COMPARISON OF READINGS FROM A LASER DOPPLER VELOCIMETER AND A HOT-WIRE ANEMOMETER IN THE WAKE BEHIND A CYLINDER

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Results of a comparison between the readings from a laser Doppler velocimeter and a hot-wire anemometer in the wake behind a cylinder in a fluid flow are described. A way to eliminate instrumental broadening of the Doppler spectrum in measurements of statistical characteristics of turbulent flow is indicated. The agreement between the experimental results from the two devices is good.

The hot-wire anemometer is at the present one of the principal means for obtaining information on the parameters of turbulent flow. Unfortunately, its shortcomings such as the disturbance of the investigated flow, nonlinear relation between the output voltage and the flow velocity, low spatial resolution, limited speed of response, strong sensitivity to the flow temperature, and finally the effect of impurities in studying liquid flows, have forced the specialists to look for new ways to study turbulence experimentally.

The application for this purpose of the Doppler effect using coherent laser light scattered by impurity particles is being intensively studied at present. Although most papers on the subject [1-4] consider only the principles of operation of Doppler meters or their application to the measurement of average velocity, we can say with confidence that the developed method promises to be free in many respects of the above mentioned shortcomings of the hot-wire anemometry. It is already clear that the main obstacle to be solved in measuring the parameters of turbulent flow with laser Doppler velocimeters (LDVM) is the instrumental broadening of the spectrum of the Doppler signal. The authors developed a LDVM whose optical scheme and electronics reduced this spectral broadening to a minimum. Suffice it to say that the noise level of this instrument at low velocities (i.e., in the most unfavorable conditions) is equivalent to 1% of the turbulence in the frequency range 0-400 Hz. The meter has a digital output of the average velocity and an analog output signal proportional to the instantaneous flow velocity. As an example, the results of measurements made in the wake of a cylinder in water flow using this LDVM are compared with those obtained with a hot-wire anemometer developed by us earlier [5].

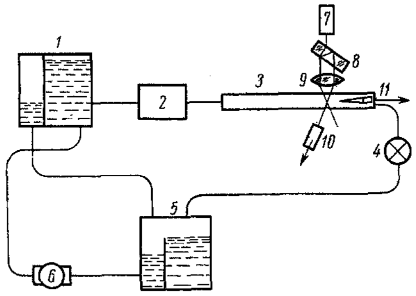

Fig. 1

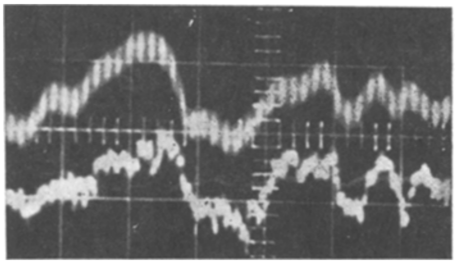

Fig. 2

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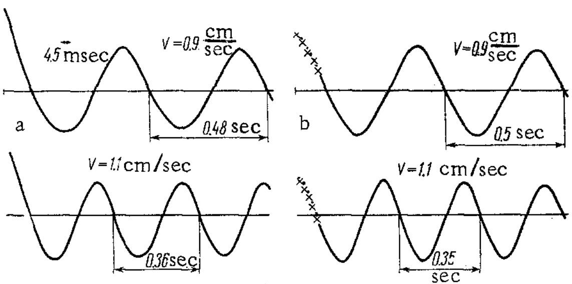

Fig. 3

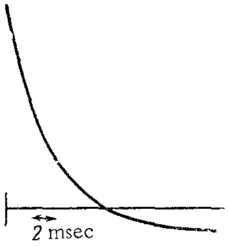

Fig. 4

The experimental arrangement is shown in Fig. 1. The hydrodynamic system consists of a pressurized tank 1, an accelerator 2, a working channel 3, a valve 4 which regulates the velocity, and a lower tank 5. The pump 6 forces the water (with Teflon added in suspension as the scattering medium) into the pressurized tank, in which a constant level is maintained by means of a partition and an additional drain. From the pressurized tank the liquid passes through the working part of the rectangular channel of cross section 16×16 mm^2. The channel side walls are made of optical glass, through which beams from the laser 7 are focused into the flow by the glass plate 8 and lens 9, and the scattered beam flux emerges onto the photodetector 10. The film sensing element of the hot-wire anemometer 11 is located in the working part of the channel such that its sensitive axis is in the immediate vicinity of the focus of the laser beams. A cylinder 5 mm in diameter is located vertically upstream (40 mm from the focus), and its wake was studied with both instruments. The sensitive edge of the sensor was oriented parallel to the cylinder axis. The flow velocity was measured with a measuring container and a stop watch. The average flow velocity at that point in the direction of the channel axis was determined from the average Doppler frequency measured on the digital readout of the LDVM from the well-known expression

$$V = \frac{\lambda f}{2 \sin {}^1\!/_2 \theta \sin \varphi}.$$

Here λ is the laser radiation wavelength; f is the Doppler frequency; θ is the angle between the reference and scattered beams; and φ is the angle between the velocity vector and the bisector of the angle formed by the directions of the incident and the separated scattered beams.

A photograph of the LDVM oscillograph screen in shown in Fig. 2 (upper trace is the hot-wire anemometer signal, lower trace is the LDVM signal). It is evident from the figure that the signals agree well. The correlation functions of the signals from the two devices were calculated on a special-purpose Didak 800 computer. The correlation functions for average velocities 0.9 cm/sec and 1.1 cm/sec are presented in Fig. 3. (The curves *a* and b are for the LDVM and hot-wire anemometer, respectively.)

The shapes of these functions show that the studied process has a significant regular pulsating velocity component. From its period we can compute the vortex dimensions. Thus, for example, at the velocity $v = 0.9$ cm/sec we have a period $T = 0.5$ sec, and the effective vortex dimension is

$$r = VT = 0.45 \text{ cm}$$

The agreement between the curves for both devices is nearly complete. The initial portions of the correlation functions are an exception. This difference is due to the LDVM noise caused by the instrumental broadening of the Doppler spectrum mentioned previously. If we assume the LDVM noise and the studied process to be statistically independent, then the correlation function of the output signal from the LDVM processor is a sum of the correlation functions of the noise and of the process. The latter can be obtained by computing the noise correlation function from the correlation function of the output signal from the processor.

Figure 4 shows the LDVM noise correlation function for laminar flow. It is natural that the variable component of the hot-wire anemometer output signal was at that time nearly zero, whereas the effective noise voltage at the LDVM output was 50 mV (1% of turbulence). The scale of the function was chosen for convenience 2.25 times coarser than in the preceding figure.

The correlation functions of the process obtained by subtracting the curve in Fig. 4 from those in Fig. 3 are shown in Fig. 3 by crosses on the curves of the correlation functions of the hot-wire anemometer signals.

The results thus show a complete agreement between the statistical characteristics of the process obtained with the laser Doppler velocimeter and with a hot-wire anemometer. Considering the advantages of the LDVM, we can expect that it will become a serious contender to the hot-wire anemometer in the near future.

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