Use of a Water Basin for Ground Effect Testing of VTOL Models

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Theme

PRELIMINARY design analysis encompasses varieties of configurations for which aerodynamic characteristics must be established. Some of the major characteristics of interest for VTOL aircraft pertain to lift, rolling moment, pitching moment, and to reingestion during hover in ground effect. The state-of-the-art for estimating these VTOL characteristics analytically is inadequate, and empirical data must be obtained. In order to acquire such data inexpensively for a variety of configurations, a test facility was established[1] which provides data with a quality suitable for preliminary assessment.

Contents

Description of Facility

The test facility consists mainly of a water basin about 1.5 m in diameter and 45 cm deep, containing 30 cm of water in which a small scale model is suspended. Aircraft jet engines are represented by tubes through which water is pumped using a flow system illustrated in Fig. 1. The basin floor can act as the ground surface for ground effect testing.

A typical model installation is shown schematically in Fig. 2. The model of approximately 25 cm span (in this case a flat plate) is suspended in the water by means of vertical rods from scales which, in turn, are attached to a support frame above the water basin. The scales measure vertical forces on the model excluding the forces on the water tubes themselves, thus indicating the interference forces of jet exhausts on the model.

The water tubes extend through openings in the model so that the tube ends are flush with the bottom surface of the model. The tubes can move independently in a vertical direction. A small-diameter Teflon ring is attached to the tubes, outside near the exits, to minimize sliding friction with the model and, in effect, to seal the gaps between the tubes and the model by leaving only a small clearance. The vertical thrust of each of the water jets is measured separately by additional scales.

The model distance to the ground can be altered by moving the entire model support frame upward or downward with respect to the water basin. Simulation of bank and pitch near the ground is provided by installing an inclined plane on the bottom of the basin beneath the model. Engine failure effects can be investigated by shutting off one of the water supply lines. Intake flow effects can be investigated by installing suction pipes. Flow visualization and reingestion measurements are made easily using pellets in the exhaust flow with a density equal to water.

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Index categories: Jets, Wakes, and Viscid-Inviscid Flow Interactions; Ground Effect Machines; Testing, Flight and Ground.

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Advantages

The facility can provide first-order assessments quickly and inexpensively. Cost savings using the water basin are based on the following:

1) The water basin is small because the models can be small, whereas force levels are generated that can still be measured easily.

2) The power is supplied by a low-energy pump without the need to use a high-capacity shop air system.

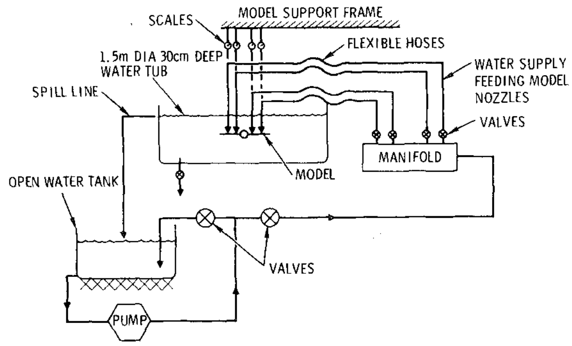

Fig. 1 Schematic of water basin facility.

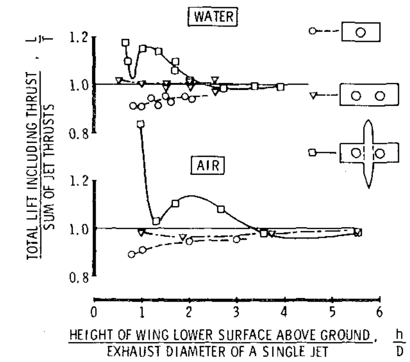

Fig. 2 Typical description of model installation.

