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Development of Flow Accelerated Corrosion Reduction Technology

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1. Introduction

The big problem occurs in pipe of PWR plant secondary system caused by pipe wall thinning. FAC mechanism is the main factor of pipe thinning.

Flow accelerated corrosion is the phenomenon that accelerates damage of the basic material by relative movement between a fluid and metal surface in carbon steel pipes. When pipe thinning continues due to damage of the basic material, the huge accident that destroys pressure boundary pipes are building might take place. Therefore, development of flow accelerated corrosion reduction technology is necessary for prevent this kind of accidents. This study deals with development of flow accelerated corrosion reduction technology through platinum injection and developed of flow accelerated corrosion reduction technology by imitating water chemical conditon in PWR secondary system in practice. In addition, in order to get reliability of water chemical simulator in PWR secondary system, analyzed and compared with test result through CFD analysis.

2. Methods and Results

The main cause of the pipe wall thickness is known as flow accelerated corrosion.

In the study, to reduce corrosion rate by flow accelerated corrosion phenomenom, platinum nano-particles is used as oxide film. The test specimen is used material of carbon steel(SA106.Gr.B) and low alloy steel(SA335.P22) that is used as a typical pipe material in plant secondary system. Additionally, CFD analysis for reliability of the result of the angle condition of test specimen and the fluid to simulate the PWR secondary system pipe of the geometric shape of test condition was performed using the ANSYS workbench. CFD analysis was carried out in the conditions of 180 degrees that is replicated the straight pipe and the conditions of 90degrees and 120 degrees that is replicated the elbow pipe.

Table 1 . FAC Test Specimen Contents

	C	Mn	P	S	Si	Cr	Mo	Ni	V	Fe
SA106 .Gr.B	0.19	1.07	0.012	0.005	0.23	0.04	0.01	0.14	0.005	Bal .
SA335. P22	0.11	0.46	0.011	0.004	0.32	2.13	0.03	0.07	0.009	Bal .

2.1 Flow Accelerated Corrosion(FAC)

Flow accelerated corrosion is not direct damage by fluid as erosion, abrasion etc., but it is phenomenon that makes corrosion speed of pipes increase by fluid flowing in pipes. This flow accelerated corrosion accelerates by these reasons: DO concentration in fluid, pH, water chemical condition like temperature, flow velocity or flux, hydraulic condition like Reynolds Number, Reducer for efficient arrangement of pipes, shape of pipes like elbow shape in several angle. Picture 1 presents heat deterioration of flow accelerated corrosion. Flow accelerated corrosion occurs with 2 continuous process, as shown in Figure 1.

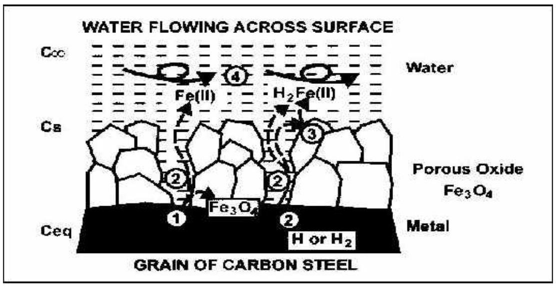

Figure 1. FAC Mechanism Schematic Diagram[3]

The first stage is that fusible iron ion was made in boundaries of oxide and fluid and the processes are: (1) oxidation of metals in boundaries of iron-magnetite. (2) spread to fluid flow of iron ion, through porous oxide film / spread to fluid of hydrogen produced in boundaries of metal-oxide, through slit of oxide film. (3) decomposition through reduction reaction of magnetite oxide film, by hydrogen. The second stage is the movement of iron ion toward inside of fluid, through the layer of diffusion boundary.[5]

2.2 Flow Accelerated Corrosion System

Flow Accelerated Corrosion System was designed to replicate water chemistry of the enviroment in PWR secondary system such as Figure 2. The maximum limit of design temperature and pressure is 250℃/ 60bar. It's possible to simulate fluid speed up to 6.5 m/s and installed DO concentration, Conductivity, pH, and ECP sensor to confirm water chemical condition all the time. In Test section of test device made by this study, as shown in Picture 3, designed angle between test specimen and fluid more than 15" to simulate specific shape of pipes.

