

Surface temperatures during sliding wear of polypropylene against polyurethane in dry and aqueous environment

Rubson M. Camporez^{1)*}, Carlos A. Rosa Neto¹⁾, Nathan F. Strey¹⁾, Rogério Ramos²⁾, Cherlio Scandian¹⁾

¹⁾Laboratory of Tribology, Corrosion and Materials, Federal University of Espírito Santo, Brazil

²⁾Oil and Gas Flow and Measurement Study Group, Federal University of Espírito Santo, Brazil

*Corresponding author: rubsonmc@gmail.com

During sliding, friction generates heat, increasing contact temperature. A semi-analytical model was used to calculate the contact temperature of polypropylene and polyurethane pair, in order to determine the conditions in which melting temperature is not exceeded. Reciprocating pin-on-flat tests were performed in distinct environments, contact pressures, and speeds. Polyurethane showed negligible wear, and polypropylene showed mild and severe wear. Adjusted surface thermal conductivities improved the fitting of the model to the experimentally determined temperatures, showing that on the surface this property is sometimes higher than in the bulk.

Keywords: polymer, reciprocating sliding wear, aqueous environment, contact temperature

1. Introduction

Polypropylene (PP) and polyurethane (PU) are polymers used in industry as thick coatings, bushings, seals, etc. due to their chemical and wear resistance, potentially withstanding aqueous environments as polymer-polymer contacts. However, low melting temperatures and low thermal diffusivities limit its use. During sliding, friction generates heat, and the temperature rises in both polymers, which can lead to softening and melting. Therefore, it is important to determine the contact temperature (T_c), but that can be a difficult task, when it comes to polymers since its thermal conductivity (k) depends on several factors, including chain alignment, temperature, and pressure [1]. In this work, a semi-analytical model (SAM) estimated T_c of PP-PU pair that is valid for different environments, contact pressures (P), and sliding speeds (v). On the other hand, tribological tests were used to define the wear regimes, friction, the temperature recorded by the thermocouple (T/C) and infrared thermometer (IRT).

2. Methods

2.1. Tribological tests

Fig. 1a shows, schematically, reciprocating pin-on-flat tests configuration (PLINT TE67, Phoenix Tribology). Tests were performed in dry (52-60 % RH), distilled water, and seawater (ASTM D1141-98) environments, under P of 2.4 and 7.2 MPa, v of 18-90 mm/s and durations of 0.3-17 h to investigate the tribological behavior of the pair with at least two replicates for each condition. The wear rate was determined by the mass loss corrected by the water absorption. The T/C attached to the PP recorded the temperature close to the surface, and the IRT measured the maximum temperature of the PU surface during sliding.

2.2. Contact temperature

SAM was based on the equation $T_c = T_{amb} + \Delta T_{nom} + \Delta T_f$ [2], where T_{amb} is the ambient temperature, ΔT_{nom} is the nominal temperature rise, due to successive strokes, and ΔT_f is the flash temperature rise on the asperities peaks. The T_c depends on material properties, environment, contact pressure, speed, and friction. T_c results using bulk

material properties overestimate the temperature recorded by T/C and IRT. Therefore, a data fitting in SAM was necessary, using two multiplying factors, β_1 and β_2 , in the k of PP and PU, respectively.

3. Results and Discussion

Mild wear for PP ($0.2-2.5 \times 10^{-3}$ mm³/m) was observed in all tested conditions, except for the highest speed in the dry environment, where severe wear occurred ($1.1-1.9$ mm³/m). On the other hand, the wear of the PU counterbody was negligible for all cases. Steady-state friction coefficients ranged from 0.14 to 0.30. For the dry environment, Fig. 1b shows that surface temperature and wear increased as a function of PV value ($P \times v$). When frictional heating increased temperatures above 393 K, a mild-to-severe wear regime transition took place on PP, due to material softening/melting, which characterizes a thermal control regime. Therefore, T_c showed great discrepancy with experimental ones during severe wear. The k was estimated to be 4 to 6 times higher on the surface than in bulk because it is influenced by local temperatures, pressures, and material structure. This finding reveals the importance of surface instead of bulk properties on models for polymer sliding contacts.

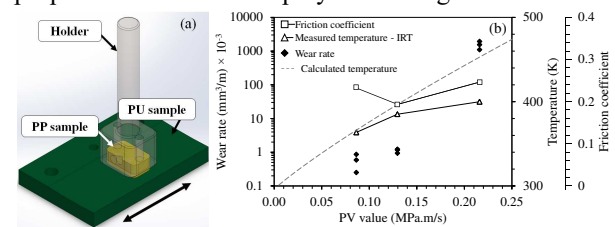


Figure 1: (a) Test configuration. (b) Tribological results for the dry environment for PP.

4. References

- [1] Huang, C.; Qian, X.; Yang, R. "Thermal conductivity of polymers and polymer nanocomposites". Mater. Sci. Eng. R Rep., 132, 2018, 1-22.
- [2] Kennedy, F. E.; Lu, Y.; Baker, I., "Contact temperatures and their influence on wear during pin-on-disk tribotesting", Tribol. Int., 82, 2015, 534-542.