Ionic liquids as a new class of lubricants for polymer-steel friction pairs

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The current state of knowledge on the application of ionic liquids as lubricants indicates their great potential in the lubrication of metal-metal friction pairs. Simultaneously, there is a lack of knowledge on their tribological behavior in metal-polymer systems. Therefore, the aim of this study was to investigate the efficiency of selected ionic liquids (imidazole and phosphonate compounds) that were used to lubricate a friction pair in the steel-polymer (PA, POM, PE) material configuration. The assessment was based on measurements of the friction torque and calculations of coefficient of friction and on a detailed topographic and microscopic analysis of the worn surfaces.

Keywords: ionic liquid, carbon nanotubes, wear, surface topography

1. Introduction

Ionic liquids are characterized by a plethora of properties that predispose them to be used as lubricants. They can take on various forms, e.g. an ionic liquid as a lubricating liquid "designed" to work with a specific material, an ionic liquid as a base liquid (an equivalent of base oil) to formulate a multi-component lubricant, or as a liquid phase in a grease composition. The most important features that should be considered in the case of ionic liquids as lubricants are their very good lubricity combined with high thermal stability (including low volatility and flammability), almost unlimited configuration options for anions and cations to form the lubricant, and high eco-friendliness as compared to traditional oils and greases. Satisfactory lubricating properties of ionic liquids have been confirmed for various configurations of metal friction pairs, particularly when the steel element is applied (e.g. steel-steel, steel-aluminum alloys, steel titanium alloys). However, little information is currently available on the use of ionic liquid as a lubricant for polymer-polymer, and particularly for metal-polymer friction pairs. Therefore, in this study the effectiveness of selected ionic liquids to lubricate a polymer-steel system was analyzed.

2. Methods

The “block-on-ring” tribometric system was used as the friction pair. The blocks were made of three polymers that are used in engineering as construction materials, namely PA6E polyamide, Ertacetal C polyoxymethylene and Tivar 1000 polyethylene. All of the blocks had dimensions of 15 x 10 x 6 mm, and their larger surface, paired with steel cylinders, was ground to a roughness of approx. Sa= 0.5 µm. The cylinders (45 mm in external diameter and 12 mm wide) were manufactured from AISI 4130 steel. Their circumferential surfaces were ground, offering anisotropic surface topography (Sa= approx. 0.5 µm). The ionic liquids used for lubrication were 1-Butyl-3-methylimidazolium bis(trifluoromethylsulfonyl) imide (IL1) and trihexyltetradecylphosphonium bis(2-ethylhexyl) phosphate (IL2). In order to obtain severe friction conditions, only 0.1 ml of the lubricant was used per test. Lithium grease and polypropylene glycol were applied as reference lubricants. Additionally, IL1 with 1% additive of carbon nanotubes was proposed as an alternative lubricant. Measurements of friction torque and calculation of the coefficient of friction were conducted in order to determine the tribological conditions. Topographic analysis was conducted by applying a 3D optical interferometer on rectangular (1 mm x 1 mm) areas in order to identify wear of the polymer surfaces.

3. Discussion

Fig. 1 presents selected changes in the coefficient of friction for Tivar 1000 polyethylene and for the various types of lubricants. The lowest friction coefficient can be observed for pure IL1. Moreover, it is the only lubricant that had a decrease in friction over the course of the test. The probable cause for this was the so-called “lumpy transfer” of the polymer as identified on the steel cylinder surfaces. Similar results were obtained for the other steel-polymer friction pairs.

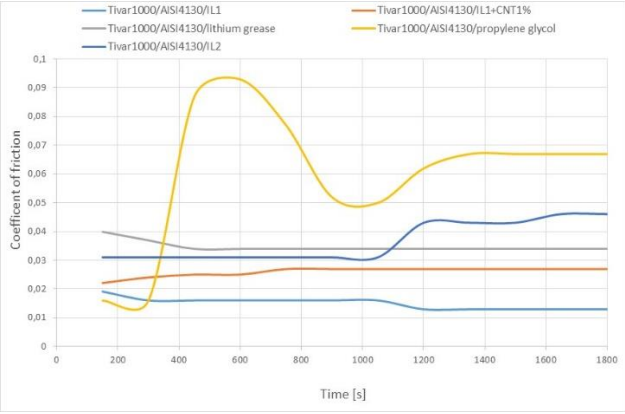

Figure 1: Selected time-dependent changes in the coefficient of friction for Tivar 1000 polyethylene – the AISI 4130 pair and various types of lubricants.

The analysis was complemented by a detailed topographic and microscopic analysis of the blocks’ worn surfaces for all of the applied types of polymers.