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ADVANCEMENTS IN IN-SPACE MANUFACTURING USING PHOTOPOLYMERS: INSIGHTS INTO EXPERIMENTS PERFORMED AND APPROACHES TOWARDS A MATURE TECHNOLOGY.

Abstract

In-space manufacturing (ISM) of external satellite structures has become an interesting approach in order to meet the increasing demand on high packing efficiency of space systems. ISM further allows overcoming limitations of conventional deployable structures: long and high-cost development phases, oversized elements to survive the high launch loads, mechanical complexity as well as constraints to the maximum structure size due to the limited volume in a satellite.

The first manufacturing of polymer rod structures in space environment was recently successfully demonstrated in open space conditions on a sounding rocket experiment by the Munich University of Applied Sciences (HM). This demonstration was performed after previous tests in microgravity on zero-g flights and laboratory ground tests. The manufacturing is performed by robotic extrusion of liquid photopolymer resin through a nozzle surrounded by UV-LEDs. This technology shows significant advantages over adaptations of typical terrestrial layer-by-layer manufacturing technologies like fused filament fabrication to space requirements. Particularly photopolymer manufacturing is characterized by low energy consumption and low process temperatures, short manufacturing time and process adaptability to different structural shapes and material property requirements.

This paper gives an insight into the technology of ISM by photopolymer extrusion and wraps up the results of the performed tests in vacuum, microgravity and open space conditions. Based on the results and experiences from these tests, system trade-offs and possible operational modes of robotic ISM mechanisms are analyzed considering typical space system requirements on launch loads, stiffness, thermal environment, safety and reliability. Potential solutions for the required system functions are identified and evaluated w.r.t. those requirements. Failure modes and operational constraints on the space system are identified and redundancy and risk mitigation concepts are presented and discussed. A particular challenge of in-space manufacturing is the quality assurance of manufactured parts in a remote environment and the handling of imperfections. In-space monitoring methods of the process itself and of the produced structures are identified and non-conformance mitigation options are discussed. Further, approaches on acceptance testing, which is challenging due to the irreversible nature of generative manufacturing processes, are addressed and discussed. Concluding, the most significant findings are compared with other in-space manufacturing technologies, giving an insight on the individual advantages and limitations from a system point of view.