figure 1. Have been used the calculation of the composition of the dust, given in [11].

Part and Parcel: Let there be given flat multiply connected area of an ideal incompressible fluid. On rigid wall is given the condition of impermeability - a normal component of the velocity is equal to zero. In suction apertures and air intake velocities along the direction of the exterior normal are known, while volume of air entering the room is equals to volume of air being removed from it. The border area is discretized by control points and attached vortices. At the test points the boundary conditions are executed for a normal component of velocity. Discrete step - distance between adjacent bound vortex or control points is about approximately the same and equals to h. Attached vortices are located on the fractures of boundary. In these confined areas of the bound vortices and calculated points are the same. At the

---

Corresponding Author: Olga Alerksandrovna Averkova, Belgorod State Technological University named after V.G.Shoukhov, Russia, Russia, 308012, Kostykova str., 46.

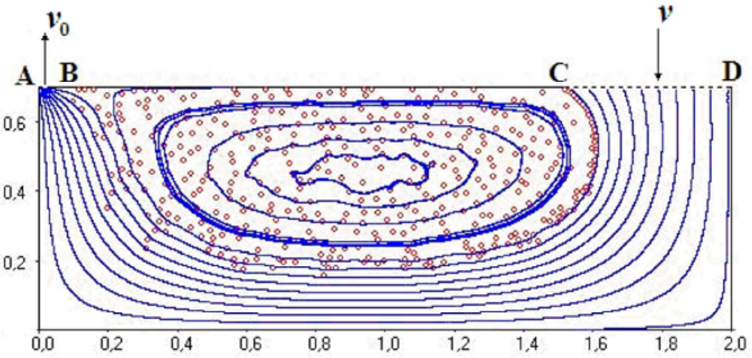

Fig. 1. The flow lines and vortex flow structure in an aspiration cover

initial moment of time the air is at rest on the whole space. At the moment of time $t = +0$ all supply and exhaust ports are "switching on".

At the moment $t = m{\cdot}\Delta t$ the system to determine the unknown circulations of bound vortices will have the form:

$$\begin{cases} \sum_{k=1}^{n} G^{pk} W^k + \Lambda = v^p - \sum_{\tau=1}^{m} G^{p\tau} \gamma^\tau, \\ \sum_{k=1}^{n} W^k + \sum_{\tau=1}^{m} \gamma^\tau = 0, \end{cases} \tag{1}$$

where p, 1,2,...,n, n W^k - circulation of bound vortices; n - number; v^p- velocity in the direction of the normal to external boundary of region of p-th control point; Λ- - a regularizing variable. Function $G^{pk}(G^{p\tau})$, reflecting the impact on p-th control point with coordinates (x_1, x_2) of single vortex, located in the k-th point (for - point of location of a free vortex, he came down with a sharp edge at the time τ [tau]) with coordinates (ξ_1, ξ_2) along the direction of unit vector $\vec{n} = \{n_1, n_2\}$ which is calculated by the formula:

$$G^{pk} = \frac{n_2(x_1 - \xi_1) - n_1(x_2 - \xi_2)}{2\mathrm{p} \cdot [(x_1 - \xi_1)^2 + (x_2 - \xi_2)^2]} \tag{2}$$

Solving a system of linear algebraic equations (1) by the Gauss method with a choice of main elements and identifying unknown circulation, flow rate can be determined at any point of domain along of any given a single direction $\vec{n} = \{n_1, n_2\}$ by the formula:

$$v_n(x) = \sum_{k=1}^{n} W^k G^{xk} + \sum_{\tau=1}^{m} G^{x\tau} \gamma^\tau, \tag{3}$$

where functions G^{xk}, $G^{x\tau}$ calculated using the same formula (2), but instead of (x_1, x_2) substituted the coordinates of interest to us of x. Separation of free vortices was performed from a sharp edged of inlet openings. In this case free vortex, which has descended at the moment [tau], has a circulation equal to circulation of the bound vortex at the point of failure, found in a previous moment of time. Henceforward available vortices move at a constant circulation along the trajectories of fluid particles. If the vortex at a certain moment of time was approaching to the rigid wall at a distance of less than h / 2, it moves away from it along the normal that distance to the boundary of the flux becomes equal to h / 2. If the same happens with vortex and supply port, the vortex disappears. Separation of free vortices was performed, when the distance between the vortex and the next one was equal to h. Modeling of dynamics of dust particles were constructed on the basis of integration by the method of Runge-Kutta of the equation:

