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E nvironmental impacts and human health effects of c arbon-containing dust pollution

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Abstract

Statement of the Problem: Negative changes in the Earth's atmosphere are mainly associated with changes in the concentration of minor components of atmospheric air. Air pollution is a major concern of the new civilized world, which has a serious impact on human health and also ruthlessly distresses the natural bio-network and ecosystems.

Coal is an important source of energy around the world—approximately 41% of the world's electricity is generated from outdoor coal combustion. Coal mining enterprises are powerful sources of pollutant emissions into the atmosphere. As a result of the operation of coal and coal refineries, significant amounts of carbon-containing dust enter the atmosphere. Researchers estimate that the air environment of the underground mine's surface complex is filled with exhaust ventilation air every minute, approximately 200,000 m3 with a dust concentration of approximately (5-7) mg/m3, which equals 1.5 tons of dust per day. This is where the possibility of long-range transport of pollutants is most often realized. Coarse dust discharged through the ventilation systems of mines intensively settles within the sanitary protection zones of mines. Fine dust is carried long distances by the wind beyond their limits, polluting the environment up to 3500 m from the coal mine. Carbon dust emissions into the atmosphere are almost always a major part of transboundary environmental pollution. The mine wastes are also an environmental threat.

Keywords: Air pollution, carbon-containing dust, environment, cardiovascular diseases, respiratory tract diseases, human health, dust prevention and control, dust reduction

Introduction

Coal dust consists of fine coal powder, which is formed during drilling, blasting, crushing, screening, crumbling, taking into account its fragile nature, mechanical and flowing transportation of coal and coal products. Air quality has the potential to be impacted by the coal dust emissions from coal mining activities, the transportation of coal from mines to designated ports and the loading operations at the port's export terminals.

Carbon-containing dust degrades air quality and ruthlessly distresses the natural bio-network and ecosystems and also has a serious impact on human health. Carbon-containing dust is a factor in increasing mortality from heart and respiratory diseases, decrease in pulmonary function in children and adults with the development of obstructive respiratory disease, and the increase in the frequency of symptoms. Health effects are associated with both short-term and long-term impact of dust particles.

The environmental risk of carbon-containing dust emissions necessitates measures to dust off mine ventilation streams and reduce dust emissions into the atmosphere. To reduce the environmental hazard of coal mine dusts (carbon-containing dust), it is recommended that they are localized using dispersed water.

Therefore, the disclosure of the peculiarities of the influence of factors on the effectiveness of the processes of interaction of dispersed water jets with carbon-containing dust in environmental pollution prevention technologies is an urgent problem, the solution of which is a prerequisite for scientific and technological progress in the field of environmental safety.

Methodology & Theoretical Orientation

theoretical and laboratory studies, experimental measurements, calculation for determining the probability of dust formation, mathematical planning (a second-degree D-optimal plan was used for construction the mathematical model), graph-analytical and mathematical planning methods.

Discussion

When studying the dynamics of dust and dispersed water flows, we will consider dust particles and droplets of liquid as separate objects moving in the ventilation stream.

Let's choose the coordinate axes (Figure 1): x - is the longitudinal coordinate along the movement of the ventilation stream, starting from the place of creation of the dust stream (location of tne combine) or from the location of the water flare, y - the transverse coordinate from bottom to top starting at the beginning near the production soil.

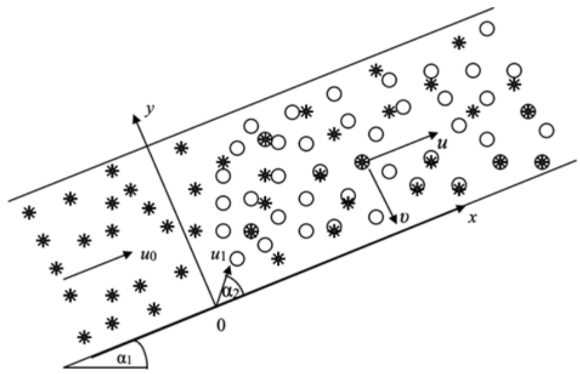

Figure 1: Scheme of motion and mechanical interaction of the sprayed liquid (circles) with carbon-containing dust (asterisks) in an incline working.

$$m_i \frac{d\vec{U}}{d} = m_i \vec{g} - \vec{W} \quad (1)$$

$\vec{U}$ – where mi - mass i – i-dust or liquid droplets, kg;

t – vector of relative velocity of a particle or droplet, m/s;

$\vec{g}$ – the time from the start of the flight of a particle or drop, p;

acceleration of gravity, m/s2;

$\vec{W}$ – force of resistance of movement of particles or drops, N.

