The impact of abrasion resistant materials on performance and tool life of lunar surface exploration and mining units: an experimental study

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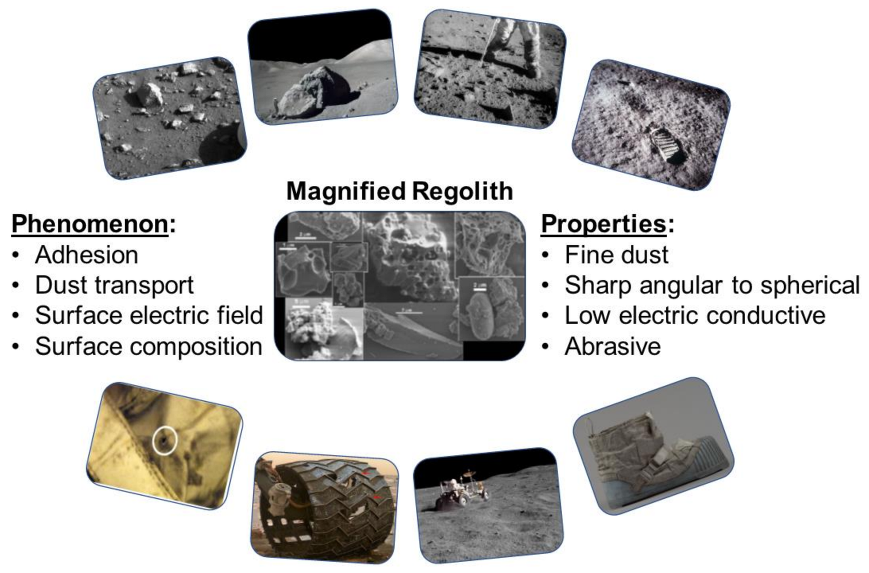
Overview and Experimental Setup

Overview



Eugene Cernan, commander of Apollo 17, stated that;
"… one of the most aggravating, restricting facets of lunar surface exploration is the dust and its adherence to everything no matter what kind of material, whether it be skin, suit material, metal, no matter what it be and it's restrictive friction-like action to everything it gets on"

- The Dust Management Project of the Exploration Technology Development Program identified equipment abrasion as a crucial factor in evaluating the impact on future lunar surface systems, based on observed characteristics of lunar dust particles
- A collaborative effort is underway at Colorado School of Mines' Earth Mechanics Institute with abrasion resistant materials manufacturers, including Technogenia Lasercrab Oklahoma Inc., to identify more robust options for future lunar surface systems using a state-of-the-art indigenously developed soil abrasion index test

Earlier Attempts

- Two-body scratch test using the fundamental interaction of a single particle on a flat surface was developed and reported by Kobrick et.al. in 2009
- Three-Body abrasion test using the same concept as ASTM International (ASTM) B611 was developed for lunar simulants and reported by Street et.al.in 2010

Experimental Setup

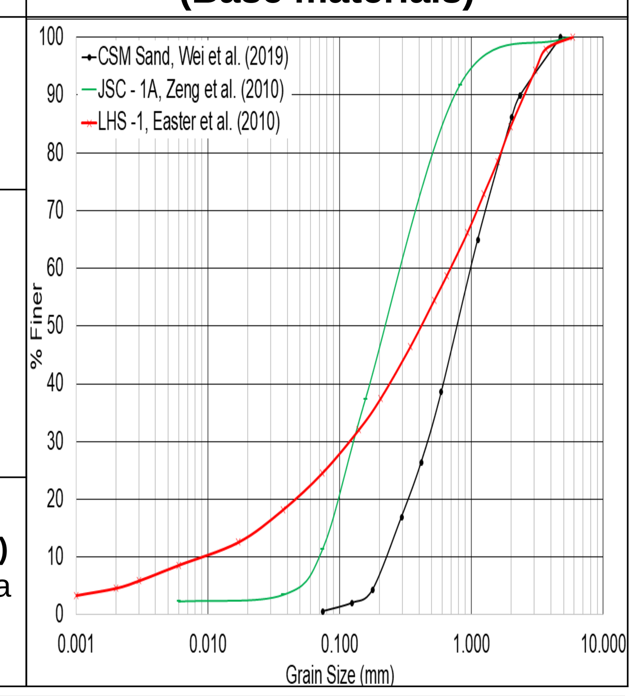
Capabilities of Soil Abrasion Index (SAI) Test Unit

- The abrasiveness of mixed material, particles up to the size of gravel, can be measured without altering the particle size distribution (PSD)
- Testing can be performed on diverse samples using varying water content
- Testing can be carried out at various ambient pressures.
- Testing can be performed at various surcharge loadings.
- Speed can be adjusted and high contact stresses can be induced.
- Tool material properties and hardness can be changed.
- The wear on the parts and torque of the system can be directly measured.

