Chemical looping combustion using biomass as fuel

Stefan Penthor, Tobias Pröll, Hermann Hofbauer

2nd Oxyfuel Combustion Conference, 12-16 September 2011, Yeppoon, Australia

Institute of Chemical Engineering:
Future Energy Technology
Prof. Hermann Hofbauer
www.vt.tuwien.ac.at
Outline

• Introduction
• Challenges and why biomass
• Solutions
• Modeling
• Results
• Conclusion/Outlook
What is CLC?

Air Reactor (AR)

Fuel Reactor (FR)

Cooling/Condensation

CO₂, (H₂O)

Solid Fuel

MeOₓ⁻¹

MeOₓ

N₂, (O₂)

H₂O

Air

Steamb
Challenges

- Decomposition of fuel
- Conversion of combustible gas species
- Avoiding loss of carbon to air reactor
- Separating ash from oxygen carrier

Objectives

- Finding suitable oxygen carrier
- Finding suitable reactor concept
Why biomass?

<table>
<thead>
<tr>
<th></th>
<th>Petroleum coke</th>
<th>South African coal</th>
<th>Woody biomass</th>
</tr>
</thead>
<tbody>
<tr>
<td>Volatiles [%]</td>
<td>10</td>
<td>21.6</td>
<td>80</td>
</tr>
<tr>
<td>Moisture [%]</td>
<td>8</td>
<td>8.3</td>
<td>25</td>
</tr>
<tr>
<td>Ash [%]</td>
<td>0.5</td>
<td>15.9</td>
<td>1.5</td>
</tr>
</tbody>
</table>

- Reactive char (compared to coal)
- Carbon neutral, low sulfur
- Below zero emission
- Stopover to coal
Solutions
Cold flow model tests

Modeling
Modeling approach

- Mass & energy balance
- Basic char gasification kinetics
- Chemical equilibrium for CO and H₂ oxidation
- Solids segregation
Solids segregation

\[ \varphi_i = \frac{\dot{m}_{i, \text{out, top}}}{\dot{m}_{i, \text{out, bottom}}} \quad \text{for} \quad i=\text{OC, Ash, Char} \]
First results
Base case

- $P_{th} = 1 \text{ MW}$
- Ilmenite as oxygen carrier
- $\phi = 1.2$
- Steam/Carbon $= 0.5$
- $OC = 0.05$
- $Ash = 0.2$
- $Char = 0.1$
- $Char = 9 - 20 \text{ s}$
- $T_{LLS} = 950 \text{ C}$
Base case

- $T_{AR} = 1015 \, \text{C}$
- $\text{sep, CO}_2 = 92.0 \%$
- Ash accumulation:
  - $x_{Ash,ILS} = 37.4 \%$
  - $x_{Ash,LLS} = 13.1 \%$
CLC using biomass as fuel
Stefan Penthor

Institute of Chemical Engineering
Future Energy Technology

\[ \text{• Ash variation} \]

- LLS @ 5kg/h OC make up
- ILS @ 5kg/h OC make up
- LLS @ 10kg/h OC make up
- ILS @ 10kg/h OC make up

Base case

Ash concentration [wt%] vs. \( \frac{\text{Ash}}{} \)
Conclusions/Outlook

- Multistage CFB can be key to solid fuel CLC
- Gas-solid contact and residence time improved
- Selective ash removal possible
- Process model created, validation necessary

- Cold flow model testing
- Build 100 kW pilot plant
Thank you for your attention!

Contact:
Stefan Penthor
stefan.penthor@tuwien.ac.at
www.chemical-looping.at

Institute of Chemical Engineering:
Future Energy Technology
Prof. Hermann Hofbauer
www.vt.tuwien.ac.at