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

Author: Dr. Mario Tindaro Migliorino
Sapienza University of Rome, Italy, mariotindaro.migliorino@uniroma1.it

Mr. Gianluca Cocirla
Sapienza University of Rome, Italy, gianluca.cocirla@uniroma1.it
Mr. Marco Fabiani
Sapienza University of Rome, Italy, m.fabiani@uniroma1.it
Dr. Marco Grossi
Sapienza University of Rome, Italy, marco.grossi@uniroma1.it
Prof. Daniele Bianchi
Sapienza University of Rome, Italy, daniele.bianchi@uniroma1.it
Prof. Francesco Nasuti
Sapienza University of Rome, Italy, francesco.nasuti@uniroma1.it

CONVECTIVE AND RADIATIVE WALL HEAT TRANSFER EVALUATION IN FILM-COOLED LIQUID ROCKET THRUST CHAMBERS

Abstract

High performance liquid rocket engines are characterized by elevated hot gas temperatures and combustion chamber pressures leading to high wall heat fluxes, which must be correctly predicted and managed to guarantee safe operation. In these severe operating conditions, active cooling systems such as regenerative cooling may result insufficient. In such cases, cooling capabilities can be enhanced by other techniques like film cooling or mixture ratio bias of peripheral propellant injectors. However, the additional cooling system has a cost in terms of performance, which yields the need of a fine trade-off between overall engine efficiency and safe structural life.

In this framework, a numerical analysis based on axisymmetric Reynolds-averaged Navier-Stokes simulations, with sub-models accounting for the effects of turbulence, chemistry, and radiation, is performed. Building upon the preliminary parametric analysis made in [1], several injection geometries and mass flow rate repartition strategies are investigated focusing on the geometry of the seven-injector thrust chamber burning gaseous oxygen and methane of the technical university of Munich (TUM) [2, 3]. Film cooling and mixture ratio bias are investigated in terms of their beneficial effect on the wall heat flux reduction, but also on the resulting loss in specific impulse. Different reaction mechanisms with increasing fidelity are considered and compared.

Furthermore, an evaluation of the effect of film cooling on the wall radiative heat flux is also performed. Radiative heat flux is computed with an in-house code [4], integrating the radiative transfer equations with the discrete transfer method, under the assumptions of gray/diffuse wall and gray/nonscattering medium. Modeled species include H2O, CO2, CO, and CH4. Coupling the radiative heat transfer evaluation to the CFD simulation, it is possible to evaluate the shielding effect as a function of thickness and composition, and to assess the effect of radiation absorption on film thickness.

[1] Concio et al., "Numerical Analysis of Film Cooling and Mixture Ratio Bias in Oxygen-Methane Liquid Rocket Engines", AIAA 2023-0513, January 2023

[2] Silvestri et al., "Characterization of a Multi-Injector GOX/CH4 Combustion Chamber," AIAA Paper 2016-4992, July 2016

[3] Concio et a.l ,“Numerical Estimation of Nozzle Throat Heat Flux in Oxygen-Methane Rocket Engines”, Journal of Propulsion and Power, Vol. 39, No. 1, 2023, pp. 71-83

[4] Leccese et al., Numerical Investigation on Radiative Heat Loads in Liquid Rocket Thrust Chambers, JPP 2019