Meet market demands for high-performance lubricant products with new additive and base oil chemistry

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Industrial lubricants and where performance matters the most

Finished lubricant volume: 14 million mt (2018)
Outline

- Challenges for industrial gear oils
  - Impact of hydraulic fluids on equipment performance
  - Hydraulic fluid performance demonstration
These are some of the most challenging industrial applications:

- Steel
- Mining
- Cement
- Wind Power
Different applications – similar demands - same need for fluid performance

Mining

Operating conditions
- Extreme loads
- Contaminants: dust, debris, water

Demands on oil
- Extreme pressure and anti-wear performance
- Corrosion protection
- Low temperature fluidity

Steel

Operating conditions
- High ambient temperature
- Heavy loads and wet conditions

Demands on oil
- Extreme pressure and anti-wear performance
- Rust and corrosion protection
- High flash point

Wind Energy

Operating conditions
- Arid/humid, cold/hot climate
- Long service intervals

Demands on oil
- Sufficient film strength and micro-pitting protection
- Excellent oxidative stability
- Low temperature fluidity
Engineering trends define the requirements for industrial gear oils

- New materials
- Surface finishing
- Lower oil volume
- High torque and high loads
- Increased power density
- High bearing temperature
- Micropitting protection
- Seal compatibility
- Oxidative and thermal stability
Why do synthetic fluids offer improved performance and high efficiency?

Colder temperatures
- Lower churning losses
- Lower friction
  → Improved mechanical efficiency
  → Better cold start behavior

Warmer temperatures
- Less leakage
- Increased film thickness
  → Improved equipment protection
Approaches to formulating high performance industrial gear oils

- Mostly formulated with non-polar base fluids
  - 6 or 8 cSt polyalphaolefin (PAO) as base fluid
  - High-viscosity PAO (e.g. PAO 100) to adjust viscosity to the desired level
  - Addition of ester (10-20%) is necessary to provide package compatibility → can cause hydrolytic stability and seal swelling issues

- Base fluid system can also be polar
  - Polyalkylene glycols (PAG) → not miscible with other base fluids

- High-viscosity base fluids with well-balanced polarity
  - Performance advantages in combination with Group III base oil or PAO
  - Excellent additive package, seal and coatings compatibility, in particular in combination with PAO
Performance benefits of synthetic fluids

- **High viscosity index**
  - Viscosity control across operating temperatures
  - Excellent cold start properties
  - Equipment protection at high temperature

- **Thermal and oxidative stability**
  - Extended fluid service life

- **Reduced frictional losses**
  - Higher efficiency
  - Lower operating temperature → longer equipment life

- **Well-balanced polarity**
  - Highly compatible with a wide range of base fluids and additive systems
**High performance OEM approved formulations**

<table>
<thead>
<tr>
<th></th>
<th>Viscosity Index (mm²/s)</th>
<th>Pour Point (°C)</th>
<th>Flash Point (°C)</th>
<th>Benefit</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>VISCObASE® 5-220</strong></td>
<td>VG 150: 28.4</td>
<td>VG 220: 37.0</td>
<td>VG 320: 45.1</td>
<td>KG 460: 51.5</td>
</tr>
<tr>
<td></td>
<td>VG 680: 58.5</td>
<td></td>
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<td></td>
</tr>
<tr>
<td><strong>NEXBASE® 3080</strong></td>
<td>%wt 68.25</td>
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<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Grp III oil lowers formulation cost</td>
</tr>
<tr>
<td><strong>VISCOpLEX® 1-180</strong></td>
<td>%wt 0.7</td>
<td></td>
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<tr>
<td><strong>VISCOpLEX® 14-520</strong></td>
<td>%wt 0.2</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Afton HITEC® 307</td>
<td>%wt 2.65</td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>KV 40</strong></td>
<td>mm²/s 151</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>KV 100</strong></td>
<td>mm²/s 20.6</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Viscosity index</strong></td>
<td>mm²/s 159</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Pour point</strong></td>
<td>°C -39</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Flash point</strong></td>
<td>°C &gt;220</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Some of the most severe tests can only be passed by synthetic fluids

- FE-8 roller bearing test
- FAG Schaeffler 4-step-test
- Filterability test
- Coatings compatibility tests
- Micropitting test FVA 54/7
- Seal compatibility tests
  - Static or dynamic
  - Liquid seal tests
- Scuffing tests
- SKF Non-metal bearing cage compatibility
Performance demonstrations in different applications

**Water Treatment**
- Sebokeng water care works, South Africa

**Mining Industry**
- Mooiplaas dolomite quarry, South Africa

**Wind Turbines**
- USA, Europe, Asia Onshore/offshore

**Inhouse**
- RAG, Germany
Wind turbine gear oils and their special requirements

Wind turbine gearbox

- Often uses a 3-step transmission, consisting of planetary and spur gears
- Typically lubricated by ISO VG 320 gear oil (300–1000 l, depending on power and size)
- Oil drain every 3..5 years, targeting >7 years

