Hybrid Rocket Fuel Development and Testing

Opportunity

The OSU hybrid rocket team needs assistance in developing a solid fuel for use in current and future rockets.

Objective

Formulate novel fuels, conduct subscale characterization tests for various formulations and report a recommended fuel composition.

Background

Hybrid Main Sections:

- Oxidizer: Liquid nitrous oxide (N_2O) is a self-pressurizing oxidizer for hybrid rockets
- Fuel grain: A solid, wax-based material that reacts with N_2O to produce thrust
- Nozzle: Reaction products are expelled quickly as exhaust to produce thrust

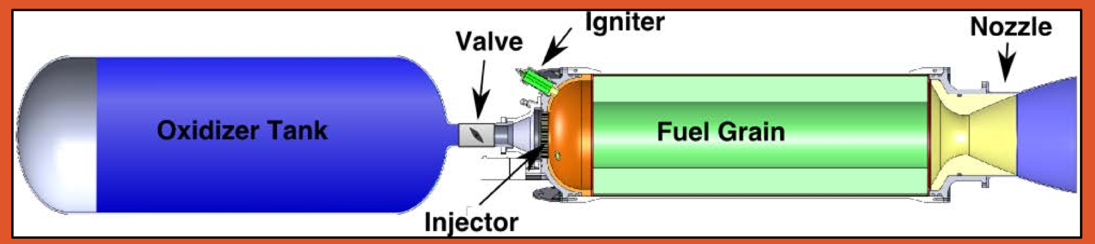


Figure 1: Standard hybrid rocket propulsion system with oxidizer tank, fuel grain, and exhaust nozzle.

Paraffin produces a melt layer determined by the formulation's viscosity.

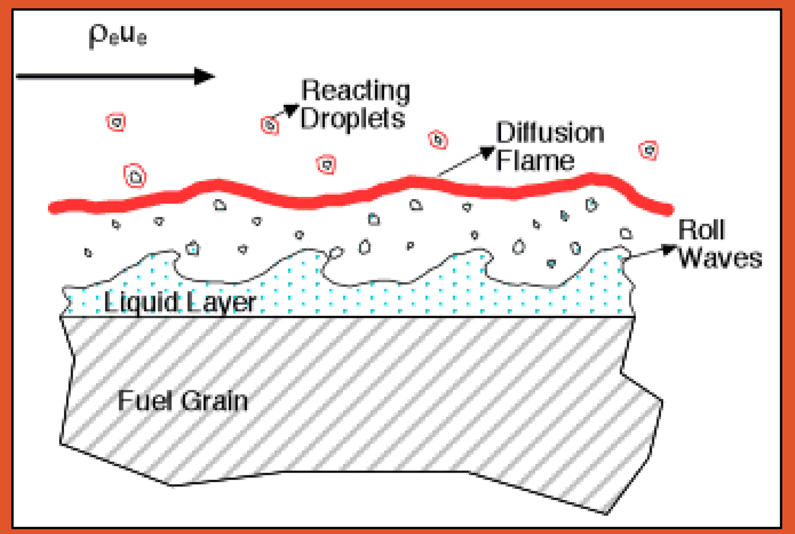


Figure 2: Melt layer diagram of the liquid solid interface.

Oregon State University

Chemistry Background

Fuel grain components react with nitrous oxide given the following reactions for paraffin, aluminum powder, lithium aluminum hydride, and hexamine.

$$C_{31}H_{64} + 94N_2O \rightarrow 31CO_2 + 32H_2O + 94N_2 \qquad \Delta H_{rxn} = -60\frac{kJ}{g}$$

$$2Al + 3N_2O \rightarrow Al_2O_3 + 3N_2 \qquad \Delta H_{rxn} = -36\frac{kJ}{g}$$

$$2LiAlH_4 + 8N_2O \rightarrow 8N_2 + 3H_2O + Al_2O_3 + 2LiOH \qquad \Delta H_{rxn} = -50\frac{kJ}{g}$$

$$C_6H_{12}N_4 + 18N_2O \rightarrow 6H_2O + 20N_2 + 6CO_2 \qquad \Delta H_{rxn} = -16\frac{kJ}{g}$$

$LiAlH_4$ is considered as an energetic additive due to its higher heat of reaction and molar production of gaseous products relative to aluminum.

