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Numerical simulation of the dynamics of an electrically charged multifractional aerosol moving in a channel under the action of the Coulomb force and aerodynamic forces

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Abstract. This work focuses on mathematical modeling of the dynamics of an electrically charged aerosol in a channel. In particular, the study models the operation of an electric filter for dispersed media. To optimize technologies for electrical filtration of dispersed media, it is necessary to understand the regularities of the dynamics of charged dispersed particles in an electric field. The mathematical model is implemented as a computer program. The program code is a finite-difference numerical algorithm for solving the equations of a mathematical model. The simulated medium consists of two components: the first component is a viscous compressible heat-conducting gas, the dynamics of which is described using the system of Navier-Stokes equations; the second component is electrically charged particles. The mathematical model took into account the intercomponent exchange of momentum and heat. The disperse component of the aerosol was described taking into account the multifractional composition. Each fraction has its own particle size, density and heat capacity of the material. It was assumed in the work that an electric potential was applied to the channel walls: a negative potential was applied to the lower wall, while a positive potential was applied to the upper wall of the channel. Calculations of the motion of a multi-fraction electrically charged gas suspension in a channel are carried out. Two cases were considered. Case 1: all fractions of the dispersed aerosol component have the same physical density of the material and different particle sizes. Case 2: the particles have the same size and differ in the density of the material. It was found that with the same density of the material, the vertical velocity of the particle and the intensity of the deposition process are greater with increasing particle size. It was also found that with the same particle size, particles with a higher density of the material are more intensively deposited. The revealed regularities can be used in optimizing the technologies of electrical filtration of dispersed media.

Keywords: numerical simulation, aerosols, polydisperse gas suspension, electrically charged media

Introduction

One of the types of irreversible processes that often occur in nature and technology is hydrodynamic processes. Hydrodynamic processes are the processes accompanied by the movement of continuous media — liquids, gases, plasma. The movement of inhomogeneous media is often found in nature and industrial applications (Altunin et al. 2012; Bastykova et al. 2021; Chekalov et al. 2021; Fedorov et al. 2015;

Ignatov 2020; Kolotinskii et al. 2021; Kutushev 2003; Nigmatullin 1978; Sinkevich 2016; Tada et al. 2016; Tukinakov 2019; Tukmakov 2022a; 2022b; 2023). A special case of inhomogeneous media is heterogeneous media, i. e., mixtures of the components which have different states of aggregation (Fedorov et al. 2015; Kutushev 2003; Nigmatullin 1978). In some cases, it becomes necessary to simulate the dynamics of electrically charged inhomogeneous media (Altunin et al. 2012; Bastykova et al. 2021; Chekalov et al. 2021; Ignatov 2020; Kolotinskii et al. 2021; Sinkevich 2016; Tada et al. 2016; Tukinakov 2019; Tukmakov 2022a; 2022b; 2023; Tukmakov, Tukmakov 2017).

The monograph (Nigmatullin 1978) outlines the theoretical foundations of the dynamics of multiphase media, presents various approaches to modeling the dynamics of inhomogeneous media, including the theory of continual mathematical models of the dynamics of multiphase media. Another monograph (Kutushev 2003) developed one-dimensional mathematical models of the dynamics of electrically neutral gas suspensions, while (Fedorov et al. 2015) developed various mathematical models of the dynamics of electrically neutral gas suspensions with solid particles. The article (Altunin et al. 2012) analyzes scientific and technical literature in order to describe the results of research and practical application of electric fields in liquid and gaseous media. In the study reported in (Bastykova et al. 2021), the evolution of dust grains from various materials used in thermonuclear power plants was studied, and a mathematical model was built to describe dust formation. The work (Chekalov et al. 2021) discusses technologies for electrostatic precipitators of gas suspensions in relation to the problems of industrial energy. The article (Ignatov 2020) is devoted to the development of mathematical models for the dynamics of dust particles moving in plasma above an electrode. The study (Kolotinskii et al. 2021) presents a mathematical model of the dynamics of negatively charged dust particles in plasma. The work (Sinkevich 2016) analyzes the stability of relatively small perturbations of the stationary state of a flat electrically charged interface between a two-phase thundercloud and a humid turbulent atmosphere, taking into account the viscosity of the medium. The article (Tada et al. 2016) investigates the influence of the electric field on heat transfer in a gas suspension with an electrically charged dispersed component.