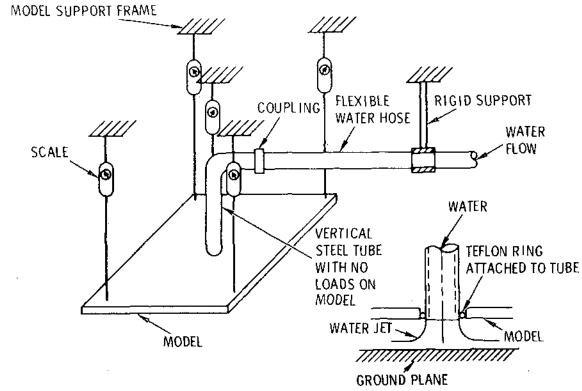

Fig. 3 Effect of flow medium on measured lift characteristics.

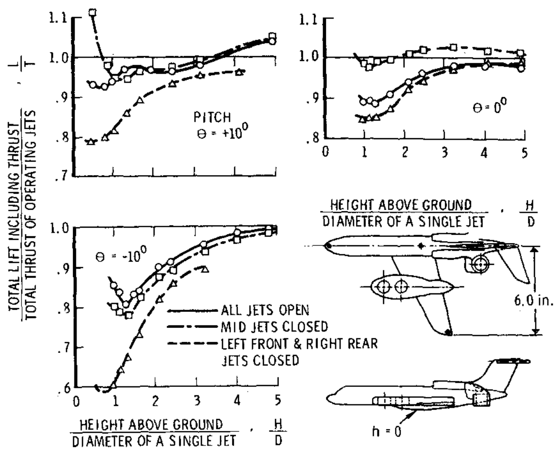

Fig. 4 Lift of a six-jet VTOL model aircraft during engine failure and pitch.

3) The facility can be operated with a crew of only two people.

4) No specialists are required to operate the facility, so the facility can be used on a demand basis with low overhead.

5) A large quantity of data can be obtained in a short time because the simplicity of the models permits quick model changes without the distraction from safety hazards, and because engine failure and bank and pitch angle changes can be set up relatively quickly.

Also, the models are very inexpensive and can be fabricated quickly because:

1) Jet exhausts are supplied by a simple water-tube system rather than by model motors.

2) The models can be small, and yet adequately large forces can be generated for measuring purposes with low flow velocities.

3) The models do not need to be engineered by a model design group for strength and safety hazards because stored energies are negligible. A simple model sketch will often be sufficient for the model maker. Generally the wings are represented by a flat plate.

Data

A comparison of lift characteristics using water vs air is presented in Fig. 3 for zero pitch and bank, illustrating the suitability for comparative testing.[2,3] However, a correction factor for the height above the ground still has to be established for noncomparative testing.

A sample model used for preliminary design support is shown in Fig. 4 along with test results.[1,3] Lift at various pitch angles and engine failure cases is presented. At some combination large lift losses are encountered, indicating the advantage of an assessment early in the design and indicating the desirability of having a test facility available such as described. Additional data of the sample model[1,3] are available.

Conclusion

A "quick look" test facility was established for measuring forces and moments of small models of VTOL aircraft in hover using water as a flow medium instead of air. The facility represents a tool for assessing the hover characteristics of many different aircraft configurations quickly and inexpensively on a relative basis as required for preliminary design support.

References

[1]Renselaer, D. J., "Description and Test Results of a Water Basin to Determine Ground Effect in Hover Using Small Models," AIAA Paper 75-145, Pasadena, Calif., Jan. 1975.

[2]Davenport, B. E. and Spreeman, K. P., "Thrust Characteristics of Multiple Lifting Jets in Ground Proximity," NASA TND-513, Sept. 1960.

[3]Anon., "Lift Fan V/STOL Flight Control System. Development Flight Simulation Model," NASA CR-114586, Dec. 1972.

[4]Renselaer, D. J. and Oberto, R. J., "Jet Effects in Hover of a VTOL Aircraft Model Using Water as a Test Medium," *Proceedings of a Work Shop for Prediction Methods for Jet V/STOL Propulsion Aerodynamics*, Naval Air Systems Command Research and Technology Group, Vol. I, July 1975, pp. 194-201.