Nanocomposite Polymers: The Future of Materials Used for Extreme Environments of Space

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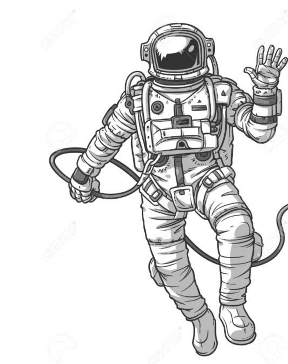
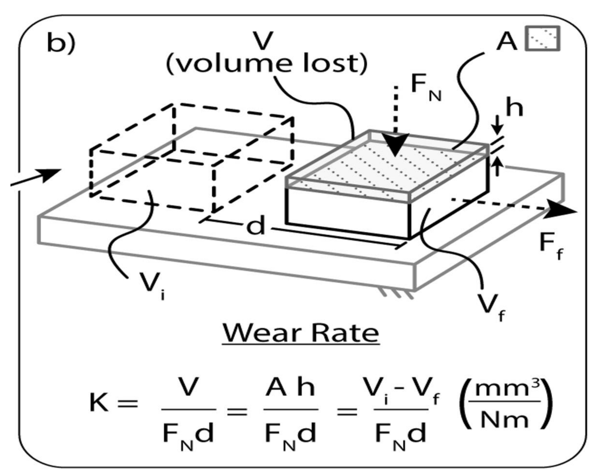


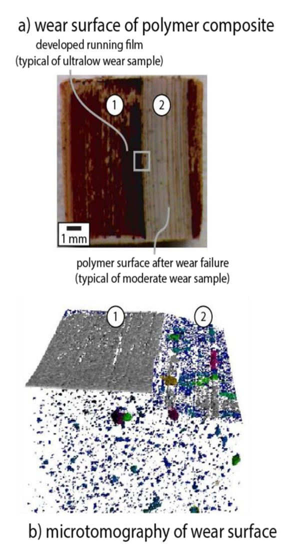
Introduction

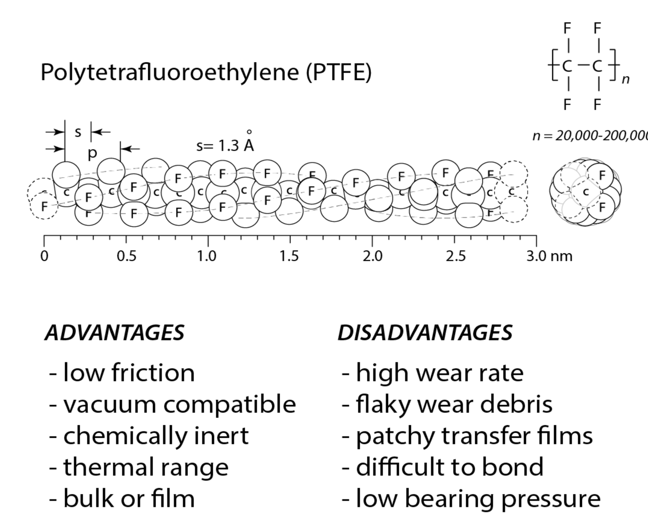
- Tribology is the study of friction and wear rates relative to interacting contacting surfaces. Tribologists apply data analysis to friction examined understand how to reduce maintenance, wear, and resistance on mechanical parts varying from spacecraft to everyday items.
- Tribometers are used to simulate sliding surface interactions between a nanocomposite polymer and a bottom surface.
- A nanocomposite polymer is often associated with a more conventional lubricant such as oil; however, nanocomposite polymers are solid in structure, have a much longer life span than a traditional lubricant, are cost effective, and can be used in harsh environments such as space.
- Data analysis has revealed reasonably low friction coefficients and wear rates of polymers when tested under a variety of conditions, demonstrating their reliability, and making them a highly desired material for mechanical lubrication.
- The proficiency noted in using polymers versus traditional lubricants sheds new light on the type of technology that humans can fabricate in the future.

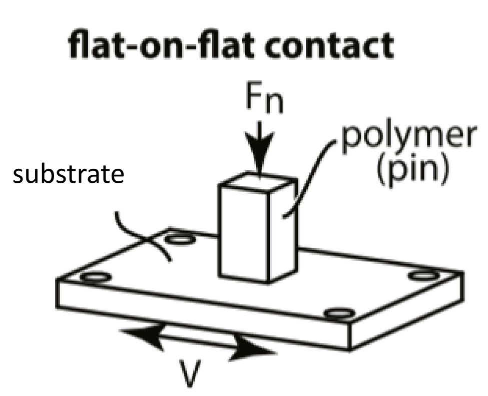
Wear and Friction Category	Friction Coefficient μ	Wear Rate K (mm^3/Nm)
Ultra-low	$\mu < 0.1$	$K < 10^{-6}$
Low	$0.1 \le \mu < 0.25$	$10^{-6} \le K < 10^{-5}$
Moderate	$0.25 \le \mu < 0.4$	$10^{-5} \le K < 10^{-4}$
High	$\mu \ge 0.4$	$K \ge 10^{-4}$

