Paper ID: 71779
student

IAF SPACE PROPULSION SYMPOSIUM (C4)
Liquid Propulsion (2) (2)

Author: Ms. Arianna Remiddi
Sapienza University of Rome, Italy, arianna.remiddi@uniroma1.it

Mr. Giuseppe Indelicato
Sapienza University of Rome, Italy, giuseppe.indelicato@uniroma1.it
Dr. Pasquale Eduardo Lapenna
Sapienza University of Rome, Italy, pasquale.lapenna@uniroma1.it
Prof. Francesco Creta
Sapienza University of Rome, Italy, francesco.creta@uniroma1.it

AN EFFICIENT NUMERICAL APPROACH FOR THERMAL CHARACTERIZATION IN LIQUID ROCKET ENGINES

Abstract

Thermal characterization is a fundamental aspect for propulsion systems design process in space industry, involving the interplay of a plethora of multi-scale and multi-physics phenomena and dealing with disparate continua. Liquid Rocket Engines (LREs) are characterized in general by high-pressure conditions, that increase the thermal load on structure and brings propellants in the trans-critical state, further enhancing the complexity of the description [1]. In this context, Computational Fluid Dynamics (CFD) is becoming a major design tool to replace expensive and time demanding experiments. Among the variety of numerical approaches, Conjugate Heat Transfer (CHT) tackles multi-region problems, solving heat and mass transfer across contiguous domains, coupled by a heat balance condition at the interface and therefore free from any thermal modeling assumption otherwise used by single-region numerical solvers.

In this contribution, we present set of numerical simulations aimed at the thermal characterization of single- and multi-injectors combustion chambers in LRE relevant conditions. The numerical solver employed is developed in the context of the OpenFOAM and OpenSMOKE open source frameworks [2]. It is based on a flamelet approach for the description of turbulent, non-premixed combustion, accounting for non-equilibrium and non-adiabatic effects [3,4], as well as pressure-dependent effects [5]. Moreover, the flamelet approach is amenable for the description of mono-species, non reacting flows, such as those employed in the active cooling systems. The solver also envisages a CHT description, solving the Fourier law for thermal conduction in solid domains and the unsteady Reynolds Averaged Navier Stokes (uRANS) equations for the fluid ones. A specific coupling strategy for the CHT description is formulated to reduce the computational effort in convection-dominated phenomena, as in the case of capacitively cooled combustors [6]. The solver aims therefore to the thermal characterization of an integrated LRE propulsion system, comprising all its fundamental parts and their interaction, from the turbulent combustion occurring in the thrust chamber to the heat transfer with the cooling system and the acceleration in the nozzle.

Bibliography

[1] M. Oschwald, et al., Combustion Science and Technology 178 (2006) 49–100.
[2] A. Cuoci, et al., Computer Physics Communications 192 (2015) 237–264.
[3] P. E. Lapenna, et al., Acta Astronautica 158 (2019) 460–469.
[4] P. E. Lapenna, et al., Joint Propulsion Conference (2018).
[5] G. Indelicato, et al., AIAA Propulsion and Energy Forum (2020).
[6] A. Remiddi, et al. AIAA Scitech Forum (2022).