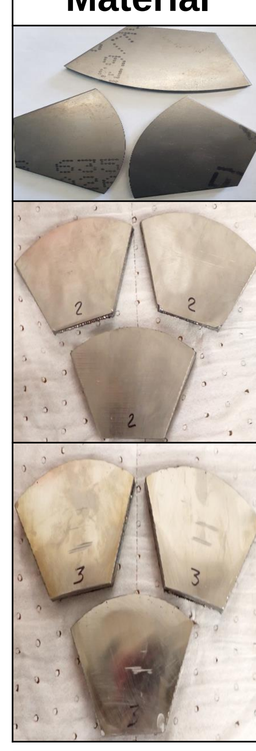
Materials, Test Matrix and Results

Base Materials

Material (Raw)	Material (Powder)	Nomenclature & composition	Particle size distribution (Base materials)
		CSM Sand Quartz rich local sand from Denver which is highly abrasive	
		LMT-1 **(Lunar Mare Type)** Prepared at CSM from the exact same basaltic feedstock as JSC-1A, sourced from Merriam Crater in Arizona	
		LHT-1 **(Lunar Highlands Type)** Prepared at CSM from a mix of anorthosite and mafic feedstocks	



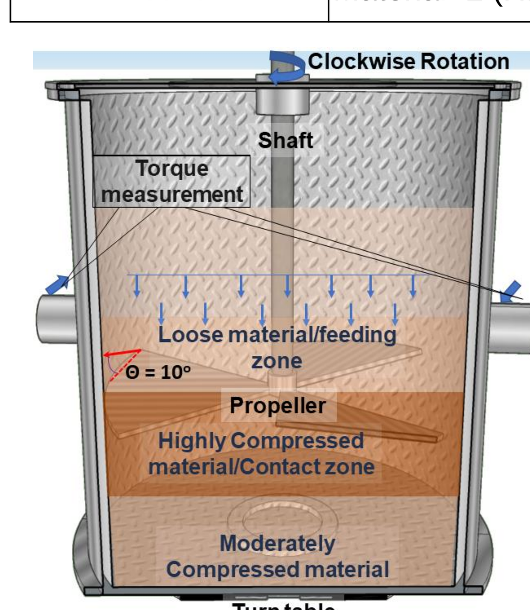
Candidate Materials



Material	Name	Composition	Properties
	Steel 1 & 2	1 (HRC 17) & 2 (HRC 43) mixture of Fe and carbon	Hardness - HRC 17 & HRC 43; Density - 7.8 g/cm³
	Material-1 (Provided by Technogenia)	HRC 64 is Fe based, using martensitic matrix with dispersed Vanadium Carbide	Hardness - HRC 64; ASTM G65 A 30S 0.100g; Density - 7 g/cm³
	Material-2 (Manufactured by Technogenia)	HRC 45 (matrix) / HV 0.2 3000 (WC - W2C) is a Ni based, consisting of Ni matrix mixed with spherical cast tungsten carbide	Hardness - HRC 45; ASTM G65 A 0.090g; Density - 11g/cm³

