FY23 Strategic Initiatives Research and Technology Development (SRTD)

Long Life, High Speed, Heaterless Mobility Actuators

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Strategic Focus Area: Long Range Lunar/Mars Surface Mobility | **Strategic Initiative Leader:** Larry H Matthies

Background:

JPL studies have identified highly demanding requirements for Lunar and Mars 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. 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.

Testing performed in FY21 and FY22 had shown promising results towards this goal, but the dry lubricants being used showed an apparent, progressive reduction in performance at low temperatures.

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 23 Objectives:

- Identify the root cause of degraded dry film lubricant (DFL) life at cold temperatures, as seen in FY22.
- Verify the identified root cause by test and demonstrate a mitigation to the observed low-temperature degradation, using a pin-on-disk test apparatus.

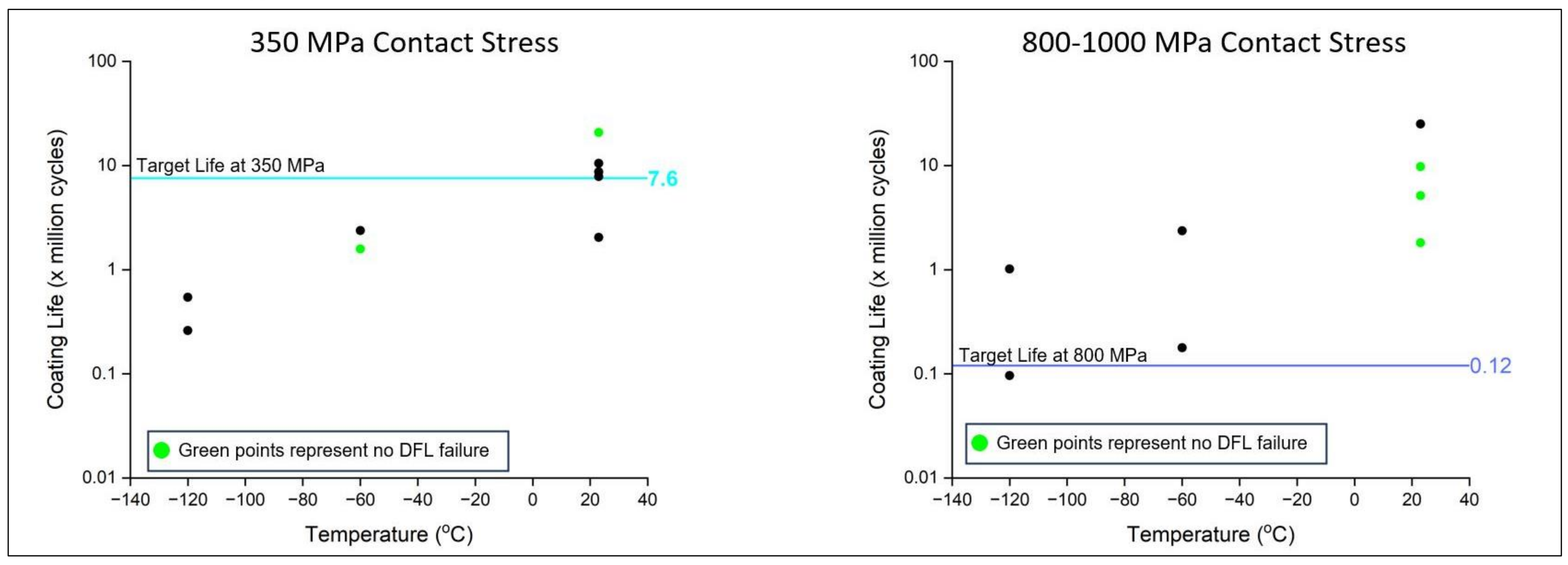
Significance of results:

If dry lubricants are to be used in low temperature applications, a change in the performance at low temperatures is obviously concerning. Understanding this phenomena, and ideally being able to change the material composition to mitigate the degradation with low temperatures could be hugely important to the exploration of cold bodies. This effort has achieved an important first step in understanding that behavior.

