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FAC test on the dissimilar metal welded pipeline in high flow conditions

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1. Introduction

The secondary system in PWR plants, consists of carbon steel or low alloy steel piping. Cooling water flowing into the piping can cause a metal ion concentration gradient on the metal surface and cause flow accelerated corrosion (FAC), resulting in wall thinning damage [1-4]. FAC has been plagued nuclear power plants and fossil power plants for many years. Due to FAC, fatalities and a considerable economic loss occurred at Surry Unit 2 in 1986 in the USA and at Mihama Unit 3 in 2004 in Japan [1]. As a result, FAC became a major issue for power plants. The research of pipe thinning has been active around the world with such a large accident as a pivot point, and an experimental test facility was developed to evaluate the various factors affecting pipe thinning such as EDF-CIROCO (France), AREVA-BENSON(Germany), B&W FAC Loop (Canada), and CRIPI-PRINTEMPS (Japan) etc. [5-7]. The codes that can predict and manage pipe thinning (CHECWORKS, CICERO, COMSY, etc.) was developed and used for pipeline management based on experiment results of these facilities. The FAC is influenced not only by the material property of the pipes but also by the chemical characteristics of the fluid in the pipe, oxygen concentration, temperature, flow velocity and phase, etc. [8, 9]. Due to many factors such as the complexity of the pipe systems and operating environment in the plant, there is a limit to predict for pipe degradation, and it is necessary to construct and operate the FAC simulation test facility to evaluate the FAC inducing environment. The FAC simulation test facility capable of testing up to the actual large scale piping was designed and manufactured by KAERI [10].

In this study, the thinning characteristics of carbon steel and low alloy steel welded pipe with diameter of 2 inch was tested at a high flow velocity of 7 ~ 12 m/s.

2. Methods and Results

FAC test facility was constructed to simulate and evaluate the wall thinning of the piping in conditions of secondary water chemistry of the nuclear power plant as shown Fig.1. This test facility is designed to evaluate the FAC effects of factors such as flow velocity, dissolved oxygen, pH, temperature and pipe shape, etc. The facility have operation specification of maximum pressure and temperature of 6.0 MPa, 270℃ with maximum flow velocity of 20 m/s for pipe diameter of 2 inch.

Fig. 1. Picture and layout of FAC simulation test facility.

FAC test was conducted on the dissimilar metal welded straight piping as shown in Fig. 2, and each pipe materials are SA106 Gr.B and SA335 P22 which are most widely used as piping materials for domestic plants. Table 1 shows the chemical compositions for major component of these materials.

Table 1. Chemical composition of pipe materials (wt%)

Alloy	C	Si	Mn	Cu	Cr	Ni	Mo
SA106 Gr.B	0.19	0.24	0.98	0.02	0.04	0.02	0.01
SA335 P22	0.1	0.22	0.42		2.08		0.94

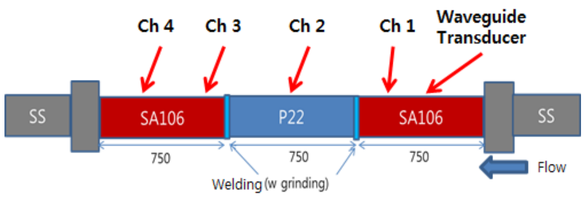

Fig. 2. Schematic drawings showing a test section pipeline welded with carbon steel (SA106B) and low alloy steel (P22) pipes with 2 inch diameter.

The distance between the welded parts was designed to be 15 times the inner diameter of the pipe. After welding, the bead inside the pipe was removed by machining to selectively remove the back bead without damaging the base material. In order to investigate the effect of the dissimilar metal distance, low alloy steel pipe (P22) welded between carbon steel pipes (SA106B). The change of pipe thickness due to thinning was measured by the ultrasonic measuring devices (UT) with on, off-line monitoring methods [11, 12]. FAC test was performed in flow conditions of 7, 10, and 12 m/s with test time of 50 days (1,200 hours) at temperature of 150 ℃. During the test, water chemistry was on-line monitored by chemical sensors, pH is maintained with about 8 and dissolved oxygen (DO) is maintained below 5 ppb.

The test results is as shown in Fig. 3, it shows the pipe wall thinning variation at different measurement positions as change of flow velocity. The test section has a structure in which the test solution flows into the measurement position A and is discharged from the position L. Each UT measurement location is marked in grid form on the pipe surface so that measurements can be made at the same location during tests. Fig. 3 shows that even at the same flow rate, there is a difference in the amount of thinning of the carbon steel pipe welded before and after the low alloy steel, so that a little bit more thinning occurs in the zone I where the initial flow is entered. However, as the flow rate increases, this effect decreases. The low alloy steel was showed the wall thinning than the carbon steel by less than 1/3, but more sensitive to flow velocity. The factors affecting pipe thinning are well understood based on experiment and experience data. But further studies are needed to quantitatively evaluate the effects of multiple factors. One of them is to investigate the influence of the fluid state and the distance between dissimilar metals on the thinning effect when pipe or structure is connected with different materials.

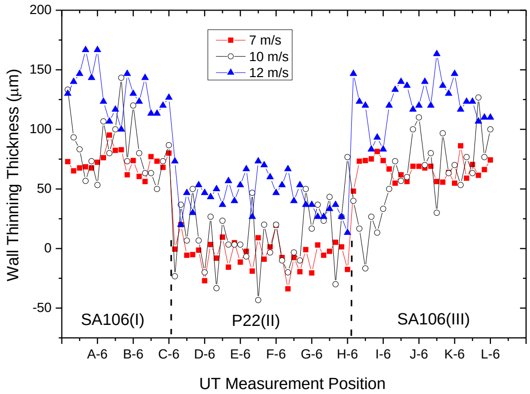

Fig. 3. Pipe wall thinning calculated from thickness measured before and after FAC tests using ultrasonic transducers.

3. Conclusions

A high temperature and high pressure flow test system was developed to simulate the secondary piping system in nuclear power plants. Using the facility, FAC tests were conducted on welded pipes of carbon steel (SA106B) and low alloy steel (SA335 P22). The FAC test was performed for 50 days at a test temperature of 150 ℃ at 7, 10, and 12 m/s, respectively and the changes in pipe thickness were measured by ultrasonic method. In the carbon steel piping, wall thinning was higher at the first contact region with the fluid. The low alloy steel was showed the wall thinning than the carbon steel by less than 1/3, but more sensitive to flow velocity. From the experiments, the multiple effects of flow velocity and dissimilar metals on FAC were evaluated using the simulation test facility.

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