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The Effect of Dustiness of Combustion Products and Coagulation Processes on the Parameters of Submicron Particles Resulting from Coal Burning

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Abstract—Homogeneous–heterogeneous bulk condensation of potassium sulfate vapor has been numerically simulated in a dusty vapor–gas flow of coal combustion products upon their cooling along a technological path. A closed model that we have proposed for the formation of submicron particles in coal combustion products has been employed. Data have been obtained on the concentration and size distribution of particles formed at varied parameters of heterogeneous condensation sites and rates of variations in the temperature of the flow. Variations in the relative contributions of the homogeneous and heterogeneous mechanisms with variations in flow dustiness have been considered. A criterion enabling one to judge the effect of flow dustiness on the bulk condensation process has been proposed. This criterion takes into account both dust parameters and rate of temperature variations in a condensation zone. Data have been presented on the influence of coagulation processes on the parameters of submicron particles resulting from coal combustion.

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INTRODUCTION

The content of ecologically hazardous submicron particles in the atmosphere is subject to control in the Russian Federation [1, 2]. Limitations on the concentration of such particles are present in quality standards of ambient air of other countries, including the United States [3]. In the People's Republic of China, the problem of reducing pollutant emissions into the atmosphere has acquired the high-priority status in national policy, which is evident from the introduction of a plan for the prevention and control of air pollution [4].

The emission of submicron particles upon coal combustion is a source of the aforementioned type of atmospheric pollution. In this case, the hazard is created by not only the particles themselves, but also the condensation of different hazardous substances, e.g., some toxic microelements contained in coals [5–7], on their surface.

The bulk condensation of vapors of the substances formed from the mineral moiety of coals in the course of combustion ("solid–vapor–particulate pathway" [8–10]) is considered to be the probable mechanism for the formation of such submicron particles. To reduce the emission of submicron particles into the atmosphere by their trapping, it is necessary to know the parameters of the aerosols resulting from coal combustion. These parameters—the concentration and size distribution of particles—may be obtained by numerical simulation of the bulk condensation process. The studies available in this field are predominantly devoted to the description of particle formation upon the combustion of certain types of coals, such as lignites, with high sodium contents [11]. The need inevitably arises to extend such results to coils of other types, with their mineral moieties containing predominantly other volatile elements, e.g., potassium.

As applied to the combustion products of coals, which are multicomponent reactive systems, it is reasonable to perform simulation using a complex—thermodynamic and kinetic—approach. At the first stage, the methods of chemical thermodynamics are used to determine the equilibrium compositions of gaseous and condensed phases and the sequence of condensation of different substances with the temperature of combustion products decreasing along a technological path. Taking into account the results of the thermodynamic analysis, the desired parameters of a condensation aerosol are determined at the second stage by solving the kinetic equation of bulk condensation. Therewith, it is assumed that the thermodynamic equilibrium remains preserved in the gaseous phase. The realization of this approach in [12] has made it possible to consider the effect of the content of aluminosilicates of volatile elements (potassium and sodium) on the parameters of condensation aerosols for various types of coals with different ash compositions. To continue the cited work, a model was realized in [13] that took into account the loss of potassium and sodium together with aluminosilicates due to the partial passage of these compounds to liquid slag after the cessation of combustion and a decrease in the temperature. At the same time, the possible influence of dustiness of coal combustion products and coagulation processes on the parameters of the condensation aerosols resulting from the combustion was not considered in [11–13].

The aforementioned problem is the object of this study. We intend to consider the homogeneous–heterogeneous bulk condensation in a dusty flow of coal combustion products with allowance for coagulation processes. The dustiness is caused by the presence of volatile ash resulting from the combustion of coal particles. Fundamental reviews [14, 15] were devoted to the general problems of heterogeneous condensation. The necessity to take into account the heterogeneous condensation arises when designing experimental studies performed, in particular, in laminar-flow diffusion chambers used for experiments with nanoparticles [16] and in wind tunnels [17].

In the former case, the heterogeneous condensation of water vapor diffusing from heated chamber walls is used for condensation growth of nanoparticles entering into the chamber with a flow of a cold carrier gas. As a result, nanoparticles coated with a water film become "visible" for optical detecting devices. The experiments in laminar-flow diffusion chambers and the interpretation of the obtained results may be successful, provided that we have a mathematical model of the processes occurring in the used setup. A corresponding model and the results of its application have been presented in [16].

In the latter case, the matter concerns the enhancement of the opportunities for performing experimental studies in wind tunnels, in particular, for reaching the maximum supercooling of a flow. In this case, a limiting factor is the heterogeneous condensation of a working substance induced by the presence of foreign particles in a flow. This circumstance stimulated numerous studies of the homogeneous–heterogeneous condensation of gaseous mixtures, in particular, air, under the conditions characteristic of wind tunnels. The corresponding results have been summarized in [17].

