

Reducing Extra-Terrestrial Excavation Forces with Percussion

High launch costs and mission requirements drive the need for low mass excavators with mobility platforms, which in turn have little traction and excavation reaction capacity in low gravity environments. This presents the need for precursor and long term future missions with low mass robotic mining technology to perform In-Situ Resource Utilization (ISRU) tasks. This paper discusses a series of experiments that investigate the effectiveness of a percussive digging device to reduce excavation loads and thereby the mass of the excavator itself.

The goal of percussive excavation is to fluidize dry regolith in front of the leading edge of the tool by mechanically separating the microscopic interlocking grains resulting in a reduced force needed to shear the soil. There are several variables involved with this technique; this experiment varied: Impact energy, frequency, and excavation speed and held constant: impact direction, depth of cut, angle of tool, and soil bulk density.

The test apparatus consisted of an aluminum truss bridge with a central pivoting arm. Attached to the arm was a winch with a load cell in line that recorded the tension in the cable and therefore the excavation load. The arm could be adjusted for excavation depth which was recorded along with the arm angle relative to the bridge. A percussive mechanism and 30" wide pivoting bucket were attached at the end of the arm simulating a basic backhoe with a percussion direction tangent to the direction of movement. Internally the mechanism used a set of die springs and barrel cam to produce the percussive blow. By changing the springs and the speed of the motor the impact energy and frequency of percussion could be varied independently. Impact energies from 11.2J to 30.5J and frequencies from 0 BPM to 700 BPM were investigated.

A reduction in excavation force of as much as 51% was achieved in this experimental investigation. Smaller percussive digging implements, tested by others, have achieved a reduction of as much as 72%. This paper will examine the effects of impact energy, frequency, scaling and their effect on excavation forces in a dry granular material such as lunar regolith.

The past several years have shown an increasing interest in mining space resources both for exploration and commercial enterprises. This work studied the benefits and risks of percussive excavation and preliminary results indicate that this technique may become an enabling technology for extra-terrestrial excavation of regolith and ice.