Deep Space Excavator: Mars Ice Drilling Challenge

Walt Mayfield, Melissa Lee, Ben List, Conor McMahon, Parham Pournazari, Gurtej Saini, Alex Zhou | Dr. Eric van Oort, Dr. Pradeep Ashok, Dr. Mitch Pryor

Petroleum and Mechanical Engineering Departments, University of Texas at Austin

***Abstract*— The objective of the Deep Space Excavator is to built a rig/excavator prototype that is capable to reach and extract water autonomously in a simulated Martian subsurface environment with dimension and power constraint.**

***Keywords*— Mars, Ice, Drilling, Excavation, Water, Autonomous**

I. Introduction

The Deep Space Excavator is a portable drilling and extraction system designed to gather water in a Martian environment. It will drill a single hole in the center of the ice test bed, then melt and extract the subsurface ice. This design is intended to minimize risk of mechanical failure and maximize ice recovery.

II. Sub Systems

A. Drilling System

The drilling system consists of a fixed cutter drill bit, a thin-walled casing for structural support, and an internal auger for cuttings removal. A top drive provides torque to the drilling system, and a draw-works raises and lowers the drill string. The top drive is designed to have a maximum power rating of 750 W and an estimated maximum torque of 200 lb-in, with a corresponding estimated rotational speed of up to 400 RPM. The thin-wall casing will not rotate, instead providing structural support in the unconsolidated overburden section and serves as a transport pathway for the drill cuttings. The large open area of the fixed cutter bit and the gap between the bit and casing provide an effective pathway for cuttings to be transported back to the surface. The draw-works uses a stepper motor and chain drive to achieve vertical motion and to control the weight-on-bit (WOB) applied during drilling.

B. Mechanical Structure

The support structure of the Deep Space Excavator is constructed using the 80/20 aluminum framing system. The strong, yet light-weight, beams provide design modularity and simplified assembly. The top drive, draw-works, and intrinsic control hardware are mounted on this frame structure. Bolts through the two horizontal foundation beams secure the structure to the testbed at the four mounting holes. The dimensions of the Deep Space Excavator are 1 m x 1 m x 1.5 m tall and weighs 49 kg.

C. Ice Melting System

Our team uses an immersion heater wrapped around the casing above the bit to melt the ice, allowing water to flow up the drill string. The portion of the casing that houses the heater will be coated in a layer of thermal-insulating material, which will focus heat on the targeted ice. Additionally if the water begins to boil a down-hole temperature sensor will cause the heater to pause and rotate the bit initiating forced convection between water and ice to maximize heat transfer.

Elevating the water temperature in the wellbore is a viable strategy on earth where the atmospheric pressure allows for a large temperature range at which water is stable. On Mars the thin atmosphere decreases this window to, at most, a few degrees celsius. This stifles the heat transfer as the water can only be a few degrees warmer than the ice. A paper published by NASA showed that Calcium Perchlorate, a naturally occurring salt on Mars could increase the range of temperature that liquid water is present to 70 degrees, comparable to what we see on earth. (Marion et al., 2009) This would require a filtration system, such as reverse osmosis, to retain the salts in the wellore.

D. Pumping and Water Treatment

Once the ice is melted downhole, it must be extracted to the surface and filtered prior to being transported to the external accumulation tank. The thin atmosphere on Mars presents a challenge for many conventional pumping systems, so we will utilize a reciprocating piston pump for our eventual on-Mars system. However, this is not necessary at standard temperature and pressure on Earth, so a simpler and cheaper pump may be employed here. We use a diaphragm pump operating in suction as the simplest, cheapest, and most effective method of transporting the liquid water.

Once the water was pumped from the wellbore, water treatment was handled by an inline carbon fiber filter. This filter was rated to remove particulate under 0.15 microns. This should be sufficient to provide clarity to the water as particulate under 5 microns have not been shown to significantly affect suspension turbidity. (Weipeng et al., 2012) In the path-to-flight, a more progressive filtration system may need to be employed to maximize filter life.

E. Electrical System

1) Top Drive System (TDS)
2) Draw-Works System (DWS)
3) Pumping System (PS)
4) Heating System (HS)
5) Sensor System (SS)

F. Safety Controls

Safety of the system will be assured by the following:

Mechanical Circuit Breakers (MCBs) on the TDS, HS, and PS, will trip if current exceeds maximum rate.

A fuse at the input of the main junction box controlling the overall electrical system, provides overcurrent protection.

Grounding of all subsystems prevents human contact with dangerous voltage.

An emergency stop button allows immediate manual termination of all voltage to the system.

G. Programming and Controls

Control voltage command signals are fed from the Real-Time Target Machine to each component through the motor drives, pump drive, and transistor circuits.

Acknowledgements

Funding and support for this project is provided by NASA's RASC-AL Special Edition: Mars Ice Challenge and Langley Research Center.

Thank you to Mr. RunQi Han, and Mr. Adrian Ambrus for their continuing support and design advice.

References

He, Weipeng, and Jun Nan. "Study on the impact of particle size distribution on turbidity in water." *Desalination and Water Treatment* 41.1-3 (2012): 26-34.

Marion, G. M., D. C. Catling, M. Claire, and K. J. Zahnle (2009), Modeling aqueous perchlorate chemistries with application to Mars, *Lunar Planet. Sci.*, XL, Abstract 1959.