DISPERSION OF A HEAVY ADMIXTURE IN A TWO-PHASE JET

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The article presents experimental data on the distribution of finely-divided powder in the cross sections of a turbulent axisymmetric jet and a qualitative analysis of the experimental data, and the possibility of their generalization is shown.

Problems of the distribution of heavy particles within a jet are of interest for various technical applications of the jet process (coal-pulverizing jet, jet method of melting metals, atomization of powdered materials). The dispersion of heavy particles in a jet depends, in particular, on their aerodynamic size. Polydispersed powders of the most diverse composition and specific weight are used in practice. Therefore, it is expedient to study the regularities of dispersion on several finely-divided powders of considerably different size.

The article presents data on the dispersion of electrolytically produced corundum powder in a two-phase jet, whose fractional composition was as follows: particles $\delta > 63\ \mu\text{m}$, 4% by weight; $\delta = 40\text{-}50\ \mu\text{m}$, 47.9%; $\delta = 40\text{-}63\ \mu\text{m}$, 84.5%; $\delta < 40\ \mu\text{m}$, 11.5%. The density of the material was $\rho = 3950\ \text{kg/m}^3$. By a two-phase jet we mean a mixture of a powdered heavy admixture with air flowing from a long horizontal pipe ($d_0 = 35$ mm) under conditions of complete acceleration of the admixture.

The flow rates of the heavy admixture and velocities of the carrier phase in the jet were measured by isokinetic suction tubes (Fig. 1). An air flow is created in the 2 mm diameter tube 1 by means of vacuum cleaner 5. The suction is regulated by valve 4 so that the velocity in tube 1 is equal to the velocity of the oncoming flow. In this case the overpressure, sensed by indicator tube 2 and regulated by micromanometer 3, is equal to zero. Isokinetic sampling of the powder-laden flow, which is cleaned of the admixture in a settling tank with a filter 6, is thereby accomplished. The quantity of the heavy admixture is determined by weighing, and the purified gases are sucked through rotameter 7. The velocity of the oncoming flow is determined by the measured flow rates and calibration data.

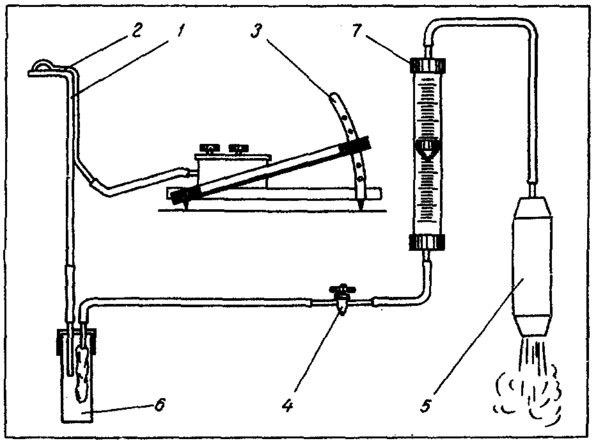

Fig. 1. Scheme of measurements.

The fields of the velocities and flow rates of the heavy admixture were measured at discharge velocities $u_{0m} = 29\text{-}60$ m/sec and mean-flow-rate initial concentrations $\varkappa_0 = 0\text{-}3.0$ g admixture/g air.

Figure 2 shows the fields of the specific flow rates of the heavy admixture g_a in cross sections located at various distances x from the nozzle end face. For a characteristic of the boundaries of the jet, the same figure shows the velocity fields of the air in the same sections. We can determine from the figure that the heavy particles are carried weakly to the peripheral regions of the jet.

It is known that in a gas–air jet the ratio of the rates of transport of the admixture and the momentum

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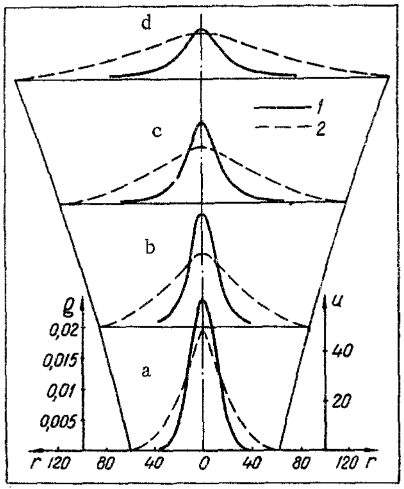

Fig. 2. Fields of specific flow rates of heavy admixture (g, g/sec · mm²) and velocities (u, m/sec) in cross sections of jet (u_{0m} = 54.5 m/sec; $\varkappa_0$ = 0.4 g/g): 1) specific flow rates; 2) velocities; a) x = 200 mm; b) 400; c) 600; d) 800.

remains constant in all cross sections, and the profile of the relative flow rate is wider than the profile of the relative momentum-flux density in each cross section. In a two-phase jet there are rather extended portions where the profile of the relative flow rate is narrower and decay of the axial flow rate occurs more slowly than that of the axial momentum (Fig. 3). And only sufficiently far from the nozzle end face, as the admixture disperses, does the position of the profiles become the same as in a jet containing a gaseous admixture.

Thus the experiments showed that the transport of the heavy admixture differs from transport of a gaseous admixture not only quantitatively but also qualitatively.

