Alkylated Naphthalenes

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St Petersburg Sept 13-15, 2011
Sandy Reid-Peters
What are Alkylated Naphthalenes (AN)?

- Alkylated aromatic fluids
- Reaction products of olefins and naphthalene
- American Petroleum Institute (API) Group V fluids
- Synthetic blendstocks for automotive and industrial lubricants
- NSF registration for Incidental Food Contact (H1 & H1-X) - All EMC Synesstic™ grades

\[
\text{Naphthalene} + \text{Olefins} \xrightarrow{\text{Catalyst}} \text{Alkylated Naphthalene (AN)}
\]
Properties of AN

- Seal Compatibility
- Thermal & Oxidative Stability
- Polarity & Additive Response
- Hydrolytic Stability
- Lubricity
- Solvency
## Thermal Stability

Thermal Stability Test: 72 hours @ 288°C under Nitrogen

<table>
<thead>
<tr>
<th></th>
<th>Adipate Ester</th>
<th>Polyol Ester</th>
<th>Branched Alkyl Benzene</th>
<th>6 cSt PAO</th>
<th>5 cSt AN</th>
<th>12 cSt AN</th>
</tr>
</thead>
<tbody>
<tr>
<td>Viscosity Change, %</td>
<td>-9.2</td>
<td>-0.1</td>
<td>-0.9</td>
<td>-9.1</td>
<td>0.4</td>
<td>1.1</td>
</tr>
<tr>
<td>TAN Change, mg KOH/g</td>
<td>53.9</td>
<td>8.1</td>
<td>0.55</td>
<td>0.22</td>
<td>0.32</td>
<td>0.24</td>
</tr>
<tr>
<td>Weight Loss, %</td>
<td>23.1</td>
<td>1.09</td>
<td>1.23</td>
<td>1.15</td>
<td>0.51</td>
<td>0.33</td>
</tr>
</tbody>
</table>

- Increased acidity
- Reduced viscosity due to thermal cracking
- Higher evaporative loss

AN exhibits improved thermal stability compared to alkyl benzene, PAO and ester base fluids

Source: Exxon Mobil data
### Oxidative Stability

(Test Method: modified in house Oxidation-Corrosion Test in the presence of air and metal coupons)

<table>
<thead>
<tr>
<th>ISO VG 32</th>
<th>Ester Blend</th>
<th>AN Blend</th>
</tr>
</thead>
<tbody>
<tr>
<td>6 cSt PAO</td>
<td>73 %</td>
<td>73 %</td>
</tr>
<tr>
<td>Adipate Ester</td>
<td>25 %</td>
<td>---</td>
</tr>
<tr>
<td>5 cSt AN</td>
<td>---</td>
<td>25 %</td>
</tr>
<tr>
<td>Additives</td>
<td>2 %</td>
<td>2 %</td>
</tr>
<tr>
<td>Viscosity Change, %</td>
<td></td>
<td></td>
</tr>
<tr>
<td>120 hours @ 163 °C</td>
<td>71</td>
<td>5</td>
</tr>
<tr>
<td>48 hours @ 177 °C</td>
<td>103</td>
<td>5</td>
</tr>
<tr>
<td>24 hours @ 191 °C</td>
<td>76</td>
<td>3</td>
</tr>
</tbody>
</table>

AN improves the oxidative performance of PAO-based formulations compared to ester

Source: Exxon Mobil data
Synergy with PAO

Blending Alkylated Naphthalene with PAO yields more oxidative resistant fluids.

Source: Exxon Mobil data
## Hydrolytic stability

Test Method: ASTM D 2619

<table>
<thead>
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<tr>
<td>5 cSt AN</td>
<td>---</td>
<td>25 %</td>
</tr>
<tr>
<td>Additives</td>
<td>2 %</td>
<td>2 %</td>
</tr>
</tbody>
</table>

**ASTM D 2619**

- Copper Corrosion, mg/cm²: 0.15 (Ester Blend) vs. 0.00 (AN Blend)
- TAN Change, mg KOH/g: 0.22 (Ester Blend) vs. 0.03 (AN Blend)
- Total Acidity of Water, mg KOH: 19.9 (Ester Blend) vs. 4.9 (AN Blend)

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Replacing adipate ester with AN improves hydrolytic stability in a formulated oil.