Aerosols are often used in various applications—solid particles suspended in a gas or liquid droplets. It should be noted that real aerosols have a polydisperse composition, which means that fractions have different particle sizes and material densities. In industry, the problem often arises of cleaning a gas stream from solid or liquid particles. For this, electrostatic precipitators are used. In this case, dispersed flows are first charged with an electric charge in the electrode, which forms a corona discharge, and then deposited on a plate with a potential of the opposite sign. In this paper, we consider the flow of an electrically charged aerosol in a channel in which potentials of different signs are applied to the channel walls.

The mathematical model implements a continuum approach to the dynamics of inhomogeneous media, in which, for each of the mixture components, a complete hydrodynamic system of equations is solved with terms that take into account intercomponent momentum exchange and heat transfer. The continuum approach to the dynamics of inhomogeneous media most fully describes the dynamics of a mixture at close mass fractions of the mixture components (Nigmatullin 1978).

The scientific novelty lies in the fact that the continuum mathematical model is used to study the dynamics of an electrically charged aerosol, taking into account the multi-fraction composition of the dispersed component in a channel with electric potentials on the walls. The mathematical model takes into account the multi-fractional composition of the dispersed component of the aerosol. Since all aerosol fractions have a positive charge, dispersed particles settle on the electrode surface with a negative potential. The paper considers the influence of the properties of the dispersed phase fractions (material density and particle size) on the parameters of particle dynamics in the channel.

Mathematical model

The motion of the carrier medium is described by the system of Navier-Stokes equations (Fletcher 1988; Loitsyansky 2003; Muzafarov, Utyuzhnikov 1993; Tukmakov 2003) for a compressible heat-conducting gas taking into account the interphase force interaction and heat transfer (Tukinakov 2019; Tukmakov 2022a; 2022b; 2023; Tukmakov, Tukmakov 2017) (1)–(5):

$$\frac{\partial \rho_j}{\partial t} + \nabla\left(\rho_j \mathbf{V}_j\right) = 0 \quad (1)$$

$$\frac{\partial \rho_1 V_1^k}{\partial t} + \nabla^i \left(\rho_1 V_1^k V_1^i + \delta_{ik} p - \tau_{ik} \right) = -\sum_{j=2}^{m} F_{kj} + \sum_{j=2}^{m} \alpha_j \nabla^k p \tag{2}$$

$$\frac{\partial \rho_j V_j^k}{\partial t} + \nabla^i \left(\rho_j V_j^i V_j^k \right) = F_{kj} - \alpha_j \nabla^k p \tag{3}$$

$$\frac{\partial (e_1)}{\partial t} + \nabla^i \left(V_1^i \left(e_1 + p - \tau_{ii} \right) - V_1^k \tau_{ki} - \lambda \nabla^i T_1 \right) = -\sum_{j=2}^{m} Q_j - \sum_{j=2}^{m} \left| F_{kj} \right| \left(V_1^k - V_j^k \right) +$$

$$+\sum_{j=2}^{m} \alpha_j \nabla^k \left(p V_1^k \right) \tag{4}$$

$$\frac{\partial (e_j)}{\partial t} + \nabla^k \left(e_j V_j^k \right) = Q_j \tag{5}$$

$$\frac{\partial^2 \varphi}{\partial x_1^{\,2}} + \frac{\partial^2 \varphi}{\partial x_2^{\,2}} = \sum_{j=2}^{m} \rho_j q_0 \tag{6}$$

$$\boldsymbol{V}_j = \left[u_j, v_j \right]; \rho_j = \alpha_j \rho_{j0}, k, i = 1,2; \; j = 1..m.$$

The electric field (6) was also taken into account in the mathematical model using the Poisson equation. The viscous stress tensor of the carrier medium is calculated as follows (7):

$$\tau_{11} = ì \left(2\frac{\partial u_1}{\partial x_1} - \frac{2}{3} D \right), \; \tau_{22} = ì \left(2\frac{\partial v_1}{\partial x_2} - \frac{2}{3} D \right), \; \tau_{12} = \tau_{21} = \mu \left(\frac{\partial u_1}{\partial x_2} + \frac{\partial v_1}{\partial x_1} \right) \tag{7}$$

$$D = \frac{\partial u_1}{\partial x_1} + \frac{\partial v_1}{\partial x_2}$$

The vector components of interphase exchange of momentum F_{1i} (8), F_{2i} (9) were described by the following equations:

$$F_{1i} = 0.75 \frac{\pm_i}{d_i} C_{di} Á_1 \sqrt{\left(u_1 - u_i \right)^2 + \left(v_1 - v_i \right)^2} \left(u_1 - u_i \right) - \alpha_i q_0 \rho_i \, \partial \varphi / \partial x_1 \tag{8}$$

$$F_{2i} = 0.75 \frac{\pm}{d_i} C_d Á_1 \sqrt{\left(u_1 - u_i \right)^2 + \left(v_1 - v_i \right)^2} \left(v_1 - v_i \right) - \alpha_i \rho_{i0} q_0 \, \partial \varphi / \partial x_2 \tag{9}$$