$$\rho_1 \frac{\mathrm{p} d_e^3}{6} \cdot \frac{d\vec{v}_1}{dt} = -\psi \cdot \frac{|\vec{v}_1 - \vec{v}|(\vec{v}_1 - \vec{v})}{2} \rho x S_m + \rho_1 \frac{\pi d_e^3}{6} \vec{g} \tag{4}$$

where ρ_1, ρ [ro]- are densities of dust particles and medium, respectively; $\vec{v}$ - velocity vector of particle; $\vec{v}$ - air speed, which is calculated by the formula (3); d_e - equivalent diameter; $S_m = \mathrm{p} d_e^2/4$ - square of a middle section; χ - coefficient of dynamic form of particle; $\vec{g}$ - acceleration of gravity falling; Ψ - coefficient of environmental resistance, calculated by the formula:

$$\psi = \begin{cases} \frac{24}{\mathrm{Re}} \quad \text{if} \quad \mathrm{Re} < 1 \text{ (Stokes formula)} \\ 24(1 + 1/6 \cdot \mathrm{Re}^{2/3})/\mathrm{Re} \quad \text{if} \quad 1 \le \mathrm{Re} < 10^3 \text{(formula of Klyachko)} \\ \frac{24}{\mathrm{Re} \cdot (1 + 0{,}065\mathrm{Re}^{2/3})^{1{,}5}} \quad \text{if} \quad \mathrm{Re} \ge 10^3 \text{(formula of Adamova)} \end{cases} \tag{5}$$

In a collision of particles with a solid wall tangential $v_{2\tau}$ and normal v_{2n} speeds calculated by the formulas:

$$v_{2n} = -k \cdot v_{0n}, \quad v_{2\tau} = v_{0\tau} + \eta \cdot f \cdot (1+k) \cdot v_{0n}, \qquad (6)$$

where $\eta = \min\left\{ -\frac{2v_{0\tau}}{7f(1+k)v_{0n}}, 1 \right\}$

k - Coefficient of restitution on impact. Ventilation hole were divided into k equal parts and each moment of time k generated random numbers (diameters). At any given time to the cover have been received k dust particles. Mass of dust coming into the considered area during Δt:

$$C_{\Delta t} = km_{av} = Cv_n a \Delta t$$

where average mass of dust particle:

$$m_{av} = \sum_{i=1}^{n} \int_{d_{ih}}^{d_{ib}} \frac{\pi x^3 l_i}{6(d_{iv} - d_{in})} \rho dx = \frac{\pi\rho}{24} \sum_{i=1}^{n} l_i \left(d_{iv} + d_{in}\right)\left(d_{iv}^2 + d_{in}^2\right)$$

Interval of time:

$$\Delta t = \frac{\pi k \rho}{24 C v_n a} \sum_{i=1}^{n} l_i \left(d_{iv} + d_{in}\right)\left(d_{iv}^2 + d_{in}^2\right)$$

For calculating the concentration of dust in the exhaust hole was chosen number n of times incoming in the area of k dust particles. Modeling of motion of particles $n{\cdot}k$ was carried out as long as they do not settle, or will not be caught by suction. m_i was calculated during the simulation - is total mass of particles that are caught in the suction.

Herewith output concentration is: $C_0 = \frac{m_0}{V}$, where $V = v_n{\cdot}a{\cdot}\Delta t{\cdot}n$.

During simulation, diameters of dust particles were remembered, captured by suction and determined the percentage of composition of the dust fractions in the exhaust air. Actually received dust concentration in the supply air was different from the specified due to the discrete model. For determining the real input of C_r concentration is calculated m_r - total weight $n{\cdot}k$ of particles received by the cover from the supply air inlet and respectively C_r =- m_r/V. With an increase $n{\cdot}k$ concentration C_r of particles close to C with any desired accuracy.

