UF | BIO/MATERIALS TRIBOLOGY LABORATORY

UNIVERSITY OF ILLINOIS URBANA-CHAMPAIGN

IMECE 2024-150314

Friction of soft solid surfaces created by controlled fracture

Abrar Mohammed*, Srividhya Sridhar**, Shaobo Zhan**, Shelby B. Hutchens**, Alison C. Dunn*

*University of Florida, Mechanical & Aerospace Engineering Department, ** University of illinois, Mechanical Science & Engineering Department

ASME SETTING THE STANDARD

IMECE Track 16-1

NSF Research Poster Competition

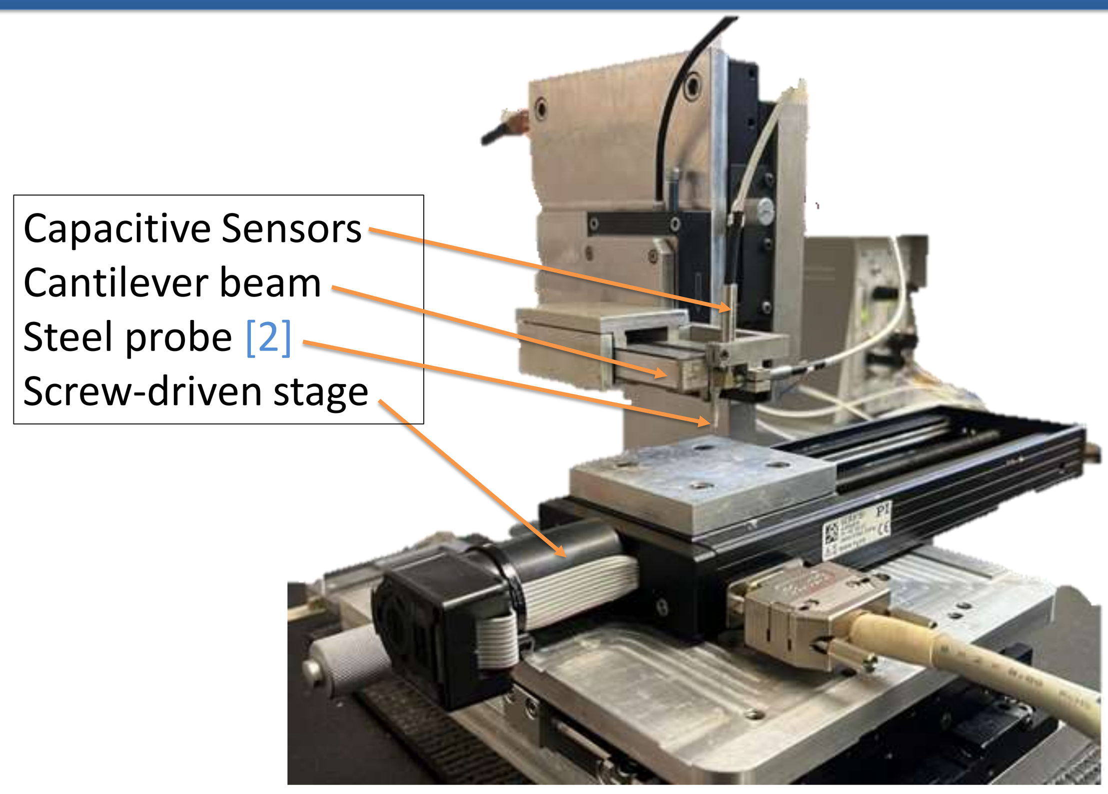
Award:2219787

BACKGROUND & HYPOTHESIS

- Patterns on soft surfaces have been shown to control the surface friction. The patterns are specifically manufactured (dimples, bumps, pillars, islands, mushrooms) [1].
- Unique surface topographies arise due to controlled fracture of soft solids. Thus, we hypothesize that the energy needed to create the surfaces is related to their surface friction through the topography.
- The aim of this study is to correlate the fracture energies to the surface friction.

