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IAF MATERIALS AND STRUCTURES SYMPOSIUM (C2)
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DESIGN FOR AM OF SMALL SPACECRAFT PROPELLANT TANKS: FDM 3D PRINTING OF POLYMERS AND COMPOSITES

Abstract

Design for Additive Manufacturing (DfAM or D4AM) is an engineering design approach that optimizes the design of parts and components specifically for additive manufacturing (AM) technologies. Additive manufacturing, commonly known as 3D printing, is transforming multiple industries through diverse technologies. In the space sector, both industrial and commercial players, as well as the scientific research community, are increasingly focusing on its applications for spacecraft systems design. Metal 3D printing has made headlines in the development of launch vehicles and spacecraft components, especially in propulsion systems, due to its major benefits over conventional subtractive manufacturing, such as faster lead time, cost reduction, and significant mass reduction. However, polymer and composite 3D printing has yet to achieve the same level of industrial and commercial adoption as metal additive manufacturing.

This paper discusses a selection of novel materials, including advanced polymeric materials and composite materials reinforced with carbon and glass fibers suitable for Fused Deposition Modeling (FDM), i.e., polyamide, polycarbonate, polyethylene terephthalate glycol, and polyphenylene sulfide, either reinforced or non-reinforced variants. The study examines the modern materials' suitability for manufacturing spacecraft components by demonstrating a prototype of spacecraft propellant tank 3D printed from carbon fiber reinforced polyamide and validated with preliminary pressurization tests. A second prototype—a CubeSat propellant tank made of non-reinforced polycarbonate—is also presented, highlighting the main printing parameters and post-processing procedures. The paper presents mechanical testing results of the used materials, evaluated under the same 3D printing configurations and conditions and curing methods as the demonstrated prototype structure, while analyzing different printing orientations and structural infills not available in the manufacturers' datasheet or in literature. The paper highlights the chemical compatibility of the base materials with several green propellants of interest. Special attention is given to the post-processing challenges of each material to suit the intended application, either a spacecraft bus structure exposed to extreme environmental conditions or a propellant storage structure under pressure.

The discussed iterative design, testing, and prototyping methodology may benefit researchers involved in DfAM when exploring potential applications or facing challenges and limitations in the use of modern FDM 3D printing materials for spacecraft development.