A LASER-TYPE ANEMOMETER FOR MEASURING THE VELOCITIES OF AIR STREAMS

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A laser-type anemometer is described which measures the mean velocity and velocity fluctuations in turbulent streams.

Laser methods, especially those based on the analysis of Doppler signals generated when light is scattered by particles in motion [1, 2, 3], rank highly among the various method of determining the velocities of gas streams.

Such a laser anemometer will be described here and the results of velocity measurements (mean velocity and velocity fluctuations) in a free turbulent jet will be shown.

The basic schematic diagram of such an anemometer with two beams is shown in Fig. 1. The instrument consists of an LG-36 laser as the light source, a photoelectronic multiplier (FEU). a model ASSh-4 spectrum analyzer, and a system of lenses and mirrors. The laser beam, after reflection from the plane mirrors M_1 and M_2, is split into two beams by the semitranslucent plate M_4. The two parallel beams are then focused by lens L_1 (focal distance f = 20 cm) on a given point in the jet. The angle between the latter two beams is varied by rotation of the semitranslucent mirror M_4, i. e., by regulating the distance between the originally parallel beams incident on lens L_1. The spatial resolution of the instrument (especially at small angles $\alpha \leq 10°$) is improved by the insertion of lens L_2 with a short focal length (f = 10 cm). The system of lenses L_2 and L_3 is designed so that an image of the point where the two beams intersect appears on the diaphragm D_2 and this makes it much easier to adjust the instrument. The purpose of diaphragm D_1 (4 mm in diameter) and the red filter (CF) is to reduce the amount of stray scattered light.

With the aid of this laser anemometer, the authors have made velocity measurements in the flow field of a free turbulent jet. The choice of a free jet as the test object was dictated by our thorough enough familiarity with such a flow and, therefore, by the possibility of comparing the results of these measurements with well known data on the structure of turbulent jets [4, 5].

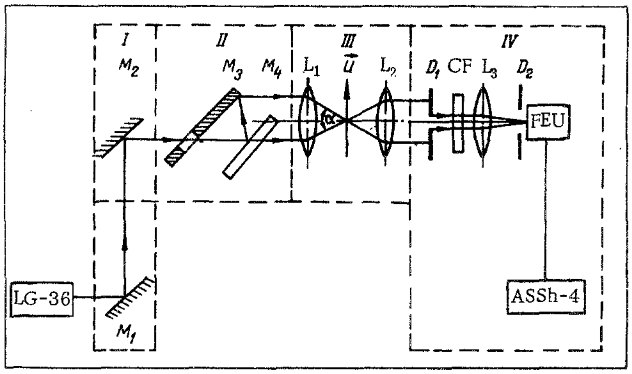

Fig. 1. Schematic diagram of the laser-type anemometer.

The velocity at various points of a cross section was measured by moving the system of lenses L_1 and L_2, by moving the complete units II and III, and by moving the optical part of the recording unit IV along the axis.

For a velocity measurement, fine particles (d ~ 1μm) were injected into the jet. The waves scattered by the solid particles with Doppler frequency shifts were mixed at the photocathode of the electron multiplier. A signal from this multiplier, carrying information about the velocity distribution of the particles, was then recorded on the screen of the spectrum analyzer. The determination of mean velocities and velocity fluctuations

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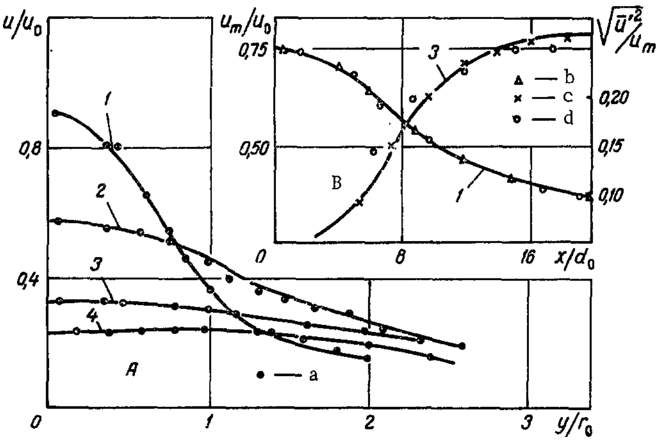

Fig. 2. Velocity distribution along the axis and cross sections of an axially symmetric jet: (A) velocity distribution across jet sections at 1) x/d = 5, 2) x/d = 9, 3) x/d = 15, 4) x/d = 20, measured a) with the laser-type anemometer, or with a Pitot tube (solid line): (B) distribution of mean velocity and of $\sqrt{\overline{u'^2}}$ along the jet axis, measured with b) a Pitot tube, c) with a thermoanemometer, and d) with this laser-type anemometer.

included a correction for the signal bandwidth due to the instrument characteristics. This correction was found by measurements in a laminar stream with fixed instrument parameters. The true velocity distribution was then found by subtracting the background noise from the signal recorded in the turbulent stream. The mean velocity was calculated according to the relation

$$\langle u \rangle = \frac{\int_0^\infty P(u)\, u\, du}{\int_0^\infty P(u)\, du},$$

with P(u) denoting the probability density of the velocity distribution of particles.

In order to determine the dispersion (the turbulence intensity), we approximated the function P(u) by the Gauss-distribution curve.

In Fig. 2 are shown some data pertaining to such velocity measurements along the axis and cross sections in a turbulent jet. For comparison, we show also mean velocities and velocity fluctuations measured with a Pitot tube or with a thermoanemometer. The graphs indicate an entirely satisfactory agreement between the results of measurements made by these various methods. Thus, we have demonstrated the effectiveness of the proposed laser-type anemometer and the feasibility of using it for measurements in a turbulent stream.

NOTATION

u	is the stream velocity;
u'	is the velocity fluctuation;
u_m	is the maximum velocity;
u_0	is the velocity at the nozzle throat;
r_0	is the nozzle radius;
d_0	is the nozzle diameter;
x	is the axial coordinate along a jet;
y	is the transverse coordinate across a jet;
$P(u)$	is the probability density of the velocity distribution;
α	is the angle between both laser beams.

LITERATURE CITED

1. Y. Yeh and H. Z. Cummins, Appl. Phys, Letters, 4, No. 10 (1964).
2. B. J. Goldstein and W. F. Hagen, Phys. Fluids, 10, No. 6 (1967).
3. B. S. Rinkevichyus, Teplofiz. Vys. Temp., 8, No. 5 (1970).
4. G. N. Abramovich, Theory of Turbulent Jets [in Russian], Fizmatizdat (1960).
5. L. A. Bulis and V. P. Kashkarov, Theory of Viscous-Fluid Jets [in Russian], Izd. Nauka (1965).