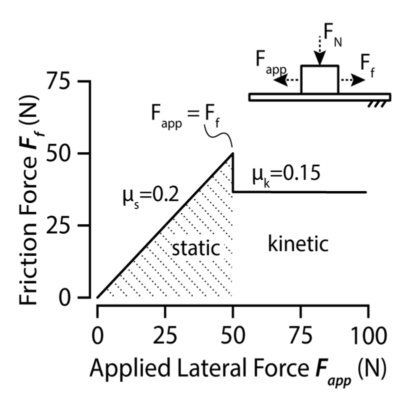
Exp. #	Cycles	Total Cycles	Minutes	Hours	Days	Sample 1 Mass Gold (g)	Sample 2 Mass Gold (g)	Sample 3 Mass Maroon (g)	Sample 4 Mass Maroon (g)	Sample 5 Mass PEEK (g)	Sample 6 Mass PEEK (g)	Sample 7 Mass Gold Plate (g)	Sample 8 Mass Maroon Plate (g)	Sample 9 Mass PEEK Plate (g)
0	0	0	0	0	0	9.27359	9.32633	9.4493	9.4422	8.9781	8.8591	60.08259	61.35112	56.25111
1	1000	1000	19.3	0.3	0.0	9.26762	9.32544	9.44889	9.4413	8.97792	8.85769	60.08151	61.35013	56.25075
2	4000	5000	77.3	1.3	0.0	9.26064	9.3251	9.44893	9.4411			60.08101	61.3484	
3	5000	10000	96.7	1.6	0.0	9.25622	9.32517	9.44887	9.44107			60.08044	61.34912	
4	10000	20000	193.3	3.2	0.1	9.25336	9.32505	9.44888	9.44112			60.0803	61.34872	
5	10000	30000	193.3	3.2	0.1	9.25094	9.32496	9.44885	9.44093			60.07876	61.34866	
6	10000	40000	193.3	3.2	0.1	9.2496	9.32488	9.44874	9.44091			60.07837	61.3485	
7	10000	50000	193.3	3.2	0.1	9.24848	9.32457	9.44865	9.44066			60.07524	61.34766	
8	50000	100000	966.7	16.1	0.6	9.2455	9.3242	9.44802	9.44044			60.07103	61.34748	
9	100000	200000	1933.3	32.2	1.3	9.24285	9.32432	9.44594	9.43991			60.07458	61.34643	
10	100000	300000	1933.3	32.2	1.3									

