4-16-2012

**Versatile In-Situ Engine Lubricant Health Sensor**

Sanjeev Acharya  
*Department of Material Science and Engineering, Boise State University*
Versatile In-Situ Engine Lubricant Health Sensor

Abstract
Lubricants which are used in engines to reduce friction, promote engine cooling, and prevent corrosion degrade with time under harsh engine operating conditions and hence need to be changed periodically. Since degradation of oil is a result of number of mechanisms such as; engine component wear, oil oxidation, water ingress, and carbon particles, a versatile and microscopic in-situ sensor that can sense quality of wide variety of engine lubricant brands at various temperatures and pressures is of great need. This problem can be resolved by applying portable interdigitated micro-sensors to examine the impedance behavior of degraded lubricants through electrochemical tests. Electrochemical measurement techniques were used on both commercially available and custom built micro-sensors (fabricated through electron beam lithography) to understand impedance behavior of a mixture of oil, wear and additive particles, and other impurities at different environmental conditions. The impedance response of the oil was found to increase with a decrease in wear and additive metal ion concentrations, total acid number (TAN) and temperature. Based on the results obtained work is ongoing to improve the measurement sensitivity and create a sensor that can effectively detect the amount of degradation oil has experienced and to isolate the influence of multiple degradation mechanisms.

Disciplines
Materials Science and Engineering
Abstract

The objective of this project is to study impedance behavior of degraded lubricants using portable interdigitated micro sensors via electrochemical testing. Electrochemical measurement techniques were used on both commercially available and custom built micro sensors (fabricated through electron beam lithography) to understand impedance behavior of a mixture of oil, wear and additive particles, and other impurities at different environmental conditions. The impedance response of the oil was found to increase with a decrease in wear and additive metal ion concentration, total acid number (TAN) and temperature. Based on these results obtained, work is ongoing to improve the measurement sensitivity and create a sensor that can effectively detect the amount of degradation oil has experienced and to isolate the influence of multiple degradation mechanisms.

Introduction

• Lubricants are used in engines to reduce friction, promote engine cooling, and prevent corrosion. These lubricants will eventually degrade with time under harsh engine operating conditions and hence need to be changed periodically.

• Degradation of oil is a result of a number of mechanisms such as; engine component wear, oil oxidation, water ingress, and combustion byproducts.

• A versatile and microscopic in-situ sensor that can sense quality of a wide variety of engine lubricant brands at various temperatures and pressures is of great need. This problem can be resolved by applying portable interdigitated micro sensors to examine the impedance behavior of degraded lubricants through electrochemical tests.

Experimental

<table>
<thead>
<tr>
<th>Oil Type</th>
<th>Composition</th>
<th>Metal ions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Base stock oil with Wear metals</td>
<td>10 µg/g</td>
<td>100 µg/g</td>
</tr>
<tr>
<td>Base stock oil with Additive metals</td>
<td>10 µg/g</td>
<td>100 µg/g</td>
</tr>
<tr>
<td>Base stock oil with various TAN</td>
<td>0.10 KOH/g</td>
<td>1.53 KOH/g</td>
</tr>
</tbody>
</table>

Using oil with known concentrations, additive metals, & TAN (Total Acid Number) and commercial electrodes (carbon and platinum), new micro sensors were designed, built and tested to optimize sensor performance.

What is EIS? How does it work?

Electrochemical Impedance Spectroscopy (EIS) was used to measure impedance on base stock oil (containing additive and wear metals).

Experimental setup:

• Teflon O-ring was placed over the sensing array to contain oil and prevent it from leaking.

• Electrochemical Impedance Spectroscopy (EIS) was conducted using a Gamry Reference 600® potentiostate. Frequency range used was from 100,000 Hz to 0.25 Hz and voltage amplitude used was 500 mV.

Custom Built Sensors

Custom built sensors (through electron beam lithography) with large spacing between electrodes.

Results

• Impedance of base stock oil decreases with increase in additive metal concentration and wear metal concentration.

• Impedance of oil is affected by total acid number (TAN).

• 10 µm spaced sensor has lower impedance than 3 µm spaced sensor.

• Impedance of oil decreases with increase in temperature.

Conclusions

• Only micro sensors have acceptable oil sensing capability.

• EIS data obtained from micro sensors were repeatable and dependent on sensor geometry.

• EIS test results were able to sense changes in oil composition including wear metals, additive metals and TAN.

• EIS results showed greater sensitivity at higher temperature indicating improved performance under typical engine operating conditions.

Acknowledgements

NSF SBIR Phase I lead by Technology Holding LLC, Feng Zhou, Tony Elongovan, Electrode fabrication help from Lynn Fuller, Electrode design help from Patrick Price.