Source: Exxon Mobil data
AN have good additive solvency for polar compounds due to their aromatic structures.

Test Method: ASTM D 611

Source: Exxon Mobil data
## Lubricity

Test Method: ASTM D 6079

<table>
<thead>
<tr>
<th></th>
<th>HFRR</th>
<th>PAO</th>
<th>5cSt AN</th>
<th>Polyol Ester</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>ASTM D 6079</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Kinematic Viscosity @ 100°C, cSt</td>
<td>3.87</td>
<td>4.83</td>
<td>4.39</td>
<td></td>
</tr>
<tr>
<td>Wear Scar Diameter, micron</td>
<td>368</td>
<td>242</td>
<td>246</td>
<td></td>
</tr>
<tr>
<td>Average Coefficient of Friction</td>
<td>0.157</td>
<td>0.110</td>
<td>0.098</td>
<td></td>
</tr>
<tr>
<td>Average Film %</td>
<td>20</td>
<td>75</td>
<td>83</td>
<td></td>
</tr>
</tbody>
</table>

Test conditions:
Stroke Length 1 + 0.02mm
Frequency 50 + - 1 Hz
Applied load 500g
Test Duration 75 mins
Fluid Temperature 60°C
24-30% Relative Humidity

AN offers similar wear protection to ester and can help reduce friction

Source: Exxon Mobil data
**Competition for the surface**

- **E** = Ester Molecule
- **A** = Additive Molecule
- **AN** = AN Molecule

Base Oil+Ester +Additive

- AN may improve additive effectiveness through less competition for the surface
## Elastomer effects

<table>
<thead>
<tr>
<th></th>
<th>Polyol Ester</th>
<th>Adipate Ester</th>
<th>6 cSt PAO</th>
<th>5 cSt AN</th>
<th>12 cSt AN</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fluoroelastomer*</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>volume change, %</td>
<td>4.7</td>
<td>3.4</td>
<td>0.4</td>
<td>0.8</td>
<td>0.4</td>
</tr>
<tr>
<td>Polyacrylate*</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>volume change, %</td>
<td>27.4</td>
<td>19.8</td>
<td>-2.2</td>
<td>17.9</td>
<td>1.2</td>
</tr>
<tr>
<td>Nitrile**</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>volume change, %</td>
<td>16.9</td>
<td>12.0</td>
<td>-3.3</td>
<td>14.1</td>
<td>0.1</td>
</tr>
</tbody>
</table>

* 240 hrs, 150 °C  
** 240 hrs, 100 °C

**AN demonstrate seal swell performance and none of the seal shrinkage associated with PAO**

Source: Exxon Mobil data
Elastomer performance

Volkswagen VW 503 VACMAC Seals on ACEA C3 SAE 5W-30 Engine Oils

AN shows similar performance to esters when used as a blend stock in PAO-based engine oils.

Source: Exxon Mobil data
An in service
# Improved additive response

Test Method: ASTM D 4472

<table>
<thead>
<tr>
<th>ISO VG 220</th>
<th>Ester Blend</th>
<th>AN Blend</th>
</tr>
</thead>
<tbody>
<tr>
<td>40 cSt PAO</td>
<td>78 %</td>
<td>78 %</td>
</tr>
<tr>
<td>Adipate Ester</td>
<td>20 %</td>
<td>---</td>
</tr>
<tr>
<td><strong>5 cSt AN</strong></td>
<td>---</td>
<td>20 %</td>
</tr>
<tr>
<td>Additives</td>
<td>2 %</td>
<td>2 %</td>
</tr>
<tr>
<td><strong>4-Ball Wear Test (D 4472)</strong></td>
<td>Wear Scar, mm</td>
<td></td>
</tr>
<tr>
<td>1800 rpm, 93 °C for 30 minutes</td>
<td></td>
<td></td>
</tr>
<tr>
<td>60 kg load</td>
<td>0.822</td>
<td>0.739</td>
</tr>
<tr>
<td>80 kg load</td>
<td>2.094</td>
<td>0.822</td>
</tr>
</tbody>
</table>

AN demonstrates improved wear protection in an ISO VG 220 gear oil formulation.

