Entrained-flow gasification to convert biomass into synthesis gas

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Matthias Rudloff, Marketing and Sales Manager
CHOREN
• German gasification technology company
• first Mover in BTL-Technology: Gasification / Fischer Tropsch
• established out of the former DBI after the German reunification (1990)

• 280 Employees (2008)
• Private co., partnership with Shell since 2005 and with Daimler and VW since Oct 2007, total < 50%
• Capital employed > €180 Mio.
• located in Germany (Freiberg & Hamburg), China and USA

• world’s first continuous non-laboratory 100% BTL production process (2003)
• world’s first commercial BTL facility (2009)
• patented Carbo-V® process
Why entrained flow gasification for syngas production?

Due to their high operation temperature (> 1200°C), just entrained flow gasifiers ensure:

- tar content below detection limit
- minimum methane
- max. CO + H₂

Diagram: Relative decrease of the synthesis gas (H₂+CO)- quantity (thermodynamical equilibrium) as function of the CH₄-content.
Challenges of entrained flow gasification for biomass

Classical entrained flow gasifiers
- only achieve limited cold gas efficiency (due to high end temperatures)
- cannot be fed with solid biomass

The Carbo-V® process was designed to
- increase efficiency via
  - chemical quenching by blowing charcoal into hot gas
  - decreasing losses in combustion chamber
- increase feedstock flexibility by transforming solid feedstock to gas and coal dust via autothermal pyrolysis (NTV)
Allothermal contra autothermal pyrolysis

Allothermal

- heating via
  - heat carrier (sand, ...)
  - transfer through the wall / steam tube inside

+ lower CO₂ content in gas
+ higher coal yield
- big reactors necessary
- no reliable reactors for operation under pressure available

Autothermal

- heating via partial oxidation of coal in the reactor
+ very compact and reliable reactor (2 to 3 times smaller than allothermal units)
The Carbo-V® Process

Low-temperature-gasifier (NTV) → Carbo-V®-Gasifier → Gas-conditioning → Gas-usage

Biomass → Pyrolysis gas → oxygen → Carbo-V®-Gasifier → Raw gas (free of tar) → Heat exchanger → syngas → deduster → Residual char, ash → Gas srubber → Waste water

Vitrified slag
NTV ~ Low Temperature Gasifier

- Rotating equipment
- Pressurized 5 bar
- Thermal cycling
Low-temperature-gasifier (NTV)

Alpha plant, 1 bar, 550°C, 1 MW

Beta Plant, Freiberg, 5 bar, 550 °C, 15 MW
HTV ~ HT Gasifier with Chemical Quench

- stationary equipment
- pressurized 5 bar suppressing methane formation
- design expertise from coal gasification
- slag protected refractory
- cracking of tars separate to char – tar free syngas
HTV ~ HT Gasifier with Chemical Quench

- thermal quench of HTV
- exit gas temperature 800-900°C
- standard downstream equipment
HTV – 45 MW HT Gasifier (Beta Plant)
Carbo-V® – gas composition

gasification of wood, gas after gas scrubber

<table>
<thead>
<tr>
<th>Component</th>
<th>Mol % in dry gas</th>
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<tbody>
<tr>
<td>CO</td>
<td>41.2</td>
</tr>
<tr>
<td>CO₂</td>
<td>24.0</td>
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<tr>
<td>H₂</td>
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<td>&lt; 0.1</td>
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<tr>
<td>N₂</td>
<td>1.1</td>
</tr>
<tr>
<td>H₂S</td>
<td>&lt; 0.02</td>
</tr>
</tbody>
</table>

Carbo-V 160/5
O₂ (99.5%)
CHOREN gasifier

Carbo-V® - 45 / 5 (Beta)

Carbo-V® - 160 / 5 (Sigma)

Clean Carbon Gasifier (CCG)
CHOREN Gasification Application Overview

Feedstock Prep and Handling
- Biomass
- Waste
- Coal
- Petcoke / Residuals

Entrained Flow Gasification Carbo-V® and CCG (Coal)

