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ADDITIVE MANUFACTURING IN SPACE: INTERFACIAL FORCE VS GRAVITATIONAL FORCE

Abstract

The demand in space technology and the thrive for reaching out to the unexplored space territories, require a better understanding of numerous aspects of processes defining the longevity of the space mission. Additive manufacturing (AM) has become a lucrative on-board technology for every space mission due to its ability to produce the product on demand. In space, with the absence of gravitational force, the interfacial forces govern the outcome of every stage of additive manufacturing process irrespective of the technique or working principle of AM process. Here, the primary objective of the present study is to investigate the performance of AM process mimicking the Fused Deposition Modeling (FDM), in particular, different processes involved in it such as material deposition, multilayer mass addition, and solidification of the deposited materials. Although plethora of studies are reported involving the AM or 3D printing in space, to the best of our knowledge the fundamental understanding of FDM in space environment with the significance of interfacial force dominance remains unresolved. Above mentioned three stages, are scrutinized at reduced gravity with the help of in-house devised setup coined as FreezDrop. For each of these stages the experiments were performed in simulated reduced gravity environment with the help of parabolic flights. Constrains associated with health hazards, limited space, surrounding environment and strong dominance of surface tension in space motivated us to propose a jet-based material deposition technique for the first study, which uses colloidal solution of metal instead of dry pulverized metal. During the parabolic maneuver we observed three distinctive metastable stages for a deposited drop for three gravity level (0g, 1g and 2g), which eventually dictated the final outcome of the solidified material. For the second stage, a spreading of the droplet before attaining the equilibrium is studied, which is further utilized to validate the mathematical model developed to predict the spreading of material on a printer bed surface. Lastly, to explain the underlying physics of the solidification of the deposited material we have analyzed the freezing dynamics of the water droplet. This study performed here has the potential to become a blueprint of an instrument for space missions where 3D printing of metal and biomaterials are required. It is worthwhile to mention that the same FreezeDrop setup can be repurposed for the measurements of surface tension and surface energy of the interfaces.