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WIND TUNNEL INTERFERENCE EFFECTS ON A 70 DEGREE DELTA WING

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CFD, Delta wing, Wind tunnel interference, Vortex breakdown.

Objectives

The aim of the work was to qualitatively assess the effect of test facility interference on the leeside vortical flow over delta wings. The ONERA 70^{o} delta wing [1] was chosen for validation purposes as part of the RTO AVT-080 Task Group on "Vortex breakdown over slender wings". The effect of wind tunnel walls and downstream structures on the leading edge vortices and breakdown locations was examined.

Method

The block structured RANS flow solver PMB3D [2] was used in all simulations, with a modified k-ω turbulence model used for closure. Given the highly sensitive nature of leading edge vortices, the methodology behind the simulations was to create a block structured grid in such a way that by removing blocks, different wind tunnel shapes could be modelled. Similarly downstream structures could also be placed in the flow. This permits a constant grid density in all simulations, therefore any variations in solution are solely due to variations in the tunnel wall proximities. Tunnel walls and support structures were modelled with no flow through and slip boundary conditions (to reduce grid requirements).

Results

A full discussion of the results and validation can be found in reference [3]. For validation purposes surface pressure, vorticity distribution, core velocities, and helix angles were compared with the experimental data of Mitchell [1]. Comparison with experiment indicated that the flow was reasonably well predicted (though there were minor discrepancies with respect to core velocity peaks and suction levels downstream of transition). Simulations were conducted with freestream conditions (no tunnel constraints), the ONERA F2 tunnel geometry (figure 1), and a second narrower tunnel. The breakdown locations for each case are given in table 1. It is clear that the presence of tunnel wall constraints promotes vortex breakdown. Examination of vortex properties, for example the chordwise distribution of circulation (shown in figure 2), indicates that the vortex strength increases, as does helix angle and core suction, which all have the effect of promoting vortex breakdown. Roof and floor proximity has little influence on vortex breakdown. Despite the presence of a possible induced camber effect, it is clear that an increase in mean effective angle of attack is the dominant factor.

Adding downstream structures of the shape given in figure 1 was found to delay vortex breakdown. This is due to a blockage effect which accelerates the flow around the support, reduces the static pressure, and provides a favourable pressure gradient which delays vortex breakdown. The breakdown locations with supports are given in table 1. Supports were found not to significantly influence the vortices upstream of breakdown.

Future

The trends predicted using CFD should be confirmed with experimental data. It is recommended an experimental investigation be carried out to confirm qualitatively and quantitatively the trends observed in the computations. A suitable experiment would impose artificial walls keeping the wing geometry constant. Measurements such as tunnel wall and wing surface pressures, as well as breakdown location would be beneficial.

References

1. Badcock, K. J., Richards, B. E., and Woodgate, M. A, "Elements of Computational Fluid Dynamics on block structured grids using implicit solvers", Progress in Aerospace Sciences, 36:351-392,2000.
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3. Allan, M. R., Badcock, K. J., Barakos, G. N., and Richards, B. E., "Wind tunnel interference effects on a 70^o delta wing", Proceedings of CEAS Aerospace Aerodynamics Conference, The Royal Aeronautical Society, London, UK, 10-12 June 2003.

Boundaries	**Model span / Tunnel width**	**Model span / Tunnel height**	**Support location**	**Support FAB**	**Breakdown location**
Farfield	-	-	-	-	69%c_r
ONERA F2	0.5	0.38	-	-	65%c_r
S/W = 0.63	0.63	0.38	-	-	60%c_r
ONERA F2	0.5	0.38	1c_r	12%	66%c_r
ONERA F2	0.5	0.38	0.5c_r	12%	81%c_r
ONERA F2	0.5	0.38	0.5c_r	6%	74%c_r

Table 1: Breakdown locations

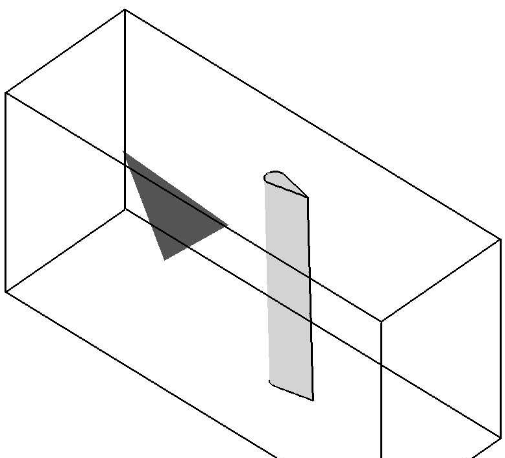

Figure 1: ONERA F2 Tunnel with generic structure

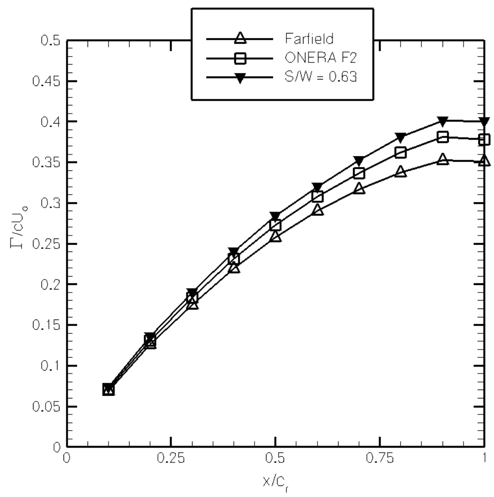

Figure 2: Variation in vortex strengths with wall proximity