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Author: Mr. Emerson Vargas Niño
University of Toronto Aerospace Team (UTAT), Canada, emerson.vargas@mail.utoronto.ca

Mr. Mohammad Reza Razavi
University of Toronto Aerospace Team (UTAT), Canada, m.razavi@mail.utoronto.ca

HYBRID ROCKET PERFORMANCE OPTIMIZATION THROUGH THERMAL PHASE CHANGE NUMERICAL SIMULATIONS OF NITROUS OXIDE

Abstract

Hybrid rockets are traditionally composed of a liquid oxidizer mixing with a solid fuel, and their performance is critically dependent on precisely controlling the mass flow rate of the propellant. Injectors are used to achieve this precise control, and they are important to the overall rocket performance and stability. Due to the self-pressurizing nature of nitrous oxide (N2O) it is the oxidizer of choice for the University of Toronto Aerospace Team in its N2O-Paraffin Engine Quasar, capable of 7kN of thrust. The drawback of N2O is that as the flow expands and accelerates across the injector it cavitates, resulting in two phase flow.

This paper covers the development and validation of a custom CFD code capable of simulating N2O thermal phase change during injection through both Axial and Venturi injector elements. The Eulerian-Eulerian multiphase solver is capable of simulating a system of 2 compressible fluid phases with phase change effects. The solver was validated through several cold flow tests using both a lab scale engine and the Quasar engine.

One focus of this paper is to accurately predict critical downstream pressure which decouples the dependence of mass flow rate on pressure drop. Decoupling the mass flow rate is critical for hybrid rocket optimization as it can guarantee a constant mass flow rate through the range of pressures the engine will operate at. The cold flow tests validated the mass flow rate predictions, and hot fire tests validated Quasar's 7 kN thrust prediction. The numerical simulation accurately predicts the critical mass flow rate with a high degree of confidence and successfully serves to optimize hybrid engine performance.