BIOGRAPHY

Stefan Romocki
Mobis Energy Inc.

Stefan Romocki is the president of Mobis Energy, a company taking a different approach to bottom of the barrel upgrading, using recoverable nano catalysts. Stefan graduated from the Rotman Commerce program at University of Toronto with a specialization in Economics. He has been working in technical sales and business development in the heavy oil industry for over a decade, with a focus in heavy oil upgrading. He is co-chair of the facilities and upgrading technical committee of the Canadian Heavy Oil Association and was recently recognized for entrepreneurship as a “Leader of Tomorrow” in Calgary Business magazine.

George Rhodey
Mobis Energy Inc.

George Rhodey is the Director, Bitumen and Heavy Oil Projects for Mobis Energy. Mr. Rhodey has BASc. and MASc. Degrees in Chemical Engineering from the University of Waterloo, Waterloo Ontario. He is a member of APPEGA, the Canadian Heavy Oil Association. His experience includes participation in development and implemented of a major NGL strategy for PetroCanada including an MTBE plant, ICG, centralized fractionation, and a development proposal to build a petrochemical complex using upgrader off gas as feedstock. Through his 40 years of experience, Mr. Rhodey has worked in the petrochemical and oil refining sectors in roles ranging from operating, marketing, and business development.

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Mobis HRH Process
Residue Hydroconversion Using a Recoverable Nano-catalyst

Stefan Romocki and George Rhodey
Mobis Energy Inc.

Conventional hydroconversion of residue has been achieved through high pressure, capital intensive processes with significant operating costs associated with maintaining catalyst activity. Despite the usefulness of heterogeneous catalysts in numerous refining processes, their potential for hydroconversion of heavy feeds with high levels of sulfur, nitrogen, resins, asphaltenes and metals is limited.

This paper will introduce a Pseudo-homogeneous Catalyst (PHC) developed for the specific chemistry of heavy hydrocarbon feeds. The term pseudo-homogeneous reflects the fact that an active catalyst is formed in the reaction system, consisting of particles having a size 2-9nm and properties close to those of a colloid solution at both room and reaction temperature.

Residue processing using a high performance pseudo-homogeneous catalyst system results in improved cracking and hydrogenation performance at lower process severity. The (PHC) system in the Heavy Residue Hydroconversion (HRH) process achieves up to 95% residue conversion at pressure below 7.3 MPa, reaction temperatures between 400 - 460 °C, with feed space velocity between 1.0-2.0 h⁻¹; making (PHC) catalyst systems well suited for deep conversion of hydrocarbon residues.

The sustainability profile of the HRH process is improved as residue conversion to liquids and process on-stream time are maximized, while up to 95% catalyst is recovered and regenerated within the process.

Pilot plant results from hydroconversion of Athabasca vacuum bottoms using a pseudo-homogeneous catalyst system are discussed.

Application of the HRH process in oilsands and refinery operations are discussed with comparative yields and economics.
Mobis HRH Process
Residue Hydroconversion Using a Recoverable Nano-catalyst

NCUT Upgrading & Refining Conference 2009
September 14-16
Agenda

- Background
- Physical and Chemical Basis of the HRH nano-catalyst
- Process Flow Description
- Pilot Plant Data
- Conceptual Yields with HRH
- HRH Projects & Facilities
Who is Mobis Energy?

- Private Canadian Technology Licensing Company
- North American Licensor of the Heavy Residue Hydroconversion
- Focus on Bringing Successful Process Innovation to New Markets
Current Conversion Practices

• Heavy Residue Processing Options;
  • Historical
    • Coking, Residue Hydrocracking and De-asphaltene
  • New Developments
    • Gasification
    • Reservoir Reactor Through Carbon Burn (THAI, CAPRI)

• Most Difficult to Process Molecules are Separated from Lighter, more Valuable Components

• Viability of Hydroprocessing Dependent upon Feedstock (Metals, S, N, Asphaltenes, ...)

Current Conversion Practices

MOBiS ENERGY INC.
Limitations of Conventional Residue Processing

Hydrogen Addition;
- High Investment Cost
- High Operating Costs
- Conversion Limitations
- Catalyst Deactivation

Carbon Rejection;
- Low Liquid Product Yields
- Low Product Quality
- Solid By-product Disposal Issues
Performance Limitations with Conventional Supported Catalysts

- Catalyst Deactivation Through Feed Metal Precipitation and Coking
- Conversion of >525°C Residual Oil Limited by Product Stability (Increased Sedimentation)
- High Gas yield as Conversion is Increased
Conventional Upgrading Processes do not Provide an Economically Effective Solution for Conversion of Residual Oil into Lighter more Valuable Products
Something Innovative... The Mobis HRH Process

Dispersed Nanocatalyst
Up to 95% Residue Conversion
Online Catalyst Regeneration
High Selectivity to Distillates
Hydrocracking at Hydrotreating Pressure

