Section 2: Biomass gasification

Characterization of Several Kinds of Coal and Biomass for Pyrolysis and Gasification

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• Sotacarbo Research Centre
• an overview of the Sotacarbo pilot plant
• aim of this work
• experimental data
• conclusion
Sotacarbo – Società Tecnologie Avanzate Low Carbon – S.p.A. is a limited company established in 1987, in accordance with the Italian law 351/85, with the aims to develop new and advanced clean coal technologies.

Shareholders:

since 1989 the company has represented Italy in the international organization IEA The Clean Coal Centre.
more than 2000 hours of experimental tests in the Sotacarbo pilot platform (since June 2008)
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  • an overview of the Sotacarbo pilot plant
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an overview of the Sotacarbo pilot plant
clean power generation and hydrogen production from coal, biomass and wastes
an overview of the Sotacarbo pilot plant: **flowsheet**

- **Coal Preparation**
  - Fuels
- **Fuels Preparation**
  - Steam
  - Air
  - O2 for air Enrichment
- **Gasifier**
  - Gasifier 80 kW/h
  - Ash
- **Water**
  - Wet Scrubber
  - Cold Gas Desulphurization
- **Power Generation Line**
  - Cold Gas Desulphurization
  - H2 for syngas enrichment
  - ICE
- **Heat Recovery**
  - Heater
  - Hot Gas Desulphurization
- **CO2 removal**
  - High Temperature WGS (450 °C)
  - Low Temperature WGS (250 °C)
- **H2 production and CO2 separation line**
  - H2 for syngas enrichment
  - PSA
  - Flare
  - CO2 removal
  - CO2 stream
an overview of the Sotacarbo pilot plant: gasifier

Power Generation Line

Cold Gas

H2 for syngas enrichment

ICE

H2

N2

PSA

Flare

CO2 removal

Low Temperature WGS (250 °C)

H2 production and CO2 separation line

Coal Preparation

Fuels

Water

Wet Scrubber

Cold Gas Desulphurization

Syngas

Gasifier 80 kW/h

Steam

Air

O2 for air Enrichment

Ash

Water
an overview of the Sotacarbo pilot plant: gas clean up
an overview of the Sotacarbo pilot plant: PGL
an overview of the Sotacarbo pilot plant: PGL
an overview of the Sotacarbo pilot plant: $H_2$ production

Power Generation Line

Cold Gas Desulphurization

H2 for syngas enrichment

ICE

H2 production and CO2 separation line

Hot Gas Desulphurization

O2 for air Enrichment

H2 for air Enrichment

CO2 removal

High Temperature WGS (450 °C)

Low Temperature WGS (250 °C)

CO2 stream

CO2 removal

O2 for air Enrichment

A heat exchanger

ESP
an overview of the Sotacarbo pilot plant: \( H_2 \) production
Amine Regeneration unit
- Operating temperature: 30–150 °C
- Operating mode: batch or continue
- Electric reboiler
an overview of the Sotacarbo pilot plant: $H_2$ production
an overview of the Sotacarbo pilot plant: SCR
an overview of the Sotacarbo pilot plant: sampling and analysis

15 syngas sampling outlets

micro gas chromatograph for syngas analysis

concentration of CO₂, H₂, O₂, CO, CH₄, N₂, H₂S, COS, C₂H₆, C₃H₈

two systems for a real-time O₂ concentration measurement
new system for a real-time monitoring of syngas composition

- CO
- CO$_2$
- CH$_4$
- H$_2$
- O$_2$
- H$_2$S

infrared detector

thermal conductivity

paramagnetic

UV detector
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COAL:

**high rank coal**
- bituminous, from South Africa

**low rank coal**
- sub-bituminous, from Italy (Sulcis mine)
- lignite from Alaska (Usibelli mine) and Hungary

ALTERNATIVE FUELS:

**biomass**
- wood chips

GASIFICATION

Characterization in terms of behavior in terms of:

*Pyrolysis performance*

*Gasification performance*
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different kinds of **coal** and **biomass**

<table>
<thead>
<tr>
<th>Classification origin</th>
<th>bituminous</th>
<th>sub-bitum.</th>
<th>lignite</th>
<th>lignite</th>
<th>wood</th>
</tr>
</thead>
<tbody>
<tr>
<td>origin</td>
<td>South Africa</td>
<td>Italy</td>
<td>Alaska</td>
<td>Hungary</td>
<td>Italy</td>
</tr>
<tr>
<td>Density (kg/dm$^3$)</td>
<td>0.8</td>
<td>0.8</td>
<td>0.8</td>
<td>0.9</td>
<td>0.2</td>
</tr>
</tbody>
</table>

**Proximate analysis** (% by weight)

- fixed carbon: 72.58, 40.65, 31.33, 17.54, 18.30
- moisture: 3.64, 7.45, 17.64, 22.90, 7.70
- volatiles: 8.81, 40.45, 41.00, 24.85, 73.63
- ash: 14.97, 11.45, 10.02, 34.71, 0.37

**Ultimate analysis** (% by weight)

- total carbon: 75.56, 66.49, 48.56, 25.43, 49.95
- hydrogen: 3.86, 6.18, 5.96, 3.63, 6.14
- nitrogen: 1.40, 1.41, 0.50, 0.48, 0.11
- sulphur: 0.57, 7.02, 0.18, 4.82, 0.00
- oxygen: n.a., n.a., 17.14, 8.03, 35.74
- moisture: 3.64, 7.45, 17.64, 22.90, 7.70
- ash: 14.97, 11.4, 10.02, 34.71, 0.37