The vector components of the interphase exchange of momentum include the aerodynamic drag force (Fedorov et al. 2015; Kutushev 2003), as well as the Coulomb force (Salyanov 1997). Here, p, ρ_1, u_1, v_1 are the pressure, density, Cartesian components of the velocity of the carrier medium in the direction of the x_1 and x_2 axes, respectively; T_1, e_1 are the temperature and total energy of the gas; α_i,ρ_{i0} ρ_i, T_i, e_i, u_i, v_i are the volumetric content, physical density, average density, temperature, internal energy, Cartesian components of the dispersed phase fractions velocity; Q_i is the heat flux between carrier medium and i-th fraction of the dispersed phase; λ and μ are the thermal conductivity and viscosity of the carrier medium, respectively. The temperature of the carrier medium is found from the equation $T_1 = (\gamma - 1)\cdot(e_1/\rho_1 - 0.5\cdot(u_1^2+v_1^2))/R$, where R is the gas constant of the carrier medium, γ is the heat capacity ratio. The internal energy of the i-th fraction of the dispersed phase suspended in gas is defined as $e_i = \rho_i C_{pi} T_i$, where C_{pi} is the specific heat at the constant pressure of the i-th fraction of the dispersed phase. Heat transfer between the i-th fraction of the dispersed phase and gas: $Q_i = 6\alpha_i Nu_{1i}\lambda (T_1 - T_i)/d_i^2$, d_i is the particle diameter of the i-th fraction of the dispersed phase. The Nusselt number (10) is determined using the well-known approximation depending on the relative Mach (11), Reynolds (12), and Prandtl (13) numbers (Kutushev 2003):

$$Nu_{1i} = 2\,exp(-M_{1i}) + 0.459\,Re_{1i}^{0.55}\,Pr^{0.33}, \tag{10}$$

$$M_{1i} = \left|\bar{V}_1 - \bar{V}_i\right| / c, \tag{11}$$

$$Re_{1i} = \rho_1 \left|\bar{V}_1 - \bar{V}_i\right| d_i / \mu, \tag{12}$$

$$Pr = C_p \mu / \lambda \tag{13}$$

The mathematical model assumed the absence of interaction between particles.

The drag coefficient of spherical particles (14) was calculated using the following expression (Kutushev 2003):

$$C_{di} = \frac{24}{Re_{1i}} + \frac{4}{Re^{0.5}_{1i}} + 0.4 \tag{14}$$

where q_0 is the specific charge per unit mass of the solid fraction and ϕ is the electric field potential. E is the electric field strength, ε is the relative dielectric constant of air, ε_0 is the absolute dielectric constant of air. The system of equations for the dynamics of a multiphase medium (1)–(5) was solved by the McCormack explicit finite difference method (Fletcher 1988) of the second order of accuracy in time and space. The calculation error is the largest value of the squared steps in spatial directions and time steps–Δx, Δy, Δt: max $(\Delta x^2, \Delta y^2, \Delta t^2)$. The monotonicity of the solution was achieved using the correction scheme (Muzafarov, Utyuzhnikov et al. 1993; Tukmakov 2003) after the transition from the n-th to a new time layer $t = t^{n+1}$. When calculating the flow of a two-phase mixture, the no-slip conditions were set for the velocity components of the carrier medium and the dispersed component at all solid boundaries; this formulation of the boundary conditions corresponds to a mathematical model of the viscous medium motion. The Poisson equation (Krylov et al. 1977; Salyanov 1997), which describes the electric field potential (6), was solved by the finite difference method using the iterative scheme (Krylov et al. 1977) on the mesh generated for gas dynamic calculations to take into account the influence of the Coulomb force (Salyanov 1997) when solving the equations of a two-phase medium dynamics, and also allow for the distribution of the "average density" of the fractions of the dispersed phase at the fragmentation nodes of the physical area at solving the Poisson equation.

