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Evaluation of damage reduction for piping material in the Secondary Side of NPPs using Pt nanoparticles

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1. Introduction

Nuclear power plants that produce electricity by using the phase change of water is inevitable the use of pipes for transporting the water, thus the pipe that is exposed to the high temperature/pressure will cause problems due to a variety of corrosion by increasing plant life extension. In order to prevent and reduce the piping damage by these corrosion, the chemical environment in the fluid is controlled using the various methods in the Nuclear Power Plant.

However, if the FAC(flow acceleration corrosion) occurs in the operating conditions of the high temperature/pressure chemical environment and high fluid velocity, the chemical environment is difficult to control by interaction in a variety of parameter including pH, DO, temperature, fluid velocity and pipe configuration in operating Nuclear Power Plant[1][2]. In the case of chemical environment in Nuclear power plant secondary system, FAC is exposed to the temperature conditions under which the acceleration.

The pipe wall thinning by the FAC causes pipe rupture accident, so it can cause huge economic damage due to plant shutdown and damage to the humans[4][5][6]. Also, in order to prevent the pipe rupture accident, even it takes enormous time and manpower by the ultrasonic inspection that performed to the piping in the Nuclear Power Plant. In order to solve it issues, it is necessary to develop a technology for reducing corrosion rate of the pipe.

In the study, it is using FAC test facility that can be simulate FAC phenomenon based on the OPR-1000 secondary system water chemistry environment. FAC simulated test is conducted in variety of parameter including DO concentration and geometric structure of pipes that FAC is the major cause.

Furthermore, for the development of corrosion reduction technology, tests was evaluated the corrosion rates by injecting Pt nanoparticle, it was also performed to evaluate the corrosion rate of the pipe material according to the amount of Pt nanoparticle.

2. Test Condition and Test Facility

2.1 Test Condition

FAC simulated test was evaluated the corrosion rate of the pipe material considering parameter including DO concentration, injecting amount of Pt nanoparticle and facing angle between fluid and test specimen. The facing angle between fluid and test specimen as mentioned earlier will be described below.

The chemistry condition of FAC simulated test were established based on operating OPR-1000 conditions in the range of pH 9.0~9.5 and temperature of 50~250℃. The pH conditions between 9.0~9.5 and temperature of 150℃ that is accelerated FAC were fixed, and flow velocity was selected 5.0 m/s as possible implemented in the test facility.

The pipe material used in FAC simulated test were selected as a carbon steel (SA106.Gr.B) that is used as primary pipe materials in the OPR-1000 secondary system. All tests were conducted by 300 hours, and were evaluated to effects on the injection/absence of the Pt nanoparticle and the injecting amount of Pt nanoparticle.

2.2 Flow Accelerated Corrosion Test Section

In order to simulate for the water chemistry condition in the OPR-1000 secondary system, FAC test facility was produced as Figure 1. FAC test facility shows the design and operating conditions at the bottom.

- The design temperature and operating condition: 280℃ (250℃)
- The design pressure and operating condition: 70bar (50bar)
- The flow velocity and operating condition: 6.3m/s (5.0m/s)

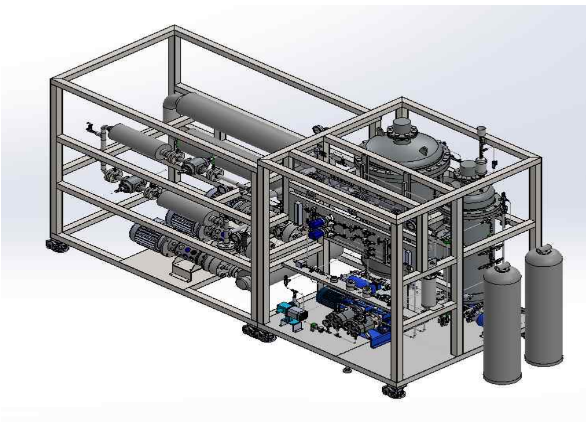

Figure 1: Flow Accelerated Corrosion Test Facility

The precise control of pH, Conductivity and DO was performed using sensor of water chemistry environment and impurities in the fluid were removed by filter of ion exchange.

The facing angle between fluid and test specimen is designed to be adjusted as low as 15 degree to simulate the geometric structure of pipes in Nuclear Power Plant in Test Section like figure 2.

