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Evaluation of the effect of asymmetric flow on pipe thinning

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1. Introduction

Pipe thinning due to flow accelerated corrosion (FAC) is one of the major degradation phenomena in fossil and nuclear power plants [1-3]. Pipeline breakage accidents at Surry Unit 2 in 1986 and Mihama Unit 3 in 2004 accidents caused human injury and economic loss [1]. It is well known that FAC is affected by water chemical environment such as dissolved oxygen, flow velocity, pH, temperature, and pipe materials [4, 5]. The pipelines of the nuclear plant consist of numerous curved sections, elbows and orifices, where flow is strongly disturbed by a formation at asymmetric fluids from an elbow and an orifice [6-9]. As a result, pipe can be asymmetrically thinned [10]. In this study, the effect of the asymmetric fluid formed on the elbow and orifice of the pipeline was evaluated using the FAC demonstration test facility. In addition, the actual assessment for FAC resistant alloy under development was performed.

2. Methods and Results

2.1 Test section design for asymmetric flow formation

In order to measure the thinning phenomenon in various parts of the pipeline, the elbow and the 40 mm diameter orifice were applied in test section. Zone 1 was designed to evaluate the effect of distance from the orifice and the elbow on pipe thinning. In addition, zone 2 was designed to observe the pipe thinning phenomena associated with the formation of asymmetric flow caused by combination of the orifice and the elbow (Fig. 1).

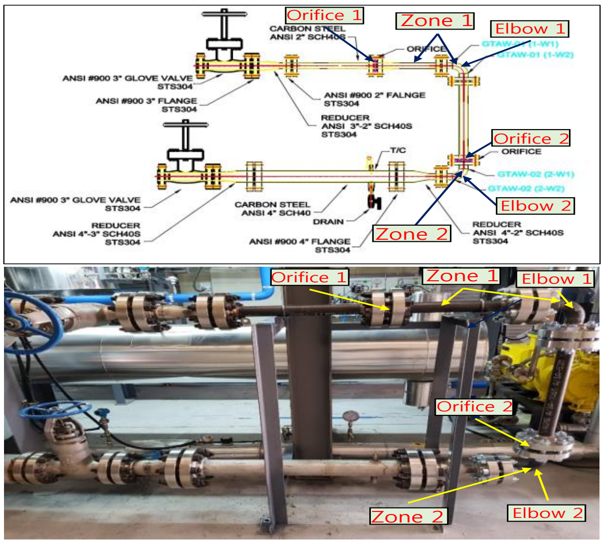
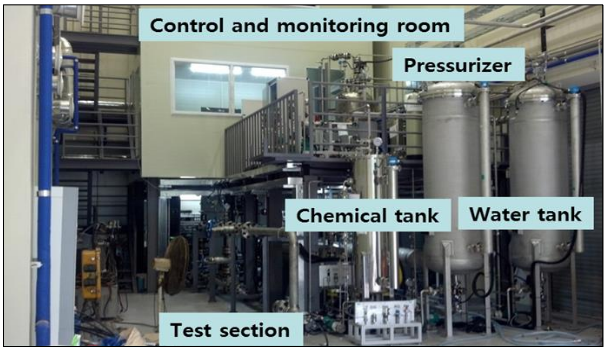


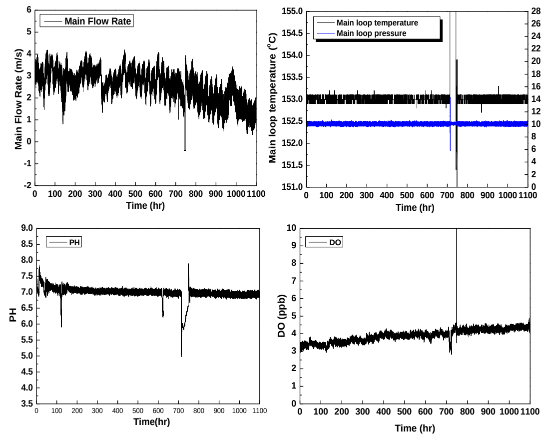
Fig. 1. Schematic and photograph of test section.

