PARTICLE SIZE DISTRIBUTION IN VARIOUS ZONES OF A SPRAY JET

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UDC 541.182.2.3

The results of an investigation of the size distribution of particles suspended at various points in an axisymmetric spray jet are presented.

Despite that extensive use of various forms of sprayers in modern technology, many processes occurring in their jets are still not clear. In particular, the kinetics of particle growth and breakup in various jet zones is not clear. In earlier experiments, groups of particles were introduced into the flow [1], which significantly distorted the aerodynamics of the flow and which would lead to considerable change in the local parameters of the distribution function of the particles in the suspension.

We used the so-called small-angle method [2, 3] to determine the parameters of the distribution function. This method, which is based on measurements at small angles of the curve for light scattering by the particles, introduces no distortions in the flow and allows one to obtain directly the particle size

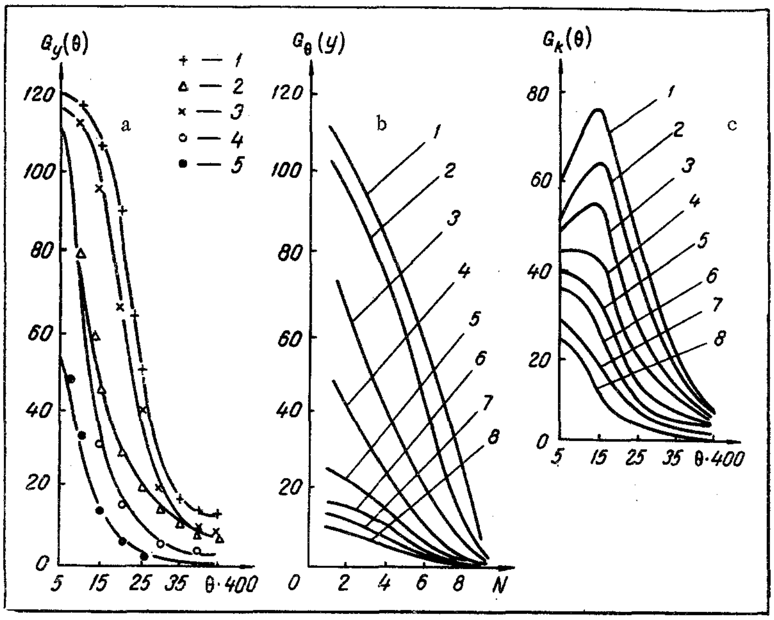

Fig. 1. Distribution of intensity of light scattered by jet spray as a function of: a) scattering angle for rays passing at different distances from the jet axis; b) distance from jet axis for various scattering angles (N is zone number); c) scattering angle for various jet zones (1-8) after conversion in accordance with Eq. (1). a: 1) y = 0; 2) y = 10; 3) y = 20; 4) y = 30; 5) y = 40 mm; b: 1) $\theta = 1°30'$; 2) $\theta = 2°15'$; 3) $\theta = 3°$; 4) $\theta = 3°45'$; 5) $\theta = 4°30'$; 6) $\theta = 5°15'$; 7) $\theta = 6°$; 8) $\theta = 6°45'$; θ, rad.

Institute of Physicotechnical and Radiotechnical Measurements, Moscow. Translated from Inzhenerno-Fizicheskii Zhurnal, Vol. 18, No. 1, pp. 105-109, January, 1970. Original article submitted January 24, 1969.

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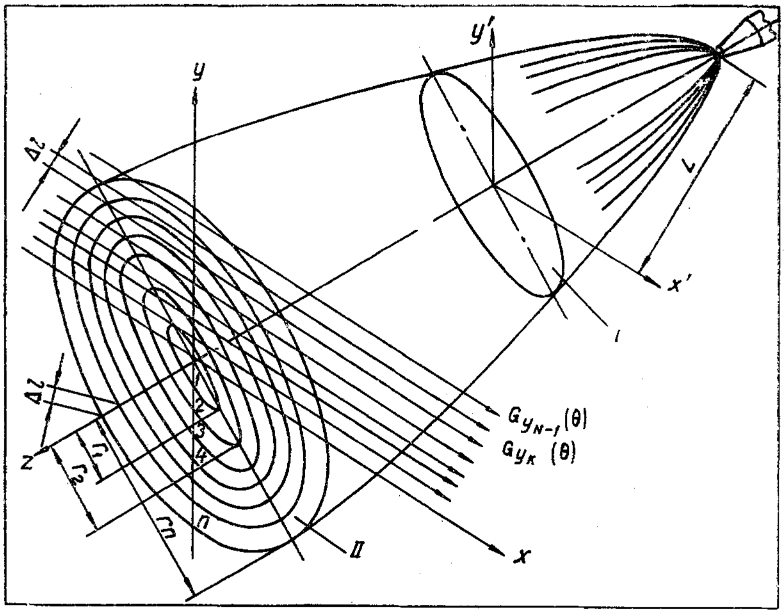

Fig. 2. Scheme for subdivision of jet regions into annular zones (I and II are the planes in which measurements were made. L is the distance from nozzle tip to the particular plane. 1, 2, 3, n are numbers of jet zones).

