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REGOLITH FLOWABILITY IN LUNAR GRAVITY AND VACUUM

Abstract

The renewed global interest in lunar exploration has driven the need for efficient in-situ resource utilization (ISRU) techniques to support sustainable lunar operations. The handling and transport of lunar regolith presents significant challenges due to its cohesive, abrasive, and electrostatically charged nature, especially under reduced gravity and vacuum conditions. This paper investigates the flowability of lunar regolith simulant under simulated lunar gravity and vacuum, aiming to improve the design of material-handling systems for future lunar infrastructure.

The study employs experimental testing through vacuum chamber experiments both during ground based testing and parabolic flight testing to simulate lunar gravity. Four distinct regolith feed system designs incorporating flow-assisting mechanisms are tested to evaluate their efficiency in preventing clogging and maintaining steady material flow through a hopper. These designs are assessed based on their ability to mitigate arching, bridging, and compaction effects, which commonly hinder granular material flow in low-gravity environments. Key design parameters are systematically varied to identify optimal configurations for lunar ISRU applications.

Preliminary results indicate that reduced gravity has the potential to significantly impede flowability of granular material, thereby leading to more pronounced arching and flow blockages. The findings suggest that larger outlet sizes, steeper hopper inclinations, and external vibration significantly enhance flowability under these more extreme conditions. Additionally, vacuum conditions exacerbate cohesive forces, necessitating tailored hopper geometries and controlled vibration to maintain consistent material discharge rates. These insights inform the development of more effective ISRU regolith conveyance systems that can function reliably in lunar environments.

This paper advances the fundamental understanding of granular flow in extraterrestrial environments and provides critical data for designing ISRU systems that facilitate a sustained lunar presence. The experimental results will contribute to optimizing material-handling techniques for excavation, processing, and transportation of lunar regolith, ultimately supporting the construction of lunar habitats, radiation shielding, and resource extraction infrastructure. Findings from this study will directly benefit space agencies and commercial entities aiming to develop lunar ISRU technologies.