Numerical Simulations of Hypersonic Reacting Flows: Progress and Challenge

Zonglin JIANG
Laboratory of High Temperature Gasdynamics, Chinese Academy of Sciences
Institute of Mechanics, CAS, 15 Beisihuanxilu, Beijing 100190, China

Abstarct

The hypersonic reacting flow characterized with two fundamental fluid physics issues: shock waves and chemical reactions is of essential importance for hypersonic technique developments from which a new hypersonic era may be born. The shock wave being a unique source from which vortices and turbulence can be generated inside fluid flows is a strong discontinuity across which some primary flow varitables go through a sharp jump. The chemical reactions, such as gas dissociations，detonations or combustions, will introduce much smaller physical scales than the flow reference length into gasdynamics and enlarge the governing equations by adding to it tens or hundrends of mess conservation equations. The combination of shocks and chemical reactions make the hyperswonic reacting flow a multi-physics and multi-scale reserach topic being full of challenges. Numerical simulations of hypersonic reacting flows are located in the frontier of computational physics, from which many challenging problems are arising, such as the grid generation for high-order boundary conditions, the mesh refinement for computing sharp discontinuities, high-resolution shock-capturing schemes, chemical rection modeling, large scale algebric system solvers, multi-scale computation, algorithm verifications and solution validations. In this talk, the progress on a new stability theory based on dispersion-controlled concept are discussed, including the role of the dispersion in numerical simulations, the mechanism of spurious oscillations near shocks, the development of dispersion conditions and dispersion-controlled dissipative schemes, algorithm verification and solution validation. The DCD schemes based on dispersion-controlled condition are distinct from conventional dissipation-based schemes, in which the dispersion terms in the modified equations are considered in the scheme construction. The basic idea is to remove the nonphysical oscillation by making use of dispersion characteristics instead of adding the artificial viscosity to dissipate oscillations. The dispersion conditions implemented with Warming's stability condition were demonstrated to work well as a new stability theory for constructing shock-capturing schemes being of no oscillations, no free parameters and no need of artificial viscosity. It indicates that the two conditions are able to serve as a fundamental stability principle for checking non-oscillatory shock-capturing schemes. Finally, other problems related with hypersonic reacting flows were also introduced breifly to rise more attemtion for further intensive researches.