Stress Corrosion Cracking of Stainless Steel Canister of Concrete Cask

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1. Background

In the dry storage of spent nuclear fuels using concrete casks, stainless steel canisters act as the final barrier to encapsulate spent fuels and radio-active materials. If the storage facility is built on costal area, canister may suffer stress corrosion cracking (SCC) by sea salt. SCC occurs when certain conditions of stress, material and environment are satisfied. Components of chemical plants that uses stainless steel like type 304 at costal area have been experienced SCC by sea salt. Referring such the case, canister may suffer the SCC at less than 100^{o}C. A design criterion for mitigation of SCC is necessary to utilize the cask system. SCC is mitigated if one of the conditions is removed. Otherwise crack propagation control is required to maintain confinement.

2. Mitigation of SCC

2.1 Environment

The SCC will not occur at lower than certain amount of salt on the canister surface. Even enough salt deposited on the canister, corrosion or cracking may not occur when salt is dried. Wet and dry of the deposited salt is ruled by temperature and relative humidity (RH) on the canister surface. Corrosion and SCC will be inert at lower than the certain temperature. These environmental factors are related to management of the SCC.

Threshold chloride density is obtained by simple corrosion test and SCC initiation test. Corrosion test results were examined as rust area ratio, and rust area of greater than 0.02% is denoted as “rusted”. SCC initiation test is uniaxial constant load test. The initiation test specimens were observed with SEM for verification of cracking. Test results are summarized on Table1.

2.2 Material

As the atmospheric SCC is induced by chloride, materials designed for marine environment has a good SCC resistivity. Chromium and molybdenum are beneficial alloying elements to resist chloride. As shown on Table1, corrosion resistant materials, S31260 and S31254, have higher threshold chloride density for SCC than 304 stainless steel. We also have a data for proving good performance of such materials by long term SCC test. Failure time or test duration time are shown on Fig.1. 304 stainless steel failed by constant load test at least 250hours, while S31254 and S31260 stainless steels do not fail for more than 60,000 hours.

2.3 Stress

SCC does not occur with compressed stress. Stress relaxation such as peening or burnishing is one of the effective SCC mitigation measure. We are currently conducting SCC test using weld joint specimens with and without stress relaxation. We also applied laser welding for expecting low residual stress.

3. Crack propagation control

If SCC is detected on the canister wall, evaluation of crack propagation is required. Crack growth rate under various conditions are measured. One of the results is shown on Fig.2. Crack propagated fast at initially, then propagation rate decrease. This is specific for the test with sea salt while test with magnesium chloride showed constant fast crack propagation. Assuming initial several mm of fast propagation as initial crack, remaining canister wall is evaluated with slow propagation rate data. We tentatively adopted crack growth rate as 1×10^{-11} m/s. Crack growth at this rate for 60years yield 19mm, but this is conservative evaluation. Due to changes in temperature and relative humidity on canister surface, SCC does not necessary propagate all the storage period. An example of calculated relative humidity on canister surface is shown on Fig.3. Summated time above threshold RH of 15% is 15,000h, and crack propagation during this period is 0.5mm.

4. Acknowledgement

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Table1 Threshold chloride density for rusting or cracking.

Material	Rusting	Cracking	PRE*
S30403	0.1	0.3	18.3
S31260	0.3	1	37.8
S31254	0.5	10**	43.3

(g/m^2 as Cl)

* PRE=%Cr＋3.3×(%Mo)＋16×(%N)

** Maximum test condition, no SCC observed

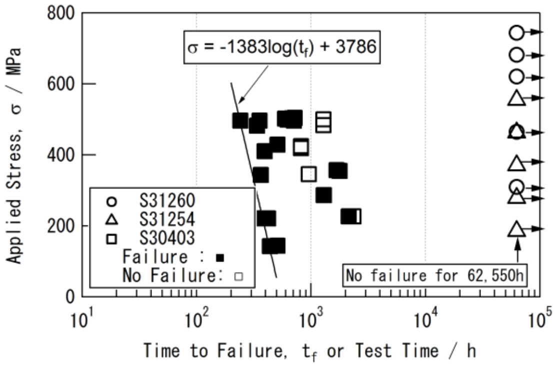

Fig.1 Result of constant load test. Test was done at 80C, 35%RH.

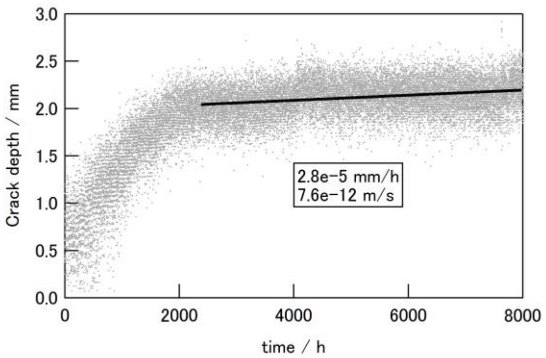

Fig.2 An Example of crack growth rate test. 4poin bend specimen of 304L stainless steel was tested in 80C, 35%RH with sea salt.

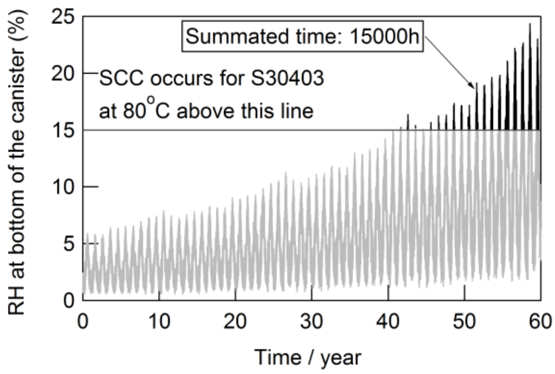

Fig.3 An Example of calculated relative humidity derived from heat decay test data and weather station data.