
Abstract #XXX *(to be filled by the organizers)*
Preferred Topics: PROPHY, CFDMPS
Corresponding author: Gianluca Cocirla
e-mail of corresponding author: gianluca.cocirla@uniroma1.it
Type: Oral
Status of corresponding author: Student

Title

Simplified Numerical Modeling of Film Cooling and Mixture Ratio Bias in Liquid Rocket Thrust Chambers

Authors

Gianluca Cocirla[1], Marco Grossi[1], Mario Tindaro Migliorino[1], Daniele Bianchi[1], Francesco Nasuti[1]*
** Corresponding author*
[1] Sapienza University of Rome, via Eudossiana 18, 00184, Rome, Italy, gianluca.cocirla@uniroma1.it , marco.grossi@uniroma1.it , mariotindaro.migliorino@uniroma1.it , daniele.bianchi@uniroma1.it , francesco.nasuti@uniroma1.it

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 to find a 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 in this study. The numerical approach has been previously validated by rebuilding the experimental wall pressure and wall heat flux of the seven-injector thrust chamber burning gaseous oxygen and methane of the technical university of Munich (TUM) [1, 2]. Building upon the preliminary parametric analysis made in [3], several injection geometries and mass flow rate repartition strategies are investigated focusing on the geometry of the TUM liquid rocket engine. 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.

Preliminary results show that, for a fixed overall mixture ratio and mass flow rate, diverting part of the fuel for film cooling yields a nearly direct proportionality between throat wall heat flux reduction and specific impulse loss. A similar result is obtained with mixture ratio bias, showing that the best propulsive performance occurs when the throat wall heat flux is at maximum.

References

[1] Concio, P., Migliorino, M.T., Bianchi, D., and Nasuti, F., "Numerical Analysis of Film Cooling and Mixture Ratio Bias in Oxygen-Methane Liquid Rocket Engines", AIAA 2023-0513, January 2023. https://doi.org/10.2514/6.2023-0513

[2] Silvestri, S., Celano, M. P., Schlieben, G., and Haidn, O. J., "Characterization of a Multi-Injector GOX/CH4 Combustion Chamber," AIAA Paper 2016-4992, July 2016. https://doi.org/10.2514/6.2016-4992

[3] Concio, P., Migliorino, M.T., Bianchi, D., and Nasuti, F.,"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. https://doi.org/10.2514/1.B38811