When implementing the numerical algorithm, uniform Neumann boundary conditions were set at the outlet boundary of the channel for all dynamic functions of the carrier medium and fractions of the dispersed phase, except for the longitudinal components of the velocity. For the longitudinal component of the velocity of the gas and fractions of the dispersed component at the inlet boundary of the channel, the initial velocity u_0 was set; for the transverse components of the velocity, uniform Neumann boundary conditions were specified. At the inlet boundary of the channel, for the average density of the fractions of the dispersed component of the gas suspension, the input values of the average density were set. On solid surfaces, the components of the velocity of the carrier phase and fractions of the dispersed phase were set equal to zero; for the function of the potential of the electric field, the values of the potential on the side surfaces and the homogeneous Neumann boundary conditions on the remaining boundaries were set. For all other dynamic functions, the homogeneous Neumann boundary conditions were set:

$$u_1(t,1,j) = u_0,\; u_k(t,1,j) = u_0,$$

$$v_1\left(t,1,j\right)=v_1\left(t,2,j\right),v_k\left(t,1,j\right)=v_k\left(t,2,j\right),$$

$$u_1\left(t,N_x,j\right)=u_1\left(t,N_x-1,j\right),u_k\left(t,N_x,j\right)=u_k\left(t,N_x-1,j\right),$$

$$v_1\left(t,N_x,j\right)=v_1\left(t,N_x-1,j\right),v_k\left(t,N_x,j\right)=v_k\left(t,N_x-1,j\right),$$

$$u_1\left(t,i,1\right)=0,u_k\left(t,i,1\right)=0,\ \ v_1\left(t,i,1\right)=0,v_k\left(t,i,1\right)=0,$$

$$u_1\left(t,i,N_y\right)=0,u_k\left(t,i,N_y\right)=0,\ \ v_1\left(t,i,N_y\right)=0,v_k\left(t,i,N_y\right)=0,$$

$$\rho_1\left(t,1,j\right)=\rho_1\left(t,2,j\right),\rho_k\left(t,1,j\right)=\rho_{k0}\alpha_0,$$

$$\rho_1\left(t,N_x,j\right)=\rho_1\left(t,N_x-1,j\right),\rho_k\left(t,N_x,j\right)=\rho_k\left(t,N_x-1,j\right),$$

$$\rho_1\left(t,i,1\right)=\rho_1\left(t,i,2\right),\rho_k\left(t,i,1\right)=\rho_k\left(t,i,2\right),$$

$$\rho_1\left(t,i,N_y\right)=\rho_1\left(t,i,N_y-1\right),\ \rho_k\left(t,i,N_y\right)=\rho_k\left(t,i,N_y-1\right),$$

$$e_1\left(t,1,j\right)=e_1\left(t,2,j\right),e_k\left(t,1,j\right)=e_k\left(t,2,j\right),$$

$$e_1\left(t,N_x,j\right)=e_1\left(t,N_x-1,j\right),e_k\left(t,N_x,j\right)=e_k\left(t,N_x-1,j\right),$$

$$e_1\left(t,i,1\right)=e_1\left(t,i,2\right),e_k\left(t,i,1\right)=e_k\left(t,i,2\right),$$

$$e_1\left(t,i,N_y\right)=e_1\left(t,i,N_y-1\right),e_k\left(t,i,N_y\right)=e_k\left(t,i,N_y-1\right),$$

$$p\left(t,1,j\right)=p\left(t,2,j\right),\ p\left(t,N_x,j\right)=p\left(t,N_x-1,j\right),$$

$$p\left(t,i,1\right)=p\left(t,i,2\right),\ p\left(t,i,N_y\right)=p\left(t,i,N_y-1\right).$$

$$\varphi\left(t,1,j\right)=\varphi\left(t,2,j\right),\ \varphi\left(t,N_x,j\right)=\varphi\left(t,N_x-1,j\right),$$

$$\varphi\left(t,i,1\right)=\varphi_{0l},\ \varphi\left(t,i,N_y\right)=\varphi_{0u}.$$

In this work, we considered the motion of an electrically charged gas suspension of a polydisperse composition in a channel open on both sides. Channel length L = 1 meter, channel width h = 0.1 meters. The number of nodes in the longitudinal and transverse directions were $N_x = 300$, $N_y = 60$, respectively. The calculation accuracy can be determined as– $\Delta = O\left(max\left(\Delta x^2,\Delta y^2,\Delta t^2\right)\right)\approx 0.00001$. When modeling, the following parameters of the carrier phase of the gas suspension were set: M = 0.029 kg/mol is the molar

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mass of air, the thermal conductivity of the carrier medium was assumed to be λ = 0.02553 W/(m K), the dynamic viscosity of the carrier medium was μ = 1, 72 10-5 Pa s, γ = 1.4, R = 8.31 J/(mol K). It was assumed that at the initial moment the medium moves with a speed u_0=3.8 m/s, the initial vertical speed is equal to zero. The initial volume content of the gas suspension fractions was $\alpha_{k0} = \alpha_0$ = 0.000033, while carrier medium density, i. e., air density ρ_{10} = 1.2 kg/m^3. For the same density of the material ($\rho_{20} = \rho_{30} = \rho_{40}$ = 1850 kg/m^3) of particles, the dispersity of the particles was d_1 = 2 μm, d_2 = 4 μm, d_3 = 10 μm. For different densities of materials, dispersion was $d_1 = d_2 = d_3$ = 20 μm. The simulated process of movement of an electrically charged gas suspension in a channel with antifoam potentials on the walls corresponds to the process of functioning of an electrostatic precipitator (Chekalov et al. 2021).

