Test Stand for the Analysis of Excavation Forces in a Simulated Lunar Environment.

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Introduction: Excavation of water-ice from lunar permanently shadowed regions is one of the topics scientists are looking into for in-situ resource utilization and building a lunar infrastructure. However, it is difficult to compare excavator types due to the inconsistent test procedures and data collection methods [1].

The force test stand utilizes eight S-type load cells to collect tensile and compressive force data while in temperatures ranging from -40°C to 20°C. This provides a mechanism for testing different types of excavators within the same environmental conditions for simplified comparison.

Methods:

Mechanical Design: The test stand comprises three motorized linear motion systems and a material bed, which supports up to a 15.4 cm cut depth and a 1-meter-long cut path (Figure 1). Load cells are strategically placed throughout the frame (Figure 2) to collect consistent tensile or compressive data for the desired cut depth and cut path.

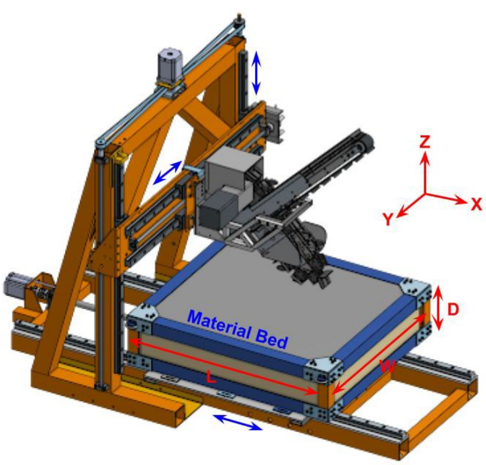

Figure 1. CAD model of the test stand with the PRIMROSE excavator [2] mounted to the gantry system, X-axis: 2.46 m, Y-axis: 1.63 m, Z-axis: 1.63 m Material bed: L =1.35 m, W = 1.02 m, D = 25.4 cm

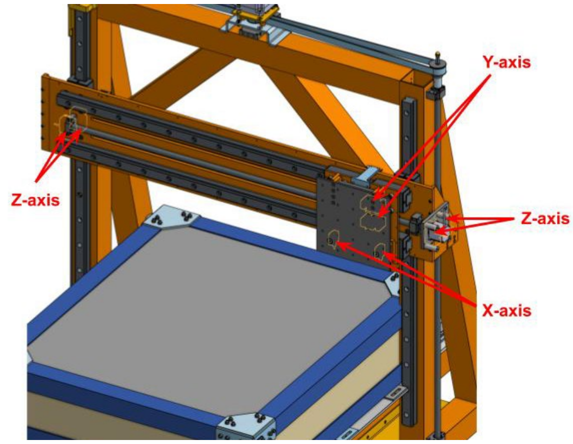

Figure 2. Placement of the eight S-type load cells on the test stand frame

Electrical Design: Due to the frigid and dusty environmental conditions, the electrical box (Figure 3c), heater, and data acquisition system are housed within an insulated pizza box (Figure 3a) with a backup heater and filter to keep the electronics warm and dust-free. The load cells are kept unheated and calibrated at both room and freezing temperatures.

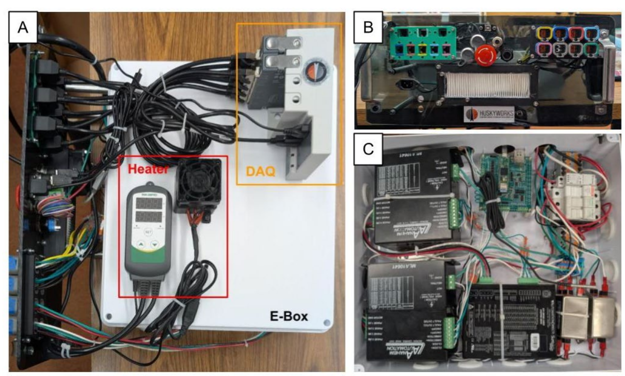

Figure 3a. The electrical box, DAQ, and heater assembly attached to the front panel of the pizza box Figure 3b. The front panel of the pizza box assembly Figure 3c. The internal electrical components within the electrical box

Controls Design: The data collection system is specifically used for load cell data and comprises a cDAQ-9174 and two NI-9237 modules. An open-source GUI [3] is used for the motion of motors and full functionality of the test stand.

Path Forward: Once the test stand assembly is fully integrated, a series of tests will be run to confirm the performance of its testing capabilities. Tests using the PRIMROSE excavator assembly [2] to excavate varying ice weight percentages of MTU-LHT-1A [4] will be run to capture force and power consumption data. This series of tests will be compared to the theoretical results for pick force calculations per the Goktan and Gunes model [5] and bucket force calculations per the Balovnev model [6]. The test data collected from excavation in this controlled environment will provide opportunities for further analysis of excavation simulation and mathematical modeling.

As the capabilities are further defined, other systems besides excavators could be mounted onto the test stand for force data collection and analysis. Novelties such as additive manufacturing on the lunar surface could be simulated with the test stand's three-axis capabilities and CNC control system.

References:

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