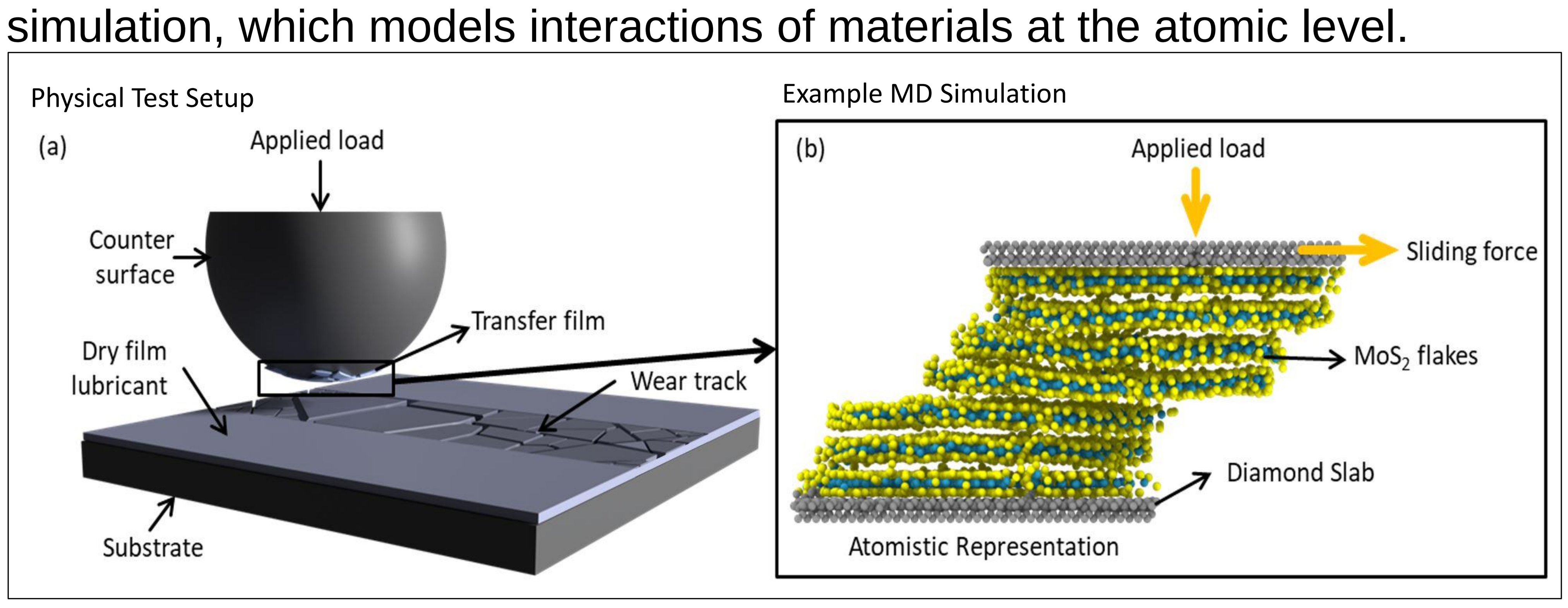
It is important to note that the performance pursued in this effort was driven by very long applications. If simple means are taken to reduce actuation system gear ratios (as proposed during the previous years of this effort), most robotic arms, other manipulators, and shorter life mobility systems are expected to tolerate the demonstrated, degraded lubricant performance (if well understood).

Simulating Dry Lubricant Performance at Low Temperature:

Testing during FY22 showed a reduction in life, which appeared to correlate to the test temperature of the candidate dry lubricants. Whether that temperature dependance direct or an indirect result of the test methods was not resolved.

