DISPERSION OF AN INERTIA MIXTURE OF VARYING SIZE IN A TWO-PHASE AXISYMMETRICAL STREAM

M. K. Laats and F. A. Frishman

UDC 532.529.5

Experimental data on the dispersion of a powdered mixture of varying size in an axisymmetrical turbulent stream are described.

Data about the dispersion of a narrow fraction range electrocorundum powder with a characteristic dimension of $\delta_x = 49\ \mu$ in an axisymmetrical turbulent stream are given in [1]. It is evident that the dispersion of a mixture must depend on its aerodynamic size, which determines the inertia of the particles, and their relative velocity in smoothened and in pulsating movements. The mechanisms of dispersion were therefore again investigated for several similar powders of varying coarseness. The fraction composition of these powders can be established from the sizing curves (Fig. 1). The experimental apparatus and the method of measurement are described in [1].

Figure 2a gives the profiles of relative specific discharges of an inertia mixture in the cross section $x/r_0 = 34.3$. These characterize the progress of the mixture up to a given cross section; the greater the nonuniformity of these profiles, the better the finer part of the mixture succeeds in dispersing in a lateral direction. Curves 1, 2, and 3 characterize the distribution of mixture No. 32 (the number of the powder indicates its characteristic dimension) at different initial concentrations. With increase in the initial concentration the profiles of the relative discharge are noticeably contracted: the nonuniformity of distribution of the mixture in the lateral cross sections of the stream increases. This characteristic of the distribution is maintained qualitatively for all the cross sections along the length of the stream (curves 1, 2, and 3 in Fig. 2b). It cannot be explained only by the special features of the initial distribution of the mixture, since with increase of $\varkappa_0$ the initial nonuniformity of the profiles of the relative discharge increases negligibly (for mixture No. 32, $\varkappa_0 = 0.3$, 0.56, and 0.77, $g_{0m}/g_{0av} = 1.52$, 1.57, and 1.6, respectively). Consequently, with increase of the initial concentration, the dispersion of the mixture slows down. This can be explained partly by the fact that the stream of varying density expands more slowly than the conventional stream [2], and also by the decrease in the intensity of turbulence under the influence of the particles.

It was assumed originally that the dispersion of a mixture in a stream must depend on the initial discharge speed, since this, according to the data of [3], determines the relative speed of movement of the particles. Experiments have shown that in the whole range of variation of the initial speed ($u_{0m} = 29$-60 m/sec) the distribution of the mixture and the damping of the discharge over the length of the stream do not vary, i.e., the same initial concentration produces the same dispersion.

In order to investigate the mechanisms of dispersion of a mixture of different aerodynamic size, the distribution of different powders in lateral cross sections of a stream with the same initial concentration $\varkappa_0 = 0.3$ was measured. The relationship between the speed of dispersion of the mixture and its size at different sections of the stream is not the same. Near the nozzle the nonuniformity of distribution increases with decrease in the coarseness of the mixtures (curves 5, 4, and 1 in Fig. 2a). This experimental fact also cannot be explained by an initial distribution; the initial nonuniformity, on the other hand, decreases with decrease in the coarseness of the mixture ($g_{0m}/g_{av} = 1.60$, 1.56, 1.52, and 1.3 for mixture No. 80, 72, 32, and 17, respectively). Consequently, a fine mixture near to the nozzle is dispersed more slowly. Since the intensity of turbulent transfer must increase with decrease of the size of the

Institute of Thermophysics and Electrophysics, Academy of Sciences of the Estonian SSR, Tallinn.
Translated from Inzhenerno-Fizicheskii Zhurnal, Vol. 18, No. 4, pp. 643-647, April, 1970. Original article submitted June 25, 1969.

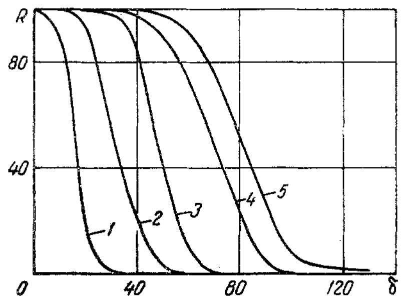

Fig. 1

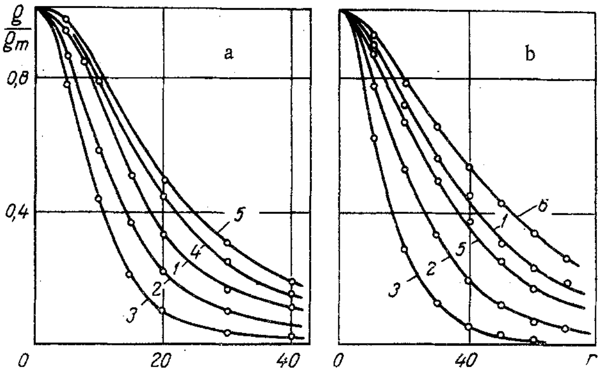

Fig. 2

Fig. 1. Sizing curves (R, %; δ, μ): 1) No. 17; 2) No. 32; 3) No. 49; 4) No. 72; 5) No. 80.