METHODS

A custom micro-tribometer was build & integrated with Python for simultaneous actuation & precise data collection (essential for micro or nanoscale experimentation).



Experimental Matrix (N=50)

Normal Load: 5-70 mN

Sliding Speed: 0.1-5 mm/s (typical needle insertion speed)

Sample characteristic surfaces: Periodic (A), and smooth (B).

Fixed Data (throughout experiments)

Cantilever beam details:

Normal stiffness = 1014.28 N/m

Lateral stiffness = 2538.85 N/m

The location of sample being slided is maintained same throughout the experiments.

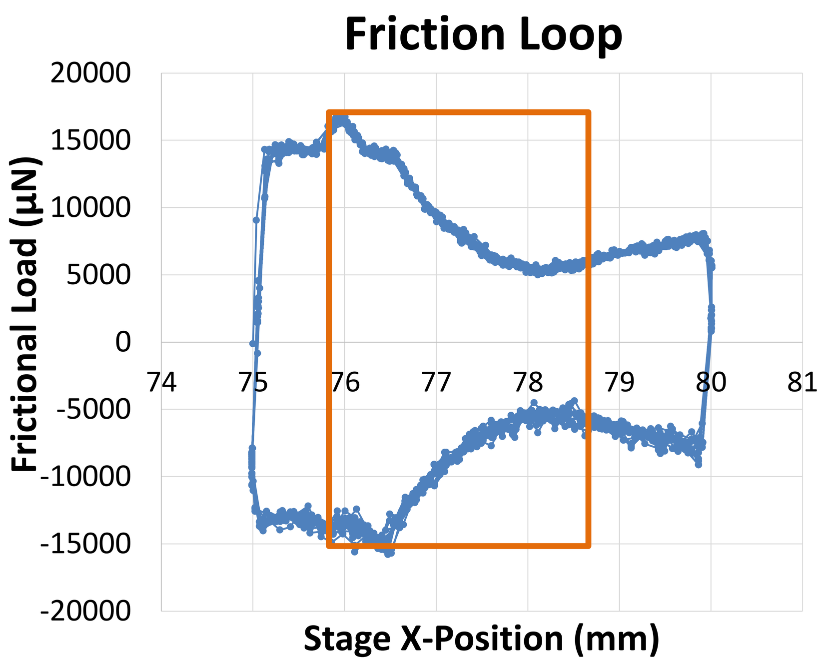
Stroke length (~5 mm), number of cycles (~20).

