ULTRASONIC LEADING EDGE FOR LUNAR EXCAVATION TOOLS.

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Introduction: The lunar surface is once again within reach as the NASA's Artemis program aims to put the first woman and the next man on the Moon by 2024. Achieving long-term human habitation on the lunar surface requires in-situ resource utilization (ISRU) technologies to be developed in order to reduce dependence on Earth commodities.

Excavation of regolith and granular ice is the first step in the production of useful resources on the lunar surface. With its low gravity and distance from Earth, the Moon presents an exceptional excavation challenge. Terrestrial excavation is based around intentionally massive machinery to produce sufficiently large reaction forces that balance against very large excavation forces. This general structure does not scale to lunar operations where landing mass on the lunar surface is exceedingly expensive and only provides 1/6th of the reaction force due to reduced lunar gravity.

Lunar excavator design must first be approached from the tool/terrain interface. This approach seeks to reduce excavation forces to minimize required reaction forces, and thus resuls in an excavator that is less massive and likely requires less total power.

The mTRAX Planetary Exploration Labs group at NASA Glenn Research Center is investigating the use of a resonantly vibrating leading edge on a bucket to reduce the penetration force as the tool engages the soil. Early studies show very successful results of ultrasonically vibrating horns and probes significantly reducing the penetration force in granular lunar soil simulants [1]–[4]. While forced vibration tools will increase end-effector power and mass, the goal is to achieve a net reduction in power consumption and overall system mass due to significant force reduction.

Currently, the research effort is looking at characterizing the behavior of an ultrasonic horn penetrating granular lunar regolith simulant in a lunar vacuum environment at a component level. The results from this experimental study will enable characterization of the impact of atmosphere on the effectiveness of the force reduction phenomenon.

In parallel, a design for an integrated leading edge on an excavator bucket is being developed for full scale testing in the Excavation Lab at NASA Glenn Research Center in ambient conditions. The Exavation Lab (Fig. 1) houses the Advanced Planetary Excavator (APEX) which is used as a highly repeatable path generation tool for excavation testing. Both the soil simulant and ultrasonic leading edge have directional properties so to better understand their coupled interactions testing via two-dimensional toolpaths generated by APEX are required. These tests will highlight toolpath restrictions for using ultrasonic blades in soil and will likely indicate which orienations are most effective at reducing penetration forces. These full scale tests will feed into the final branch of this research effort is working to develop modeling capabilities for the APEX platform. The purpose of the model is to enable more efficient design and development of novel excavation tools. This work will present the state of development of the ultrasonic bucket tool at NASA Glenn Research Center.

Figure 1. The APEX excavation platform in the Excavation Lab at NASA Glenn Research Center with the first generation Ultrasonic Bucket prototype attached as the end effector.

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