

Low-Toxicity High-Lubricity Ionic Liquids for Eco-Friendly Lubrication

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Here we report the successful development of low-toxicity, high-lubricity ionic liquids (ILs) as novel additives for environmentally acceptable lubricants (EALs). Candidate ILs were synthesized and firstly screened by their oil solubility, thermal stability, and corrosivity. Selected ILs were blended into a PAG and an oil soluble PAG (OSP) for tribological and aquatic toxicity testing. In boundary lubrication, selected ILs outperformed a commercial ZDDP with additional 20-30% friction reduction and 80-90% wear reduction. The top-performing ILs had little negative impact on *Daphnia* survival or reproduction in U.S. EPA standard chronic aquatic toxicity tests, while ZDDP caused 100% mortality.

Keywords: ionic liquid, lubricant, anti-wear additive, eco-friendly, aquatic toxicity

1. Introduction

About 50% of the lubricants sold worldwide end up into the environment or 36.9~61 million liters per year. Thus, the environmental impact of lubricants is increasingly recognized in addition to meeting the rheological and tribological requirements. There are four types of USA EPA-approved base fluids for Environmentally Acceptable Lubricants (EALs), including water, vegetable oil, synthetic ester, and polyalkylene glycols (PAGs). However, there is lack of additives that are both non-toxic and effective in wear protection. For example, the most widely used anti-wear additive ZDDP is toxic and conventional ashless additives have inferior wear protection and thermal stability.

Ionic liquids (ILs) have been reported as effective anti-wear additives. [1] While several studies claimed ILs to be environmentally friendly but did not provide any toxicity data. In the broader area of ILs research, toxicity measurements were conducted on some ILs, but none of the ILs were designed for lubrication. This study developed new ILs possessing both low toxicity and high lubricity for eco-friendly lubrication.

2. Methods

Two base oils chosen for this study were PAG and Oil Soluble PAG (OSP) with viscosities at 40 °C around 32 cSt. More than a dozen of ILs were synthesized. All candidate ILs have solubility > 5 wt% in PAG and OSP.

Aquatic toxicity tests were conducted using *Daphnia* on selected ILs following standard EPA protocols [2] in the Aquatic Ecology Lab at ORNL. *Daphnia* were exposed to a dilution containing 0.5 ppm of each candidate IL. Survival and reproduction data were recorded daily.

The lubricity of oil-IL blends in boundary lubrication was tested using a steel ball reciprocating sliding against a steel flat. Test conditions are 100 N load, 10 Hz, 10 mm stroke, 82 °C, and 1,000 m sliding distance.

Toxicity and lubricity results of candidate ILs were compared with those of a commercial ZDDP tested in the same conditions.

3. Results and Discussion

In aquatic toxicity tests, *Daphnia* had 70-100% survival rates when exposed to the new candidate ILs, but zero survival when exposed to the ZDDP or previously developed ILs for engine lubrication. In lubricity evaluation, selected ILs outperformed the ZDDP by additional 20-30% friction reduction and 80-90% wear reduction. Selected results are shown in Fig. 1.

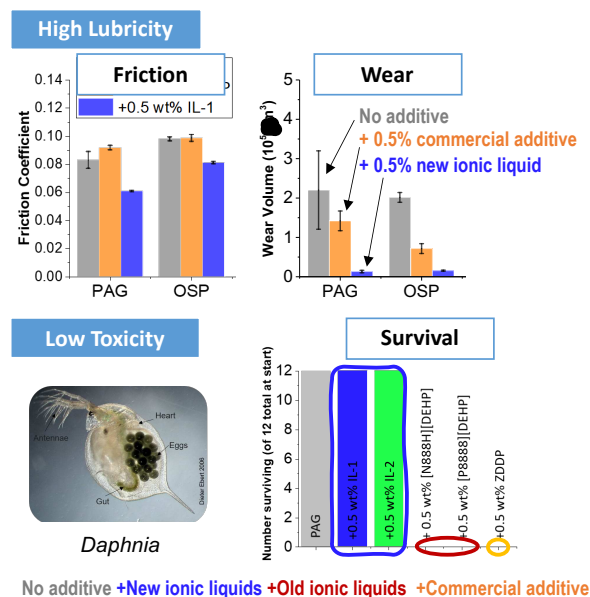


Figure 1: New candidate ILs demonstrated lower toxicity and higher lubricity than ZDDP.

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4. References

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