Fig. 2. Distribution of a mixture in the lateral cross section of a stream (a) $x/r_0 = 22.8$; b) $x/r_0 = 57.1$; r, mm): 1) No. 32, $\varkappa_0 = 0.3$; 2) No. 32, $\varkappa_0 = 0.77$; 3) No. 32, $\varkappa_0 = 1.4$; 4) No. 72, $\varkappa_0 = 0.3$; 5) No. 80, $\varkappa_0 = 0.3$; 6) No. 17, $\varkappa_0 = 0.3$.

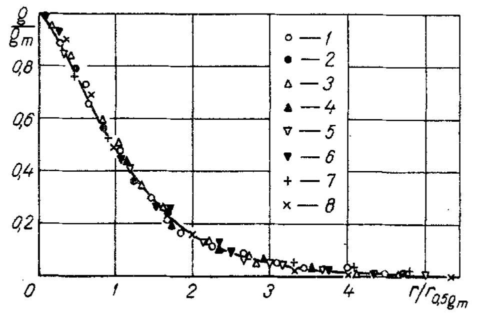

Fig. 3

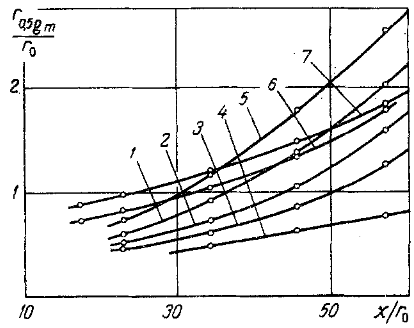

Fig. 4

Fig. 3. Profile of the specific discharges of the mixture: 1) No. 17, $\varkappa_0 = 0.3$, $x/r_0 = 22.8$; 2) No. 17, $\varkappa_0 = 0.3$, $x/r_0 = 57.1$; 3) No. 32, $\varkappa_0 = 1.4$, $x/r_0 = 45.6$; 4) No. 32, $\varkappa_0 = 0.56$, $x/r_0 = 34.3$; 5) No. 49, $\varkappa_0 = 0.4$, $x/r_0 = 34.3$; 6) No. 80, $\varkappa_0 = 0.3$, $x/r_0 = 17.1$; 7) No. 80, $\varkappa_0 = 0.8$, $x/r_0 = 45.6$; 8) No. 72, $\varkappa_0 = 0.3$, $x/r_0 = 34.3$.

Fig. 4. Lines of half discharges: 1) No. 32, $\varkappa_0 = 0.3$; 2) No. 32, $\varkappa_0 = 0.56$; 3) No. 32, $\varkappa_0 = 0.77$; 4) No. 32, $\varkappa_0 = 1.4$; 5) No. 17, $\varkappa_0 = 0.3$; 6) No. 72, $\varkappa_0 = 0.3$; 7) No. 80, $\varkappa_0 = 0.3$

particles, then such an unnatural dispersion procedure can be explained either by the influence of the mixture on the turbulence of the stream, which is greater, the finer the mixture, or by the fact that on the section close to the nozzle, apart from the turbulent transfer, a certain factor, which causes a concentration of the mixture in the areas near the axis has an influence in the direction of the concentration and velocity gradients.

With increasing distance from the nozzle, the dispersion rate of a fine mixture increases more rapidly than a coarse mixture, and in the final result, the arrangement of the profiles of the relative discharge in the distant cross sections becomes natural, which indicates a more intensive resultant dispersion of a fine mixture (curves 5, 1, and 6 in Fig. 2b).

In spite of the special features of dispersion of an inertia mixture indicated above, its distribution in lateral cross sections of the main part of the stream ($x/r_0 > 20$) has a universal character. The profiles of the relative discharges of the mixture independently of its coarseness, and initial concentration are satisfactorily generalized in the coordinates $g/g_m = f(r/r_{0.5g_m})$ (Fig. 3), and they are approximated with sufficient accuracy by the function

$$g/g_m = \exp\left[-0.69\,(r/r_{0,5g_m})^{1.33}\right].$$

The intensity of dispersion of the mixture along the length of the stream, in the case of similarity, is characterized by lines of constant values of the relative discharge, for example, half discharge ($r_{0.5g_m}/r_0 = f(x/r_0;\ \varkappa_0;\ \delta)$), given in Fig. 4. It is seen from the arrangement of these lines that with increasing

