Characterization and Refinery Processing of Partially-upgraded Bitumen

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JGC Corporation
Outline

- Background
- Properties of Partially Upgraded Product
- Characterization
  - Olefin Saturation by Hydrotreating
  - Olefin Analysis
- Refinery Processing
  - Compatibility Test
  - Heat Exchanger Fouling
  - Desalting Performance
- Summary
Heavy Oil Transportation

- Diluent shortage
- High diluent price

- Complex scheme
- Large oil field

- Simple scheme
- No diluent
Partial Upgrading of Bitumen

◆ Advantage over Dilution
  ◆ Diluent cost can be reduced
  ◆ Pipeline size can be reduced
  ◆ Environmentally safe (diluent easily vaporized)

◆ Advantage over Full Upgrading
  ◆ Lower capital cost
  ◆ Smaller footprint
  ◆ Smaller by-product
## Ongoing Partial Upgrading Project

<table>
<thead>
<tr>
<th>Process</th>
<th>(Licensor)</th>
<th>Process type</th>
</tr>
</thead>
<tbody>
<tr>
<td>CCU</td>
<td>(UOP)</td>
<td>RFCC</td>
</tr>
<tr>
<td>HTL</td>
<td>(Ivanhoe)</td>
<td>Thermal (Coking)</td>
</tr>
<tr>
<td>I(^\gamma)Q</td>
<td>(ETX)</td>
<td>Thermal (Coking)</td>
</tr>
<tr>
<td>HI-Q</td>
<td>(MEG)</td>
<td>Thermal + SDA</td>
</tr>
<tr>
<td>Eureka</td>
<td>(Chiyoda)</td>
<td>Thermal</td>
</tr>
<tr>
<td>HSC</td>
<td>(TEC)</td>
<td>Thermal</td>
</tr>
<tr>
<td>SDA</td>
<td>(KBR)</td>
<td>SDA</td>
</tr>
<tr>
<td>SCWC</td>
<td>(JGC)</td>
<td>Thermal + Extraction</td>
</tr>
</tbody>
</table>

- Many partial upgrading technologies are existing
- Most of them are thermal cracking and/or extraction (SDA)
# Properties of Partially-upgraded Bitumen

**SCO produced by thermal cracking and extraction**
(5BPD scale pilot plant, SCO yield : ~70vol%)

<table>
<thead>
<tr>
<th>ANALYSIS</th>
<th>METHOD</th>
<th>UNIT</th>
<th>Upgraded Bitumen</th>
<th>TARGET</th>
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<tbody>
<tr>
<td>OLEFIN</td>
<td>1H-NMR</td>
<td>wt%</td>
<td><strong>3.67</strong></td>
<td>&lt;1.0</td>
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<tr>
<td>DENSITY</td>
<td>ASTM D4052</td>
<td>g/ml</td>
<td>0.9166</td>
<td></td>
</tr>
<tr>
<td>API</td>
<td></td>
<td>°</td>
<td><strong>22.9</strong></td>
<td>&gt; 19</td>
</tr>
<tr>
<td>KINETIC VISCOSITY</td>
<td>@ 10C (Calc.)</td>
<td>cSt</td>
<td><strong>32.1</strong></td>
<td>&lt; 350</td>
</tr>
<tr>
<td>Sulfur</td>
<td>ASTM D4294</td>
<td>wt%</td>
<td>3.23</td>
<td></td>
</tr>
<tr>
<td>SATURATES</td>
<td>ASTM D2007M</td>
<td>wt %</td>
<td>37.2</td>
<td></td>
</tr>
<tr>
<td>AROMATICS</td>
<td></td>
<td>wt %</td>
<td>37.3</td>
<td></td>
</tr>
<tr>
<td>POLARS</td>
<td></td>
<td>wt %</td>
<td><strong>9.9</strong></td>
<td></td>
</tr>
<tr>
<td>ASPHALTENE</td>
<td>ASTM D4055M</td>
<td>wt %</td>
<td>0.05</td>
<td></td>
</tr>
<tr>
<td>-360°C</td>
<td>ASTM D2887</td>
<td>wt%</td>
<td>55</td>
<td></td>
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<tr>
<td>360-540°C</td>
<td></td>
<td>wt%</td>
<td>41</td>
<td></td>
</tr>
<tr>
<td>540°C+</td>
<td></td>
<td>wt%</td>
<td><strong>4</strong></td>
<td></td>
</tr>
<tr>
<td>MCRT</td>
<td>ASTM D4530</td>
<td>wt%</td>
<td>0.5</td>
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</tr>
<tr>
<td>TAN</td>
<td>ASTM D664</td>
<td>mg KOH/g</td>
<td>2.87</td>
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</tr>
<tr>
<td>DIENE VALUE</td>
<td>UOP326</td>
<td>g I2/100g</td>
<td>1.94</td>
<td></td>
</tr>
</tbody>
</table>
Properties of Partially-upgraded Bitumen

SCO produced by thermal cracking and extraction
(5BPD scale pilot plant, SCO yield : ~70vol%)

<table>
<thead>
<tr>
<th>Fraction</th>
<th>BP</th>
<th>Yield wt%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Naphtha</td>
<td>IBP-200</td>
<td>10</td>
</tr>
<tr>
<td>Distillate</td>
<td>200-343</td>
<td>39</td>
</tr>
<tr>
<td>HGO</td>
<td>343+</td>
<td>51</td>
</tr>
</tbody>
</table>

