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SPACE PROPULSION SYMPOSIUM (C4)
Hypersonic and Combined Cycle Propulsion (9)

Author: Mr. zhang yan
Beihang University, China, rechard_1982@sina.com

Prof. Lin Yuzhen
China, 18600369549@163.com
Mr. Liu Wei
Beihang University, China, rechard_1982@sina.com
Mr. Wang Jianchen
Beihang University, China, rechard_1982@sina.com

NUMERICAL STUDY OF VITIATION EFFECTS ON SUPERSONIC COMBUSTION

Abstract

In ground test facilities, the high enthalpy inflow of the dual-mode scramjet combustor was mainly obtained via the combustion of hydrogen or hydrocarbon fuel. This heating process introduced levels of vitiates in the test inflow, such as water and carbon dioxide, that were not present in atmospheric air. In present paper, the vitiation effects of water and carbon dioxide on the combustor performance and operability of a dual-mode scramjet combustor was numerically investigated. The reacting turbulent flow was solved using the shear stress transport (SST) k-ω turbulence model, particles stochastic trajectory model, steady-flamelet model and a skeletal chemical reaction mechanism of n-dodecane with 57 species and 204 reactions. The numerical simulations were performed at three different levels of water vapor and carbon dioxide additions, which corresponded to the levels of vitiates found in hydrogen, methane, and alcohol combustion-heated facilities, respectively. The numerical results under the clean inflow condition acted as the reference case, and have been validated by the experimental data from the Supersonic Combustion Facility in Beihang University. The inflow had the total temperature and pressure of 1000K and 0.85MPa, and entered the isolator entrance at a Mach number of 2.03. The integrated transverse injector and series dual-cavity acted as the injection/flameholder system. The cold liquid n-dodecane acted as the fuel, and the fuel equivalence ratio was held constant to 0.27. The numerical results compared the combustor peak pressures, combustion efficiencies, and total pressure losses under different levels of vitiates. Both thermodynamic and chemical kinetic effects were investigated by numerically obtaining the presence and levels of radical species. Furthermore, the effects of vitiation on the mixed subsonic and supersonic nature of the flow in the dual mode scramjet combustor was also examined.