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EXPERIMENTAL & NUMERICAL INVESTIGATION OF GOX/GCH4 COMBUSTION IN 7-ELEMENT SUB-SCALE COMBUSTOR

Abstract

Methane based propulsion systems have attracted lot of attention in recent years because of its clear advantages over LOX/H2 or LOX/Kerosene propellant combinations. Methane fueled high thrust rocket engines like Raptor (SpaceX) and BE-4(Blue Origin) are being developed for launch vehicle and interplanetary travel applications, considering advantages of methane like higher density impulse, higher cocking limit, lower tank insulation requirement and its availability in Martian atmosphere. In this scenario, design development of methane powered propulsion system is imperative. To understand the combustion characteristics of methane, a combined experimental and numerical investigation is initiated. A multi-element combustor with a modular design to incorporate seven swirl coaxial injector elements is designed. The injector configuration is chosen based on in-house experience with similar injectors existing in LOX/H2 engine. A radiative cooled combustion chamber is realized, with flexibility of conducting hot tests incorporating single, three, five or seven number of injector elements. The combustor is designed to handle required mass flow rate to obtain chamber pressure up to 10bar, to simulate ignition condition in a typical full-scale engine. The study involves systematic measurement of chamber pressure, chamber wall temperature and dynamic pressure at varied GOX/GCH4 mass flow rates/equivalence ratio. Combustion characteristics and stability at varied inlet conditions is assessed through short duration tests with maximum chamber pressure of 5bar. The goal of experimental study is to create a database for validation and development of CFD based combustion model. Combustion modeling of 7element combustor is performed to check combustor design adequacy and to develop validated methodology. Steady state RANS based simulations were carried out to check multi-element flow and flame features. GOX/GCH4 chemistry was modeled using steady laminar flamelet combustion model, which accounts for non-equilibrium effects introduced due to flame stretching. GRI Mech3 chemkin mechanism was used to generate sufficient flamelets for mean property tabulation in a preprocessed PDF table. Simulation captured the evolution of strong swirl associated with bidirectional swirl injectors. Preliminary results of temperature, Mach number and tangential velocity along the length of chamber displayed good trend, with efficient mixing combustion within designed chamber length. The combustion simulations verified the combustor design, which is further validated with successful short duration hot tests. Development of validated computational methodology for combustion simulations will be the final aim of this combined study.