Subscale Testing and Setup

Subscale tests with 8" length, 0.8" inner diameter fuel grains are performed at the OSU propulsion lab. Thrust and pressure data are obtained and used to make inferences on fuel performance.

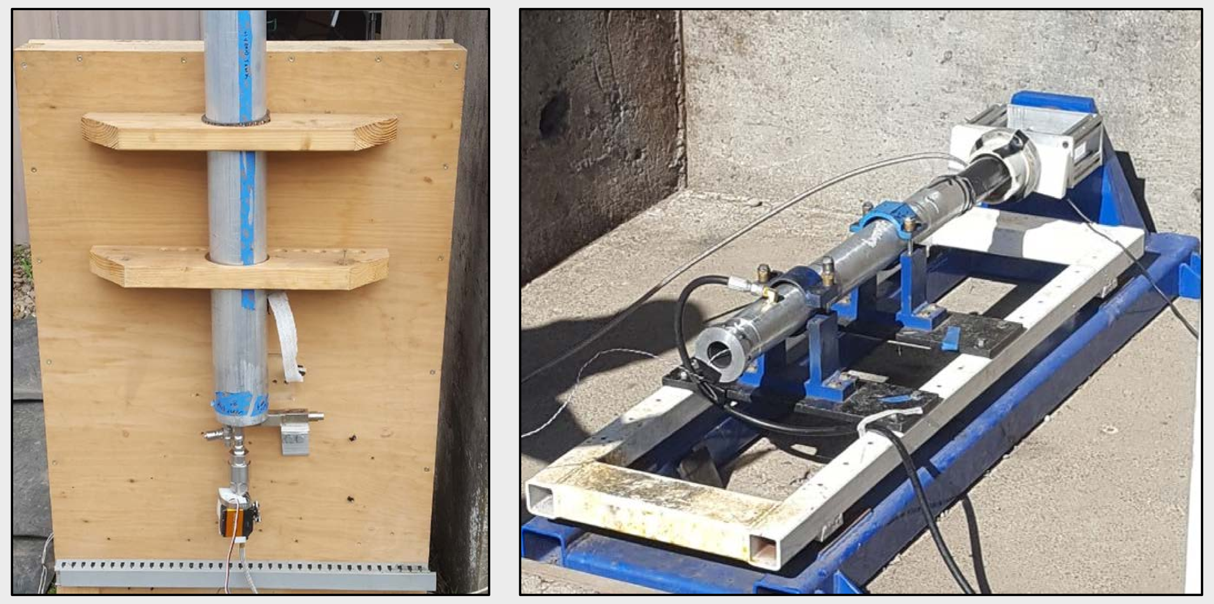


Figure 3: Sub-scale testing setup includes a nitrous holding tank as well as the subscale motor on the thrust sled.

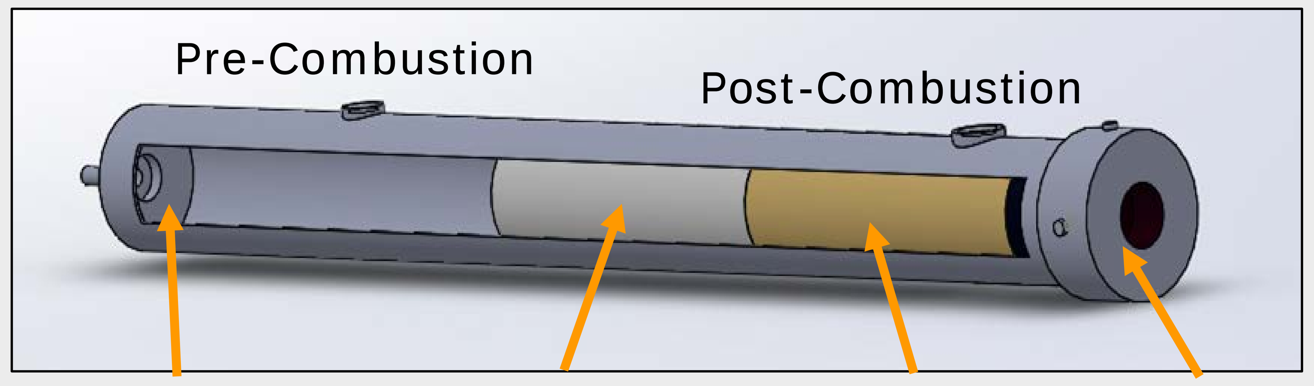


Figure 4: A rendition of the motor tube with important components labeled.

