Engineering Notes

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Effect on Surface Pressures of Trapezoidal Holes in a T-38 Stabilator

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Introduction

SURFACE-pressure distributions were measured in a subsonic wind tunnel on a T-38 stabilator with four configurations of trapezoidal holes, as part of a study of the effects of damage on the aeroelastic characteristics of wings and tails.[1] A literature search[2] found no measured pressures for through-hole damage; the trapezoidal holes were selected as an idealized damage case for which computational solutions could be obtained while providing a beginning step toward the complex shapes of actual damage.

The dimensions of the stabilator are given in Fig. 1 which also shows to scale the size and location of the four holes having areas of 1 to 2% of the stabilator planform area; Table 1 gives the locations of the hole edges. The tests were run in a 5×7 ft open-circuit wind tunnel at $M=0.186$ and an average Reynolds number of 5.29×10^6 based on the mean chord. Fifteen pressure orifices were located at each of 10 spanwise stations. The test setup, procedure, and tabulated pressure coefficients are discussed in detail in Ref. 3.

Results

The inboard hole, centered at 43% span, had a smaller, more localized effect than did a similarly sized outboard hole; therefore only the outboard holes will be discussed herein. These three holes, at 75% span, had qualitatively similar effects, and the intermediate size (1.5%) was selected as representative of all three for presentation in this Note. The 64A004 airfoil of the stabilator is subject to leading-edge separation which starts at 4 to 5 deg angle of attack and progresses aft as the angle increases. At the higher angles there is substantial separation with attendant spanwise and reverse flow. The effects of the holes on surface pressures were found to follow two patterns, one for attached flow and another for separated flow.

Attached Flow

The effects of the hole were negligible at zero angle of attack and became increasingly strong up to about 6 deg, where separation started to become significant. Generally, the pressure decreased ahead of the hole on the lower surface and aft of the hole on the upper surface with the latter effect the strongest. There was separation and reattachment on the upper surface behind the hole, with the perturbation extending to 60% chord when the hole reached 37% chord.

The pressure distributions were consistent with the flow pattern which might be expected. There was reduced pressure on the forward part of the lower surface where attached air flowing into the hole was being accelerated. A stagnation "line" was formed on the rear face of the hole, i.e., on the honeycomb core, and flow from this region over the sharp upper corner produced the separation and attendant reduced pressures. Along each side of the hole, on the upper surface, the pressures were moderately increased with a rapid spanwise return to the undisturbed level. The spanwise effect extended about the width of the hole, in both directions, with the upper surface being influenced more than the lower.

Separated Flow

For this case, the strongest changes were near the hole, but the influence was felt over the entire upper surface. Figure 2 shows the measurements along the centerline of the hole, which extended from 8 to 37% chord, and Fig. 3 is for a chord 7-cm inboard of the hole. The lower surface again indicates an area of inflow to the hole just aft of the leading edge, where C_p is reduced. The attached flow on the lower surface also tended to localize the disturbances to the first 60% chord, as discussed above. Surface-oil and tuft patterns indicated a

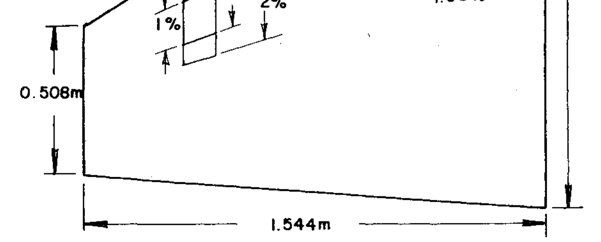

Fig. 1 Stabilator dimensions and hole locations.

Table 1 Hole locations

Span, %	Chord, %	Area, %
71.6 to 78.6	17.4 to 37.0	1.0
71.6 to 78.6	8.0 to 37.0	1.5
71.6 to 78.6	8.0 to 46.2	2.0
36.9 to 49.8	12.8 to 27.0	1.96

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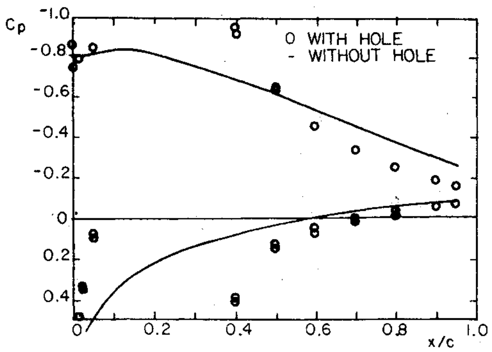

Fig. 2 Chordwise C_p along centerline of 1.5% area hole at 75% span, $\alpha = 9.8$ deg.

