ground planes can be used if

$$C_L b/ \text{Æ} H < 3.3 \tag{9}$$

This is nearly equivalent to the condition just prior to flow breakdown where

$$C_L b/ \text{Æ} H < \pi \tag{10}$$

Turner[4] depicts a graph (Fig. 2) showing regions where moving-belt ground planes are needed. The slope of the line depicted on the graph very nearly corresponds to $1/\pi \text{Æ}$. Turner's graph therefore shows flow breakdown occurs when

$$C_L b/ \text{Æ} H = \pi \tag{11}$$

This basic flow breakdown concept is applicable to VTOL, STOL, and conventional aircraft if C_L is the total lift coefficient.

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Behavior of a Subsonic Turbulent Slot Jet in Crossflow

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Introduction

THE problem of a round turbulent jet exhausting from a large flat plate into a crossflow has received considerable attention from many investigators (for example, Refs. 1-4). This flat plate problem contains the essential features of the interaction associated with a lifting jet and a freestream flow during the transition of a VTOL aircraft from vertical to horizontal flight. However, in some applications it is desirable to have the jet issuing from a slot (with longer dimension parallel to the freestream) rather than from a round hole. This Note presents some experimental observations on the behavior of such a slot jet.

Apparatus

The jet issued vertically upwards from a flat plate 48×66 in. in the chordwise and spanwise directions, respectively, which was mounted 12 in. above the floor of the Georgia Tech 9-ft. wind tunnel.[5] Two different nozzles were mounted in the supply pipe at the center of the plate. One nozzle had a circular exit of 2 in. diam. (round jet); the other nozzle was a slot 1 in. wide, with a 0.5 in. radius at either end (Fig. 1), which was aligned with the longer dimension in the streamwise direction (slot jet). Both exits had the same area. The jet air, which was supplied by a centrifugal compressor, exited at approximately 170°F, allowing the shape of the jet to be determined by means of a thermocouple probe. The probe had a spherical tip 0.04 in. in diameter and was traversed by a remote-controlled actuator. Two other probes were used to measure reference temperatures. One thermocouple probe inserted through the wind tunnel wall was used to measure freestream temperature T_∞, while a second probe in the jet plenum chamber just below the nozzle recorded the jet stagnation temperature T_j. The local temperature T in the jet plume was recorded on an X-Y plotter, while the probe was moved by the actuator in the vertical z direction at a maximum speed of 0.2 in./s. It is recognized that the thermocouple measurements are insensitive if the probe is exposed to jet fluid and crossflow in some intermittent fashion.

Results

Results are presented in terms of contours of constant temperature parameter C_T, where $C_T = (T - T_\infty)/(T_j - T_\infty)$. It is estimated that the values of C_T are in error by less than ±0.02. All of the data were taken at a jet effective velocity ratio (square root of the ratio of the jet dynamic pressure to the freestream dynamic pressure) of $\lambda = 8$.

Figure 1 shows pressure and temperature centerlines (where a centerline is defined as a series of maximum points taken from pressure and temperature profiles measured by making vertical surveys along the z axis) for both the circular and slot jets in the plane of symmetry ($y = 0$) plotted against distance nondimensionalized by the circular jet diameter, d. The pressure centerline is the locus of points of maximum total pressure, while the temperature centerline is the locus of points of maximum temperature. The pressure centerlines are taken from Mosher,[6] who used the same apparatus; these were spot-checked in the current study. As has been noted elsewhere,[6-8] the slot jet penetrates further into the crossflow than does the circular jet for the same velocity ratio λ. It was observed by Kamotani and Greber[9] that the temperature centerline for the circular jet falls considerably below the pressure centerline. The present data agree with their results taken at $(T_j - T_\infty) = 75°F$. Note, however, that the temperature and pressure centerlines almost coincide in the case of the slot jet.

Figure 2 shows the extent and shape of the slot jet in y-z planes perpendicular to the freestream (x) direction at two

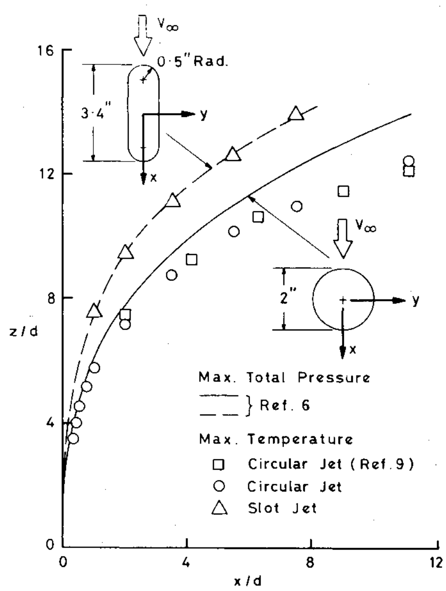

Fig. 1 Pressure and temperature centerlines ($y = 0$) circular and slot jet, $\lambda = 8$.

