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# Study of the tribological performance of a halogen-free pure lubricant in a steel-steel contact

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**ABSTRACT** – The consumption of materials is too high due to the short lifetime of these. The necessity to use an efficient and "green" lubricant grow more and more. In the present study, a halogen-free lubricant was used in a steel-steel contact and the friction and wear were measured. The work was performed to analyze the protective tribofilm formed between the two moving parts. The experiments show a lower friction and wear when the new lubricant is used than with a conventional base oil. The XPS analysis confirms the low friction especially because of the presence of specific compounds in the tribolayer. Further analysis will be performed in a future work to confirm the chemical composition of the thin film.

## 1. INTRODUCTION

In bearings application, the need to lubricate properly the contact is very important. The possibility to reduce the friction, the corrosion and increase the lifetime of the materials is great. A novel-type of additive, developed in the study [1] , was investigated, so-called ionic liquid. An ionic liquid is a solution containing specifically charged species (ions) at room temperature. The cations (positive charge) and anion (negative charge) form an ion paired easily separable. The most common ionic liquids used as lubricant or additives contain halogen compounds that give high tribological performance but also high corrosion and not environmentally friendly by-products. In this research, two halogen-free phosphonium borate based ionic liquids were tested as pure lubricants in comparison to a base oil (BO) poly-alpha-olefin. These ionic liquids are boron- and phosphorus-based that are well known to reduce friction and wear.

## 2. EXPERIMENTAL DETAILS

The friction test was performed with a ball-on-disc tribotester (CSM instruments). The 6mm diameter 100Cr6 steel ball is in contact with a 40x4.5mm 100Cr6 steel disc. The normal load is 15N ($p_{max}$=1.63GPa), the speed is 200mm/s and the total distance is 1000m. The volume of lubricant is 1mL. The tests were executed at room temperature (~20°C) and at 100°C and a humidity between 36 and 38%. The lubricants used are two halogen-free ionic liquids.

The wear was measured with a white light profilometer Taylor-Hobson CCI-HD). The X-RAY photoelectron spectroscopy (XPS) characterization was performed with a PHI VersaProbe II Scanning Microscope.

Before the tribological tests, the steel discs and steel spheres were cleaned with acetone in an ultrasonic bath for 5 minutes. After the tests, the samples were transported under vacuum to avoid the oxidation of the tribofilm. The samples then undergo the centrifugal spinning process for 10 minute at 8000rpm to remove the maximum of non-used lubricant and keep the tribofilm unspoiled. The XPS analysis is then easier.

The low vapor pressure of the ionic liquids allow the use of this kind of liquid under the vacuum of the XPS chamber. Unfortunately, the base oil has a higher vapor pressure, the lubricant should then be totally removed from the steel surface. The cleaning process was done with heptane that is removing the liquid without affecting the protective tribofilm.

## 3. RESULTS AND DISCUSSION

At engine temperature (between 90 and 105°C), the friction is 60+% lower with one ionic liquid than with the base oil. The structure of the ionic liquids molecules at the steel surfaces seems to generate an easy-to-shear film that reduce the friction.

The XPS sputtering reveals the presence of different compounds in the tribofilm. At the top layer the concentration of carbon is high corresponding to alkyl chains from the cation. Indeed, the spinning centrifugal process did not remove 100% of the pure lubricant.

The results of the deconvolution process of the oxygen atom was also performed. NIST database was used to determine which energy value correspond to which chemical compounds. A maximum error of 0.1eV is accepted. Different compounds oxygen-based are present. Shah *et al.* [2] stated that boron oxide provides low friction that correspond to the friction data. Another analysis reveals that the phosphorus concentration is close to zero.

The concentration of oxygen is higher at 100°C (25-30%) than at room temperature (20-25%). The formation of oxide may explain why the wear is higher at elevated temperature. The oxidation of the nascent surface of steel and the soft oxide layer formed could be the reason.

## 4. CONCLUSION

The ionic liquid as pure lubricant presents better tribological performance than the conventional base oil. The XPS measurements explain the low friction by detecting the lubricious boron oxide. The low wear at low temperature could be related with the relative concentration of oxygen in the tribolayer. The perspective of a future work should be the confirmation of these compounds with e.g. infrared spectroscopy.

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