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Invitation à la soutenance de thèse

DEVELOPMENT OF A 1.5-D COMBUSTION CHAMBER MODEL OF A HYBRID ROCKET ENGINE FOR A SYSTEM DESIGN TOOL

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Résumé

In recent years, hybrid space propulsion has become increasingly attractive as an alternative to conventional chemical propulsion systems for safety, cost and performance reasons. This kind of propulsion is considered for orbital applications (satellite positioning or de-orbiting), micro-launchers or even for space tourism.

The optimized design of this technology requires the characterization of the engine behavior and the knowledge of its performances in different configurations.

The high costs implied in the realization of experimental test campaigns in the space domain, has boosted the development of complex (usually steady) 2-D computational fluid dynamics (CFD) models of the combustion chamber. These codes couple combustion, turbulence and parietal fuel injection models that provide precise information on the aerothermodynamic field in the combustion chamber. Nevertheless, the large computation time thereof represents a fairly substantial hindrance for their application in the engine pre-design phases.

On the other side of the spectrum, the simple 0-D/1-D combustion chamber models implemented in system design tools, allow the obtaining of a solution in a shorter period of time. However, these models are based on semi-empirical relationships, which prevent their applicability to a general configuration of the engine.

The preliminary design phases of the propulsion systems, nonetheless, require a compromise between the accuracy of the results and the computation time to efficiently test a great number of hybrid rocket engine (HRE) configurations. One of the solutions that can be considered is the use of 1.5-D models.

The objective of this thesis is therefore the development of a system design tool for a HRE using a 1.5-D model for the combustion chamber, thus allowing us to reach a compromise between the precision and complexity of the calculations.

In order to do so, an unsteady and axisymetric 1.5-D combustion chamber model (non-reactive at first and reactive afterwards) and the associated 1-D nozzle model are developed. The fuel regression rate of this model is based on the Arrhenius law. Moreover, the Gas-Surface Interacton model allows the description of the mass and heat exchanges on the fuel surface. This combustion chamber and nozzle models are then validated by using both the literature and a lab-scale HRE (HYCAT).

A sensitivity analysis has been performed afterwards to complete such validation and to quantify the impact of the physical parameters intervening in the combustion chamber model.

In parallel to the development of these two models, the mass flow rate regulator and the catalyst have been modeled in 0-D and validated.

These four models are ultimately used to create a system design tool enabling the simulation of the complete operation of a HRE in a few minutes on a desktop computer. This tool is developed in a modular way in order to facilitate the addition or replacement of the elements constituting the engine. This architecture allows the simulation of a wide variety of engine configurations: from an isolated component up to the complete propulsion system. Moreover, an iterative method based on the pressure convergence in the combustion chamber is used to solve the whole system of equations between three parts of the engine: the feeding/injection sub-system, the combustion chamber, and the nozzle. The whole HRE system design tool is eventually validated using several tests performed on the HYCAT engine.

Mots clés

Hybrid propulsion, System design tool, 1.5-D model, Combustion chamber, Fluid Mechanics