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A NEW SYSTEM DESIGN TOOL FOR A HYBRID ROCKET ENGINE APPLICATION

Abstract

This paper presents the development of a system design tool allowing the simulation of the whole operation of a Hybrid Rocket Engine (HRE). The aim of this tool is to use it as a predictive mean to estimate HRE performances in preliminary design studies or to precede the preparation of experimental test campaigns. The algorithm of the numerical application is made in such a way that allows the simulation of an individual component of the engine or of the whole propulsive system.

Contrary to most system design applications, which use 0-D models to describe the physics inside the combustion chamber, the present tool includes a 1.5-D combustion chamber model, which allows to combine both the speed and the simplicity (characteristics that can be found in 0-D models) with the precision required for a conception phase of the engine. This kind of modeling is an approximation of the two-dimensional equations of the flow: it is based on the integration of the fluid dynamics equations along the radial direction of the chamber, followed by the numerical computation of the resulting equations through the axial direction. A Gas-Surface Interaction model is used to describe the heat and mass transfers at the solid fuel surface, with the use of an Arrhenius law to define the fuel pyrolysis. This latter fact increases the applicability of the model to a wide range of engine configurations and dimensions in comparison with empirical fuel regression rate laws (mostly used for system design tools) and whose coefficients depend on the test conditions.

In this research, the models of the main elements (tank, injector, catalyst, combustion chamber, nozzle, etc.) composing the HRE are evaluated and their results are compared to the experimental measurements in temperature and/or pressure for three tests that have been performed at the laboratory with the purpose of validating the present system design tool throughout the whole duration of the engine operation. Furthermore, the combustion chamber modeling is also assessed through the temporal evolution of the measured thrust and fuel regression rate. The latter, representing a key parameter in the determination of the HRE performances.

Eventually, this tool will be improved to serve as an optimization means in order to determine the best engine configuration concerning the motor performances (couple of reactants, geometry, inlet oxidizer mass flow law, etc.) for some specified conditions.

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