Lunar Environment Simulation for a High Performance Motor

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ABSTRACT:

NASA and the Canadian Space Agency (CSA) through a CSA contractor, Argo Space/Robotics Division, partnered to perform environmental performance tests on a high torque producing motor. CSA provided the motor and NASA provided a thermal vacuum chamber capable of achieving high vacuum (P < 1 E-5 torr) and temperatures between 25 and 400 K. NASA also provided a dynamometer system capable of measuring and or applying break torque between 0 and 28 Nm. The two primary goals of the test were to simulate sun exposed and shadow condition expected on the lunar surface in order to determine survivability of the motor at extreme temperature conditions and to operate the motor under a constant break load of 6.8 Nm in the temperature range of 30K to 415K. A secondary objective of the test was to operate the motor for 15 km under 6.8 Nm of load. The primary goals of the test were fully achieved. The secondary goal was partially achieved.

1. INTRODUCTION

Mechanical systems developed for interplanetary missions must function in extremely hostile thermal environments. Problems can arise due to lubrication performance degradation. Extreme cold conditions can cause increases in lubrication viscosity resulting in placing a higher than expected load on power supplies. Thermal expansion and contraction can cause interferences or slippage in parts and drive trains that require tight tolerances reducing efficiency or even causing catastrophic failure.

Engineers at the Langley Research Center (LaRC) developed a thermal vacuum chamber capable of thermally conditioning payloads between 30 K and 400 K. The chamber is capable of reaching pressures below 1 E-5 Torr. The chamber, referred to as the Cryo-mechanism Test Chamber, also incorporates a Magtrol dynamometer system that can measure or apply torque accurately and precisely between 0 and 28 N*m.

2. CRYO-MECHANISMS TEST CHAMBER

The Cryo-mechanism Test Chamber, (Cryo-mech) chamber was procured from Janis Corporation. The chamber has a rough working volume of 225 L (13800 cubic inches). There are eight feed through ports spaced radially. Two of the feedthrough ports are configured with mechanical rotation feed throughs, two of the feedthrough ports are configured for electrical penetrations. The remaining four are blanked off.

The top of the chamber is fitted with a window. Payloads are thermally conditioned by a conductive platen. The chamber has an interior radiation shield that is independent of the main platen but can only be forced to cool. Figure 1 depicts the Cryo-mech chamber and the dynamometer as seen from behind the dynamometer.

Figure 1: The Cryo-mech chamber and Dynamometer

Figure 2 depicts the ambient side motion transmission line from the chamber rotational feed through to the dynamometer.

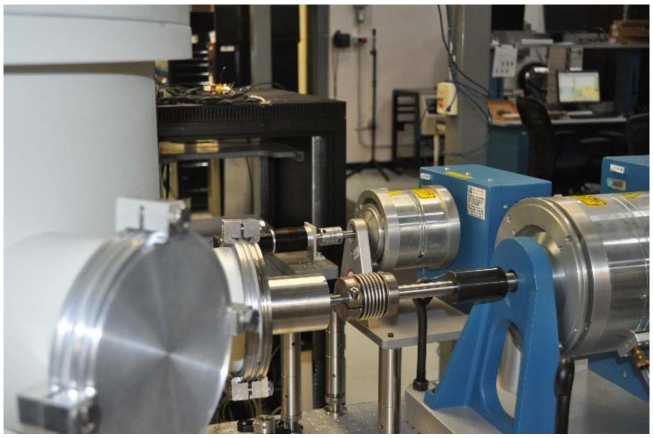

Figure 2: Rotational Motion Transmission Line

The Cryo-mech chamber is divided into three subsystems: vacuum, thermal, and torque measurement. Vacuum is achieved in two stages: a roughing pump evacuates the chamber until the ultimate pressure does not exceed 500 mTorr. When the pressure goes bellow 500 mTorr the roughing/backing pump on a Edwards E218 turbo pump continues roughing the chamber down to crossover pressure. Crossover is accomplished by manually operating two valves in the pump system. Pressure is monitored using an Inficon Model BCG450. Operational vacuum is considered to be established when the ulitimate pressure is consistently below 5 E-5 Torr.

