6th European Conference on Computational Mechanics (ECCM 6)
7th European Conference on Computational Fluid Dynamics (ECFD 7)
11 – 15 June 2018, Glasgow, UK

CIRCUMVENTING SHOCK ANOMALIES: A HYBRID RIEMANN SOLVER IN CONJUNCTION WITH HIGH-ORDER SCHEMES

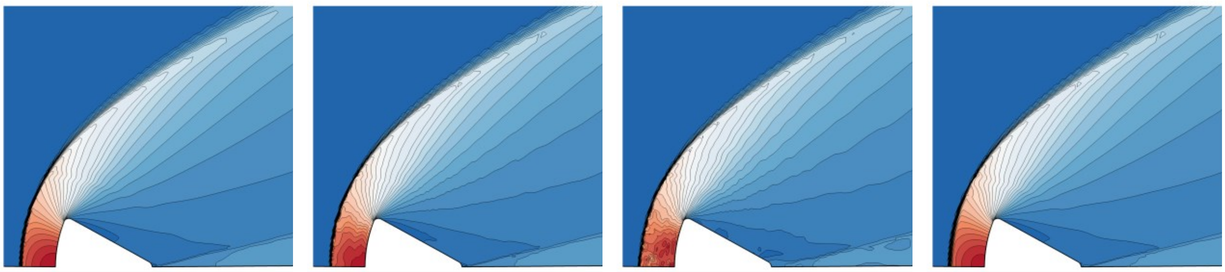
IOANNIS W. KOKKINAKIS and DIMITRIS DRIKAKIS
University of Strathclyde
75 Montrose Street, G1 1XJ, Glasgow, United Kingdom
ioannis.kokkinakis@strath.ac.uk, dimitris.drikakis@strath.ac.uk

Key Words: *high-order, finite volume, shockwave, Riemann solver, shock capturing.*

Over the past 4 decades, there has been several publications on high-resolution methods and their applications to shock waves and turbulence. Despite the above efforts, the numerical behaviour of such schemes in the presence of very strong shockwaves, e.g., for Mach numbers greater than 10, is rather limited. In particular, the effect of grid misalignment to strong normal shockwaves is known to lead to unphysical phenomena that adversely affect the quality and even validity of the resulting flow (see [1, 2, 3] and references therein). The problem becomes particularly severe for Finite Volume (FV) methods when a contact resolving Riemann solver is used.

Riemann solvers that have a single formulation and claim to be carbuncle-free typically introduce a shear viscosity component in some form or another. This stabilizes the simulation, but it also results in inaccuracies in the prediction of steady shear waves, thus leading to a poor resolution of boundary layers. Hybrid Riemann solvers provide an alternative because the numerical dissipation can be better controlled within specific flow regions. In this study, we investigate a hybrid HLLC – HLL Riemann solver in conjunction with 2nd and higher-order schemes.

Several flow examples are presented, including numerical evidence showing that the hybrid Riemann solver does not generate artificial flow structures in the presence of very strong shocks. The effects of the spatial order of reconstruction on the accuracy and stability of the simulations is also discussed.



a) HLL + 2nd order (Van Leer) b) HLL + 5th order (MUSCL) c) HLLC + 5th order (MUSCL) d) HYBRID HLLC 5th order MUSCL + HLL 1st order

Figure 1: Steady 2D inviscid flow at Mach 32.4 around the Apollo 4 re-entry capsule.

REFERENCES

[1] J. Quirk, "Contribution to the great Riemann Solver Debate," *International Journal for Numerical Methods in Fluids,* vol. 18, pp. 554-574, 1994.

[2] Z. Shen, W. Yan and G. Yuan, "A robust HLLC-type Riemann solver for strong shock," *Journal of Computational Physics,* vol. 309, pp. 185-206, 2016.

[3] Z. Chen, X. Huang, Y.-X. Ren and M. Zhou, "General Procedure for Riemann Solver to Eliminate Carbuncle and Shock Instability," *AIAA Journal,* vol. 55, no. 6, pp. 2002-2015, 2017.