LASER DOPPLER METER FOR MEASURING PARTICLE SIZE

V. M. Zakharov, G. M. Krouchenitsky and V. E. Rokotyan
Hydrometeorological Service of the USSR, Moscow, USSR

ABSTRACT

The report is devoted to the study of the applicability of a laser Doppler velocimeter to the determination of aerosol spherical particles size within the range corresponding to meteorological atmosphere.

I. The relation between particle size and particle velocity distribution in a steady homogeneous isotropic gas flow.

The momentary value of particle velocity is close to that of flow velocity in the point of particle location, that is why the equation of particle motion can be written on the basis of Stokes' law. When flow velocities are low in comparison with the sonic speed, the mean particle velocity coincides with the mean flow velocity, while the velocity dispersion of particles with the radius a is related to the flow velocity dispersion as

$$\sigma^2 = \sigma_0^2 + \frac{2}{3}\varepsilon\tau \qquad (1)$$

where ε is the power transforming into heat per unit mass of gas; $\tau = \frac{2a^2d}{9\eta}$ the particle temporal constant; d the particle density; η the viscosity of gas.

The assumption concerning a Gaussian velocity distribution of monodisperse particles in a flow allows to write an integral equation for the function of $n(\tau)$ distribution:

$$\int_0^\infty \frac{\{\exp[-u^2(\sigma_0^2 + \frac{2}{3}\varepsilon\tau)^{-1}]\}n(\tau)d\tau}{(\sigma_0^2 + \frac{2}{3}\varepsilon\tau)^{1/2}} = \sqrt{2\pi}\, f(u) \qquad (2)$$

where $f(u)$ is the function of the distribution by the deviations from the mean velocity measured by a laser Doppler velocimeter. By $f(u)$ behaviour around zero one can estimate σ_0 and $\varepsilon\bar{\tau}$, where $\bar{\tau}$ is the mean τ value. Thus, a numerical solution of Eq. (2) defines $n(\tau)$ function at an arbitrary choise of an argument scale. It is shown that the above method is applicable to particle sizes of 4 μ up to 40 μ.

II. The relation of a Doppler signal spectrum with particle size conditioned by particle thermal movement.

The estimated values show that laser Doppler velocimeter is sensitive to the microstructure of Brownian particle movement, i.e. the effect of averaging thermal movement per one light wave vibration is negligible and one can make use of Maxwell's function of the distribution by angular and linear velocities. Doppler signal spectrum for a single particle satisfies the ratio

$$\frac{E''(f_0)}{E(f_0)} = -\sqrt{\frac{2}{7}}\,\frac{2\pi da^3}{3kTb^2} \qquad (3)$$

where E is the spectral density; f_0 the frequency corresponding to E(f) maximum; k Boltzmann's constant; T the absolute temperature; b the proportionality factor expressing the relation between the frequency shift and velocity. It is shown that the method is applicable to particle sizes less than 1 μ.