Paper ID: 32159
oral
student

SPACE PROPULSION SYMPOSIUM (C4)
Interactive Presentations (IP)

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IMPINGING INJECTOR DESIGN FOR A PARAFFIN-NITROUS OXIDE HYBRID ROCKET ENGINE USED IN SOUNDING ROCKETS PART I: CFD SIMULATION OF CANDIDATE DESIGNS

Abstract

This paper presents the candidate designs, CFD simulations, and critical performance metrics used in the design selection for a hybrid rocket engine impinging injector plate. The University of Toronto Aerospace Team (UTAT) Rocketry Division's fourth-generation sounding rocket "Deliverance" is powered by a 4kN-thrust paraffin-nitrous oxide hybrid engine, with a target altitude of 25 000ft above ground level. Varying jet separation distances and hole diameters were compared for arrangements of impinging doublets. The key performance objectives of the injector were: (1) provide an average mass flow rate of 1.7kg/s at a steady-state pressure difference of 350psia; and (2) atomize the stored liquid oxidizer and promote mixing to support combustion. Furthermore, the injector had to meet *a priori* blow-out and quenching constraints.

ANSYS Fluent was used to generate steady-state, 3D simulation results. Tetrahedral elements were used throughout the computational domain, which terminated 20cm upstream and downstream the injector assembly. The realizable k-ω turbulence model was selected based on recent work by Najafi. A comparison of Reynolds, Ohnesorge, and Weber numbers in the pre-combustion region helped characterize the extent of atomization and turbulence. A total of six candidate designs were compared.

Simulations predicted that the target mass flow rate can be achieved with 7 pairs of 2mm-hole doublets, impinging at a 60-degree angle, with a discharge coefficient of approximately 0.70. Higher hole length-to-diameter ratios tended to increase the size of the dispersion cloud. Shorter jet separation distances yielded larger dispersion clouds as a result of greater kinetic energy concentrated at the impingement point. The maximum diameter of the dispersion cloud was typically attained 1-2 inches downstream the injector plate. In a separate paper, these simulations are compared to experimental cold-flow results to validate these predictions.