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DESIGN, ANALYSIS, AND VALIDATION OF A THREE-PIECE COMPOSITE ROCKET FUSELAGE MANUFACTURED BY AUTOMATED BY AUTOMATED FIBER PLACEMENT.

Abstract

Sounding rockets need to be designed to survive the intense conditions of a launch event. This demands the rocket to be structurally robust while remaining lightweight and aerodynamic. In modern rocketry, this prompted the move towards composite structures. As new research emerges in composite material sciences, so have new methods for manufacturing rockets. This paper presents the analysis and validation of a new rocket fuselage design: a complete composite fuselage manufactured using automated fiber placement (AFP) technology. This design makes use of new manufacturing techniques to yield greater structural rigidity and strength while reducing weight. In addition to being lighter and stronger, the proposed design simplifies the assembly procedures for suborbital launch vehicles and is CubeSat-compatible.

Unlike traditional sounding rockets which require multiple sections, this single staged launch vehicle only requires three pieces: the forward section, the coupler, and the aft section. This was made possible by integrating the nose cone with the cylindrical portion of the forward section, eliminating the need for additional attachment points or a secondary coupler. This allows for rapid assembly of the vehicle and omits the use of doors which can be a source of weakness in the body of rocket.

The AFP process allows for in-situ consolidation without the need for secondary processing in an autoclave, while producing an acceptable void and defect content, and allowing the ability to provide strength in the desired direction. The use of a custom-designed mandrel provides the ability to continue placement of the fiber tape over a changing diameter, allowing layup over an LD-Haack nose cone. Holes in the body of the rocket will be made using thermally assisted piercing, an experimental method of producing holes in thermoplastic composites, resulting in a composite structure up to 85% stronger than those using traditional methods (Brown, 2016).

The layup sequence of the fuselage was determined utilizing a gradient descent algorithm applied to classical laminate theory calculations, which optimized the layup angles for our input loads and material properties. The expected loads experienced by the rocket during supersonic flight are verified through a series of analyses, and the resulting design is subsequently validated through testing. More specifically, the computed layup sequence is simulated using an ANSYS finite element analysis (FEA) and validated by performing compression tests on cylindrical shell composite samples. A final ultrasonic inspection determines the quality of the manufactured composite pieces.