An investigation into the effects of chloride ion concentration and crevice geometry on denting corrosion

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1. Introduction

It has been reported that Stress Corrosion Cracking (SCC) can lead to damage of the steam generator tubes in a nuclear power plant. Denting corrosion can occur between the steam generator tubes and tube support plate (TSP) or top of tube sheet (TTS), and it is therefore considered that denting is one of the factors related to the occurrence of SCC. Denting occurs when brackish or seawater is used for the cooling system. On the other hand, it has been known that oxidizers such as dissolved oxygen can create acidification at the crevice region in the case of pure-water cooling. These factors regarding the denting phenomenon have been evaluated based on the concentrations of dissolved oxygen, chloride ion, temperature, pH, crevice geometry, and so on.

In this work, we look into the effects of crevice geometry and chloride ion concentration on the denting corrosion rate.

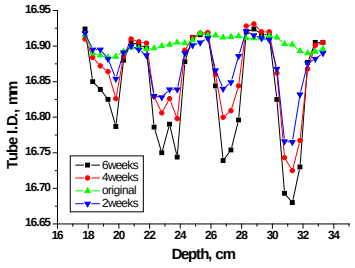
2. Experimental procedure

A denting autoclave design was prepared for a static autoclave system. A cartridge heater was located inside an Alloy600 tube. Before the test, the tube diameter was measured using a bore gauge. We checked the variation of the tube diameter every 2weeks. The inner section of the Alloy600 tube was filled with 25ml of pure water, and the outside was filled with a 1.6ℓ solution of 3500ppm NaCl + 0.2 M $CuCl_2$ for the crevice geometry test, and 3ppm NaCl + 0.2 M $CuCl_2$ for the chloride ion concentration test. SA508 rings were attached to the outside of the alloy600 tube. The crevice geometry was 50 ㎛, 100 ㎛, and 200 ㎛, with another 200 ㎛ rings was supported on the Alloy600 plate at the bottom to prevent corrosion products from falling. To create a boiling state, a heat flux flow from inside to outside the tube was conducted, with a temperature difference of 20℃ (280℃-300℃).

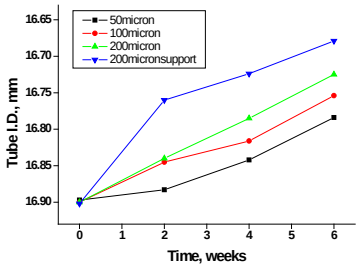
3. Results and discussion

3.1 The effect of the crevice geometry

Fig. 1. shows the measured tube diameter variation after 3500ppm NaCl + 0.2M $CuCl_2$ was applied for 8 weeks for the denting corrosion test. As a result, the denting corrosion rate was increased incrementally base on the crevice gap size. The test also revealed that the corrosion rate of an Alloy600 with 200 ㎛ crevice gap size and support plate specimen the fastest.

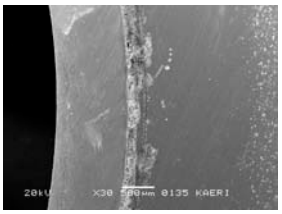


(a)

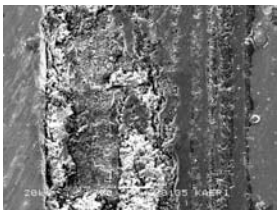


(b)

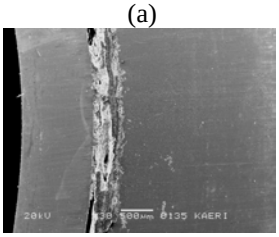
Fig. 1. The measurement of the tube I.D. after the crevice geometry test. (a) The variations of tube diameter over 6 weeks. (b) The denting corrosion rate of specimens with different crevice geometries.



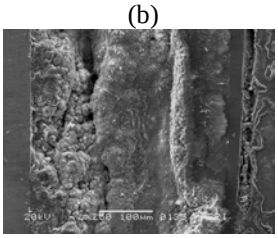
(a)



(b)



(c)

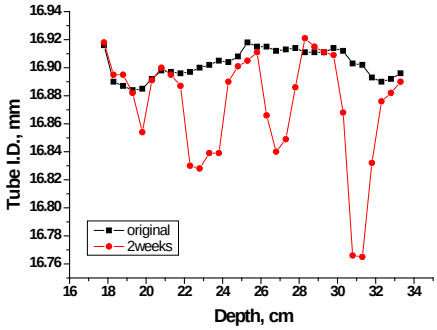


(d)

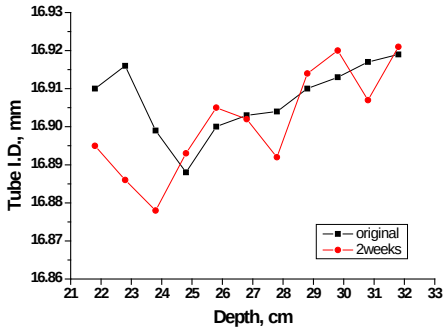
Fig. 2. SEM images of the corrosion product between Alloy600 tube and SA508 rings. (a) crevice gap of 100㎛ (b) a magnification of (a), (c) crevice gap of 200㎛, and (d) a magnification of (c).

Fig. 2. shows the corrosion product between Alloy600 and SA508 rings. There are corrosion products in all crevice gaps. It was observed that there are two different areas between Alloy600 and SA508 rings. In other words, one denting corrosion layer is dense, while another is relatively thin. It was assumed that the layer was formed in the early stage, was then compressed, and finally became a dense layer.

3.2 The effect of the concentration of the chloride ion



(a)



(b)

Fig. 3. The change of the tube I.D. (a) 3500ppm NaCl + 0.2M $CuCl_2$ solution (b) 3ppm NaCl + 0.2M $CuCl_2$ solution.

Fig. 3. shows the changes of tube diameter after a denting corrosion test. As the figure shows, the denting corrosion rate was decreased with a decrease in the concentration of chloride ions. It was assumed that the acid chloride in the crevice affects the denting corrosion formation. Thus, the denting corrosion rate was decreased with a reduced chloride ion concentration.

4. Summary

A denting corrosion test was conducted using different crevice gaps and NaCl concentrations. A static autoclave with a 20℃ temperature difference (280-300℃) was used. In summary, 200㎛ crevice gap size with alloy600 support plate specimen had the fastest corrosion rate. The crevice gap was filled with dense and thin layers. The denting corrosion decreased with a reduced chloride ion concentration.

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