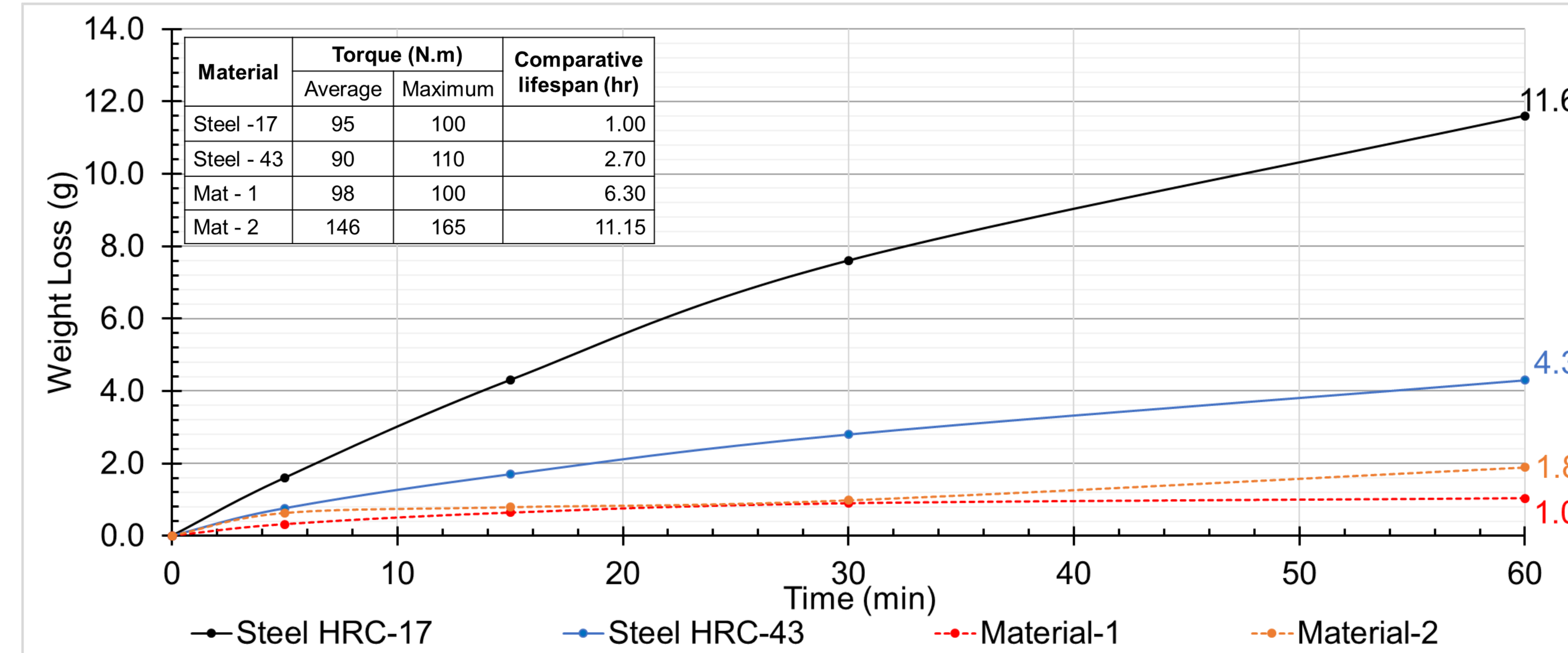
Test Matrix and Mechanics

Base Material	Target Materials	Number of Tests	Test Parameters
CSM Sand	Steel (HRC 17 & 43)	2	Rotation per minute (RPM) - 60; Propeller pitch angle - 10º; Base material weight - 80lbs; Cumulative time interval to record weight loss and torque @ 5, 15, 30 and 60 min
	Material -1 (HRC 64)	1	
	Material-2 (HRC 45)	1	
LMT-1 (Lunar Mare Type)	Steel (HRC 17 & 43)	2	
	Material -1 (HRC 64)	1	
	Material- 2 (HRC 45)	1	
LHT-1 (Lunar Highlands Type)	Steel (HRC 17 & 43)	2	
	Material -1 (HRC 64)	1	
	Material- 2 (HRC 45)	1	



