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COANDA CONTROL OF A THICK WALL-JET IN THE STATIC CASE (U)

IR Project 1660-610

Nov-82

G.G. Huson

(U) The thrust from a turbofan engine top-mounted on a circulation control (CC) wing was recently found to vector downward (and in some cases more than 90 degrees downward, producing thrust reversal) when the CC Coanda jet is activated. Experimental research was undertaken to provide a basis for understanding this phenomenon, for projecting its practical limits, and for exploiting its benefits. Within the range of parameters investigated, thrust-turning performance tended to improve with increases in aspect ratio of the upstream nozzle, thickness of the wing trailing edge, and nondimensional distance of the upstream nozzle ahead of the trailing edge. Maximum thrust turning was found to correspond to a relatively constant minimum ratio of trailing edge surface pressure to ambient pressure; suggesting the hypothesis that a trailing edge shape designed to produce uniform reduced static pressure over the trailing edge would be optimum.

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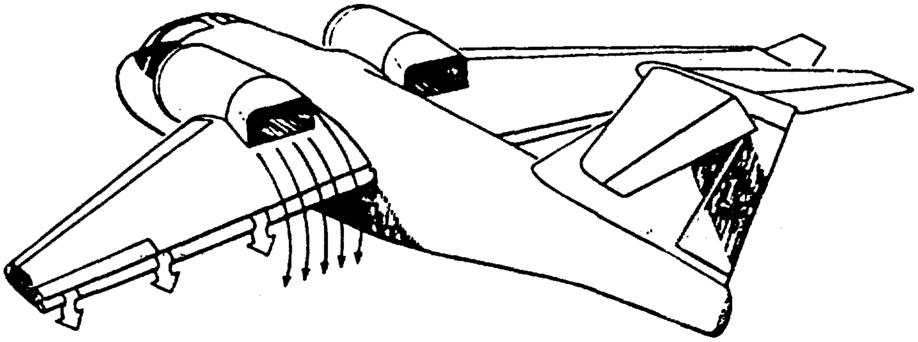

(U) Figure - Circulation Control Wing-Upper Surface Blowing Advanced High Lift, Short Takeoff and Landing (STOL) Aircraft Concept

(U) Circulation control (CC) has been the subject of extensive research at the Center. Most research has been directed toward using a rounded trailing edge on an airfoil with a pressurized jet of gas exhausting tangent to the trailing edge from the upper surface at the initiation of the turn. This jet flows over the trailing edge conforming to its shape (Coanda effect) and induces upstream air on the upper surface to follow the jet flow. This phenomenon effectively increases the lift an airfoil can generate, and, when installed on an aircraft, significantly reduces the take-off and landing distance required as well as the mechanical complexity of the

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wing. It was recently discovered that the CC trailing edge can also produce substantial downwash turning of the net thrust from a turbofan engine top-mounted on the wing, as shown in the next figure. The combination of upper-surface blowing (USB) with a CC wing may have great practical use in many applications, depending upon the efficiency with which it can be produced and the physical limitations to which it is subject.

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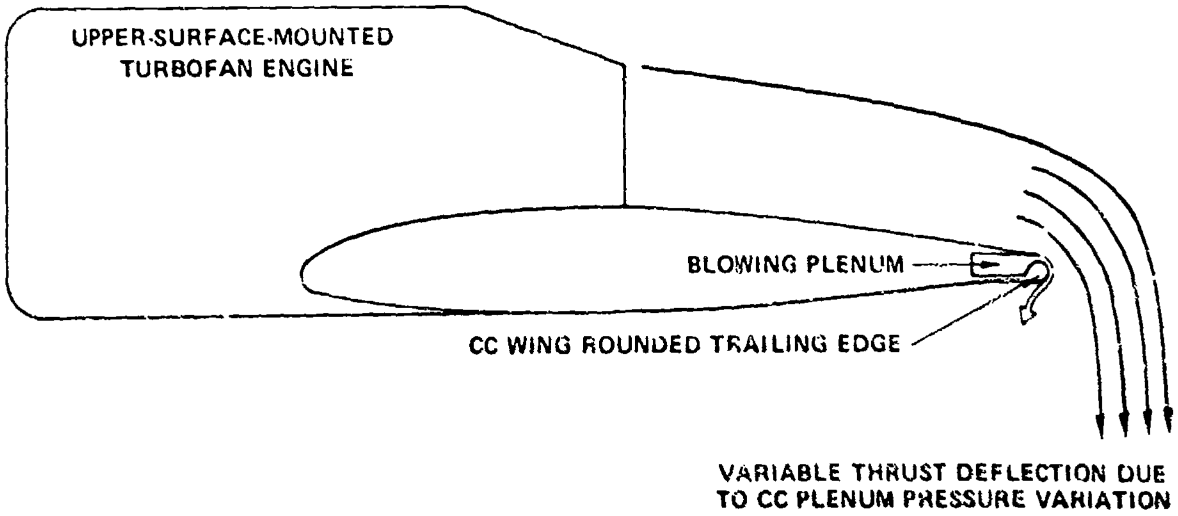

(U) Figure - Circulation Control--Upper Surface Blowing Engine Thrust Deflector

(U) The intent of the project was to experimentally determine what parameters influence the performance of the CC jet exhaust deflector and what combinations of these parameters produce the most efficient turning, and to achieve some first-order theoretical understanding of the phenomena involved. Experimental data covering a broad parametric matrix of geometric and flow variables were generated and some basic hypotheses have been formulated.

