Stress Corrosion Cracking of Stainless Steel Canister of Concrete Cask

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This work has been carried out under the contract from NISA/METI.
Background

Chemical plants at coastal regions have been experienced external stress corrosion cracking (ESCC) by air containing sea salt.

Location of nuclear power plants in Japan
Stress Corrosion Cracking

**Environment**
- Sea salt, humidity

**Material**
- Stainless steel
- Austenitic stainless steel
- Rust

**Stress**
- Residual stress of weldment

Sub-processes:
- Deposition of sea salt particles
- Deliquescence of sea salt
- Pitting or crevice corrosion
- Crack occurs around weld
SCC mitigation

• Environment
  - Keep Cl density lower than threshold value
  - SCC does not occur at lower than threshold temperature or threshold relative humidity

• Material
  - High chromium or high molybdenum steel

• Stress
  - Stress relaxation / Compressed stress
Crack growth evaluations

• Crack growth measurement with CT specimen or 4-point bend specimen
• Atmospheric SCC almost do not depend on K value, so crack length depends on operation time.
• Considering threshold relative humidity for SCC, constant crack growth during all the storage period seems conservative.
Environmental requirement

Specify the storage system
- Facility (Structure, Salt intrusion rate)
- Cask (Structure, Material, Spent fuel)

(a) Salt density critical to initiate SCC*
(b) Salt density that deposit on canister

- Decrease the salt deposition
- Utilize corrosion resistive material

* Initiation of SCC is defined as follows
- Emerge of rust (precursor of cracking)
- Initiation of small crack
Assessment for design

Modification is required to:
• Decrease salt deposition
• Increase threshold for corrosion (change of material for canister)
Chloride density for Rusting

Satisfy absolute humidity of 30g/m³
Yield stress was applied on specimens.
Threshold Cl density for SCC

<table>
<thead>
<tr>
<th>Material</th>
<th>Rusting</th>
<th>Cracking</th>
<th>PRE*</th>
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</thead>
<tbody>
<tr>
<td>S30403</td>
<td>0.1</td>
<td>0.3</td>
<td>18.3</td>
</tr>
<tr>
<td>S31260</td>
<td>0.3</td>
<td>1</td>
<td>37.8</td>
</tr>
<tr>
<td>S31254</td>
<td>0.5</td>
<td>10**</td>
<td>43.3</td>
</tr>
</tbody>
</table>

(g/m² as Cl)

* PRE = %Cr + 3.3 × (%Mo) + 16 × (%N)

** Maximum test condition, no SCC observed

<table>
<thead>
<tr>
<th></th>
<th>C</th>
<th>Si</th>
<th>Mn</th>
<th>P</th>
<th>S</th>
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<tbody>
<tr>
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<td>&lt;0.030</td>
<td>&lt;0.75</td>
<td>&lt;2.00</td>
<td>&lt;0.045</td>
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<td>&lt;0.75</td>
<td>&lt;1.00</td>
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<td>&lt;0.030</td>
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<tr>
<td>UNS S31254</td>
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<td>&lt;0.80</td>
<td>&lt;1.00</td>
<td>&lt;0.030</td>
<td>&lt;0.010</td>
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</table>

<table>
<thead>
<tr>
<th></th>
<th>Cu</th>
<th>Ni</th>
<th>Cr</th>
<th>Mo</th>
<th>N</th>
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<tbody>
<tr>
<td>UNS S30403</td>
<td>–</td>
<td>8.00–12.00</td>
<td>18.00–20.00</td>
<td>–</td>
<td>&lt;0.10</td>
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<td>5.50–7.50</td>
<td>24.00–26.00</td>
<td>2.50–3.50</td>
<td>0.10–0.30</td>
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<tr>
<td>UNS S31254</td>
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<td>17.50–18.50</td>
<td>19.50–20.50</td>
<td>6.00–6.50</td>
<td>0.18–0.22</td>
</tr>
</tbody>
</table>
SCC resistant material

Test condition: 80°C, 35%RH, 10g/m² as Cl(sea salt)
Experiment for residual stress relaxation

Weld (TIG, Laser)

(Left: g/m² as Cl)

After 2000h in 50°C, 35%RH

This specimen has no stress relaxation.
Crack Growth Test

4 point bend test
Type 304 stainless steel, 80°C, 35%RH, 270MPa
About 10g/m² as Cl of sea salt

Potential drop data was converted to crack depth data, assuming half elliptical crack propagated.
Example of crack growth evaluation

Calculated RH with data from Tsuruga weather station and data of heat decay test with model canister.

CGR: $1 \times 10^{-11}$ m/s

19mm / 60 years
0.5mm / 15000h
Summary

• Threshold chloride density for SCC is obtained.
• SCC resistivity of high chromium, high molybdenum stainless steels are shown.
• Stress relaxation test is in progress.
• Taking into account of environmental condition, crack growth evaluation suggests that crack do not penetrate canister wall.