IAF SPACE EXPLORATION SYMPOSIUM (A3)
Moon Exploration – Part 2 (2B)

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FFLD EVERYDAY HARDWARE FABRICATION TO SUPPORT LUNAR ACTIVITIES: ADVANCING SUSTAINABLE LUNAR EXPLORATION THROUGH FUSED FIBER LAYER DEPOSITION 3D PRINTING USING LUNAR REGOLITH

Abstract

This submission builds upon our previous work, which was initially submitted but withdrawn to allow for further refinement and development. The current study presents significant advancements in the methodology and findings, strengthening the case for Fused Fiber Layer Deposition (FFLD) in lunar additive manufacturing. In-Situ Resource Utilisation (ISRU) is an essential strategy for achieving sustainability in lunar exploration, aiming to reduce reliance on Earth-based resources. This paper explores the utilisation of lunar regolith in Additive Manufacturing (AM), specifically emphasising the novel technique of Fused Fiber Layer Deposition (FFLD) within the broader context of Fused Layer Deposition (FLD). FFLD is a novel approach that involves not only extruded regolith layers but also embedded fibres within the molten regolith matrix material. The fibres, made from lunar material, act as reinforcement for fused layer deposits, promising an improvement in mechanical properties for everyday glassy hardware elements. While processes exist for the integration of fibres and extraterrestrial concrete blocks, there are no proposals for additively manufacturing fibre-reinforced glassy products from regolith feedstock to date. The approach to lunar component manufacturing promises increased autonomy for Moon missions, reducing reliance on Earth's resources. Building upon the successful FLD project under the ESA OSIP OFF-EARTH MANUFACTURING AND CONSTRUC- TION CAMPAIGN-STUDY SCHEME, this study centres on the optimisation of the existing FLD 3D printer application through the introduction of FFLD. In FLD, parts are fabricated through layerwise melt extrusion of the regolith, which undergoes oven annealing during and after the printing process. Annealing is recognized as an essential step for minimizing cracks in glassy materials, such as lunar regolith.

The new FFLD project development strategy revolves around the exploration of different high-temperature

resistant fibres, fibre production, the design and integration of a fibre unwinding system and extrusion trials with varied parameters. Various printing campaigns produced samples that underwent mechanical testing assessing compressive and flexural strength comparing annealed and non-annealed samples to conventional, alternative AM techniques. The strategy concludes with iterative geometry adjustment, resulting in a comprehensive technology roadmap and application scenarios. The approach aims to validate and optimise Fused Fiber Layer Deposition 3D printing for lunar regolith, contributing to sustainable lunar exploration. This early technology development signifies a stride toward sustainable lunar exploration showcasing the feasibility and advantages of FFLD 3D printing using lunar regolith. The paper outlines the technical benefits, development objectives and a comprehensive plan for advancing lunar exploration through innovative AM technologies.