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FEASIBILITY OF IN-ORBIT 3D PRINTING OF CONTINUOUS FIBRE REINFORCED COMPOSITES

Abstract

In-Space manufacturing (ISM) is actively being investigated as a method to fabricate large, complex, yet resource efficient structures in orbit. Novel technologies such as fused filament fabrication (FFF) based additive manufacturing (AM) using thermoplastics have been identified as potential sustainable production technologies for ISM due to their inherent manufacturing flexibility and low waste. Fibre reinforced composites have been hypothesized to facilitate ISM by realising functional structures with strength, stiffness and mass advantages. In this study, we propose and establish an adapted FFF process that enables manufacturing of continuous fibre reinforced composite (CFRC) structures in space, beyond the confines of crewed space stations. Using continuous fibre and thermoplastic filament as feedstocks, a flexible printing setup is developed. It enables in-situ impregnation and coextrusion of tailored CFRC to directly print composite structures with desired matrix-fibre combination for a specific use case. First, the feasibility of the in-situ impregnation and coextrusion process to function in the low-pressure space environment was assessed. The setup was successfully tested in a vacuum chamber using a modified 3D printer, and the impact of low pressure on FFF manufactured CFRC was studied. Initial investigations show positive results with increased fibre impregnation, and reduced porosity for the samples produced in low-pressure environment compared to samples manufactured in atmosphere. Next, the viability of the proposed setup to fabricate large, free-form composite structures in the free-floating space environment was evaluated. The proposed coextrusion setup was used to print large-format CFRC trusses in a simulated free-floating environment in the Experimental Lab for Proximity Operations and Space Situational Awareness (ELISSA) air bearing table at the Institute of Space Systems in TU Braunschweig. Combining the reach of a free-flying satellite simulator with the accuracy afforded by a robotic arm in conjunction with coextruding print-head, large support-free CFRC trusses were manufactured. By simultaneously coordinating the movement of the satellite simulator with the robotic arm and using a continuous tool-path, printing of complex, metre-scale, free-standing CFRC structures with sub-millimetre resolution was successfully demonstrated.