Transactions of the Korean Nuclear Society Spring Meeting
Taebaek, Korea, May 26-27, 2011

AE signal characteristics of the initial Stress Corrosion Crack in the STS 304 pipe

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1. Introduction

The stress corrosion crack is one of the life-limiting mechanisms in nuclear power plant conditions. During the operation of a power plant stress corrosion cracks can initiate and grow in dissimilar metal weld pipe joints of primary loop components. In particular, stress-corrosion cracking usually occurs when the following three factors exist at the same time; susceptible material, corrosive environment, and tensile stress (including residual stress). Thus, residual stress becomes very critical for stress-corrosion cracking when it is difficult to improve the material corrosivity of the components and their environment under operating conditions. Since the research conducted by Coriou et al., it is well known that Ni-based alloy and stainless steel are susceptible to stress corrosion cracking (SCC) in deaerated pure water at high temperature and the SCC is difficult to be reproduced in laboratory. [1],[2]

In this study, stress corrosion crack was artificially produced on STS 304 pipe. And a characteristic of the AE (acoustic emission) signal, which is generated at crack initiation time, was investigated.

2. Experimental Methods

2.1 Block diagram of stress corrosion crack producing apparatus

The test material was austenitic STS 304, which is used as pipelines in the Reactor Coolant System of a nuclear power plants (O.D.= 89mm, t=7.7mm). The fabricating mechanism of the stress corrosion crack formation is shown Fig. 1.

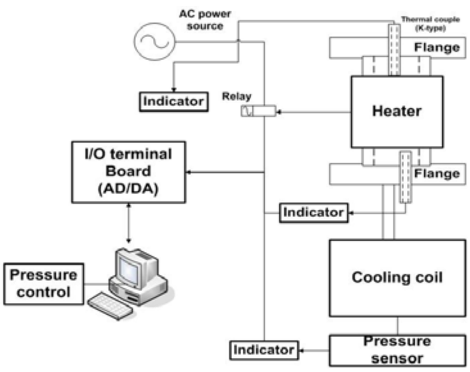

Figure 1. Mechanism of stress corrosion crack formation

SCC tests were performed using the STS 304 pipe in Na_2SO_4 and NaOH solutions. The length of specimen is 150mm. The welding machine was used for giving the residual stress. Table I shows chemical composition and mechanical properties of the STS 304. To generate vapor pressure in the inner pipe during the test, the pipe was heated by the heating coil.

Table I: Chemical composition and mechanical properties of STS 304

Element	C	Mn	P	S	Si	Ni	Cr
Composition	0.005	1.65	0.029	0.008	0.12	8.16	18.23

Yield strength(MPa)	Tensile strength (MPa)	Elongation (%)
410	669	66.5

2.2 Acoustic emission equipment set-up

A high temperature sensor was installed on the side of the flange. Figure 2 is the picture of the stress corrosion crack forming equipment and position of high-temperature AE sensor. The model of the sensor was S9125 (manufactured by PAC), which 400 kHz resonance frequency, max using temperature 500℃ and used 1222 charge preamplifier. Threshold level of 40~45dB was set as float type that can control the sensitivity of detection by keeping the voltage threshold of detection above the average background noise to minimize the noise effect.

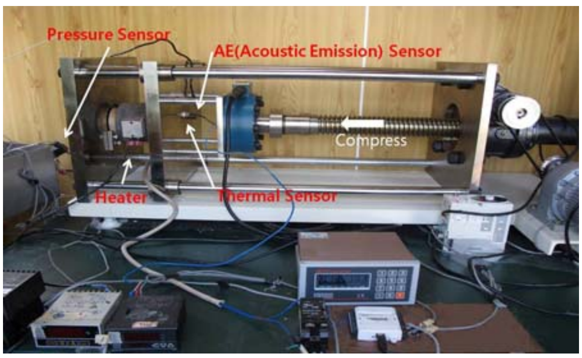

Figure 2. Stress corrosion crack forming equipment and layout for AE system

3. Results and Disscussions

3.1 Temperature and pressure

The stress corrosion crack was fabricated using the custom-made manufacturing system. Figure 3 shows the temperature and pressure variation during test. The maximum temperature and pressure, which were measured 331℃ and 85bar by thermocouple and pressure sensor, were similar environmental condition in the nuclear power plant. It is confirmed that the new forming equipment of artificial stress corrosion cracks can be imitated environmental conditions in the NPP. The vapor pressure was decreased after about 7 hour. The vapor pressure was induced hoop stress in the pipe. Circumferential stress in a cylindrically shaped part as a result of internal or external pressure is called hoop stress. In a closed pipe such as our specimen, force applied to the cylindrical pipe wall by a rise pressure will ultimately give rise to hoop stresses.

