Investigation on the Effects of Denting Occurring in Alloy 600 SG tubing on Environmental Parameters in Operating Nuclear Power Plants

Joung Soo Kim, Myong Jin Kim, Hong Pyo Kim, and Sung Sik Hwang
Korea Atomic Energy Research Institute
jskim6@kaeri.re.kr

1. Introduction

Steam generator in operating nuclear power plants(NPPs) is one of main facilities, which is a pressure boundary between the primary and secondary systems in NPPs and generating steam to operate a turbine of electric generator to make electricity. Therefore, if the steam generator is failed to operate, the operating nuclear power plants should be tripped unexpectedly. This results in a tremendous loss economically and a safety issue which is very important to public opinions. One of main issues for its safe operation is steam generator tube failure by denting corrosion which causes primary and secondary stress corrosion cracking inducing the leakage of the primary cooling water into the secondary system during operation. This leakage can contaminate the secondary system with radioactive materials causing safety problems in operating nuclear power plants (NNPs). In order to mitigate and/or prevent denting corrosion occurring in operating NNPs, the effects of the environmental parameters on denting corrosion should be evaluated in their operating conditions.

In this study, in order to examine the effects of parameters on denting corrosion, denting corrosion experiments were performed in various test conditions.

2. Experimental

Denting experiments were carried out in a static autoclave of 1 gal. made of Ti, through a cap of which a tube of Alloy 600 heated with a cartridge heater inside was inserted. Outside the tube, an acid solution containing chloride ions was contained in the autoclave. Three specimens having different crevice gap sizes of 50, 100 and 200㎛ made of carbon steel rings were immersed in the solution containing 3,500ppm NaCl + 0.2M $CuCl_2$ (pH=3 adjusted by HCl). For 200㎛ crevice gap, two ring specimens were inserted. One ring specimen was closed with an Alloy 600 plate at its bottom end to block flows of the solution through the gap in order to simulate the situation of the tubesheet. In addition, in order to simulate the local boiling effect on the outer surface of the tube, the temperatures inside and outside the tube were kept at 300 and 290°C, respectively. A temperature of the bulk solution in the autoclave was maintained at 280°C. The effects of chloride ion concentrations (3, 3,500 and 35,000ppm as NaCl) was also evaluated with two different crevice gap sizes (100, 200㎛). In addition, the effect of NiB on the denting corrosion was also investigated in a solution of 35,000ppm NaCl + 0.2M $CuCl_2$ (pH=3). The degree of denting was evaluated by measuring the inner diameter change of the tube. Each measurement was done every two week for twelve weeks.

3. Results

The results showed that denting rate increased with the increasing crevice gap size at an initial stage (in two weeks) and became nearly constant afterwards.(Fig. 1) The highest denting was observed to occur in the 200㎛ gap specimen the bottom end of which was blocked. Denting rate also was found to be a strong function of the concentration of chloride ion in aqueous solutions. As the concentration of NaCl increases, the extent of denting increases very sharply. In the 3 ppm NaCl solution, denting occurs in negligibly small extent in 2 weeks, comparing to the case of the 3,500 and 35,000 ppm solutions(refer to Fig. 1). The addition of a NiB powder of 4 g/L in to the acid-chloride solution of 35,000ppm NaCl + 0.2M $CuCl_2$ (pH=3) was observed to suppress the denting rate significantly. (Fig. 2) These experimental results show that denting corrosion occurring at crevices between steam generator tubes and tubesheets, or tube support plates can be mitigated by adding NiB powder in to the secondary cooling water in operating NNPs.

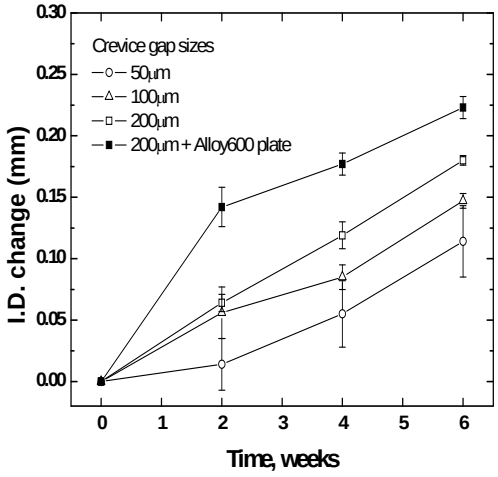

Fig. 1. Denting corrosion rate with different crevice geometry in a solution containing 3,500 ppm NaCl solution.

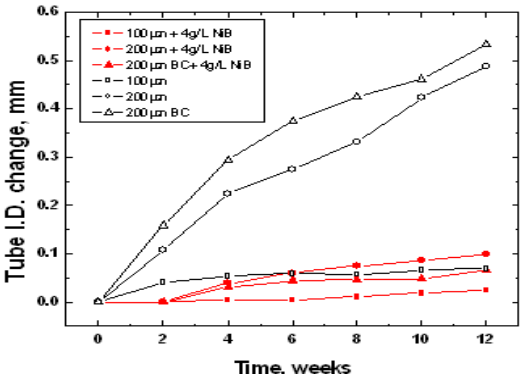

Fig. 2 Tube I.D. variation of Alloy 600 tube tested in 35,000ppm NaCl + 0.2M CuCl2, pH=3.0 (adjusted by HCl) w/wo 4g/L NiB solutions for 12 weeks.

4. Summary

The degree of denting in the system used in this study was concluded to be a strong function of the crevice gap size and concentration of chloride ions. NiB was observed to act as a good inhibitor to denting in a simulated operating conditions of nuclear power plants.

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