Transient Burning of Hybrid Fuels in a Lab-scale Burner by an Optical Technique

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Hybrid Rocket Engines (HREs) offer possible advantages over Solid Rocket Motors (SRMs) and Liquid Rocket Engines (LREs) such as thrust throttling and possible multiple ignitions. Considering the high safety and reliability of HREs, these attractive features could answer to novel and urgent operating applications such as active de-orbiting of satellites and spacecrafts, and soft-landing systems. SPLab (Space Propulsion Laboratory) of Politecnico di Milano has developed several experimental techniques and test-rigs in order to investigate the ballistics of HREs at lab-scale level. In particular, a time-resolved optical technique for regression rate measurement has been developed and presented. The latter is based on the sampling of the central port diameter evolution in time during combustion. Starting from interpolation in time of the achieved data, ballistics of the system is therefore defined. The Thickness Over Time (TOT) technique is considered for consistency check for the acquired time-resolved information and comparison with literature data.

The time-resolved optical technique was used to investigate the ballistics of two different fuel formulations based on Hydroxyl-Terminated Polybutadiene (HTPB): a baseline formulation (HTPB) and a metallized one (HTPB loaded with 10% nAl). Both steady state and transient operating conditions were investigated during tests. In the former case both the oxidizer mass flow rate and the combustion chamber pressure did not change with time during test, in the latter both of them were modified. Chamber pressure was varied in the range from 4 to 16 bar, while oxidizer mass flow rate was changed from the initial value of 210 nlpm [corresponding to a nominal initial oxidizer mass flux of ~470 kg/(m²s)] to 130 nlpm. Under the investigated conditions, the baseline formulation was relatively insensitive to changes in chamber pressure, while the oxidizer mass flow changes exhibited a significant influence (see Figure 1).

Possible overshoot/undershoot phenomena can characterize the combustion under transient oxidizer mass flow rate. These latter dynamics could be related to a variation in convective heat exchange blockage and possible heat-conduction effects in the solid fuel grain. Investigations of HREs burning under transient regime can therefore provide a better understanding of the phenomena involved in hybrid combustion.

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Figure 1. Baseline (HTPB), Test No.01HT (Hat Transient), diameter change in time under chamber pressure of 16 bar and non-steady oxidizer mass flow rate.