HYPERSONIC SEPARATED FLOWS: COMBINING EXPERIMENT AND CFD.

Sean Creighton, Richard Hillier and Simon Williams
Department of Aeronautics, Imperial College London

Hypersonic aerodynamics presents a very demanding research area, experimentally, so that there is a special advantage in combining CFD and experiment as closely as possible. Experimental measurement of many important properties is often difficult or impossible and model manufacture is expensive and time-consuming. Thus CFD can assist in configuration development and can also 'probe' flow field areas that are not accessible to experiment. In turn, well defined experiments are required, both to assist in the interpretation of flow physics and also to provide 'benchmark' data for code 'validation' or 'assessment'. Our work has therefore focussed very much on combining CFD with experiment. We have considered a range of problems, but this paper concentrates on the specific area of separated flows.

Two classes of separated flows are considered: cavity flows and flare-induced separations. In all cases the experimental geometries have been based upon bodies of revolution, tested in a Mach 9 gun tunnel. This geometry permits high quality reference two-dimensional (axisymmetric) flows to be produced. Our studies also include three-dimensional interactions, which have been introduced in a controlled manner by some deliberate geometrical pertrurbation of the basic axisyymetric case. This enables us the construct flows that might be regarded as ranging from 'weakly' to 'strongly' three-dimensional.

The cavity flows have been designed in large part using preliminary CFD modelling and address three cases:

- two-dimensional axiymmetric steady laminar flow
- three-dimensional steady laminar cavity flow, produced by controlled perturbation of the body from the basic axisyymetric case
- unsteady laminar cavity flows on bodies of revolution.

A comparison between experimental schlieren visualisation and CFD-based 'schlieren' is shown in Fig. 1 for a a large axisymmetric cavity formed on a conical body at zero incidence. This case is highly unsteady, so that it has been necessary to match the phase of the cavity cycle correctly between the CFD (lower part of the figure) and experiment (upper part).

The flare-induced separation study is a high Reynolds number turbulent boundary layer investigation. It has produced a high quality two-dimensional (axisymmetric) data set, using a reference case of a cylinder-flarebody. A controlled three-dimensional separation is then produced by offset of the flare axis, and angle, relative to that of the cylindrical forebody. In the same way that the axisymmetric separation is free from any 'end effect contamination', the three-dimensional separation is entirely generated by the geometrical changes rather than being influenced by other unknowns. The paper will include CFD/experiment comparisons both for the reference two-dimensional flow and for the controlled three-dimensional case.

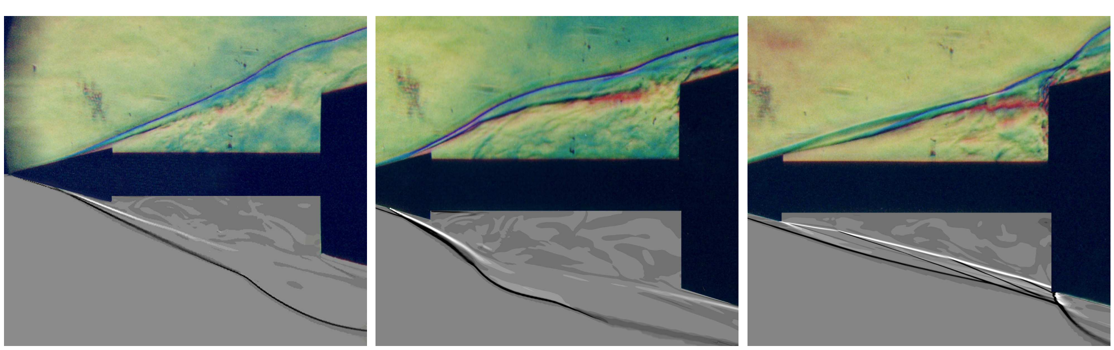

Figure 1: Unsteady cavity flow on body of revolution. Comparison between experimental (top half) and CFD schlieren (bottom half)