Wear Rate & Friction Dependence on Contact Pressure for PTFE-PEEK Polymer Composites

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Background:

PTFE (Teflon©) based polymers are often mixed with fillers such as PEEK (poly ether ether ketone) metals, metal oxides or other materials to improve their wear rates and coefficients of friction. Many experiments have been conducted measuring the effect of different weight precents of filler materials, mainly PEEK, in PTFE; yet not many studies have looked at the effect varying normal load for different compositions has on the wear rates and friction coefficient. This research study looked at PTFE polymer composites with 40 percent PEEK by weight. After mixing, molding, sintering, and machining three pins of each composite polymer were tested at normal loads (contact pressure between polymer and coutnersample) of 50N, 150N, and 250N on a six-load-cell tribometer under humid conditions. The samples were massed after each test's number of cycles had concluded until the full experiment had completed. The samples travelled a total sliding distance of 20 kilometers with a stroke length of 20mm one way.

PEEK: Polyetheretherketone (PEEK) is a thermoplastic polymer used in coatings and insulation (Jarman-Smith et al., 2019). A thermoplastic is a specific type of polymer that can be softened and/or melted using heat and can then be processed in this heat-softened state (Biron, 2016).

PTFE: Polytetrafluoroethylene (PTFE), known commonly as Teflon, is a synthetic polymer made only of carbon and fluorine making it hydrophobic, nonreactive, and a good insulator. It is also known for its low coefficient of friction (Radulovic & Wojcinski, 2014). However, it has an unusually high wear rate which has reduced its utility as an engineering polymer. To circumnavigate this issue, mixing certain filler materials can be mixed into PTFE in order to decrease its wear rates and improve its performance for things such as solid lubricant applications (Pitenis et al., 2013).

Tribometer: A tribometer is a device that measures friction and wear (Stachowiak et al., 2004). The tribometers used in Dr. Krick's laboratory can run multiple samples at once at different contact pressures (pressure of the polymer sample against the counter sample). They can also run samples under different conditions such as ambient, vacuum, low temperature (using liquid nitrogen), and many more.

Materials

I. PEEK powder
II. PTFE powder
III. Isopropyl Alcohol-Anhydrous (IPA)

Methods

Part 1: Mixing, Molding, Sintering, and Machining Polymers

1. Combine the PTFE and PEEK powders and suspend them in a 5:1 ratio (IPA:powder)
2. Sonicate the solution three times at five-minute intervals and leave mixture for 3-5 days to allow IPA to evaporate completely
3. Once dry, powder mixture was loaded into a stainless-steel cylindrical mold and compressed using a hydraulic press to 5000 pounds
4. Polymer samples were free sintered in an oven after being removed from the mold
5. Polymers machined to desired shape (figure 3)

Part 2: Testing & Data Collection

1. Three pins of 40wt% PEEK were massed and measured using a caliper to determine density
2. Polymer pins loaded into a six-load-cell tribometer operating in a controlled environment with a relative humidity of 30 ±1%
3. The three pins of each PEEK wt% were loaded to contact pressures of 50N, 150N, and 250N
4. Testing was preformed with a stroke length (S), of 20 mm and a sliding velocity of 5 mm/s
5. 12 test cycles varying from 1k cycles to 100k were allowed to run and complete.
   - One cycle is two strokes (40 mm/back and forth once)
6. At the end of each test, each load cell was massed to determine the change in volume
7. In total, 500k cycles were preformed equaling a total of 20 kilometers travelled by each polymer pin