In the projections on the axis of coordinates of the equation of motion of the particles of dust and liquid droplets are represented in the form

$$\frac{du}{dt} = -g\sin\alpha_1 - \frac{6}{\rho\pi d_i^3}W_x; \quad \frac{d\upsilon}{dt} = -g\cos\alpha_1 - \frac{6}{\rho\pi d_i^3}W_y \quad (2)$$

where u, υ – the projections of the velocity vector on the coordinate axis, m/s;

g- acceleration of gravity (assumed equal to 9,81m/s2);

α1 – working angle to the horizon, degrees;

ρ – the density of the particle or droplet (usually assumed equal to 1300 kg/m3 – for coal dust particles and equal 1000 kg/м3 – for wate);

d_i – diameter i – particles or drops, m;

W_x, W_y - projections of the vector of the force of motion resistance, N.

It is believed that the forces of resistance of movement of the body in the air are proportional to the kinetic energy of the relative motion and the area of the midsection of the body [3]. In vector form, this dependency can be represented as

$$\vec{W} = c_n \frac{\pi d_i^2}{4} \frac{\rho_0 |U| \vec{U}}{2}, \quad (3)$$

where c_n – a drag coefficient that depends on the velocity and diameter of the particles or droplets;

ρ0 – air density, kg/m3.

For relative motion in the air flow, the formula (3) in the projections on the coordinate axis, taking into account the sign of the direction of motion (on or against the flow) will take the form:

$$W_x = c_x \frac{\pi d_i^2}{4} \frac{\rho_0 |u \pm u_0| (u \pm u_0)}{2}; \quad W_y = c_y \frac{\pi d_i^2}{4} \frac{\rho_0 |\upsilon| \upsilon}{2} \quad (4)$$

where cx, cy – - projection of the drag coefficient on the coordinate axis;

u_0 ventilation flow velocity, m/s.

Substituting expression (4) into the system of equations (2), we obtain

$$\frac{du}{dt} = -g\sin\alpha - \frac{3\rho_0 c_x}{4\rho d_i}|u \pm u_0|(u \pm u_0); \quad \frac{d\upsilon}{dt} = -g\cos\alpha - \frac{3\rho_0 c_x}{4\rho d_i}|\upsilon|\upsilon \quad (5)$$

Add to the equations of system (5) the initial conditions on the assumption that particles or droplets at the site of their formation acquire at an angle of inclination to the ground of production a velocity that does not coincide with the velocity of air:

$$1) u(0) = u_1 \cos\alpha_2; \quad 2) \upsilon(0) = u_1 \sin\alpha_2 \quad (6)$$

where u_1 – initial velocity of dust particles or liquid droplets, m/s;

α2 – the angle of inclination of the initial velocity of movement of particles or droplets to the soil of production, degrees.

Numerous experimental studies [3] show that the coefficient of resistance of a spherical shape obeys the two-term law and can be assumed to be sufficiently

$$c_n = 0,5 + \frac{24\nu}{|U| d_i} \quad (7)$$

In Fig. 2 shows the calculated curve (7) and the experimental data [3] depending on the coefficient of resistance of motion of bodies of spherical shape from the local Reynolds number during the transition from laminar mode to turbulent.

The local Reynolds number [1] is meant to the ratio of the dynamic forces of a particle of dust or a drop of liquid to the forces of air viscosity

$$\mathrm{Re}_x = \frac{|u - u_0| d_i}{\nu}; \quad \mathrm{Re}_y = \frac{|\upsilon| d_i}{\nu} \quad (8)$$

The maximum error of the calculated data, as shown by the comparison with the experimental data, does not exceed 10 - 20%. An analysis of the possible values of the local Reynolds number implies that it can vary widely. Therefore, taking the minimum diameter d_{min} = 1 μm and the minimum velocity u_{min} = 0.1 m / s, we obtain Re = 0.007. And taking the maximum diameter d_{max} = 1000 μm and the maximum velocity u_{max} = 100 m/s [2], we get Re = 6667.

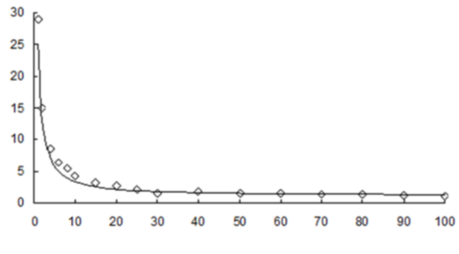

Figure 2: Dependence of the coefficient of resistance of the motion of globular bodies on the local Reynolds number during the transition from laminar to turbulent mode

So, the movement of dust particles and liquid droplets will shift from turbulent to laminar, capturing the transition mode. Therefore, considering only laminar mode using the Stokes law, as in [4, 5], can lead to gross errors.

