Senior Design / BS Project
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Design and Testing of Hybrid Rocket

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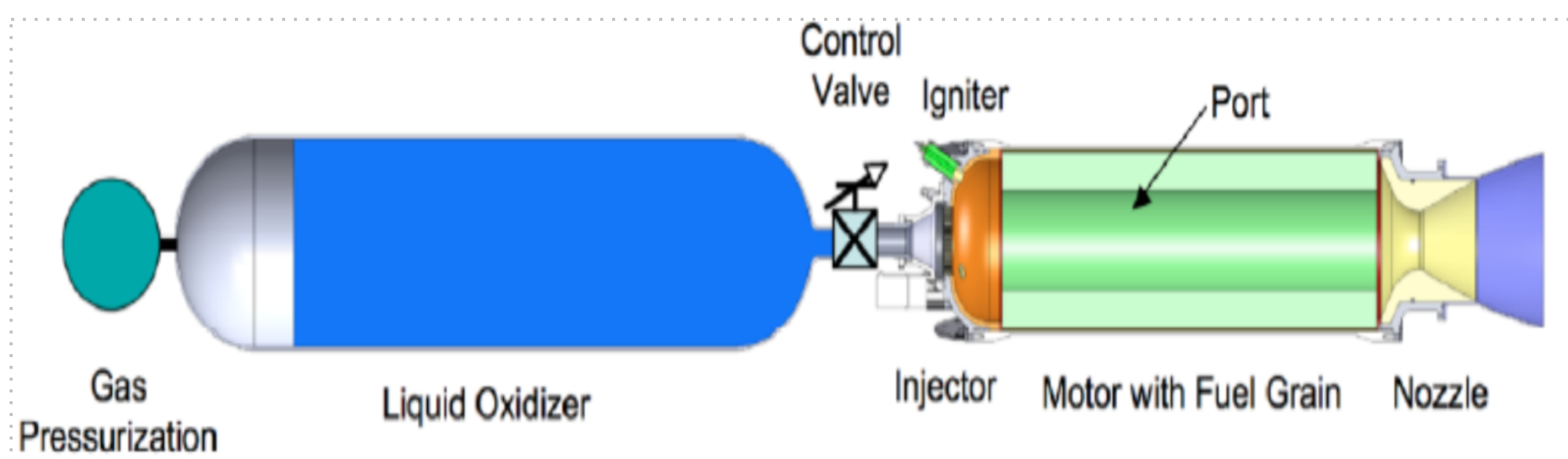
SENIOR DESIGN EXPO

Abstract

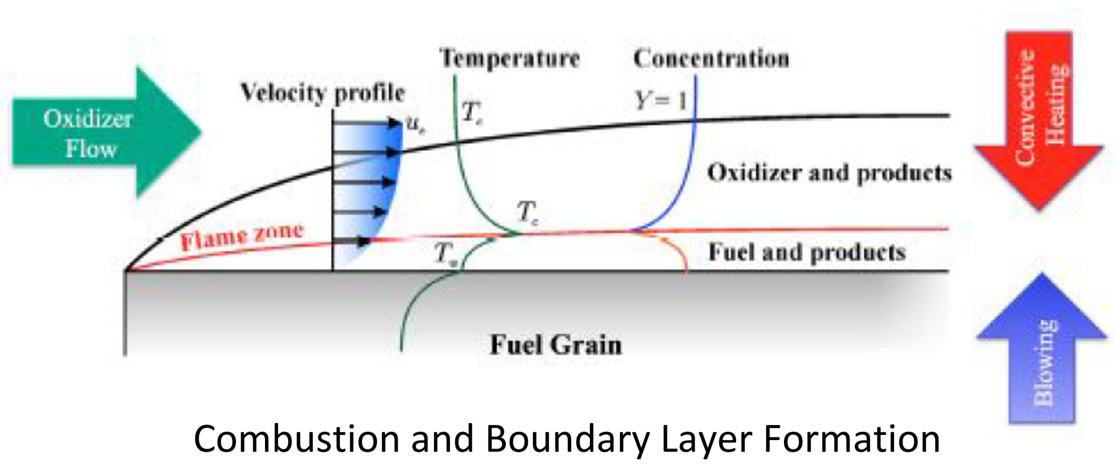
This project aims to design and test hybrid rocket composite fuel ports with complex geometries. Gaseous oxygen (GOX), Acrylonitrile Butadiene Styrene (ABS) pellets, copper powder, a filastruder, a filawinder, a 3D printer, and several measurement devices are used to produce ABS-Cu filament of 0-6% copper composition by mass, 3D-print the fuel port, and test it during simulated operating conditions. Four main port shapes named straight star, star swirl, helical circular, and helical star are used as the conceptual design. Experiments were conducted over the fuel ports, and the results indicated an improvement in regression rate and combustion efficiency of all the fuel grains with respect to the most basic straight circular design. While the highest regression rate was found in the helical port, the highest combustion efficiency appeared in the star swirl design.

Introduction

Hybrid Rockets are made up of a solid fuel component, and a fluid oxidizer. Different shapes for the fuel port in the solid fuel have been shown to increase regression rate, and therefore thrust. Fuel additives have also been shown to increase regression rate.