(U) The experimental arrangement is shown in the third figure, comprised of a CC thrust deflector, a turbofan propulsion simulator (thick wall-jet generator), three interchangeable two-dimensional nozzles, two six-component balances, and the supporting structure. (For convenience, the rig is constructed "upside down" so that the wall-jet produced by the turbofan simulator is turned upward differing from other illustrations of the concept.) The varying parameters are as follows:

Radius of the rounded trailing edge, r

Thickness of the Coanda jet, h_j

Entrainment length--the distance between the exit plane of the thick wall-jet nozzle and the Coanda jet nozzle exit plane, x_j

Thick wall-jet exit momentum, or thrust, T

Coanda jet momentum, $\dot{m}V_j$

Width of the Coanda control jet and surface, w

Thick wall-jet aspect ratio, w/h

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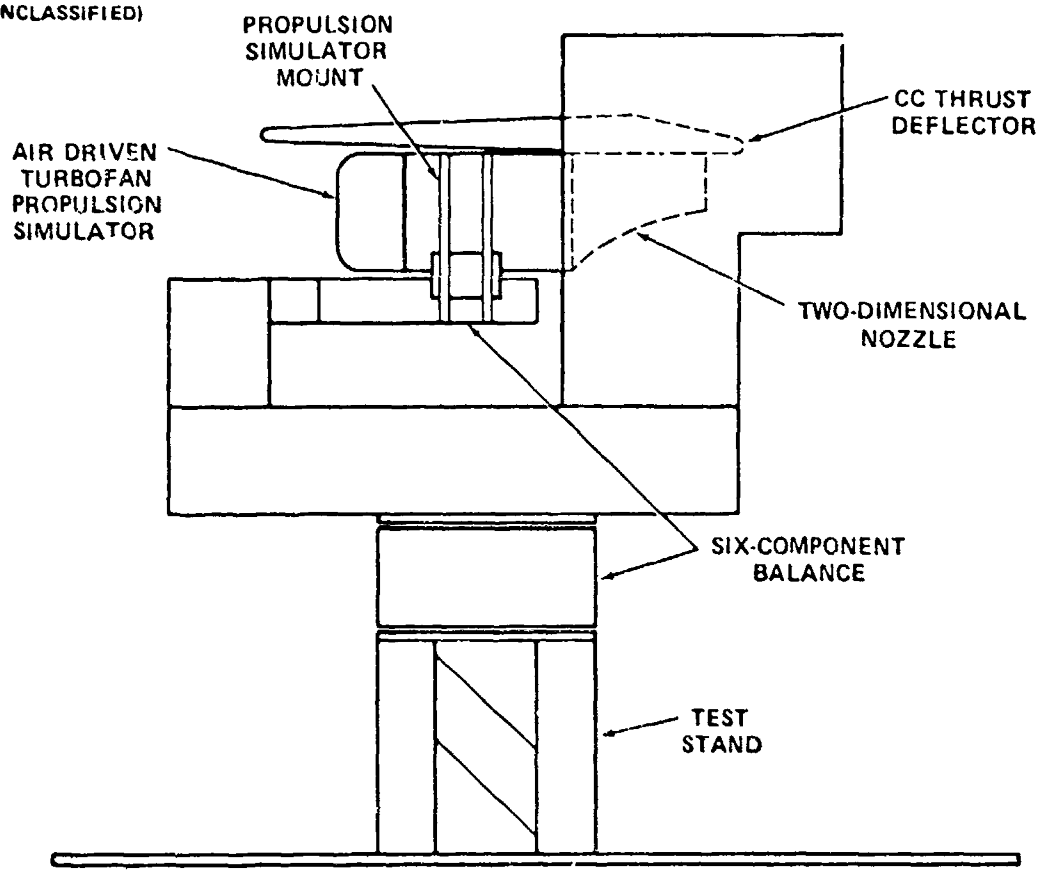

(U) Figure - Thrust Turning Research Experimental Arrangement

(U) Static pressure measurements as well as force measurements were recorded. Referring to the arrangement shown in the figure, static pressure taps were located along the center span of the CC thrust deflector in the region where the profile outline is dashed. The pressures sensed by these taps were integrated, yielding a resultant force which was resolved into its horizontal and vertical components. Two strain gage balances were used for similar purposes. The balance located directly beneath the turbofan simulator measured the force produced by the simulator alone while the second balance recorded the total system forces. The difference between the two balance measurements is a measure of the thrust turning efficiency.

