National Aeronautics and Space Administration

Long Life, High Speed, Heaterless Mobility Actuators

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Program: FY22 R&TD Strategic Initiative
Strategic Focus Area: Long Range Lunar/Mars Surface Mobility - Strategic Initiative Leader: Larry H Matthies

Overall Objective:

Develop mobility actuators operable from -230ºC to +125ºC without preheating for day and night driving at 30 cm/s, at comparable mass & volume to the state of the art.

FY 22 Objectives:

Dry lubricant characterization and testing: Traditional actuators use wet lubricants, which require heating at temperatures below ~-55ºC. Dry lubricants do not require heating, but their life has not been adequately characterized. In order to properly design a dry lubricated actuator, design guidelines of allowable stress vs. life are required. This task aimed to develop those design guidelines for operating temperatures down to -230ºC.

Manufacturability of Large Bulk Metallic Glass (BMG) Gearing: Previous efforts have shown greater than 2x improvement in gear life with BMG, as compared to high performance steels. Whereas the thickness of metallic glass parts has been limited to thicknesses of ~3/8" or less, this effort aimed to demonstrate the manufacturability of "large" BMG gears (>Ø1").

Background:

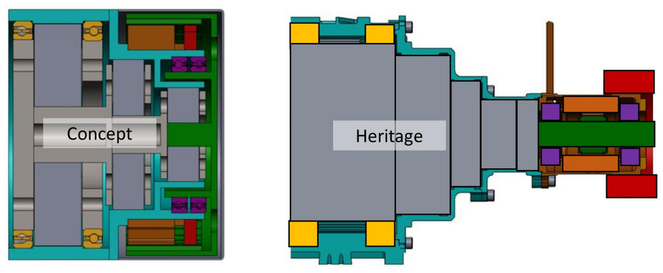
Lunar and Mars mission studies have identified highly demanding requirements for surface mobility, which far exceed that demonstrated by the current state of the art actuators in traverse speed, traverse distance, and energy allowed for heating (the current state of the art actuators require heating to at least -55ºC, in flight). As such, actuator technology that provides extremely long life, velocities up to 30 cm/s, and operation at -230°C without preheating would be enabling to these missions.

Significance of results:

The results at ambient have shown that the studied dry lubricants would allow dry lubricated actuators to be used in long life mobility applications. However, the results at low temperatures to date have not been consistent with the performance shown at ambient. With the performance shown at cold, the actuator size would become prohibitive in long-life applications. A number of theories have been proposed to explain this as either an issue with the testing, or a fundamental issue with the lubricant. More work is required to better understand this phenomenon.

Approach and Results

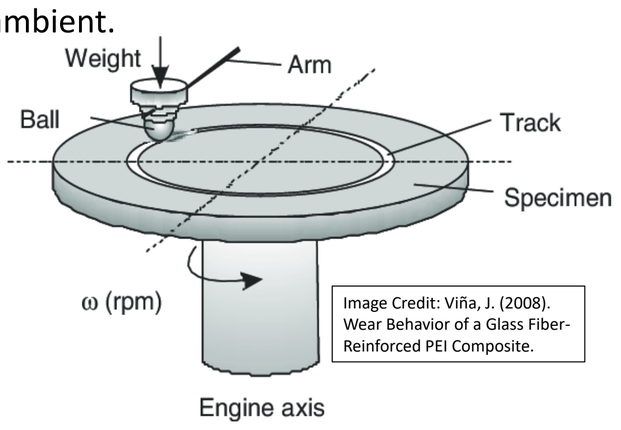
Concept Actuator:



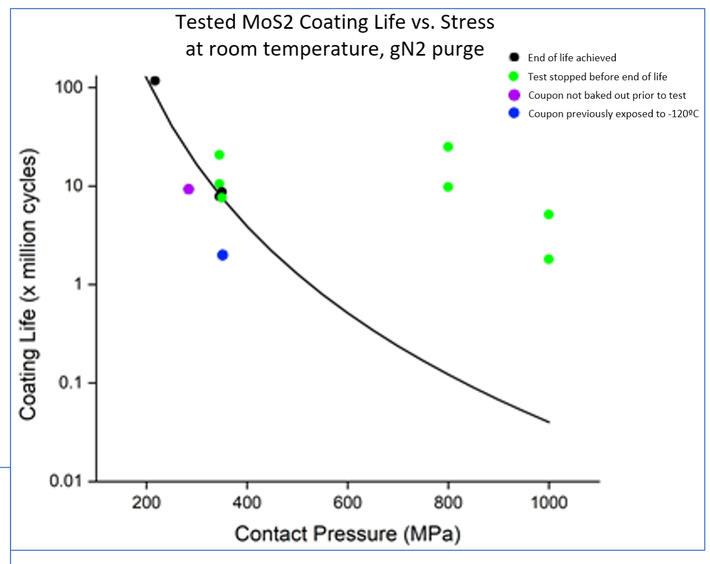
The concept actuator, left, uses a large diameter, torque dense, outer rotor motor to allow for a significantly reduced gear ratio, as compared to the current state of the art (right). This reduces the requirements on the motor bearings and input gearing, enabling the opportunity of replacing wet lubricants with dry lubricants that do not increase in drag at low temperature.

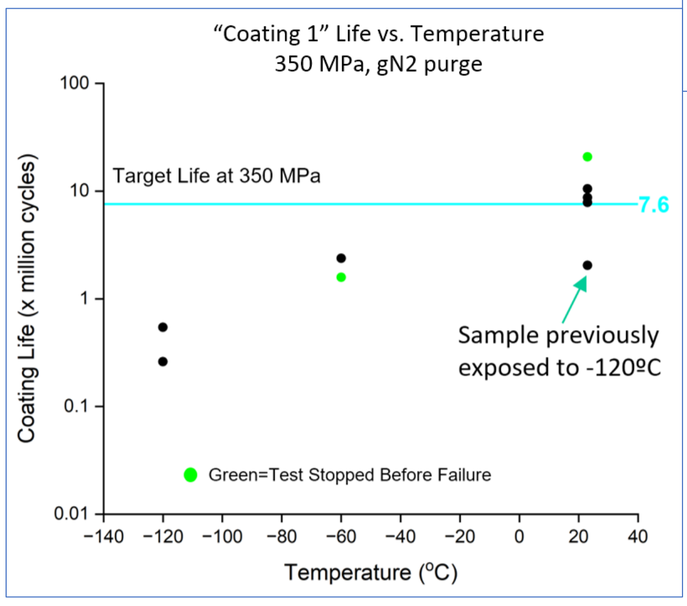
Dry lubricant characterization:

The team completed the pin-on-disk characterization of a MoS_2 based dry film lubricant, in gN2 purged environment, at ambient temperatures. The life demonstrated far exceeded that required for the highest stresses (by a factor of >10x), but came up just short in some tests at the middle stress. On balance, this was taken as a very successful demonstration of the objective at ambient.



Schematic view of a pin-on-disk test apparatus





This was followed by testing in a lower temperature, gN2 environment, however at temperatures below 0ºC, performance initially dropped precipitously. It is still not conclusive that these effects were due to the coating or the test environment.

Large Bulk Metallic Glass (BMG) Gearing:

The thickness of cast BMGs is limited by the rate at which the material must be cooled. If parts are too large, and cooling is too slow, then the parts will crystalize and not yield the desired mechanical properties. After some development, our vendor successfully cast a series of 6x Ø1.4" metallic glass planet gears (right), which are larger than that needed for the largest foreseeable JPL robotic mobility applications.

Ø1.4" metallic glass gear

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Publications:

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