Dynamic Simulation of a Conceptual 600MW Oxyfuel Combustion Power Plant

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Process simulation

◆ Steady-state simulation
  ○ mass and energy balances
  ○ material and energy flows
  ○ exergy analysis, thermoeconomic evaluation,...

◆ Dynamic simulation
  ○ dynamic characteristics
  ○ system operation/design/optimization
  ○ control strategy
  ○ safety analysis
  ○ ......
Outline

- From steady-state simulation to dynamic simulation
- Dynamic analysis
- Conclusion
Steady state model

Coal, an unsupported material in Aspen dynamics

✓ Pseudo-coal \((C_aH_b+S+N+O)\) to meet proximate and ultimate analysis.

## Pseudo-coal validation

<table>
<thead>
<tr>
<th>Composition</th>
<th>Air combustion</th>
<th>Oxyfuel combustion</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Real coal</td>
<td>Pseudo coal</td>
</tr>
<tr>
<td>O$_2$ (%)</td>
<td>3.14</td>
<td>3.15</td>
</tr>
<tr>
<td>N$_2$ (%)</td>
<td>73.30</td>
<td>74.24</td>
</tr>
<tr>
<td>Ar (%)</td>
<td>0.92</td>
<td>0.93</td>
</tr>
<tr>
<td>H$_2$O (%)</td>
<td>7.59</td>
<td>7.70</td>
</tr>
<tr>
<td>CO$_2$ (%)</td>
<td>14.99</td>
<td>13.92</td>
</tr>
<tr>
<td>NO (ppm)</td>
<td>252</td>
<td>254</td>
</tr>
<tr>
<td>NO$_2$ (ppm)</td>
<td>0.77</td>
<td>0.77</td>
</tr>
<tr>
<td>SO$_2$ (ppm)</td>
<td>395</td>
<td>377</td>
</tr>
<tr>
<td>SO$_3$ (ppm)</td>
<td>5.26</td>
<td>5.03</td>
</tr>
<tr>
<td>CO (ppm)</td>
<td>0.51</td>
<td>0.47</td>
</tr>
</tbody>
</table>

Relative error less than 8.3 %
Steady-state model converted into dynamic model

Dynamic model of a conceptual 600MWe Oxyfuel pulverized coal-fired boiler
## Dynamic simulation validation

<table>
<thead>
<tr>
<th>Items</th>
<th>Steady model</th>
<th>Dynamic model</th>
<th>Items</th>
<th>Steady model</th>
<th>Dynamic model</th>
<th>Items</th>
<th>Steady model</th>
<th>Dynamic model</th>
<th>Items</th>
<th>Steady model</th>
<th>Dynamic model</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Gas Composition</strong></td>
<td></td>
<td></td>
<td><strong>Flow rate (kmol/s)</strong></td>
<td></td>
<td></td>
<td><strong>Temperature (°C)</strong></td>
<td></td>
<td></td>
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</tr>
<tr>
<td>O₂, %</td>
<td>3.13</td>
<td>3.16</td>
<td>Flue gas (w)</td>
<td>17.72</td>
<td>17.58</td>
<td>Burner</td>
<td>1100</td>
<td>1100</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>N₂, %</td>
<td>6.26</td>
<td>6.31</td>
<td>Fuel (Coal)</td>
<td>0.50</td>
<td>0.50</td>
<td>Superheater</td>
<td>1023</td>
<td>1023</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Ar, %</td>
<td>3.39</td>
<td>3.42</td>
<td>Oxygen</td>
<td>5.15</td>
<td>5.15</td>
<td>Reheater</td>
<td>891</td>
<td>889</td>
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<tr>
<td>H₂O, %</td>
<td>14.20</td>
<td>13.46</td>
<td>Air-Inleak.</td>
<td>0.31</td>
<td>0.31</td>
<td>Economizer</td>
<td>792</td>
<td>790</td>
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<td></td>
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<tr>
<td>CO₂, %</td>
<td>72.82</td>
<td>73.44</td>
<td>Recy. flue gas</td>
<td>10.90</td>
<td>10.75</td>
<td>Air prehe.</td>
<td>174</td>
<td>177</td>
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<tr>
<td>NO, ppm</td>
<td>73.50</td>
<td>74.26</td>
<td>Flue gas (d)</td>
<td>15.68</td>
<td>15.47</td>
<td>Cooler</td>
<td>30</td>
<td>24</td>
<td></td>
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<tr>
<td>NO₂, ppm</td>
<td>0.22</td>
<td>0.23</td>
<td></td>
<td></td>
<td></td>
<td>Stack</td>
<td>172</td>
<td>181</td>
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<tr>
<td>SO₂, ppm</td>
<td>1970</td>
<td>1983</td>
<td></td>
<td></td>
<td></td>
<td>Primary air</td>
<td>110</td>
<td>115</td>
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<tr>
<td>SO₃, ppm</td>
<td>26.21</td>
<td>26.54</td>
<td></td>
<td></td>
<td></td>
<td>Second. air</td>
<td>330</td>
<td>339</td>
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<td></td>
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</tr>
<tr>
<td>CO, ppm</td>
<td>2.49</td>
<td>2.49</td>
<td></td>
<td></td>
<td></td>
<td>Oxygen</td>
<td>30</td>
<td>35</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Relative error less than **5.2%**
Outline

