Successful Commercialization of an Ester-Functionalized High Viscosity PAO Base Stock

Brian Fox, Senior Scientist, Head of Base Fluids (PAO and Ester)
STLE 2018, Commercial Marketing Forum, Minneapolis, MN
Outline

1. Elevance Aria™ WTP 40 – the basics

2. Elevance Aria™ WTP 40 Properties and Performance Comparisons

3. Summary
Elevance Aria™ WTP 40

Background

- Licensing arrangement between Elevance Renewable Sciences and LANXESS
- LANXESS licensed the global rights to develop, derivatize, manufacture, use and sell products incorporating the Elevance Aria® WTP technology in lubricant applications
- First commercial material produced under this arrangement successfully completed and available to the market earlier this year.
Elevance Aria™ WTP 40

Unique Ester-Functionalized High Viscosity PAO

- High performance base stock combines the performance of Groups IV and V into one base stock
- “Bound” ester adds polarity and functionality to PAO within same macromolecule
- The Unique long chained ester is away from steric hindrance of backbone allowing it to “perform”
- Catalytic polymerization of linear alpha-olefins and linear alpha-olefin esters (9-DAME)
9-DAMe Differentiated Catalyst Technology

Allows for conversion of complex molecules such as fatty acids and esters

Traditional Catalyst

- Ethylene
- 2-butene
- Propylene
- Propylene

Proprietary Olefins Metathesis Catalyst

- Methyl oleate
- 1-decene
- 9-decenoic acid methyl ester (9-DAME)

A B C D
A B C D
A B C D
A B C D
A B C D
Elevance Aria™ WTP 40 Advantages

Advanced lubricant performance – Balanced formulation flexibility

- High viscosity index
- Enhanced additive solvency
- Elastomer seal compatibility
- Increased film thickness at boundary conditions
- Reduced friction and wear
- Lubricity and micropitting resistance
- Improved cleanliness and varnish control
- Partial bio sourced
- Food grade approved (NSF HX-1)
# Elevance Aria™ WTP 40 Applications

<table>
<thead>
<tr>
<th>Industrial Lubricants</th>
<th>Transportation Lubricants</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Gear</td>
<td>• Axle</td>
</tr>
<tr>
<td>• Compressor</td>
<td>• Engine Oil</td>
</tr>
<tr>
<td>• Hydraulic</td>
<td>• Transmission</td>
</tr>
<tr>
<td>• Food Grade</td>
<td>• Grease</td>
</tr>
<tr>
<td>• Metalworking</td>
<td></td>
</tr>
<tr>
<td>• Grease</td>
<td></td>
</tr>
</tbody>
</table>

---

STLE 2018, Commercial Marketing Forum, Minneapolis, MN
Elevance Aria™ WTP 40
Properties
Elevance Aria™ WTP 40 Properties

Combines chemical and physical properties of PAO and ester into a single base stock

<table>
<thead>
<tr>
<th>Property</th>
<th>T7M15T729</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kv, cSt @ 100C</td>
<td>39.63</td>
</tr>
<tr>
<td>Kv, cSt @ 40C</td>
<td>348.3</td>
</tr>
<tr>
<td>VI</td>
<td>165</td>
</tr>
<tr>
<td>Pour Point, C D-97</td>
<td>-36</td>
</tr>
<tr>
<td>Flash, C, D-92</td>
<td>266</td>
</tr>
<tr>
<td>Specific Gravity (60F)</td>
<td>0.883</td>
</tr>
<tr>
<td>Color, APHA</td>
<td>28</td>
</tr>
<tr>
<td>Moisture, ppm, KF</td>
<td>62</td>
</tr>
<tr>
<td>TAN, mg/g KOH, D-974</td>
<td>0.02</td>
</tr>
<tr>
<td>Brookfield Viscosity @ -26C, cP</td>
<td>92,700</td>
</tr>
<tr>
<td>Aniline Point, C</td>
<td>103.5</td>
</tr>
</tbody>
</table>
WTP 40 Balanced Solvency Enables Robust Formulations

Balanced aniline point for improved formulation compatibility and performance

Test Method: ASTM D611
WTP 40 Provides Additive Solvency and Compatibility

Clarity, brightness and color demonstrate excellent solubility of additives

Base Stocks + 6% Add Pack = Fully Formulated GL-5 Gear Lubricant

WTP 40 PAO 40 PAO 40 / 10%ester

WTP 40 PAO 40 PAO 40 / 10%ester

No compatibilizers added  Compatibilizers
Formulation Simplicity Through Elimination of Ester

<table>
<thead>
<tr>
<th></th>
<th>Conventional</th>
<th>Elevance Aria™</th>
</tr>
</thead>
<tbody>
<tr>
<td>WTP 40 (%)</td>
<td>--</td>
<td>83.0</td>
</tr>
<tr>
<td>PAO 40 (%)</td>
<td>83.0</td>
<td>--</td>
</tr>
<tr>
<td>PAO 4 (%)</td>
<td>4.32</td>
<td>14.32</td>
</tr>
<tr>
<td>Ester (%)</td>
<td>10.0</td>
<td>--</td>
</tr>
<tr>
<td>Additive package (%)</td>
<td>2.68</td>
<td>2.68</td>
</tr>
<tr>
<td><strong>Kv @ 100C</strong></td>
<td>25.83</td>
<td>27.13</td>
</tr>
<tr>
<td><strong>Kv @ 40C</strong></td>
<td>230.2</td>
<td>220.2</td>
</tr>
<tr>
<td><strong>VI</strong></td>
<td>150</td>
<td>158</td>
</tr>
<tr>
<td><strong>Bv @ -26C, cP</strong></td>
<td>49,600</td>
<td>40,200</td>
</tr>
<tr>
<td><strong>Demulsibility @ 82C</strong></td>
<td>43/37/0 (10)</td>
<td>43/37/0 (15)</td>
</tr>
<tr>
<td><strong>Seal Compatibility (NBR-VDA) 168 hrs @100C</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Volume Change, %</td>
<td>4.95</td>
<td>1.94</td>
</tr>
<tr>
<td>Points Hardness Change</td>
<td>-1</td>
<td>1</td>
</tr>
<tr>
<td>Tensile Strength Change, %</td>
<td>-13.4</td>
<td>-7.8</td>
</tr>
<tr>
<td>Elongation Change, %</td>
<td>-40.2</td>
<td>-36.3</td>
</tr>
</tbody>
</table>
Elevance Aria™ WTP 40
Performance Comparisons
WTP 40 Performance