Data Acquisition

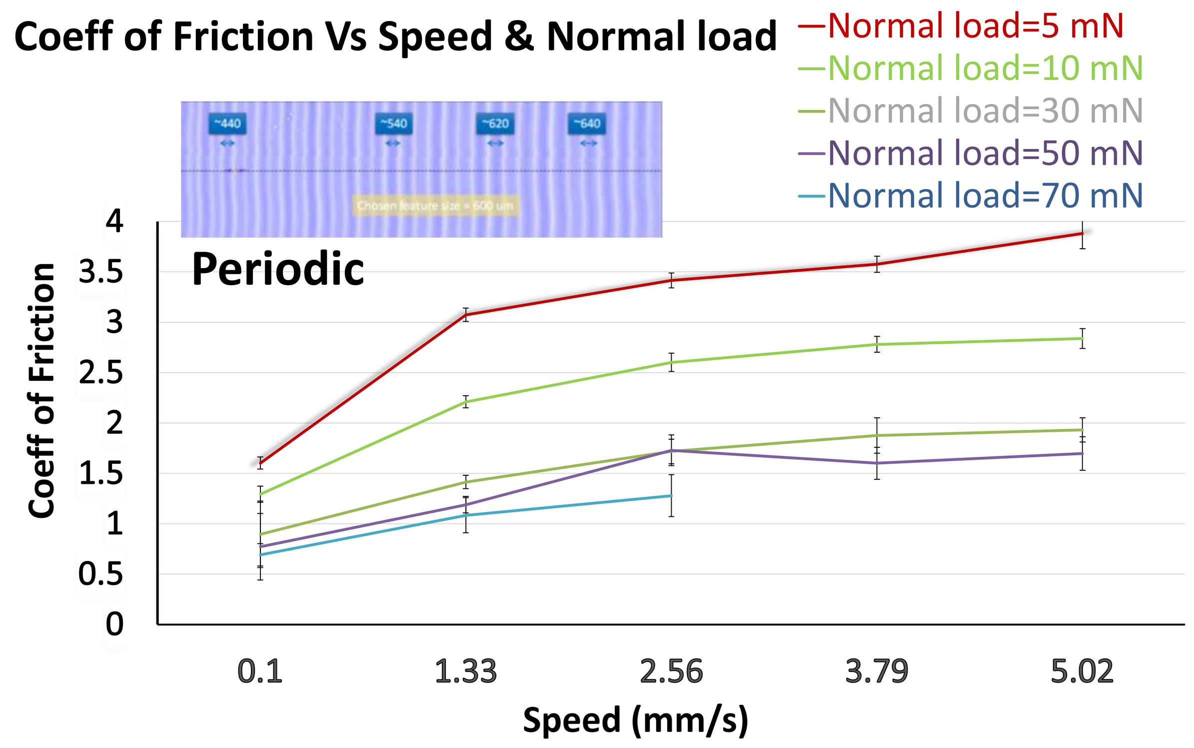
Average the loads & St. Deviation of all cycles, Save (separate .txt file), Calculate & plot Avg Friction Coefficient.

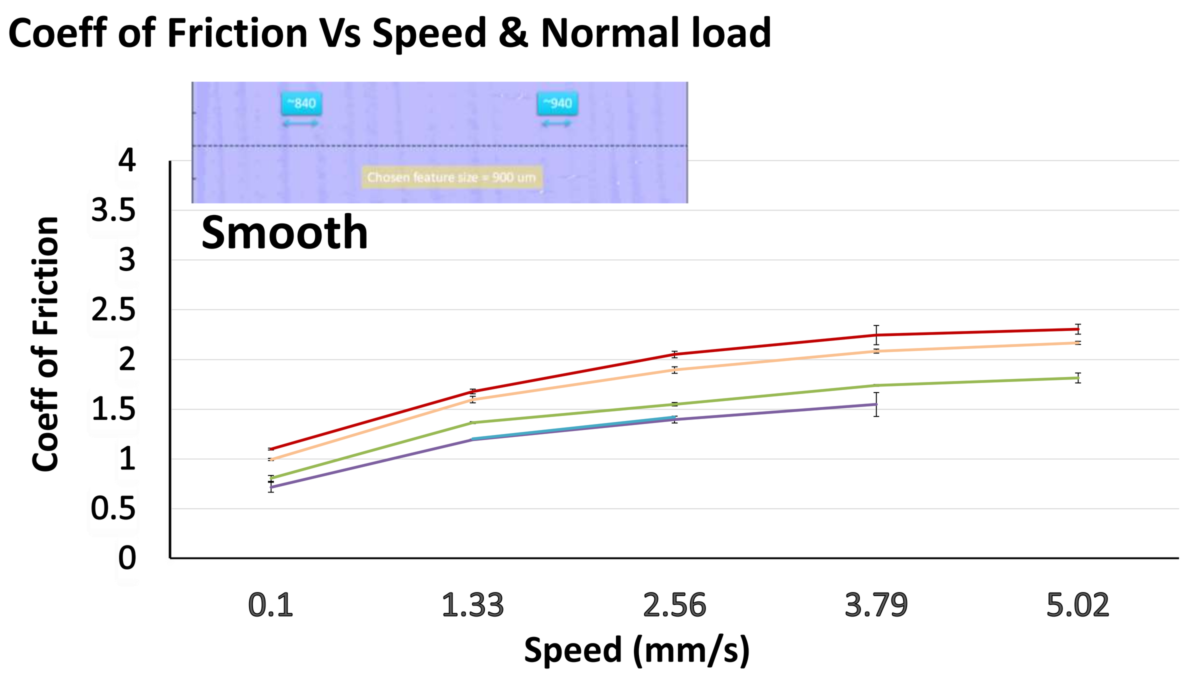
$$Avg\ Cof = \frac{Avg\ Ff\ - Avg\ Fr}{2\ x\ Avg\ Fn}$$