Manufacturing

Paraffin (fuel base) and additive compositions are weighed out and mixed in metal tins until homogenous. The contents are then poured into casting tubes and spun at 360 rpm. A spin cast prototype was manufactured to speed up manufacturing times.

Figure 5: Melted wax with hexamine. Melting and mixing of components were done in a fume hood.

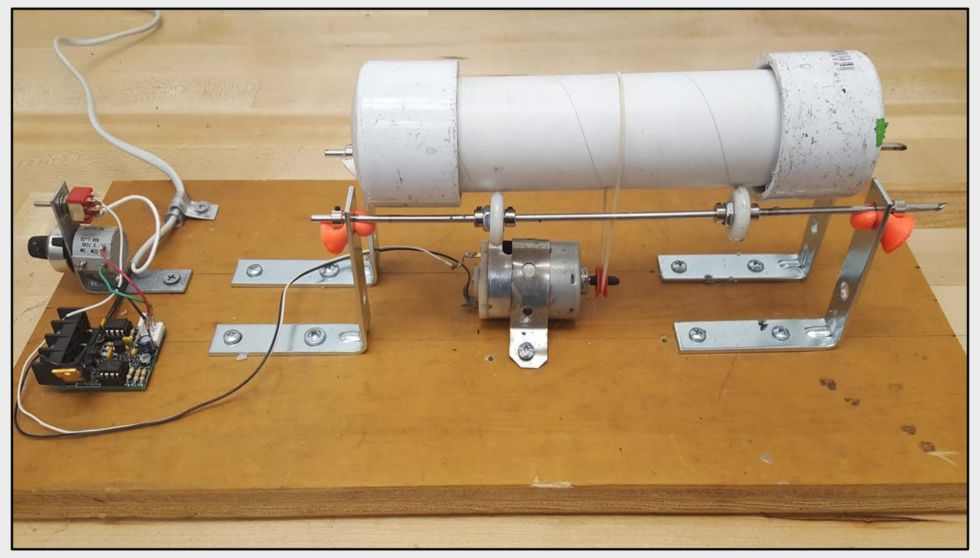


Figure 6: Spin casting system developed for fuel grain manufacturing.

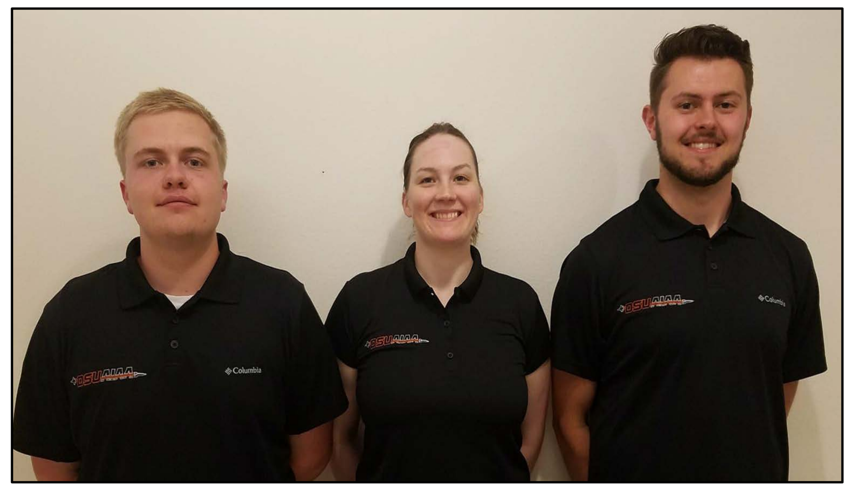
Before **After**

Figure 7: Finished fuel grain after spin casting and casting tube after a subscale test combustion.