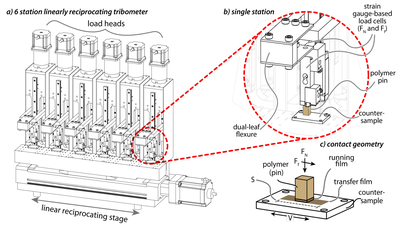


Figure 1: Tribometer setup

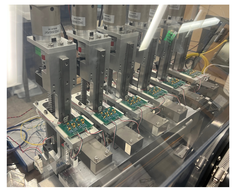


Figure 2: Tribometer used for testing

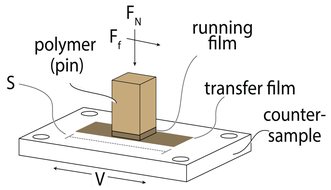
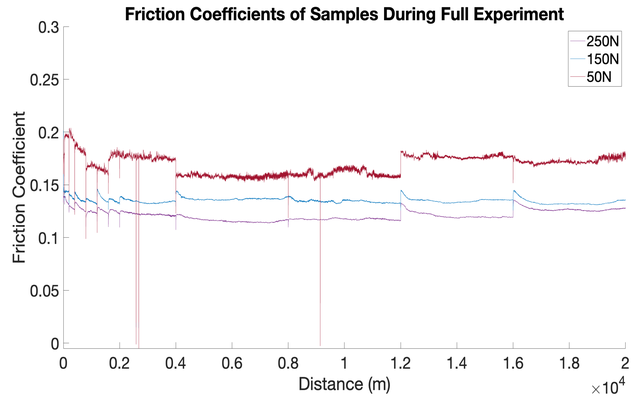


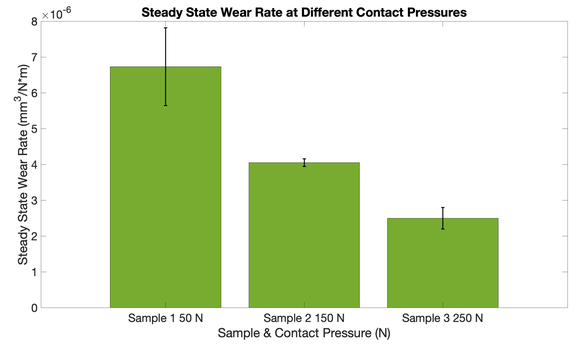
Figure 3: Polymer Contact Geometry

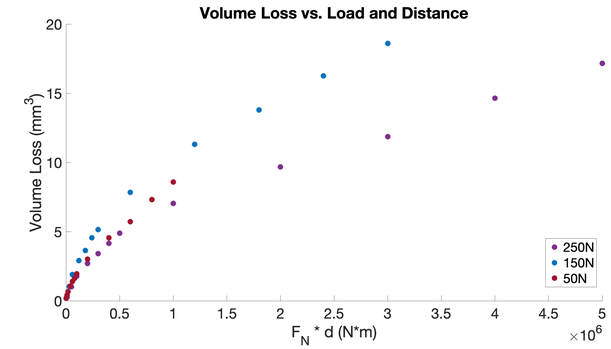
Powder Type	Weight % (wt%) of Total Sample	Mass (grams)
PEEK	40	12
PTFE	60	18

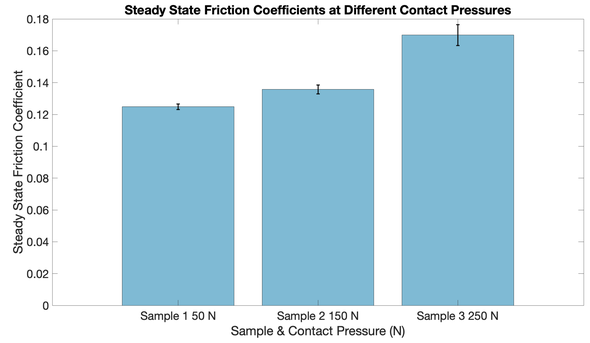
Figure 4: Composition of Polymer Powder

Results









Conclusions

I. Steady state was achieved for all three samples during test 10, 11, and 12.
II. Based on overall volume loss, a contact pressure of 250N showed a decreasing rate of volume loss over the duration of the experiment as the slope on the Volume loss vs. Contact Pressure * Distance graph (equal to the wear rate) gets flatter throughout the duration of the experiment.
III. Looking at the steady state wear rate bar chart showing that, 250N has the lowest friction out of the three samples.
IV. Pure PTFE is known to have wear rates and friction coefficients that do not vary with contact pressure, so the variations in the wear rate and friction coefficient can be attributed to the PEEK present in the samples (Uchiyama & Tanaka, 1980).
V. Depending on the contact pressure the material may be subjected to and the desired characteristics, a 40 wt% PEEK and 60 wt% PTFE composite polymer may be ideal for some applications and not others.
VI. Further research needs to be conducted looking at the relationship of contact pressure vs wear rate and contact pressure vs. friction coefficient.

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