Better boundary lubrication / Lower Friction

Mini-Traction-Machine (MTM)

- Heater block
- Load: Variable Force
- Test fluid

Disc / ball rotation (variable speed)
Measure Friction coefficient $f_c$ vs.

Entrainment speed or Slide to Roll Ratio

<table>
<thead>
<tr>
<th>Test Conditions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Contact Pressure, GPa (37N Load)</td>
</tr>
<tr>
<td>1.2</td>
</tr>
</tbody>
</table>

(stainless steel (AISI 52,100)
WTP 40 Shows Reduced Friction and Wear vs. PAO/ester

Improved friction and wear when compared to PAO 40/ester

Friction performance at 80C

Wear performance at 80C

MTM Data
WTP 40 Gives Increased Film Thickness at Low Speeds

Demonstrates better boundary lubrication compared to PAO 40

*EHL test was done by Dr. Girma Biresaw, USDA
WTP 40 Demonstrates Less Micro-pitting in Screener Tests

**Elevance Aria™ WTP 40 base stock shows reduced tendency micropitting when compared to PAO 40**

Micropitting Test Rig (MPR)
PCS Instruments

- Temperature = RT - 135°C
- Velocity = 0 - 4m/s
- Load = 0 – 1250N (3GPa)
- SRR = 0 - 200%
- ~1x10^6 contact cycles/hour
Micropitting Screener

Micropitting Test Rig (MPR)
Test Roller

Pretest

Micropitting
WTP 40 Advantage

MPR Test Conditions - to mimic wind turbine

- Temperature = 90°C
- Velocity = 3 m/s
- Load = Varies based on track width
- SRR = 20%
- Time = Four 1 hour intervals
- Ring and Roller Material = 16MnCr5
- Oils:
  - Elevance Aria WTP 40
  - PAO40

Low and stable vibration predictive of micropitting wear resistance
WTP 40 Advantage

WTP 40 shows reduced micropitting as evidenced by no horizontal blue wear scars

- Post Test Roller Roughness and Wear Comparisons

PAO 40 Base

WTP 40 Base
WTP 40 Lubricity

- Conditions
  - 1000 rpm
  - 5 wt% total additive in Oil
  - 14.3 mm depth

WTP 40 can be used as an additive

Microtap Testing
Forming Tap 6061 Al

<table>
<thead>
<tr>
<th>Torque Avg (N\text{*}cm)</th>
<th>T-22</th>
<th>SO</th>
<th>SO / ZDTP</th>
<th>ZDTP</th>
<th>SO</th>
<th>SO / WTP40</th>
<th>WTP 40</th>
</tr>
</thead>
<tbody>
<tr>
<td>5 wt%</td>
<td>190</td>
<td>180</td>
<td>170</td>
<td>160</td>
<td>150</td>
<td>140</td>
<td>130</td>
</tr>
</tbody>
</table>
WTP 40 Advantage

Long chain ester provides thicker more durable film

Strong, thicker adsorbed film, due to large polar molecules and intermolecular attractions which can stand higher load and shear at contacts.

Thinner adsorbed film due to small ester molecules and is easily to broken down and removed at contacts.
# WTP 40 in GL-5 Gear Oil Enhances System Cleanliness

**Impressive varnish reduction demonstrated vs. PAO 40/ester blends**

<table>
<thead>
<tr>
<th></th>
<th>GL-5 Spec</th>
<th>PAO 40/ester</th>
<th>WTP 40</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Adipate</td>
<td>TMP</td>
</tr>
<tr>
<td>Sludge</td>
<td>&gt;9.4</td>
<td>9.7</td>
<td>9.7</td>
</tr>
<tr>
<td>% Visc Inc.</td>
<td>&lt;100</td>
<td>7</td>
<td>8</td>
</tr>
<tr>
<td>Varnish</td>
<td>&gt;7.5</td>
<td>7.5</td>
<td>7.7</td>
</tr>
</tbody>
</table>

*Automotive Gear Oil Oxidation Test, L-60-1 (ASTM D5704)*
Key Takeaways

- Lanxess has successfully produced our first batch of Elevance Aria™ WTP 40 for commercial sales.
- Elevance Aria™ WTP 40 is a high viscosity base stock that can help meet today’s lubricant demands for severe industrial and transportation applications.
- The molecular design of WTP 40, with chemically-bound ester, provides improved performance due to its inherent polarity and its stronger and thicker adsorbed fluid film under boundary conditions.
- These features can help provide advantages over simple PAO/ester blends in friction and wear performance, cleanliness and provides formulation simplicity.
LANXESS
Energizing Chemistry

Booth 127 / 129
Sales contact: David Stonecipher
email: david.stonecipher@lanxess.com  phone:+1 440-522-8405