Calculation results

An electric potential φ_1 = 25,000 V was applied to the upper wall of the channel (y = h), and an electric potential φ_2 = –25,000 V was applied to the lower wall (y = 0) (see Fig. 1). The specific mass charge of the dispersed phase was taken equal to q_0 = 0.0001 C/kg.

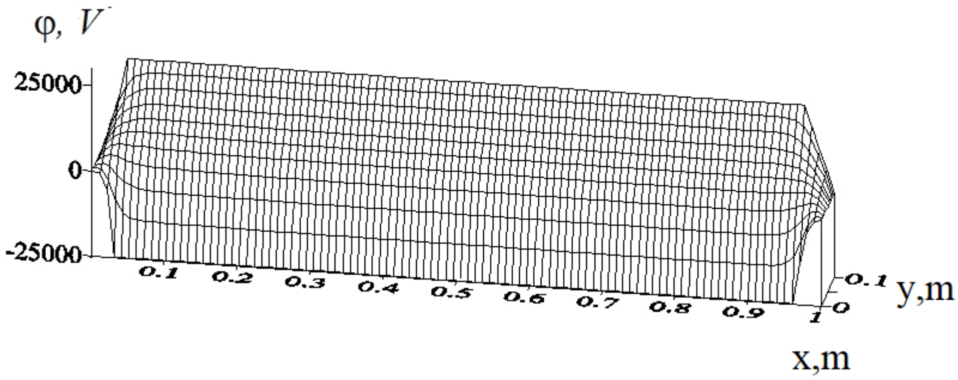

Fig. 1. Distribution of the electric field potential

Fig. 2 shows the spatial distribution of the velocity modulus of the carrier medium $V_1 = \sqrt{u_1^2 + v_1^2}$ at the time t = 0.5 s. One can observe a “parabolic” viscous profile of the flow of the carrier medium in the channel (Loitsyansky 2003).

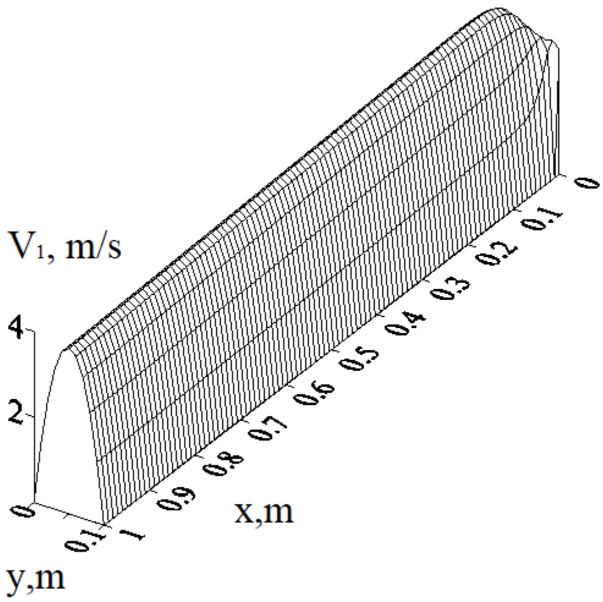

Fig. 2. Distribution of the modulus of gas velocity in the channel, time t = 0.5 s

The results of calculations of the specific Coulomb force demonstrate that at the entrance to the channel, the particles are slowed down by the Coulomb force, and at the exit from the channel, the Coulomb force accelerates the movement of the dispersed phase fractions in the longitudinal direction (see Fig. 3). Thus, we can note the influence of the boundaries of the computational domain, i. e., the "edge effect" on the specific Coulomb force acting on the dispersed component of the aerosol. Along the channel in the direction of the x-axis, the value of the y-component of the specific Coulomb force is directed to the bottom plate. In the direction of the x-axis, the y-component of the specific Coulomb force is distributed evenly (Fig. 4a). In the transverse direction, the specific Coulomb force acts in the direction of the lower negatively charged plate (Fig. 4b). The highest absolute value of the specific Coulomb force is observed near the bottom wall of the channel.