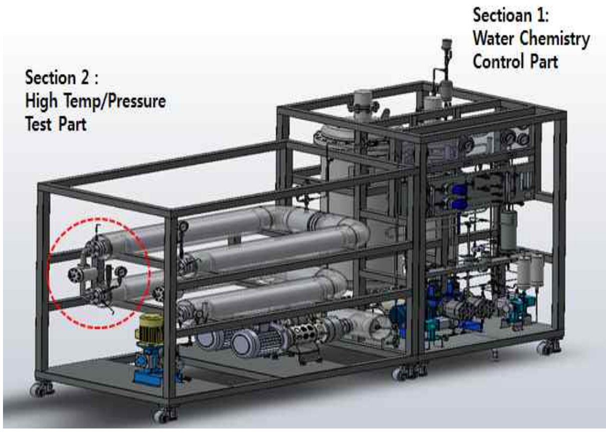

Figure 2. Flow Accelerated Corrosion System

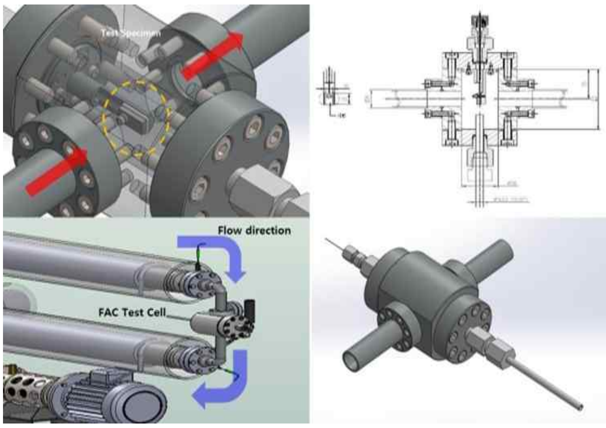

Figure 3. Test Section of FAC system

2.3 CFX Analysis

In this study, the result of experiment for simulating shape of pipes in test of simulating flow accelerated gets reliability though CFD analysis. Like simulation test, did modeling for condition of 90', 120' and 180'. The standard of pipes used for test was done modeling, adopted ASME B.16 CODE, equall with elbow size in 4 inch outside diameter, and main design values are shown in Table 2.

This study used numerical analysis of ANSYS CFX and decided mesh by comparing with each result of increasing mesh to 4 steps and alayzing sensitivity of mesh. The fluid speed is 5m/s that is same with its condition of simulation test, and mesh is 8778, 20748, 478240, and 1048416. In conclusion, similar values are taken in more than 478240 test, so adopted 478240. For comparing results of test, did modeling in test section of simulation test simultaneously. Also, this study did numerical analysis using above, by adopting Shear stress transport turbulence model and selected "No Slip" in Wall influence.

Table 2. CFD main design values

properties & spec	Value
Inside diameter of pipe	4.026 inch
Operating Fluid	Water
Density	997 kg/m3
Viscosity	0.001139 kg/m·s
Inlet Velocity	5 m/s

2.4 Results

2.4.1 FAC Test Results

In this study, flow accelerated corrosion test was performed in the chemical conditions to replicate the operation conditions in PWR plant secondary system.

Test was injected with Pt nanoparticles in order to reduce the flow accelerated corrosion rate as a test variable. It was also tested by adjusting the angle at which the test specimen and the fluid forms in order to replicate the geometric pipe forms of PWR plant secondary system. The test result of each case and detail test Matrix is equal as a Figure 3.

The results of this study, it is not applied to direct pwr secondary system, but It is expected to show a certain effect from the viewpoint of reducing the sludge reducing the amount of flow accelerated corrosion rate as applied of BWP plant.

2.4.1 CFD Results

This study did CFD analysis using ANSYS CFX

Table 3. Test Matrix and Corrosion rate results

Parameter	Test No.	Test Material	Test angle (degrees)	DO concentration (ppb)	Temp. (℃)
Material Factor	Test1	SA106.Gr.B	90	<5	150
	Test2	SA335.P22	90		
Angle Factor	Test3	SA106.Gr.B	120		
	Test4	SA106.Gr.B	180		
Pt Injection Factor	Test5	SA106.Gr.B	90		
	Test6	SA335.P22	90		

Parameter	Test No.	Test Material	pH	Flow rate (m/s)	Corrosion rate (MPY)
Material Factor	Test1	SA106.Gr.B	9.0~9.5	5.0<	24.30
	Test2	SA335.P22			3.24
Angle Factor	Test3	SA106.Gr.B			11.34
	Test4	SA106.Gr.B			4.32
Pt Injection Factor	Test5	SA106.Gr.B			4.86
	Test6	SA335.P22			0.54

and modeling in simulating device for flow accelerated corrosion and pipes. To analyzing flow accelerated corrosion presented pressure affecting pipes when doing ANSYS CFX analysis.