CONCLUSION

The dynamics of polyfractional dust cloud consisting of 30,000 dust particles with initial dispersed composition of which is specified in Table 1, is given in Figure 2. Let us note that initially we used data for calculating the aerodynamics inside the cover (Fig. 1). After when free vortices completely filled computational area, the vortex structure of the flow in process of time is not significantly changed, free vortices were staying and i.e. air flux has become stationary. Then dust particles began arriving from the supply inlet to the cover. As you can see (Fig. 2), dust particles encircle area of the central vortex.

It is obvious that the amount of dust particles that are run from the supply ports in the suction cover may depend on required parameters of the aerosol stream (dispersed composition and concentration). Therefore, we have been conducted methodological studies according to the amount of dust on required parameters.

Table 1: Variation the dispersed composition and concentration of dust cloud according to the number of particles of which it consists

Disperse composition of dust in the air intake			
5-6 microns	6-10 microns	10-20 microns	20-40 microns
0,1	0,3	0,25	0,35
Disperse composition of dust in the exhaust air outlet In simulation of dust particles 60 (N = 60) The ratio of the concentrations for supply air intake and exhaust outlet: C_i/C_e = 1,492			
0,097	0,194	0,290	0,419
N = 300, C_i/C_e = 1,552			
0,081	0,256	0,219	0,444
N = 3000, C_i/C_e = 1,591			
0,082	0,278	0,225	0,415
N = 9000, C_i/C_e = 1,595			
0,080	0,270	0,234	0,416
N = 30000, C_i/C_e = 1,572			
0,082	0,259	0,230	0,428
N = 60000, C_i/C_e = 1,575			
0,083	0,260	0,233	0,424

