A Reverse-Tripod-Multi-Actuator Type Planetary Drilling System for Detecting Lunar Icy-Soil Deposits

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Introduction: Various planetary drilling equipments have been proposed for scientific exploration in the Moon and Mars[1][2][3]. NASA announced that ice exists in the Moon and international space agencies are planning to detect icy-soil deposits in the Moon. This paper presents the conceptual design of a drilling equipment which possesses high recovery capability from jamming hazard and evaluates subsurface strengthes in depth during drilling to detect icy-soil deposits.

Reverse-Tripod-Multi-Actuator Type Highly Reliable Drilling Equipment (RTMA-Drill): A single vertical directional rail transport system of some drilling equipments has been adopted [1][3], but the RTMA-Drill uses an inverted tripod type multi-axis actuator system for vertical movement to improve the reliability of autonomous operation. When pulling stuck drilling rig, only troubleshooting method of a single vertical rail transport system is one-directional (vertical) pulling with reverse rotation. The multi-actuator type transport system allows the drilling axis to swing out in the twisting direction in a jamming situation. In general, a vertical-percussive method is used to compensate for insufficient reaction force during drilling. The RTMA-Drill also adopts a percussive drilling system, but the percussion works in rotational direction. The two key functions enble the RTMA-Drill to escape from jamming hazard and so improve its reliability.

Subsurface Strength Measurement: Subsurface strength was estimated with the power (voltage and current) of rotating motor during drilling[4], but the method is expected to gradually increase the error from aging process of motor. The RTMA-Drill is designed to estimate real-time subsurface strengthes in depth from the reaction forces and torques measured in the drilling axis and icy-soil deposits can be detected from subsurface strength profile.

References: [1] K. Zacny. et al. (2016) *Lunar Resource Prospector Drill*, 47th Lunar and Planetary Science Conference. [2] J. Captain. et al. (2016) *Resource Prospector Instrumentation for Lunar Volatiles Prospecting, Sample Acquisition, and Processing*, Earth and Space 2016. [3] K. Zacny. et al. (2012) *Mobile In-Situ Water Extractor (MISWE) for Mars, Moon, and Asteroids In Situ Resource Utilization*, AIAA SPACE 2012 Conference & Exposition. [4] B. J. Thomson. et al. (2013) Estimating rock compressive strength from Rock Abrasion Tool (RAT) grinds. Journal of Geophysical research.

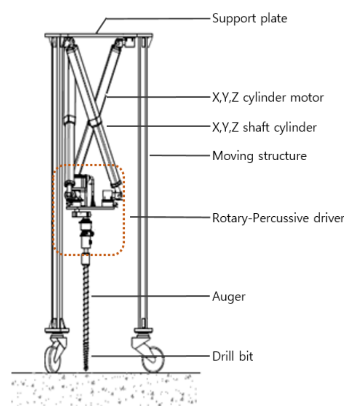

Figure 1. Reverse tripod multi-actuator type highly reliable drilling equipment.

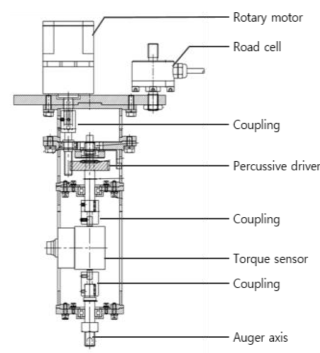

Figure 2. Rotary-percussive driver design.

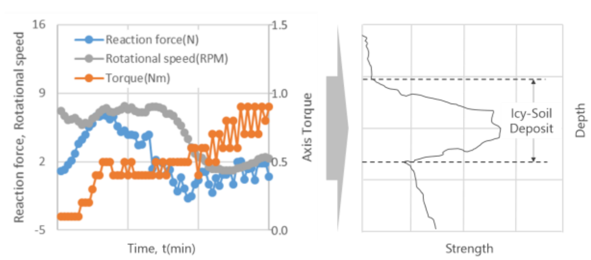

Figure 3. Conceptual subsurface strength assessment.

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