Solving second order algebraic equations (6, 7), we find the limit value of velocity projections

$$u_2 = \mp u_0 - \frac{2g\sin\alpha_1}{a_1 + \sqrt{a_1^2 + 4a_2 g\sin\alpha_1}}; \qquad (9)$$
$$\upsilon_2 = \frac{-2g\cos\alpha_1}{a_1 + \sqrt{a_1^2 + 4a_2 g\cos\alpha_1}}$$

From formula (9) it follows that at a2 = 0 the mode of motion is laminar and at a1 = 0 - turbulent.

Figure 3 presents the dependence of the maximum vertical velocity on the diameter of the particles or droplets set by the second formula (9). From Fig. 3 turns out that using Stokes' law when assessing vertical velocity is possible only with a diameter particles or droplets less than 200 microns.

Yes, it's hard to believe that a 0.5 mm diameter drop was moving at a speed of 7 m/s. Given the turbulence of the flow, its velocity will be according to Fig. 3 only 2.5 m/s.

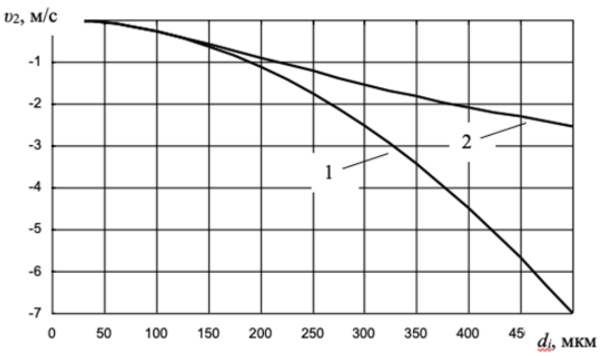

Figure 3: Dependence of the maximum vertical velocity of a particle or droplet on its diameter during laminar (curve 1) and mixed modes (curve 2)

Moreover, it is impossible to use the Stokes law for longitudinal velocity in the active zone of the nozzle plume, where the local Reynolds numbers, as already noted, can be several thousand.

Findings

The mechanism of sedimentation of suspended carbon-containing dust on the working soil due to the action of gravitational and electrostatic forces has been clarified. It consists in the fact that as a result of the natural or forced charge of the dust cloud, its particles are attracted to the droplets of liquid, creating new nuclei, which, falling into the sphere of influence of electrostatic forces are deposited more effectively due to the fact that their mass is equal to the total mass of droplets liquid and particles of dust. As a result of theoretical and experimental studies using existing formulas was developed a mathematical model of the dynamics of the interaction of dust and dispersed water flows in gravitational and electrostatic fields.

Conclusion & Significance

Air pollutions have major impacts on human health, triggering, and inducing many diseases leading to high morbidities and mortalities. Atmospheric air protection is one of the most pressing problems in today's technological society, as scientific and technological progress and expansion of production is associated with an increase in negative anthropogenic impacts on the atmosphere. The paper presents a new solution to the current scientific problem of reducing carbon-containing dust content based on the disclosure of the laws of the aerodynamic interaction of dust and water flows in gravitational and electrostatic fields.

Based on the known theoretical and experimental data on the interaction of dispersed liquid with air-suspended dust, the mechanism for capturing suspended coal dust by fluid droplets in the ventilation stream has been clarified: dust particles do not have to be wetted and immersed in liquid droplets. This may not be in the case of natural and forced charge of a dust and dispersed water flows. Having fallen into the sphere of influence of electrostatic forces, particles rush to drops until they fall on the soil of a mine working, before they have time to coagulate. After particles of carbon-containing dust get onto the wet soil, the de-dusting effect of the ventilation flow will be achieved.

It has been proved that the movement of dust particles and droplets of fluid will pass from turbulent mode to laminar, capturing also the transition mode. Therefore, considering only laminar mode using Stokes law, as in the works of predecessors, can lead to gross errors. Studies have shown that using the Stokes law when estimating the vertical velocity of motion is only possible with diameters of particles or droplets of less than 200 microns. Moreover, its not allowed to use the Stokes law for the longitudinal velocity in the active zone of the nozzle plume, where local Reynolds numbers can reach several thousand.

Technologies to reduce air pollution at the source of carbon-containing dust formation should be used in all new industrial development. The results obtained reveal the mechanism of interaction of the sprayed liquid with coal dust and can be used in the development of new effective means of controlling the carbon-containing dust. The principles and practices of sustainable development, coupled with local research, will help contain or eliminate health and environmental risks resulting from air pollution by carbon-containing dust.

Biography:

Gorobei Maryna Serhiivna was a Master of Science, Senior Researcher at Scientific Park Chornobyl State Institution State Environmental Academy of Postgraduate Education and Management, Ukraine