Wind turbine gear oils must pass demanding tests

- Micropitting test (grey staining)
- FZG scuffing test (at two different loads)
- FAG FE-8 four stage test (steel/steel & steel/brass)
- Static elastomer test (NBR @100°C, FKM @110°C)
- Freudenberg dynamic elastomer test
- Flender foam test (also with corrosion preventive contamination)
- …and many others

Source: Repower Systems AG
Comparison of fluids in a Moventas gear box

- Test setup consisted of two PLH-1400 gearboxes that were run back-to-back
- One gearbox was filled with a gear oil using novel base oil technology and the other with a commercial PAO gear oil
- Temperature was measured at 8 spots, oil pressure was measured at 3 spots
- Gears were painted to examine the contact patterns:
  - No abnormal behavior
  - No hard end contacts
  - No marks of particles
  - No sludge or varnish
  - Improved cleanliness
## Performance comparison of industrial gear oil technologies

<table>
<thead>
<tr>
<th></th>
<th>Thermal efficiency</th>
<th>Bearing protection</th>
<th>Micropitting protection</th>
<th>Additive compatibility</th>
<th>Total fluid cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mineral based</td>
<td>Low</td>
<td>Medium</td>
<td>Medium</td>
<td>High</td>
<td>Low</td>
</tr>
<tr>
<td>PAO based</td>
<td>High</td>
<td>High</td>
<td>Medium</td>
<td>Low</td>
<td>High</td>
</tr>
<tr>
<td>New technology</td>
<td>High</td>
<td>High</td>
<td>High</td>
<td>High</td>
<td>Medium</td>
</tr>
</tbody>
</table>
Outline

- Challenges for industrial gear oils
- Impact of hydraulic fluids on equipment performance
- Hydraulic fluid performance demonstration
Hydraulic fluids represent a highly fragmented market

Finished lubricant volume: 5 million mt (2018)
Industrial efficiency has many faces

- Oil drain interval
- Fuel economy
- Fast system response
- Productivity
- Extended wear protection
- Machine uptime
- Noise level
- Fast start-up
The requirements vary with the application…

<table>
<thead>
<tr>
<th>Manufacturing equipment</th>
<th>Mobile construction equipment</th>
<th>Special application: door closer</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Equipment availability</td>
<td>• High productivity</td>
<td>• Long life</td>
</tr>
<tr>
<td>• Long oil drain interval</td>
<td>• Good cold start behavior</td>
<td>• Good seal compatibility</td>
</tr>
<tr>
<td>• Wear protection</td>
<td>• Wide temperature range</td>
<td>• Low foam and good air release</td>
</tr>
<tr>
<td>• Maximized energy efficiency</td>
<td>• High fuel efficiency</td>
<td>• Low noise</td>
</tr>
<tr>
<td>• Precision</td>
<td></td>
<td>• Wide temperature range</td>
</tr>
</tbody>
</table>
…but the right lubricant can meet many challenges

Lubricants consist of base oils and additives

- Base oils define the basic properties of the lubricant
- Additives determine the full range of performance

<table>
<thead>
<tr>
<th>Base oil</th>
<th>Additives</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Viscosity index (VI) improver</td>
</tr>
<tr>
<td></td>
<td>Antiwear additive</td>
</tr>
<tr>
<td></td>
<td>Corrosion inhibitor</td>
</tr>
<tr>
<td></td>
<td>Antioxidant</td>
</tr>
<tr>
<td></td>
<td>Pour point depressant (PPD)</td>
</tr>
<tr>
<td></td>
<td>Demulsifier</td>
</tr>
<tr>
<td></td>
<td>Anti-foam agent</td>
</tr>
</tbody>
</table>

Performance package

Typical treat rate 0.5-3.0 %
Protection against wear and corrosion is guaranteed through OEM approvals

<table>
<thead>
<tr>
<th>Denison HF-0</th>
<th>Bosch Rexroth RDE 90235</th>
<th>Eaton E-FDGN-TB002-E</th>
</tr>
</thead>
</table>

- Hybrid piston/vane pump
- Up to 280 bar at 1,700 rpm
- 608 hours
- Dry and wet phase
- Very sensitive to corrosion

- Piston pump and piston motor
- Up to 500 bar at 4,000 rpm
- 510 hours
- Dry
- Severe shear requirements

- Vane pump
- Up to 207 bar at 2,400 rpm
- 3*50 hours
- Dry
- Sensitive to wear
Performance and efficiency

