CALIFORNIA STATE SCIENCE FAIR
2004 PROJECT SUMMARY

Name(s)
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Project Number
S0105

Project Title
Design, Analysis, and Optimization of Solid Fuel Rocket Engines

Abstract

Objectives/Goals
Increasing rocket engine efficiency requires maximizing the total impulse generated and tailoring thrust production to the mass of the rocket. By controlling the design elements of an engine, the total impulse generated can be maximized and the thrust profile can be customized. Last year, I demonstrated that optimal rocket flight parameters can be achieved by matching the rocket mass to engine thrust profile. The goal of this project is to identify critical design elements that can be manipulated to maximize total impulse and customize the engine thrust generation profile to optimize rocket lift.

Methods/Materials
I designed rocket engines that allowed me to investigate the contribution of the nozzle inlet shape, nozzle throat diameter and fuel core length and diameter to engine performance. All rocket engines were built to my design specifications and tested in a static engine test device that I built. Data from the test device was documented using a chart recorder that I designed and built. The Y axis (force) of the chart recorder was calibrated using a spring balance. The data from each engine was analyzed by dividing the area under the curve into 0.1second increments.

Results
Completion of this project identified 2 important design parameters, nozzle shape and fuel core structure. The shape of the nozzle inlet was the single most critical factor. A nozzle inlet angle of 90O resulted in the greatest thrust production; however, approximately 40% of the engines engaged the safety device. In contrast, when the nozzle inlet angle was decreased to 74O, the safety device was never engaged; however, the total impulse was significantly reduced. I increased the total impulse generated without engaging the safety device by increasing the nozzle inlet angle to 86O. Additional design elements that were manipulated to increase the total impulse generated include decreasing the diameter of the nozzle bore, increasing the length of the fuel core and increasing the diameter of the fuel core.

Conclusions/Discussion
Four critical design parameters: nozzle inlet shape, nozzle throat area, fuel core length and fuel core diameter were identified and manipulated to maximize the total force generated and to control the thrust generation profile. By carefully integrating these parameters into the final rocket engine design, individual engines can be customized to achieve the maximum lift of individual rockets.

Summary Statement
This project was designed to identify the key design elements of solid fuel rocket engines that can be manipulated to maximize engine efficiency.

Help Received
Ms. Coordt, Ms. Atkinson, Mr. Preske and Mr. Park helped me to understand the new math and physics concepts that I encountered. My Father built the rocket engines.