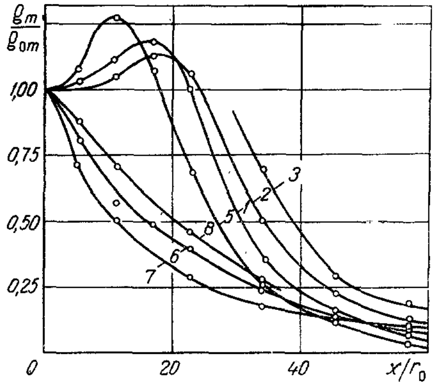

Fig. 5. Damping of the axial specific discharge: 1) No. 32, $\varkappa_0 = 0.3$; 2) No. 32, $\varkappa_0 = 0.56$; 3) No. 32, $\varkappa_0 = 0.77$; 5) No. 17, $\varkappa_0 = 0.3$; 6) No. 72, $\varkappa_0 = 0.3$; 7) No. 80, $\varkappa_0 = 0.3$; 8) No. 49, $\varkappa_0 = 0.3$.

distance from the nozzle, the intensity of dispersion $dr_{0.5g_m}/dx$) increases, attempting to reach a certain constant value; this occurs all the more rapidly, the finer the mixture. With increase of the initial concentration of the mixture the dispersion slows down (curves 1, 2, 3, and 4), but the nature of its relationship with the coarseness is maintained (curves 5, 1, 6, and 7).

By using the law of conservation of the mass of the mixture in lateral cross sections of the stream

$$G = g_m \int_0^F g/g_m dF = \text{const}$$

and the fact of similarity of the field of the relative discharge, it is possible to connect the damping of the axial specific discharge with the half radius

$$\bar{g}_m = \frac{g_m}{g_{0m}} = \frac{\pi}{7.5} n_g \frac{1}{r^2_{0.5g_m}},$$

where n_g is the coefficient of nonuniformity of the initial profile of the discharge. It decreases with increase of the initial concentration of the mixture, and with increase of the size of the particles. In the investigated range of variation $\varkappa_0 = 0.1$–2 kg/kg and $\delta = 17$–$80\ \mu$, $n_g = g_{0av}/g_{0m} = 0.6$–$0.75$. For calculation it is necessary to connect the intensity of dispersion ($dr_{0.5g_m}/dx$) with parameters which determine the dispersion. The initial concentration, for example, has a considerable influence on the dispersion of the mixture, but curves 1, 2, 3, and 4 in Fig. 4 are nonequidistant. This indicates that the dispersion of a mixture of a given size is determined not by the initial concentration, but by certain parameters depending on it, which are characteristic of a given cross section. Such parameters can be the axial or other characteristic concentration, the relative speed of movement of the particles, etc. Information about the growth of the stream is necessary in order to establish these.

Near the nozzle where there is no flow similarity, the dispersion of the mixture can be characterized by the damping curves of the axial specific discharge (Fig. 5) (on the section of flow similarity they correspond fully with the variation of the lines of the half discharge). The experimental data show that the mixture is dispersed here more slowly the finer the mixture, and for a fine mixture even an unusual increase of the axial specific discharge is observed with increasing distance from the nozzle (curves 1, 2, and 5). It is possible to suppose that it is connected with rotation of the particles in a gradient flow. The angular velocity $\omega \approx du/dr = 2000$–$3000\ \text{sec}^{-1}$ calculated by taking this hypothesis into account corresponds in order of magnitude with observations [3]. If it is assumed that the rotation of the particles has a direction determined by the gradient, then in certain layers of the stream the occurrence of a lifting aerodynamic force directed to its axis is possible. In order to substantiate the effect of this factor, additional research on the movement of particles in the stream is necessary.

Hence for more or less full understanding of the dispersion process of an inertia mixture in a stream, it is necessary to connect the special features of dispersion of the mixture with the special features of the growth of the two-phase stream.

NOTATION

x is the distance from the nozzle edge;
r_0 is the radius of the nozzle;
r is the flow radius;
g is the specific discharge of the mixture (kg/sec · m²);
$\varkappa$ is the concentration of the mixture (kg mixture/kg air);
u is the velocity of the air phase;
δ is the dimension of the particles.

Subscripts

0 is the initial value;
m is the axial value;

$0m$ is the maximum value on the outlet from the nozzle;

$0av$ is the mean-discharge initial value;

$r_{0.5g_m}$ is the distance from the axis to the point with half discharge.

LITERATURE CITED

1. Yu. Ivanov, M. Laats, and F. Frishman, Inzh.-Fiz. Zh., 18, No. 3 (1970).
2. G. N. Abramovich, The Theory of Turbulent Streams [in Russian], Fizmatgiz, Moscow (1960).
3. A. P. Chernov, Izv. Akad. Nauk KazSSR, Énergiya Series, No. 3 (1955).