Measurement of Flow Around V/STOL Aircraft with an LDV System

A.D. Zalay,* M. R. Brashears,† A. J. Jordan,‡ K. R. Shrider‡ and C. D. Vought§
Lockheed Missiles & Space Company, Inc., Huntsville, Ala.

Abstract

AN experimental research program for measuring the flowfield around a 70 percent scale V/STOL aircraft model in ground effect is described. The velocity measurements were conducted with a ground-based laser Doppler velocimeter at an outdoor test pad. The study shows that it is feasible to use a mobile laser Doppler velocimeter to measure the flowfield generated by a large scale V/STOL aircraft operating in ground effect.

Contents

Propulsion-induced lift effects play an important role in the design of V/STOL aircraft. A complex flowfield is generated by a V/STOL aircraft operating near the ground during takeoff and landing as sketched in Fig. 1. The flowfield is characterized by: 1) the turbulent free jets from the lift cruise engines; 2) the wall jet regions; 3) the fountain upwash flow region; and 4) flow along the fuselage.

The traditional experimental techniques for determining propulsion induced lift effects consist of: 1) measurements of the forces and moments about the aircraft center of gravity using strain gage balances; 2) measurements of the distribution of static pressure at the surface of the aircraft or near the ground with pressure transducers; and 3) measurements of the distribution of temperature at the surface of the aircraft or near the ground with thermocouples. The balance measurements show the effect of variations in aircraft configuration and operating conditions on the induced lift. The pressure and temperature measurements provide a qualitative characterization of the external flow. However, these techniques cannot provide detailed information about the turbulent three-dimensional flowfield which is the underlying cause of the propulsion induced lift effects.

A mobile laser Doppler velocimeter (LDV) has been developed for remote sensing of atmospheric flows.[1,2] The LDV holds considerable promise for providing detailed surveys of the flowfield of V/STOL aircraft. Recognizing the necessity for advanced flow measurement techniques, NASA Ames Research Center and the U.S. Navy supported the present study.

The specific objectives of the present effort were to: 1) evaluate the LDV as a possible method of measuring the flow velocities around a hovering three-fan V/STOL aircraft method; 2) obtain flow velocity measurements around a three-fan 0.7 scale V/STOL aircraft model during static tests; and 3) determine the usefulness of velocity measurements taken by the LDV in the study of ground effect of hovering V/STOL aircraft. The results of the V/STOL flowfield surveys with the mobile LDV system are described in this paper including a discussion of the instrumentation, experimental tests and the results of the measurements.

Description of Experimental Tests

A two-week test sequence was carried out at NASA Ames Research Center to survey the velocity distribution around a large-scale V/STOL aircraft in ground effect. Two-hundred and ten surveys, each of approximately one minute duration, were obtained with an LDV system of the velocity distribution in the wall jet, fan jet exhaust, fountain, and the flow along the aircraft fuselage. The test conditions included two ground heights, 1.5 and 3 m, and six fan rpm's (2000, 2400, 2800, 3200, 3600, 4000).

The velocity measurements were obtained by the LDV in the following manner: 1) the flowfield generated by the V/STOL aircraft was scanned by a 20 W CO_2 laser; 2) the radiation backscattered from the aerosol in the flow was collected; 3) the radiation was photomixed with a portion of the transmitted beam on a photodetector; 4) the amplified signal from the detector was fed into a spectrum analyzer; 5) the spectrum analyzer displayed the Doppler frequency (abcissa) vs returned signal strength (ordinate); 6) a frequency tracker (or minicomputer) determined the location of the Doppler peak and converted the spectrum analyzer output into a direct velocity readout; and 7) a minicomputer recorded on digital magnetic tape the velocity information and scan parameters and processed and displayed the magnitude of the line-of-sight velocity (or other measurement parameters).

The LDV system consists of two units: 1) step van which houses the laser, optics, and electronics equipment, and 2) a trailer which contains a PDP 11/34 general purpose

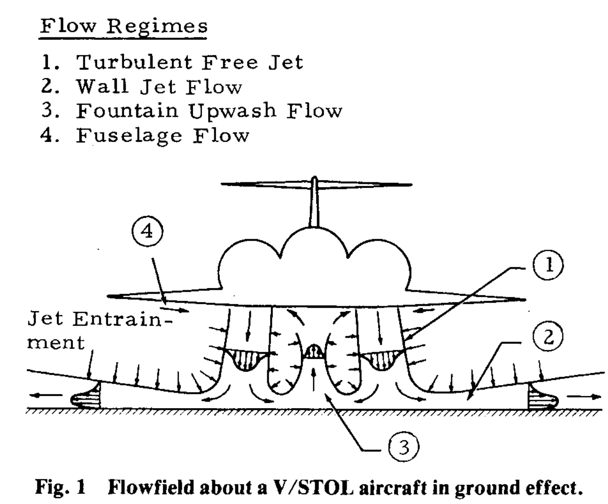

Fig. 1 Flowfield about a V/STOL aircraft in ground effect.

