Gasified Biomass for Biofuels Production: Foster Wheeler’s Technology Developments for Large Scale Applications
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Foster Wheeler CFB Gasifier

11 gasifiers built in 1981-2008

Readiness to offer atmospheric plants for over 100 MWth air-blown applications for various wood and waste based fuels

Readiness to offer pressurized oxygen-steam blown gasifiers up to ~300 MW for biorefinery applications with wood based fuels

Development program to increase the operating pressure and plant efficiency further

Process conditions according to fuels and applications

Long history (originally developed end 70s/beginning 80s)

Commercial applications

New developments in progress

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FW air-blown biomass gasification in brief

Atmospheric clean gas applications
Demonstrated in pilot scale
Next step commercial scale demonstration

Pressurized air-blown gasification
Demonstrated

Raw gas applications
Commercial
Status of pressurized oxygen-steam-blown gasification at Foster Wheeler aiming at BtL, SNG, etc. applications
Development Steps Summary

- Development in Finland started in 2004 in publicly funded project
- Technology is based on O₂-H₂O-blown fluidized-bed gasification
- R&D phases:
  - **Phase 1:** Process development in 0.5 MW scale (completed)
  - **Phase 2:** Long term demonstration in 12 MW scale (completed)
  - FWE 3D modeling for design development and optimization (on going)
  - **Phase 3:** Commercial scale demonstration (next step)

[Source: VTT, Technical Research Centre of Finland]
Phase 1 / VTT Otaniemi
UCG Pressurized pilot plant process

[Source: VTT, Technical Research Centre of Finland]
Phase 2 / NSE Biofuels Oy – Varkaus Test Plant

[Photo: NSE Biofuels Oy]
Varkaus 12 MW$_{th}$ O$_2$-H$_2$O Demo plant and 5 MW$_{th}$ slip stream

Demonstration of O$_2$/steam-blown gasification using different types of biomass
Demonstrated successfully in atmospheric pressure
~9000 hours

Demonstration of product gas treatment: cooling, cleaning and tar reforming
Demonstrated successfully in atmospheric pressure
~5500 hours

Availabilities

<table>
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<tr>
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<th>2010</th>
<th>2011</th>
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<tbody>
<tr>
<td>O$_2$-H$_2$O gasification</td>
<td>94.30%</td>
<td>96%</td>
</tr>
<tr>
<td>5 MW Slip-stream</td>
<td>47.20%</td>
<td>93%</td>
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FT supplier was impressed with the quality of the ultra cleaned gas. => technically feasible
R&D work at Varkaus Demo plant

• Oxygen-steam-blown gasification 06/2009 – 06/2011
  – Oxygen content in fluidization gas 30-50 m-%
  – Fluidization gas distribution (primary and secondary; different secondary gases)
  – Gasification temperature range 830-940 C
  – Fuels
    o Wood chips, saw dust, bark, forest residues
    o Moisture, particle size
  – Bed materials
    o Sand / limestone / MgO
    o Relative and absolute amounts

• Gas cleaning and cooling, long term testing
  – Gas coolers
  – Gas filtration in two different filtration units
  – Gas scrubber

• Material testing and analyses
  – Metals (gas coolers and filters)
  – Refractories
  – Filter elements
Typical gasification conditions at Varkaus Demo plant

- Gasification temp: 870-890 °C
- Fluidization gas: O\textsubscript{2} 40-50 %-m and H\textsubscript{2}O
- Bed material: Mixture of limestone and sand, 70/30 (50/50)
- Fuel: Wood based biomass (wood chips, bark, forest residues, etc)

- Typical raw gas composition on wet basis:
  - CO 17 %
  - CO\textsubscript{2} 22 %
  - H\textsubscript{2} 21 %
  - C\textsubscript{x}H\textsubscript{y} * 7 %
  - H\textsubscript{2}O 33 %

* Contains components from CH\textsubscript{4} to heavy tars.

Gas composition can vary to some extent and is affected by process conditions, fuel type and particle size, bed material, etc.
3D modeling of gasification process at Foster Wheeler
In co-operation with Lappeenranta University of Technology
Scale up in MW

O2-H2O

Validated 3D model

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Basic gasification reactions have been implemented in CFB3D-model, which is a semi-empirical code for three-dimensional simulation of a circulating fluidized-bed furnace in a steady-state condition.
Model capabilities

- Applied to CFB combustion and gasification processes and to calcium looping processes.
- Flow dynamics of gas and solids.
  - Semi-empirical submodels.
- Combustion and gasification of fuel.
  - Drying, devolatilization, char combustion, water-gas and Boudouard reactions.
- Comminution of solids.
- Homogeneous combustion and gasification reactions.
- Heat transfer within bed and to surfaces.
- Sorbent reactions and sulfur capture.
- Post-solver for NO\textsubscript{x} emissions.
- Solid material types:
  - fuel, sand, sorbent (unlimited number of each)
    - combustible fuel = char+volatiles+moisture
    - inert ash handled separately
    - sorbent = CaCO\textsubscript{3}+CaO+CaSO\textsubscript{4}+CaS+inert
- Gas components:
  - O\textsubscript{2}, CO\textsubscript{2}, H\textsubscript{2}O, SO\textsubscript{2}, CO, H\textsubscript{2}, CH\textsubscript{4}, C\textsubscript{2}H\textsubscript{4}, C\textsubscript{g}, H\textsubscript{2}S, NO, N\textsubscript{2}O, HCN, NH\textsubscript{3}, Ar, N\textsubscript{2}
Water-gas reaction [kg/m$^3$s]
C + H$_2$O -> CO + H$_2$
Hydrogen [mol-%]
Oxygen [mol-%]
Fuel feeding disturbance
Commercial scale $\text{O}_2\text{-H}_2\text{O}$ gasification plant
Large scale case: 300 MWth pressurized gasifier
Summary / Foster Wheeler FB Gasification Experience

Processes

• Atmospheric raw gas applications
• Atmospheric clean gas applications
• Pressurized applications
• Oxygen-steam blown applications

Fuels

• Wood based biomass (chips, bark, first felling wood, forest residues, ...)
• Agrobiomass
• Peat
• Recycled fuels (REF, RDF, plastics, etc)
• Coal
• Sludge, tyres
Status of $\text{O}_2\text{-H}_2\text{O}$ gasification technology development

• Test runs at Varkaus demonstration plant completed
  – Complete FT production chain demonstrated successfully
  – $12 \text{ MW}_{\text{th}} \text{O}_2\text{-H}_2\text{O}$ gasifier (~9000 h)
  – $5 \text{ MW}_{\text{th}}$ slip stream (~5500 h)
  – $0.1 \text{ MW}_{\text{th}}$ gas ultra cleaning and FT synthesis
  – FT supplier was impressed with regard to the gas quality

• Foster Wheeler 3D gasification model actively used in design development
  – Enables testing of parameters/designs beyond pilot scale
  – Commercial size design calculations (~300 MW) performed
    – 3D calculations has had a big effect to the design
    – Design alternatives evaluated up to 12 barg pressure level

• Low pressure (4 bar) design for a commercial size $\text{O}_2\text{-H}_2\text{O}$ gasifier exists, internal high pressure development program proceeding
  – Plans presented to selected customers
  – Test runs at elevated pressure at VTT facility continuing in public 2G2020 project as a part of the development program