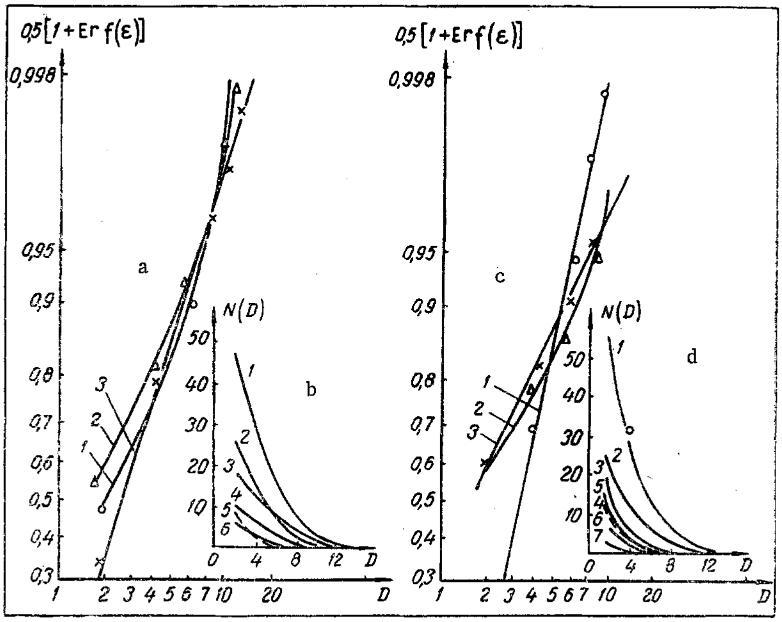

Fig. 3. Particle size distribution for various jet zones on linear (b, d) and log-normal (a, c) scales (Erf(ε), Kramp function of D): a: 1) k = 1; 2) k = 2; 3) k = 3; b: 1) k = 1; 2) k = 2; 3) k = 3; 4) k = 4; 5) k = 5; 6) k = 6; c: 1) k = 1; 2) k = 2; 3) k = 3; d: 1) k = 1; 2) k = 2; 3) k = 3; 4) k = 4; 5) k = 5; 6) k = 6; 7) k = 7; for a) and b), L = 40 mm; for c) and d), L = 80 mm. D in μ.

distribution function with averaging taking place over a considerable set of particles. It is shown below that this method can be used to determine the distribution function in a comparatively small annular zone. The experiments were performed on the apparatus described in [5]. We used as a sprayer a pneumatic jet with air and liquid nozzle diameters of 2.6 and 4 mm respectively. When spraying water, the air pressure was 0.7 atm. The intensity $G_y(\theta)$ of the scattered light was found experimentally as a function of the scattering angle θ at various distances y from the axis of the jet (Fig. 1a); the relative location of jet, coordinate axes, and planes in which measurements were made is clear from Fig. 2.

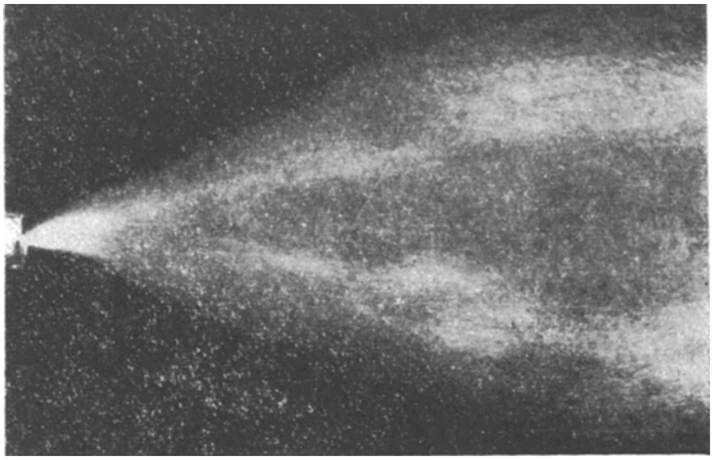

Fig. 4. Pulse photograph of spray jet.

