IAF MICROGRAVITY SCIENCES AND PROCESSES SYMPOSIUM (A2)
Interactive Presentations - IAF MICROGRAVITY SCIENCES AND PROCESSES SYMPOSIUM (IP)

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ENHANCED NOZZLE DESIGNS FOR FIBER-REINFORCED ENDLESS PHOTOPOLYMER EXTRUSION FOR IN-SPACE MANUFACTURING

Abstract

In this paper, enhanced nozzle concepts designed for in-space manufacturing applications of external satellite structures are presented. These structures will be produced through a process where a photopolymer is fed through a nozzle and cured by UV light, known as Direct Robotic Extrusion of Photopolymers. The presented nozzles are designed for embedding reinforcing fibers in those extruded structures. They have closed cross sections, such as tubes, as well as open cross sections, such as I-beams. With previous nozzle concepts developed at the Munich University of Applied Sciences, it was already possible to extrude and cure tubular profiles. However, those nozzle concepts were not designed for fiber integration, leading to the necessity of a comprehensive redevelopment and testing of the nozzles using a dedicated test setup. The primary intention of integrating reinforcing fibers into the profiles is to reduce the resin content in the final extrudate. This enhances the extrudate's mechanical and thermal properties.

Extrusion tests are conducted to determine the feasibility of integrating fibers into the extrusion process. For this purpose, parameters such as the feed rate and LED intensity, as well as changes to the nozzle geometry, are optimized. Based on the results, the technical realization of nozzle geometries is presented, along with the morphological artifacts of the samples produced. To evaluate the quality of fiber embedding, dimensional and weight measurements, visual inspection, computed tomography, and laser scanning of the extrudate profile are used. The experiments demonstrated a successful production of tubular profiles using the newly developed nozzles, initially with four fibers and later with eight fibers.

In addition to the nozzles for tubular profiles, nozzles for the extrusion of open profiles were tested. They proved successful in producing an I-beam profile without fibers. Later modifications to these nozzles enabled the successful integration of six fibers into the I-beam extrudate.

The identified parameters and the new nozzle design will be experimentally investigated as part of the REXUS program in the first quarter of 2025, using a sounding rocket. In this experiment, the extrusion of photopolymers with fibers will be conducted to verify the in-space manufacturing process for the production of space system structures in microgravity and vacuum conditions.