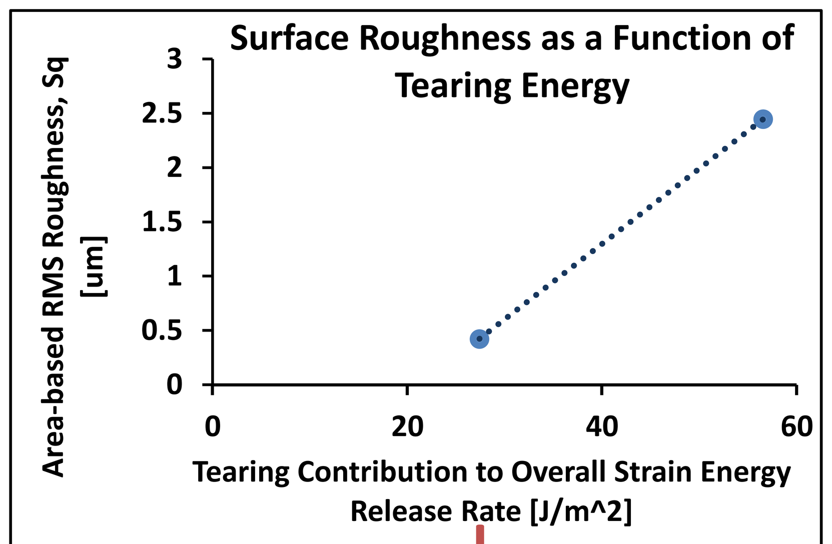
Ff, Fr- Forward & Reverse friction loads, Fn-Normal load, Cof- Coeff of Friction.