The thermal platen is a gold plated OFHC Copper plate and is depicted in Figure 3. It is cooled by a Cryomech AL230 cryopump. The cryohead is directly attached to the platen. The platen is then heated by three Cryocon 50 Watt cartridge heaters. The cartridge heaters are powered by two Sorensen Model DLM 150-4. The radiation shield is cooled by its own Cryomech AL230 cryopump. Temperature is monitored by eighteen T-type thermocouples and the TC signals are acquired by a National Instruments PXI-e data acquisition system.

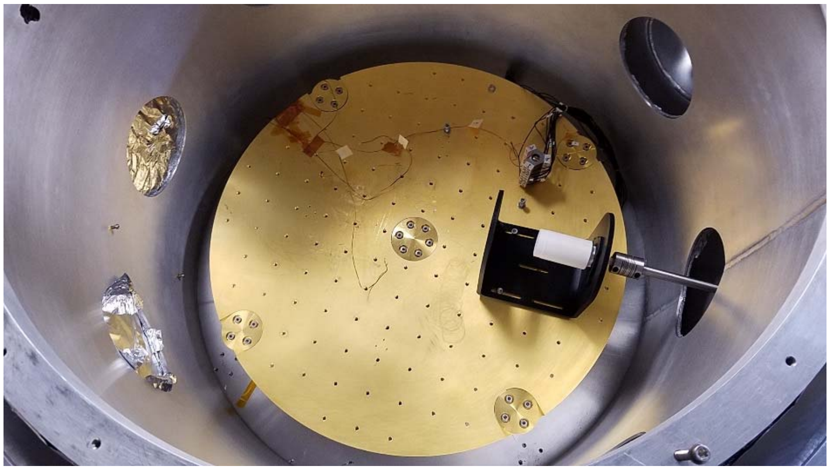

Figure 3: Thermal Platen with a motor payload mock-up

Torque and rotational speed are measured using a Magtrol HD-805-6N-0100 dynamometer. This dynamometer can measure torque between 0 and 28 N*m and rotational speeds up to 10,000 RPM. Data is acquired on a Magtrol DSP6001 controller. Figure 4 depicts the Magtrol dynamometer, the chamber, and the feed through used to power payloads and units under test.

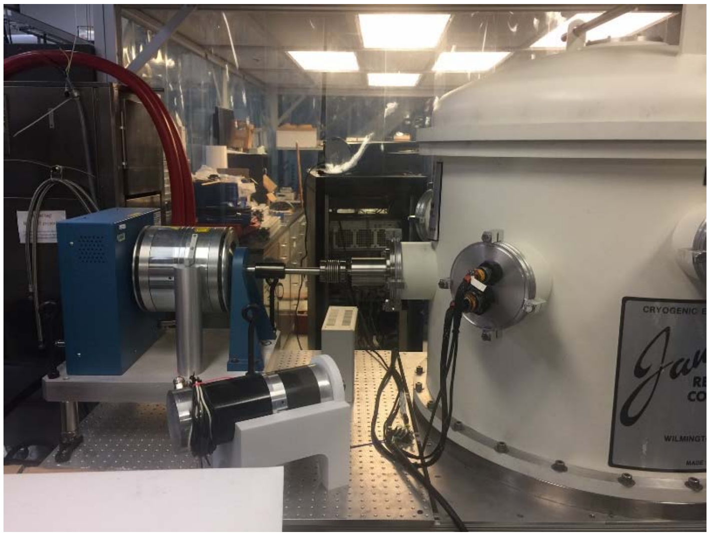

Figure 4: Magtrol Dynamometer, Cryo-mech Chamber, and UUT Power Feedthrough

3. TYPICAL TESTING RESULTS

The Cryo-mech chamber is capable of transitioning from ambient temperature to roughly 25 K in 4 hours when set to the maximum transition rate. The radiation shield does significantly lag behind which is expected due to the geometry of the radiation shield's thermal control interface. The radiation shield also is susceptible to significant temperature gradients between the control interface surface and the top of the radiation shield cylinder. Figure 5 depicts the cool down curves for the platen and the radiation shield. The radiation shield plot is the average of the three sensors used to monitor the shield temperature. The coldest was in close approximation to the platen, while the top most sensor was closer to 100 K.

