TRANSIENT SEPARATION OF COMPRESSIBLE FLOWS OVER CONVEX WALLS

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Declaration

I hereby declare that the entire report in this thesis is my unaided original work, unless where clearly stated with proper acknowledgement. It is being submitted as a requirement for the award of the Doctor of Philosophy to the University of the Witwatersrand, Johannesburg, South Africa.

Signed this 11th day of March 2011

Adam Olatunji Muritala

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PUBLICATIONS

Aspects of this work have appeared in the following publications:

1. Muritala A.O, Skews B.W, Law C (2010) Near-wall effects on the global flow behaviour behind a diffracted shock wave, Seventh South African Conference on Computational and Applied Mechanics, Paper 100, University of Pretoria, South Africa.
2. Skews B W, Muritala A.O, Lucovig L and Law C (2010) Large scale shock wave diffraction experiments, 29th International Congress on High-Speed Photography of Photonics, Moricha, Japan, 2010.

ABSTRACT

This study investigated the shock induced transient separation of compressible flows over convex walls using both numerical and experimental analysis. The numerical simulations solved the Reynolds Averaged form of the Navier–Stokes equations, using unstructured quadrilateral cells. Some results are presented in numerical schlieren images for analysis. Experiments were conducted in a purpose built shock tube that allows for a large scale testing an order of magnitude greater than previously examined. The images of the interactions were captured with schlieren arrangement and later compared to the pictures from numerical schlieren analysis.

Three flow situations were examined: 30° corner in which the presence of the wall influences the flow; a 90° corner in which the internal flow features were not affected by the wall downstream; and a convex circular wall with flow influenced by the wall radius.

The development of instabilities and the break-up of shear layer into vortices are evident in both experimental and numerical images especially on a 90° corner wall. The flow over the 30° corner wall developed instability at very low incident shock Mach numbers. At incident shock Mach 1.5 series of lambda shocks formed above the shear layer with strong instability under it. The instability developed into a homogenous turbulent flow after long times of the diffraction process.

The flow behind the diffracting shock Mach number of 1.5 on curved walls did not separate at small times but separated after long time of diffraction process. A three-shock configuration was observed in the perturbed region from incident Mach number 1.5 while two were observed at higher Mach numbers but the upper triple point faded away with time when the Mach number is approaching 3.0. Both the secondary and recompression

shocks exist for the range of incident shock Mach numbers between 1.5 and 2.0. However, the secondary shock could not be sustained at higher Mach numbers and the recompression shock was fading away as the diffraction process progresses downstream before finally disappearing at a later time.

The movement of separation point increases with time for high incident shock Mach numbers but decreases with time for low incident shock Mach numbers. Separation and shear angle are independent of the wall radius for high Mach number incident shocks. A kink that is formed at the lower extremity of the contact surface is proposed to be due to sudden change in radial velocity as a result of near wall effects which enhanced an increase in tangential momentum.

For high Mach number incident shocks the flow features are similar for the three geometries except that two triple points are formed on curved walls. Many flow features that only appeared at high incident shock Mach numbers in the conventionally sized shock tubes were observed at low Mach numbers in the present large scale tests.

The final analysis showed that the global flow behaviour behind a diffracted shock wave is well captured in large scale experimentations and the detailed flow behaviour is predicted better using SST k-ω turbulent model.

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