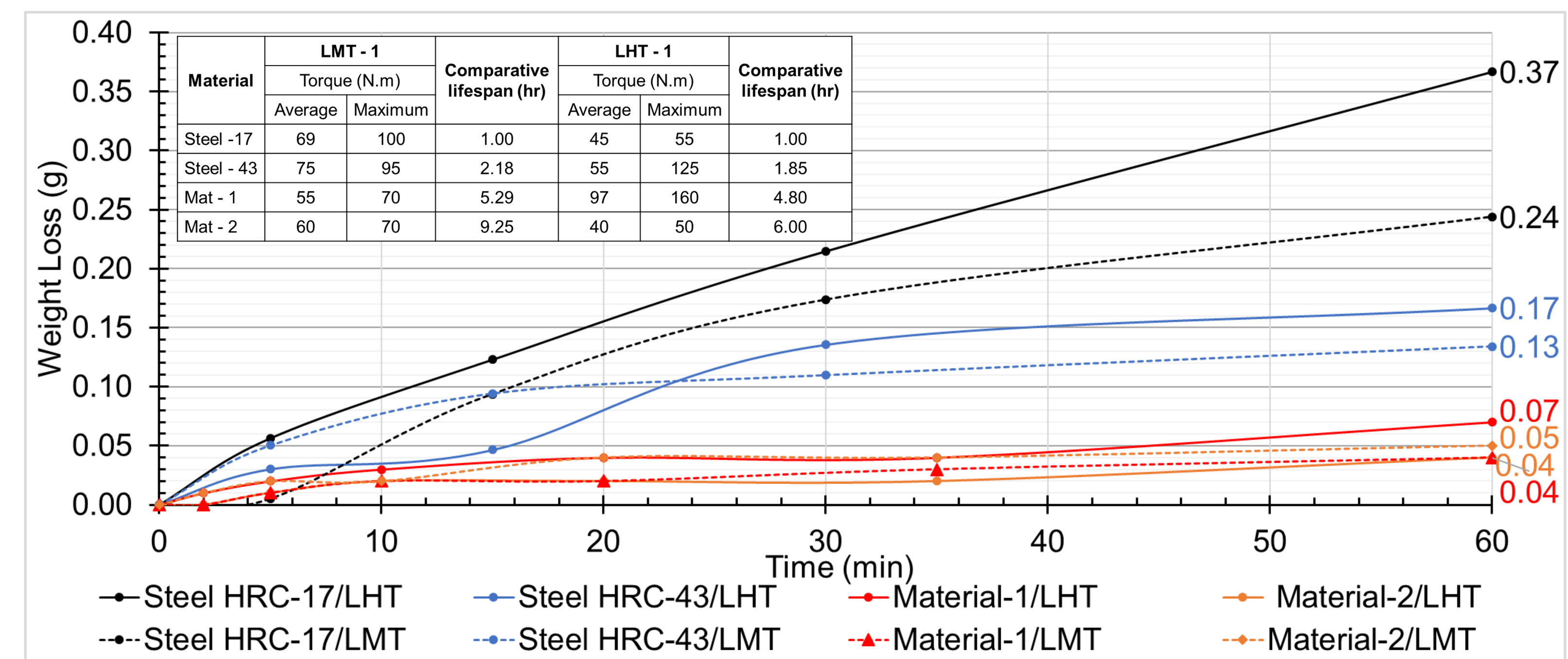
- As the propeller runs in a clockwise direction due to the pitch angle, it pulls material from above and compresses under it
- A progressive increase is typical for compressible material
- As the compression in the soil is not uniform with depth, hence maximum compression is in the contact zone
- Turn table ensures smooth rotation hence torque is measured from the side handles

Results - CSM Sand as Base Material



Material	Torque (N.m) Average	Torque (N.m) Maximum	Comparative lifespan (hr)
Steel -17	95	100	1.00
Steel - 43	90	110	2.70
Mat - 1	98	100	6.30
Mat - 2	146	165	11.15

Results – Lunar Simulants as Base Materials



Material	LMT - 1 Torque (N.m) Average	LMT - 1 Torque (N.m) Maximum	Comparative lifespan (hr)	LHT - 1 Torque (N.m) Average	LHT - 1 Torque (N.m) Maximum	Comparative lifespan (hr)
Steel -17	69	100	1.00	45	55	1.00
Steel - 43	75	95	2.18	55	125	1.85
Mat - 1	55	70	5.29	97	160	4.80
Mat - 2	60	70	9.25	40	50	6.00

Conclusion & Future Work

- The LHT-1 appears to be more abrasive than the LMT-1, making EVA on highlands more challenging and necessitating more cautious equipment handling (LHT~ 1.2 - 1.8 times more abrasive than LMT)
- Hard faced laser cladding outperform conventional and hardened steel plates
- Incorporating wear-resistant technology is crucial for developing durable materials for drilling and excavation tools in future Lunar surface systems
- Comprehensive test matrix with varying particles up to size of gravels
- Abrasion index test of regolith with a mix of frozen matrix
- Inclusion of products from other manufacturers to make a ready reckoner for system developers

References

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