Viscosity Index = width of Temperature Operating Window

<table>
<thead>
<tr>
<th>High tier monograde fluids</th>
<th>Top tier multigrade fluids</th>
</tr>
</thead>
<tbody>
<tr>
<td>VI ~ 110…130</td>
<td>VI ~ 160…200</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Conventional monograde fluids</th>
<th>Conventional multigrade fluids</th>
</tr>
</thead>
<tbody>
<tr>
<td>VI ~ 100</td>
<td>VI ~ 140…160</td>
</tr>
</tbody>
</table>

Selection of additives and base oils
The temperature operating window of hydraulic fluids

- ISO VG 32
  - VI 100
  - VI 160

- ISO VG 46
  - VI 100
  - VI 160

Temperature/ °C

-20  0   20  40  60  80  100
Power losses in hydraulic systems - balance is essential

Power losses at low viscosity
- Internal leakage
- External leakage
- Poor lubrication
- Compressibility

Power losses at high viscosity
- Hydrodynamic friction
- Churning losses
Criteria for energy efficient high VI hydraulic fluids

<table>
<thead>
<tr>
<th>Performance requirement</th>
<th>Comment</th>
<th>Unit</th>
<th>ISO VG 32</th>
<th>ISO VG 46</th>
<th>ISO VG 68</th>
</tr>
</thead>
<tbody>
<tr>
<td>Viscosity index</td>
<td>Fresh oil</td>
<td></td>
<td>-</td>
<td>&gt; 160</td>
<td></td>
</tr>
<tr>
<td>Shear stability</td>
<td>KV100 after 40 min sonic shear</td>
<td>mm²/s</td>
<td>&gt;5.9</td>
<td>&gt;7.5</td>
<td>&gt;10.0</td>
</tr>
<tr>
<td>Low temperature viscosity</td>
<td>Brookfield viscosity</td>
<td>mPa·s</td>
<td>&lt;750</td>
<td>&lt;750</td>
<td>&lt;750</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>at -15°C</td>
<td>at -8°C</td>
<td>at -2°C</td>
</tr>
</tbody>
</table>

![ISO VG 32](image1)

![ISO VG 46](image2)

![ISO VG 68](image3)
Outline

- Challenges for industrial gear oils
- Impact of hydraulic fluids on equipment performance
- Hydraulic fluid performance demonstration
What are the limiting factors to productivity?

Construction and mining

- Volumetric losses limit the speed and maximum payload of the equipment
- Hydromechanical losses delay equipment start-up
- Frequent maintenance and oil drains cause downtime

Rubber processing

- Oil heat-up limits the power output of the equipment

Manufacturing

- Pack and hold time in plastics injection molding
- Dynamics of the hydraulic unit (e.g. injection molding fast runner, dynamic presses and cutters)
Hydraulic fluid performance demonstration

Equipment

- Two hydraulic excavators using axial piston pumps
- Two dump trucks, on-site truck scale, wheel loader
- Test phases: truck loading and digging at 90° and 180°

Parameter variations

- Two operators
- Four different oil temperature ranges
- Test sequence A-B-A under repeatable conditions

Statistical analysis

- Thorough statistical evaluation of the performance of 19 different hydraulic fluids
Example truck loading at 90° swivel angle

High VI oil
ISO VG 46

Low VI oil
ISO VG 46
(Reference)

Increase in Productivity: 18%

122 seconds
144 seconds
Example truck loading at 90°/180° swivel angle

Results from 128 truck loadings per oil with statistical analysis

90° swivel angle
Productivity (tons/hour)

180° swivel angle
Productivity (tons/hour)

Increase in
Productivity: 15-18%
Performance demonstration results: shear stability

<table>
<thead>
<tr>
<th></th>
<th>Test fluid 1</th>
<th>Test fluid 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reference fluid</td>
<td>ISO 46 – VI 100</td>
<td></td>
</tr>
<tr>
<td>Test fluids</td>
<td>ISO 46 – VI 170 poor shear stability</td>
<td>ISO 46 – VI 170 excellent shear stability</td>
</tr>
<tr>
<td>Type of work</td>
<td></td>
<td>Digging &amp; Truck loading</td>
</tr>
<tr>
<td>Efficiency improvement (☉)</td>
<td>3%</td>
<td>13%</td>
</tr>
<tr>
<td>Productivity improvement (☉)</td>
<td>4%</td>
<td>16%</td>
</tr>
</tbody>
</table>

A combination of **good shear stability** and a **high VI** of the fluid can significantly increase efficiency and productivity.
Conclusion

High performance industrial lubricants offer a wide range of benefits over conventional fluids

- Increased productivity
- Longer oil drain interval
- Improved system durability and machine life extension
- Lower energy/fuel consumption
- Reduced operating temperature (e.g. bearings)
- Improved gearbox cleanliness
- Avoidance of costly downtime losses

Thank you for your attention.