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*Currently Research Scientist, AeroVironment Inc. Member AIAA

†Currently ATP Payload Manager, Lockheed Palo Alto Research Labs. Member AIAA.

‡Scientific Programming Specialist.

§Research Specialist.

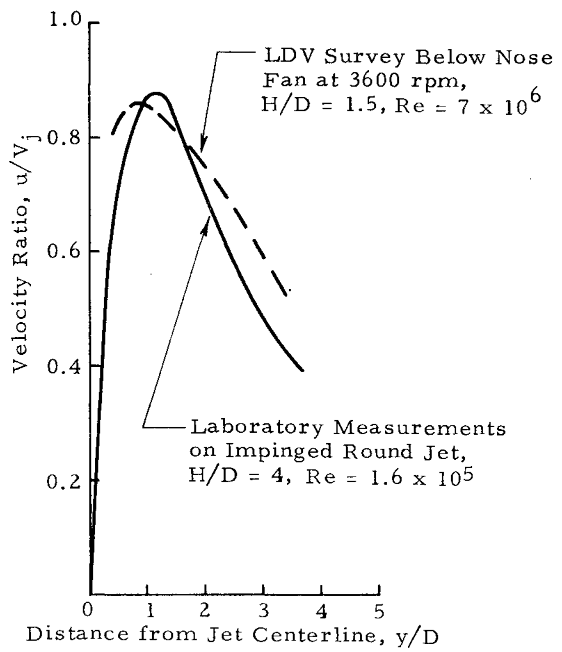

Fig. 2 Distribution of peak velocities near ground below nose fan.

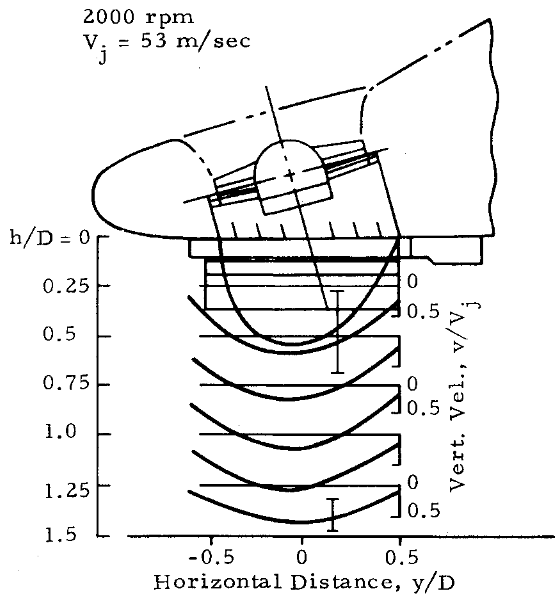

Fig. 3 Distribution of vertical velocity along aircraft centerline at location of nose fan.

minicomputer for data logging, display, and processing. The minicomputer is interfaced with the laser van to record the velocity spectrum and other scan information and parameter values. Software was developed for this effort to display and process the velocity information from the V/STOL flowfield in both real time and playback modes.

Wall Jet Decay

The decay of the wall jet near the ground is shown in Fig. 2 for the nose fan. The horizontal velocity distribution was obtained from a series of 60 or more successive 1 s range scans illustrated earlier. The range excursions were segmented into 100 discrete bins and the maximum value of the line-of-sight velocity was saved in each bin. A curve was faired through the maximum of the values in the bins to eliminate any biases due to a lack of sampling points or particles in the focal volume. The distribution of velocity 0.2 to 0.5 diam above the ground indicates a peak velocity ratio of 0.85 at approximately one jet diameter from the nozzle exit. For comparison, laboratory measurements obtained on an impinged round jet with a jet Reynolds number $RE = 1.6 \times 10^5$ are included in the figure.[3]

Fan Jet Exhaust

The distribution of vertical velocity along the aircraft centerline at the location of the nose fan is shown in Fig. 3. The velocity distribution was obtained by fairing points obtained from a series of 13 range scans through the traverse mounted remote mirror assembly. The large fluctuations in the measurements, shown by the vertical bars, suggest high turbulence levels in the flow.

Velocity distributions in the fountain and fuselage flow were also obtained for the aircraft which are discussed in Ref. 4.

Conclusions

The present study has shown the following results:

1) Measurements were obtained of the flow around a three-fan 0.7 scale V/STOL aircraft model during static tests and the following trends were noted:

a) Wall jet—Maximum horizontal velocity is 85% of the jet exhaust velocity and occurs at 1 to 2 diam from jet centerline at 0.2 to 0.5 diam above ground.

b) Fan jet—Vertical velocity measured by the LDV at the nozzle exit is approximately 100% of the jet exhaust velocity and occurs near the ground at the centerline between the two lift cruise engines.

c) Fountain—Maximum vertical velocity is 40 to 50% of the jet exhaust velocity and occurs near the ground at the centerline between the two lift cruise engines.

d) Fuselage flow—Horizontal velocity along aircraft underside ranges from 10 to 20% of the jet exhaust velocity for two-fan operation.

2) The velocity measurements obtained by the LDV have been compared with available velocity measurements based on pressure surveys and show similar trends.

Acknowledgments

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