Figure 4 presents the result of specimen simulation in several angles of flow accelerated corrosion test device, using ANSYS CFX. A is modeling of 90 elbow pipe, B is modeling of 120 elbow pipe, and C is modeling of straight pipe in Picture 4. The pressure is the highest in A and the lowest in C, as shown in Picture 4.

Figure 5 the result of modeling for flow accelerated corrosion test device, using ANSYS CFX. A is modeling of 90 elbow pipe that is used in PWR plant secondary system. B and C is indicating 120 elbow pipes and straight pipes each. Consequently, the pressure is the highest in A and the lowest in C, as previous case Figure 5. Comparing with figure 4 and 5, the results are simliar each other. The pressure is the highest in A, 90 elbow pipes, second is B, and the lowest in C on both cases. Based on this result of CFD analysis, this study is expecting that FAC simulation test device can get reliability for adopting pipe simulation to experiment.

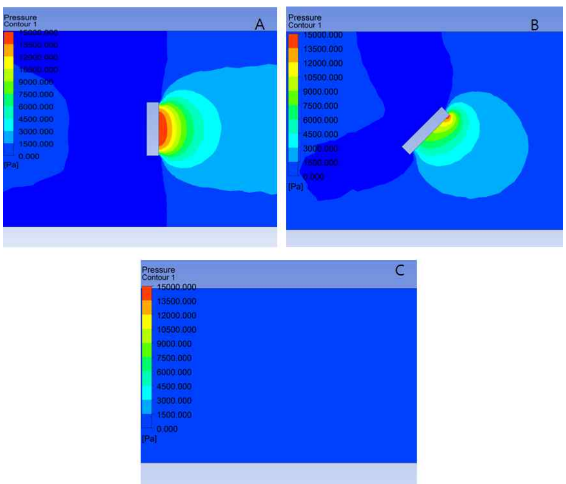

Figure 4. Result of FAC simulation test device

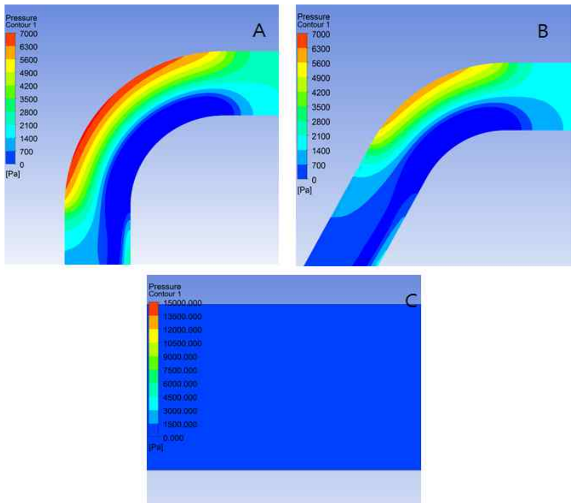

Figure 5. Result of Pipe in PWR plant

3. Conclusions

This study composed test device that can simulate water chemical environment in PWR secondary system, in order to develop flow accelerated corrosion reduction , and evaluated the ratio of corrosion in water chemical environment in PWR secondary system. In conclusion, corrosion ratio of low alloy steel material that includes more Cr and Mo was lower. And the results were confirmed to be the maximum corrosion rate in the case that replicate the 90elbow. Additionally, inserted Pt nano particle for developing flow accelerated corrosion rate reduction technology, the test results, it was confirmed for about 80% of the flow accelerated corrosion rate reduction than before input.

In order to ensure the reliability of the test result of geometric pipe shape replicated test through the angle adjustment in test seciton of this test device, CFD analysis were carried out. In the test result was possible to obtain the same CFD flow analysis result and the results of the corrosion rate test.

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