Ashwin Bharadwaj
Evaluating locomotive engine oils with novel oil soluble polyethers as additives

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Topics

• An intro to polyalkylene glycol (PAG) architectures
  • Functionality and utility
• Motivation
• Oil soluble polyethers (OSP) as additives in locomotive engine oils
  • Friction
  • Wear
  • Deposits
  • Oxidation stability
• Conclusions
Water Soluble, Water Insoluble and Oil Soluble Polyethers

Conventional Polyalkylene Glycol (PAG) Advantages
- High VI’s (up to 250)
- Lower friction coefficients
- Excellent deposit control
- Pour point up to -45°C
- Biodegradability: 10-90%
- Good hydrolytic stability

Oil Soluble Polyethers (OSP) features
- Derived from butylene oxide as one of the commercially available building blocks
- OSP’s have slightly lower VI’s but improved pour points
- Carry conventional benefits of traditional polyethers and are oil miscible
Utility of Polyethers

**Uses of EO and PO**

**Primary base oil in formulations**
- Compressor and refrigeration oils
- Hydraulic fluids
- Textile lubricants
- Gear & Bearing oils

**Additives**
- Viscosity builder in water glycol hydraulic fluids
- Lubricity aid in water miscible metalworking fluids

**Uses of OSPs**

**Primary base oil in formulations**
- Compressor/refrigeration oils
- Hydraulic fluids
- Gear & Bearing Oils
- Engine Oils

**Co-base oil**
- Upgrade Group I-III mineral oils
- Upgrade PAOs

**Additives**
- Deposit control additive
- Friction modifier
- Viscosity builder in mineral oils

Oil soluble polyethers as additives for engine oils
Locomotive Engine Oils

Engine oil attributes

- Zinc free
- Silver bearings
- Deposit control
- Extended drain intervals: 90 or 180 days
- Fuel economy (FE)
- 20W 40 (Generally group II)

Locomotives

- Fuel consumption varies by size and geography
- ~ 100,000 gallons per year
- ~ 200-300 gallon oil capacity
- Fuel economy and operation efficiency interest end users and formulators
- 0.5% FE across a fleet may be significant
Motivation

- Following benefits with oil soluble polyethers as additives have been observed
  - Friction reduction
  - Enhanced solubility
  - Deposit control

- As additives or co-base oils, what is the performance of existing locomotive engine oils with oil soluble polyethers
Initial Survey of Base Oils

- Group II base oils show higher traction coefficients than other base oils and oil soluble polyethers
- Method: Mini-traction machine (MTM), ball on disc
- Conditions: 1000mm/s, 0-150%SRR, 0.9MPa contact pressure
# Formulations Tested

## Components

<table>
<thead>
<tr>
<th></th>
<th>Formulation 1</th>
<th>Formulation 2</th>
<th>Formulation 3</th>
<th>Formulation 4</th>
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<tbody>
<tr>
<td>Commercial locomotive</td>
<td>90</td>
<td>90</td>
<td>90</td>
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<tr>
<td>Oil soluble polyethers</td>
<td>7.0 (OSP A+OSP B)</td>
<td>7.0 (OSP C +OSP D)</td>
<td>9.70(OSP C+OSP D)</td>
<td>9.25(OSP C+OSP D)</td>
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<td>Antioxidant (AO) package</td>
<td>3.00</td>
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## Viscosity

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<tr>
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<th>KV 40°C (cSt)</th>
<th>KV 100°C (cSt)</th>
<th>Viscosity Index</th>
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<td>Commercial locomotive</td>
<td>136.4</td>
<td>15.1</td>
<td>118</td>
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Friction Comparison: Commercial Locomotive Oil with Oil Soluble Polyethers
Friction Comparison at 80°C

- Conditions: 50% slide to roll ratio (SRR), 50 N force
- 10-30% friction reduction observed in boundary lubrication

Commercial Locomotive Oil with OSP Friction Comparison, 80°C
Friction Comparison at 150°C

- Conditions: 50% slide to roll ratio (SRR), 50 N force
- Lower friction reduction (~10-20%) observed at higher temperature
- Conclusion: Oil soluble polyether additive packages lowers friction coefficients in boundary lubrication at 50 N and across temperature ranges
Higher SRR Friction Comparison

- Conditions: 150% slide to roll ratio (SRR), 50 N force
- Friction reduction of 20-30% observed in boundary lubrication
Higher SRR Friction Comparison

- Conditions: 150% slide to roll ratio (SRR), 50 N force
- Friction reduction (~10-20%) in boundary lubrication for formulation 3
- Conclusion: At higher slide to roll ratios, friction reduction can be observed with certain oil soluble ether additive packages.
Wear Evaluation

Method: ASTM D4172
Load: 40 kgf
Speed: 1200 rpm
Temperature: 100 and 150°C
Duration 1 h

- No significant difference in wear scars across temperatures
- Oil soluble polyether additive package does not adversely effect wear
- Further testing on silver bearings needed to validate wear performance
Deposit Evaluation by Panel Coker

Test conditions:
FTM-791B
Method 3462

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<tr>
<td>Panel Temperature</td>
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<tr>
<td>Oil Temperature</td>
<td>125°C</td>
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<tr>
<td>Splasher Speed</td>
<td>1000 rpm</td>
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<tr>
<td>Panel Type</td>
<td>Aluminum</td>
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</table>
Deposit Evaluation by Panel Coker

- Deposits increase at low AO concentration (Formulation 3)
Dow Thermo Oxidative Stability Test – Set Up

- Two spur gears with the large gear rotated at 1750 rpm
- Air bubbling
- 150°C with test duration of 300 h
- Track Total Acid Number (TAN)
- Copper steel coil in flask
- Outlet air passes through condenser to condense the vaporized oil
- Guidance taken from ASTM D5704
  - Generally used for manual and transmission axles
Dow Oxidation Test Results: Total Acid Number

Conclusions

- Total acid number increased significantly for lower antioxidant treat levels (Formulation 3)
- Clean copper steel coils and round-bottom flasks observed (example of formulation 2 shown)
- A minimum amount of AO with oil soluble polyethers may be required to maintain durability
Summary

• Using oil soluble polyethers as additive packages may lower friction coefficients in boundary lubrication

• No adverse effect on wear was observed

• Appropriate antioxidant level may be required

• Oil soluble polyethers as additives are currently being evaluated at a lubricant formulator for locomotive engine oils
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