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VISUALIZATION OF THE LIQUID LAYER COMBUSTION OF PARAFFIN FUEL

Abstract

Hybrid rockets have often been overlooked as alternatives to conventional chemical rockets due to the low regression rate of classical hybrid fuels. The slow burning rate translates into either a reduced thrust level or the requirement for a complicated, multiport fuel grain to increase the available burning area. These major disadvantages can be completely negated by using liquefying hybrid fuels, such as paraffin. Paraffin enjoys a regression rate of about 3-4 times that of classical hybrid fuels (e.g. HTPB). This increase is enough to allow for simple, single port designs. It makes them competitive and viable options for a multitude of missions including suborbital space tourism, launch to LEO, a Mars Ascent Vehicle as part of a sample return campaign, and for planetary orbit insertion.

The high regression rates of liquefying hybrid fuels occur through the presence of a droplet entrainment mass transfer mechanism in addition to the conventional evaporative mass transfer. This mechanism has been predicted theoretically [1]. A benchtop visualization system is currently being built at Stanford University to study this mechanism. The combustion chamber is brass with three rectangular windows, on both sides and the top, to allow visual access to the combustion chamber from multiple vantage points and a variety of lighting options. A flow conditioning system is utilized to insure that the flow of the gaseous oxygen entering the combustion chamber is uniform and predictable. A small slab of paraffin is fixed to a cantilevered support. This design was selected to insure that the combustion is not disrupted by the walls (or windows) of the device. The liquid layer combustion will be captured with a Casio Exilim EX-F1, capable of 1200 frames per second. We plan to use the results to develop improved scaling laws for hybrid combustion mass transfer rate.

References:

[1] Karabeyoglu, M. A., Cantwell, B. J. and Altman, D. Development and Testing of Paraffin-Based Hybrid Rocket Fuels. AIAA 2001-4503. 37th AIAA/ASME/SAE/ASEE Joint Propulsion Conference and Exhibit July 2001, Salt Lake City, Utah.