- From steady-state simulation to dynamic simulation
- Dynamic analysis (mode switching)
- Conclusion
Switching from air-combustion to oxy-combustion (17 min)

- CO₂: 13.92% to 73.44%; H₂O: 7.68% to 13.46%; CO concentration increases slightly.
- NOₓ concentration decreases slightly, and follows with the oxygen concentration evolution.
- SOₓ concentration increases to 5.3 times of that of air combustion, and follows with the CO₂ concentration evolution.
Switching from air-combustion to oxy-combustion

- Operating air, recycled flue gas (RFG) and oxygen with individual flow rates
  - Cutting off air: 1.56kmol/min;
  - Oxygen injection: 0.39kmol/min (8-13min) and 0.72kmol/min (13-20min);
  - Recycled flue gas by the pressure PID controller.

- Recycle ratio Increases to 69.5% and changes in three stages.
  - From 3 to 8 min, it increases gradually, while it changes flatly from 8 to 13min. At last, it increases in another rate from 13 to 20 min.
Switching from air-combustion to oxy-combustion

- **Oxygen concentration**
  - Oxygen concentration in flue gas at the exit of furnace is maintained at 2 to 7% to make similar heat transfer profile with that of air-combustion.
  - The oxygen concentration decreases to 18.61% in primary gas and increases to 38.55% in secondary gas.

- **Flue Gas Temperature**
  - Superheater, reheater, economizer: decrease slightly;
  - Primary and secondary airs, air heater flue gas: change drastically.
  - Reducing the heat transfer area in the air preheater to regulate the PA and SA temperature.
Switching from oxy-combustion to air-combustion

- The dynamic processes evolve in an opposite way.
- Difference rates to Cut off the oxygen, Supply the air and Recycle flue gas.
Outline

- From steady-state simulation to dynamic simulation
- Dynamic analysis (disturbances)
- Conclusion
Load Change

- the load increases 6% with 5 hours, then stabilizes within 9 hours, and finally drops 5% within 5 hours
- the concentrations of CO₂, SO₃ in final flue gas and O₂ in primary and secondary airs respond the load change very fast
Outline

- From steady-state simulation to dynamic simulation
- Dynamic analysis
- Conclusion
Conclusion

- **Dynamic model** of a 600MWe Oxyfuel pulverized coal-fired boiler in Aspen Dynamics was established and validated.

- **Switching process** from air-combustion to oxy-combustion and then back to air-combustion was realized.

- **A switching strategy**, which operates the oxygen, air and recycled flue gas simultaneously at individual rates, was developed.

- The effect of **some planned disturbances** on dynamic characteristics was investigated.
THANK YOU FOR YOUR ATTENTION!