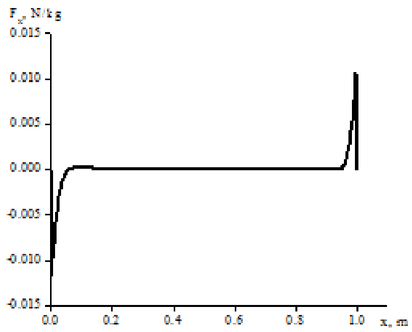

Fig. 3. Spatial distribution of the x-component of the specific Coulomb force in the direction of the x-axis, time t = 0.5 s

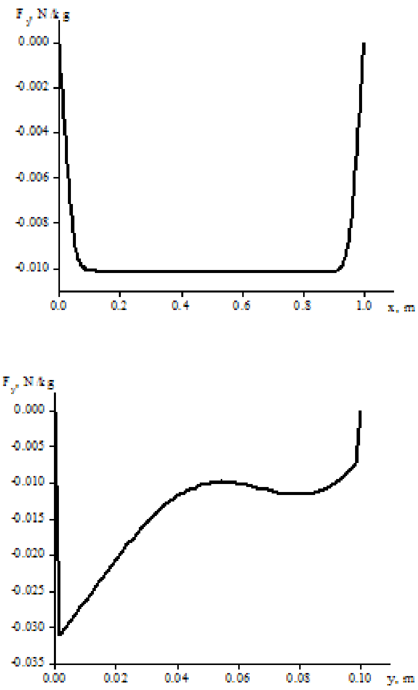

Fig. 4. Distribution of the y-component of the Coulomb force in the direction of the x-axis (y = h/2).
Fig. 4a. Distribution of the y-component of the Coulomb force in the direction of the y-axis (x = L/2);
Fig. 4b. time point t = 0.5 s

Let us consider the effect of particle dispersion of the same particle material density (ρ_{i0} = 1,850 kg/m^3, i = 2–4) on the process of mass transfer of fractions of the dispersed component of a gas suspension in an electric field. Both in the direction of the x-axis (Fig. 5a) and in the direction of the y-axis (Fig. 5b), large particles have a greater value of the y-component of the velocity of movement in the direction of the lower plate, to which the potential of the opposite value is applied. This can be explained by the fact that larger particles have more mass, which means that in the mass model of electric charge, the electric charge of larger particles is greater and thus they are more affected by the electric field. For all particle sizes, the distribution of the vertical component of the velocity of fractions of the dispersed component

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of the gas suspension reaches the maximum value in modulus on the lower, negatively charged plate and is uniformly distributed in the longitudinal direction.

The action of the Coulomb force on particles of different fractions, differing in particle size, determines the volume content of the fractions in the longitudinal and transverse directions. As the particle size of the fractions of the dispersed component increases, the absorption of the volume content of the fractions increases when moving through the channel in transverse and longitudinal sections (Fig. 6 (a–b)).

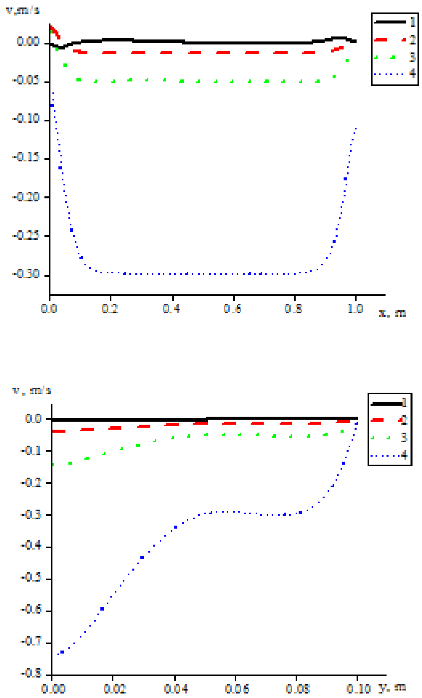


Fig. 5. Distributions of the y-component of the velocity of the gas suspension components along the x-axis (y = h/2). Fig. 5a. Distribution of the y-component of the velocity of the gas suspension components along the y-axis (x = L/2); Fig. 5b. Line 1—carrier medium, line 2—d = 2 μm, line 3—d = 4 μm, line 4—d = 10 μm, time t = 0.5 s