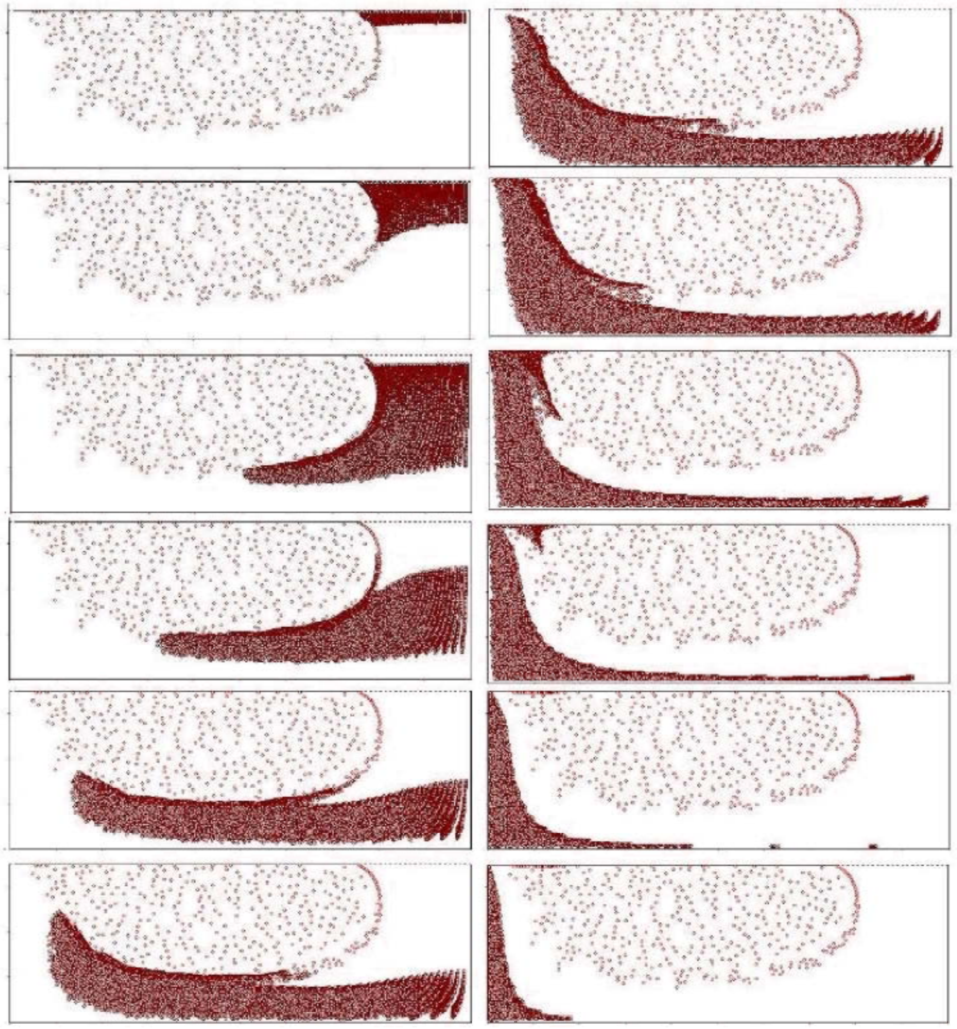

Fig. 2. The dynamics of dust polyfunctional cloud consisting of 30 000 dust particles (downward over time)

Initial data for calculation: density of the particles ρ = 3050 кг/м^3, coefficient of dynamic particle shape x = 1,8, air velocity in the supply hole v = 1m/s, in the exhaust hole - v_0 = 15,3 m/s, - width of inlet hole is AB = 0.0314 m; CD = 0,48 m.

The time step to calculate the motion of dust particles is 0.0002961 seconds, the number of free vortices 424. At any time nearly 30 dust particles of different sizes arrive in the area of cover.

As you can see from Table 1, dispersed composition and concentration ratio of supply air intake and exhaust outlet are stabilizing with increasing amounts of dust particles. It is sufficient to investigate the flight of 3000 dust particles. It is of interest to investigate how changing parameters of aerosol intake flux when geometric and kinematic characteristics of cover are vary.

With an increase velocity inside the cover there is a small amount of dust particles involved in the circulation of an air. They are not capturing or precipitating in suction. Change dispersed composition and concentration is not significant (Table 2).

Area of the vortex is growing in size, with increasing the width of exhaust port and reducing the width of central air inlet,. The dust cloud is moving between the boundaries of cover and central vortex. Therefore the fraction of precipitating particles increases. If AB = 0.4 m CD = 0.0314 m dust completely settles to the bottom cover. Dispersed composition and concentration of dust aerosols are practically unchanged for fixed values of inlet and outlet ports with decreasing altitude of covers. Proportion of fraction particles for 20-40 microns decreases insignificantly.

Table 2: Variation of disperse composition and concentration of dust cloud of 3000 particles depending on changing flow rate and geometry of cover

Disperse composition of dust in the air intake			
5-6 microns	6-10 microns	10-20 microns	20-40 microns
0,1	0,3	0,25	0,35
Disperse composition of dust in the air intake Speed in the supply air inlet 1.5v; the time step for the simulation of particle dynamics Δt_p = 0,0001974s; step in time for air Δt_a = 0,0065c; = 1,407			
0,075	0,257	0,230	0,438
2v; Δt_p = 0,0001481s; Δt_p = 0,005c; C_i/C_e = 1,295			
0,075	0,244	0,228	0,453
2,5v; Δt_p = 0,0001184s; Δt_p = 0,004c; C_i/C_e = 1,492			
0,076	0,264	0,247	0,413
3v; Δt_p = 0,0001974c; Δt_a = 0,003s; C_i/C_e =1,435; C_i 0,000002			
0,075	0,256	0,256	0,413
Changing the size of inlet and outlet ports for v = 1			
AB =0,1; CD=0,3314; C_i/C_e =1,542; Δt_p = 0,0002887s; Δt_a = 0,01; C_i 0,000002			
0,102	0,318	0,271	0,310
AB =0,2; CD=0,2314; Δt_p = 0,0002515s; Δt_a = 0,01c; C_i/C_e = 2.05; C_i 0,00001			
0,111	0,366	0,279	0,243
AB =0,3; CD=0,1314; Δt_p = 0,0002294s; Δt_p = 0,01c; C_i/C_e = 6,42; C_i = 0,00002			
0,144	0,433	0,311	0,112
AB =0,4; CD=0,0314; Δt_p = 0,0003266s, Δt_a = 0,01s, C_i 0,00008			
0	0	0	0
Variation the height h of the cover for AB =0,0314; CD=0,48; v = 1			
Δt_p = 0,0002961s; Δt_a = 0,01s; C_i = 0,00004; h = 0,6; C_i/C_e =1,6			
0,083	0,269	0,229	0,419
Δt_p = 0,0002961s, Δt_A = 0,01s, C_i 0,00004; h = 0,5; C_i/C_e =1,59			
0,082	0,271	0,231	0,416
Δt_p = 0,0002961s, Δt_A = 0,01s, C_i 0,00004; h = 0,4; C_i/C_e =1,6			
0,084	0,280	0,232	0,404

