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SOIL PENETRATION DARTS (SPDS) FOR DEEP SOIL SAMPLING

Abstract

The moon, being the only natural satellite of the Earth, has gained significant attention from humans since ancient times. In many lunar exploration missions, the core goal is to investigate regolith composition and identify potential substances for in-situ resource utilization (ISRU). The collection of samples in most lunar exploration missions is done by drilling. Despite the number of missions conducted, no drill was able to penetrate the lunar surface deeper than three meters. The penetrability of regolith rapidly decreases with depth due to increased soil density. With each Kilogram of payload costing millions of dollars, taking heavy and powerful drills to the lunar surface is not cost-effective. Therefore, reaching higher depths and acquiring soil samples from beneath that three-meter barrier is still considered an ambitious task in lunar exploration missions.

The motivation of this paper is to present an alternative concept for collecting deep soil samples. The major elements of the proposed system consist of a lunar orbiter, lunar rover, and Soil Penetration Darts (SPDs). A dart is a simple spear-shaped mechanism that will be deorbited from the lunar orbiter to a descending trajectory that ends on the lunar surface with an impact. A dart would gain enormous velocities when reaching the surface, thereby gaining enough momentum to pierce through the surface to reach a higher penetration depth. A controlled release of pressurized gas from the latter part of the dart, through staged combustion of solid propellants, moves soil particles to the surface without making a rapid deformation to the soil layer. The rover can then reach the impact site to acquire samples from the surface, which is a mixture of soil from both surface and deep layers.

Sample collection through an impact poses many technical challenges compared to drilling, with heat and high impulsive forces generated on the dart, being the greatest challenge. The paper aims to tackle these challenges through optimization of trajectory, terminal and rotational velocity, shape, and materials of the darts. This paper also presents details of the engineering models and simulations carried out to verify and validate the performance of the suggested dart mechanism.