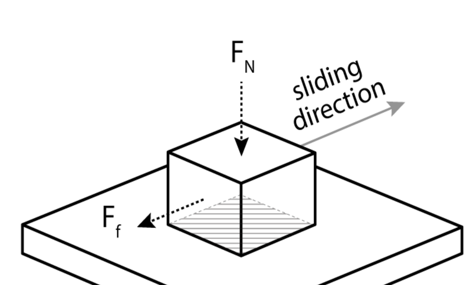


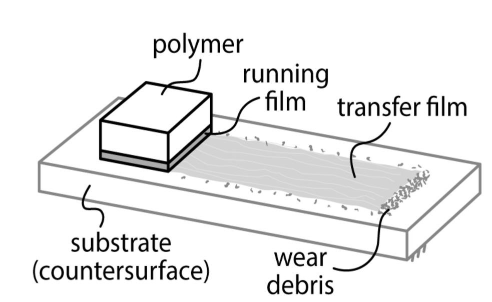


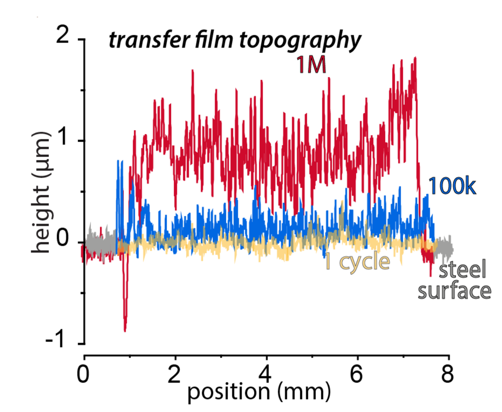


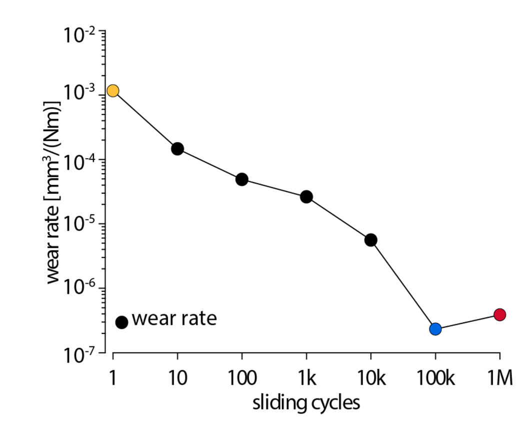


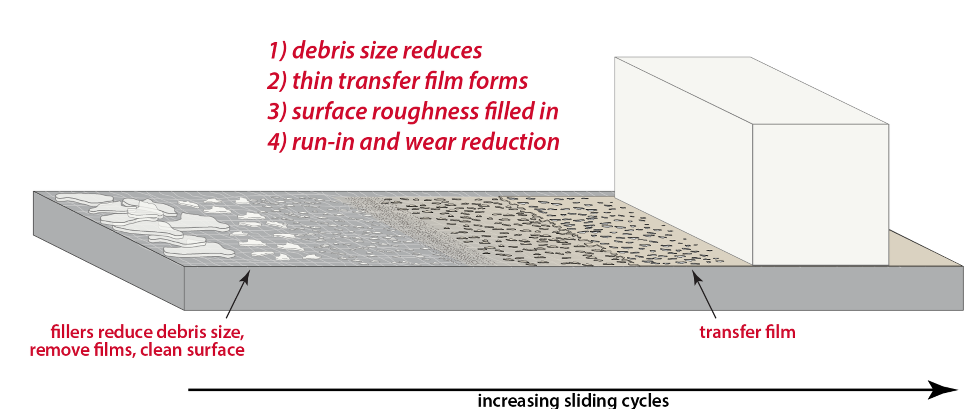












Methods

- The polymers used in this experiment were two separate Rulon Golds, Rulon Maroons, and PEEKs, totaling six polymers.
- For each set of polymers, one sample of each was slid against steel, and the other sample of each was slid against an alike surface, such as a PEEK polymer against a PEEK surface.
- The principle of measure was volume loss; this was found by sliding the polymer against a constant material at a continual force of 250 Newtons, in a humidity box with a relative humidity of 60%, for a determined number of cycles for each experiment.
- Polymers labeled 1 through 6 and were massed on their own and inside of a polymer pen before testing. The masses for the polymers without the pen before starting were 0.92978 for 1, 0.93089 for 2, 1.06064 for 3, 1.05412 for 4, 0.62695 for 5, and 0.61973 for 6.
- Then, the polymers were massed after each test to measure the volume lost in the experiment and determine the new volume.
- The polymers were also measured to determine density which factors into the volume loss formula. The density was then put into a volume loss formula stated as: (the initial mass - the current mass)/ (density).

Results/ Discussion

Experimentally, PEEK, Rulon Gold, and Rulon Maroon have been observed with varying wear rates depending on the contact surface that they are paired with and various other circumstances such as relative humidity, production process, etc.

- Running an overall sum of 10 experiments to a totality of 300,000 cycles, with a normal load of 250 Newtons on the tribometer, Rulon Gold and Rulon Maroon polymers that were passed perpendicular to one other in a tribological self-mated formation were observed as attaining lesser friction and better wear rates than identical composites that were run on steel in the same amount of time and conditions.
- It was recognized that, to achieve low wear rates and friction, it does not necessitate using metal as a contact surface material in the trial.
- This experiment exposed better wear rates were more probable when the polymer pen was running on a self-mated surface.
- Little self-mated polymer material collected on the contact surface of Rulon Gold and Rulon Maroon, showing that their friction is probable to be lower due to the underlying properties of the substance.
- PEEK used in the trial was shown as much weaker than the Rulon material and could not withstand the same amount of impact as the Rulon Gold and Maroon; this may be due to the industrialized composition of Rulon Gold and Rulon Maroon.
- Overall, this experiment was helpful in establishing an understanding of the most reliable contact surface to use to achieve the best results and showed that the industrialized polymers Rulon Gold and Rulon Maroon are more resilient and have better endurance than traditional PEEK nanocomposite polymers used in the field.

References

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Conclusion

- Friction and wear in mechanical systems has become one of the most important topics in the modern world.
- On average, 23% of the world's total energy consumption originates from tribological contacts due to mechanical systems. Traditional lubrications, such as oil, cause the system to be restricted on the environments in which it can work.
- The successes of studies conducted of nanocomposite polymers in settings like space and water, that traditional lubricants would consider as harsh environments have opened new horizons on mechanical instruments.
- These polymers could have a huge impact on the global economy by nearly eliminating servicing and replacement costs, reducing CO_2 emissions, and saving a record 8.7% on global energy consumption annually.