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COMBUSTION CHARACTERSTICS OF LOX-METHANE IN SWIRL COAXIAL INJECTOR HYDROGEN PROPULSION SYSTEM

Abstract

Propellant combinations such as Liquid Oxygen (LOX)-hydrogen and LOX-kerosene are commonly used in liquid rocket engines. Recently, LOX-methane combination has attracted considerable attention for future development of reusable launch vehicles (RLV). Methane is widely accepted as an alternative fuel for new generation propulsion systems because of soft cryogenic, high density impulse and low coking properties. A possibility of converting existing LOX-hydrogen rocket propulsion system to LOX-methane is under consideration. It is essential to understand the combustion characteristics/efficiency of methane for any possible conversion of existing hydrogen propelled rocket engine. In regard to same, a numerical study is initiated to explore and compare combustion characteristics of LOX-methane in existing hydrogen propulsion system.

Swirl injectors are extensively used to enhance atomization, mixing and combustion process in liquid rocket engines. Several investigations were done on swirl coaxial injectors at subcritical conditions in recent years, but very limited studies have been conducted in supercritical conditions. An initial numerical study at single element level is conducted, which is followed by combustion modeling in multi-injector domain to understand combustion behavior and flame shape of LOX-methane combination.

Propellants show large variation in thermodynamic properties when subjected to supercritical conditions. The non-ideal thermo-physical properties are modeled using Soave-Redlich-Kwong (SRK) real gas equation of state. Chemistry closure is achieved using non-premixed probability density function (PDF) based chemical equilibrium approach. Favre-averaged Navier-stokes equations are solved using finite volume methodology with SST k- model for turbulence closure. Combustion characteristics of both hydrogen and methane are analyzed at chamber pressure of 6.8MPa. A detailed comparison of hydrogen and methane flame shape in single element domain is carried out. Results showed localized difference in flame shape/structures in methane and hydrogen combustion cases. A larger and rapid radial expansion of flame was seen for hydrogen compared to LOX-methane case. Both simulations showed, flame anchored at fuel post and formation of recirculation region to help in flame stabilization by further igniting the incoming propellants. A full scale thrust chamber combustion modeling is initiated to determine flow characteristics and flame dynamics in multiple swirl coaxial injector elements.