Gas Cleanup

Utility Integration

Product Conversion Technologies*
- Synthesis Gas
- Methanol
- Ethylene
- Propylene
- Acetic Acid
- \( \text{H}_2 \)
- DME
- Ammonia
- Ethanol
- Urea
- SNG
- FT-Products
- Power / Steam

*Non-exhaustive technologies list for clarity
Biomass-to-Electricity Direct Firing (BtE)

CO₂-Neutral Electricity or Fuel Gas via Biomass Syngas Direct Firing

Biomass → Carbo-V® Gasification → Gas Cleanup → Existing Boiler → Heat Recovery and Steam Turbine → Electricity
Biomass-to-Electricity (BtE)

CO$_2$-Neutral Electricity via Biomass Integrated Combine Cycle (BIGCC)

Biomass → Carbo-V® Gasification → Gas Cleanup and Compression → SynGas Turbine → Heat Recovery and Steam Turbine → Electricity
Biomass-to-Liquids (BtL)

“Green” SynFuels for high Energy Independence

Biomass → Carbo-V® Gasification → Gas Cleanup and Compression → FT-Synthesis → SynFuel
Biomass and Coal-to-Liquids (BCtL)

CO₂-Balance Improved Coal-to-Liquids Production, Large Scale

Biomass → Carbo-V® and/or Coal Gasification → Gas Cleanup and Compression → FT-Synthesis → SynFuel
Biomass and Coal-to-Electricity (BCtE)

CO₂-Balance Improved Electricity via Biomass and Coal Integrated Combine Cycle

- Carbo-V® and Coal Gasification
- Gas Cleanup and Compression
- SynGas Turbine
- Heat Recovery and Steam Turbine
Carbo-V®-Development stages


Pilot plant with air blown gasifier

Alpha 1 MW O₂

Scaleup * 45 (one line)

BETA Freiberg First commercial BTL plant 45 MW

Beta: 15 ktpa

15 MW air

30 MW O₂

45 MW O₂ HTV

Scaleup * 4 (multiple lines)

Sigma plant 640 MW 4 parallel gasifiers à 160 MW

BTL Sigma: 200 ktpa

Scouting FED 1-3 FID Execution Operation
Beta-Plant

45 MW thermal  68,000 t/a feedstock  18.0 mio. l SunFuel

1. Alpha-Plant
2. Biomass storage (wood chips)
3. Carbo-V\textsuperscript{\textregistered} Gasifier
4. Power station
5. Fischer-Tropsch-synthesis
6. Tank farm
Start of Commissioning – April 17th 2008
Beta project schedule

2003
Construction begins 2003 Phase I – NTV & HTV

Carbo-V® in operation

2004
Banking finance & loan guarantee program

2005
Construction continues 2005/06 Phase II Fischer-Tropsch

Technical up-grade & review of safety systems

2006
April 2008 – Mechanical completion

Implement SIL & red loop checks

Commissioning

2007

2008

2009

Beta plant – Carbo-V® in operation
Σ Schwedt

- 640 MW_{th}
- 1.000.000 t/a biomass
- 200.000 t/a BTL

Advantages:
- Biomass availability
- Refinery integration
- Logistics
- Infrastructure
- Public support
Current Layout Status (08.01.2008)
CHOREN Industries GmbH, Freiberg
CHOREN services for biomass gasification plants

Licence for Carbo-V® technology

Feasibility studies

Services (obligation if licence agreement signed)

- PDP / Basic-Engineering-Package
- Supply of main components (Proprietary Equipment)
  - Low Temperature Gasifier
  - High Temperature Gasifier incl. burners
  - coal fluidisation and transport system
- Commissioning
  - monitoring / support
  - operator training

Additional services

- detail engineering for special components:
  - feedsystem for feedstock
- After Sales Service
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