The development and operation of an optimised gasifier for syngas production from biomass

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Why syngas from biomass?

Production of synthesis gas from biomass with the Carbo-V® process

Fischer-Tropsch-Synthesis

Synthesis of liquid products

Fuels for the existing market

Biomass
Criteria for the selection of a process for the production of syngas from biomass (gasification process)

• Gas quality
  – Content of hydrocarbons (methane, tar,...) in raw gas
  – $H_2 / CO$ ratio
  – Impurities
• Cold gas efficiency
• Feedstock flexibility
• Operation under pressure
• Max. power per unit / scaleability
• Investment and operation costs
## Assessment of biomass gasifiers

<table>
<thead>
<tr>
<th></th>
<th>Fixed bed</th>
<th>Fluidized bed</th>
<th>Combined processes (Flash)Pyrolysis + Entrained flow</th>
<th>Carbo-V</th>
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<tbody>
<tr>
<td><strong>Cold gas efficiency</strong></td>
<td>++</td>
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<td><strong>Hydrocarbons in raw gas</strong></td>
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<td><strong>Feedstock</strong></td>
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<td><strong>max. power per unit</strong></td>
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<tr>
<td><strong>Maturity for syngas production</strong></td>
<td>not suitable</td>
<td>+</td>
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<td><strong>Investment costs</strong></td>
<td>o</td>
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<td><strong>Operation costs</strong></td>
<td>o</td>
<td>o</td>
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</table>

- bad | o not pretty good | + good | ++ excellent

Feedstock:
- Not suitable
- + good
Conclusions of CHOREN’s evaluation

- A low hydrocarbon gas can only be achieved by entrained flow gasifiers
- Classical entrained flow gasifiers
  - only reach low efficiency
  - 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 because of indirect cooling
  - increase feedstock flexibility by transforming solid feedstock to gas and coal dust via autothermal pyrolysis (NTV)
The Carbo-V® Process

1. **Biomasse**
   - Low-temperature-gasifier (NTV)

2. **Pyrolysis gas**
   - Carbo-V®-Gasifier

3. **Raw gas (free of tar)**
   - Gas-conditioning

4. **Vitrified slag**
   - Gas-usage

5. **Char**

6. **Residual char, ash**

7. **Heat exchanger**

8. **Steam**

9. **Syngas**

10. **Gas scrubber**

11. **Waste water**
Cooling of combustion chamber

Spec. losses for cooling:

- 150 ... 200 kW/m² (Combustion chamber forced by pressure)
- 40 ... 50 kW/m² (Lower gas temperature)

Combustion chamber not forced by pressure.
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)
Low-temperature-gasifier (NTV)

Alpha plant, 1 bar, 550 °C, 1 MW

Beta Plant, Freiberg, 5 bar, 550 °C, 15 MW
Operation Behaviour NTV (1)

Uhrzeit

Menge in kg/h

- Holz
- Luft
- Koks
Operation Behavior NTV (2)
Advantages of Carbo-V® Gasification

1. Absolute **tar-free combustion or synthesis gases** (no catalytic gas cleaning required!)
2. Low methane content even under 30 bar operation
3. High **performance**, efficiency of energy conversion > 80%
4. High **flexibility in feedstock** (all dry and carbon-containing feedstock possible)
5. Conversion of ash to **slag** (granules suitable as a construction material)
6. More than **17,000 operation hours** (by end of 2004) in the alpha plant
CHOREN BtL R&D Program

1997/98: Construction and Commissioning of the Carbo-V® pilot gasification unit (1MW)

1998 - 01: Holistique experimentation program

2001: Demonstration of gas engine with clean wood gas

2002/03: Construction of the synthesis unit
CHOREN BtL R&D Program

2001
First BtL from bio-syngas in laboratory scale

13 April 2003:
First liquids (methanol) from wood produced

6 May 2003:
After the production of 11,000 liters, the R&D program for methanol was finished

June 2003:
First production of FT-liquids from wood

2004:
Process and product optimization in the EU 6th frame program (RENEW)
16 September 2002:
Cooperation with DaimlerChrysler and Volkswagen publically signed
September 2003: Industrial syngas production plant in operation
Gasifying reactor 50 MW
BKPA Freiberg

TAF
Thermische Apparate Freiberg GmbH
Test campaigns in the Beta-plant - Objectives

In IV/ 2003 commissioning of the β-plant with the following goals:

- Proof of the components in hot operation
- Test of all components in common operation
- Approval procedure for the reactor cooling system by the authorities
- Test of control and security system under operating conditions
Test campaigns in the Beta-plant - impressions
Results

1. All necessary approvals were submitted by the authorities
2. The biomass input system into the NTV was prooven: a continuous and stable gas production in the NTV could be achieved
3. The whole char conditioning and transport system was prooven
4. Successful operation of the gasifier:
   • Slagging of the wall of the combustion chamber
   • No damages on the lining
5. Some minor problems could be identified and solutions were developed.
## Beta Unit – First SunDiesel® Q1/2007

### Task Name

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<th>Qtr 3</th>
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### Key Details

- **45 MW Thermal**
- **16.5 Mil lt SunDiesel**
- **75,000 tpa BioMass**

**Beta Unit – First SunDiesel® Q1/2007**

**45 MW Thermal**

**16.5 Mil lt SunDiesel**

**75,000 tpa BioMass**
1 Biomasselagerung
1a Aufbereitungshalle
2 Holztrocknung
3 Carbo-V
4 Syntheserestgasverwertung
5 Kraftwerk, Dampf
6 Synthese
7 Gaskonditionierung
7a Zusatzgaserzeugung
9 Tanklager fuel Diesel / Benzin
9a Tanklager Ethanol
13 Büro
14 Werkstatt, Büro, Zentrallager, Sozialbereich
15 Elektroenergieversorgung
16 Nebenanlagen Wasser
17 Lüfterlegungsanl., Gasversorgung (O2, N2, LUD)
18 Pilotanlagen UET
19 Parkplatz
20 Rückkühlsystem
21 Pufferspeicher (WAO, WAB)
22 Notstromaggregat
23 Labor
24 Wasserstoff-Trailer für CVPA
25 Reservefläche BP
26 Synthesegasverdichter
27 PSA-Anlage
28 Wasserstoff-Racks
C = Kohlenstoff
H = Wasserstoff
O = Sauerstoff
REN = Renewable