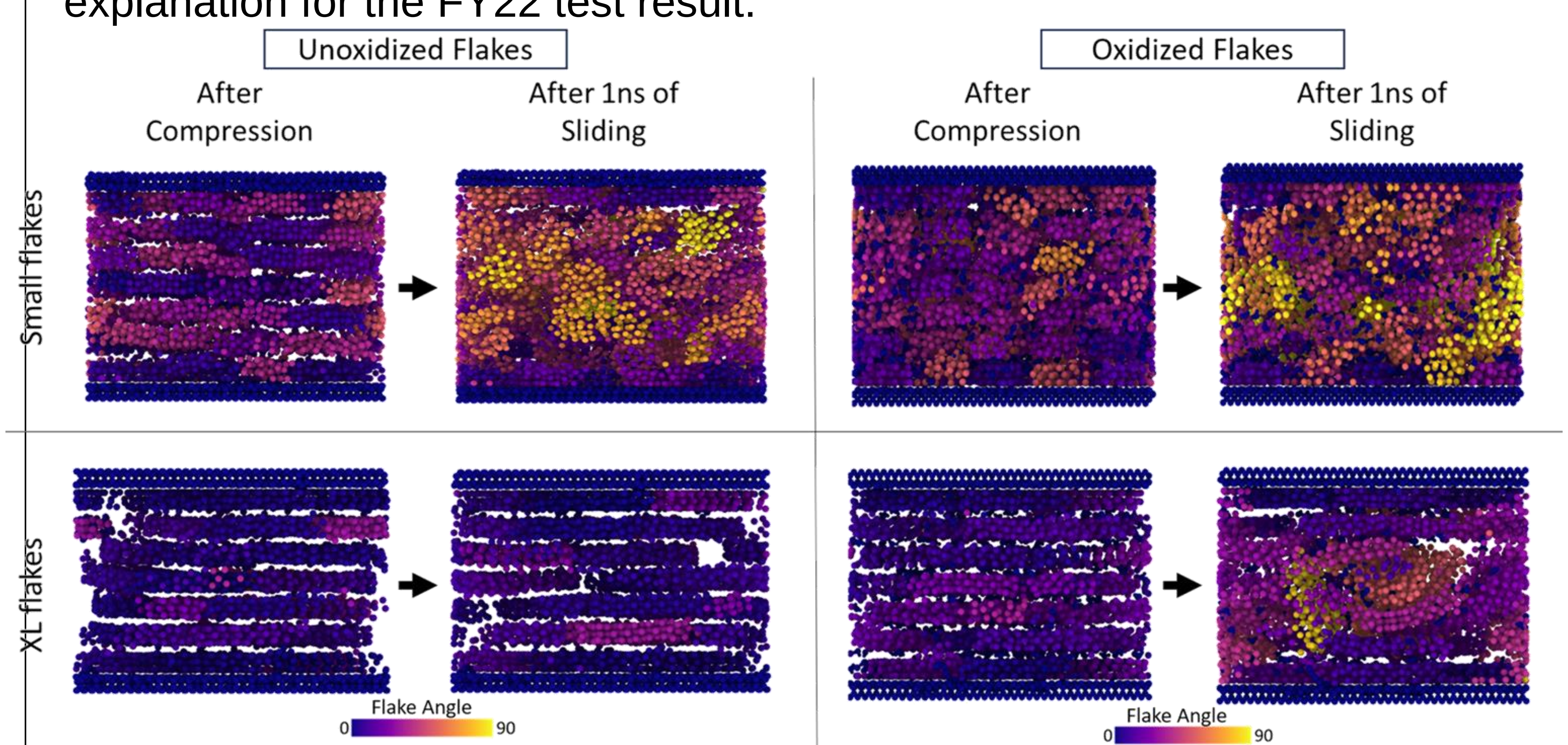


This apparent relationship was investigated using Molecular Dynamic (MD) simulation, which models interactions of materials at the atomic level.



Simulations showed a strengthening of the lubricant bonds at lower temperatures. While this might have been expected to produce a more resilient coating, the eventually effect appears to be the opposite. Since these bonds are effectively required to be broken as the material is run-in and subsequently worn, the higher strength leads to higher released strain energy, and subsequently smaller flake are generated upon rupture.

It was then investigated how these smaller flakes behaved, as compared to larger flakes. Upon compression and sliding, the smaller flakes mixed turbulently, rather than sliding smoothly along the intended basal planes. This produced a higher effective coefficient of friction, and presumably more damage for both oxidized and unoxized flakes – providing a compelling explanation for the FY22 test result.



It is hoped that subsequent work can build on these results and ideally inform a change in the lubricant to mitigate the degradation seen in testing.

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