National Aeronautics and Space Administration

Improved geotechnical assessment of regolith strength properties using the Mars 2020 abrading bit

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Objectives: Picture the Perseverance rover on the surface of Mars. Fifty meters away is a target of significant interest to the science team. Between the rover and target, however, lies a slope, series of ripples, or region of flat, unconsolidated regolith. Can the rover safely traverse to the science target? The premise of this technology is that JPL currently lacks the ability to provide a quantitative, data-driven answer to this question and that the development of an enabling technology would be of strategic benefit to the lab. This task aims to thoroughly develop a methodology by which the Perseverance rover abrading bit can be used to measure the mechanical strength and spatial variation of regolith on Mars.

Background: An instrument to measure the strength and spatial variation of Martian regolith has never flown, as such an engineering instrument would consume mass and volume otherwise available for other science payloads. The lack of geotechnical equipment onboard the rover has precipitated the use of anecdotal evidence and a-posteriori curve-fitting as the state-of-the-art for assessing terrain trafficability, which lacks predictive capability. The Perseverance rover abrading bit has a similar form factor to a Bevameter, a tool commonly used to characterize soil mechanical properties. This work aims to demonstrate how the Perseverance rover abrading bit, primarily a science instrument, can also be used to assess terrain geotechnical properties, thereby providing JPL the ability to characterize Martian regolith strength and provide a quantitative assessment of terrain trafficability.

Approach and Results: To demonstrate the use of the abrading bit as a Bevameter to characterize soil strength, team members, using commercial off-the-shelf components, designed and built a portable testbed that mimics the flight system (Figure 1). The testbed comprises an80/20 housing, electronics box, and drill feed mechanism. The testbed is controlled over ethercat by multiple beckhoff modules and Elmo Gold Whistle motor controllers, to which commands are sent via a Panasonic Toughbook running the Casah2 software environment. The corer assembly was designed and built to be flight-like, taking much of its design from the flight version. It is capable of pre-loading the bit up to 250 N (per flight), and has been tuned to operate with the same control bandwidth as expected in flight.

A data-processing pipeline was developed to convert raw measurements to soil strength. Tests were performed on three characterized simulants with different mechanical properties, i.e., Mojave Mars Simulant (MMS) Dust, JCS-1A Lunar simulant, and #90 M2020 Mobility Dune Simulant (Figure 2). Each of the materials was sent to a third-party vendor, Cal Test & Inpsection, for independent characterization using equipment conforming to ASTM standards. The purpose of this testing was to establish baseline strength characteristics against which measurements using the abrading bit can be referenced. Results show that the abrading bit is indeed capable of making bearing and shear strength measurements (Figure 3) and demonstrate, for the first time, the ability to perform geotechnical analysis using a standard science instrument.

Significance/Benefits to JPL and NASA: This work may enable in-situ assessments of mobility, inform the design of mobility subsystems for Mars Sample Return, and provide a geotechnical database that can be used to refine the design of ISRU systems and for collaboration with other agencies and academia. Future benefits also include downstream applications to Ocean Worlds mobility studies where terrain properties are highly uncertain.

Publications - None

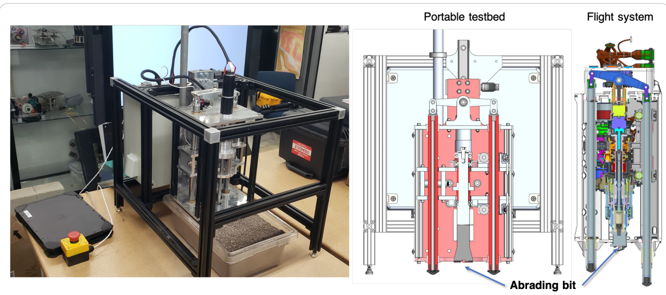
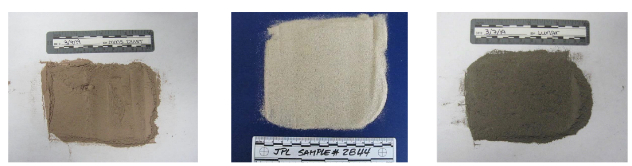


Figure 1: The Abrading Bit geotechnical measurement verification testbed

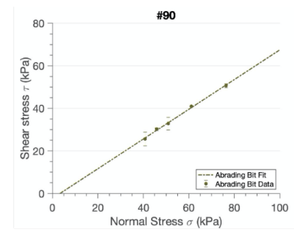


Mojave Mars Simulant (MMS) Dust

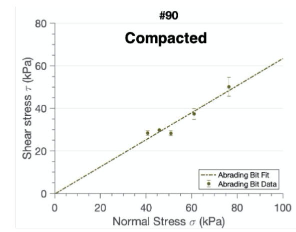
#90 Mars 2020 Mobility simulant

JSC-1A Lunar simulant

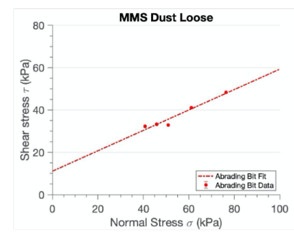
Figure 2: Planetary soil simulants



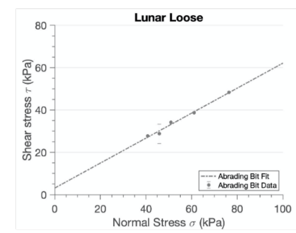
#90	Abrading bit	Direct Shear	
		Ultimate	Peak
Internal friction angle ϕ (deg)	34.9	31	36
Cohesion c (kPa)	0 [fixed at bound]	3.4	6.9



#90 Compacted	Abrading bit	Direct Shear	
		Ultimate	Peak
Internal friction angle ϕ (deg)	32.5	31	36
Cohesion c (kPa)	0 [fixed at bound]	3.4	6.9



MMS Dust	Abrading bit	Direct Shear	
		Ultimate	Peak
Internal friction angle ϕ (deg)	25.7	32	33
Cohesion c (kPa)	11.1	2.0	1.4



Lunar	Abrading bit	Direct Shear	
		Ultimate	Peak
Internal friction angle ϕ (deg)	30.5	33	35
Cohesion c (kPa)	3.1	2.8	4.8

Figure 3: Shear strength results of Abrading Bit testbed and ASTM methods providing internal friction angle and cohesion of the soil

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