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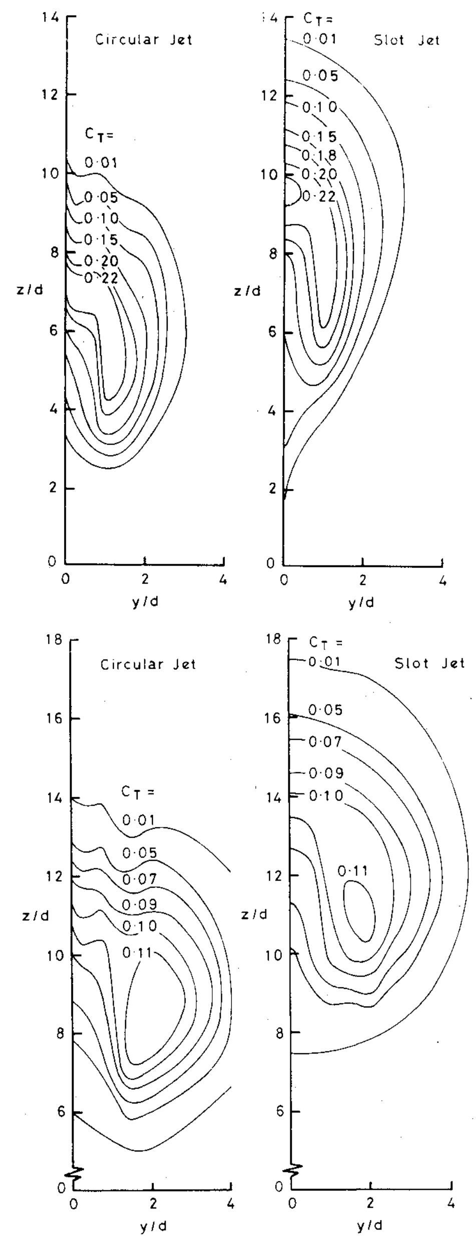

Fig. 2 Contours of C_T in y-z plane, circular and slot jet, $\lambda = 8$: a) $x/d = 2.0$; b) $x/d = 7.5$.

different downstream locations. Similar results for the circular jet are provided for comparison. It is seen that the slot jet has a distinct thin region behind the jet near the surface of the flat plate. Temperature contours in the plane of symmetry indicate that the mixing, at least near the plane of symmetry, is more intense in the region just downstream of the slot jet than it is for the circular jet. This thin region behind the slot jet persists at least to $x/d = 3.5$, and disappears by $x/d = 7.5$ (Fig. 2b). By $x/d = 7.5$ the shape of the slot jet in the y-z plane is not very different from that of the circular jet.

Concluding Remarks

The flowfield associated with a slot jet in crossflow differs in several respects from that of a round jet. Immediately downstream of the exit, the mixing of the jet and freestream fluid is much more pronounced for the slot jet than for the round jet. Also, the relative positions of the temperature and pressure centerlines are different for the two jets.

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Behavior of Vortex Wakes from Oscillating Airfoils

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Introduction

THE vortex wake of an oscillating airfoil has long been studied,[1] and it is now well known that under certain conditions strong nonlinear interactions can develop.[2,3] This appears in the form of agglomerations of vortex elements resulting in discrete concentrations of vorticity which can then be analyzed as separate vortices.[4]

In this Note, we present a simple and rapid numerical technique for calculation of the time-dependent growth and evolution of wakes. The parameters influencing the rollup are examined and the ranges of reduced frequencies for which such instabilities occur are determined.

Analysis

A thin airfoil moving along a curved path in an incompressible inviscid fluid is analyzed. Pitching and heaving motions, as well as finite rigidity of the foil can cause displacement $h(x,t)$ of points on the foil from the average trajectory (Fig. 1). This motion is limited in the present analysis to cases where the local angle of attack including effects of angular motion ω is always in the linear part of the lift slope curve, and the displacements are such that $h/c \ll 1$ (where c is the chord length).

The velocity potential ϕ of the flow can be written, and solved, in two parts – as a result of the linearizing limitations above. Thus the disturbance potential due to the foil motion ϕ_0 is separated from the wake potential ϕ_w.

In order to deal with arbitrary, nonsteady planar motions of the foil, the wake potential ϕ_w is given in the form of a row of adjacent discrete vortices (Fig. 1). At any given time the

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