SCO produced by thermal cracking and extraction (5BPD scale pilot plant, SCO yield: ~70vol%)
Objectives of Study

◆ Investigate product quality of partial upgrading
  ➔ Characterization
    ◆ Olefin Saturation by Hydrotreating
    ◆ Olefin Analysis
  ➔ Refinery Processing
    ◆ Compatibility Test
    ◆ Heat Exchanger Fouling
    ◆ Desalting Performance
Characterization

- Olefin Saturation by Hydrotreating
- Olefin Analyses
Olefin Saturation by Hydrotreating

- Target olefin content: < 1.0wt% (1H-NMR)
- Less hydrogen consumption
  - Less cracking, less desulfurization, less saturation of aromatic compounds
- Maximize liquid yield

- Test unit: bench scale hydrotreating (packed bubble column reactor, 30cc of catalyst)
**Product Quality**

- Target olefin content was achieved at all conditions.
- Lower desulfurization and aromatic saturation were observed at lower temp.
Fraction Yields

- Distillation curve does not change

<table>
<thead>
<tr>
<th>Fraction</th>
<th>BP</th>
<th>FEED STOCK Yield wt%</th>
<th>RUN 2 PRODUCT Yield wt%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Naphtha</td>
<td>IBP-200</td>
<td>10</td>
<td>11</td>
</tr>
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<td>Distillate</td>
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<td>39</td>
</tr>
<tr>
<td>HGO</td>
<td>343+</td>
<td>51</td>
<td>50</td>
</tr>
</tbody>
</table>
Olefin Conversion in Fraction

- Olefin in naphtha and distillate fraction was drastically reduced

```
<table>
<thead>
<tr>
<th></th>
<th>Conversion %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Naphtha</td>
<td>77.2</td>
</tr>
<tr>
<td>Distillate</td>
<td>74.2</td>
</tr>
<tr>
<td>HGO</td>
<td>≈ 100</td>
</tr>
</tbody>
</table>
```

Olefin Conversion in Fraction

- Naphtha: 77.2 wt%
- Distillate: 74.2 wt%
- HGO: ≈ 100 %
Detail Analysis for Olefin in Naphtha

- **Naphtha (IBP-200°C):** GCxGC, TOF-MS

**Alkenes**

- Alkenes in naphtha were reduced significantly.

**Diene/Cycloalkenes**

- Diene/Cycloalkenes were reduced only close to 50%.
Detail Analysis for Olefin in Distillate

Distillate (200-343°C): HPLC, GCxGC, TOF-MS

- Alkenes in distillate were reduced significantly
- Diene/Cycloalkenes slightly increased.
  → Cycloalkenes were formed by hydrogenation of aromatics??
Characterization of Olefin

- Olefin target (<1.0wt%) can be achieved at various operating conditions.
- Lower temperature would be preferred to reduce hydrogen consumption.
- Olefin is concentrated mostly in naphtha.
- Alkenes in naphtha and distillate were reduced significantly by hydrotreating.
Refinery Processing

- Compatibility Test
- Heat Exchanger Fouling
- Desalting Performance
Test Method for Compatibility Test

- Test Method: Wiehe’s oil compatibility model
  - $I_N$: Insolubility number
  - $S_{BN}$: Solubility blending number
- Blending partially-upgraded Bitumen (SCO) with WCS
Blended samples were compatible at any ratios.
Test Method for Fouling Evaluation

- Test unit: Alcor unit
- Test conditions: 400°C, 4 hours
- Criterion for fouling
  - [Defined by Brons, (400°C, 3 hours)]
    - Low fouling: ΔT < 15°C
    - Medium fouling: 15°C < ΔT < 30°C
    - High fouling: ΔT > 30°C
  - [Defined by Shell Canada, (400°C, 4 hours)]
    - Low fouling: %F < 23%
Equipment for Fouling Evaluation

Schematic diagram of experimental unit

- Spent Sample
- Fresh Sample
- PUMP
- Heating Section
- TC1 (Inlet)
- TC2 (Outlet)
- TC3 (Heated Tube)
- TC4 (Room Temp)
- Heater Tube
- Outlet Temp (To)
- Movable TC (Ts)
Temperature Trend during Test

Sample: SCO before hydrotreating

$\Delta T = 10^\circ C$

$\Delta T=10^\circ C$ is defined as low fouling
Test Method for Desalting

- Test Method: Mixing and Settling Test
- Sample: 20ml of water and 80ml of oil
- pH 5~8
Separation was carried out within 5 minutes at various pH.

Water in oil were 0.18~0.25%.
<Characterization>
◆ Olefin target can be achieved by hydrotreating.
◆ Olefin is concentrated mostly in the naphtha.

<Refinery Processing>
◆ No problem was found for blending, fouling tendency or desalting performance with SCO before hydrotreating.

This study will be continued for understanding about quality of cracked products
Acknowledgement

◆ This study was consulted by OMNICON Consultants Inc..

◆ Hydrotreating, heat exchanger fouling tests and analytical works were performed by CanmetENERGY.

◆ Detail analysis of olefins was performed by NHMFL at FSU.

◆ Desalting test was performed by Nalco Champion.
Test Method for Storage Stability

- Test Method: ASTM D4625 (Accelerated Stability Test)
- Conditions: 43.5°C for 24 weeks
Total insoluble increased with the time.

But leveled off after 12 weeks