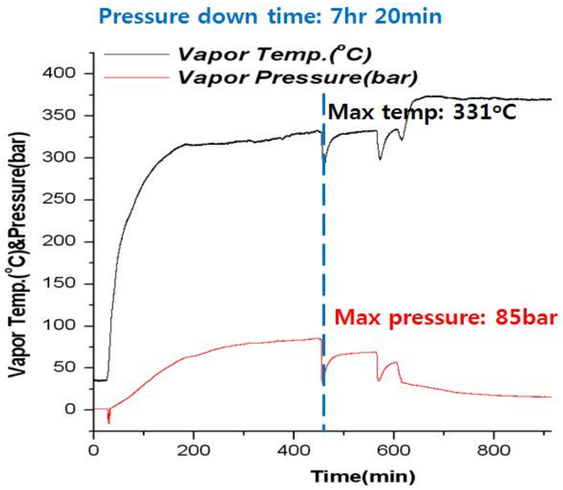

Figure 3. Temperature and vapor pressure inner pipe

3.2 Stress Corrosion Crack

Many cracks in the inner surface (a top and bottom view) of the pipe were observed by the visual test. Figure 4 shows the outer shape of the specimen and cross section (Ⅹ12.5) of the inner surface pipe. It is confirmed that the cracks were propagated according to inner of the grain. The trans-granular stress corrosion cracks are clearly revealed..

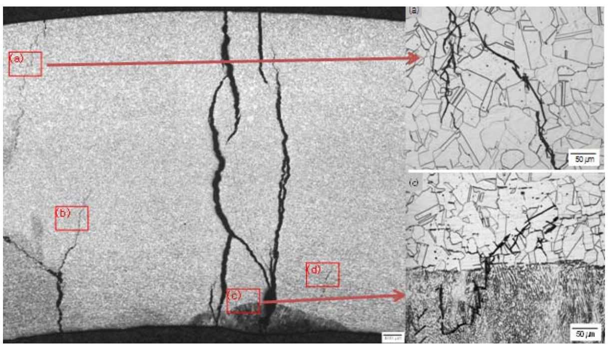

Figure 4. Fractography of the SCC

3.3 Pressure and AE data correlation

In Figure 5, it was observed that the AE events were reduced and then disappeared from 160minutes. But from 200 minutes, secondary intense events were occurred again. And 7 hours and 20 minutes later, the distribution shows leaking characteristic which has high energy and count value. From the pressure graph, in Figure 3, there is a pressure drop point around 200 minutes. And also it shows a pressure down point after 7 hours and 20 minute later. The pressure variation in the specimen has been dropped and became irregular since the leakage occurs. From the comparison of the graph from the measured pressure and AE event distribution, high intensity of AE events occurred from the initial stage of the experiment as pressure increases in the pipe. The reason that the comparison shows such a characteristic is the strain increase when the circumferential stress (Hoop stress) affects on the specimen due to the pressure increase.

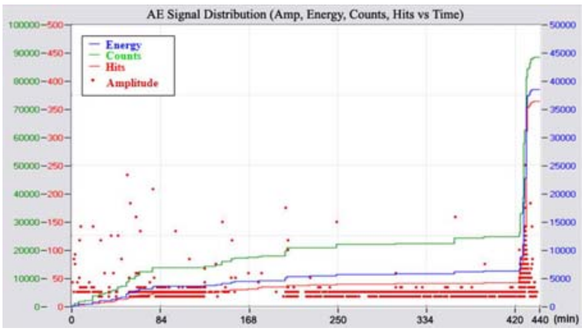

Figure 5. Acoustic emission signal distribution

4. Conclusion

In this study, stress corrosion crack was artificially produced on STS 304 pipe. It is confirmed that the cracks were propagated according to inner grain. The trans-granular stress corrosion cracks are clearly revealed. It is recognized that stress corrosion crack was accelerated by additional hoop stress caused by vapor pressure. And the events of the AE signals increase when the circumferential stress (Hoop stress) affects on the specimen due to the pressure increase. In the future, if AE system used for evaluating the integrity of the nuclear power plant, the presence of defects such as thermal fatigue and stress corrosion crack would be evaluated by events of the AE signal.

5. Acknowledgments

This work was supported by the Korea Science and Engineering Foundation (KOSEF) through the National Research Lab. Program funded by the Ministry of Science and Technology (No. M20604005402-06B0400- 40210).

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