Engineering Notes

Feasibility Investigation of Aerodynamic Round-Lip Inlet

R. LAVI* AND J. W. HEADLEY†
Northrop Corporation, Norair Division, Hawthorne, Calif.

SHARP-LIP inlets are required for efficient operation of supersonic aircraft at cruise conditions, thereby imposing a large penalty on aircraft takeoff capability. To minimize this penalty, the inlet-lip geometry normally chosen is a compromise between the sharp-lip, for good cruise performance, and round-lip geometry which is necessary to obtain acceptable pressure recovery levels during takeoff and low-speed flights. Therefore, the aircraft propulsion system suffers a performance penalty at both ends of the flight regime.

Various methods and techniques have been used or proposed for improving the performance of the sharp-lip inlet at takeoff. These include inflatable lips, translating cowl, and suck-in doors, all of which impose mechanical complexity and some weight penalty. Search for simple means of improving the static performance of a sharp-lip inlet without affecting its cruise performance revealed a novel concept. The concept was based on aerodynamically creating a round-lip geometry by utilizing a jet of air blowing out near the inlet lip as shown in Fig. 1.

A simplified method was used to calculate the path of the jet issuing from a narrow slot at the inlet tip.[1] This method assumes that a constant pressure differential exists across the jet, which causes the flow to bend in a curved path. The pressure differential is caused by the higher flow velocity near the inlet lip as compared to the local velocities immediately behind the air jet. The flow path was determined as a function of the initial direction of the jet, ratio of jet mass flow to inlet mass flow, and freestream jet and inlet Mach numbers. The jet path was calculated to the approximate point where the flow becomes parallel to the inlet axis. The definition of the jet at this point is not well defined and cannot be estimated rigorously. However, it was assumed that as the flow continued a curved path, it would turn back toward the inlet providing, effectively, an edge which is considerably rounded than the inlet sharp edge.

A small increase in inlet lip radius results in a large increase in inlet pressure recovery.[2] This influence is particularly significant at higher inlet Mach numbers at static conditions. Based on the calculated jet profiles, it was anticipated that effective (r/D) values of greater than 0.03 might be achieved utilizing approximately 3 to 4% of inlet airflow.

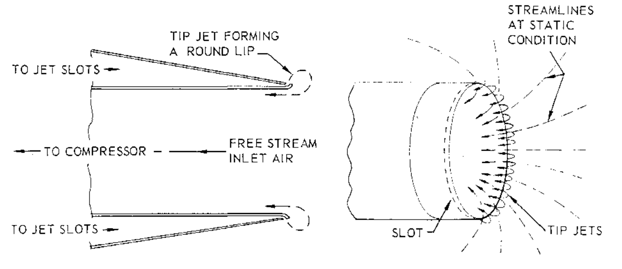

Fig. 1 Aerodynamic-round-lip inlet schematic.

Received October 10, 1966. [3.02, 4.02]

* Engineering Specialist, Aerodynamics Research and Technology Group. Member AIAA.

† Senior Engineer, Aerodynamics Research and Technology Group. Member AIAA.

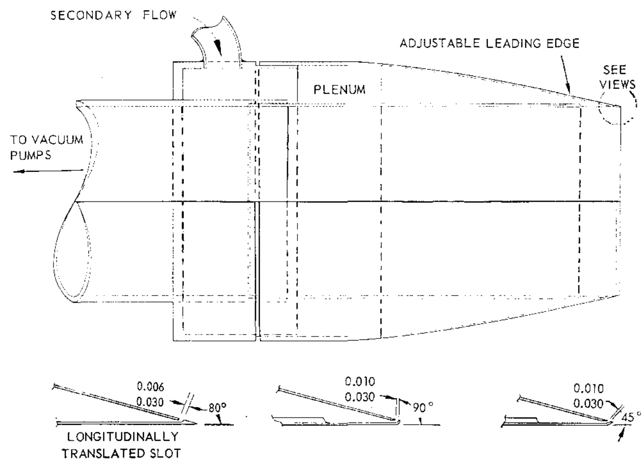

Fig. 2 Aerodynamic inlet test model.

