Environmentally Acceptable Lubricants: safe or a safety hazard

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Presentation documents:
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Page 14: Rob Harrison, Shell Marine

Part of
Marine Lubricants
Webinar Week
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Castrol

riviera
WHAT MAKES AN EAL STERN TUBE LUBRICANT?

NOW!

- Readily biodegradable
- Minimum eco-toxicity
- Non-bioaccumulating
- Preferred bio-sourced

• Regulatory Drivers
• Corporate responsibility
“ARE ALL EALs THE SAME?”

<table>
<thead>
<tr>
<th>ISO CLASSIFICATIONS</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>HETG</strong></td>
</tr>
<tr>
<td>Hydraulic</td>
</tr>
<tr>
<td>Environmental</td>
</tr>
<tr>
<td>Triglycerides</td>
</tr>
<tr>
<td><strong>HEES</strong></td>
</tr>
<tr>
<td>Hydraulic</td>
</tr>
<tr>
<td>Environmental</td>
</tr>
<tr>
<td>Ester oil</td>
</tr>
<tr>
<td>Synthetic*</td>
</tr>
<tr>
<td><strong>HEPG</strong></td>
</tr>
<tr>
<td>Polyalkylene glycol</td>
</tr>
<tr>
<td>Base (i.e. polyglycol)</td>
</tr>
<tr>
<td><strong>HEPR</strong></td>
</tr>
<tr>
<td>Hydraulic</td>
</tr>
<tr>
<td>Environmental</td>
</tr>
<tr>
<td>PAO and Related</td>
</tr>
<tr>
<td>product</td>
</tr>
</tbody>
</table>

* Most commonly used. Huge variation
## OXIDATION STABILITY
Un-additivated

<table>
<thead>
<tr>
<th>ISO Class</th>
<th>Oil Type</th>
<th>Oxidation time (mins)</th>
</tr>
</thead>
<tbody>
<tr>
<td>HETG</td>
<td>Vegetable Esters</td>
<td>&lt; 30</td>
</tr>
<tr>
<td>HEES</td>
<td>Oleochemical <strong>Unsaturated</strong> Esters</td>
<td>&lt;30</td>
</tr>
<tr>
<td>HEES</td>
<td>Oleochemical <strong>Saturated</strong> Esters</td>
<td>&gt; 180</td>
</tr>
<tr>
<td>HEES</td>
<td>Petrochemical Esters</td>
<td>&gt; 200</td>
</tr>
<tr>
<td>HEPG</td>
<td>Polyalkylene glycols</td>
<td>&lt;30</td>
</tr>
<tr>
<td>HEPR</td>
<td>PAO / ‘New’ PAO</td>
<td>&gt; 120</td>
</tr>
</tbody>
</table>

- Rapidoxy – static oxidation tester (ASTM 7545)
- Sample ~ 5mls
- Pressure vessel charged with O$_2$ at 700 kPa
- Temperature maintained at 140°C
- Test completed when O$_2$ pressure drops by 10%
HYDROLYTIC STABILITY
Includes commercial additive pack, Test method (RR1006)

- Triglycerides
- PAGs, PAOs Diesters
- Polyol Esters
- HV Non-Biodegradable; Non-bioaccumulating ester
EALs are a viable and effective option for stern-tubes.

Not all EALs are the same!

If HEES:
- Mono, Di or Polyol?
- Complex or Polymer?
- Bio or Petro based?

Careful oil selection is paramount.

DESORED EFFECTS

Film Forming Behaviour

Oxidation

ELIMINATE ENGINEERING ISSUES

REDUCE OIL DEGRADATION

MINIMISE RISK OF STERN TUBE FAILURE
Environmentally Acceptable Lubricants: safe or a safety hazard?

Statement PANOLIN:

*It is NOT appropriate to categorize “all EALs as the same”*

– they are not!
5 base oil types generally accepted in EALs....
Many more base oil blends developed as alternatives to the bench mark: Mineral oil

<table>
<thead>
<tr>
<th>Lubricant base oil</th>
<th>Positive Characteristics</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mineral oil [ reference ]</td>
<td>Low price, world wide availability</td>
</tr>
<tr>
<td>Triglyceride (Vegetable oil)</td>
<td>Fully renewable resource</td>
</tr>
<tr>
<td>Polyglycol</td>
<td>Broad operating temperature range</td>
</tr>
<tr>
<td>Synthetic Hydrocarbon (PAO)</td>
<td>Hydrolytic stability</td>
</tr>
<tr>
<td>Synthetic Ester (unsaturated)</td>
<td>Lower price than saturated ester</td>
</tr>
<tr>
<td>Synthetic Ester (saturated)</td>
<td>Good temperature/oxidation stability, proven base for long-life lubricants</td>
</tr>
</tbody>
</table>
EAL failures - oil deterioration

Causes……

• **High temperature:**
  - Oxidation – varnish deposits in system
  - Polymerization – increase in viscosity

• **Low temperature:**
  - Crystallization – additive solubility

• **Shear instability:**
  - Decrease in viscosity – film thickness

• **Water ingress:**
  - Hydrolysis – base oil decomposing
  - Emulsification - corrosion

