

Effects of pH and pH Control Agents on Corrosion Behavior of SA106 Gr.B in Simulated PWR Flowing Secondary Water

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1. Introduction

In the secondary system of a pressurized water reactor (PWR), corrosion products are released from the surfaces of carbon steel pipes by flow accelerated corrosion (FAC), transported into steam generator (SG) by feedwater [1]. Corrosion products in a state of ionic and particulates are deposited to form magnetite (Fe_3O_4) particles on SG tube surfaces, tube support plates, and tube sheet [2,3]. This causes a decrease in the heat transfer efficiency and an acceleration in the corrosion related degradation of SG tubes [4].

Since FAC rate is mainly influenced by water chemistry, secondary water is strictly controlled in an alkalized reducing condition. Typically, the pH is maintained in the range of 9 to 10 at 25 °C using ammonia (NH_3) or ethanolamine (ETA) [5].

In this study, the effects of pH and pH control agents on corrosion behavior were investigated in simulated PWR flowing secondary water condition. After the test, corrosion rates of SA106 Gr.B carbon steel was calculated. Furthermore, properties of oxide layers were analyzed.

2. Experimental Methods

Test coupons were fabricated from SA106 Gr.B pipe. Each corrosion test was performed for 500 h using a single-phase water circulating loop system at 150 °C. Table I shows the detailed corrosion test conditions. Dissolved oxygen concentration was maintained below 5 ppb by blowing N_2 gas. When the test conditions (i.e. solution temperature and pH) was stabilized, corrosion coupons were rotated so that linear velocity at the surface of coupons was 5 m/s for 500 h.

Table I: Corrosion test conditions

Test No.	pH _{25°C}	pH control agent	Temp. & Time & Flow velocity
Test 1	9	NH ₃	150 °C, 500 h, 5 m/s
Test 2	10		
Test 3	9	ETA	
Test 4	10		

After the corrosion tests, the corrosion rates of the test coupons were calculated using weight changes of the coupons before and after test. The properties of oxide layers such as morphology and electrochemical behavior were investigated using scanning electron microscopy (SEM) and Mott-Schottky plots.

3. Results and Discussion

Fig. 1 shows the corrosion rates of SA106 Gr.B after each test. The significant difference of the corrosion rates was not observed according to the pH control agents at the same pH value. However, the corrosion rates decreased about 63 % in the pH_{25°C} 10 solution than in the pH_{25°C} 9 solution. This indicates that the FAC rate of SA106 Gr.B is more dependent on the pH than pH control agent in the secondary water conditions. In other words, increasing pH is more effective to reduce the formation of corrosion products than changing the pH control agent under single-phase water conditions.

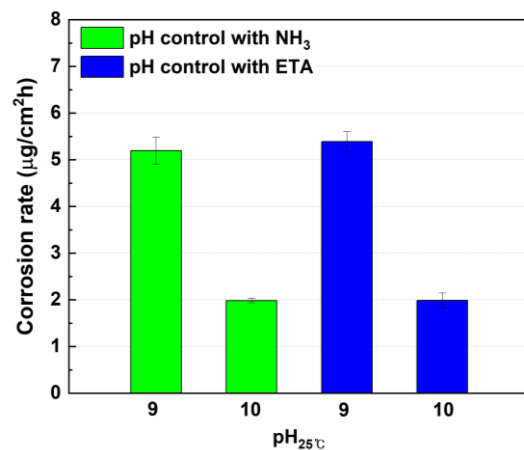


Fig. 1. Corrosion rates of the SA106 Gr.B coupons after the FAC tests.

Fig. 2 shows the cross-sectional SEM images of the oxide layers after the corrosion test in the ETA solution. The aspect of the oxide layers formed under all test conditions was similar regardless of the pH control agents. In the pH_{25°C} 9 solution, thick and porous oxide

layers were formed. On the other hand, the oxide layer formed in the pH_{25°C} 10 solution was thinner and denser than that in the pH_{25°C} 9 solution. This means that the dissolution rate of oxide layer decreased in high pH solution, reducing the formation of corrosion products.

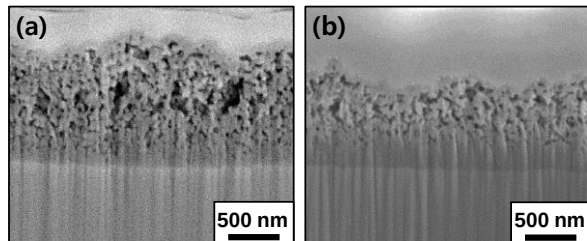


Fig. 2. Cross-sectional SEM images of oxide layers formed on SA106 Gr.B in the ETA solution: (a) pH_{25°C} 9, (b) pH_{25°C} 10.

4. Conclusions

In the flowing secondary water conditions, the corrosion rates of SA106 Gr.B decreased when pH_{25°C} increased from 9 to 10, regardless of the pH control agent type. Oxide layers were thick and porous than that formed in the pH_{25°C} 10 solution. The FAC rate of SA106 Gr.B is more dependent on the pH than pH control agent in the secondary water conditions.

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