Modeling of Liquefying Fuel Regression Rates in Hybrid Propulsion

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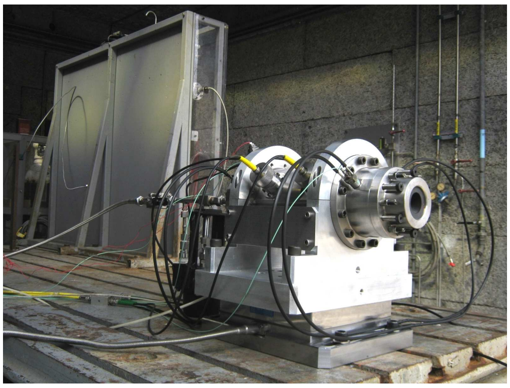
Hybrid rocket could be considered half way from solid and liquid technologies since this chemical propulsion system stores the oxidizer and the fuel in two distinguished states. The most often presented configuration considers a liquid or a gaseous oxidizer which flows through a solid fuel channel and burns with the pyrolysis gases coming from the solid fuel regression. In this case, the fuel grain acts as a combustion chamber referring to solid propulsion whereas the oxidizer, stored in a separated tank, and the injection system refer to liquid technology [1]. This technology is associated to simplified, low cost, faster and thrust modulated operations with a high level of performance, reliability and availability. To be competitive in term of propulsive performance compared to other chemical propulsion systems, the solid fuel regression rate of the hybrid rocket engine needs to be increased. Liquefying fuels, which undergo degradation to the gaseous phase by forming a thin, hydro-dynamically unstable liquid layer which is then atomized, provide regression rates three to five times higher than the values encountered with classical polymeric fuels.

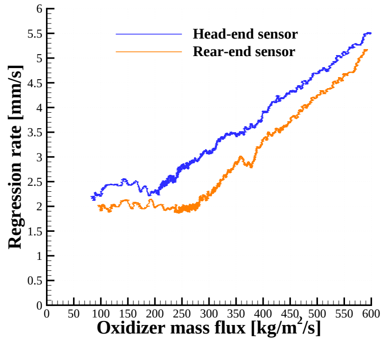
The solid fuel regression rate is one of the most important values for the design of the hybrid rocket engine. To predict if the hybrid rocket engine can fulfill the mission needs in terms of performances, the regression law has to be determined for each oxidizer/fuel pair either experimentally or numerically. The numerical approach is of course cheaper both in time and cost but requires a reliable numerical tool. ONERA has developed the one-dimensional numerical tool Dephy for predicting the regression law of polymeric fuels [2]. The models used in this tool are not adapted to liquefying fuels since, on the one hand, the liquid film formed by the melting of the solid fuel and the atomization process are not considered and, on the other hand, heat and mass transfer phenomena encountered for the two kinds of fuel are completely different. A new one-dimensional tool of the regression mechanism of liquefying fuels (Hydres) has been recently developed. The tool is based on the transport of the gaseous flow and the liquid film which is developing along the solid fuel grain. The regression rate depends on mass and energy transfers between these three phases.

To validate the HYDRES tool, experimental tests were performed thanks to two facilities. The Hycarre test bench considers a solid fuel sample placed in a 2D test-section and subjected to a non reacting gas flow [3] whereas the Hycom test bench is a lab-scale hybrid engine [4] (Figure 1a). The measurement of the instantaneous oxidizer mass flow rate and of the instantaneous regression rate of the solid fuel, thanks to ultrasonic sensors, in both facilities provides directly the instantaneous regression law of the oxidizer/fuel pair (Figure 1b).

This work was performed through a PhD Thesis at ONERA supported by the CNES and defended at the end of December 2012. The paper will provide an overview of the HYDRES numerical tool and will focus on the experimental tests performed on the Hycom facility to validate the numerical tool.



(a) HYCOM facility



(b) Regression law obtained during a HYCOM test

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