PhD Dissertation Defense Announcement
Mechanical and Aerospace Engineering Department
University of Texas at Arlington

METHOD-OF-CHARACTERISTICS MODELS FOR FLOWFIELD EVALUATION OF HYPERVELOCITY TEST FACILITIES

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10:30 AM, Tuesday, December 12, 2023

Woolf Hall 200, Teams

Abstract

This work reports a systematic study which has successfully extended the method-of-characteristics (MoC) employed in classical gasdynamics to thermochemical nonequilibrium flows. The study progressed from the simplest calorically perfect gas (CPG) model to full thermochemical nonequilibrium model. Typically, the approach involved developing MoC sub-routines for resolving gasdynamic phenomena such as compression/rarefaction waves, contact surfaces & shock waves. Initially, CPG MoC subroutines were developed based on numerical methods existing in the literature. These subroutines were used to develop a reduced-order model for a detonation-driven shock tube (DDST). This phase also included experiments conducted at the Aerodynamics Research Center to validate the MoC model. Then, the CPG MoC approach was first extended to chemically reacting flows. Utilizing the new MoC subroutines, steady flows representing supersonic combustion, dissociation behind a normal shock wave and recombination in a hypersonic nozzle were simulated and validated against ODE solvers. The CPG MoC algorithm was then improved by vectorization for thermally perfect gas (TPG) flows. Subroutines developed in this phase were used to evaluate an expansion tube flow field and the results were validated against analytical Riemann solution. Similarly, subroutines for thermochemical equilibrium gas flows were developed. MoC models were built for an expansion tube and a DDST, followed by validation against theory and experiments (available in the literature). Finally, the vectorized MoC approach was extended to thermochemical nonequilibrium flowfields. This phase also included the development of thermochemistry solver based on Arrhenius type finite-rate chemistry with Park's two-temperature approximation. Vibrational relaxation resolves both vibration-translation and vibration-vibration exchanges. Final models include steady-state nozzle flowfield with vibrational, thermochemical relaxation and an expansion tube flowfield. These results were validated against experimental results, state-to-state and CFD models existing in the literature.