UNIVERSITY OF SOUTHAMPTON

ABSTRACT

FACULTY OF ENGINEERING, SCIENCE & MATHEMATICS

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Doctor of Philosophy

NUMERICAL SIMULATION OF LAMINAR FLOW OVER HYPERSONIC COMPRESSION RAMPS

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A numerical scheme which is able to capture three dimensional laminar shock-boundary layer interactions in perfect gas has been implemented. The method used is a Godunov's scheme with the HLLC approximate Riemann solver [145]. In order to be able to use large three-dimensional grids and alleviate the computational cost an implicit discretisation [12] was applied. A second order extension of the method is performed through the MUSCL approach [155]. The code was compared against theoretical, experimental data and results from different codes at a wide range of configurations.

Numerical steady state simulations of a Mach 6.85 Nitrogen flow over compression ramps (flap/body-flap junction) were performed at different ramp angles (15^o, 25^o and 35^o) at a constant Reynolds number of 2.45×10^6 /*m*. The computational results were compared with experimental data from the hypersonic wind tunnel at the University of Southampton [132]. The 2-D results have shown extensive recirculation regions at all angles with secondary vortices embedded at high angles. Large discrepancies were observed in the separation point position and in the heat transfer at reattachment with the experimental values. However, the results obtained are in agreement with laminar correlation laws. The 3-D results show a rich three-dimensional structure with complex shapes of the recirculation bubbles. At low angles a good agreement was found with the experimental separation point although a large heat transfer difference persists.

Periodic disturbances were introduced in the system producing a striation pattern in the heat transfer and Görtler type vortices at reattachment. A large increase in the heat transfer at reattachment was observed despite the modest perturbations applied. Görtler vortices were also observed using a more compressive limiter without external disturbances. The average wave length obtained in this case is similar to the one experimentally observed and the one predicted by linear theory.