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The manufacturing of Stress Corrosion Crack (SCC) on Inconel 600 tube

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1. Introduction

The Stress Corrosion Crack (SCC), taken a center stage in recently accidents about nuclear power plants, is one of the environmentally induced cracking occurred when a metallic structure under tensile stress is exposed to corrosive environment. It can induce damage to the structure because of difficulty of detecting initial cracking. So, by means of the first step to detect initial cracking, manufacturing the SCC in the simulated nuclear power plant environment is important.

In this study, the SCC was manufactured in the simulated corrosive environmental conditions on Inconel 600 tube that widely applied in the nuclear power plants. The tensile stress which is one of the main factors to induce SCC was given by GTAW welding in the inner surface of the specimen. The corrosive environment was simulated by using the sodium hydroxide (NaOH) and sodium sulfide (Na_2S).

2. Methods and Results

2.1 Materials

The test material was the Inconel 600 tube, which is widely used in pipelines of the nuclear power plant's reactor coolant system because of its excellent properties (especially, corrosion resistance and strength) at high temperature.

In the experiment, the specimen was 89mm in diameter, 7.6mm in thickness and 150 mm in length as shown in Figure 1.

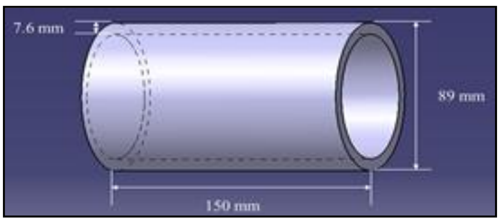


Fig. 1. Specimen for SCC manufacturing

2.2 Corrosive environment

In this study, the corrosive environment was made with the sodium hydroxide (NaOH) and sodium sulfide (Na_2S). The NaOH aqueous solution is a strong alkaline and also accelerates the corrosion rate of chrome and chromium-nickel alloys in the specific temperature and pressure. And the concentrated Na_2S in corrosive environments increases the corrosion sensitivity of Ni-Cr based alloy [1].

2.3 Welding

The welding is essential working in manufacturing of metallic structures. The welding structure has heat affected zone, fusion zone and residual stress by quenching. Especially, residual stress takes 30% in cause of generating of the SCC. So, in this study, the residual stress of the specimen was given by GTAW (Gas Tungsten Arc Welding).

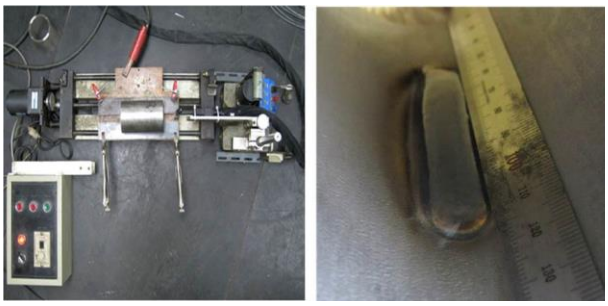


Fig. 2. Equipment for GTAW and Welding bead

2.4 Manufacturing system

In order to simulate an actual condition of generating of the SCC in nuclear power plants which of temperature is 300°C and pH are 6, the SCC generating device is set. The Figure 3 shows the diagram of SCC manufacturing equipment.

Contrary to existing methods for manufacturing the SCC, the etchant in the specimen are heated by a coil heater which covers the specimen. And ends of the specimen are sealed by gasket and an inner pressure of vapor gives a stress to the specimen. Also, values of inner temperature and pressure are measured by thermocouples and pressure sensor.

The temperature in the specimen is maintained uniformly by controlling system that I/O terminal board makes a coil heater turned off if the temperature in the specimen exceeds setting temperature. The setting temperature is set to 300°C.

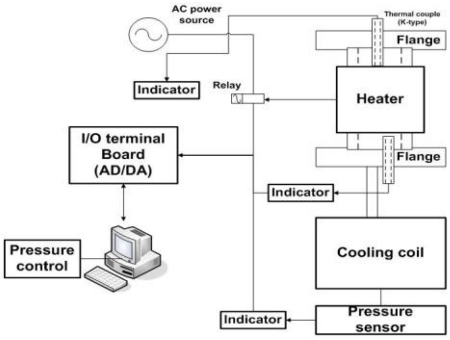


Fig. 3. Diagram of SCC manufacturing equipment.

2.5 Experimental result

As shown in Figure 4, the through-wall crack was detected nearby welding bead by using visual test when the experiment was over. In addition, the crack was branch-type crack.

