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GRANULAR VIBRATION PUMPING SYSTEM FOR LIFTING LUNAR REGOLITH

Abstract

In-situ resource utilization (ISRU) is a pivotal concept for facilitating long-term space explorations on the Moon. It will reduce the cost and risk of procuring consumables and materials from the Earth. ISRU employs the utilization of valuable components, such as metals, oxygen, and possibly water, contained in the lunar regolith, to harness astronauts' life activities and supply fuels and materials for unmanned systems. A large amount of regolith needs to be processed in ISRU operations, which include drilling, sampling, storage, beneciation, and chemical processing. The handling systems for these granular materials are basic but indispensable. Many different types of the handling techniques have been developed, and we focus on a granular vibration pumping system in this study. The system operates on the principle of particles ascending in a vertically oscillating tube immersed in a bulk of granular materials. In principle, the device relies only on a vibrating tube to transport particles, thus it has several advantages for use on the Moon, such as high tolerance to dust contamination, no need for gas or liquid, and a simple design that is small and lightweight. Although this phenomenon has been reported in some previous studies and the application for lunar regolith simulant has been demonstrated, the effects of particle size in ranges of lunar regolith have yet to be investigated. Therefore, we have conducted the experiments to reveal the transport performances for spherical glass beads and regolith simulant particles in various sizes ranging from 10 to 1000 μm. The transport characteristics of the particles, each categorized by particle size, under a variety of vibration conditions were elucidated, and we were able to lift lunar regolith simulants larger than 100μm for a distance of approximately 1m or more. In addition, comparing transport of glass beads with that of lunar regolith showed that the transport efficiency of the less fluid lunar regolith is compromised due to shape effects. However, as the particle size increases, the impact of shape diminishes, resulting in transport performance comparable to that of spherical particles. Furthermore, we demonstrated that transport efficiency can be enhanced for small cohesive particles by optimizing the pipe diameter. These tests were conducted under terrestrial gravity, and we foresee performance enhancements under the Moon's low-gravity conditions.