2.2 FAC test

FAC experiments have been performed using the FAC demonstration test facility (Fig. 2a), which was designed and manufactured by Korea atomic energy research institute (KAERI) since 2016 [11]. In this work, the pipe thinning under unpredictable asymmetric fluid environment in secondary system pipelines of nuclear power plants was studied. The test was performed under the conditions of temperature of 150 ℃, DO <5 ppb, pH 6~7, and flow rate of 3 m/s for 46 d (1,100 h). These experimental data were acquired during all the test times (Fig. 2b).



(a)

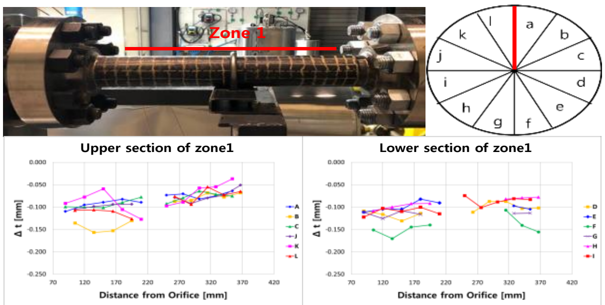


(b)

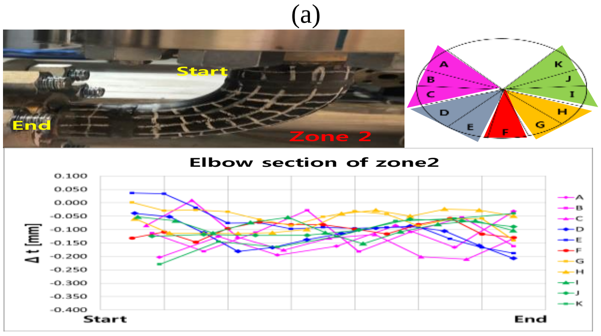
Fig. 2. (a) Photo of FAC demonstration test facility, (b) various test conditions of this work.

2.3 Pipe thinning measurement

First, the initial thickness was measured by using ultrasonic test (UT) and computed tomography (CT) for the elbow and straight pipe. The initial thickness of the straight pipe was 4.45 mm, the outer thickness of the elbow was 4.20 mm, and the thickness of the inner pipe was 4.70 mm. After FAC experiment, pipe thickness was measured for zones 1 and 2 using UT. In zone 1, when the distance was increased from single component such as an orifice and an elbow, the wall thinning rate was decreased (Fig. 3a). Compared to the zone 1, the pipe was more severely and asymmetrically thinned in zone 2 (Fig. 3b) unlike symmetric thinning in zone1.



(a)



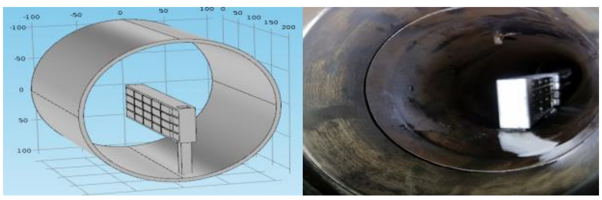
(b)

Fig. 3. Photograph and pipe thickness data of (a) zone 1 and (b) zone 2.

2.4 Application example for FAC-resistant alloy development

In order to evaluate the actual assessment of FAC-resistant alloy under development. The specimens were fixed with PTFE specimen holder (Fig. 4a). After that, the specimen holder was hanged inside a 4 inch pipe (Fig. 4b).

(a)



(b)

Fig. 4. (a) Photograph of FAC-resistant alloy fixed with PTFE holder, (b) design and installed photo of specimen assembly.

3. Conclusions

In this paper, the effect of asymmetric flow on pipe thinning was investigated using the FAC demonstration test facility. Thickness of pipelines were measured by non-destructive inspection after the test. When the orifice and elbow affect pipe thinning simultaneously, thickness of the pipe was more decreased asymmetrically compared to the other parts affected by single component (orifice or elbow), which is due to the formation of asymmetric fluids in zone 2.

Acknowledgements

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