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FAC characteristics according to the concentration of chromium at 150℃

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1. Introduction

Since the Surry Unit 2 accident in 1986, flow accelerated corrosion (FAC) has been extensively studied. However, many accidents caused by FAC have been reported such as an accident at Mihama Unit 3 in 2004 and at domestic plants [1-3]. During the FAC, a protective oxide layer on carbon steel dissolves into flowing water leading to a thinning of the oxide layer and accelerating corrosion of the base material. As a result, severe failures occur in the piping and equipment of nuclear power plants (NPPs). Numerous parameters such as the geometry, pH, flow velocity, steam quality, dissolved oxygen (DO), temperature, and materials have an influence on FAC [4,5]. This paper describes the effect of chromium content on the FAC of carbon steel at 150℃.

2. Experimental

We designed a small-scale FAC test loop and constructed it to test carbon steel in an NPP environment, as shown in Fig. 1. and Fig. 2. This loop consists of two 1 gallon stainless steel autoclaves with a magnetic driver, one 0.5gallon stainless steel static autoclave, a 100ℓ chemical makeup tank, a high-pressure pump, a charging pump, a pre-heater, a cooling system, a back-pressure regulator, an ion-exchange system, and several valves. The dissolve oxygen (DO), conductivity, pH, pressure, flow rate, and temperature were measured in the loop.

Fig. 1. Photograph of FAC evaluation test loop.

The chemical compositions of the specimens used in this work are shown in Table 1. Specimens with different chromium content were tested to validate the effect of chromium content on FAC. The SA106 Gr. B is used in the secondary piping of the domestic nuclear power plants. The test specimen dimension was 20 x 30 x 3 (mm^3) and the test holder is shown in Fig. 3. The initial pH value of the solution was 6.3. Before testing, the solutions were deaerated with high-purity (>99.99%) nitrogen gas for an hour to adjust the DO content below 1ppb. The FAC test was performed at a flow velocity of 4m/sec, 2m/s, and under static conditions at 150℃ for a 190 h duration. The surface was observed through optical microscopy, and oxide on the specimens was examined with SEM/EDS, and TEM,AES after the FAC test.

Fig. 2. Rotating cylinder combined in the autoclave

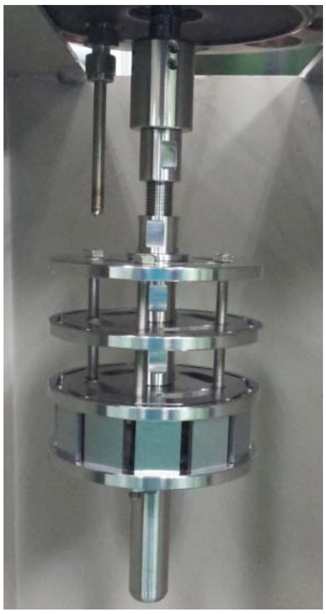

Fig. 3. Feature of the test specimen holder.

Table 1
Chemical compositions of specimens (%)

	Cr	Mo	C	Cu	Mn	Ni	Fe
SA106 Gr.B	0.02	0.01	0.19	0.04	0.37	0.02	bal
SA 508 Gr.3	0.17	0.46	0.22	0.03	1.22	0.68	bal
A534 8620H	0.61	0.21	0.21	0.20	0.88	0.48	bal
SA508 Gr.4N	1.803	0.491	0.184	0.001	0.330	3.441	bal
A336 F22V	2.4	0.9	0.10	0.1	0.4	0.1	bal

3. Results and Discussion

After the test under 4m/s conditions, the surface of the specimens was covered with a magnetite. Pits were observed on the specimen surface, indicating that a test duration of 190 hours is the initiation stage of FAC as shown in Fig. 3. The region around the pit was examined with SEM-EDS, as shown in Fig. 4. The specimen surface that had been in contact with the specimen holder was exposed to a very low flow velocity because the flow was restricted in that surface. FAC was not observed on that surface because of a low flow velocity. The weight loss of specimen decreased with increasing chromium content in the material. 2m/s and static conditions are not yet ready for testing.

Fig. 3. The left photograph does not show any pits(FAC) (ASTM A336 F22V), and the right photograph shows more pits(SA 508 Gr.3)

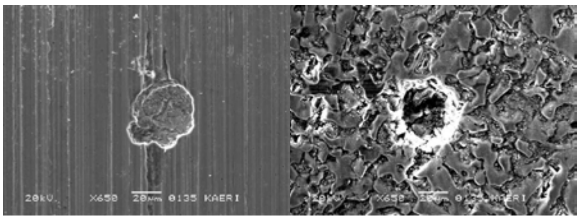

Fig. 4. The left photograph is an SEM image of ASTM A336 F22V, and the right is SA 508 Gr.3

4. Summary

A small-scale FAC test loop was constructed and used for an evaluation of the chromium content on FAC in a nuclear power plant environment. The DO was maintained at less than 1ppb. SEM observations of an Orange Pearl specimen with low chromium content were made. The appearance of the specimen surface, oxide in the specimen, degradation mode and weight loss were examined and discussed in terms of the chromium content in the material.

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