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NASA TECH BRIEF

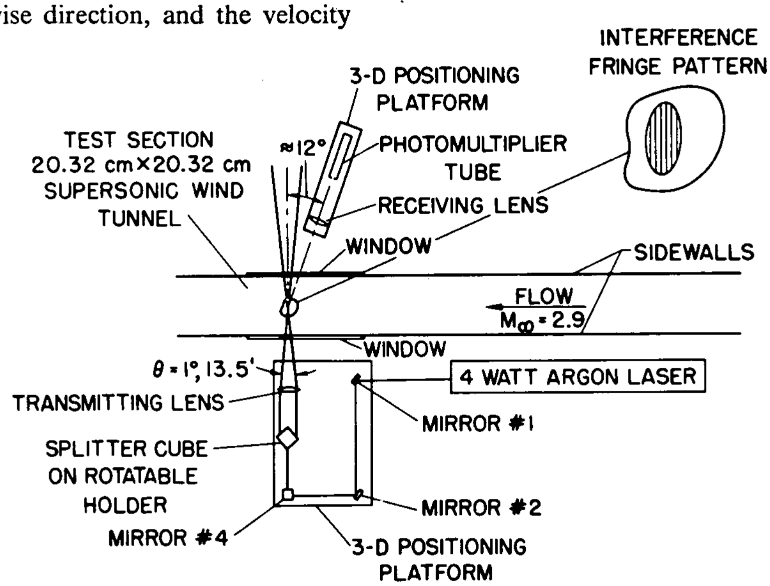
Ames Research Center

Laser Velocimeter Measurements of High-Speed Compressible Flows

The laser velocimeter appears to be especially well suited for the measurement of turbulence transport properties in compressible flows because of its nondisturbing characteristic, sole velocity sensitivity, and instantaneous velocity capability. However, there has been some question as to whether the velocimeter can provide accurate turbulence measurements in the compressible boundary layers of a high-velocity gas stream. Results of a study of a turbulent boundary layer in a supersonic wind tunnel have demonstrated that the streamwise mean velocity, the turbulence intensity in the streamwise direction, and the velocity correlation $\overline{u'v'}$ can be measured in high-speed compressible flows by laser velocimetry.

The study was conducted in a 20- x 20-cm supersonic blowdown wind tunnel at a free-stream Mach number of 2.9, a stagnation pressure and temperature of 6.8 atm and 291°K, respectively, and a free-stream unit Reynolds number of 5.7 x 10^7/m. The region of interest was the turbulent unseeded boundary layer on the nearly adiabatic upper nozzle wall for which a detailed flow-field survey had previously been made by pitot and static pressure measurements.

A schematic representation of the laser velocimeter system employed in the study is shown in the diagram. The optical arrangement was of the standard "dual scatter" or "fringe mode" type with forward-scatter light collection. The velocity component that is sensed with this system lies in the plane formed by the two incident laser beams and is perpendicular to their bisector. Thus, by simply rotating the splitter cube, various sensitivities to u and v with the attendant insensitivity to the w components can be obtained (u=velocity component parallel to free stream velocity, v=velocity component normal to upper wind



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tunnel wall, w=transverse velocity component). The Reynolds stress term, $\overline{u'v'}$, was determined by taking measurements with the laser beams oriented at +45° and −45° with respect to the streamwise direction.

Single-particle, time-domain signal processing was employed which enabled the measurements to be made at the very low particle concentrations naturally present in the flow (estimated to be submicron in size). For each measurement station and laser beam orientation, several hundred instantaneous velocity measurements were obtained from which the turbulence quantities of interest were calculated by statistical methods.

The laser velocimeter results were compared and found to be consistent with those obtained with conventional measurement techniques and existing compressible boundary layer theory. Hence, for the first time, turbulence information at supersonic speeds, including the $\overline{u'v'}$ correlation, has been successfully obtained in a compressible boundary layer with a laser system.

Reference:

Johnson, D. A.: Laser Velocimeter Mean and Fluctuation Velocity Measurements of a Mach 2.9 Wind Tunnel Wall Turbulent Boundary Layer. A.I.A.A Journal, vol. 12, no. 5, May 1974.

Note:

No additional documentation is available. Specfic questions, however, may be directed to:

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Patent status:

NASA has decided not to apply for a patent.

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