The Role of VI Improvers in the Formulation of Fuel Efficient Engine Oils with Long Drain Intervals

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KSTLE Lubricants SYMPOSIUM
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1) Importance of Fuel Economy
2) Which Parameter Influence FE
3) Comb Polymers
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5) Results from NEDC FE Testing
6) Summary and Conclusion
Importance of Fuel Economy
Consumer: EPA New Fuel Economy Label

- This new label provides more comprehensive fuel efficiency information and five-year fuel costs or savings compared with the average vehicle, as well as environment impact information.
Historical fleet CO2 emissions performance and current or proposed standards

Source: ICCT, Global Comparison of Light-Duty Vehicle Fuel Economy/GHG Emissions Standards, Update: June 2012

[1] China’s target reflects gasoline vehicles only. The target may be lower after new energy vehicles are considered.

US-LDV | Canada-LDV | EU | Japan | China | S. Korea | Mexico

Historical fleet fuel economy performance and current or proposed standards

Source: ICCT, Global Comparison of Light-Duty Vehicle Fuel Economy/GHG Emissions Standards, Update: June 2012

[1] China’s target reflects gasoline vehicles only. The target may be higher after new energy vehicles are considered.
How to Measure Fuel Economy 
Current Status per Region

Source: Naitoh, SAE Asia 2009 Open Forum, March 4, 2009

Combined FE = 1/(0.55/FE[City] + 0.45/FE[Highway])

Source: Akiyama et.al., SAE932690

Source: Ando, Lubricants Russia 2010

JP JC08 mode (Current)

Source: Naitoh, SAE Asia 2009 Open Forum, March 4, 2009
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Which Parameter Influence Fuel Economy

- Sheared high temperature (KV100) viscosity
- HTHS at various temperatures
- KV40
- DI package chemistries
- Friction modifier
- Viscosity modifier
- High VI polymers, high VI PAMA
- Key is viscosity (plus e.g. FM)

However, correlation between these parameters and real life improvements in Fuel Economy is not straightforward
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Comb Polymer

- Linear
- Star
- Comb
- Hyperbranched
- Network
Improved V/T Performance of Comb vs. PAMA at Same PSSI
Benefit of the V/T Improvement for Engine Oil Application

- Lowering viscosity to achieve FE, while keep engine durability

Log log viscosity, e.g., HTHS vs. Log temperature

Low viscosity oil

Engine Durability

• Lowering viscosity to achieve FE, while keep engine durability
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Targets for Blend Study

Investigate the role of VI improve to formulate fuel efficient engine oils

- HTHS limit at 150°C
- 2.6; 2.9; 3.5 mPa.s
- NOACK limit
- DI package A
- Group III base oil
- Different VIIs
- Different SSI
- Different chemistry

Formulated fluids which best Viscosity/Temperature (V/T) performance
Investigated VII for Blend Study

<table>
<thead>
<tr>
<th>VII</th>
<th>SSI*</th>
<th>Architecture</th>
</tr>
</thead>
<tbody>
<tr>
<td>Comb</td>
<td>4</td>
<td></td>
</tr>
<tr>
<td>PAMA</td>
<td>23, 45</td>
<td></td>
</tr>
<tr>
<td>dPAMA</td>
<td>45</td>
<td></td>
</tr>
<tr>
<td>HE-OCP</td>
<td>25</td>
<td></td>
</tr>
<tr>
<td>LE-OCP</td>
<td>25</td>
<td></td>
</tr>
<tr>
<td>HIS Star</td>
<td>25</td>
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</tbody>
</table>

- Base stock: Group III
- DI package A

* Bosch 30 cycle
Blend Study – Part 1

- Comb and PAMA lowest KV 40C at given/different HTHS level
Blend Study – Part 2

- Comb and PAMA lowest KV 100C & HTHSV 100C at given HTHS level
• Comb lowest HTHSV 100C at given HTHS level although almost no vis. down by permanent share
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Car for NEDC Testing

*Daimler CGI 350*
How to Measure Fuel Economy
EU: NEDC

<table>
<thead>
<tr>
<th>Characteristics</th>
<th>Unit</th>
<th>ECE 15</th>
<th>EU DC</th>
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<tbody>
<tr>
<td>Distance</td>
<td>km</td>
<td>4×1.013=4.052</td>
<td>6.955</td>
</tr>
<tr>
<td>Duration</td>
<td>s</td>
<td>4×195=780</td>
<td>400</td>
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<tr>
<td>Average Speed</td>
<td>km/h</td>
<td>18.7 (with idling)</td>
<td>62.6</td>
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<tr>
<td>Maximum Speed</td>
<td>km/h</td>
<td>50</td>
<td>120</td>
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Repeatability of Test

Standard fluid

%age of extra fuel saved compared to test average

run a
run b
run c
run d
run e
## Blend Data for NEDC Testing

<table>
<thead>
<tr>
<th>DI Package</th>
<th>B</th>
<th>B</th>
<th>B</th>
<th>B</th>
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<tbody>
<tr>
<td>VII</td>
<td></td>
<td></td>
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<tr>
<td>Comb</td>
<td>X</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>D-PAMA</td>
<td>-</td>
<td>X</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>HSI Star</td>
<td>-</td>
<td>-</td>
<td>X</td>
<td>-</td>
</tr>
<tr>
<td>LE-OCP</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>X</td>
</tr>
<tr>
<td><strong>Base Oil</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4 cSt group III</td>
<td>X</td>
<td>X</td>
<td>X</td>
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### Viscometrics

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<th>B</th>
<th>B</th>
<th>B</th>
<th>B</th>
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</thead>
<tbody>
<tr>
<td>HTHS @ 150°C</td>
<td>3.5</td>
<td>3.5</td>
<td>3.5</td>
<td>3.5</td>
</tr>
<tr>
<td>Viscosity at 40°C, cSt</td>
<td>42.86</td>
<td>66.57</td>
<td>78.62</td>
<td>70.45</td>
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<tr>
<td>Viscosity at 100°C, cSt</td>
<td>10.94</td>
<td>13.79</td>
<td>13.52</td>
<td>12.02</td>
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<tr>
<td>Viscosity Index</td>
<td>259</td>
<td>216</td>
<td>176</td>
<td>168</td>
</tr>
<tr>
<td>CCS Viscosity @ -30°C, cP</td>
<td>4025</td>
<td>4427</td>
<td>4542</td>
<td>5487</td>
</tr>
<tr>
<td>MRV @ -35°C, cP</td>
<td>9010</td>
<td>9100</td>
<td>30500</td>
<td>17000</td>
</tr>
<tr>
<td>MRV @ -40°C, cP</td>
<td>19700</td>
<td>18500</td>
<td>104500</td>
<td>33700</td>
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<tr>
<td>Yield Stress</td>
<td>&lt;35</td>
<td>&lt;35</td>
<td>&lt;70</td>
<td>&lt;35</td>
</tr>
</tbody>
</table>
Fuel Economy Data – NEDC
Fuel Economy Improvement vs Oil Viscosity

* All of Oils HTHSV150C were set to 3.5mPa.s
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Summary and Conclusion

- FE hot topic for the whole industry from OEM to consumer
- Different ways to measure FE → World harmonized test in the future?
- Different parameter are important for FE
- Lowering viscosity is key for FE → more accepted through the industry
- Lower viscosities over viscosity range and keep HTHS level high (high VI)
- FE ranking: Comb > PAMA > LE-OCP > HIS Star
- Future: oil is seen as a design element for new engine technologies
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