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Author: Mr. Jason Noe
Michigan Technological University, United States, jnoe@mtu.edu

Dr. Paul van Susante
Michigan Technological University, United States, pjvansus@mtu.edu
Dr. Laurent Sibille
Southeastern Universities Research Association (SURA), United States, Laurent.sibille-1@nasa.gov
Mr. ben wiegand
Michigan Technological University, United States, bdwiegan@mtu.edu
Mr. Parker Bradshaw
Michigan Technological University, United States, psbradsh@mtu.edu
Mr. Eli Sierra
Michigan Technological University, United States, emsierra@mtu.edu

LUNAR REGOLITH BEHAVIOR IN VACUUM FOR ISRU TRANSPORTATION AND STORAGE

Abstract

With humanity's return to the surface of the moon set for 2025 by NASA's Artemis program, there has been a reinvigoration of development for lunar technologies. A priority for these technologies is how to return in a sustainable way. Currently, the only way to send (a payload) something to the moon is with the use of rockets launched from the Earth, with estimates of 1.2M USD per kilogram landed on the surface of the moon. This is not sustainable for long-duration missions. The most promising technology area that is tackling this problem is In Situ Resource Utilization (ISRU). ISRU is the concept of using the resources in the local environment for power generation, production of consumables, manufacturing, and construction. Some popular ideas for lunar ISRU involve lunar regolith, loose and unconsolidated rocky material that covers the lunar surface. Research is being conducted on the lunar regolith to be used as a primary resource to make rocket launch pads, habitats, oxygen, small parts with additive manufacturing, and to extract ice trapped in the regolith.

Lunar regolith is the common denominator for all processes that aim to produce consumables on the lunar surface, therefore the transportation and storage of lunar regolith become integral to their success. Regolith hoppers act as the interface between storage systems and transportation systems, regulating the flow of material between the two. Hoppers are well understood under terrestrial conditions but the flow of non-homogeneous granular material is significantly changed under lunar ultra-high vacuum and low gravity conditions. Under terrestrial conditions, as material flows through a hopper, the air gets trapped and permeates through the system as it flows, sometimes fluidizing the material. This behavior can also affect the location of material stagnation in certain hopper geometries. Under vacuum, this variable is not present resulting in different flow behavior of the material. This research investigates the flow behavior of selected regolith simulants in multiple 3-dimensional hopper geometries (cylindrical, square, rectangular) under vacuum and atmospheric conditions. Additionally, material stagnation points specific to each geometry are also examined. This was accomplished by assessing the hopper inclination angle, simulant compaction, fill volume, and hopper exit diameter. Mass flow rate, stagnated mass, and

stagnation points were then observed to measure hopper performance. These test results are analyzed to guide hopper selection and design for a variety of ISRU technologies.