EXPERIMENTAL INVESTIGATION OF TRANSIENT DISPERSION IN A WIND TUNNEL BOUNDARY LAYER

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INTRODUCTION

This report describes the construction and the general application of a laser light scattering probe to time-dependent dispersion processes. Instantaneous concentrations are sensed by means of a 5 mW He-Ne gas laser incident light source, dioctyl phthalate aerosol tracer particles, a fiber optics light transmitter, and a photomultiplier. The design of an instantaneous ground-level source is discussed. The instrument was used for unsteady concentration measurements, it can also be utilized for other turbulent mixing studies as well. Several possible applications are discussed in this paper.

For experimental studies on turbulent diffusion tracer materials usually have different properties which can be identified by physical or chemical means. Concentration samples are conventionally withdrawn from a background flow field at a rate equivalent to the local mean convective velocity and analyzed outside the wind tunnel. The technique is referred to as the isokinetic sampling (IKS) method. The IKS method is sufficient to measure mean concentration values at a fixed location, for instance, mean concentration from a stationary source. For an unsteady (in the time frame) stationary (in the spatial frame) source or a moving source, the concentration at a fixed point does not have a constant mean value with time. In such situations the IKS method would fail to detect the concentration variations as it would only give a volumetrically integrated value.

Rosensweig, Hottel, and Williams (1) in 1961 utilized scattered light from aerosols to measure concentration fluctuations, with a D-C powered chromatic incident light source. Their optical system was again reviewed by Becker, Hottel, and Williams (2) in 1967. This system provided valuable data on statistics of concentration fluctuation. However, the bulky nature of the optical system is not suitable to study dispersion in a large wind tunnel. Liu and Karaki (3) (1971) overcame these problems by using fiber optics as flexible light transmitters (for both the incident and scattered lights), A high-intensity chromatic light was also used in their work. In the present study, a stable monochromatic laser light is used as an incident light source. The great advantage of using a laser beam over an incandescent light source is that the monochromatic characteristics of a laser beam defines the wave length of the scattered light. Not only can the total scattered energy be computed, it also leaves room for further information retrieval which require coherent monochromatic light.

BASIC COMPONENTS AND DESIGN OF THE PROBE

The major components of this probe are listed in Table 1. A front surfaced mirror was utilized to reflect the coherent laser beam to a desirable forward scattering angle. Tracer particles are estimated to be 4 microns in diameter and reasonably uniform in size. A 3-foot fiber optics cable was used to transmit the scattered light to the photomultiplier. The small dimension of the fiber optics reduced the disturbance in the flow near the measuring point. The light weight of the fiber optics eliminates the needs for a bulky structure to support the probe head.

BASIC COMPONENTS[4]

TABLE I

NAME	FUNCTION	REMARKS
	a. Incident light system	
Laser	Light source	5 mW, Spectral Physics model 120, 6328 A, polarized, model 256 exciter
Reflecting mirror	Light deflector	12 mm diam., 0.15 mm thick front-surfaced
	b. Aerosol particles	
Dioctyle phthalate particles	Light scatterer	Atomization principle: air blast at mean diam 4 microns
	c. Receiving system	
Optical aperture	Increase spatial resolution	Scattering angle: 12°
Fiber optics	Scattered light transmitter	Transmission 4000-8000 A, Dolan-Jenner Industries, BXL-36 3 ft long
Photomultiplier	Light sensor	RCA 7265, 14 stages: operating voltage: 2800 V dc S-20 response: 3000 to 8000 A

A schematic diagram of the probe is shown in Fig. 1. Further details of the probe head can be seen in Fig. 2. A 5 mW He-Ne gas laser was installed in a plywood case. The supporting frame of the probe head was made of small tubes. The laser beam was deflected by a 1.2 cm diam, thin, front-surfaced mirror. An optical aperture was used to reduce the actual sample volume. The relative positon of the deflected laser beam and the axis of the aperture was so chosen that the scattering angle was small but only a slight amount of incident light entered the aperture. Distortion of the flow caused by the presence of the probe was negligible since the sample volume was slightly ahead of both the mirror and the aperture.