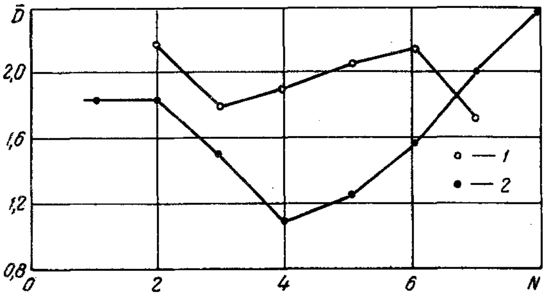

Fig. 5. Median particle diameter, $\bar{D}$, for various jet zones (N is zone number). 1) L = 40 mm; 2) L = 80 mm. D in μ.

In the general case, a ray passes through various zones in the jet and the resultant curve is an average over these zones. To determine the local value of the distribution function, it is necessary to find the quantity $G(\theta)$ related to some one zone. The jet can be considered axisymmetric at small distances from the nozzle; one can therefore use an Abelian transform [6]. In doing this, the family $G_\theta(y)$ (y is the argument and θ a parameter) is determined from the family $G_y(\theta)$ (θ is the argument and y the parameter). In addition, the jet is subdivided into n annular zones (Fig. 2) such that $r_k < r_{k+1} \ll r_n$, where r_k is the radius of the zone numbered k and $0 \leq k \leq n-1$. It is usually assumed that the desired function is constant within an annular zone; in our case, the relative error would then be 15-20%. The transformations used later on are sensitive to small deviations in the quantity $G_k(\theta)$ and the resulting error becomes even larger. It is therefore assumed that the intensity of scattered radiation varies linearly within each zone. In this case, the equation for the Abelian transformation has the form

$$G_\theta(k) = \frac{2}{\pi\Delta l}\sum_{k=1}^{n-1}\frac{G_\theta(k+1)-G_\theta(k)}{[(k+1)^2-i^2]^{1/2}+(k^2-i^2)^{1/2}}, \qquad (1)$$
$$0 \leqslant i \leqslant k, \quad y = k\Delta l, \quad R = n\Delta l,$$

where Δl is the size of a jet subdivision, which was 5 mm in our experiments; R is the radius of the jet; and $G_\theta(k)$ is the intensity of the light scattered at an angle θ as a function of the zone number k.

With equal mean square errors σ for all measurements along chords of the jet, the resultant error ε_k in the determination of the intensity of radiation scattered at a given angle in the k-th zone will be

$$\varepsilon_k = \frac{2\sqrt{2\sigma}}{\pi(2k+1)^{1/2}}.$$

In our case, ε_k was less than 3-4%.

The functions $G_\theta(k)$ obtained from Eq. (1) were replotted as $G_k(\theta)$. The family of $G_k(\theta)$ curves for zones 1-8 are shown in Fig. 1c. The particle size spectra were determined by the equation proposed in [3]

$$N(\rho)\rho^2 = c\int_0^\infty \frac{d[\theta^3 G_k(\theta)]}{d\theta}\,\frac{J_1(\rho\theta)Y(\rho\theta)}{k^2(\rho,\ m)}\,\rho\theta d\theta,$$

where c is a constant; $N(\rho)$ is the size distribution function; ρ is a diffraction parameter, $\rho = \pi D/\lambda$; D is the particle diameter; λ is wavelength; $J_1(\rho\theta)$ and $Y(\rho\theta)$ are Bessel functions of first and second order respectively; $k(\rho, m)$ is the effective particle cross section and m is the index of refraction.

The particle size distribution in the various zones of the jet is shown in Fig. 3. It is clear that particle concentration is greater near the axis of the jet and the dispersion of the distribution increases toward the periphery. Considerable turbulence arises at the boundary of the jet (this is also clear from Fig. 4) and the indicated behavior is not realized. The average particle diameter 40 mm from the nozzle tip is in the range 2.2-4 μ; at 80 mm, it is in the range 2.9-3.8 μ.

The particle size distribution was also measured in an axial section of the jet at various distances from the nozzle tip. The spectra obtained are satisfactorily described by the log-normal law. At small distances from the end of the nozzle (out to 40 mm), the particle density distribution is approximately identical; the average dimension then increases (in the range 40-100 mm) and finally falls with a further increase in distance (Fig. 5). The mass flow rate along various zones of the jet is described by a more complex behavior that proposed in [1] which is evidently associated with the considerable increase in turbulence at the periphery of a free jet.

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