AN INVESTIGATION OF THE EFFECT OF THE SHAPE AND DENSITY OF SOLID PARTICLES ON THEIR MOTION IN AN ISOTHERMAL CURVILINEAR FLOW

V. E. Maslov and V. D. Lebedev

UDC 532.529.5

The results of an experimental and theoretical investigation of the motion of an aerosol with variation of its shape, density, and size are presented.

The problem of the effect of the shape and density of an aerosol on the character of its motion in a turbulent curvilinear gas flow has been inadequately studied. In particular, calculations of the motion of aerosols in a turbulent flow give rise to the following question: is it legitimate to substitute spherical particles for aerosols of irregular shape but of the same hydraulic diameter if the latter is obtained by the method of air classification in a laminar flow [1]?

The present article is devoted to a determination of the experimental paths (and subsequent comparison with the calculation) of solid particles of different shape and density. The object of investigation was a flat annular channel of diameter 1000 mm. The method of producing narrow fractions of dust and determining its experimental path are described in [2]. As an aerosol we used the dusts of cation-exchangers KU-1G and sulfonated coal (ρ = 1128 nsec^2/m^4), potassium bichromate (ρ = 2688 nsec^2/m^4), and iron (ρ = 7720 nsec^2/m^4. The shape of the particles of cation-exchanger KU-1G was spherical and the particles of the other dusts had the shape of flat irregular rectangles. The quantity of dust of potassium bichromate that settled on the sticky surface of a rod was determined by the iodometric method, iron was determined by the complexometric method of analysis, and the cation exchangers by the photometric method using the MF-4 microphotometer as the measuring device.

Calculation of the paths was performed according to [2] with consideration in the equations of motion of the complete spectrum of velocities of the dust-laden flow, which was predetermined experimentally by a five-channel sphere probe of diameter 6 mm. The investigations were carried out at a very low average-volume concentration of dust in the flow (less than 6×10^{-5} kg/m^3), which enabled us to neglect both the interaction forces between particles and the effect of the solid phase and structure of the laden flow.

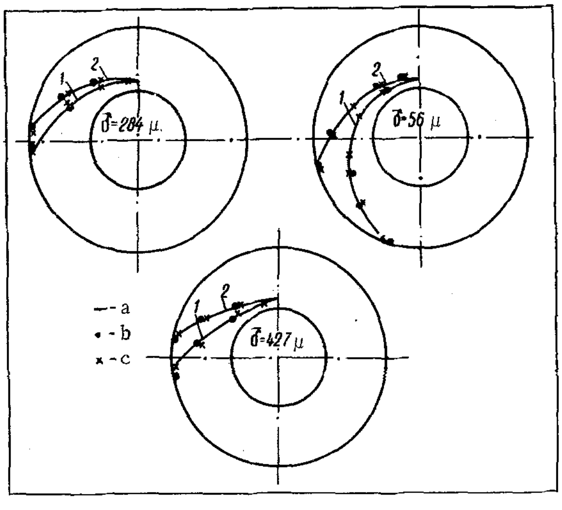

Fig. 1. Experimental (points) and calculated (curves) paths of aerosols: a) calculated paths; b) sulfonated coal; c) KU-1G; 1) V = 4.6 m/sec; 2) 17.5.

Eastern Branch, All-Union Thermal-Engineering Institute, Chelyabinsk. Translated from Inzhenerno-Fizicheskii Zhurnal, Vol. 19, No. 5, pp. 929-932, November, 1970.

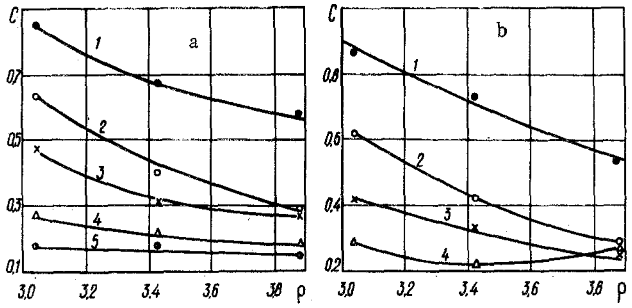

Fig. 2. Dependence of angle of aerosol separation on its density: a) $W_{\varphi_0} = 1$; b) $W_{\varphi_0} = 0$; 1) $\bar{\delta} = 16.5\ \mu$; 2) 37.5; 3) 56.0; 4) 126.5; 5) 427.

