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

Impact of Heat Transfer on a 1-Inch Rotating Detonation Rocket Engine

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The demand for advanced satellite propulsion for cislunar space applications has increased in recent years, revealing a need for propulsion systems that are both versatile and highly efficient. Rotating detonation rocket engines (RDREs) have emerged as a promising solution due to their potential for higher thermodynamic efficiency and reduced susceptibility to combustion instability. However, heat transfer has proven to be a particularly critical challenge in device development, as laboratory RDREs are often constrained to short run times due to overheating of hardware.

This numerical study aims to enhance understanding of heat transfer in small-scale RDREs through computational fluid dynamic (CFD) simulations of a nominally 1-inch outer diameter RDRE using hydrogen-oxygen propellants. Simulations with and without centerbodies are conducted at lean and rich conditions ($\phi = 0.43$ and $\phi = 1.25$). The numerical framework used in this simulation is constructed using components from OpenFOAM, which solves the compressible reacting Navier-Stokes equations with multi-species transport and finite-rate hydrogen-oxygen chemistry using an 11-species version of the Foundational Fuel Chemistry Model Version 1.0 (FFCM-1) reaction model.

The results of the RDRE are first validated using experimental results of the same configuration. Simulations with adiabatic and slip walls under-predict plenum pressure and thrust when compared to experiment, while over-predicting the wave speed. Preliminary simulations with non-adiabatic, isothermal combustor walls suggest that the detonation is relatively insensitive to wall heat loss. Subsequent analysis of the internal scalar and flow fields shows that significant heat release occurs in the deflagration mode.