In the general case, when simulating heterogeneous condensation, a question arises as to allowance for the polydispersity of heterogeneous condensation sites (dust particles). Proceeding from an assumed pattern of the spectrum of heterogeneous sites, inequalities have been formulated [15], the fulfillment of which ensures the closeness of results obtained with and without allowance for polydispersity. A set of moment equations for consistent taking into account the polydispersity has been derived in [17]. At the same time, the numerical data presented in [17] for the homogeneous–heterogeneous condensation in a dusty flow have been obtained under the monodisperse approximation. The numerical simulation of the bulk condensation in a dusty vapor–gas flow with allowance for dust particle size distribution has been performed in [18]. The mass fraction of dust particles has been used in [17] as a criterion enabling one to judge the effect of flow dustiness on the bulk condensation process. The relative total surface area of dust particles has been used in addition to their mass fraction in [18]. In this work, we propose a new criterion that takes into account both the dust parameters and the rate of temperature variation in the condensation zone.

The mathematical model of the studied process, the simulation results, and the discussion thereof have been described in the first part of the work, while the second part presents the conclusions inferred from the study.

MATHEMATICAL MODEL

We considered a stationary one-dimensional flow of dusty products of combustion in a channel at a constant velocity and a preset axial temperature gradient, which simulated the cooling of combustion products in a technological path. It was assumed that the sizes of dust particles and droplets allowed us to use a single-velocity model, while the low concentration of condensing components in the combustion products made it possible to use a single-temperature approximation, under which the temperatures of the droplets and the gaseous phase are equal. The model used for the formation process of submicron particles (droplets) in coal combustion products comprised the following features:

(1) formation of a condensable component (potassium sulfate) in the gaseous phase under the approximation of thermodynamic equilibrium and

(2) formation of a potassium sulfate aerosol via the homogeneous–heterogeneous condensation with account of the process kinetics.

The driving force of the condensation process is the excess partial pressure of a condensing component relative to its equilibrium value at a given temperature, with the excess pressure being characterized by the degree of supersaturation. As applied to the case under consideration, the degree of supersaturation may be written in the following form [12]:

$$s = \frac{N_{K_2SO_4}}{N^{s}_{K_2SO_4}}. \quad (1)$$

Here, $N_{K_2SO_4}$ is the current number of potassium sulfate moles in the gaseous phase corresponding to the one-phase (upon "frozen" condensation) thermodynamic equilibrium in gaseous phase (analog of partial vapor pressure) and $N^{s}_{K_2SO_4}$ is the number of potassium sulfate moles in the gaseous phase corresponding to the two-phase thermodynamic equilibrium in the system (analog of saturation vapor pressure)

At each step of the numerical simulation of bulk condensation kinetics, the degree of supersaturation was calculated as follows. The following temperature dependence was obtained for the denominator of Eq. (1) in [12] from the calculated data of the thermodynamic stage of the complex approach:

$$\log N^{s}_{K_2SO_4} = A^{s} - B^{s}/T, \quad (2)$$

$A^s = 4.42991$ and $B^s = 1.55904 \times 10^4$.

To determine the numerator, the following relation was derived [12]:

$$N_{K_2SO_4} = \left(\sqrt{1 + 8\Sigma_K K_{eq}} - 1\right)^2 / 16K_{eq}, \quad \Sigma_K = N^0_K - \Delta N_K. \quad (3)$$

Here, N^0_K is the potassium concentration in coal; ΔN_K is the loss of potassium in the gaseous phase during the homogeneous–heterogeneous condensation, which was determined at each step of the numerical integration of the equations of condensation kinetics (see below); K_{eq} is the equilibrium constant for the reaction of potassium sulfate formation in the gaseous phase of the combustion products. In [13], on the basis of the data calculated at the thermodynamic stage of the complex approach, the temperature dependences of the equilibrium constants for 15 coals were approximated by two-term polynomials as follows:

$$\log K^{(i)}_{eq} = A_i + B_i/T. \quad (4)$$

Parameters $A_i = -2.471$ and $B_i = 2.93 \times 10^4$ were used in this work for one of the coils (Yanzhou, People's Republic of China).

