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VISUALIZATION OF THE LIQUID LAYER COMBUSTION OF PARAFFIN FUEL AT ELEVATED PRESSURES

Abstract

High regression rate fuels have brought hybrid rockets to the forefront of propulsion research. These fuels form a thin melt layer during combustion, which is unstable under the oxidizer flow. The shear force between the liquefied fuel and vaporized oxidizer creates roll waves in the liquid layer and forces droplets of fuel to separate and entrain into the flow. This process is essentially a fuel injection system, which dramatically increases the mass transfer in and therefore the regression rate of the fuel (by 3-4 times that of classical hybrid fuels.) The thrust levels required by most classical hybrid propulsion systems led to the need for increased burning areas in order to provide sufficient mass flux. This was often realized by complex, multi-port fuel grain designs that have been responsible for most of the disadvantages associated with hybrid rockets. The increased mass transfer of liquefying hybrid fuels enables simple, single-port fuel grain designs to make competitive candidates for a variety of launch systems or in-space missions.

The mechanism responsible for the fast regression rates of liquefying fuels has been predicted theoretically; however, is still poorly understood. An apparatus to visualize the liquid layer combustion of paraffin fuel with oxygen has been designed and constructed at Stanford University. It is capable of oxidizer mass fluxes up to 60 kg/m^{2}s and pressures up to 1.7 MPa. A flow conditioning system was modeled after a low speed wind tunnel to produce a uniform and repeatable flow at the inlet to the combustion chamber. The combustion chamber was machined out of a single brass cylinder. The test section is 5.08 by 5.08 cm and has three windows that allow visual access to the combustion chamber by multiple instruments and various lighting options. The fuel is suspended in the combustion chamber by a cantilevered beam to minimize interactions with the windows. Individual droplets from the liquid layer combustion will be captured optically with a high-speed video camera.

The goal of this experiment is to support improved combustion models and simulations of these fuels through observing entrained droplets and flame propagation. Preliminary speed, size and trajectory information will be collected at elevated pressures. A similar experiment has been conducted at atmospheric pressure. However, visualization at elevated pressures is more representative of the physical system. We hope to determine how the droplets change with pressure and make our combustion models more closely resemble the physical processes.