CFB GASIFICATION OF BIOMASS AND WASTE AT PILOT AND COMMERCIAL SCALE

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69TH IEA – FBC MEETING, 26th of September 2014
Altawest Group – LLT Solutions

**Leroux & Lotz Technologies**

- Modular plants
- Special heavy Machines
- Subsea Equipments
- Industrial boilers & EnfW
- Biomass boiler Islands

- CHP
- Environment
- Power generation
- Industry
- Traction
- Oil & Gas
- Marine

• Jeumont electrique
• Inova
• Leroux & Lotz Technologies
• Leroux & Lotz Timolor
• Leroux & Lotz Turbomachine
• Leroux & Lotz Maintys

l'énergie imaginative
LLT Heat & Power Division

- **Commercial & Industrial range:**
  - Boiler range for *Waste and RDF*: 10 to 150 MW$_{th}$
  - Boiler range for biomass
    - *FT* range: 1 to 15 MW$_{th}$
    - *WT* range: 15 to 150 MW$_{th}$ (up to 540 °C, 130 bars)

- **Custom Combustion System**
  - Biomass Burner (*BioSwirl™*, MultiFuel)
  - Bubbling Fluidised Bed (BFB)
  - Step type Grate
  - Spreader stoker (with partner)
  - Watercooled reciprocating grate (with partners)

- **Custom Gasification System**
  - Bubbling Fluidised Bed (BFB)
  - Circulating Fluidized Bed (CFB)
Global solution provider for energy generation

Fuel Handling  Combustion system  Heat/ Steam generation  Flue gas treatment  Ash extraction  Control & Regulation

Customer requirements  Basic & detail engineering  Execution  Erection  Commissioning  After sale service

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Context & objectives

- Gasification
  - Efficient thermal treatment to convert various solid fuels (wood, agricultural residues, wastes) into valuable syngas
  - Various applications: power/CHP generation, biofuels production...

- Technical barriers
  - Variability of the feedstock → fuel injection, reactivity, agglomeration in FB...
  - Syngas cleaning stage before its valorization

- Present works target
  - Feedback on a 2 MW\textsubscript{th} pilot CFBG and on an industrial 15 MW\textsubscript{th} gasifier – the Greve in Chianti plant (set up by TPS)
    - Process characteristics
    - Mass balance
    - Technical barriers encountered and solutions organized
Material & Methods: 2MW$_{th}$ CFBG

- Design in 1985 for operation with 500 kg/h of biomass or waste fuels
- Feedstock: RDF
- Operated between 820 and 880°C
- Air blown CFB gasifier, atmospheric conditions
- Connected to a tar cracker (900-950°C)
- Gas analysis of the syngas:
  - heated extraction pipe and sintered metal filter maintained at 400°C,
  - cooling system and gas analyzer (GC)

<table>
<thead>
<tr>
<th>Moisture (% wt.)</th>
<th>13.4</th>
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</thead>
<tbody>
<tr>
<td>Volatile matter (% wt.db.)</td>
<td>75.2</td>
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<tr>
<td>Ash (% wt. db.)</td>
<td>5.7</td>
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<tr>
<td>Fixed carbon (% wt. db.)</td>
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</table>

<table>
<thead>
<tr>
<th>C (% wt. db.)</th>
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<tr>
<td>H (% wt. db.)</td>
<td>5.8</td>
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<td>N (% wt. db.)</td>
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<tr>
<td>S (% wt. db.)</td>
<td>0.06</td>
</tr>
<tr>
<td>Cl (% wt. db.)</td>
<td>0.06</td>
</tr>
<tr>
<td>O (% wt. db.)</td>
<td>35.1</td>
</tr>
</tbody>
</table>
Results: 2MWₜh CFBG

- 3 days syngas composition after the gasifier

- Raw gas calorific value: ~5 MJ/Nm³
  - N₂: ~58% vol.
  - CO₂: ~17% vol
  - H₂: ~11% vol
  - CO: ~8% vol
  - CH₄: ~4%

- NH₃: 28-32g/Nm³ - Corresponds to about 70-80% of fuel nitrogen converted to ammonia (N content in fuel: about 7% wt. on dry basis)

- Tars emissions: 4.3 – 10.7 g/Nm³
Results: $2\text{MW}_{\text{th}}$ CFBG

- **Tars emissions:**
  - An increase of the gasifier temperature leads to a slight decrease of the amount of tars.
  - The level of tars decreases with increasing bed pressure loss in the gasifier.
Results: 2MW\textsubscript{th} CFBG