As in [18], the homogeneous–heterogeneous condensation kinetics was described on the basis of the fact that two groups of droplets are present in the flow: (1) microdroplets resulting from the homogeneous nucleation in the bulk of the vapor–gas mixture and (2) macrodroplets resulting from the vapor condensation on dust particles. The processes of the formation and growth of microdroplets are described by the kinetic equation, which, in the case of the homogeneous condensation in a one-dimensional stationary flow with no account taken of coagulation, has the following form (see, e.g., [19]):

$$u\frac{\partial f}{\partial x} + \frac{\partial(\dot{r}f)}{\partial r} = \frac{I}{\rho_\Sigma}\delta(r - r_{cr}), \quad (5)$$

where f is the particle size distribution function normalized with respect to the number of particle in unit mass of the vapor–gas mixture, u is the flow velocity, r is the droplet radius, $\dot{r}$ is the rate of droplet growth, I is the rate of nucleation, ρ_Σ is the density of the vapor–gas–droplet mixture, δ is the δ-function, and r_{cr} is the critical radius.

Provided that the droplet size is much smaller than the mean free path, Eq. (5) is successfully solved by the moments method, which yields a set of moment equations that is equivalent to Eq. (5) for the first four moments of the distribution function [19]:

$$\frac{d\Omega_n}{dx} = n\frac{\dot{r}}{u}\Omega_{n-1} + \frac{I}{u\rho_\Sigma}r^n_{cr}, \quad n = 0–3. \quad (6)$$

The distribution function moments are determined in the following way:

$$\Omega_n = \int_{r_{cr}}^{\infty} r^n f dr. \quad (7)$$

The parameters of a condensation aerosol are expressed via following distribution function moments:

the number of droplets in unit volume,

$$n_d = \rho_\Sigma\Omega_0, \ \text{m}^{-3}; \quad (8)$$

the average droplet size (radius),

$$r_d = \Omega_1/\Omega_0, \ \text{m}; \quad (9)$$

and the mass concentration of droplets,

$$\rho_d = 4\pi\rho_l\rho_\Sigma\Omega_3/3, \ \text{kg/m}^3, \quad (10)$$

where ρ_l is the condensate density. The distribution function itself is restored from the results of the solution. Set of equations (6) was integrated using the classical Volmer–Frenkel–Zel'dovich theory [20] to calculate the rate of nucleation and the Hertz–Knudsen formula [21] to obtain the rate of droplet growth.

For macrodroplets, the kinetic equation has the form of

$$u\frac{\partial f_M}{\partial x} + \frac{\partial(\dot{r}f_M)}{\partial r} = 0. \quad (11)$$

Here, f_M is the macrodroplet size distribution function. In contrast to Eq. (5), the right-hand side of Eq. (11) is equal to zero, because the number of macrodroplets is constant and equal to the number of heterogeneous nucleation sites (dust particles). This statement is valid, provided that the size of the dust particles is larger than the size of critical nuclei upon the homogeneous nucleation for all considered values of the degree of supersaturation. It is this situation that is considered in our work. Equations (5) and (11) have different initial conditions: for microdroplets, the distribution function in the inlet cross section is equal to zero, while for macrodroplets, it is determined by the distribution function of dust particles. The study of the effect of these (dust) particles on the bulk condensation in the flow was the goal of this work. The assumption of the ideal wettability of the heterogeneous condensation sites yielded the upper estimate of their effect on the process of bulk condensation. The results of the numerical study [18] have shown that the allowance for the polydispersity of the heterogeneous nucleation sites leads to a change in the number concentration of droplets and the condensate mass fraction within 10% relative to the monodisperse approximation at the same mass fraction of dust particles. Taking into account this circumstance, we, in this work, used the monodisperse approximation, which made it possible to obtain from Eq. (7) the following expression, which determines the kinetics of vapor condensation on dust particles:

$$\frac{dc^{\text{het}}}{dx} = \frac{4\pi\rho_1}{\rho_\Sigma u} n_\text{p} r_\text{p}^2 \dot{r}_\text{p}. \quad (12)$$

Here, c^{het} is the mass fraction of the condensate formed on the dust particles; n_p and r_p are the number of the dust particles in unit volume and their radius, respectively; and $\dot{r}_\text{p}$ is the rate of condensation growth of the dust particles, which is determined by the Fuchs equation [21]:

$$\dot{r}_\text{p} = \frac{\alpha(p_\text{v} - p_\text{s})}{\rho_1\sqrt{2\pi RT/\mu_\text{v}}}\left(1 + \frac{\alpha}{D}\sqrt{\frac{RT}{2\pi\mu_\text{v}}}\frac{r_\text{p}^2}{r_\text{p} + \langle l \rangle}\right)^{-1}, \quad (13)$$

where α is the condensation coefficient; p_v and p_s are the vapor partial pressure and the saturation pressure, respectively; R is the gas constant; μ_v is the vapor molar mass; D is the diffusion coefficient; and $\langle l \rangle$ is the mean free path of vapor molecules.