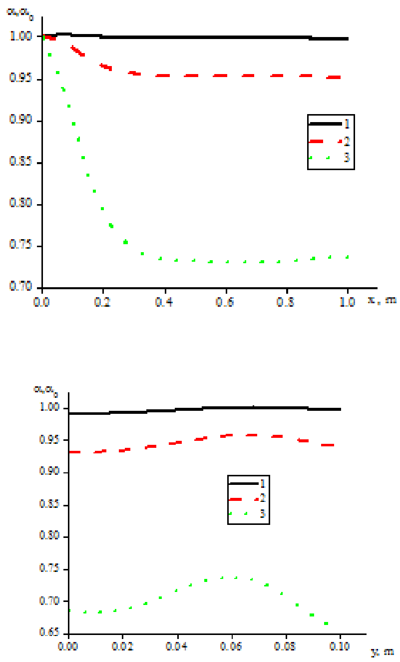
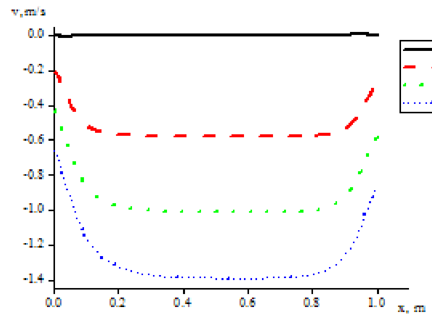


Fig. 6. Distribution of the volume content of the fractions of the dispersed component of the gas suspension along the x axis (y = h/2); Fig. 6a. Distribution of the volume content of fractions of the dispersed component along the y-axis (x = L/2); Fig. 6b. (ρ_{i0} = 1850 kg/m^3) line 1—d = 2 μm, line 2—d = 4 μm, line 3—d = 10 μm, time t = 0.5 s

Let us consider the influence of the physical density of the material of dispersed particles on the dynamics of particles in the Coulomb field with the same dispersion of particles, d_i = 20 μm, i = 2–4. Particles of denser materials have a higher settling rate (Fig. 7 (a–b)). This can be explained by the fact that in the mass model of the electric charge of the dispersed aerosol component, the charge of a dispersed particle with the same size is determined by its mass. For the same size of electrically charged dispersed particles, the density of the material affects the volume content of gas suspension fractions. For the same dispersion of particles and different densities of the particle material, the distribution of the vertical component of the velocity of the fractions of the dispersed component of the gas suspension reaches the maximum value in modulus on the lower negatively charged plate and is uniformly distributed in the longitudinal direction.

Distribution of the volume content of fractions as in the longitudinal section of the channel (Fig. 8a) and in the cross section (Fig. 8b), demonstrate that the loss of the volume content of fractions during the passage of the channel with the same dispersion of particles is directly proportional to the density of the material of the fraction. This pattern can be explained by the influence of the particle material density on the settling rate of particles having the same size.



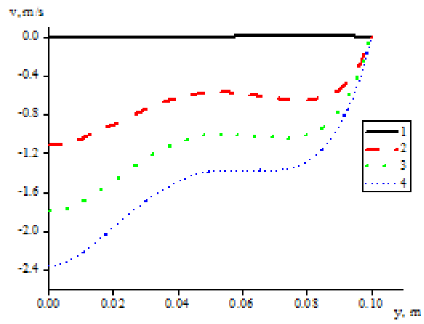
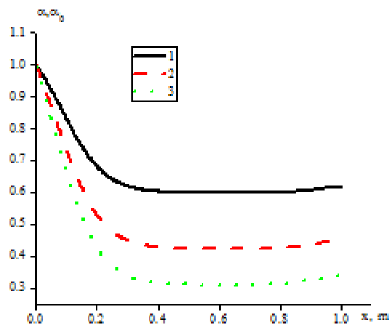


Fig. 7. Distributions of the y-component of the velocity of the gas suspension components along the x-axis (y = h/2). Fig. 7a. Distribution of the y-component of the velocity of the gas suspension components along the y-axis (x = L/2); Fig. 7b (d = 20 μm) line 1—carrier medium, line 2—ρ_{20} = 1,000 kg/m³, line 3—ρ_{30} = 1,850 kg/m³, line 4—ρ_{40} = 2,700 kg/m³, time t = 0.5 s



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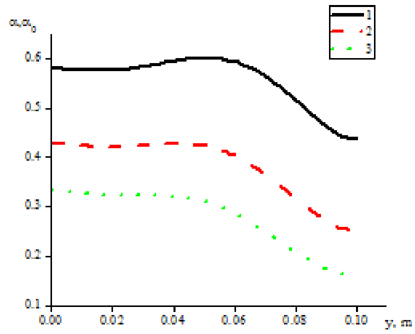

Fig. 8. Distribution of the volume content of the fractions of the dispersed component of the gas suspension along the x axis (y = h/2). Fig. 8a. Distribution of the volume content of fractions of the dispersed component along the y-axis (x = L/2); Fig. 8b. (d = 20 μm) line 1—ρ_{20} = 1,000 kg/m^3, line 2—ρ_{30} = 1,850 kg/m^3, line 3—ρ_{40} = 2,700 kg/m^3, time t = 0.5 s

