NONSTEADY COMBUSTION SIMULATION OF 2D HYBRID ROCKET FLAME

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Thrust throttleability and reignition are some of the most appealing features of hybrid rockets, which derive directly from some peculiarities shared with liquid propulsion systems. In particular the capability of thrust modulation is a mandatory need for some types of missions such as planetary soft landing but it also grants flexibility to typical launching operations, orbital maneuvering, suborbital flights, or deorbiting.

A general description of quasi-steady combustion process was given by Marxman and Gilbert [1]. The self-sustained diffusive flame results from a balance between the heat coming from the flame and the enthalpy consumed for fuel pyrolysis, if possible entrainment phenomena are neglected for simplicity. Hybrid rocket thrust variation is accomplished by controlling mass flow rate of liquid or gaseous oxidizer through a valve, being the solid fuel regression rate dependent on the mass flux. However, the behavior during transient conditions is complex, since it is the result of overlapped physical and chemical processes involving turbulent combustion, chemistry, fluid dynamics, and heat transfer.

Previous works have addressed the numerical simulation of hybrid rocket flow field with different degrees of complexity and detail. A good documentation review can be found in the book by Chiaverini and Kuo [2], [3]. Also the Space Propulsion Laboratory has worked in the field of hybrid rocket numerical simulation and developed a software tool grounding on OpenFOAM framework technology focused on the simulation of a 2D slab geometry [4]. Thanks to the parallel activities performed on the 2D slab experimental facility at SPLab, studies and validation were conducted mainly for steady state boundary conditions [5]. In the present paper, the analysis of transient operations will be investigated. Proper extension to the simulation code will be accomplished for throttling control. Variable mass flow rate will be addressed in order to assess the response behavior of the regression rate, screening the governing parameters of this behavior (namely, throttling rate, or thermal inertia of the solid phase). For consistency with validation data, the analysis will be conducted for HTPB non metalized fuels but extension to paraffins are envisaged.

References

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