Vapor concentration was calculated by the material balance equation

$$\frac{dc_\text{v}}{dx} = -\left(\frac{dc^{\text{hom}}}{dx} + \frac{dc^{\text{het}}}{dx}\right), \quad (14)$$

where $c^{\text{hom}} = \rho_\text{d}/\rho_\Sigma$ is the mass fraction of the condensate formed by the homogeneous mechanism.

The set kinetic equations (6), (12), and (14) for homogeneous–heterogeneous condensation describes the condensation mechanism of the effect of flow dustiness on the parameters of the formed submicron particles (droplets). This mechanism is realized upon the collisions of vapor molecules with dust particle surfaces. In addition, the effect of flow dustiness may be realized via the coagulation mechanism upon the collisions of submicron droplets with dust particles. When estimating the effect of coagulation processes, we also took into account the collisions of droplets with each other (under the approximation of the Brownian coagulation of monodisperse spherical particles by analogy with [22, 23]) and with dust particles (collisional coagulation). The coagulation-induced decrease in the number of droplets was calculated via the following expression:

$$u\frac{dn_\text{d}}{dx} = -\left(K_0 n_\text{d}^2/2 + K_1 n_\text{d} n_\text{p}\right), \quad (15)$$

where K_0 is the Brownian coagulation constant and K_1 is the collisional coagulation constant. Taking into account the approximate character of the approach, the calculations were performed at constant value $K_0 = 6 \times 10^{-19}$ m^3/s, which made it possible to match calculated and experimental data in [24]. The value of K_1 was determined taking into account the fact that the size of dust particles (10 μm and more) is substantially larger than the size of submicron droplets:

$$K_1 = \pi r_\text{p}^2 v_\text{rel}, \quad (16)$$

where v_rel is the velocity of collisions between droplets and dust particles. The correct calculation of this value is a separate complex problem (see, e.g., [25]). In this work, the effect of the collisional coagulation was estimated using v_rel values equal to 1 and 10% of flow velocity u. As follows from expressions (15) and (16), the dustiness of the flow affects the coagulation of the formed droplets via complex $n_\text{p} r_\text{p}^2$.

RESULTS AND DISCUSSION

One of the coals considered in [12, 13] was used as an object of simulation. Numerical simulation data on the formation of submicron particles (droplets) in the combustion products of coal Yanzhou (People's Republic of China) upon the homogeneous–heterogeneous condensation of potassium sulfate are presented in Figs. 1–11. Concentration and size of dust particles, as well as the temperature gradient in the condensation zone, were used as variable parameters. It is natural to assume that the higher the rate of vapor condensation on dust particles, which is determined by Eq. (8), the stronger their effect. Taking into account that, in the simulation, the dust particle size was varied from 10 μm and above, the condensation growth rate of heterogeneous droplets at such sizes becomes inversely proportional to the radius (diffusion growth regime [21]). As a result, the effect of dust particles must be determined by complex $n_\text{p} r_\text{p}^2$. The calculations performed with variations in the values of n_p and r_p have confirmed this conclusion.

Figure 1 illustrates vapor concentration variations in the zone of homogeneous–heterogeneous condensation at different values of parameter $n_\text{p} r_\text{p}$ and a fixed rate of temperature variation (480 K/s). The data on the purely homogeneous case are presented for comparison. Two regions are distinctly seen in the curves for a decrease in the vapor concentration: the initial region, which is characterized by a smooth variation in the vapor concentration upon heterogeneous condensation, and the final region, which is characterized by an abrupt change in the vapor concentration due to homogeneous condensation. As $n_\text{p} r_\text{p}$ increases, the length of the zone of the heterogeneous condensation on the duct particles and the contribution of this process to the vapor loss increase. At the same time, the zone of the homogeneous condensation shifts toward lower temperatures and vapor concentrations and, simultaneously, toward higher degrees of supersaturation (Fig. 2). As a consequence, the number of droplets resulting from homogeneous nucleation increases

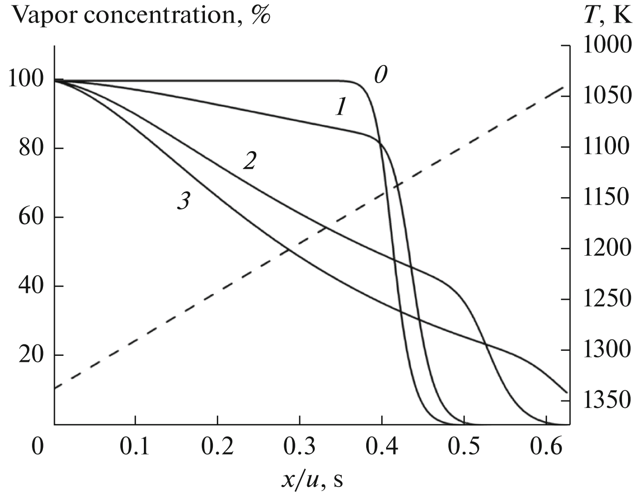

Fig. 1. Variations in vapor concentration (solid curves) and temperature (dashed curve) along the channel axis at different values of $n_p r_p$: (*0*) 0, (*1*) 250, (*2*) 1000, and (*3*) 1500.