CONCLUSIONS

We have developed a mathematical model and its computer realization of the dynamics polyfractional dust cloud inside the aspiration cover. Conducted methodological research has shown that for determining dispersed composition and concentration of dust in the air is enough to study the movement of 3000 dust particles. We determined dispersed structure and concentration of dust aerosols at different geometric dimensions and speed regimes of cover. The height of cover and an increase the speed in the supply air inlet has no effect on structure of the aerosol flow in the suction branch pipe. Reduction in the concentration of dust aerosols and dispersed composition of dust in the direction of fine fractions is observed with a decrease in supply inlet and an increase in exhaust outlet that is connected with growth of the central vortex in an aspiration cover. Obtained results can be used for designing efficient aspiration covers and scientifically-based choice of dedusting devices.

ACKNOWLEDGMENTS

The researchers are being supported by the Council for Grants of the President of the Russian Federation (projects NSH-588.2012.8), RFBR (project number 12-08-97500-p_center_a) and Strategic Development Plan of BSTU named after. V. G. Shukhov (project number # A-10/12).

REFERENCES

1. Klassen, V.K., 2006. Improving working conditions in the areas of cooling and transporting the cement clinker [Text] / V.K. Klassen, V.I. Belyaev / / Life Safety. 3: 31-33.
2. Logachev, K.I. and A.I. Puzanok, 2004. Computational Modeling of Air-and-coal Flows next to Suction Holes. ECCOMAS 2004 - European Congress on Computational Methods in Applied Sciences and Engineering, e-Book Full Papers, pp: 19.

3. Anzheurov, N.M. and O.A. Averkova, 2008. Software for computing dusty air flows in ventilation systems. Refractories and Industrial Ceramics, 49(3): 229-234.
4. Logachev, KI., A.I. Puzanok and V.U. Zorya, 2006. Numerical study of aerosol dust behaviour in aspiration bunker. ECCOMAS CFD 2006 - European Conference on Computational Fluid Dynamics, e-Book Full Papers, pp: 11.
5. Averkova, O.A., V. Yu. Zorya and K.I. Logachev, 2007. Behavior of aerosol particles in suction bunker of standard design. Chemical and Petroleum Engineering, 43(11): 686-690.
6. Logachev, I.N., K.I. Logachev and O.D. Neikov, 1995. Localization of dust generation during the pressing of powders. Powder Metallurgy and Metal Ceramics, 34(3-4): 203-206.
7. Logachev, K.I. and N.M. Anzheurov, 2003. Flow Analysis of Slit-Type Suction Ports Shielded with Slender Visors. Refractories and Industrial Ceramics, 44(3): 145-148.
8. Averkova, O.A., V. Yu. Zorya, I.N. Logachev and K.I. Logachev, 2010. Numerical simulation of air currents at the inlet to slot leaks of ventilation shelters. Refractories and Industrial Ceramics, 51(3): 177-182.
9. Averkova, O., A. Logachev, I. Logachev and K. Logachev, 2012. Modeling of gas separated flows at inlet of suction channels on the basis of stationary discrete vortices. ECCOMAS 2012 - European Congress on Computational Methods in Applied Sciences and Engineering, e-Book Full Papers, pp: 20.
10. Logachev, K.I. and V. N. Posokhin, 2004. Calculation of a Flow in the Vicinity of a Round Suction Pipe. Proceedings of the higher educational institutions. Aircraft Engineering, 1: 29-32.
11. Bans, F.G., 1979. Dust removal and purification of gases in the building materials industry [Text] / FG Bans, A.D. Malgin. - Moscow: Publishing House building products, pp: 351.