The fields of specific flow rates, shown in Fig. 2, are generalized well in coordinates $g/g_m = f(r/r_{0.5g_m})$ (Fig. 4), but the similarity occurs slightly farther from the nozzle end face ($x \simeq 8d_0$) than for the usual jet fields.

It was originally supposed that the shape of the universal profile should depend on the initial concentration $\varkappa_0$, which determines the development and expansion of the jet, and also on the initial discharge velocity u_{0m}, which determines the inertia of the particles. The initial concentration has a noticeable effect on the dispersion of the heavy admixture: with an increase of $\varkappa_0$ the fields of the specific flow rates in the cross sections narrow considerably, and the similarity occurs even farther from the nozzle end face. However, in the indicated coordinates the experimental points lie on the universal profile for all investigated values of $\varkappa_0$ (the experimental points are given in Fig. 4 for $\varkappa_0$ = 0.8 g/g). In the case of large loads of the flow with the admixture the similarity occurs at a distance of the order of 20 d_0, which explains the deviation of the points in Fig. 4 for $\varkappa_0$ = 3 g/g. It was not possible to reveal differences in the shape of the universal profile by changing the initial velocity u_{0m} within the limits indicated above.

The profile of the specific flow rate of the heavy admixture can be approximated by the function

$$g/g_m = \exp\left[-0.7\,(r/r_{0.5g_m})^{1.33}\right]. \tag{1}$$

From the condition of conservation of mass of the admixture and with consideration of similarity (Eq. (10)), we can easily obtain the formula for determining the decay of the axial specific flow rate of the admixture in the main portion of the jet:

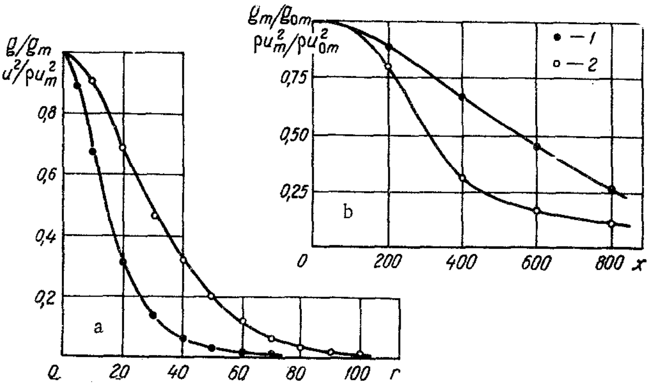

Fig. 3. Relative field of specific flow rate of heavy admixture and momentum flux in cross section of jet (a) and decay of axial flow rate and momentum over the length of the jet (b): 1) axial specific flow rate; 2) axial momentum.

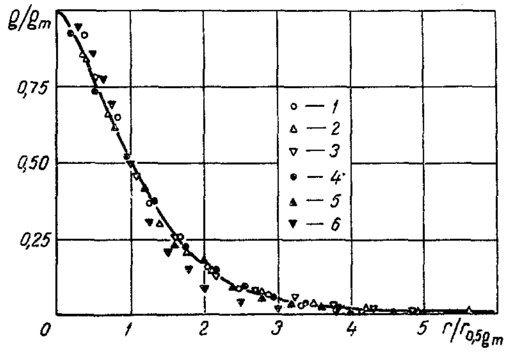

Fig. 4. Profile of specific flow rate of heavy admixture: 1) x = 0.4 m, $\varkappa_0 = 0.4$ g/g; 2) 0.6 and 0.4; 3) 0.8 and 0.4; 4) 0.6 and 0.8; 5) 0.8 and 0.8; 6) 0.6 and 3.

$$\frac{g_m}{G_0} = \frac{1}{2\pi r^2_{0.5g_m}\int\limits_0^{\xi_{bo}} f(\xi)\,\xi d\xi} = \frac{1}{7.5 r^2_{0.5g_m}}. \tag{2}$$

The fact of a universal character of the distribution of a heavy admixture in the cross sections of a jet together with the data on expansion $r_{0.5g_m} = f(x, \varkappa_0)$ gives us hope for the possibility of calculating the dispersion of a heavy admixture in a turbulent jet. For this purpose we must accumulate experimental data on the dispersion of a heavy admixture of different sizes.

NOTATION

δ	is the particle size;
x	is the distance from the nozzle end face;
r	is the distance from the axis of the jet;
d_0	is the diameter of the tube (nozzle);
$r_{0.5g_m}$	is the distance from the axis of the jet to the point where the specific flow rate is half of the axial flow rate;
g	is the specific flow rate of the heavy admixture, g/sec · mm^2;
g_m	is the specific flow rate on the axis of the jet;
g_{0m}	is the maximum specific flow rate at the nozzle exit;
G_0	is the initial flow rate of the heavy admixture, g/sec;
$\varkappa_0$	is the mean-flow-rate initial concentration, g admixture/g air;

$\xi = r/r_{0.5g_m}$;

$\xi_b = R/r_{0.5g_m}$;

R	is the distance from the axis to the boundary of the jet.

LITERATURE CITED

1. G. N. Abramovich, Theory of Turbulent Jets [in Russian], Fizmatgiz (1960).
2. M. K. Laats, Inzh.-Fiz. Zh., 10, No. 1, 11-15 (1966).