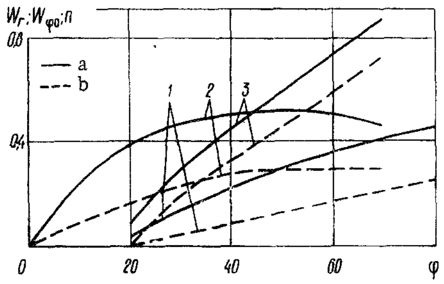

Fig. 3. Change of tangential (W_φ) and radial (W_r) velocity components of aerosol on its path: v = 17.5 m/sec; $W_{\varphi_0} = 0$. a) $\rho = 1128$ $nsec^2/m^4$; b) 7720.

In Fig. 1, the experimental (points) and calculated (lines) paths of aerosols of KU-1G and sulfonated coal (having the same density but different shape) are shown for the case of zero initial velocities of the aerosol ($W_{\varphi_0} = 0$). It is evident from Fig. 1 that for the investigated range of particle size (δ = 56–427 μ) the paths of the dusts considered practically coincide with one another and with the calculated paths. This gives a basis for the replacement of aerosols of irregular shape by spherical particles of the same hydraulic diameter in solving differential equations of motion in a turbulent curvilinear flow.

Plotting the angles of aerosol separation ($C = \varphi_s/360$) as a function of aerosol density (Fig. 2) shows that when V = 4.6 m/sec the density of the dust has a substantial effect on its motion for particles of size $\bar{\delta} \leq 56\ \mu$. With an increase of particle size ($\bar{\delta} > 56\ \mu$) the effect of density decreases, and for the case $W_{\varphi_0} = 0$ (Fig. 2b, curve 4) the function $C = f(\log \rho)$ acquires a complex character: at first an increase of density leads to a decrease of the angle of separation, but with further increase of ρ the angle of separation of the dust particles increases. The increase of the path length of dust at a greater ρ is explained by an increase of the effect of gravity which begins to prevail over forces of inertia. In connection with this, it is of interest to examine the character of the change of the tangential (W_φ) and radial (W_r) velocity components of aerosol on its path, as taken from calculation. For this purpose we plotted in Fig. 3 the relations $W_\varphi = f(\varphi)$ (curve 2), $W_r = f(\varphi)$ (1), and $n = W_r/W_\varphi$ (3) for zero initial velocities of the dust particles.

It is known that when comparing two paths of dust the shorter is that which has a greater ratio of the radial component of the particle velocity to its tangential component.

A comparison of the paths with $\bar{\delta} = 427\ \mu$ for aerosol densities $\rho = 1128\ nsec^2/m^4$ and $\rho = 7720\ nsec^2/m^4$ shows that even with relatively high flow velocities (V = 17.5 m/sec) the ratio W_r/W_φ is less for the greater aerosol density. With a smaller flow velocity the effect of density on the motion of the aerosol increases still more. This circumstance can apparently explain the fact that in a theoretical investigation [3] the authors obtained an extreme dependence of the particle separation time in a melting chamber on the density of the material used.

NOTATION

ρ, $\bar{\delta}$ are the density and average size of aerosol obtained by the air classification method;
V is the velocity of dust-laden flow;

$W_{\varphi_0} = W_\varphi / V$ is the relative initial velocity of aerosol;

W_φ is the initial velocity of aerosol;

$C = \varphi_S/360$ is the relative angle of aerosol separation;

φ_S is the angle characterizing point of impact of aerosol on outside wall of channel.

LITERATURE CITED

1. V. I. Ignat'ev and N. I. Zverev, Teploenergetika, No. 2 (1960).
2. V. E. Maslov, V. D. Lebedev, and S. G. Ushakov, Inzh.-Fiz. Zh., 15, No. 3 (1968).
3. V. A. Emel'yanov, V. N. Kuz'min, and A. D. Klyuchnikov, Izv. VUZ. Energetika, No. 2 (1963); No. 7 (1964); No. 4 (1966).