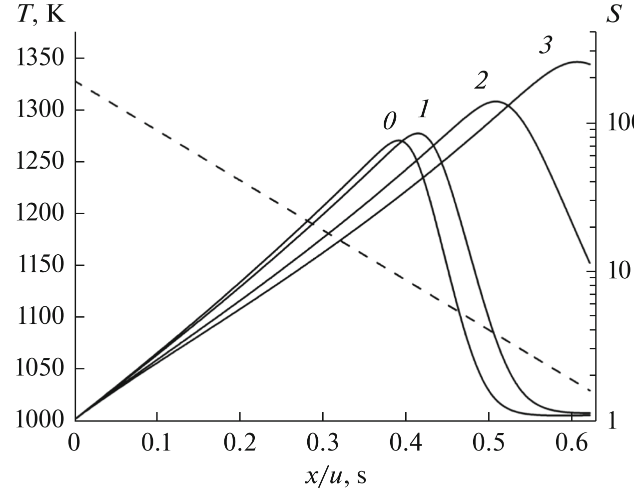

Fig. 2. Variations in the supersaturation ratio (solid curves) and temperature (dashed curve) along the channel axis at different values of $n_p r_p$: (*0*) 0, (*1*) 250, (*2*) 1000, and (*3*) 1500.

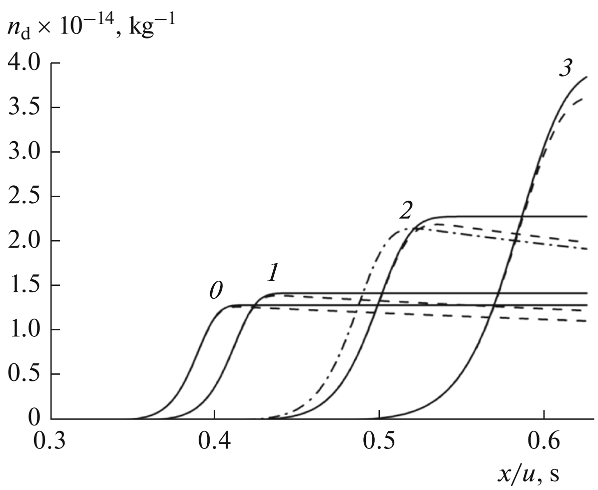

Fig. 3. Variations occurring along the channel axis in the concentrations of droplets resulting from homogeneous nucleation with no regard to coagulation (solid curves) and with regard to coagulation (only Brownian (dashed curves) and Brownian and collisional (dash–dot curves) at different values of $n_p r_p$: (*0*) 0, (*1*) 250, (*2*) 1000, and (*3*) 1500.

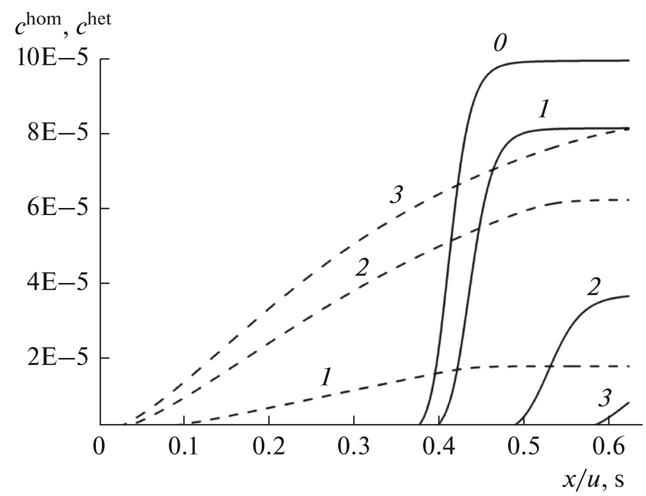

Fig. 4. Variations occurring along the channel axis in condensate mass fractions upon homogeneous (solid curves) and heterogeneous (dashed curves) condensation at different values of $n_p r_p$: (*0*) 0, (*1*) 250, (*2*) 1000, and (*3*) 1500.

(Fig. 3, solid curves) with a simultaneous decrease in their mass (Fig. 4).

The results of calculating the droplet concentration with allowance for the coagulation processes are presented in Fig. 3 by the dashed and dash-dot curves. The dashed curves represent the data of the calculations performed taking into account only the Brownian coagulation. The dash-dot curve reflects the data of the calculations carried out with account of both the Brownian coagulation and collisional coagulation at $v_{rel} = 0.1u$. At $v_{rel} = 0.01u$, the effect of the collisional coagulation is inconspicuous against the background of the Brownian coagulation. The effects of these processes are seen to be weak for both the dust-free and dusty flows.