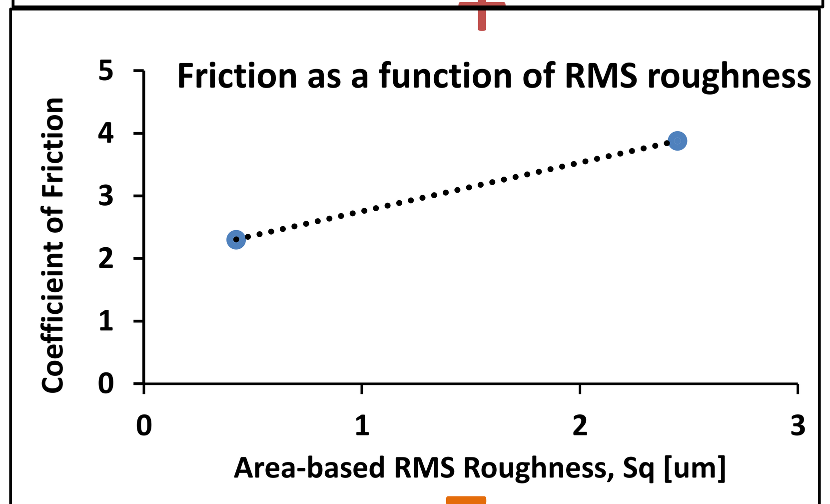


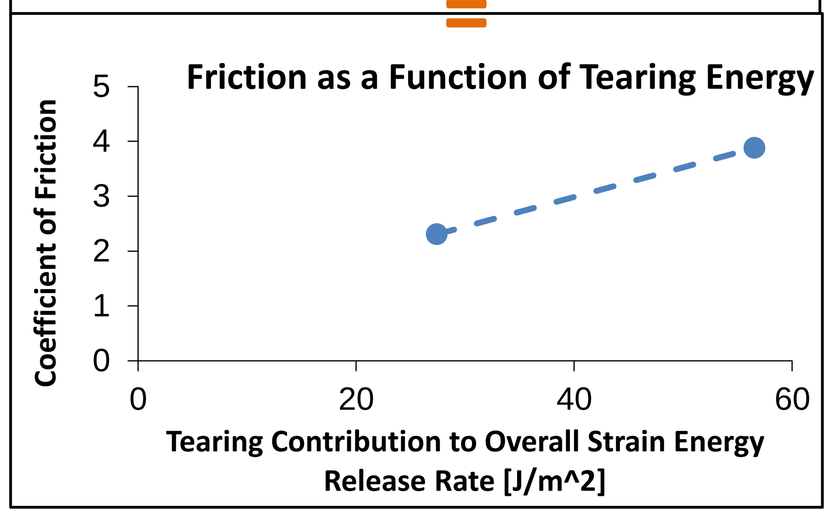
RESULTS





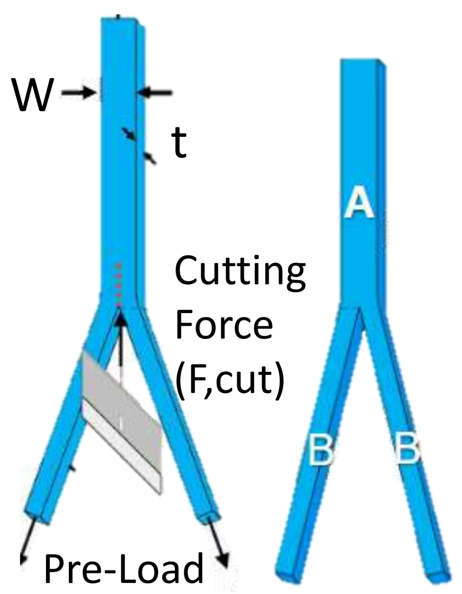




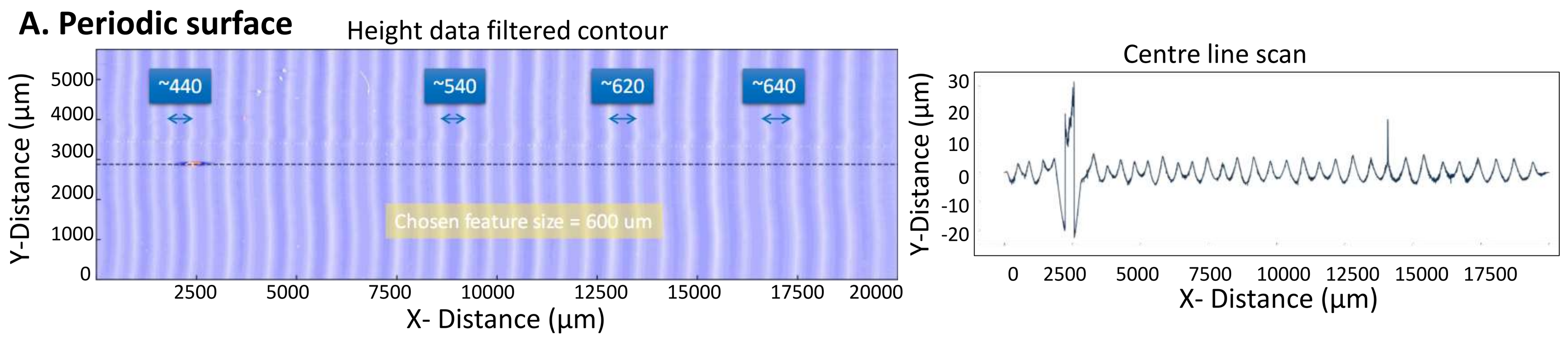


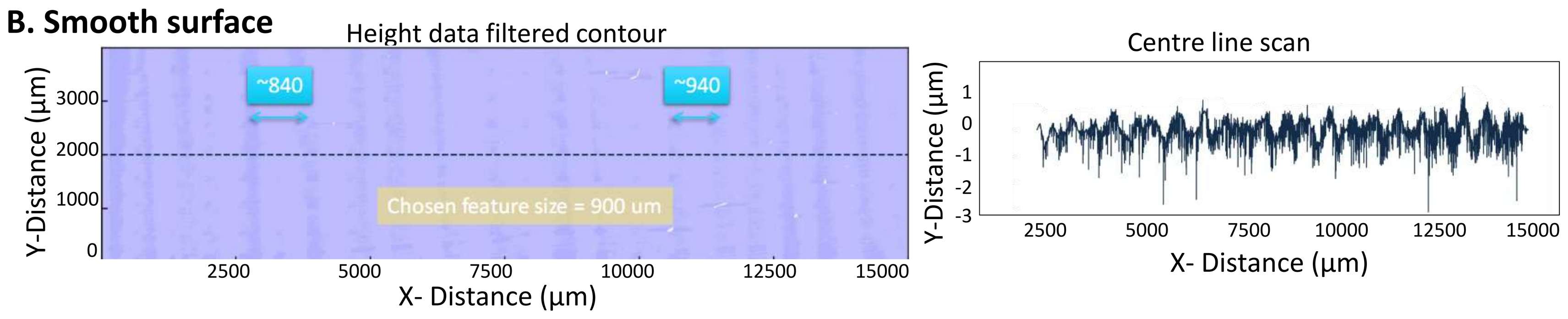
	Tearing energy [J/m^2]	Cutting energy [J/m^2]	(G_{cut}) [J/m^2]	Sa [µm]	Sq [µm]	Highest Coefficient of Friction
Smooth	27.41	120.99	148.4	0.259	0.423	2.305
Periodic	56.56	95.88	152.44	2.019	2.447	3.881

FRACTURED SOFT SOLID SURFACES



Cut samples:





To achieve controlled surfaces, oil-infused Silicone materials are fractured by Y shaped cutting method. By varying experimental conditions & the cutting energy release rate (G_{cut}) the surface topography can be controlled [3].

Silicone-based organic polymers (e.g., Polydimethylsiloxane-PDMS) are known for its tradeoff in flexibility, low surface energy, biocompatibility and easy to fabricate. They are widely used in soft-robotic components and biomimetics (bio-implants).

CONCLUSIONS

- According to the results, relatively lower speeds (0.1 mm/s), higher normal loads (70 mN) and smooth surfaces attains the lowest coefficient of friction for soft characteristic silicone surfaces.
- The friction coefficient measured at the fastest speed was 60 % lower on smooth surface sample versus the periodic surface.
- Preliminary results for 2 characteristic surfaces show that the coefficient of friction is related to the tearing energy needed to create the surfaces.

FUTURE DIRCTION & CHALLENGES

- Many more samples to confirm the correlations and get statistics & predict the forces inferred during needle-insertion procedures.
- Determining a friction-fracture relationship as a function of cutting strain energy.
- If frictional instabilities due to uneven surfaces can be eliminated, it could have the potential to develop new soft materials with tailored frictional properties.

REFERENCES

1. Peng, Y. et al. Elastohydrodynamic friction of robotic and human fingers on soft micropatterned substrates. Nat. Mater. **20**, 1707–1711 (2021).
2. Shen, G., Zhang, J., Culliton, D., Melentiev, R. & Fang, F. Tribological study on the surface modification of metal-on-polymer bioimplants. Front. Mech. Eng. **17**, 26 (2022).
3. Zhang, B. & B. Hutchens, S. On the relationship between cutting and tearing in soft elastic solids. Soft Matter **17**, 6728–6741 (2021).

1-Minute Video

SQUISHIOSITY