(U) The fourth figure presents the turning results and thrust recovery obtained in the prior experiment which provided motivation for this research. As illustrated with increasing Coanda jet pressure $\left(P_{T_D}\right)$ the thrust turning increased while the thrust recovery decreased. Results from the IR project configuration with the 0.875-inch radius trailing edge and the aspect ratio 6 nozzle show that the thrust turning angle ranges from 0 degree to 173 degrees for low thrust settings of the thick wall-jet.

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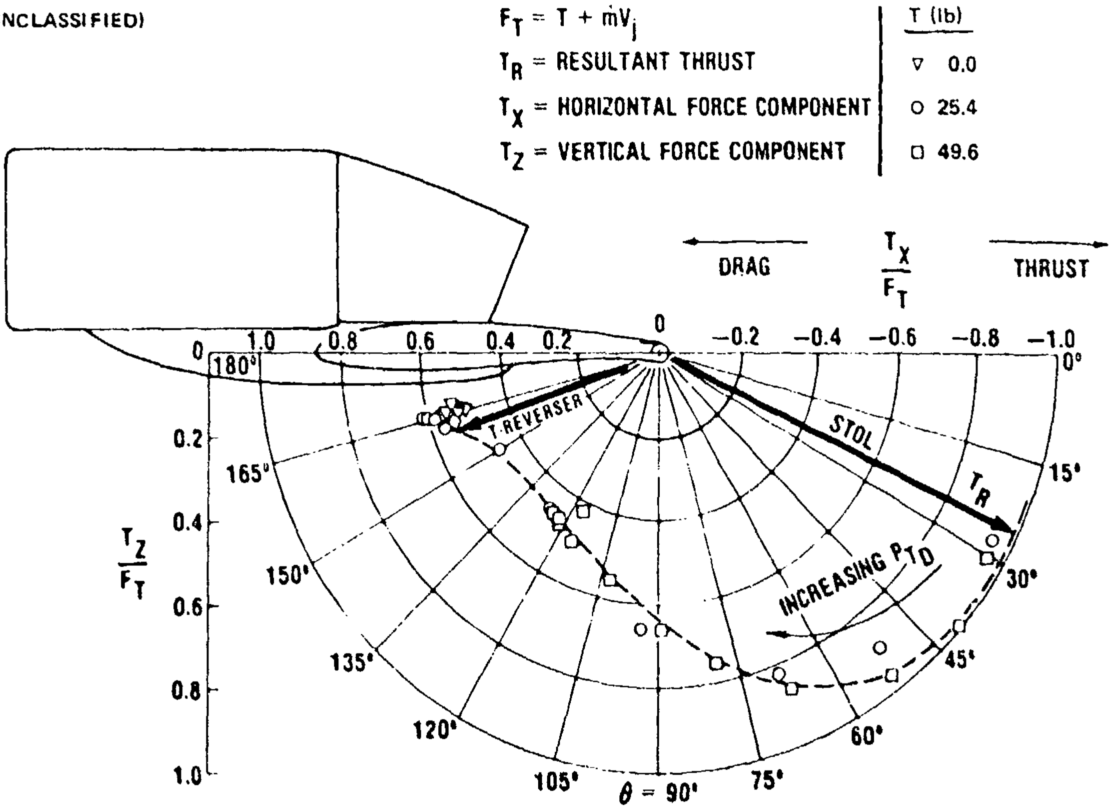

(U) Figure - Circulation Control--Upper Surface Blowing Turning Angle and Thrust Recovery Efficiency

(U) The following trends were apparent from the experimental data (not included). The increments of variation in nozzle aspect ratio 2, 4, and 6 indicate that an increase in aspect ratio permits higher thrust turning angles for the same Coanda jet mass flow setting. With higher aspect ratio nozzles the maximum turning angle is slightly higher and is reached earlier as the Coanda jet mass flow is increased. The entrainment length of the thick wall-jet nozzle affects the turning performance. As the thick wall-jet nozzle is moved from 0 to 6 thick wall-jet heights away from the Coanda jet exit, thrust turning improves, but at a diminishing rate. In addition, variation in the trailing edge radius influences the maximum turning capabilities of the thick wall-jet. As the radius is increased, the turning performance of the thick wall-jet improves. For a given trailing edge radius, maximum turning angle is increased as thrust is reduced.

(U) A first-order analytic estimate of the thick wall-jet turning produced by the thin wall-jet was developed as

$$\cos \theta = -\frac{2rw\Delta p}{T}$$

where θ is the turning angle and Δp is the pressure differential between ambient and surface static pressure on the trailing edge. This estimate was found to agree quite closely with the experimental data, and emphasized the importance of maintaining as large a pressure differential over as much of the trailing edge surface as possible.

(U) The results have been encouraging and further detailed analysis of these parametric data is being supported by the Naval Air Systems Command's Aircraft Exploratory Development program. Continuing research in this area includes static CC/USB thrust turning investigations using both a Harpoon missile turbojet engine and using the NASA Quiet Short-haul Research Aircraft (QSRA). Once static data have substantiated the appropriate design parameters, flight tests may be conducted on an aircraft such as the QSRA.