Tribological Performance of Diamond-Like Carbon (DLC) in Extreme Environments

Katherine Miller, Adam Delong, Brandon A. Krick

[1]FAMU-FSU College of Engineering, Florida State University, Tallahassee, FL, US
[2]Aero-propulsion, Mechatronics, and Energy Center, Florida State University, Tallahassee, FL, US

Background Information

- Tribology is the study of how surfaces interact with each other, which includes the study of the properties of friction, wear, and lubrication
- Lubricating spacecraft poses an interesting tribological challenge as many traditional lubricants fail to withstand the extreme environmental conditions found in space (varying temperatures, radiation exposure, microgravity)
- Solid lubricants, or solid materials applied to surfaces in thin layers to reduce friction and wear between surfaces are more commonly used for spacecraft
- Diamond-like carbon (DLC) is advantageous due to its high hardness, low friction, and resistance to change composition across a wide temperature range
- Current research fails to document the tribological properties of DLC in temperatures of as low as -60ºC
- This research will expand upon current knowledge of the tribological properties of DLC, helping to improve engineering and manufacturing of spacecraft
- NASA's James Webb Space Telescope uses DLC as a solid lubricant on some of its ball bearings, which have been experiencing increased friction and wear in recent years

	DIAMOND	DLC (Diamond Like Carbon)	GRAPHITE
STRUCTURE	Crystalline (sp^3 Bondings)	Amorphous (sp^3 and sp^2 Bondings)	Crystalline (sp^2 Bondings)
CONSTITUTIVE ELEMENT	C	C・H	C

Figure 1. Structure of DLC as compared to diamond and graphite

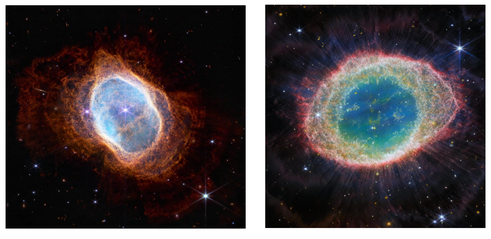

Figure 2. Images taken by NASA's James Webb Space Telescope, which uses ball bearings lubricated with DLC

Methods

- Tribometer was recalibrated from a load of 250 N to 1 N to properly test samples
- Low load cells were calibrated by hanging weights and measuring the voltage (V)
- A slope was calculated from these values
- DLC was deposited onto 440C Stainless Steel balls (simulating ball bearings) via Chemical Vapor Deposition (CVD)
- Once prepared, samples were placed into the tribometer for testing
- Stripe tests were performed on each sample at 20 and -60ºC
- Custom MATLAB code used to collect friction data from each test
- A white light interferometer was used to measure the wear present on the surface where tests were conducted
- 3D renderings of the surface where tests were conducted were created and the total volume of material removed was measured

Sample Preparation & Data Collection

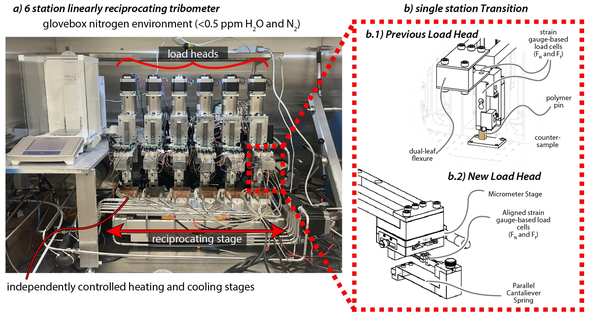

Figure 3. Data is collected using a custom six station linear reciprocating tribometer that was reconfigured to accommodate lower loads and desired geometries

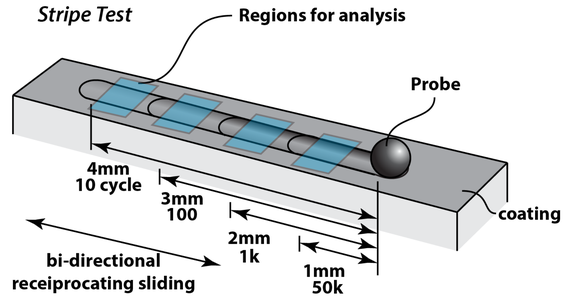

Figure 4. Stripe tests (tests where stroke length decreases with an increased cycle number) were performed on each sample at 20 and -60ºC

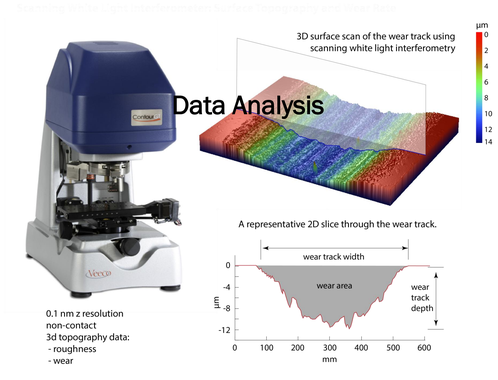

Figure 5. White light interferometer is used to measure the wear present on the surface where tests were conducted by creating a 3D rendering of the surface and measuring the total volume of material removed.

Results

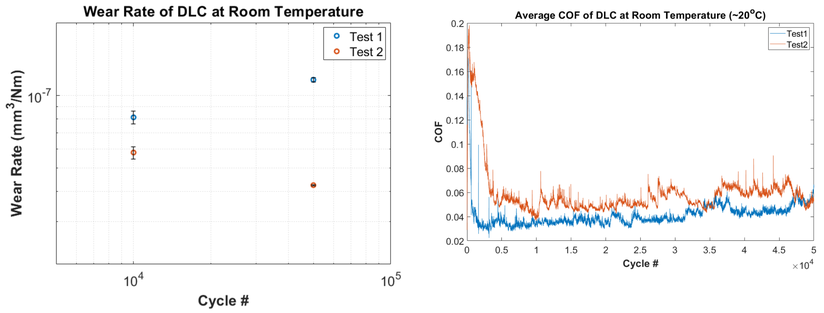

Figure 6. Wear rate and Average Coefficient of Friction of DLC in Room Temperature

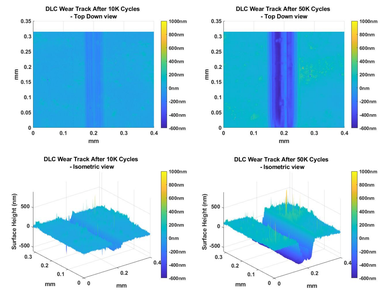

Figure 7. DLC Wear Track present after 10K and 50K cycles

- Unable to obtain data in -60ºC
- Current research supports that DLC will perform worse in -60ºC as compared to a room temperature environment (~20ºC)

Discussion

- Overall, DLC is shown to perform better frictionally in room temperatures
- Though DLC is shown to perform worse in -60ºC, the frictional performance of DLC is good in comparison to other solid lubricant films
- DLC has applications as a solid lubricant film for aerospace purposes
- Further research exploring the optimal conditions for DLC would help improve its application

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References