A test program was conducted to investigate the feasibility of the aerodynamic round-lip inlet concept, and to determine the influence of various jet and primary flow parameters on the sea-level static pressure recovery of a sharp-lip inlet.

The test model was an axisymmetrical inlet of 4.875-in. diam (Fig. 2). The basic inlet including the blowing air jet plenum chamber was fixed; two leading-edge configurations were used to simulate jet initial direction, and one which showed the effect of longitudinal translation of the slot on inlet performance. The slot widths on the leading edge were adjustable to permit varying the slot flow rate. Slot width variations from 0.006 to 0.03 in. corresponding to weight flows of 1.5 to 13.1% of the primary flow were evaluated.

The instrumentation consisted of 1) a total pressure rake with 14 probes located at the center of simulated compressor face equal areas, 2) a row of static pressure taps located from the tip to the rake station, 3) a plenum chamber pressure tap, and 4) orifice meters to determine total inlet and slot airflows.

The performance of each inlet lip configuration was obtained for various mass flows up to the choked condition (5.05 lb/sec). Similar runs were then made with tip-jet flow for various slot flow rates. Slot airflows as high as 13.1% of the primary inlet flow were investigated.

Additional runs were made to observe and photograph the jet flow path and simulated round lip. Oil smear flow visualization technique, in conjunction with a splitter plate located in and around the inlet, was effectively used for this purpose.

The performance of the leading-edge configurations, tested with variable slot flows, are shown in Fig. 3, in terms of inlet total pressure recovery as a function of inlet mass flow. It is apparent that the inlet pressure recovery did not improve with blowing for the range of the slot mass flow rates evaluated. At high inlet mass flows, the recovery actually suffered slightly.

Figures 4a and 4b show the influence of the slot flow in forming an aerodynamically round-lip for the various slot flows tested. The portion of the jet profile predicted was very close to the actual jet shape near the inlet lip. The pressure recovery improvements predicted for various flow rates, however, were based on the assumption that the round-lip would be formed on the external part of the inlet geometry