MEASUREMENTS OF AN INSTANTANEOUS SOURCE

Because of its fast response time, the probe system is able to follow the concentration history from an instantaneous source. It has been, however, a difficult task to design an instantaneous source without any physical intrusion in the flow field. The final device used by the authors is illustrated in Fig. 3. The source releasing mechanism utilizes a bursting process of a gas bubble rising from a tank or water. The gas bubble was pre-filled with dioctylphthalate particles. The device provides a repeatable, instantaneous source without having any mechanical obstruction above the wind tunnel floor. Consequently, the source presents minimum disturbance in the flow. The total time duration for the diffusing "puff" to pass a distance of 0.5 meter from the source is about two seconds, and approximately five seconds at a distance of four meters.

GENERAL APPLICATIONS AND REMARKS

Because of the simplicity in design, this type of probe can be easily assembled. Certainly, the overall size of the probe can be much further reduced by using a smaller laser and photomultiplier tube. "pocket size" lower energy gas lasers are commercially available at a very low price (~$200.00). The total cost for the necessary components is around $1,500.00

With an aerosol generating device, this system can be used to continuously scan the mean concentration profile within a plume. In situations where the absolute maximum concentration or the persistence of certain concentration level becomes essential, this system can be used for evaluating the concentration history. Examples are the assessment of reactor accident (loss of coolant accident), leakage of radioactive materials from containment vessels, accumlation of pollutants in valley, highway, or building wakes. Information obtained would aid in the selections of air conditioning intakes, street planning, parking lot sizing and power plant siting.

Another potentially important application is the measurements of the correlation terms in the basic three unknown correlation terms-namely u'c', v'c', and w'c', where u', v', w' are the fluctuating velocity components, and c' is the concentration fluctuation. Traditionally, turbulent diffusivities are used to close the equation. However, as long as the correlation terms remain unknown, the distribution of the turbulent diffusivities must remain unknown.

It is suggested that this system be incorporated with a cross-beam laser doppler velocimeter which measures instantaneous velocity fluctuation components. The laser beams used for measuring velocity may, or may not have the same frequency as the one designated for concentration measurement.

REFERENCES

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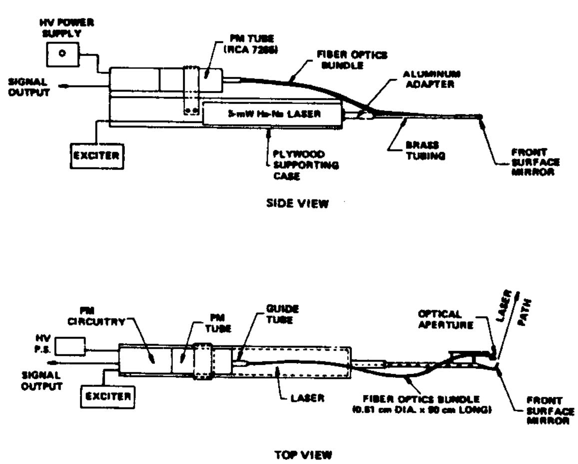

Fig. 1 Schematic diagram of the light scattering probe

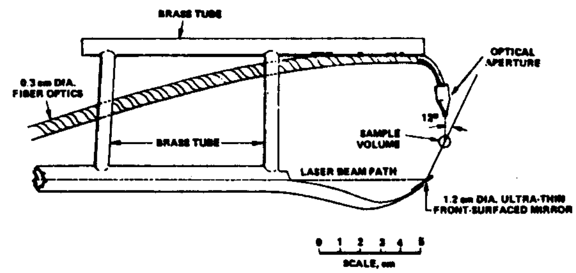

Fig. 2 The probe head

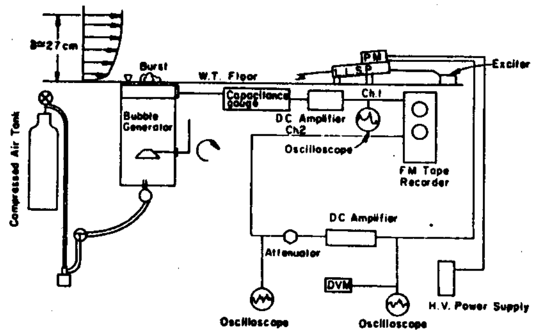

Fig. 3 Experimental arrangement for an instantaneous source