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NUMERICAL STUDY OF LOX/KEROSENE COMBUSTION IN A SINGLE ELEMENT COAXIAL BI-SWIRL INJECTOR AT SUPERCRITICAL CONDITIONS

Abstract

Liquid rocket engines operate at high pressures are generally above the critical pressure of propellants. Combustion in liquid rockets occurs at supercritical conditions where thermodynamic properties of propellants deviate from ideal behavior. Real gas effects should be taken into account for these deviations. In the present study, Liquid Oxygen (LOX)/Kerosene combustion is modeled numerically in a single element coaxial bi-swirl injector. The Study investigates the real gas effects at supercritical pressure (P = 5.5 MPa) using commercial CFD code (ANSYS Fluent 15). Kerosene is introduced tangentially at 340 K whereas LOX is injected at 117 K from tangential and axial inlets. Chemistry closure is achieved using a non-premixed combustion model with chemical equilibrium assumption. At high pressures, turbulence greatly affects the combustion phenomenon because of the straining of flames. Non chemical Equilibrium effects due to the straining of flames have been studied using laminar steady flamelet model. An Assumed shape PDF method is used for turbulence/chemistry interaction. Real gas effects are taken into account using Soave-Redlich-Kwong (SRK) real gas model. To accurately predict the flow and flame characteristics due to presence of highly turbulent flows, study has been performed on full 3D geometry. Substantial difference in the densities of propellants at supercritical pressure has been observed with Ideal gas and SRK real gas equation. LOX/Kerosene chemistry is infinitely fast, which indicates reaction rates are controlled by turbulent mixing. Two equation RANS model and SST k-ω have been used for turbulence closure. Results of non-premixed model with chemical equilibrium assumption and laminar steady flamelet simulation which accounts for non-chemical equilibrium effects are discussed in detail. The present study aims to explore flow fields and flame structures at supercritical conditions. Results show that the flame is anchored at the end of fuel post where co-flowing LOX and kerosene mix together in a free shear layer. A recirculation zone is formed near the fuel post which helps in flame stabilization. Mixing and Combustion process completes in the main combustion zone and uniform mixture of combustion gases is formed downstream of combustion chamber. The mixture temperature results are validated with the gas temperatures obtained in single element injector combustion experiments as well as with mixture temperatures predicted by NASA CEA code.