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EXPERIMENTAL & NUMERICAL INVESTIGATION OF GOX/GCH4 COMBUSTION IN A 7-ELEMENT ROCKET COMBUSTOR

Abstract

Methane based propulsion systems have attracted lot of attention in recent years for reusable launch vehicle and interplanetary travel applications. A lab-scale experimental investigation of GOx/GCH4 combustion is imperative to understand the combustion dynamics and wall heat transfer characteristics in a full-scale engine. A systematic experiments can generate a database for validation and refinement of CFD models for full-scale engine simulations. In the present work, a combined experimental and numerical investigation of GOx/GCH4 combination is conducted in a lab-scale combustor. A multi-element combustor with a modular design to incorporate seven bi-directional swirl coaxial injector elements is designed to handle chamber pressure up to 10 bar. A proven injector configuration is chosen based on in-house experience with LOx/H2 engine. A radiatively cooled combustion chamber is realized, with flexibility of conducting hot tests incorporating single, three, five or seven number of injector elements. The key aspect of this study is to simulate ignition condition of a typical full-scale engine in a lab-scale combustor. The study involves multi-element flame-flame and flame-wall interaction with systematic measurement of chamber pressure, wall temperature and dynamic pressure at varied GOx/GCH4 mass flow rates. Performance,heat transfer and stability aspects are assessed at fuel rich conditions through short duration tests at 5 bar. The combustor is ignited with spark plug based torch igniter operating on GOx/GCH4 propellants. Multiple hot tests are carried out to generate combustion and heat transfer database for validation and development of CFD based combustion model. In this study, a concurrent 3D RANS and high fidelity large eddy simulation (LES) based CFD modeling is initiated to simulate dynamic features at hot test specific operating conditions. A non-adiabatic steady laminar flamelet formulation is used to model GOx/GCH4 chemistry in both RANS and LES framework. The model considers non-equilibrium effects and is suitable for hydrocarbon flames. Turbulence-chemistry interaction is modeled by probability density function. A detailed GRI Mech3 kinetic mechanism is used to generate flamelets for mean property tabulation in a preprocessed lookup table. Simulation captured the evolution of strong swirl associated with bidirectional swirl injectors, with flame temperature, Mach number and tangential velocity displaying physical trend along the length of chamber. CFD model showcased efficient mixing, combustion performance and evolution of required chamber pressure close to the test conditions. The characterization of wall heat transfer and combustion dynamics in LES framework is conducted with a final aim to develop validated numerical methodology for full scale engine applications.