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SPACE PROPULSION SYMPOSIUM (C4)
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NUMERICAL SIMULATION OF A MACH 6 AIRBREATHING HYPERSONIC FLIGHT TEST VEHICLE POWERED BY TRIPLE-MODULE SCRAMJETS

Abstract

In this paper, a mach 6 airbreathing hypersonic flight test vehicle with highly integrated triple-module scramjets has been designed and analyzed with computational fluid dynamics (CFD) tools. Scramjets with three dimensional sidewall compression inlets are arranged in parallel at the abdomen of the vehicle. The flow phenomena in the three dimensional sidewall compression inlets are characterized by the crossing shock wave and turbulent boundary layer interactions, the resultant effects are complicated and may include flow separation and generation of vortical structures. During the vehicle flight test, there are three distinct mission phases: inlets closed with shut-down engines, inlets opened with shut-down engines, inlets opened with working engines, and all the three mission phases are analyzed with CFD tools. Two modules (aerodynamic module and propulsion module) have been built to solve the external and internal flow field of the vehicle. The wall pressure and surface friction of the airframe, tails, forebody and the external walls of the engines are calculated with the aerodynamic module, and the flow field of the propulsion flowpath including the inlets, isolators, combustors and external nozzle are solved with the propulsion module. In the aerodynamic module, a multi-block, structured grid, upwind-based flow solver has been developed to solve the 3-D Full Navier Stokes equations and calculate the aerodynamic characters of the vehicle. In the propulsion module, a computational code ChemTur3D has been developed to simulate the reacting flows in scramjet engine combustors. To accurately compute the flow of a hydrogen/air mixture and combustion at high temperature, the turbulent and chemical nonequilibrium effects must be taken into account. The 3D Reynolds averaged Navier-Stokes equations and species conservation equations are solved using a finite volume, cell vertex scheme on three-dimension structured grids. Chemical reactions is modeled using finite rate chemistry between hydrogen and air consisting of seven species and eight reactions, and turbulent mixing is modeled using the Menter's Shear-Stress Transport (SST) approach. The flow conditions for the calculations include variations of Mach number and angle of attack around the Mach 6 test point. The wall pressure and surface friction are integrated to calculate the lift force, the drag force and the pitching moment coefficients to evaluate the longitudinal performance of this hypersonic flight test vehicle. According to the numerical simulations, a preflight aerodynamic database of the vehicle could be built for the hypersonic flight experiments.