Numerical Investigation of Methane/Oxygen and Methane/LOX Counter-flowing Spray Flames at Elevated Pressure

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Abstract

In liquid rocket propulsion systems, methane and kerosene have been discussed as alternative fuels to hydrogen because of their high energy content. Methane has some advantages compared to kerosene because of its cleaner burning characteristics. The present study concerns the numerical investigation of laminar methane/air and methane/oxygen flames where different mixtures of nitrogen and oxygen in the oxidizer stream are studied. Moreover, liquid oxygen (LOX) spray flames with carrier gas methane against a methane stream are investigated in the counterflow configuration. These structures may be used in (spray) flamelet computations or flamelet generated manifolds for the simulation of turbulent combustion. The governing two-dimensional gas-phase equations are transformed into one-dimensional equations using a similarity transformation. For the LOX, a standard discrete droplet model is used. The numerical simulation concerns the axi-symmetric configuration with an adaptive numerical grid for the gas phase. Detailed models of all relevant processes are employed; in particular, a detailed chemical reaction mechanism is used which comprises 35 species involving 294 elementary reactions. The thermodynamic data for CH_4 and O_2 below 300K are implemented for normal and elevated pressures for cryogenic methane/LOX combustion. For the CH_4/air and an oxygenated flame, the present results are compared with both experimental and computational results from the literature. The CH_4/O_2 flame is studied for elevated pressures up to 2MPa. Extinction conditions are evaluated for use in future turbulent flamelet computations. It is shown that oxygen dilution, pressure, and strain rate have a pronounced effect on the flame structure and extinction conditions. The combustion of methane/LOX under cryogenic conditions has a pronounced effect of the liquid phase on gas temperature. After initial cooling of the gas phase due to droplet evaporation, the flame temperature is considerably higher compared to pure gas phase combustion.

Key words: Methane/oxygen, detailed chemistry, liquid oxygen, extinction, flamelet library

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