REGRESSION RATE MEASUREMENTS IN LAB-SCALE HYBRID ROCKETS

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Hybrid rocket propulsion is an attractive solution for suborbital flights, space exploration, orbital transfer and, in particular, active debris removal of large abandoned objects still orbiting in Low Earth Orbit (LEO). The most significant advantages are throttleability and reignition [1]. Despite these great features, the solid fuel regression rate (r_f), in a hybrid rocket, changes over time, due to the variation of specific oxidizer mass flow rate, and over the grain length, due to the strong influence of fluid dynamic on the combustion. In particular, a significant irregularity is caused by swirling oxidizer injection, as observed also during some combustion tests performed with a high speed camera at the Space Propulsion Laboratory (SPLab) of Politecnico di Milano, burning PMMA pierced cylinders. The swirl intensity tends to decay along the distance from the injection section and so also the fuel regression rate. This paper deals with the comparison between three different methods to evaluate the quasi-steady regression rate of solid fuel in lab-scale micro-burner, developed at the SPLab. The first approach considers an intrusive analog sensor, inserted in the solid fuel during the manufacture process. Exploratory tests have shown the feasibility of these kind of measures. More than one sensor can be inserted in the solid fuel grain, in order to measure the r_f along the fuel length. Multi-sensor configuration is useful to take into account the different regression rate between the aft and the fore sections of the fuel cylinder. The second is a non-intrusive method [2], which exploits a high speed camera to visualize the flame structure. The video is subsequently analyzed by an *OpenCV* automatic software developed for this purpose or directly by user, who gains manually the diameter variation over time. The regression rate measure is evaluated on the aft face of the fuel cylinder. The software, using special filters, is made able to recognize the regression surface and to create a virtual profile which follows the surface during the combustion. This application shortens significantly the post-processing of the recorded videos of combustion. The two methods are described and resulting measures are compared, focusing on advantages and disadvantages of each approach. The third method concerns fiber optics placed into the fuel sample. In the first implementation of this technique, a fiber optic array allows detecting the signal of the fuel sample regression, following the sequence of activation of the corresponding photodiodes array. Knowing the spacing between fibers and the time of activation it is possible to measure the regression rate.

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