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NUMERICAL MODELING OF SCALE EFFECTS IN PARAFFIN-HYDROGEN PEROXIDE HYBRID ROCKETS WITH SWIRL INJECTION

Abstract

Hybrid rockets are considered a promising future propulsion alternative for specific applications, as they can be throttled, restarted, and can potentially employ green, safe, and non-toxic propellants. In order to raise their technology readiness level, one important aspect is the evaluation of scale effects when passing from lab-scale experiments to higher thrust-level testing. This is crucial to optimize experimental procedures but also to ensure their safety, avoiding for example excessive regression rates or chamber pressures and/or overly oxidizer-rich mixture conditions.

The engine under consideration in this work is based on an experimental setup developed in the framework of the PHAEDRA (Paraffinic Hybrid Advanced Engine Demonstrator for Rocket Application) project coordinated by the Italian Space Agency. The propellants are paraffin-wax with polymeric additives and hydrogen peroxide. A vortex injector is employed in order to tailor the regression rate to a specific test objective, and to improve propellant mixing and combustion stability.

The objective of this work is to analyze scale effects with the use of axisymmetric Reynolds-averaged Navier–Stokes reactive simulations with sub-models for fluid–surface interaction and radiation heat transfer. Simulations are performed at different swirl intensities, geometries, and thrust levels, which allow to highlight the dominant features of the flowfield and the internal ballistics thanks to the predictive capabilities of the computational approach.