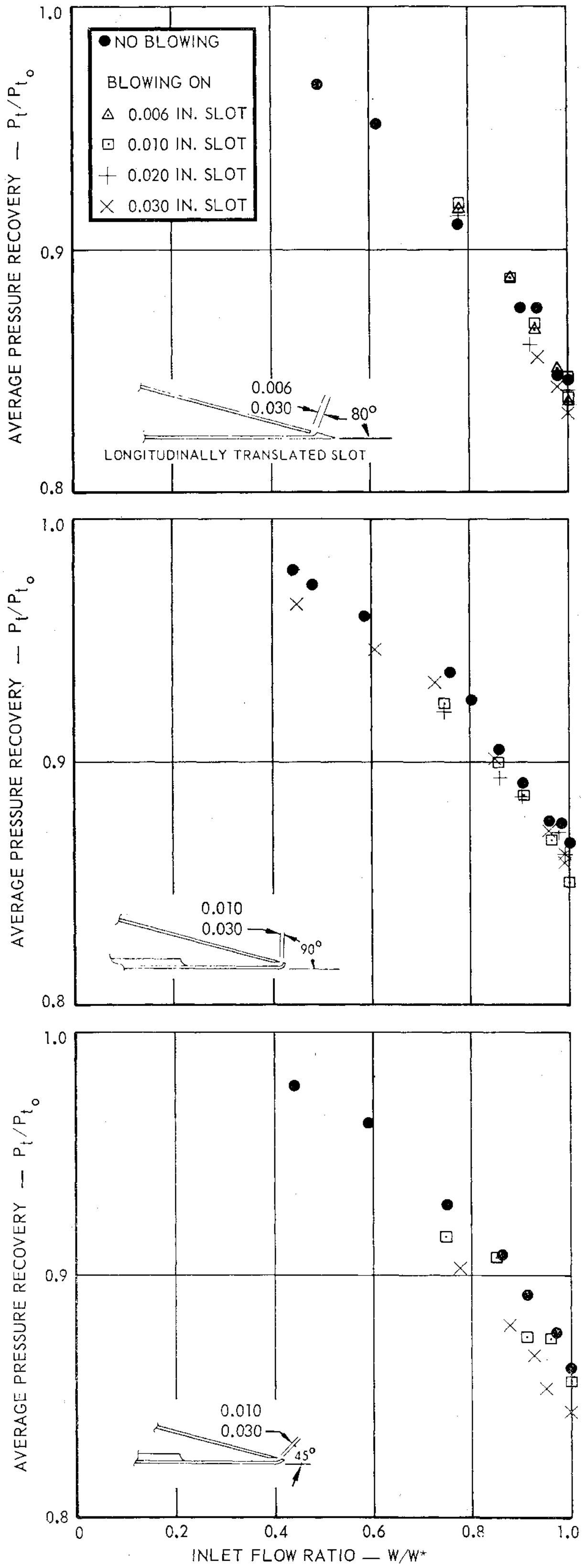

Fig. 3 Inlet performance comparisons.

and that the jet flow would attach at the inlet lip. The inspections of Fig. 4 shows that the round lip, created by the jet flow, extended well inside the inlet lip and restricted the inlet flow area. Thus, the pressure recovery improvements that might have been realized as the result of rounding the lip were offset by higher pressure losses associated with inlet flow area restriction.

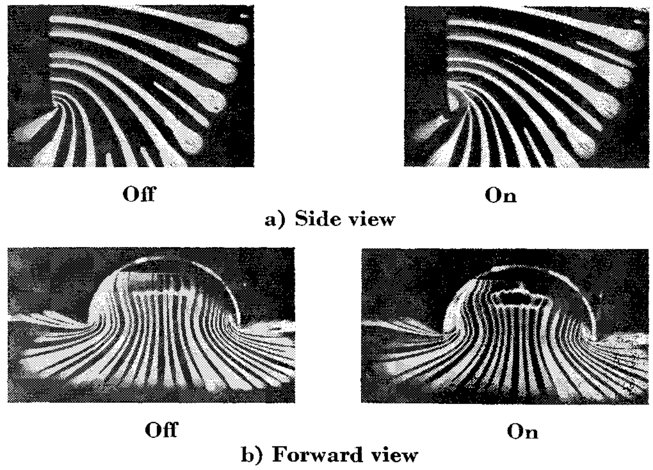

Fig. 4 Inlet streamlines with and without blowing.

In conclusion, the test program showed that the concept was not feasible, regardless of the amount of jet flow. Should some technique for attaching the blown air at the lip develop, the predicted improvements may be possible.

References

[1] Abramovich, G. N., *The Theory of Turbulent Jets* (Massachusetts Institute of Technology Press, Cambridge, Mass., 1963).

[2] Blackaby, J. R. and Watson, E. C., "An experimental investigation at low speeds of the effects of lip shape on the drag and pressure recovery of a nose inlet in a body of revolution," NACA TN 3170 (April 1954).

Vortex Separation above Delta Leading Edges

F. X. Hurley*

Lockheed-California Company, Burbank, Calif.

As the inclination of a delta wing in a subsonic or moderately supersonic flow increases, there is a tendency for vortex separation to occur and cause a lowering of pressure

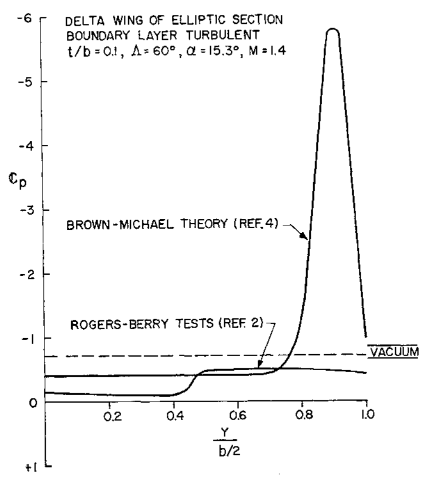

Fig. 1 Comparison of theory and experiment for upper-surface, spanwise pressure distribution.

Received November 14, 1966. [3.02]

* Aerodynamics Engineer, Flight Sciences Division of Advanced Design; now Graduate Student, Rice University. Associate Member AIAA.