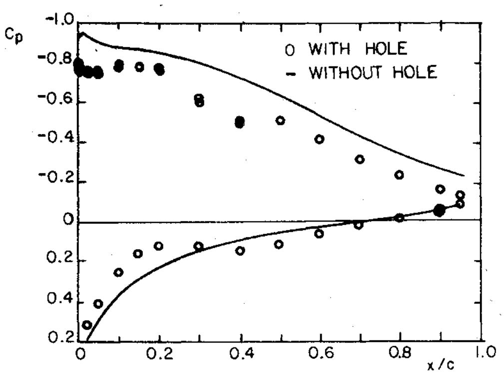

Fig. 3 C_p along a chord 7-cm inboard of hole, $\alpha = 9.8$ deg.

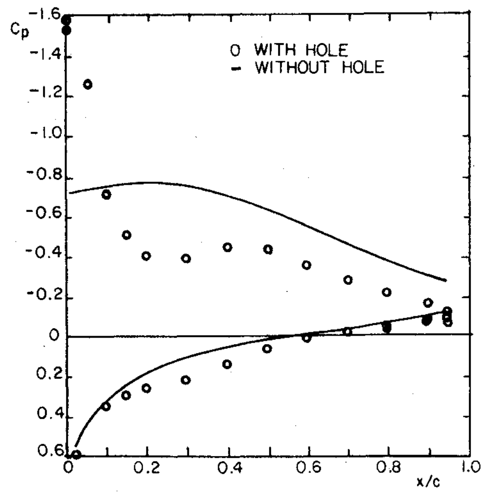

Fig. 4 C_p along a chord 7-cm outboard of hole, $\alpha = 9.8$ deg.

turbulent wake behind and under the hole outflow, with substantial reverse flow on the upper surface. The upper-surface pressures were increased at most stations in a manner similar to that seen in Fig. 3.

The largest perturbations occurred outboard of the hole on the upper surface, as shown in Fig. 4. In this region, oil-flow data indicated strong reverse flow in the separation bubble on the stabilator without any hole. When the hole was added, the flow over the aft 80% chord was restored to the streamwise direction, with the hole outflow acting somewhat as a fence. The C_p distribution of Fig. 4, with a leading-edge suction peak, is similar to that found at lower angles where the flow was attached.

Conclusions

The hole effects were found to be dependent on the extent of leading-edge separation on the stabilator. At angles of attack below about 6 deg, separation was limited and the effects extended laterally beyond the hole to a distance approximately equal to the hole width and streamwise to about 60% chord; these localized effects were moderate in magnitude. At higher angles of attack with separation, all upper surface pressures were perturbed; the strongest effects were outboard of the hole where the normally separated flow was attached by the fence-like action of the flow through the hole. At the higher angles, the effects were also localized on the lower surface.

Acknowledgment

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References

[1] Scott, D.S., Westkaemper, J.C., Sigal, A., and Stearman, R.O., "The Influence of Ballistic Damage on the Aeroelastic Characteristics of Lifting Surfaces," AFOSR TR 80-0220, May 1979.

[2] Scott, D.S., "Potential Flow Modeling of a Through-Hole Type Damage in a Lifting Surface Utilizing a Kernel Function Procedure," M.S. Thesis, Aerospace Engineering, University of Texas at Austin, May 1979.

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New Frequency Parameter for Unsteady Aerodynamics

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Background and Basis

AEROELASTIC analyses require unsteady aerodynamic coefficients at a large number of reduced frequency values (k). For transports the range of reduced frequency that must be accurately defined is from $k = 0$ to about $k = 1.0$ (where $k = b\omega / V$, and b is the reference semichord, ω is the circular frequency, and V is the freestream velocity). Because the computation of these unsteady coefficients is expensive, many aeroelastic programs rely on precomputed tables which are interpolated to determine the unsteady aerodynamics. An accurate representation of the aerodynamics requires a large number of entries in the table, particularly in the low k area, where the aerodynamics vary most rapidly. The cost of the computation and the need for accuracy, therefore, motivate the search for a parameter that would transform the reduced

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