Efficacy and Wear of a Bucket Ladder for ISRU Regolith Excavation in Vacuum

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Introduction

NASA, industry and others are working toward a permanent presence on the lunar surface. For sustainable activities one of the key elements is the ability to excavate and transport large quantities of lunar regolith for construction and processing. To minimize excavation forces due to limited traction due to low gravity many small scoops instead of a large bucket are beneficial. For large quantities of material to be moved a continuous stream of buckets allows excavation speeds in the 1000-2000 kg/hr with a system weighing less than 50kg with relatively low power use and a 1 m depth of reach.

Bucketladder Trencher Design

Bucketladders have long been considered a good option for lunar excavation. The first one was built in 2005 at CSM as a senior capstone design project under supervision of Dr. van Susante. Since then many variations have been built and tested, among others in the NASA centennial excavation challenge, the NASA lunabotics and robotic mining competitions etc. where the winning designs consistently apply variations of bucketladders. None of these were ever tested under vacuum conditions until last year by the Planetary Surface Technology Development Lab at MTU. This past year various modifications and improvements have been made to the test setup, resulting in the ability to translate in the x and z directions while excavating as well as 3 versions of the bucketlader. Figure 1 shows the first version for atmospheric testing down to 1 m depth. Figure 2 shows the first vacuum test version whereas Figure 3 shows the current version 3 with improved wire management, improved test buckets and modified angle for improved deposition of excavated regolith simulant while excavating multiple passes going deeper with every pass. The system has been tested in atmospheric and vacuum conditions.

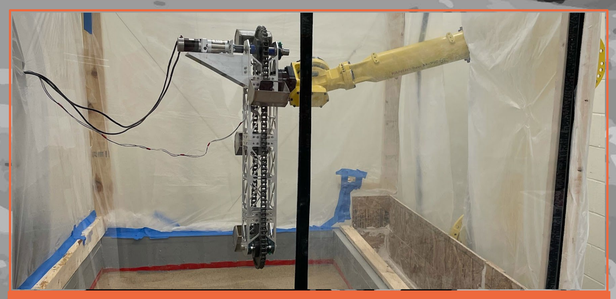

Figure 1: V1 of bucketladder trencher

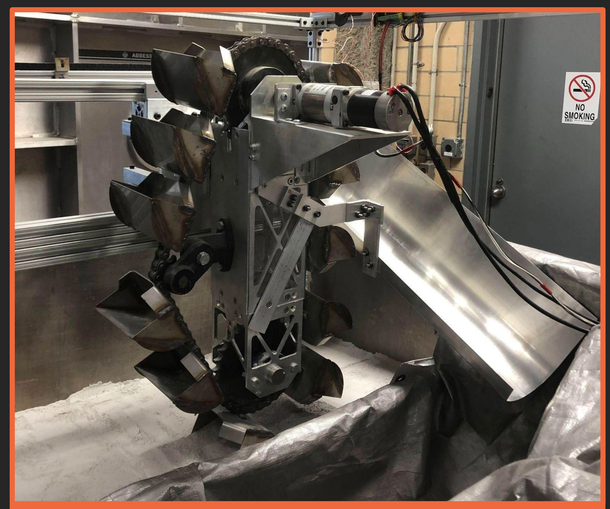

Figure 2: V2 of bucketladder trencher

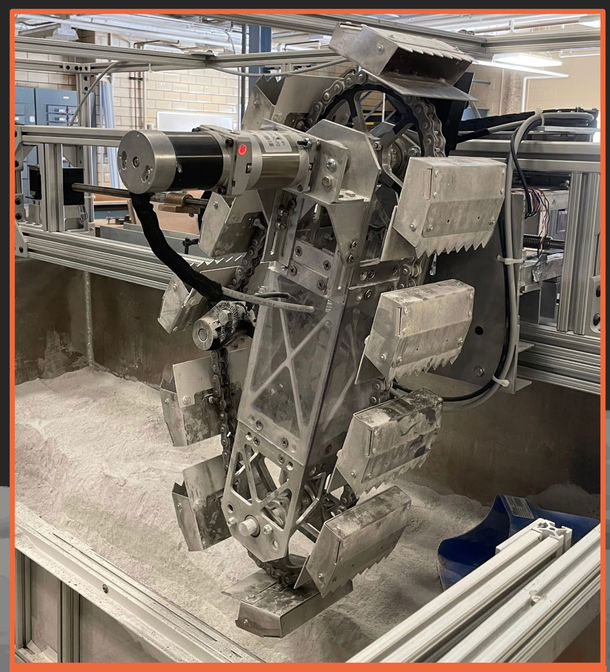

Figure 3: V3 of bucketladder trencher

Bucketladder

The bucketladder has performed well in atmospheric and vacuum conditions. One observation is that in vacuum conditions, far less dust is generated and far less dust contamination is experienced since the dust falls ballistically regardless of particle size. A challenge due to the geometry is the deposition of the excavated regolith. An increased angle and modified bucket scoops allow deposition on the transfer chute and deposition in the other half of the box for weighing.

