A Strong Tribofilm Formed By an Imidazolium Ionic Liquid Friction Modifier

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An imidazolium ionic liquid (IL) additive was synthesized and employed as a friction modifier in polyethylene glycol (PEG) in the boundary lubrication regime. Compare to neat PEG, the use of the IL additive results in reductions of friction coefficient and wear track width of 17.72 % and 16.25% respectively. These improvements were attributed to the formation of a tribofilm, whose existence was confirmed by electrical contact resistance measurements and Raman spectroscopy. This improved performance sustained for a long time even after the friction modifier was removed from the base fluid, suggesting a strong adhesion of tribofilm on steel surface.

Keywords (from 3 to 5 max): friction modifier, ionic liquid, PEG, tribofilm

1. Introduction

Friction modifiers (FMs) are commonly used in lubricants to reduce friction, especially when contact between rubbing surfaces is expected [1]. In general, the effectiveness of a FM, governed by its structure and chemistry, is partly influenced by its interaction with rubbing surface and the tribofilm that formed in the rubbing process. In this work, the effectiveness of an imidazolium ionic liquid (IL) as a FM in the boundary lubrication regime with a steel-steel point contact was explored.

2. Methods

Polyethylene glycol 400 (PEG) was employed as the base fluid. Its viscosity was 43.40 mPa·s at 40 ºC. An imidazolium ionic liquid, as shown in Figure 1, was employed as a friction modifier. Friction tests were conducted using a High Frequency Reciprocating Rig (HFRR), a ball on disk tribometer. They were carried out at frequency 100 Hz with a stroke length 1 mm. The applied load was 7.84 N, corresponding to an average Hertzian pressure at 0.88 GPa. Based Dowson and Hamrock's Equations [2], the average central film thickness is 31 nm, which is larger than the ball roughness 20 nm. This results in a contact experiencing a mixed to boundary lubrication regime. The electrical contact resistance (ECR) of the contact point was recorded during the test.

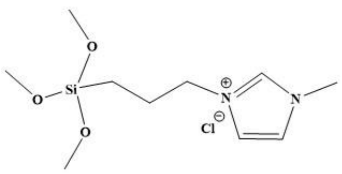

Figure 1 Chemical structure of imidazolium ionic liquid

2.1 Results

As shown in Figure 2a, the friction coefficient of PEG was reduced substantially with the introduction of 5 wt% ionic liquid during the initial 7200 s of the test. Interestingly, the friction coefficient of 0.08 obtained from the IL containing PEG is maintained for another 7200 s after the IL containing base fluid was replaced by neat PEG. The Raman spectrum of the wear track shows two distinct peaks at 1320 cm^{-1} and 673 cm^{-1}, which correspond to amorphous carbon and iron oxide respectively. The intensity of the amorphous carbon peak is higher than that of iron oxide on the wear track lubricated PEG， while the opposite is observed with IL containing PEG (Figure 2b).

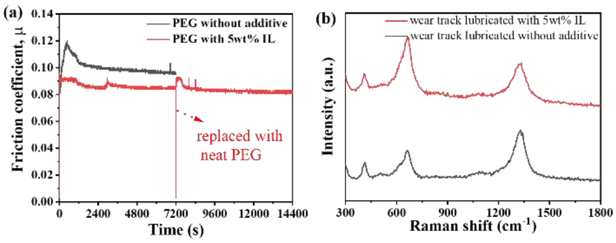

Figure 2 (a) The friction coefficient and (b) The Raman spectra of the wear track lubricated without FMs and with 5wt% IL.

3. Discussion

These results support that IL interacts strongly on a steel surface and subsequently forms a tribofilm. Once formed, the tribofilm maintains its effectiveness even after IL additives were depleted from the bulk lubricant. The relatively constant friction coefficient after IL depletion indicates that the tribofilm might have a multilayer structure, with top layers easily removed. In contrast, the bottom of the tribofilm was strongly bonded on the rubbing surface. The film thickness and chemistry of the tribofilm are examined by ECR, XPS and FIB-TEM, and results will be presented.

4. References

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