The Application of FFF Printed Parts in High Power Rocketry for the 6th International Symposium on Academic Makerspaces

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Introduction

High power rocketry sees individuals and teams construct advanced launch vehicles capable of flying thousands of feet into the air and returning to the ground safely. Collegiate teams participate in competitions such as the annual Spaceport America Cup with complex rocket and payload designs that push the boundaries of hobby rocketry.

Traditionally, construction materials for high power rockets have included wood and composites, or even machined parts for more technical applications [1]. As Fused Filament Fabrication (FFF) 3D printing has become more widespread, it has been applied to various parts of the rocket design and construction process.

Advantages of FFF 3D Printing

FFF 3D printing can enable numerous capabilities that would be difficult or impossible to achieve with traditional manufacturing techniques. The speed and precision of rapid prototyping technology allow parts to be evaluated and improved upon quickly and efficiently. FFF 3D printing equipment is now affordable enough to be accessible to even the hobbyist, further expanding its scope.

Demonstrated Use Cases

Worcester Polytechnic Institute's High Power Rocketry Club (WPI HPRC) has utilized FFF 3D printing for numerous applications on competition rockets. Much of this printing was enabled by the WPI Makerspace Prototyping Lab.

A. *Prototyping*

FFF 3D printing plays an essential role in the prototyping phase of the iterative design process in high power rocketry. For example, the team designed a novel airbrake system that allows the rocket to accurately achieve a 10,000 ft apogee by controlling the rocket's drag [2]. To verify the functionality of the actuator plate coupling together the four fins and ensure the components fit together correctly, the team assembled a prototype composed of laser-cut acrylic plates and FFF printed PLA fins. Ultimately, the fins were milled out of aluminum because they were load bearing. Nevertheless, additively manufacturing the fins allowed the team to quickly conduct initial airbrake actuation testing and identify necessary design modifications before committing an extensive amount of time to manufacturing the flight-ready fins.

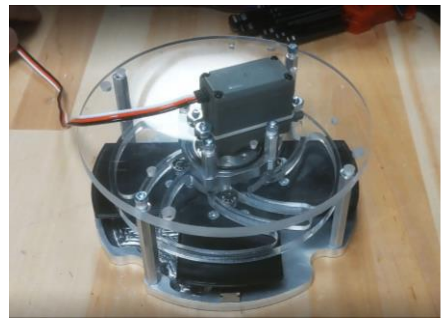

Fig.1 Airbrakes

The couplings are a joint that attach the non-separating airframe sections. The couplings feature a freely rotating nut that ensures rotational alignment while providing preload, and thus stiffness to the joint. The design proved to be lighter and faster to assemble than traditional coupler tubes and offered mounting features for internal components. While the final versions of the couplings were machined out of aluminum, the FFF 3D printed prototype shown in Fig. 2 demonstrated a proof of concept for the design.

Fig.2 Couplings

The payload self-righting system from HPRC's 2021 vehicle was designed to be able to bring the payload to an upright position from any landing orientation using three petal arms positioned equidistantly about the perimeter of the payload's baseplate [3]. Upon landing on the ground, the drive system activates and begins to lower each petal until all three petals have fully deployed, by acting as lever arms against the ground these petals bring the payload to an upright position. When developing the design for the self-righting mechanism, the team assembled a prototype that included 3D-printed petal arms, input and output gears of the drive system, and the input and output gears of the potentiometer.

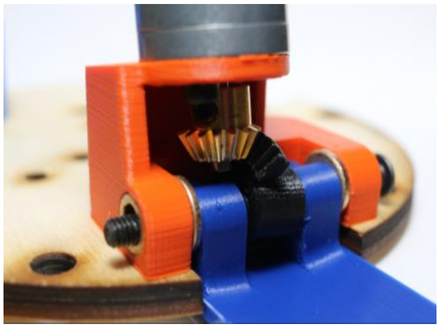

Fig.3 Payload Self-Righting Mechanism

B. *Tooling*

From molds for manufacturing composites to final motor assembly, there are a multitude of tooling applications in high power rocketry. To fabricate a fiberglass tail cone, the team required a mold to conduct the lay up on. With the ability to customize the tail cone shape and easily remove the print from the actual part, FFF 3D printing a PLA mold was the ideal technique.

Fig.4 Tailcone mold for fiberglass lay up

Assembly of some components of the rocket requires custom tooling to ease the process. To achieve a motor mount flush with the bottom of the airframe, a custom tool was printed to tighten the motor retainer. The geometry of the tool would have been significantly more difficult to create with any other manufacturing method.

Fig.5 Motor retainer assembly

C. *Flight Hardware*

With the proper material selection, FFF 3D printed parts can be flown on the rocket as flight hardware. PLA, though affordable and easy to work with, is not suitable for flight hardware since it is brittle and relatively weak.

The fins of a rocket experience significant aerodynamic loads during flight and must be attached rigidly to the rest of the vehicle. To accomplish this a 3D printed fin bracket was constructed using Nylon-X filament, a nylon reinforced with carbon fiber that results in a very stiff print. This 3D printed part successfully retained the fins at speeds approaching Mach 1.

Fig.6 Fin retention

FFF 3D printing offers the ability to create complex geometry suitable for electronics mounting, including wire routing features and battery holders within a single part. The avionics sled was printed from polycarbonate, chosen for its strength, impact resistance, and high heat tolerance, which are necessary properties to withstand the high heat experienced at the desert launch site.

Fig.6 Avionics Sled

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