A Fundamentally New Concept
Mobis HRH
Back to First Principles

The Chemistry which Drives Conversion Reactions Takes Place on a Molecular Level
Catalyst Geometry

- **Size Matters!**
  - The Geometry of a Supported Catalyst Limits Access to Reactive Surface Area
  - High Molecular Mass Feed Components Require a Catalyst to be Engineered with Larger Pore Size to Maintain Activity
  - Catalyst Surface Area is Reduced as Pore Size is Increased, Thereby Reducing the Effective Potential of a Catalyst
Ultra-Dispersed Nano-catalyst Tailored for Effective Residual Oil Conversion

- Unsupported Catalyst Structure Tailored from the Atomic Level
- Molecule Sizes 2-9 nm Ensure Maximum Reactive Surface Area
- Catalyst Geometry Provides Effective Contact for Conversion of Asphaltenes and Resins

4 nm MoS\textsuperscript{2} Nanocrystal \textsuperscript{(1)}

Asphaltene Molecule \textsuperscript{(2)}

(2) Proposed Molecular Structure of Asphaltene, INTEVEP S.A. Tech. Rept., 1992
Online Catalyst Regeneration

- Substantially Lower Operating Costs Catalyst is Recovered and Reused
- Reduced Environmental Footprint Approaches Zero Solid Waste
- Constant Catalyst Activity with Unconstrained Time On-Steam
- Eliminates Disposal Liabilities Associated with Spent Catalyst and Coke Handling
HRH – Colloid Chemistry

Mycelium Safety Layer

\[
\text{(NH}_4\text{)}_6\text{Mo}_7\text{O}_{24}4\text{H}_2\text{O}
\]

\[
\text{H}_2\text{O} + \text{H}_2\text{S} = \text{MoS}_2
\]

3-5 nm

\[
\text{MoS}_2 + \text{H}_2 + \text{R} = \text{RH}
\]

Asphaltenes

RRR 1-10 nm

Asphaltene Radicals

R

200-600 nm

Colloid

\[
\text{(NH}_4\text{)}_6\text{Mo}_7\text{O}_{24}4\text{H}_2\text{O}
\]

\[
\text{H}_2\text{O} \rightarrow \text{(NH}_4\text{)}_6\text{Mo}_7\text{O}_{24}
\]

\[
\text{(NH}_4\text{)}_6\text{Mo}_7\text{O}_{24}4\text{H}_2\text{O} \rightarrow \text{MoO}_3
\]

\[
\text{MoO}_3 \rightarrow \text{MoS}_2
\]
Benefits of Improved Molecular Efficiency

- Up to 95% Conversion with Product Stability
- Hydrocracking at Hydrotreating Pressure (1000 psig range)
- Low Gas yield with Selectivity of Conversion to Liquids
- Fewer Process By-products
- Enhanced Throughput – Low Residence Time
- Simple Reactor Design
- Lower Capital, Operating and Maintenance Costs
## Upgrading Athabasca Residue

### Feedstock Properties

<table>
<thead>
<tr>
<th>Property</th>
<th>HRH Feed</th>
</tr>
</thead>
<tbody>
<tr>
<td>API Gravity</td>
<td>3.5</td>
</tr>
<tr>
<td>Sulfur, wt%</td>
<td>4.54</td>
</tr>
<tr>
<td>Nitrogen, wt%</td>
<td>1.00</td>
</tr>
<tr>
<td>Asphaltenes + Resin, wt%</td>
<td>40.4</td>
</tr>
<tr>
<td>Nickel + Vanadium, ppm</td>
<td>349</td>
</tr>
</tbody>
</table>
Upgrading Athabasca Residue

HRH Product Properties 73 vol. % Conversion

<table>
<thead>
<tr>
<th></th>
<th>Wt%</th>
<th>°API</th>
<th>S</th>
<th>N</th>
<th>Ni+V</th>
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</thead>
<tbody>
<tr>
<td>Naphtha</td>
<td>C5 - 180°C</td>
<td>10.48</td>
<td>58.41</td>
<td>0.69</td>
<td>0.08</td>
</tr>
<tr>
<td>Diesel</td>
<td>180°C - 350°C</td>
<td>40.1</td>
<td>26.76</td>
<td>1.7</td>
<td>0.26</td>
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<tr>
<td>Gas Oil</td>
<td>350°C - 520°C</td>
<td>18.2</td>
<td>17.07</td>
<td>2.12</td>
<td>0.83</td>
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<tr>
<td>Product</td>
<td>C5 - 520°C</td>
<td>29.02</td>
<td>1.66</td>
<td>0.39</td>
<td>Trace</td>
</tr>
<tr>
<td>Residue</td>
<td>&gt;520°C</td>
<td>21.6</td>
<td>-11.02</td>
<td>3.49</td>
<td>1.56</td>
</tr>
</tbody>
</table>

