

SPACE PROPULSION SYMPOSIUM (C4)
Hypersonic and Combined Cycle Propulsion (5)

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AN UNSTRUCTURED RANS/FLAMELET CFD SOLVER FOR NUMERICAL SIMULATION OF THE
SUPERSONIC COMBUSTION IN AN INTEGRATED ARI/GP SCRAMJET COMBUSTOR

Abstract

Supersonic turbulent combustion is one of the key points for the development of a high-performance scramjet. Numerical tools play a more and more important role in these combustion flows prediction. Due to very short fuel residence times, the flame stabilization mechanisms are governed by auto-ignition. Thus, detailed chemical kinetics is required to accurately model the ignition and extinction phenomena. In this case, the traditional species transported finite-rate kinetic method becomes useless for the vast species transporting equations and the stiffness. An alternative approach is based on the flamelet concept by Peters et al. In this paper, a parallel finite volume RANS/Flamelet CFD solver is developed for supersonic turbulent combustion simulation. The computational domain is meshed with unstructured polyhedral cell, i.e., a mesh element can be tetrahedron, wedge, pyramid or hexahedron in the grid system for 3D case. The implicit LU-SGS algorithm is adopted as the time integration method. The convective fluxes are computed with the HLLC approximate Riemann solver. The states at the cell faces are reconstructed with a second-order interpolation in conjunction with Barth's slope limiters. The turbulence model equations and flamelet table index scalar equations are solved in sequence at each time step of the LU-SGS integration of RANS. Two turbulence models, i.e., Spalart-Allmaras and Menter's SST k -model, are implemented. Interaction of turbulence and chemistry is accounted for with the assumed β -PDF model. The chemistry model is based on the LLNL (Lawrence Livermore National Laboratory) mechanism for hydrocarbon fuels. The flamelet table is constructed using the FlameMaster 3.9 code by Pitsh. To account for the compressibility effects, Overmann's method is adopted, that is, only the species mass fraction in the flamelet table are used, and temperature is computed from the total energy directly. The solver is used to simulate the supersonic combustion for the Aerodynamic-Ramp-Injector/Gas-Portfire (ARI/GP) scramjet combustor in BUAA (Beijing University of Aeronautics and Astronautics). The ARI/GP scramjet combustor consisting of an aeroramp injector and a gas-portfire igniter. Several experiments had been conducted in the supersonic wind tunnel in the university, formally. The fuel is ethylene (C_2H_6). The equivalent ratio varying from 0.05 to 0.5, and the gas-portfire momentum flux ratio from 0.64 to 1.43. Computed wall pressure and temperature are in good agreement with the experimental results, which are obtained by pressure sensor and TDLAS (tunable diode laser-based absorption spectroscopy), respectively. The results demonstrate that the unstructured RANS/Flamelet solver is suitable for supersonic combustion simulation.