International Conference on Numerical Combustion
Rome, Italy, October 14-17, 2025
www.icnc2025.com

Large Eddy Simulation of advanced injection strategies under liquid rocket engine operating conditions

Davide Schintu[1], Gianluigi Sicat[1], Davide Cavalieri[1], Pasquale Eduardo Lapenna[1], Domenico Molinaro[2], Domenico Simone[2], Daniele Liuzzi[2], Francesco Creta[1]

*lead presenter: Pasquale Eduardo Lapenna, pasquale.lapenna@uniroma1.it
1 – Sapienza University of Rome, Italy
2 – AVIO, Italy

In this contribution, we present numerical simulations of advanced injection strategies for liquid rocket engines (LRE), featuring supercritical pressure conditions and oxygen-methane as a propellant combination. In particular, we investigate: (i) the crossflow injection of cryogenic propellants under transcritical conditions, and (ii) a generic tricoaxial injection strategy for methane and oxygen as propellants. These two paradigmatic configurations are chosen as representatives of advanced injection strategies and, therefore, investigated using medium to high fidelity numerical simulations.

The crossflow injection has been widely investigated under standard thermodynamic conditions in the context of ideal gases, while conditions of relevance for LRE are significantly less investigated [1]. This promotes a significant interest in simulating such a configuration under LRE conditions and developing new surrogate models for jet development and penetration. Regarding the second configuration discussed, recent experiments have shown that the tri-coaxial injection enhances the combustion performance under LRE conditions by means of a rapid near-field mixing [2], motivating a substantial technological interest. Starting from these observations, numerical investigations of the two configurations are carried out in the present contribution. The simulations are performed using Large Eddy Simulations (LES) and a consistent flamelet-based turbulent combustion model implemented in the OpenFOAM framework and developed in the context of LRE injection [3] and heat transfer [4].

References

[1] D. Schintu et al.,” Large eddy simulations of cryogenic oxygen jets in crossflow under supercritical pressure conditions” *EUCASS Conference*, Rome, 2025.
[2] Keller, Alex R., et al. "Additively-manufactured shear tri-coaxial rocket injector mixing and combustion characteristics." *Aerospace Science and Technology* 155 (2024): 109680.
[3] D. Cavalieri et al., “Characterization of turbulent pseudo-boiling in transcritical and doubly-transcritical oxygen-methane flames” *International Journal of Heat and Mass Transfer,* (under review).
[4] G. Indelicato et al. “Dataset of Wall-Resolved Large-Eddy Simulations Turbulent Pseudoboiling in Cryogenic Hydrogen Pipe Flows” *Journal of Thermophysics and Heat Transfer*, vol 3, (2023).