Operating Conditions
Residence Time  41 minutes
Reactor Temp     460°C

Single Pass Conversion;
• 73% volume
• 63% Desulfurization
• 60% Denitrogenation
• Total elimination of feed metals
HRH Product Composition Compared to Delayed Coking and EB Hydrocracking

Assumes Athabasca Vacuum Residue as Feed
## Canadian Upgrader Yields – 200MBPD Feed

<table>
<thead>
<tr>
<th></th>
<th>DELAYED COKER with Gasifier</th>
<th>EBULATED BED with Gasifier</th>
<th>HRH 95% Conversion</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fuel Gas MMBTU/Hr</td>
<td>1925</td>
<td>0</td>
<td>-6790</td>
</tr>
<tr>
<td>H2 SCF/B Feed</td>
<td>1243</td>
<td>1933</td>
<td>2083</td>
</tr>
<tr>
<td>Synthetic Crude</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>API</td>
<td>36.7</td>
<td>33.4</td>
<td>32.7</td>
</tr>
<tr>
<td>Wt % Sulphur</td>
<td>0.06</td>
<td>0.1</td>
<td>0.15</td>
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<tr>
<td>Naphtha MBPD</td>
<td>42.9</td>
<td>21.0</td>
<td>17.8</td>
</tr>
<tr>
<td>Distillate MBPD</td>
<td>76.7</td>
<td>85.9</td>
<td>100.0</td>
</tr>
<tr>
<td>VGO MBPD</td>
<td>56.2</td>
<td>83.4</td>
<td>97.6</td>
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<tr>
<td>Total MBPD</td>
<td>175.8</td>
<td>190.3</td>
<td>215.4</td>
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<tr>
<td>% Feed</td>
<td>87.9</td>
<td>95.2</td>
<td>107.7</td>
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</table>
Effect of Volume on Upgrader Economics

Base Graph Courtesy Strategy West Inc. Volume Expansion Effect Estimated by MOBIS

Mine, Extraction & Upgrading

Internal Rate of Return

Volume Expansion Effect at $100,000

WTI Price (2008 US$/b)

$60 $80 $100 $120 $140

0% 5% 10% 15% 20% 25%

$100,000 per b/d
$120,000 per b/d
$140,000 per b/d
$160,000 per b/d
## Refinery Yields – 200MBPD Feed

<table>
<thead>
<tr>
<th></th>
<th>CATCRACKING + COKER</th>
<th>CATCRACKING +HRH</th>
<th>HYDROCRACKING +HRH</th>
</tr>
</thead>
<tbody>
<tr>
<td>H₂ SCF/B Feed</td>
<td>430</td>
<td>730</td>
<td>890</td>
</tr>
<tr>
<td>Products</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Gasoline MBPD</td>
<td>89.8</td>
<td>101.5</td>
<td>63.7</td>
</tr>
<tr>
<td>Middle Distillates MBPD</td>
<td>69.2</td>
<td>92.7</td>
<td>78.4</td>
</tr>
<tr>
<td>Resid /Asphalt MBPD</td>
<td>35.0</td>
<td>1.1</td>
<td>52.5</td>
</tr>
<tr>
<td>Petchem MBPD</td>
<td>5.4</td>
<td>9.2</td>
<td>4.3</td>
</tr>
<tr>
<td>Sub Total</td>
<td>199.4</td>
<td>204.5</td>
<td>198.90</td>
</tr>
<tr>
<td>% Feed</td>
<td>99.7</td>
<td>102.3</td>
<td>99.5</td>
</tr>
<tr>
<td>Residue Coke Tonnes /day</td>
<td>1770</td>
<td>1770</td>
<td>0</td>
</tr>
<tr>
<td>Sulphur Tonnes/day</td>
<td>205</td>
<td>220</td>
<td>318</td>
</tr>
<tr>
<td><strong>Increase in Motor Fuel Yield</strong></td>
<td><strong>22.1%</strong></td>
<td></td>
<td><strong>43.3%</strong></td>
</tr>
</tbody>
</table>

*Note: HRH stands for Hydrocracking Reactor.*
HRH Projects & Facilities

- 180,000 BPD Heavy Oil Refinery – Basic Design Complete
- 200 BPD Demonstration Plant
- Pilot Plants from 0.5 LPD to 2 BPD
Conclusion – Benefits of the HRH process Using a Recoverable Nano-catalyst

- Any Residue can be Upgraded to 29 – 34°API SCO or refined oil products
- High Liquid Yield with Distillate Selectivity
- Hydrocracking at Mild Pressure (1000 Psig)
- Catalyst Recovered, Remanufactured and Re-used within the Process
- Time On-stream Unconstrained by Catalyst
- Enhanced Throughput -- Low Residence Time
- Approaches Zero Solid Waste
- Piloted, Demonstrated with First Commercial Project Underway
Thank You!

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