To determine the volume of precipitated particles of the j-th fraction, the scheme of right-handed rectangles was used for the numerical integration of a certain integral of right-handed rectangles (Verzhbitsky 2002):

$$V_j(t) = \int_0^L \alpha_j(x,0,t)\,dx \approx \sum_{i=2}^{N_x} \alpha_j(x_i - x_{i-1}) = \sum_{i=2}^{N_x} \alpha_j(x_i,0,t)\Delta x \,. \tag{15}$$

The volumes of fractions of the dispersed phase deposited on the lower surface of the channel are directly proportional to the particle size of the fraction at the same density of the particle material (Fig. 9). The volumes of precipitated fractions are also directly proportional to the density of the particle material (Fig.10). Calculations indicate that deposition of dispersed particles on the electrode surface in an electric field is determined by the mass of the particles. With the same particle material density, larger particles are more intensively deposited since larger particles are more massive. With the same particle size, particles from denser materials are more intensively deposited.

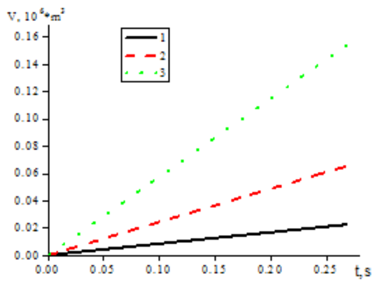

Fig. 9. Time dependence of the volume of dispersed particles of gas suspension deposited on the bottom plate for different particle sizes (ρ_{i0} = 1,850 kg/m^3), line 1—d = 2 μm, line 2—d = 4 μm, line 3—d = 10 μm

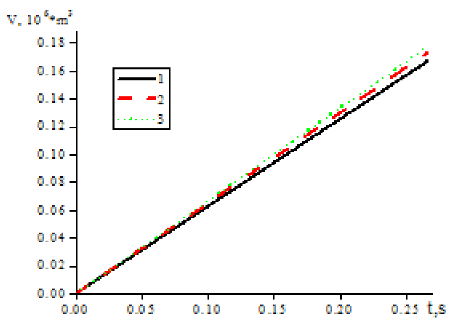

Fig. 10. Time dependence of the volume of dispersed particles of gas suspension deposited on the bottom plate for different particle material densities (d_i = 20 μm), line 1—ρ_{20} = 1,000 kg/m^3, line 2—ρ_{30} = 1,850 kg/m^3, line 3—ρ_{40} = 2,700 kg/m^3

Conclusions

In this work, numerical calculations of the dynamics of an electrically charged polydisperse gas suspension in a channel in which potentials of different signs are applied to the side surfaces are carried out. The influence of the parameters of dispersed particles on the dynamics of particles in a channel under the action of aerodynamic forces and the Coulomb force has been analyzed. When moving along the channel, the vertical component of the particle velocity is directed to the plate, to which a potential with a sign opposite to the sign of the charge of dispersed particles is applied. It was determined that at the same density of the material, the intensity of sedimentation of the fraction is determined by the size of the particles; at the same dispersion of particles, the fractions of particles with a higher density of the material are most intensively deposited. In this case, the dispersity of the particles of the fraction has a greater effect on the volume of the fraction deposited on the electrode plate than the density of the material of the fraction.

The vertical component of the velocity of the fraction of the dispersed component increases with an increase in the particle size; at a fixed particle size, the vertical component of the particle velocity increases with an increase in the density of the material.

The influence of the parameters of the fractions of the electrically charged dispersed aerosol component on the dynamics of a multifractional aerosol in an external electric field is considered. As a result of the analysis of the results of numerical calculations, the influence of the particle size and density of the fraction material on the vertical component of the velocity, the volume content of the fraction in various sections of the channel, and the rate of deposition of particles of the fraction on the electrode plate were determined.

The regularities obtained by numerical simulation can be explained by the fact that particles of a larger size or particles of denser material (provided particles are of the same size), have a larger electric charge and, therefore, a larger Coulomb force acts on them. In this case, particles of large sizes overcome the aerodynamic resistance of the gas more easily. As a result of mathematical modeling, it was determined that the intensity of fraction filtration by an electric filter is determined by particle size and material density. The revealed regularities can be used in optimizing electric filters for gas suspensions. The regularities revealed in the work suggest the possibility of separating fractions of an electrically charged aerosol into fractions with different density and particle size. The development of the presented mathematical model of the dynamics of an electrically charged multifractional aerosol will take into account different charges of particles of different fractions.

Conflict of Interest

The author declares that there is no conflict of interest, either existing or potential.

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