THE UNIVERSITY OF WASHINGTON

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PROGRESS REPORT NO. 3

for

EXPERIMENTAL AND THEORETICAL INVESTIGATION OF WIND TUNNEL GEOMETRY, EMPHASIZING FACTORS PERTINENT TO V/STOL VEHICLES TESTING

for

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by

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INTRODUCTION

During the reporting period, September 16, 1965 through March 15, 1966, considerable progress was made on all fronts of the investigation of problems connected with wind tunnel testing of V/STOL models.

THE EXPERIMENTAL PROGRAM

The test program was directed at measuring the effects of testing near either end of the test section of a two-test section wind tunnel. The specific object was to clearly show the effects of the converging flow fields predicted in the analytical work. The difficulties encountered in the previous reporting periods were overcome by testing at higher advance ratios. In this way, we were able to avoid the downwash regions shown by Rae to give doubtful results, and to avoid the conditions where air speed measurements were both sensitive and suspect.

Pitching moments and lift were measured on a powered rigid rotor at the centerline of the test section and at a station near the downstream contraction of a test section having a length to height ratio of three. Lift characteristics showed no change, but the pitching moment slope with angle of attack showed a 20% increase in stability, thus clearly demonstrating that the converging flow field exists ahead of the contraction and that it has the expected result on pitching moments.

These tests will be continued at other locations in the test section to define the region of flow convergence that can give noticable results and to compare these effects with the calculated flow fields.

INTERNAL FLOW FIELD ANALYSIS

The analysis of internal flow fields in a two-test section tunnel by the Vortex ring method was extended and essentially completed during this reporting period. The vorticity of the discrete rings has been distributed in a linear piece-wise continuous manner and then used to calculate the internal flow fields with improved results near the tunnel walls. Mechanical difficulties encountered earlier have been overcome and velocity profiles can now be computed at sections not containing the center line.

An extension of the method has been made that is more suitable for calculating flow through an open circuit wind tunnel. In this application, the remote airstream velocity is set to zero, the Kutta condition abandoned at the tunnel exit, and one vortex strength chosen arbitrarily. The method has been used to design an intake section now being built as a part of the experimental program.

A final report is being written describing this part of the work.

THE TUNNEL INTERFERENCE PROBLEM

The next step taken after obtaining a solution for the trajectory of the vortex wake of a lifting system in free air, as reported previously, was to approach the calculation of the wake trajectory in a closed wind tunnel.

The tunnel walls were represented by a pattern of square vortex rings lying in the plane of the tunnel walls. With the limitation of square rings, only tunnels of constant cross section and finite length can be represented. The cross section can be composed of any number of sides of equal length arranged in any polygon. A control point was located in the center of each square, and the boundary condition of no flow through the wall was satisfied at each such control point. A wing in the tunnel is represented by a bound and trailing vortex system, initially trailing straight downstream. This system of simultaneous equations is solved on the computer for the unknown strengths of each of the vortex rings.

The wall vortex rings are used to calculate the velocities at the wing trailing system and this system is relocated such that it is everywhere parallel to the local flow. Then the first calculation of wall vorticity is re-iterated and the process cycled to convergence.

It has been shown that the process does converge and that the wake trajectory can be found in the wind tunnel. The original hypothesis, that the wake vortex would change its position significantly with respect to its free air position, has been confirmed.

Effects on pitching moments had not been calculated at the closing date of this reporting period, but later calculations have already shown that in some cases the influence of the shifting vortex wake on a tail at the tunnel center line can more than cancel the pitching moment interference due to the walls. A major effort in the next period will be to complete the calculation of wind tunnel wall interferences, including the effect of the relocation of the wake on the tail.

In order to check the adequacy of this representation, the classical case of a simple wing with undeflected wake in a circular tunnel was solved. The results agree exactly with those of Prandtl and Glauert at the wing. The vorticity in the wall agrees in the limiting case as the span of the wing approaches zero with that found in closed form for a doublet in the center of a circular tunnel. The downwash interference along the tunnel center line was calculated as well, but no theoretical solution is available for comparison. The best one found is an approximate solution by Lotz in TM 801.

This result is being written up for publication.