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Small-Scale Supersonic Inlet Test Facility

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Abstract

THE results of a series of small-scale isolated inlet model tests conducted in a newly developed low-cost small-scale supersonic inlet testing facility at United Technologies Research Center (UTRC) demonstrate the efficacy of such tests as a means of determining full-scale supersonic inlet performance. The test data demonstrate that the tunnel can accommodate both axisymmetric and two-dimensional isolated inlets of a size permitting installation of sufficient instrumentation to obtain all necessary inlet performance data. The inlet performance data obtained were in good agreement with data obtained on the same or similar inlet models tested in larger facilities.

Contents

During the past few years there has been a trend toward elimination of intermediate-size supersonic wind tunnel facilities because of insufficient usage. This fact together with the high cost of testing in large supersonic wind tunnel test facilities has resulted in a lack of test facilities suitable for exploratory inlet tests, screening tests, and new-concept evaluations. Unlike the approach used in large supersonic wind tunnel facilities wherein a detailed test plan and all model parts including model variables are required prior to a test, the type of tests appropriate for preliminary research investigations require a more flexible type of test plan. The effects of inlet test variables on performance need to be evaluated on-line, followed by appropriate hardware modifications and subsequent testing to determine the effects of the changes. This procedure is iterative, with time required between tests to make model changes, and therefore necessitates the use of a facility with low operating costs and an adaptable test schedule.

This desirability of low-operating-cost inlet test facilities has prompted the development of a small-scale supersonic inlet test facility.

Test Facility

A schematic diagram of the small-scale supersonic inlet testing facility with a typical model installed is presented in Fig. 1. The tunnel test section has a 4-in. × 4-in. (10-cm × 10-cm) cross section and has an adjustable upper wall in its subsonic diffuser. Flow Mach numbers of approximately 2, 3, and 4 can be generated in the test section by inserting available nozzle blocks. A Pyrex window 10 in. (24 cm) in diameter is located on each side of the test section to allow visual observations and Schlieren photographs by means of an overhead single-pass Schlieren system.

The tunnel contains a model support system which permits adjustment of model position and angle of attack within the test section. Inlets can be attached to the tunnel support system so that either pure angle of attack or pure yaw can be achieved. Angles of attack and yaw between approximately −4 deg and 9 deg can be tested. (These local flow angles are representative of those encountered by typical ramjet inlets installed on a vehicle operating at angles of attack up to 18 deg.) A photograph of the two-dimensional inlet installed in the facility with the right sidewall removed is shown in Fig. 2.

Discussion of Results

Two test series were conducted to demonstrate the efficacy of testing in a small-scale facility as a means for obtaining full-scale supersonic inlet performance. Both axisymmetric and two-dimensional inlet models were tested in the small-scale wind tunnel at Mach numbers of 2 to 4 and angles of attack from −4 deg to −9 deg. The inlet pressure recoveries were obtained by continuity averaging four static pressures measured at a station approximately three duct diameters downstream of the inlet subsonic diffuser, and the inlet weight flow rate was measured by a facility venturi.

A typical inlet performance map and Schlieren photographs for the two-dimensional model are presented in Fig. 3. (The performance scales have been removed to preserve the classification of the ALARM data.) As shown, the inlet was

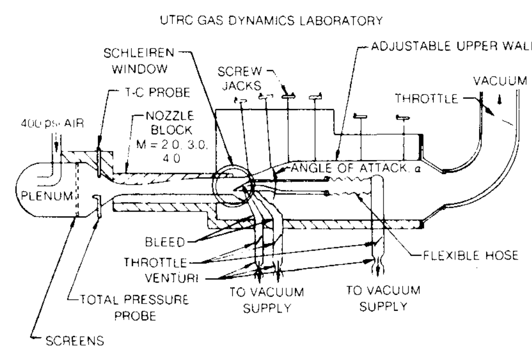

Fig. 1 Small-scale supersonic inlet test facility.