**Thermal analysis** (MJ/kg)

- HHV: 28.10, 22.59, 19.46, 9.21, 18.76
- LHV: 27.18, 21.07, 17.75, 7.89, 17.25

**PROXIMATE ANALYSIS:** based on the ASTM D 5142-04 “Moisture Volatile Ash” standard;

**ULTIMATE ANALYSIS:** based on ASTM D 5373-02 for carbon, hydrogen and nitrogen and ASTM D 4239-05 for sulphur

**HIGHER HEATING VALUES:** according to the standard ISO 1928:1995.
Experimental TGA characterization has been carried out by using a LECO TGA-701 thermogravimeter.
Experimental gasification results

### Experimental data: gasification

<table>
<thead>
<tr>
<th>Feedstock(1)(2)</th>
<th>S.African</th>
<th>Usibelli</th>
<th>Hungarian</th>
<th>Sulcis</th>
<th>Wood ch.</th>
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</thead>
<tbody>
<tr>
<td>Process parameters</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fuel (kg/h)</td>
<td>8.00</td>
<td>24.00</td>
<td>11.00</td>
<td>9.20</td>
<td>12.00</td>
</tr>
<tr>
<td>Air (kg/h)</td>
<td>36.80</td>
<td>57.60</td>
<td>20.00</td>
<td>39.20</td>
<td>11.30</td>
</tr>
<tr>
<td>Steam (kg/h)</td>
<td>3.70</td>
<td>3.70</td>
<td>2.00</td>
<td>2.50</td>
<td>0.00</td>
</tr>
<tr>
<td>Raw syngas composition (molar fractions, dry basis)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>CO</td>
<td>0.1807</td>
<td>0.2368</td>
<td>0.1957</td>
<td>0.1583</td>
<td>0.2207</td>
</tr>
<tr>
<td>CO₂</td>
<td>0.0947</td>
<td>0.0771</td>
<td>0.0870</td>
<td>0.0948</td>
<td>0.0797</td>
</tr>
<tr>
<td>H₂</td>
<td>0.1889</td>
<td>0.1779</td>
<td>0.1050</td>
<td>0.1205</td>
<td>0.3342</td>
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<tr>
<td>N₂</td>
<td>0.5128</td>
<td>0.4730</td>
<td>0.5849</td>
<td>0.5655</td>
<td>0.3418</td>
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<tr>
<td>CH₄</td>
<td>0.0151</td>
<td>0.0173</td>
<td>0.0163</td>
<td>0.0236</td>
<td>0.0119</td>
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<tr>
<td>H₂S</td>
<td>0.0003</td>
<td>0.0002</td>
<td>0.0011</td>
<td>0.0121</td>
<td>0.0000</td>
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<tr>
<td>COS</td>
<td>0.0001</td>
<td>0.0001</td>
<td>0.0000</td>
<td>0.0019</td>
<td>0.0000</td>
</tr>
<tr>
<td>O₂</td>
<td>0.0074</td>
<td>0.0176</td>
<td>0.0100</td>
<td>0.0233</td>
<td>0.0117</td>
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<tr>
<td>Raw syngas properties (dry basis)</td>
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<td></td>
<td></td>
<td></td>
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</tr>
<tr>
<td>Mass flow. (kg/h)</td>
<td>46.83</td>
<td>79.67</td>
<td>24.19</td>
<td>48.91</td>
<td>23.31</td>
</tr>
<tr>
<td>Vol. flow (Nm³/h)</td>
<td>42.90</td>
<td>72.90</td>
<td>20.34</td>
<td>41.55</td>
<td>25.48</td>
</tr>
<tr>
<td>LHV (MJ/kg)</td>
<td>4.50</td>
<td>5.14</td>
<td>3.55</td>
<td>3.59</td>
<td>7.49</td>
</tr>
<tr>
<td>Spec. heat (MJ/kg K)</td>
<td>1.23</td>
<td>1.23</td>
<td>1.12</td>
<td>1.14</td>
<td>1.47</td>
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<tr>
<td>Pressure (MPa)</td>
<td>0.14</td>
<td>0.14</td>
<td>0.14</td>
<td>0.14</td>
<td>0.14</td>
</tr>
<tr>
<td>Temperature (°C)</td>
<td>120</td>
<td>127</td>
<td>150</td>
<td>120</td>
<td>97</td>
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<tr>
<td>Gasification overall performance</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Max. temper. (°C)</td>
<td>1034</td>
<td>993</td>
<td>900</td>
<td>950</td>
<td>730</td>
</tr>
<tr>
<td>Cold gas efficiency</td>
<td>96.93%</td>
<td>96.13%</td>
<td>98.97%</td>
<td>90.60%</td>
<td>84.33%</td>
</tr>
<tr>
<td>Hot gas efficiency</td>
<td>93.28%</td>
<td>95.97%</td>
<td>97.08%</td>
<td>90.32%</td>
<td>84.25%</td>
</tr>
<tr>
<td>Gasif. yield (Nm³/kg)</td>
<td>5.36</td>
<td>3.04</td>
<td>1.85</td>
<td>4.52</td>
<td>2.12</td>
</tr>
<tr>
<td>SGR-GL (kg/m² h)</td>
<td>113.2</td>
<td>339.5</td>
<td>155.6</td>
<td>130.1</td>
<td>169.8</td>
</tr>
</tbody>
</table>

Best performance
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Characterization of fuels by means of pyrolysis and gasification tests has been conducted.

**BASED ON THE RESULTS OBTAINED SO FAR:**

For a fixed-bed, updraft gasification technology at atmospheric pressure:
- Usibelli coal is the most suitable (among tested fuels);
- Low reactive coals are not suitable.

**OUR WORK IS STILL IN PROGRESS**
Thank for your attention

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