With no account taken of coagulation processes, the droplet size distribution function normalized with respect to the number of the droplets in unit mass of the vapor–gas mixture has the pattern presented in Figs. 5 and 6. As follows from Figs. 2, 5, and 6, if the degree of supersaturation within the condensation zone decreases to values, at which the nucleation pro-

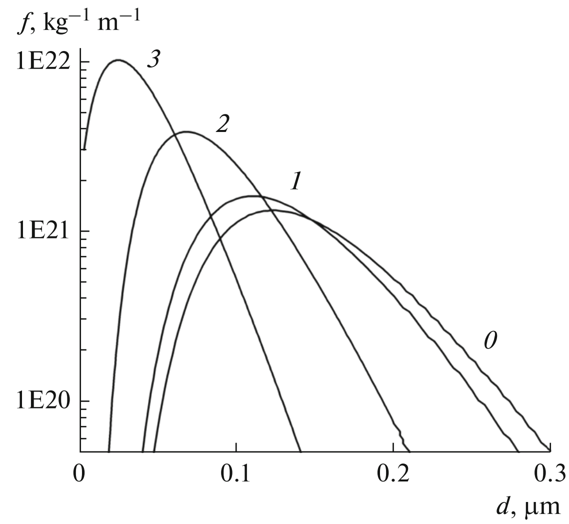

Fig. 5. Distribution functions for droplets resulting from homogeneous nucleation at different values of $n_p r_p$: (*0*) 0, (*1*) 250, (*2*) 1000, and (*3*) 1500.

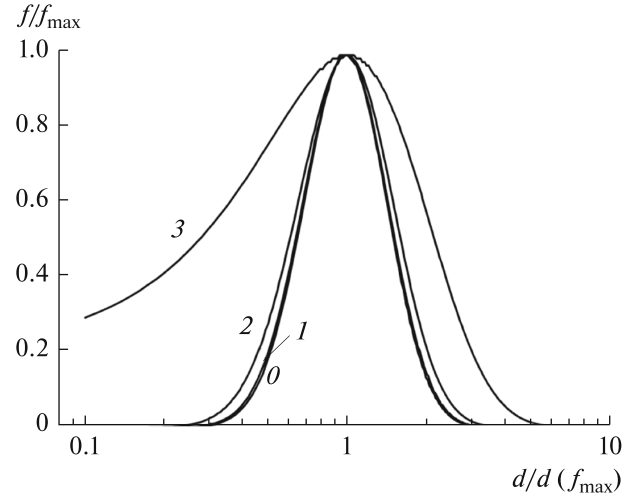

Fig. 6. Normalized distribution functions for droplets resulting from homogeneous nucleation at different values of $n_p r_p$: (*0*) 0, (*1*) 250, (*2*) 1000, and (*3*) 1500. Normalization has been performed with respect to parameters corresponding to the maxima of the curves in Fig. 5.

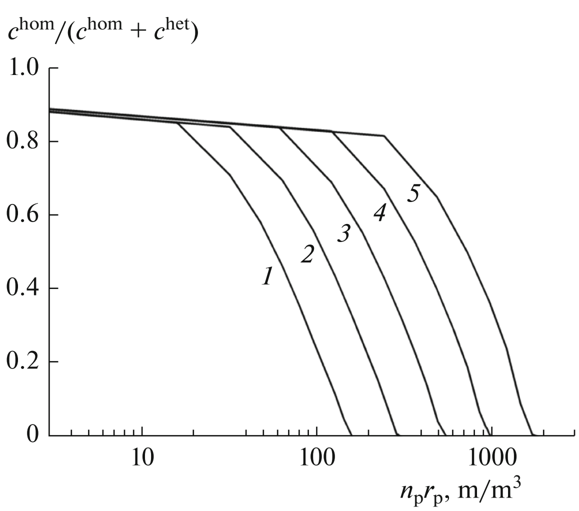

Fig. 7. Variations in the contribution of homogeneous condensation to an increase in condensate mass fraction as depending on the value of complex $n_p r_p$ at different rates of temperature variation: dT/dt = (*1*) 30, (*2*) 60, (*3*) 120, (*4*) 240, and (*5*) 480 K/s.