• **Incompatibility issues:**
  - seals, paints, mixing of oils
# Cases of EALs failing

<table>
<thead>
<tr>
<th>EAL base fluid type</th>
<th>Effects</th>
</tr>
</thead>
<tbody>
<tr>
<td>Unsaturated Ester</td>
<td>Polymerizing, sludge (sticky, resin-like)</td>
</tr>
<tr>
<td>Poly-alpha-olefin</td>
<td>Viscosity loss (shear unstable), sludge, equipment wear, seal damage</td>
</tr>
<tr>
<td>Vegetable</td>
<td>Oxidation, thickening, seal damage: hardening, cracking</td>
</tr>
<tr>
<td>Polyglycol</td>
<td>System corrosion, smelling</td>
</tr>
<tr>
<td>Emulsifying lubricants</td>
<td>Permanent mix with water, corrosion, bacterial growth (\rightarrow) decomposing</td>
</tr>
</tbody>
</table>

All failures end up with:  
- damage of the equipment  
- high drydocking costs  
- loss of vessel operational availability  

and ultimately:  
- CLIENT DISSATISFACTION

**PANOLIN** marine products:  
Not one reported case of PANOLIN stern tube lubricant failing !
Cases of EALs failing

Design changes

- Slow steaming (lower shaft rpm)
- Heavier propeller
- Single aft stern tube bearing
- Resin bonding of stern tube bearings – reduction of heat sink
- AFT seal: small oil volume - overworked oil

Transient Conditions –

- New Building sea trials – new shaft : bearing roughness, hard turns
- Cold starts – High Viscosity Index oil = low cold oil viscosity
- Heavy seas – shaft impacts
- Un-laden vessel conditions - propeller slapping

→

DNV GL study: effect of reduction in viscosity at higher bearing pressure
Is the void space seal an option?

The void space seal (or Air Seal):
  • A very environmentally ‘friendly’ sealing system

But…. 
  • Requires trained personnel to operate/monitor it 
  • Potential damage (e.g. wire wrapping around propeller) → oil leakage, in case of mineral oil – violation of VIDA/VGP2013 
  • EPA statement (April 22, 2015):
    “EPA cannot provide any type approval or "clean" endorsement that an alternative seal system [Void Space seal] would eliminate the discharge”
PANOLIN Performance Lubricants

- 5 base oil types generally accepted in EALs as alternatives to mineral oil
- EAL failures often linked to weak performance of base oils
- EAL failures are not linked to base fluid and film thickness, only;
  → good lubricant performance: optimized combination of base fluid and additives
- PANOLIN Saturated Synthetic Esters exhibit performance characteristics closer to those of mineral oil than other base oils
  – including Pressure-Viscosity Relationship

- It is NOT appropriate to categorize “all EALs as the same”
  – they are not!

Your Vessel lubricants are assets
Select them carefully - Look after them!
Environmentally Acceptable Lubricants

Safe or a safety hazard?

Rob Harrison
Technical Services Manager
Shell Marine
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OIL-LUBRICATED STERN TUBE FAILURES: Why they happen & what you can do.

- Striebeck curve illustrates that rotational speed is required to create a lubricant film.
- Viscosity plays a large part of the oil film thickness in conjunction with the pressure/viscosity coefficient.
- Bearing design, clearances and materials along with the vessel design can all influence the lifetime of a stern tube.
WHY TRANSIENT CONDITIONS NEED TO BE FACTORED IN

- The harshest stern tube conditions are seen with;
  - hard manoeuvring at high ship speeds
  - during mooring trials
  - operating with a partly submerged propeller

- All these conditions involve hydrodynamic lubrication but very close to mixed lubrication

- During normal vessel operation these conditions are unlikely
IS THE VOID SPACE SEAL OPTION A Viable ALTERNATIVE?

- The air gap causes an “oil– air -sea” configuration hence no “oil – sea” interface
- Air gap stern tube bearings still require a lubricant but are exempt from using EAL’s
- Alternatives are water lubricated stern tube bearings
WHAT MAKES FOR AN ACCEPTABLE STERN TUBE LUBRICANT?

- Ultimately the stern tube lubricant must last a 5 year Dry Dock period.
- Ability to remove water
- Resistance to hydrolysis
- Range of viscosities to suit various OEM requirements
IS IT FAIR TO CHARACTERISE ALL EALs AS THE SAME?

NO

- There are many types of EAL products besides it being an oil or a grease.
- Non-emulsifying vs. emulsifying hence water removal or not is one example.
- Base oil used:
  - Vegetable oil, Ester, Polyalkylene Glycol – all lubricants will biodegrade
WHAT RECENT TESTING ON THERMAL STABILITY, OXIDATION AND EFFECT OF WATER, WILL REVEAL ABOUT THE PERFORMANCES OF DIFFERENT EALs

- Thermal stability and oxidation occur at higher temperatures
  - Saturated and unsaturated esters will perform differently

- The ability to remove water will extend the lubricant life by:
  - reducing hydrolysis
  - reducing acid formation
  - extend seal life
  - maintain viscosity
  - prevent equipment corrosion