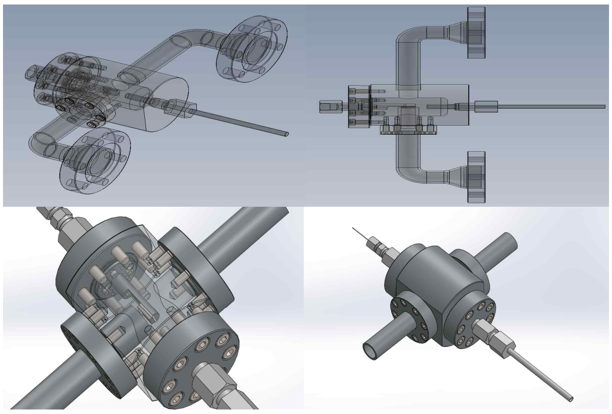

Figure 2: Test Section

3. Test Results

FAC simulated test were performed divided as impact evaluation of facing angle between fluid and test specimen of piping material on secondary system of Nuclear Power Plant and impact evaluation of injection amount of Pt nanoparticle.

The effects of facing angle between fluid and test specimen were evaluated through 3 test cases which contain from the case of 90 degree for simulating the elbow pipe to case of 180 degree for simulating straight pipe. The facing angle which showed the highest corrosion speed was used in DO concentration test and Pt nanoparticle injection test. The details are shown in Table 1.

T-1, T-2 and T-3 are tested as facing angle between fluid and test specimen considering pipe configuration in the Nuclear Power Plant secondary system as mentioned above. T-1 simulating the elbow pipe had the highest corrosion rate of 24.30 MPY, while that of T-3 simulating a straight pipe had slowest corrosion rate of 4.32MPY. It means that the effect of FAC is more significant in case of elbow pipe than in case of the straight pipe. In DO concentration test, MPY in T-4 in which the DO is larger than 100ppb is 16.2MPY lower than that of T-1 in which the DO is less than 5ppb. It means that FAC can be reduced by ensuring the certain quantity of dissolved oxygen to generate the protective oxide layer on the pipe surface.

The corrosion speed of T-5 in which Pt nanoparticles were injected is 4.86MPY reduced to 80 % of that of T-1 which is absent of Pt particle injection. It implies that the injection of Pt nanoparticle is favorable to the reduction of pipe corrosion speed.

The impact evaluation of injection amount of Pt nanoparticle on corrosion speed is performed varying the concentration as 0, 0.1, 1.0 and 10.0 ppb. The details are shown in table 2.

It is confirmed that the corrosion speed is reduced as the injection amount of Pt nanoparticle decreased. The corrosion speed of T-8 in which Pt nanoparticles of 10 ppb were injected is shown a corrosion reduction effects that reduced to 96% compared with that of T-6 which is absent of Pt nanoparticle injection.

Table 1: FAC Simulated Test

Test No.	Test Material	Test angle (degrees)	Test temp (℃)	DO concentration (ppb)	Weight loss (mg)	Corrosion rate (MPY, mils/year)
T-1		90		< 5	45	24.30
T-2		120		< 5	21	11.34
T-3	SA106.Gr.B	180	150	< 5	8	4.32
T-4		90		100 <	15	8.10
T-5 (Pt injection)		90		< 5	9	4.86

Table 2: FAC Simulated Test 2

Test No.	Test Material	Test angle (degrees)	Test temp (℃)	DO concentration (ppb)	Pt Nanoparticle injection(ppb)	Corrosion rate (MPY, mils/year)
T-6 (Pt injection)		90		< 5	0	23.0(0%)
T-6 (Pt injection)	SA106.Gr.B	90	150	< 5	0.1	17.0(26%)
T-7 (Pt injection)		90		< 5	1.0	6.5(72%)
T-8 (Pt injection)		90		< 5	10.0	1.0(96%)

4. Conclusion

In the study, in order to develop pipe corrosion reduction technology, test that is parameter of FAC major factor was conducted by producing FAC simulated facility. It is confirmed a significant amount of corrosion reduction from test result. Especially, test in which Pt nanoparticle were injected was confirmed corrosion reduction effects of pipe. In conclusion, if the Pt nanoparticle is injected to the Nuclear Power Plant, it is expected to help prevent accidents such as pipe rupture occurs and is judged to be useful in plant operation.

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