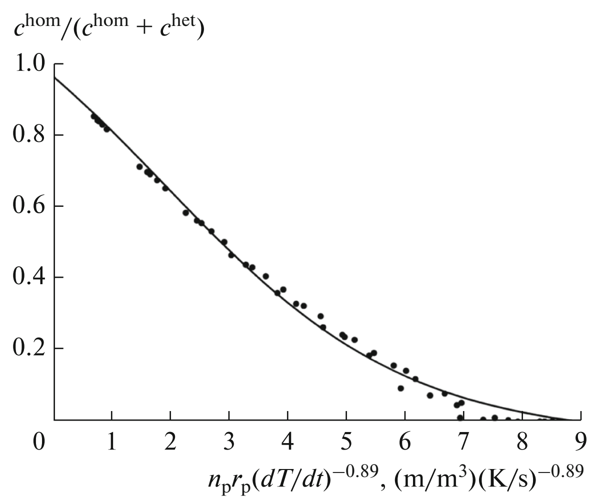

Fig. 8. Variations in the contribution of homogeneous condensation to an increase in condensate mass fraction as depending on the generalizing criterion. Symbols denote the results of the calculations at different values of parameter $n_p r_p$ and rates of temperature variation dT/dt.

cess stops, the presence of heterogeneous sites does not change the qualitative pattern of the homogeneous droplet size distribution function, which corresponds to the lognormal distribution. As can be seen in Fig. 5, an increase in parameter $n_p r_p$ leads to a shift in the distribution function maximum toward smaller droplet sizes. This agrees with the aforementioned rise in the number of the formed droplets and a reduction in their mass with an increase in parameter $n_p r_p$ (Figs. 3, 4).

Variations in the contribution of the homogeneous condensation to an increase in the mass fraction of the condensate as depending on the value of complex $n_p r_p$ at different rates of temperature variation dT/dt are shown in Fig. 7. It can be seen that, as dT/dt increases, the influence of the heterogeneous sites on the condensation process diminishes. In particular, the same reduction in the contribution of the homogeneous condensation is reached at higher values of complex $n_p r_p$.

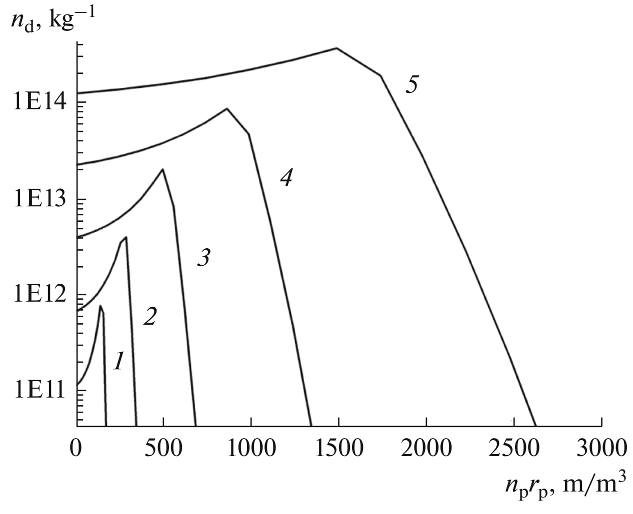

Fig. 9. Dependences of the numbers of particles resulting from homogeneous nucleation on the value of complex $n_p r_p$ at different rates of temperature variation: dT/dt = (*1*) 30, (*2*) 60, (*3*) 120, (*4*) 240, and (*5*) 480 K/s.

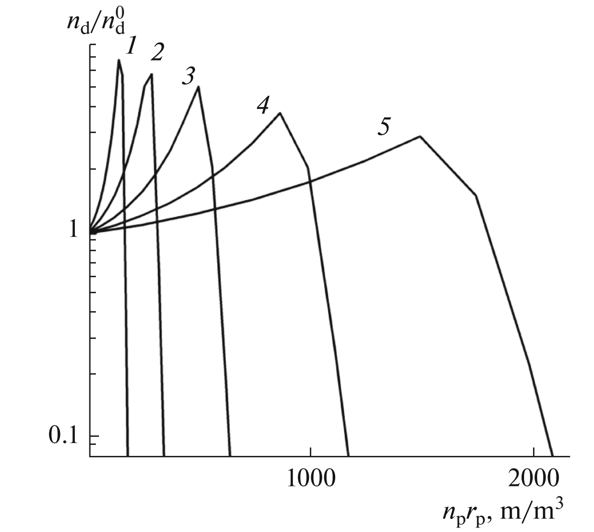

Fig. 10. Dependences of relative number of particles resulting from homogeneous nucleation on the value of $n_p r_p$ at different rates of temperature variation: dT/dt = (*1*) 30, (*2*) 60, (*3*) 120, (*4*) 240, and (*5*) 480 K/s.

