RESIDUAL DISTRIBUTION SCHEMES FOR ATMOSPHERIC ENTRY AEROTHERMODYNAMICS: AN EFFECTIVE TREATMENT OF NUMERICAL SHOCK WAVE INSTABILITES

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The aim of this PhD thesis is to develop and validate a reliable and performing numerical method based upon Residual Distribution discretization techniques. This method will be employed to predict the thermal loads acting on spatial vehicles undergoing an atmospheric entry process. The numerical tool obtained will be validated against experimental data obtained by means of high-enthalpy wind tunnels and will be applied to the design of the thermal shields protecting reentering vehicles.

During this year, certain aspects of the technique needing some adjustments to deal with the distinctive characteristics of the hypersonic regime have been identified. Among them, extensive attention has been given to the subject of the carbuncle phenomenon, a critical numerical instability preventing the accurate simulation of hypersonic flows around blunted configurations. The known remedies for this instability have been reviewed, and the single one usable in the Residual Distribution context has been studied in depth. Its sensitivity with respect to its single controlling parameter has been investigated. The fix effectivity in avoiding the carbuncle has been proven. A simple technique to cure an, as far as we know, previously unreported lack of convergence has been found. The importance of a consistent treatment of energy dissipation has been assessed, and as a result a complete family of carbuncle fixes has been derived. This numerical treatment has finally been validated for the flow around a cylinder in hypersonic conditions.

At the present moment, our efforts are addressed at extending a linearization procedure to the thermal and chemical non-equilibrium conditions of our interest, so that flow discontinuities can be captured in a conservative and positive manner.

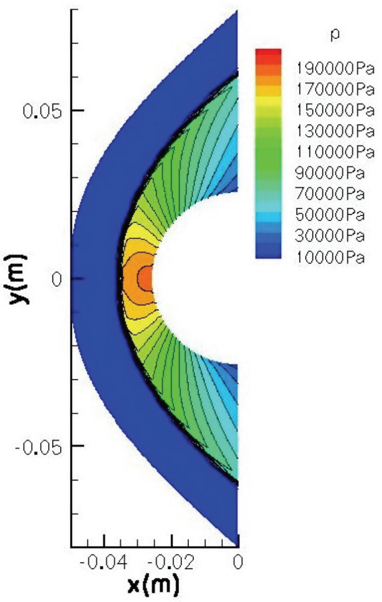

Figure 1 : Ma = 15.0, 400 × 20 nodes
Pressure isolines

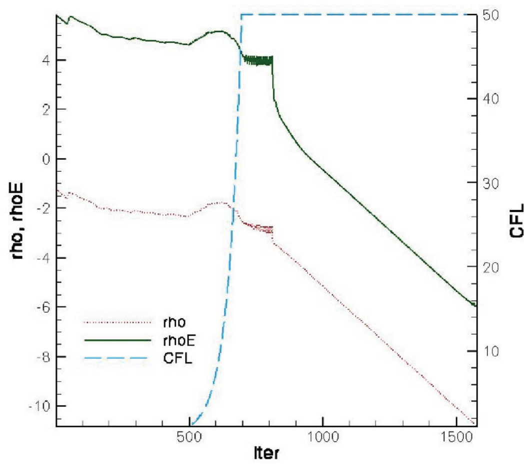

Figure 2 : BE time stepping
Convergence history

Garicano, Lani et al., "An effective treatment of numerical shock wave instabilities with RD schemes". 7th European Symposium on Aerothermodynamics for Space Vehicles, Brugge, Belgium, 2011.
Lani, Garicano et al., "A residual distribution method for symmetrized systems in thermochemical non-equilbrium", 20th AIAA CFD Conference, 2011.