Source: Exxon Mobil data
Improved additive response

Synthetic heavy duty engine oils blended with PAO and AN demonstrate improved wear performance to PAO/ester formulations.

Source: Exxon Mobil data
Boosted oxidation stability

Bulk oxidation tests on SAE 5W-30 Engine Oils

100% Increase test limit

Add. Pkg. #1 Reference
Add. Pkg. #1 with 10% AN
Add. Pkg. #2 Reference
Add. Pkg. #2 with 10% AN

Alkylated Naphthalene improves oxidation stability of 5W-30 engine oils based on group II base stocks with market general GF4 additive packages

Source: Exxon Mobil data
Improved engine deposits

Caterpillar 1-K Diesel Test*

<table>
<thead>
<tr>
<th>Wt.% AN</th>
<th>0</th>
<th>20</th>
</tr>
</thead>
<tbody>
<tr>
<td>WDK (Weighted deposit demerits)</td>
<td>500</td>
<td>385</td>
</tr>
<tr>
<td>TGF (Top groove fill)</td>
<td>19</td>
<td>12</td>
</tr>
</tbody>
</table>

TEOST MHT-4 Test

Alkylated Naphthalene helps provide improved deposit protection in engine oil formulations

* CI-4 quality oil in Gp II base stocks

Source: Exxon Mobil data
ISO VG 46 compressor oil

AN improves oxidative and hydrolytic stability with the potential to extend compressor oil lifetime

Source: Exxon Mobil data
Greases

Two Greases Manufactured:
1. 100% AN
2. 100% PAO

- NLGI #2 Grease
- Lithium Complex Thickener
- Base oil viscosity - 110 cSt
- Commercial Additive package

The solvency of AN allows improved thickener efficiency with good mechanical stability in synthetic grease manufacture.

Source: Exxon Mobil data
Greases

NLGI #2 Li Complex grease
110cSt base oil viscosity
Same additive package

Fretting wear (Test Method: D 4170)

AN offers good protection in greases

Source: Exxon Mobil data
Challenges for formulators of food grade fluids

- New laws on food health and safety are being developed world-wide

- Limited selection of H1/HX-1 base stocks which can provide improved oxidation, solvency and seal performance

- Limited selection of additives approved for food grade applications

- Treat rates of additives approved for food grade applications may be limited

- Food-related applications are often in high-temperature, and moist environments, making oxidative, thermal and hydrolytic stability key performance challenges

- The FDA has approved Synesstic™ AN base stock fluids for use as a component of lubricants with incidental food contact

- H1, HX-1 registration with NSF
Synesstic™ AN base stocks
Sludge performance

ISO VG 46 - Cincinnati Milacron Test (ASTM D 2070)

Addition of Synesstic™ AN base stocks to PAO increases overall blend solubility and cleanliness in formulated industrial oils.

Source: Exxon Mobil data
Synesstic™ AN base stocks
Oxidation stability

ISO VG 46 - Rotary Pressure Vessel Oxidation Test (RPVOT) (ASTM D2272)

Addition of Synesstic™ AN base stocks to PAO improves the oxidation performance of formulated industrial oils.

Source: Exxon Mobil data
Synesstic™ AN base stocks benefits

Synesstic™ AN base stocks provide:

• Thermal and oxidative stability for improved oil life and deposit control

• Good hydrolytic stability for use in high moisture environments

• Solvency for additives and oxidation products

• Seal compatibility enhancement

• Improved additive effectiveness (when replacing esters)

For more information visit: www.synesstic.com
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