The performed calculations have shown that the entire set of the calculation points, which was used to plot the curves in Fig. 7, may, with a good accuracy, be described by a dependence on parameter $\xi = n_p r_p (dT/dt)^{-0.89}$ (see Fig. 8). The experience of the calculations has shown that, at the maximum of supersaturation ratio and $n_p r_p = 0$, dc^{hom}/dx linearly depends on dT/dt. On the other hand, dc^{het}/dx linearly depends on $n_p r_p$. Hence, by its physical meaning, parameter ξ is the rate ratio between the condensation on dust particles and the homogeneous condensation at the maximum of supersaturation ratio.

The number of the droplets resulting from the homogeneous nucleation is presented in Fig. 9 as depending on the value of complex $n_p r_p$ at different rates of temperature variations dT/dt. It is seen that an increase in dT/dt leads to a rise in the number of the droplets. At each value of dT/dt, as parameter $n_p r_p$ increases to a certain limiting value, which is related to the length of the condensation zone, the number of droplets also increases due to the shift of the homogeneous condensation zone toward lower temperatures and higher supersaturation ratio (Figs. 2, 3). When the limiting $n_p r_p$ value is exceeded, the supersaturatio ratio and droplet concentration within the condensation zone decrease. For all values of dT/dt, the condensation zone was defined to be consistent with a temperature decrease of 300 K.

The effect of the heterogeneous sites on the number of formed droplets is characterized by the n_d/n_d^0 ratio, where n_d^0 is the number of droplets formed in the absence of the heterogeneous sites. The dependences of n_d/n_d^0 on the value of complex $n_p r_p$ at different rates of

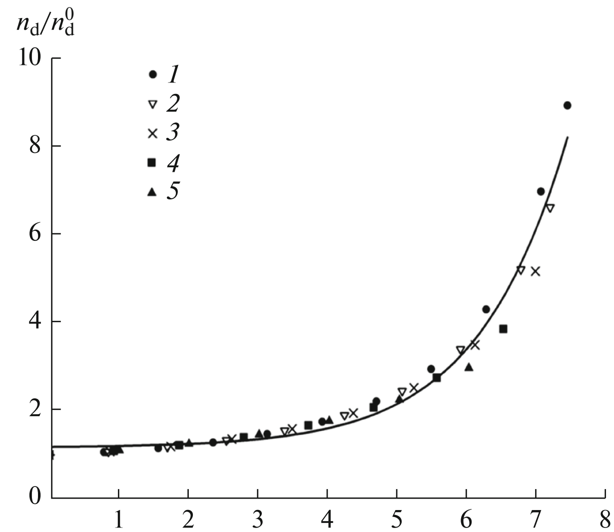

Fig. 11. Variations in relative numbers of droplets resulting from homogeneous nucleation as depending on the generalizing criterion. Symbols denote the results of the calculations at different values of parameter $n_p r_p$ and rates of temperature variation: dT/dt = (*1*) 30, (*2*) 60, (*3*) 120, (*4*) 240, and (*5*) 480 K/s.

temperature variation dT/dt are presented in Fig. 10. It should be noted that the effect of the heterogeneous sites (complex $n_p r_p$) on the number of formed droplets decreases with a rise in dT/dt. In particular, the same n_d/n_d^0 value is reached at higher values of complex $n_p r_p$.

Note that, at a substantial increase in dT/dt to values characteristic of a flow in a nozzle (~10^6 K/s), the value of n_d/n_d^0 decreases below unity [24]. In this case, the depletion of the vaporous phase at expense of the heterogeneous condensation appears to be greater than the rise in the supersaturation ratio upon the shift of the homogeneous condensation zone downstream. The use of parameter ξ enables us to represent, with a good accuracy, the data corresponding to the increasing branches of the curves in Fig. 10 by a single curve (Fig. 11).

CONCLUSIONS

In these studies, data on the parameters of submicron particles formed upon coal combustion have been obtained taking into account the effect of flow dustiness. The assumption of the ideal wettability of the heterogeneous condensation sites (dust particles) has yielded the upper estimate of their effect on the process of bulk condensation. It has been revealed that flow dustiness leads to a decrease in the mass concentration of submicron particles due to the partial condensation of vapor on the dust particles. At the same time, the number concentration of the submicron particles increases and their size decreases, and this circumstance must be taken into account when planning the trapping of such particles. The aforementioned effect depends on not only the parameters of flow dustiness, but also the rate of temperature variation in the condensation zone.

A criterion has been proposed that enables one to judge the effect of the flow dustiness on the bulk condensation process, with this criterion taking into account both the parameters of dust and the rate of temperature variation in the condensation zone. The performed assessments have shown that there is a slight effect of coagulation processes on the parameters of submicron particles resulting from coal combustion.

Possible charging of volatile ash resulting from the combustion of coal particles, which may markedly intensify the process of vapor condensation on volatile ash particles, has been beyond the scope of the discussion in this work. This circumstance requires separate consideration.

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