Modelling and Process Integration of Black Liquor Gasification with Fischer-Tropsch Synthesis

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Black liquor colloquium
Jyväskylä 2006-08-02

Picture source: NSD

Chemical pulping process

Bleached softwood kraft pulp, typical
Pulp yield: 43-44%
Losses: 1-2%
Black Liquor: 55%

Picture source: Aker Kvaerner
Chemical pulping process

**Bleached softwood kraft pulp**, typical

- Black Liquor
  - Value, ~100 EUR per tonne pulp

- Future Value, 200-400? EUR per tonne pulp

**Pulp**
- Value, ~500 EUR per tonne pulp
Projects

- **BLGMF, “Black Liquor Gasification with Motor Fuels Production”**
  - Methanol/DME
- **STFI-PF Biorefinery Cluster**
  - Modelling of BLGFT
- **BLGMF II**
  - Synthetic diesel (Fischer-Tropsch)
- **RENEW**
  - DME in demo scale
- **BLG program**
  - Activities tied to DP-1 in Piteå

Work method

Reference mills

Models (WinGEMS, Aspen, HYSYS)

Economic assessment

Material and energy balances

Lab data
BLGFT Concept

Air Separation
- Oxygen
- Black Liquor
 Gasification
- Smelt
- Gas Cooling
- S Removal & Recovery
- CO Shift
- CO₂ Removal
- Auto-thermal Reforming
- CO₂
- Pressure Swing Adsorption
- Green Liquor
- Hydrogen
- Steam
- Oxygen
- Purge Gas
- CO2
- Distillation
- C1-C4
- Hydrocracking
- Hydrogen
- CS+
- Gas/Liquid Sep
- FT Reactor
- Gas Clean-Up
- MeOH/DME
- FISCHER-TROPSCH
- MILL STEAM SYSTEM
- COMBINED CYCLE
- AIR SEPARATION
- GASIFICATION/ GAS AND GREEN LIQUOR COOLING

Process models
Product composition FT

![Graph showing the product composition of FT with data points for Hydrocracker feed, Shell data, and Hydrocracker product.]

Distillation curve for FT products

![Graph showing the distillation curve for the FT product with points at 180°C, 285°C, 320°C, and 360°C.]

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FT fuels from a 2000 ADt/d mill

- Black liquor: 3400 tDS/d
- FT-diesel: 320 t/d
- FT-naphtha: 160 t/d

Energy Balances

<table>
<thead>
<tr>
<th>Fuel options</th>
<th>Methanol</th>
<th>DME</th>
<th>FTD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Biomass consumption</td>
<td>414 MW</td>
<td>408 MW</td>
<td>378 MW</td>
</tr>
<tr>
<td>Black liquor consumption</td>
<td>487 MW</td>
<td>487 MW</td>
<td>487 MW</td>
</tr>
<tr>
<td>Fuel production, total</td>
<td>273 MW</td>
<td>275 MW</td>
<td>244 MW</td>
</tr>
<tr>
<td>Fuel production, total</td>
<td>410,600 t/year</td>
<td>286,000 t/year</td>
<td>109,700 t/year (+56,200 t/year)</td>
</tr>
<tr>
<td>Energy efficiency (LHV): Black liquor to fuel</td>
<td>56%</td>
<td>56%</td>
<td>33% diesel + 17% naphtha</td>
</tr>
<tr>
<td>Energy efficiency (LHV): Biomass to fuel</td>
<td>66%</td>
<td>67%</td>
<td>43% diesel + 22% naphtha</td>
</tr>
</tbody>
</table>

(Ekbom, Berglin, Lögdberg, 2005)
Production Costs

<table>
<thead>
<tr>
<th>Capital investment and Production costs</th>
<th>BLGMF Methanol</th>
<th>BLGMF DME</th>
<th>BLGMF FTD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Equipment and assembly</td>
<td>M EUR 290</td>
<td>304</td>
<td>317</td>
</tr>
<tr>
<td>Total investment cost</td>
<td>M EUR 345</td>
<td>361</td>
<td>375</td>
</tr>
<tr>
<td>Additional investment cost</td>
<td>M EUR 174</td>
<td>190</td>
<td>205</td>
</tr>
<tr>
<td>Total additional capital cost</td>
<td>M EUR/year 19.3</td>
<td>21.1</td>
<td>22.7</td>
</tr>
<tr>
<td>Total incremental operating cost</td>
<td>M EUR/year 66.3</td>
<td>66.1</td>
<td>68.2</td>
</tr>
<tr>
<td>Total incremental cost</td>
<td>M EUR/year 85.6</td>
<td>87.1</td>
<td>90.9</td>
</tr>
<tr>
<td>Production cost, EUR ¢/kWh</td>
<td>3.8</td>
<td>3.8</td>
<td>4.5b</td>
</tr>
<tr>
<td>Production cost, EUR/GJ</td>
<td>10.5</td>
<td>10.6</td>
<td>12.4b</td>
</tr>
<tr>
<td>Production cost, EUR/tonne</td>
<td>209</td>
<td>205</td>
<td>549b</td>
</tr>
<tr>
<td>Production cost, petrol/diesel equivalent litre, EUR ¢/equivalent litre</td>
<td>32.8</td>
<td>36.4</td>
<td>42.8b</td>
</tr>
<tr>
<td>Production cost, petrol/diesel equivalent litre, SEK/equivalent litre</td>
<td>3.1</td>
<td>3.5</td>
<td>4.1b</td>
</tr>
</tbody>
</table>

(Ekborn, Berglin, Lögdberg, 2005)

Sasol, South Africa

97 gasifiers, 150 000 bpd, 200 products