Modeling Used to Advance the Recovery Process

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CFD Application to Recovery Boilers

• Model development and validation at UBC since early 1990s
• Over 50 recovery boilers being modeled at PSL
• Wide cooperation with pulp and paper mills, research institutes, boiler and air system manufactures
• Expertise in CFD, boiler, combustion, visualization
• PSL being an independent consultant
Modeling Application - Air System (1)
Modeling Application - Air System (2)

Air ports:
- Width: 6.625" = 0.1683 m
- Height: 18.868" = 0.4792 m

Burner ports:
- Width: 6.625" = 0.1683 m
- Height: 20" = 0.508 m
Modeling Application - Carryover Reduction

--- drying
--- pyrolysis
--- char
--- smelt

Carryover Mass flux (g/M²/s)

Case 1

Case 6
Modeling Application - Load Increase

Existing operation and air system
Liquor fired: 1.65 MlbDS/day

Future operation and new air system
Liquor fired: 2.4 MlbDS/day
Modeling Application - NCG Burning

Existing operation: no DNCG

Future operation: burning DNCG
**Modeling Application - Wall Corrosion (1)**

- **Kinetic data of the two reactions of pyrolysis**
  \[ a_1 = 0.202 \]
  \[ A_1 = 1.999 \text{ [1/s]} \]
  \[ Ea_1 = 7 \times 10^3 \text{ [J/mole]} \]
  \[ a_2 = 0.54 \]
  \[ A_2 = 15 \text{ [1/s]} \]
  \[ Ea_2 = 3 \times 10^4 \text{ [J/mole]} \]

- **H₂S recapture reaction**
  \[ H₂S + Na₂CO₃ = Na₂S + H₂O + CO₂ \]

- **Reaction rate**
  \[ k = A[H₂S] \exp(-Ea/RT) \]
  \[ A = 8 \times 10^4 \text{ [1/s]} \]
  \[ Ea = 10^5 \text{ [J/mole]} \]

- **H₂S oxidation reaction**
  \[ H₂S + 1.5O₂ = H₂O + SO₂ \]

- **Reaction rate**
  \[ k = A[O₂]^a[H₂S]^b \exp(-Ea/RT) \]
  \[ A = 3 \times 10^7 \text{ [1/s]} \]
  \[ Ea = 7.54 \times 10^4 \text{ [J/mole]} \]
  \[ a = 1.0 \quad [O₂] < 4\% \]
  \[ a = 1.3 \quad [O₂] \geq 4\% \]
  \[ b = 1.05 \]

---

**Sulfur Evolution and Oxidation Model**
H2S Concentration in Columbus Boiler

Case 7RD

H2S [vol, ppm]
- 1000
- 100
- 10
- 1
- 0.1
- 0.01

Btu/Hr/Ft²
- 45000
- 42500
- 40000
- 37500
- 35000
- 32500
- 30000
- 27500
- 25000
- 22500
- 20000
- 17500
- 15000
- 12500
- 10000
- 0

Front Wall
Right Wall
Left Wall
Rear Wall

PSL
Modeling Application - BL Gasification (1)
### Modeling Application - BL Gasification (2)

#### Log-normal droplet size distribution

- **Base case**
- **Black liquor gasification**
- **Fine droplet**

#### Steam
- 10% more for 1 hole
- 10% less for 1 hole
- Average for others

#### Table: Gas Production and Heat Value

<table>
<thead>
<tr>
<th></th>
<th>Case 1</th>
<th>Case 2</th>
<th>Case 3</th>
<th>Case 4</th>
<th>Case 5</th>
<th>Case 6</th>
<th>Case 7</th>
<th>Typical</th>
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</thead>
<tbody>
<tr>
<td><strong>Mass fraction, dry, %</strong></td>
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<tr>
<td>CH$_4$</td>
<td>0.31</td>
<td>0.23</td>
<td>0.3</td>
<td>0.3</td>
<td>0.3</td>
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<td>26.41</td>
<td>29.14</td>
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<td>4.11</td>
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<td>1.07</td>
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<tbody>
<tr>
<td><strong>Volume fraction, dry, %</strong></td>
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<td><strong>Heat value, dry</strong></td>
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<td>kJ/mole</td>
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<td>kJ/m$^3$</td>
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Modeling Application - Airport Crack Study (1)

- Boiler 1
- Global Boiler Modeling
- Single Airport Modeling
- Global Boiler + Single Airport Modeling
Modeling Application - Airport Crack Study (2)

Recirculation extends to the bottom of the port.

Recirculation locates far from the port.
Visualization - ProcessCam Technology
Visualization - Simulator Technology

Operator experience

Measurements

Physical Model

Process Model

\[ \partial \left( \rho u \phi_j - \Gamma_j \partial \phi_j \right) / \partial x_i = S_j \]

Process knowledge

Simulator Core

Operational Simulators

Training Simulators

Virtual Cameras
Conclusions

• An effective way to optimize design and operation.
• Helpful to understanding mechanisms and problem root-causes.
• Saving costs and reducing risks.
• Useful as a training tool for operators and process engineers.
• Further improvements on sub-models.
Other Equipment PSL Models

- Bark Boiler
- Utility Boiler
- Cyclone
- Headbox
- Kiln
- Electrostatic Precipitator
Publications


