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ASSESSING IMPURITY EFFECTS ON LO-X/METHANE AND LO-X/NATURAL GAS MIXTURES IN ROCKET PROPULSION SYSTEMS

Abstract

As the commercial space industry matures, space travel is expected to expand similar to how air transportation did in the 20th century. However, the cost of fueling is a current bottleneck and needs to be directly addressed to make space affordable. One solution under investigation is the use of liquid methane (LCH4) as a primary fuel source. Liquid methane gained popularity as a rocket fuel because engines that use LCH4 are thought to be significantly more reliable when used for multiple launches and are far less likely to soot than kerosene-based fuels. Commercially available CH4 has widespread availability and low cost compared to the kerosene-based RP-x liquid aerospace fuels while simultaneously being less harmful to the environment. However, for rocket applications, LCH4 can contain no more than 10 ppm of impurities without its ignition and chemical kinetic properties being affected. Thus, it is necessary to determine the optimal impurity level for a low-cost, readily available, aerospace-grade LCH4 fuel. This requires experimentally investigating the chemical kinetics and ignition properties of LCH4 and other CH4-based fuels with varying levels of impurities.

Ignition characteristics of methane/natural gas blends with varying levels of impurities has been investigated, but results are confined to pressures relevant to low-pressure applications. The chamber pressures for rocket engines are significantly higher (on the order of 300 bar), which far exceeds the current literature. Therefore, new experimental ignition delay time measurements at relevant pressures are essential to ensure that chemical kinetic models capture the ignition behavior at these elevated conditions.

Ignition delay times and species-time histories are collected at the University of Central Florida's shock tube facilities as shock tubes are nearly ideal environments for studying gas-phase high-temperature pyrolysis and oxidation phenomena. Experiments are conducted using pure O2 and pure CH4 at stoichiometric conditions over a large range of pressure (up to 300 bar) and temperature (1000-2000 K). Equivalence ratios from 0.5 to 2 are then investigated to simulate relevant engine conditions. Results from these measurements are then used to assess the predictive abilities of literature chemical kinetic models. A sensitivity and reaction pathway analysis are carried out based on the collected data, and, where relevant, improvements are made to the models. Finally, simulations are conducted with the improved models for canonical rocket combustor flow analysis.