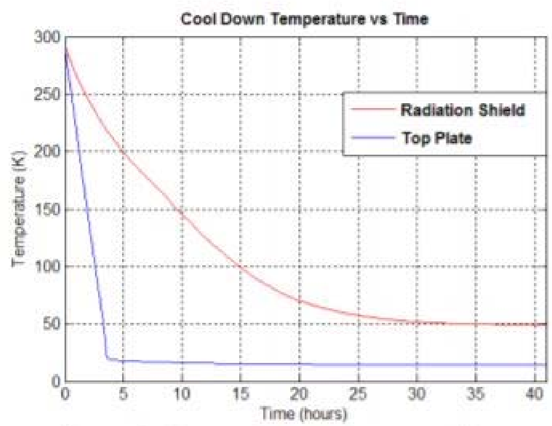

Figure 5: Cool Down Chart

Figure 6 is representative of one of the extreme tests conducted for the CSA and their contractor during their motor characterization campaign. This was near one of the last days of testing. Note that the transition form 200 K to 400 K was accomplished in approximately 2.5 hours. Cool down from 413 K to 32 K was accomplished in approximately 7 hours.

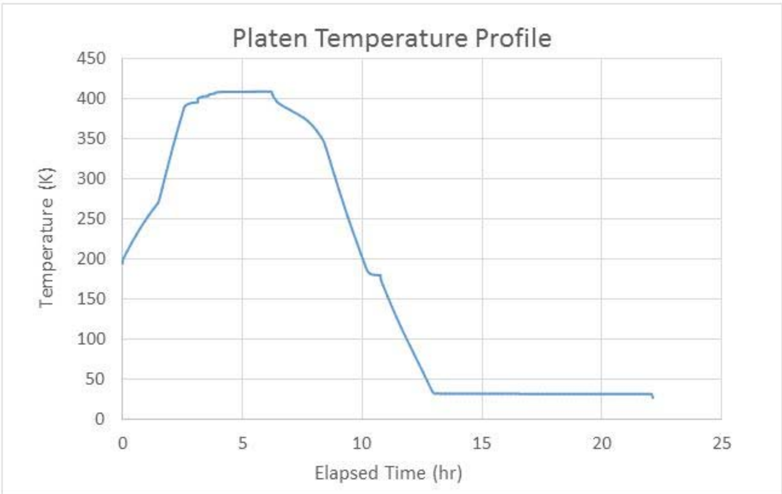

Figure 6: Final Day of Testing Thermal Profile CSA Motor Campaign

The Magtrol Dynamometer is operated by the OEM’s software package. The data files can then be loaded into the software and plotted as desired. Figure 7 depicts the data generated when testing the motor at the cold extreme. Torque and rotational speed are plotted here.

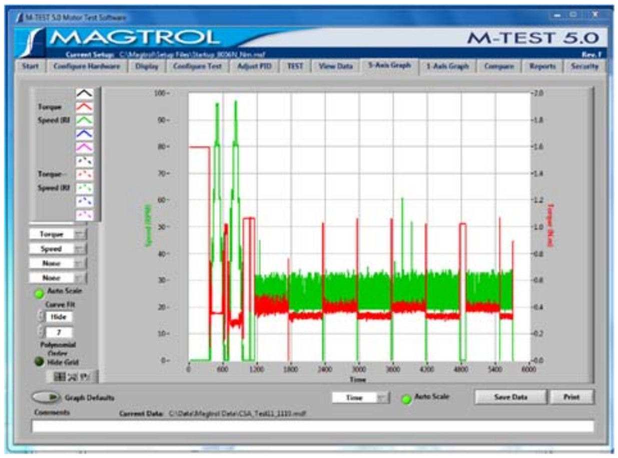

Figure 7: Torque and Rotational Speed Data plotted using OEM Software.

CONCLUSION

The NASA Langley Research Center developed a cryo-mechanical test chamber capable of operating at pressures of less than 5 E-5 Torr. The typical operating pressure is generally less than 1 E-6 Torr and approaches the theoretical limits of the o-ring seals when the thermal system is operating at cryogenic temperatures. The cryo-mechanical test chamber is equipped with a dynamometer that can accurately measure the torque and rotation speed of a motor operating under high vacuum conditions and at very harsh temperature conditions between 30 K and 415 K. The joint effort between NASA and CSA demonstrated that this facility is ready to accept payload for testing with very high confidence of generating meaningful data.

References:

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