Experimental Testing of Oxy Combustion in a Pilot Scale CFB Boiler

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Outline

• Background of the study
• Oxy combustion
• Pilot process with Circulating Fluidized Bed (CFB) technology
• Test period, aims and test types

→ To be continued in the next presentation
Background of study

- Oxy combustion development at VTT and Foster Wheeler
- Pilot scale CFB (circulating fluidized bed) boiler at VTT, Jyväskylä, Finland – air firing and oxy firing
- Foster Wheeler’s FlexiBurn™ CFB combustion technology
- Studying oxy combustion dynamics with the aim of developing and validating combustion controls
- Simulation studies
- Study continued in a larger-scale (CIUDEN 30 MW\textsubscript{th}) unit
CIUDEN 30 MWth / Compostilla 300 MWe oxy-CFB projects

BENCH SCALE REACTOR (BFB/CFB)

CIRCULATING FLUIDIZED BED REACTOR

ŁAGISZA 460 MWe supercritical OTU CFB

CIUDEN 30 MWth / Compostilla 300 MWe oxy-CFB projects

MODELING TOOLS

0D dynamic/stationary models
1D dynamic/stationary models
1D design model
3D model

0D dynamic/stationary models
Oxy combustion

- Fuel burnt with oxygen (and inert flue gas) instead of air – result: flue gases very high in CO₂
- In demonstration phase
- Motivation: CO₂ mitigation in power plants

- CCS - CO₂ capture and storage
  “separation of CO₂ from industrial and energy-related sources, transport to a storage location and long-term isolation from the atmosphere” (IPCC 2005)
- Short and medium term solutions to the CO₂ issue in fossil power plants include CCS, increasing energy efficiency, cofiring with / switching to CO₂ neutral fuels

- Oxy combustion
- Post-combustion capture
- Pre-combustion capture
- Chemical looping
Oxy combustion – changes in gas composition and properties

<table>
<thead>
<tr>
<th></th>
<th>Gas constituents, % (wet basis)</th>
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<tbody>
<tr>
<td></td>
<td>Combustion with air</td>
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<tr>
<td>Windbox</td>
<td></td>
</tr>
<tr>
<td>O₂</td>
<td>21</td>
</tr>
<tr>
<td>N₂</td>
<td>79</td>
</tr>
<tr>
<td>CO₂</td>
<td>0</td>
</tr>
<tr>
<td>H₂O</td>
<td>small</td>
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<tr>
<td>others</td>
<td>–</td>
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<tr>
<td>Flue gas</td>
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</tr>
<tr>
<td>O₂</td>
<td>3–4</td>
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<tr>
<td>N₂</td>
<td>70–75</td>
</tr>
<tr>
<td>CO₂</td>
<td>12–14</td>
</tr>
<tr>
<td>H₂O</td>
<td>10–15</td>
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<tr>
<td>others</td>
<td>NOₓ, SO₂</td>
</tr>
</tbody>
</table>

- Oxygen (purity 95-99%) produced in an air separation unit, mixed with recycled flue gas (RFG)
- Oxidant gas contains little N₂, high amounts of CO₂ and H₂O
- Significantly higher gas density and heat capacity
- In oxy combustion, the oxygen amount is not limited to 21 vol-
- Different oxidant flows may have different O₂ content

(Davidson & Santos 2010)
Air and oxy combustion in the same boiler: Flexi-Burn™

- Air and oxy firing can be used in the same CFB boiler
- Approximately the same conditions for both firing modes
- Dual firing enhances flexibility
The pilot CFB test rig at VTT

- Fuel power 50-100 kW in oxy mode, 20-50 kW in air mode
- Siemens PCS7 automation system
- Two fuel containers
- Containers for limestone, sand and other additives
- Primary gas fed through the grid, secondary gas added at different levels
- Gas flows and compositions can be adjusted independently for primary and secondary gases
- Oxidant gas consists of air, bottled O₂, RFG, CO₂, N₂
- Flue gas recirculation system (fan with flow measurement and control)
- Several separately controlled electrically heated and water/air cooled zones
- Extensive temperature and pressure measurements
- Flue gas composition measured by FTIR spectrometer and traditional on-line gas analyzers
- Gas and solids sampling ports, bottom ash discharging
Test period with the CFB pilot

- Dynamical behaviour needed for control design
- Finding the best operation procedures

- Test matrix was designed to reveal the essentials in boiler dynamics
  - Load steps: AIR, OXY
  - Load ramps: OXY
  - Switches: AIR-OXY, OXY-AIR

- Output measurements of interest: gas compositions, flue gas $O_2$, furnace pressures, temperature profiles and dynamic behaviour...
Load steps

- Air: 100 → 90 → 75 → 90 → 100 % load
- Oxy: 100 → 85 → 70 → 85 → 100 % load

- stepwise simultaneous changes in fuel and gases
Load ramps in oxy combustion mode

- Slow ramp 1%/min -> 15% change
- Fast ramp 5%/min -> 15% change
- Slow ramp 1%/min -> 30% change
Combustion mode switch: air-oxy, oxy-air

- Straight from air (O\textsubscript{2} 21 vol-%) to oxy mode (O\textsubscript{2} 28 vol-%), keeping fluidization constant
- Simultaneous load change
Further studies

• A hot-loop (furnace) simulation model developed to be validated based on the measurement data
• Current study will be continued in a larger-scale (CIUDEN 30 MWth) unit.
Thank You for Your attention!

Compostilla power station, Spain

CIUDEN 30 MWth CFB oxy combustion and CCS test facility (21 November 2011 first oxy combustion)