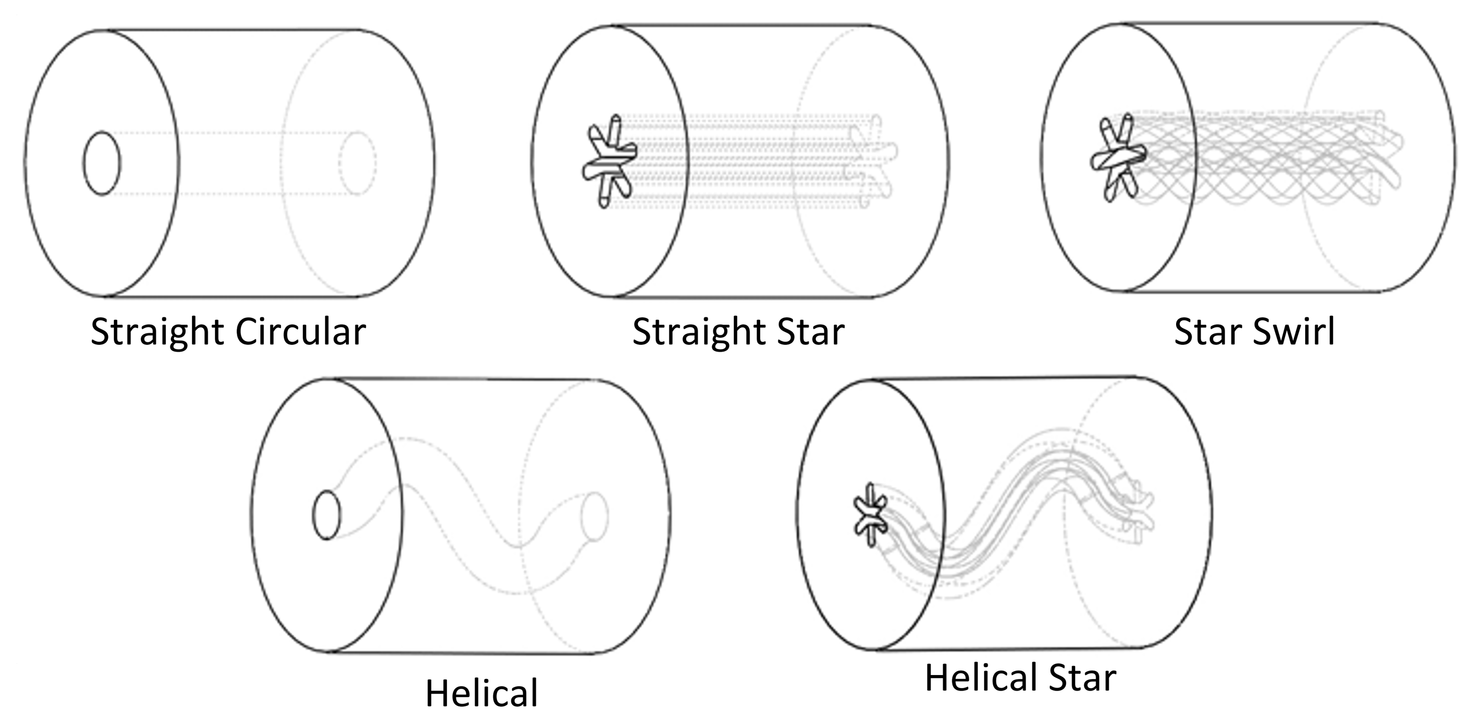
Hybrid Rocket Schematic



Combustion and Boundary Layer Formation

Methods | Design | Analysis

- Materials: ABS-Cu as the solid fuel and GOX as the oxidizer
- Performance Parameters: Regression rate, oxidizer-to-fuel ratio, characteristic velocity
- Improvement in regression rate and combustion efficiency from complex port geometry that introduces centrifugal forces, increases combustion area, and induces turbulent flow
- Filastruder, Filawinder, and 3D-printer used to produce the fuel grains
- Fire test conducted to obtain fuel grain behavior from temperature, pressure, mass flow rate, and change in port geometry over burn time measurements



Results

	Straight	Straight Star	Star Swirl	Helical
Effective Starting Diameter (mm)	8.00	8.56	8.56	5.99
Adjusted Final Diameter (mm)	15.85	18.14	17.26	16.95
Burn time (s)	7.95	8.65	8.75	8.06
Regression Rate (mm/s)	0.258	0.467	0.625	0.679

Four ports composed of pure ABS (no copper additives) were tested with about eight seconds of burn time. The helical port achieved the highest regression rate with the star swirl port reaching the next highest, followed by the straight star and lastly, the straight circular port. The star swirl port, however, achieved the highest combustion efficiency, then followed by the helical, straight star, and the straight circular port.

Conclusion

The results showed an improvement in regression rate and combustion efficiency of all the fuel ports when compared to the performance of a basic straight circular fuel grain. Although more tests are needed to validate these results, the indication is that our fuel port designs significantly improve the performance parameter of a small size rocket engine prototype. Future work for this project includes the testing of more fuel grains with our selected fuel composition, and the development of an analytical or numerical model for comparison with the experimental results.

Acknowledgments

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