

## Lubrication control with electric potentials using ionic liquid mixtures

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The direct but not mechanical control of the frictional properties of bodies moving against each other is one of the major goals in tribology. A suitable combination of lubricant and external trigger represents an enormous challenge. We used ionic liquid mixtures (ILM) consisting of a long-chain cation and different anions to induce a change in friction by an externally applied electrical potential. This change in frictional properties is probably due to changes in the surface charging. This influences molecular adsorption, the exchange of adsorbed ions and their molecular orientation. In addition, a correlation between lubricant film thickness and the quantity of change in the coefficient of friction was found.

**Keywords:** ionic liquids, programmable friction, wear, charged steel surface, macroscopic friction

### 1. Introduction

Currently optimization of friction and wear is achieved by adapting materials and lubricants to the respective application or tribological system. However, this approach always involves a compromise, since the lubricants cannot be adapted to the entire load spectrum of an application. Therefore, there is still enormous potential for increasing efficiency in tribology [1]. This work presents an approach how the friction properties can be changed by the combination of ionic liquids (ILs) and electrical potentials. This could lead to the development of a programmable friction system that automatically adjusts to automatically changing loads to the optimal operating point.

### 2. Methods and Results

The experimental setup (Figure 1) is a tribological cell connected to a potentiostat to induce charged surfaces in the sliding contacts between the rotating ball and the three lower stationary pins (working electrode, WE). The controllability of the COF was tested with a constant current after a running-in phase (300  $\mu$ A) between WE and counter electrode (CE) resulting in either positively or negatively charged surfaces. Two different ILs and their mixtures were used as lubricants. The tribological tests were performed with a normal force of 50 N (23.6 N per pin) on a rotating  $\frac{1}{2}$  inch 100Cr6 steel ball on three 100Cr6 steel pins at 100 rpm (speed: 0.05 m/s) at room temperature (25 °C). Two commercially available ionic liquids with the same phosphonium cation [P666(14)] were used. The anions were either a phosphate-based variant [DEHP] or a sulfonylimide variant [BTA]. The tests were performed with pure [P666(14)][DEHP] (D), pure [P666(14)][BTA] (B) and seven mixtures of both in different proportions. The selection of these two ionic liquids was based on previous experience at our institute.[2] With a mass mixing ratio of D:B like

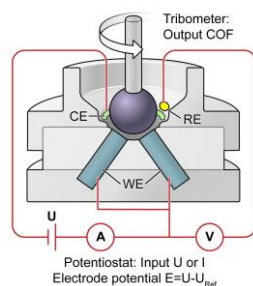


Figure 1: Tribological set-up with connected potentiostat.[3]

1:3 a COF increase of 45 % could be achieved with an anodic potential compared to a neutral surface. With a cathodic potential a COF reduction of 10 % compared to an electrically neutral state was obtained with a mixing ratio of D:B like 1:1.[3] For each of the seven experiments, the Stribeck parameter (SP) was calculated at the end of the experiment. The viscosity ( $\eta$ ) of the lubricant is multiplied by the velocity ( $v$ ) and divided by the pressure ( $p$ ) (Figure 2).

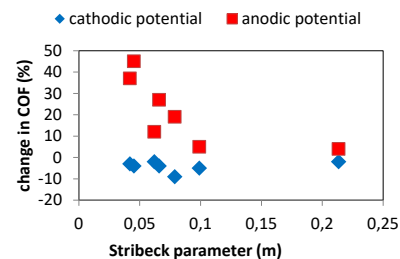


Figure 2: Stribeck parameter in correlation to the change of COF compared to the neutral surface.[3]

### 3. Discussion

Figure 2 clearly shows that there is a tendency that the smaller the Stribeck parameter and thus the lubricant film thickness, the greater the change in COF during anodic switching. With a small Stribeck parameter, the targeted electrochemical adsorption of the IL molecular layers has a greater effect on the coefficient of friction than at lower pressure and high lubricant film thickness. It is assumed that the near-surface structure of the ILs is changed by the external charging. Without electric field, anions and cations are statistically distributed in the lubrication gap. With an anodic polarization, an increase in the concentration of the smaller anions in the near-surface contact is induced. The cations, which have a larger volume than the anions and have long alkyl chains with lubricating properties, are forced out of the lubricating gap and friction increases. In case of contrary polarization, the anions are forced out and friction and wear are reduced.

### 4. References

- [1] Holmberg, K. et al., Tribol. Int. 5, 389–396 (2019).
- [2] Dold, C. et al., Phys. Chem. Chem. Phys. 17, 10339–10342 (2015).
- [3] Gatti, F. et al., Scientific Reports 10, 17634 (2020).