Corrosion of various metals under simulated WTE conditions; and Sequestration of HCl in WTE Combustion Chambers

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Shang-Hsiu Lee
Columbia University
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Research progress since last meeting

- In 2006 WTERT meeting
  - Corrosion survey results (distributed in 2005)
  - Chemical analysis of slag from WTEs
- Corrosion experiments
  - Verification of chlorine induced corrosion mechanism
  - Corrosion kinetics – 10, 25, 40, 80, and 100 hrs
  - Effect of various HCl gas concentrations on corrosion rates – 0, 500, 1000 ppm HCl
- HCl/Cl₂ sequestration tests
  -Injecting a slurry of calcium hydroxide into the combustion chamber that reacts with HCl to form calcium chloride
    \[ \text{Ca(OH)}_2 + 2\text{HCl}(g) = \text{CaCl}_2 + 2\text{H}_2\text{O}(g) \]
**Corrosion experimental setup**

- The thermal gradient between the gas and test metal surface
  - Condensation of vaporized species
- Composition of the synthesis gas
  - Simulating the flue gas composition of the WTEs

- 6 samples per test
- Sample dimensions: 1” x 1” x 0.04”
## Corrosion experimental matrix

- Duration of each test: 100 hrs

<table>
<thead>
<tr>
<th>Test sample</th>
<th>major composition (wt.%)</th>
<th>metal temp. (composition)</th>
<th>Test environment (atmosphere)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>C</strong></td>
<td><strong>Si</strong></td>
<td><strong>Mn</strong></td>
<td><strong>P</strong></td>
</tr>
<tr>
<td><strong>SA178A</strong></td>
<td>0.07</td>
<td>0.06</td>
<td>0.47</td>
</tr>
<tr>
<td><strong>SA213</strong></td>
<td>0.08</td>
<td>0.28</td>
<td>0.43</td>
</tr>
<tr>
<td><strong>T11</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>NSSER-4</strong></td>
<td>0.04</td>
<td>2.5</td>
<td>0.8</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Corrosion experimental procedures

Sample Preparation & Pre-Test Mass Measurements by ASTM G1-03

Corrosion Test in the Furnace (100 hrs)

Post-Test Analyses

- Surface and Cross-Section Metallographic Analyses by Scanning Electron Microscope (SEM)
- Corrosion Products Analyses by SEM with Energy Dispersive Spectroscopy (EDS)
- Mass Loss Corrosion Rate Measurements by ASTM G1-03

ASTM G1-03: Standard Practice for Preparing, Cleaning, and Evaluating Corrosion Test Specimens
Surface morphologies of samples after 100 hr test

- **Alloy NSSER-4**
  - (a) 570°C
  - (b) 630°C
  - (c) oxides / sulphides

- **Alloy SA213 T11**
  - (a) 565°C

- **Alloy SA178A**
  - (a) 540°C
  - (b) 600°C
  - (c) Iron sulfate, magnetite/ wustite, ferrous sulphide
Verification of the corrosion mechanism

- Alloy NSSER-4
  - Cross sectional SEM image of sample and elementary analysis of each spot

<table>
<thead>
<tr>
<th>Spot</th>
<th>O</th>
<th>Si</th>
<th>Cl</th>
<th>Cr</th>
<th>Fe</th>
<th>Mn</th>
<th>Ni</th>
<th>P</th>
<th>S</th>
</tr>
</thead>
<tbody>
<tr>
<td>a</td>
<td>8.85</td>
<td>0.01</td>
<td>39.53</td>
<td>2.28</td>
<td>46.99</td>
<td>0.00</td>
<td>1.48</td>
<td>0.35</td>
<td>0.52</td>
</tr>
<tr>
<td>b</td>
<td>0.00</td>
<td>0.00</td>
<td>39.38</td>
<td>2.94</td>
<td>50.09</td>
<td>0.00</td>
<td>2.19</td>
<td>0.49</td>
<td>0.67</td>
</tr>
<tr>
<td>c</td>
<td>0.24</td>
<td>0.27</td>
<td>41.75</td>
<td>3.47</td>
<td>52.24</td>
<td>0.00</td>
<td>1.11</td>
<td>0.29</td>
<td>0.64</td>
</tr>
<tr>
<td>d</td>
<td>0.00</td>
<td>2.38</td>
<td>3.16</td>
<td>20.48</td>
<td>70.79</td>
<td>0.00</td>
<td>1.36</td>
<td>0.36</td>
<td>1.47</td>
</tr>
<tr>
<td>e</td>
<td>0.00</td>
<td>2.14</td>
<td>1.70</td>
<td>18.51</td>
<td>74.52</td>
<td>0.00</td>
<td>1.08</td>
<td>0.46</td>
<td>1.59</td>
</tr>
<tr>
<td>f</td>
<td>0.00</td>
<td>2.32</td>
<td>1.06</td>
<td>18.97</td>
<td>74.36</td>
<td>0.11</td>
<td>1.21</td>
<td>0.54</td>
<td>1.44</td>
</tr>
<tr>
<td>g</td>
<td>0.00</td>
<td>2.39</td>
<td>1.84</td>
<td>19.12</td>
<td>71.43</td>
<td>0.00</td>
<td>0.07</td>
<td>0.34</td>
<td>1.55</td>
</tr>
</tbody>
</table>

- Higher concentration of Cl on the surface of the remaining sample (scale/metal interface)
Corrosion kinetics

- Alloy SA178A
- Test duration: 10, 25, 40, and 100 hrs
- Gas temperature: 750 °C
Effects of HCl gas concentrations on corrosion rates

- Alloy SA213 T11

(a) $570^\circ$C, 100 hrs, non-HCl
(b) $565^\circ$C, 100 hrs, 1000 ppm HCl
Effects of HCl gas concentrations on corrosion rates

- Alloy SA213 T11
- Alloy SA178A
- NSSER-4

Corrosion Rate [mils per year]

Metal Temp. [°C]

Corrosion Rate [mils per year]

Metal Temp. [°C]

Corrosion Rate [mils per year]

Metal Temp. [°C]
HCl/ Cl₂ sequestration tests setup

compresssed air

Ca(OH)₂

slurry

flue gas

compressed air

synthetic flue gas (HCl, SO₂, O₂, CO₂, and etc.)

test samples
**HCl/ Cl₂ sequestration tests setup**

- Injection system – similar to the spray system of a SDA

![Diagram of injection system](image)
**HCl/Cl₂ sequestration tests result**

- Gas composition: 8% O₂, 12% CO₂, 10% Water Vapor, 1000 ppm HCl, 100 ppm SO₂, and bal. N₂
- Gas temperature: 750°C
- Metal temperature: 700°C

<table>
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<tr>
<th></th>
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<th>SA213 T11</th>
<th>NSSER-4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Baseline (no Ca(OH)₂)</td>
<td>3058 (mpy)</td>
<td>3463 (mpy)</td>
<td>17 (mpy)</td>
</tr>
<tr>
<td>Ca(OH)₂ : HCl = 2 : 1</td>
<td>2145 (mpy)</td>
<td>2824 (mpy)</td>
<td>12 (mpy)</td>
</tr>
<tr>
<td>Corrosion reduction</td>
<td>29.85%</td>
<td>18.46%</td>
<td>30.39%</td>
</tr>
</tbody>
</table>
Refinement of the sample carrier

- Sample carrier II - lower metal temperature and larger thermal gradient
Acknowledgement

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