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AN EXPERIMENTAL INVESTIGATION OF MICROGRAVITY CONDITIONS ON FDM-BASED IN-SPACE ADDITIVE MANUFACTURING

Abstract

In-orbit additive manufacturing (AM) can break through the limitations of launch vehicle capabilities (i.e. space and weight), thereby expanding the feasible domain of space structure design. In the process of in-orbit AM, materials are melted and formed in a microgravity environment, experiencing the combined effects of temperature, load, and motion. As it is difficult to control liquid and powder materials in microgravity conditions, the current main technology used in orbit additive manufacturing is Fused Deposition Modeling (FDM), which primarily uses filament materials. In FDM fabrication, the surface tension of molten droplets, gravity, and atmospheric pressure affects the layer deposition, which in turn affects the dimensional precision and mechanical properties of printed structures. A considerable amount of theoretical and experimental research has been conducted; findings indicate that gravity has significant impacts on layer height in FDM-AM and interfacial bond strength between layers.

This paper focuses on the gravity effect on interlayer fusion and the global mechanical properties of AM structures by printing test specimens at different angles relative to gravity direction, ranging from 0 to 90 at 15 intervals. In this context, 0 represents a condition akin to zero gravity (the gravitational force is parallel to the interface of deposition layer), while 90 simulates the full effect of gravity, akin to printing on Earth. All layers were printed with 90 raster. The experimental work involved the manufacturing of tensile and compressive specimens. Five samples were tested for each angle and specimen type. The aim is to determine and quantify the parameters that lead to optimal mechanical properties.

Tensile tests were conducted at a constant strain rate of 5 mm/min. From the stress-strain curves, Young's modulus, ultimate strength, and elongation at fracture were extracted. Significant impacts on the mechanical properties are found: (i) ultimate strength and elongation decreases from 0 to 90 to the loading-direction, (ii) stress-strain curves show significant loading/unloading phenomena as the printing angle varies from 0 to 90, and (iii) Young's modulus is not significantly affected by the printing angles. Compression tests conducted at a strain rate of 1.3 mm/min indicated similar trends, but the compressive modulus showed no significant change with angle variation. These findings reveal that the gravity condition plays a prominent role in interlayer bonding and affects the overall mechanical properties of the products. Surface roughness seems unaffected by any factor. These findings provide valuable information for optimizing 3D printing techniques for in-space additive manufacturing.