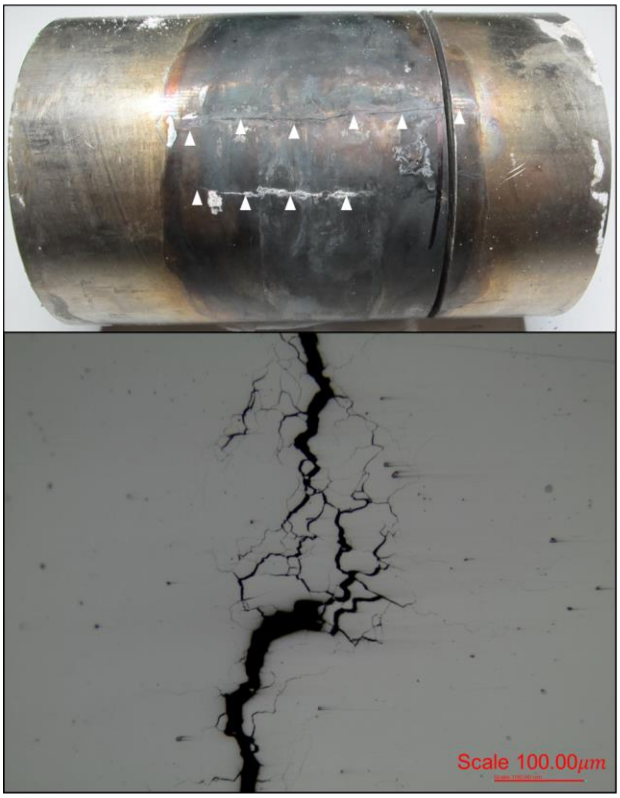
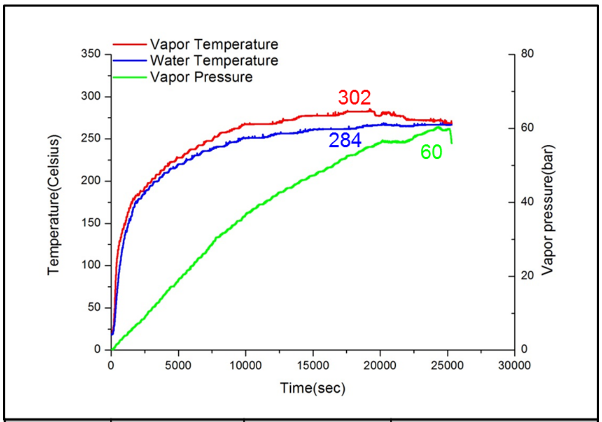


Fig. 4. Optical microscopic images of outer surface and cross-section (200x) of specimen

Also as shown in Figure 5, the maximum temperature and pressure were 302°C and 60bar, respectively. And total experiment times (until penetration) were 25200 sec (about 7 hours).

2.6 Crack propagation

As shown in Figure 6, the crack did not cross the grain but propagated along the grain boundary.



Material	Vapor T_{max} (℃)	Vapor P_{max} (bar)	Penetr. time (sec)
Alloy 600	302	60	25200 (7hr)

Fig. 5. Maximum temperature and pressure, and total experiment time (until penetration)

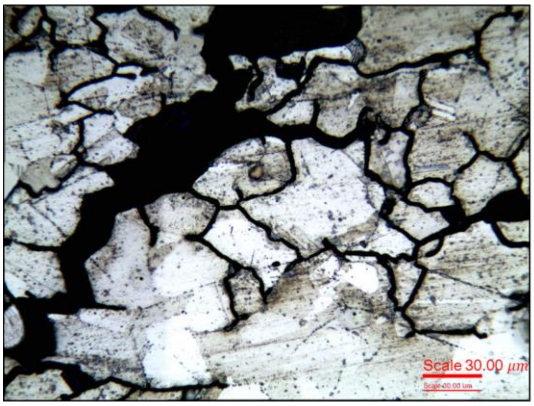


Fig. 6. Optical microscopic images of cross-section(500x) of etched specimen

3. Conclusions

In this study, SCC was manufactured in the simulated corrosive environmental conditions with Inconel 600 tube that widely applied in the nuclear power plants.

1) The SCC was manufactured on Inconel 600 tube in simulated operational environments of nuclear power plants. In the experiment, the welding heat input which is enough to induce the cracking generated the SCC near the welding bead. So, in order to prevent the SCC, the residual stress on structure should be relaxed.

2) The branch-type cracking was detected. And it did not cross the grain but propagated along grain boundary. Generally, it is called to 'IGSCC (Intergranular Stress Corrosion Crack)'.

REFERENCES

[1] Toshio Terasaki : Effect of Welding Conditions on Residual Stress Distributions and Welding Deformations in

Welded Structure Materials, Proceedings of The Twelfth, International Offshore and Polar Engineering Conference, Kitakyushu (2002).

[2] C.E. Kim, C.S. Kang, K.K. Baek, H.J. Kim, “The variation of SCC Resistance in Duplex Stainless Steel Weldment”, Journal of the Korean Welding Society, Vol.5, No.4, pp.36-46 (1987).

[3] J.S. Park, B.K. Na, I.Y. Kim, “Mechanics Evaluations of Stress Corrosion Cracking for Dissimilar Welds in Nuclear Piping System”, The Korean Welding and Joining Society (2005).

[4] Y.K. Woo, J.Y. Nam, S.S. B.Y. Lee, “A frequency characteristic understanding on Acoustic emission of the Stress Corrosion Crack in STS 304 pipe (2011).