

DESIGN & FABRICATION OF HYBRID ROCKET PROPELLANTS BY USING POLYMER FUELS WITH METAL ADDITIVES

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ABSTRACT

Rocket is a tall and thin vehicle that is used to carry a payload into space. And fueled by liquid propellants, solid propellants and hybrid propellants. liquid fuels use fuel and oxidizer both in Liquid form to generate Thrust which involves high cost and complexity where as Solid propellants produce high thrust and uncontrollable. SO, there comes the development of Hybrid rocket propellants in Recent Times to fulfill the drawbacks Hybrid rocket motors are easily controllable and cost effective at same time.

KEYWORDS:

Hybrid Rocket engine, Polypropylene, Aluminium metal powder, mechanical properties, Extrusion process, Izod Impact, Dumbbell specimen, tensile testing, Elongation, Thermal Conductivity, Calorific Value, SEM images,

INTRODUCTION

Rocket propulsion plays a vital role in aerospace, defense, and space research sectors Hybrid rocket engines use solid fuel and liquid/gaseous oxidizer, combining advantages of both systems

Polymer fuels are widely used due to ease of fabrication and safe handling

Addition of metal powders such as aluminum improves:

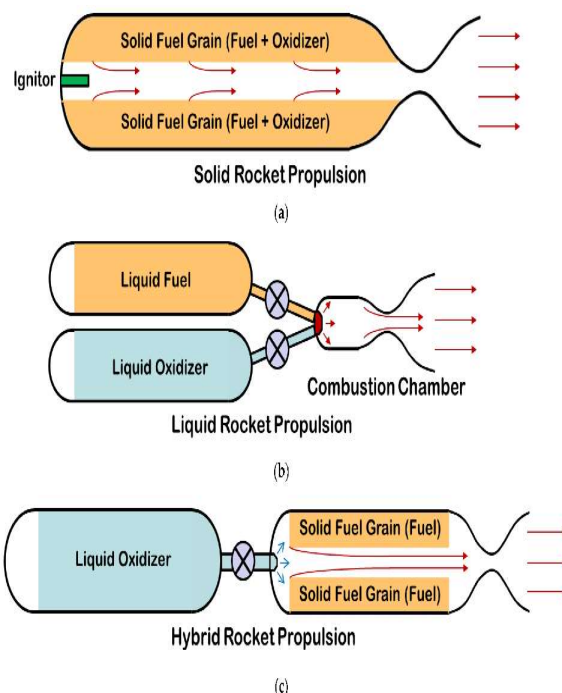
Heat release, Combustion efficiency, Thrust performance

This project aims to design and fabricate hybrid rocket propellants using polymer fuel with metal additives for enhanced performance

LITERATURE SURVEY

- Sutton & Biblarz (2017) Rocket Propulsion Elements
- Karabeyoglu et al (2008) hybrid rocket engines Regression rate improvement
- Chiaverini (2012) Review of hybrid rocket engines with Performance with Enhancement Method

PP + Al Hybrid Rocket Propellant Methodology



METHODOLOGY

1. Material Selection

Polypropylene (PP) was selected as the base fuel due to its thermoplastic nature, ease of fabrication, and good combustion characteristics. Aluminium (Al) powder was chosen as an additive to enhance energy output.

2. Material Preparation

PP granules were cleaned and dried to remove moisture. Aluminium powder of suitable particle size was measured according to the required composition ratio.

3. Mixing Process

The PP was heated above its melting temperature and aluminium powder was gradually added. Continuous stirring ensured uniform dispersion of Al particles within the molten polymer.

4. Fuel Grain Fabrication

The homogeneous mixture was poured into cylindrical Molds and allowed to cool at room temperature to form solid fuel grains.

5. Machining and Finishing

The solidified grains were machined to obtain the desired geometry (central port configuration) suitable for hybrid rocket combustion.

6. Material Characterization

The fabricated samples were visually inspected for defects, uniformity, and structural integrity. Basic thermal and physical properties were evaluated.

7. Theoretical Performance Analysis

Since no static firing test was conducted, expected performance parameters such as regression rate and combustion efficiency were estimated based on Hybrid Rocket Propulsion principles and literature data.

8. Safety and Handling Measures



Proper precautions were followed during heating, mixing, and moulding processes to ensure safe handling of materials and prevent contamination.

MATERIAL SPECIFICATION (OR) USED

1. Polymer Fuel Engineering (Polypropylene – PP)

Study of thermal behaviour, melting characteristics, and regression rate of PP during combustion.

2. Metal Additive Technology (Aluminium Particles)

Focus on particle size, distribution, and its effect on energy release and combustion efficiency.

3. Mechanical Properties

Analysis of how PP + Al reacts under high temperature, flame structure, and oxidation process.

TYPE OF TEST	STANDARDS
TENSILE TEST	ASTMD638
ELONGATION TEST	ASTMD638
MODULUS TEST	ASTMD638
METAL FLOW INDEX	ASTMD1238
IZOD IMPACT	ASTM256

4. Thermal conductivity and Heat of combustion

Study of heat resistance, nozzle material interaction, and protection against high-temperature gases and Al_2O_3 deposition.

5. Microstructure & Surface Analysis (SEM)

Examination of fuel grain surface, burn patterns, and residue (Al_2O_3) using SEM for material characterization.

RESULTS AND DISCUSSION:

The Propellant successfully prepared:

- Engineered a hybrid material blending polypropylene and Aluminium Metal powder resulting in an increase in durability/strength.
- Mechanical strength of pp/al Composite propellant fuel does not have any adverse effect
- Reduction of cost
- In future this propellant is to be developed for Static Combustion test

CONCLUSION

It is to be concluded that the addition of Al metal powder does not have any adverse effect on the mechanical properties of the propellant grain. But the Al metal powder significantly enhances the combustion properties of propellant such as heat of combustion, flame temperature T_f , and velocity of

gaseous combustion products and thereby enhances the thrust and specific impulse.

This work demonstrates the successful design and fabrication of a PP-Al based hybrid rocket fuel for lab-scale applications. The study confirms that polypropylene is a suitable fuel binder due to its ease of processing, mechanical strength, and thermal behaviour. The incorporation of aluminium enhances the theoretical energy output of the propellant system.

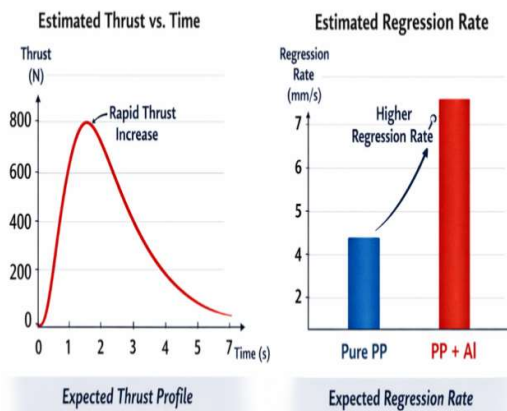
Although experimental combustion validation was not performed, the material preparation and characterization results indicate strong potential for application in hybrid rocket motors. Future work should focus on conducting static firing tests to evaluate key performance parameters and to study combustion behaviour, residue formation, and nozzle interactions.

Overall, the developed PP-Al hybrid fuel system provides a promising, cost-effective, and safe approach for experimental propulsion research and academic investigations.

This above graph shows an expected performance graph with thrust vs. time and regression rate comparison for PP + Al fuel.

REFERENCES

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