- **Tar emissions:**
  - Amount of tar from gasifier is increasing with increasing fuel feed rate (slightly lower heat up rate of the fuel fed)
  - A lower amount of tars with dolomite as bed material

![Graph showing tar content vs. fuel feed rate](image-url)
Greve in Chianti plant: historical aspects

- The Greve in Chianti plant case: an installation operated for about 10 years
  
  - Commissioning of the plant in 1993
  
  - Two 15 MW$_{th}$ circulating fluidized beds to provide syngas used in a cement kiln and in a boiler for power generation
  
  - Plant stopped in 2004
Material & Methods: the Greve in Chianti plant

Feedstock

Pellets of RDF (LCV = 19.4 MJ/kg)

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Moisture (% wt.)</td>
<td>3.2</td>
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<tr>
<td>Volatile matter (% wt.)</td>
<td>73.7</td>
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<tr>
<td>Ash (% wt.)</td>
<td>12</td>
</tr>
<tr>
<td>Fixed carbon (% wt.)</td>
<td>11.1</td>
</tr>
<tr>
<td>C (% wt.)</td>
<td>43.1</td>
</tr>
<tr>
<td>H (% wt.)</td>
<td>7.7</td>
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<tr>
<td>N (% wt.)</td>
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<tr>
<td>S (% wt.)</td>
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<tr>
<td>Cl (% wt.)</td>
<td>0.8</td>
</tr>
<tr>
<td>O (% wt.)</td>
<td>32</td>
</tr>
</tbody>
</table>

(Greve in Chianti RDF analysis - June 2000)

Gasification

- 800-880°C
- Atmospheric pressure
- Air-blown CFB gasifier
- Solid separation units: U-Beam chamber + cyclone
- Bottom ash discharged by gravity
Material & Methods: the Greve in Chianti plant

- **Application 1: cement industry**
  - Syngas temperature for transportation: 450°C

- **Application 2: power generation**
  - Syngas combustion in a boiler -> temperature of 1050-1200°C
  - Supplement of methane in a post combustion chamber (2 s at T > 850°C)
  - Subsequent urea injection to limit NOx emissions
  - Steam generation (380°C – 42 bar)
  - Steam turbine for electricity production (up to 6.7 MWe)
Syngas characteristics

- Raw gas calorific value: 6.6 MJ/Nm³
- High content of solid particles and tars
- Cl and S mainly converted to HCl and H₂S
Results: the 15MW\textsubscript{th} gasifier

- **Ashes characteristics**
  - No unburned material in gasifier bottom ashes

- **Inorganics partition**
  - High volatile metals – as Hg, Cd and Pb – 100% contained in raw syngas
  - Only 20-30% of alkaline metal input is discharged by gasifier and cyclone

### Bottom ashes characteristics

<table>
<thead>
<tr>
<th>Moisture (%)</th>
<th>Gasifier bottom ash</th>
<th>Cyclone bottom ash</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ash (%)</td>
<td>99.86</td>
<td>94.06</td>
</tr>
<tr>
<td>C (%)</td>
<td>0.67</td>
<td>5.97</td>
</tr>
<tr>
<td>H (%)</td>
<td>-</td>
<td>0.11</td>
</tr>
<tr>
<td>N (%)</td>
<td>-</td>
<td>0.12</td>
</tr>
<tr>
<td>S (%)</td>
<td>0.23</td>
<td>0.24</td>
</tr>
<tr>
<td>Cl (%)</td>
<td>2.22</td>
<td>2.57</td>
</tr>
</tbody>
</table>

### Inorganics partition in syngas, in gasifier and cyclone ashes
No major problems related to the gasifier

- Difficulties with fuel injection (when used with fluff) → design of a low density fuel feeding system
- Bed sintering during commissioning, due to the injection of too much primary air into the gasifier → respect of the design stoichiometric ratio
- Particle concentration in the syngas higher than expected → addition of a second cyclone
- Bottom ash extraction system blocked because of metal pieces in RDF → continuous unloading at lower velocity
Conclusions

- RDF gasification at pilot scale (2 MW<sub>th</sub>)
  - Validation of the design of the CFBG and of the operating conditions

- RDF gasification at commercial scale (15 MW<sub>th</sub>)
  - Production of a syngas with a calorific value of about 6MJ/Nm<sup>3</sup>
  - Syngas valorized in a cement kiln and for power generation
  - No major problems related to the gasifier after the commissioning of the installation

- Extensive feedback for LLT from the design, commissioning and operation of a RDF gasifier
  - Design, process characteristics and mass balance
  - Solutions organized (fluff fuel injection, bottom ash extraction...)
Thank you for your attention!

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