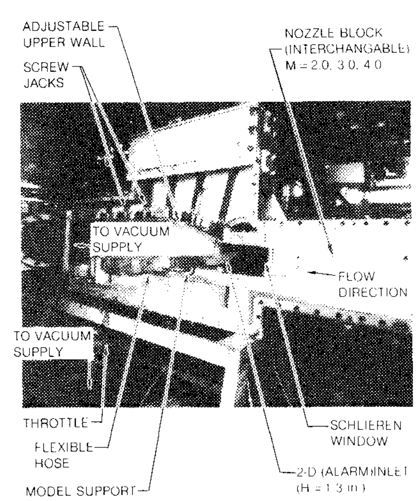

Fig. 2 Two-dimensional inlet installed in test facility—sidewall removed.

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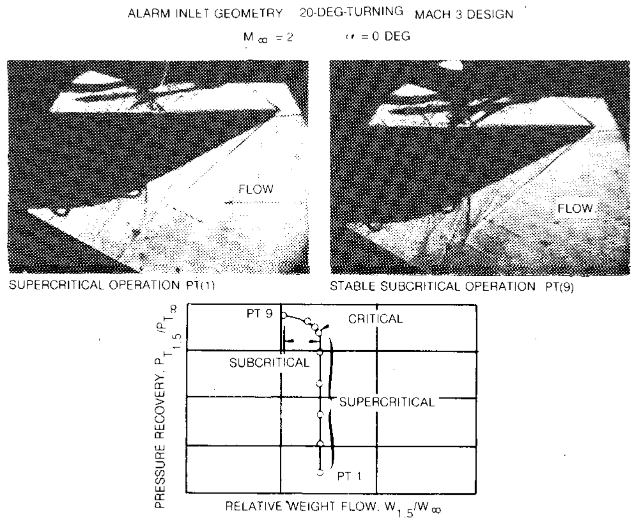

Fig. 3 Two-dimensional inlet performance data.

operating at Mach 2 and zero angle of attack (designed for shock-on-lip at Mach 3), so that the inlet was spilling flow during supercritical operation. The Schlieren photographs show the external shock structure at 1) a supercritical condition, with the terminal shock located within the inlet and 2) a stable subcritical condition, with the normal shock located upstream of the cowl on the external ramp.

The performance of the two-dimensional inlet is summarized as a function of Mach number in Fig. 4. Also included for comparison in both figures are 1) the data obtained from previous ALARM inlet tests, which were conducted in the much larger UTRC 17-in. × 17-in. supersonic wind tunnel with a model approximately twice as big as the current model

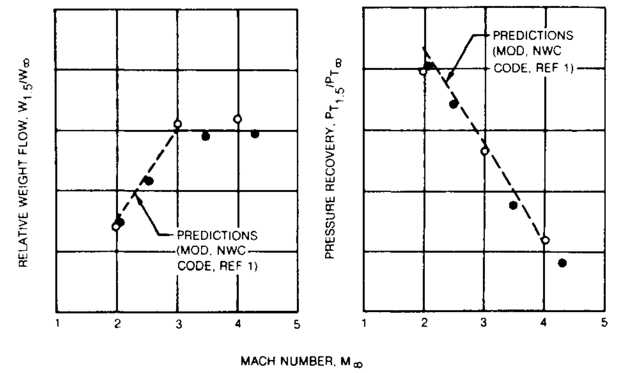

Fig. 4 Two-dimensional inlet performance summary: ALARM inlet geometry, 20-deg-turning, Mach 3 design, isolated inlet; $\alpha = 0$ deg; open symbols, present data; solid symbols, ALARM data.

and 2) the performance levels predicted using the modified NWC inlet design procedure.[1] Reasonably good agreement between the two sets of data was obtained.

Conclusions

As a result of the development program reported herein, it was concluded that useful full-scale isolated-inlet performance can be determined from tests in a small-scale facility. Furthermore, Reynolds simulation comparable to that obtained during installed-multi-inlet tests in a much larger test facility is possible in the UTRC small-scale wind tunnel.

References

[1] Sobel, D., "Modifications to the Navy Inlet Design Procedure," UTRC Report R79-111899-2, Dec. 1979.