Bucket scoops

The bucket scoops can have many variations in material, teeth, geometry and size. For ease of manufacturing, bent sheet metal was chosen. When a deposition geometry issue was revealed, a backplate was added so that the regolith would be deposited in the chute instead of on and into the chain and excavator. The goal is to examine wear of the teeth and chain over time. Specific teeth and chain links are marked and will periodically be examined under a specific microscope to measure roughness and image the material surface and shape.

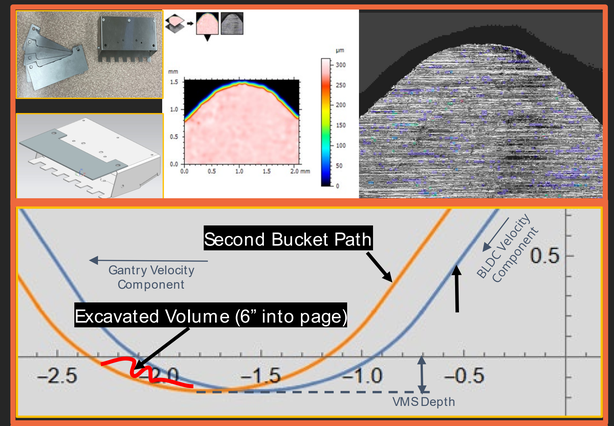

Figure 4: DTVAC with Regolith Cart filled with Lunar Simulant

Figure 5: DTVAC with Regolith Cart filled with Lunar Simulant

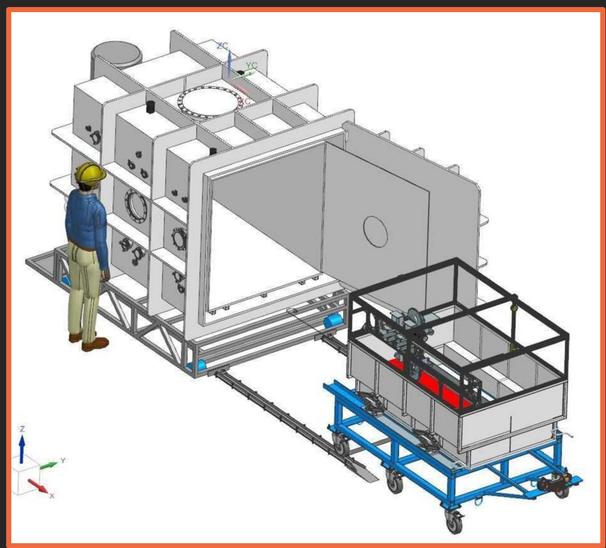

Figure 6: MINE Bucket Ladder Testing in DTVAC

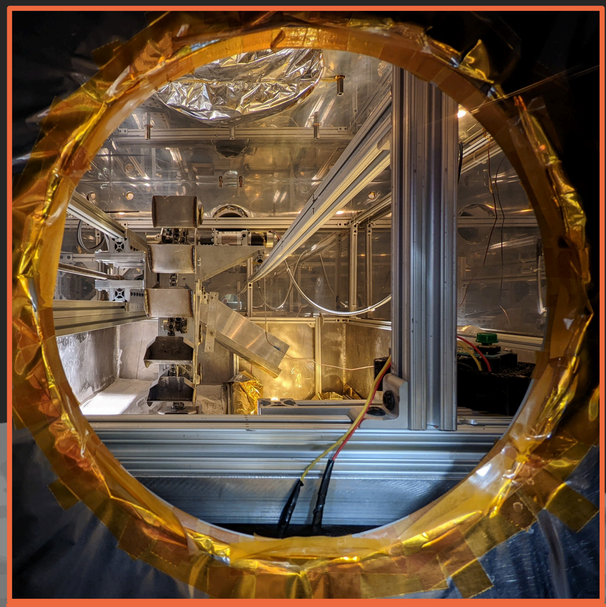

Figure 7: DTVAC with Regolith Bin filled with Lunar Simulant

Other Active Research

Testing of the bucketladder will continue in the PSTDL's DTVAC. Once the test campaign is complete, we will expand to testing with icy regolith simulant in the freezer container and eventually in the DTVAC. A new excavation force measurement rig developed for the Break the Ice Challenge will be used to do icy regolith excavation testing using the bucketladder and other excavation implements.

For questions, contact pjvansus@mtu.edu or visit https://www.huskworks.space