Impulse [N·s]: Defined as a change in momentum, proportional to rocket altitude.

Specific Impulse [s]: I_{sp}, average thrust divided by mass flow rate.

$$I_{sp} = \frac{Thrust_{avg}\Big|_{t_i}^{t_f}}{g\left(\dot{m}_{ox} + \dot{m}_{fuel}\right)}$$



TEAM MEMBERS
Dylan Haugen
Michaela Patching
Auston Clemens

TECHNICAL ADVISOR(S)
Dr. Nancy Squires
Mr. David Ha
Dr. Philip Harding

PROJECT SPONSOR
OSU American Institute of Aeronautics and Astronautics

OSU AIAA

PROJECT STATUS

The team will conduct additional subscale tests to evaluate the effect of viscosity on performance and test $LiAlH_4$ with a cornstarch binder.

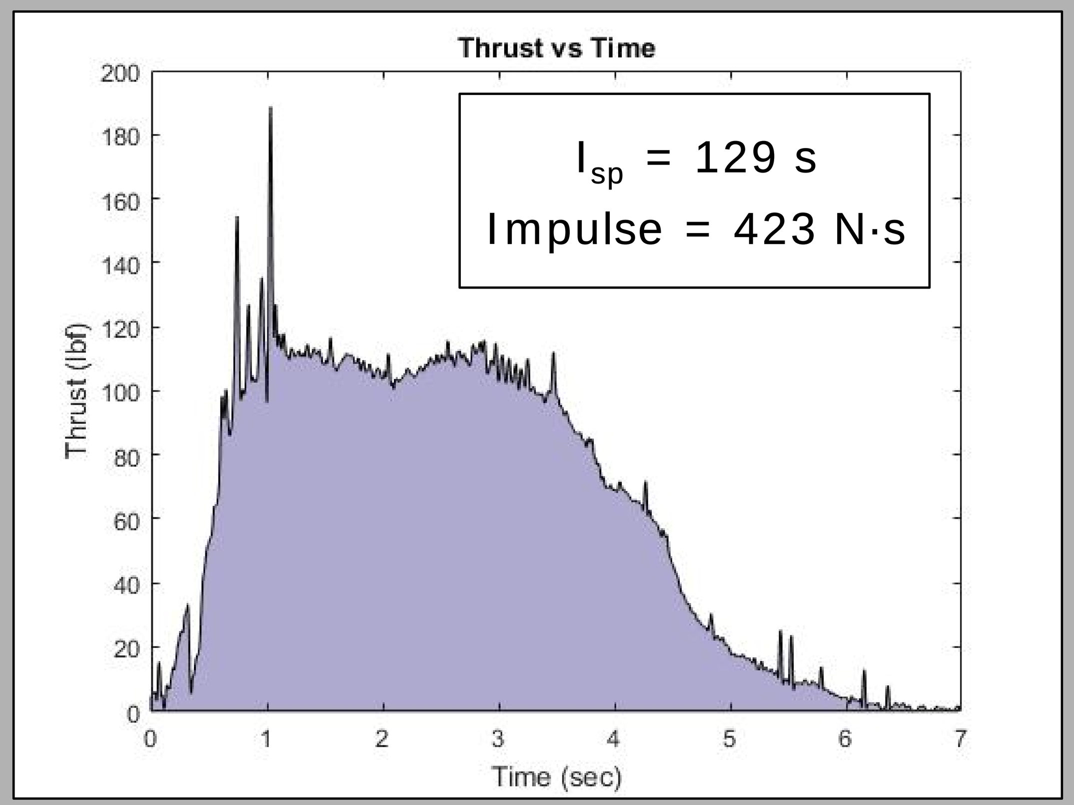


Figure 8: The thrust curve given by the load cell (shown in Figure 5) for the composition of 25% Al, 10% cornstarch, 2% carbon black, 63% paraffin.

Acknowledgements

- Andy Brickman - Machining guidance
- Dr. Lerner - Additive chemistry
- Propulsion sub-team - Subscale support
- John Cochran - Lab assistance