The manufactured position control of Stress Corrosion Cracking using welding heat input

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1. Introduction

The Stress Corrosion Cracking (SCC) is one of the environmentally induced cracking. SCC results from the combined action of a tensile residual stress, a structure with alloy and corrosive environment. Many researches about the cracks were done in a way of a slow strain rate test, U-bends and so on. But it has a little difference with actual crack generating conditions. And these methods have a disadvantage which is long experiment time. So confirming the effect of experimental variables is some difficult. It is need to manufacture SCC in the simulated nuclear power plant environment with short experimental time and easy control possibilities.

In this study, SCC was manufactured in the simulated corrosive environmental conditions with STS 304 tube that widely applied in the nuclear power plants. The residual stress which is one of the main factors to induce SCC occurrence was given by GTAW welding in the inner surface of specimen with pure argon shielding gas. The corrosive environment was simulated using the sodium hydroxide (NaOH) and sodium sulfide (Na_2S).

2. Experimental Procedure

2.1 Materials and equipments

The test material was as AISI 304 stainless steel tube, which is widely used in pipelines of the nuclear power plant's reactor coolant system. Stainless steel is apt to have a residual stress in heat affect zone due to a low thermal conductivity and big coefficient of linear expansion. [1]

In the test, the dimensions of specimen were 89.1mm in diameter, 7.6mm in thickness and 150 mm in length.

The yield stress of specimen is decreased when the specimen is heated. So an experimental formula was used to estimate the specimen's yield stress

$$\text{Yield stress} = -0.129T+185.1$$

In this study, the corrosive environment was made by the sodium hydroxide (NaOH) and sodium sulfide (Na_2S).

The NaOH aqueous solution is a strong alkaline. The stainless steel has a high sensitivity in alkaline corrosive environment. The concentrated NaOH accelerates the corrosion rate of chrome and chromium-nickel alloys in a specific temperature and pressure. And the presence of Na2S in concentrated corrosive environments enhances the corrosion sensitivity of stainless steel. [2]

The residual stress in inner surface of specimen was given by gas tungsten arc welding (GTAW) with 100% argon shielding gas.

The specimen was heated using a ceramic heating coil. The experimental system was controlled by vapor temperature.

Table 1 Mechanical properties of austenitic stainless steel STS 304

Properties	Value
Modulus of elasticity	193 GPa
Coefficient of thermal expansion	18.4×10^{-6}/K
Specific heat capacity	502 J/Kg·K
Thermal conductivity	21.5 W/m·C
Possion's ratio	0.29

3. Result and Discussion

The welding heat input can be calculated using arc efficiency, welding current, welding voltage, and welding speed.

In this study, the two specimens were welded in different condition in welding speed. The welding heat input was calculated using the arc efficiencies, 0.21 and 0.48.

The crack was detected at the solution surface level in the test 1specimen when the test was over. It means that the residual stress from the welding was not enough to induce the crack generating. However, the crack was generated near the welding bead in test 2 specimen. The inner pressure in test2 was 34 bar which was given the 17% tangential direction stress of the yield stress at the specimen's surface temperature.

Table 2 Welding conditions of two specimens

	Current	Voltage	Welding speed	Heat input	Welding location
Unit	A	V	cm/min	J/mm	
Test 1	260	14	20	229.32-524.16	Top of the tube
Test 2	260	14	15	305.76-698.88	Top of the tube

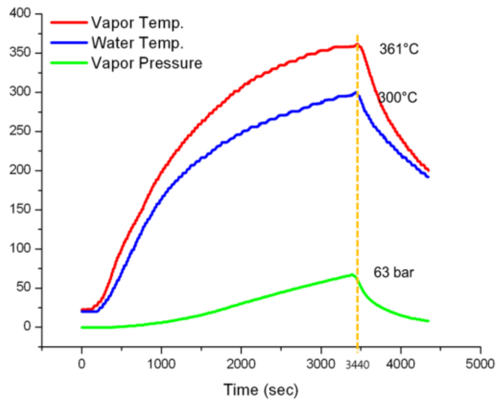

Fig. 5 Temperature and Vapor pressure variation of specimen 1

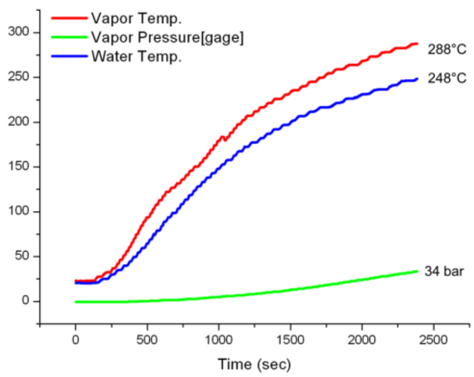

Fig. 8 Temperature and Vapor pressure variation of specimen 2

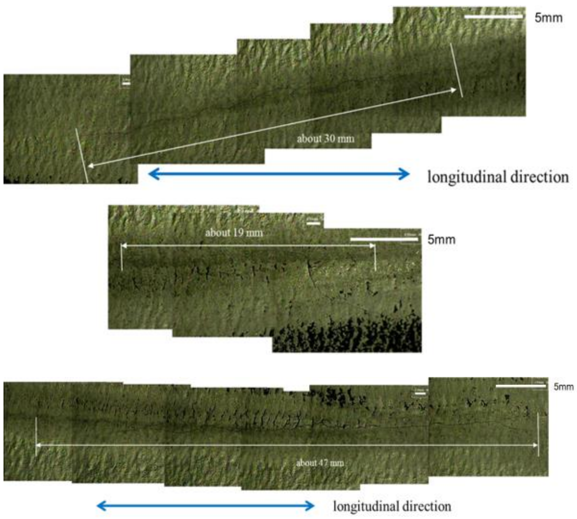

Fig. 7 Endoscopy (X40) results of test 1 specimen

The crack in the specimen 2 occurred at 2mm away from the welding bead. The tensile residual stress distribution was assumed using satoh equation of 300 series stainless steel.[3] The maximum distance of tensile residual stress zone was from 1.7mm to 3.8mm

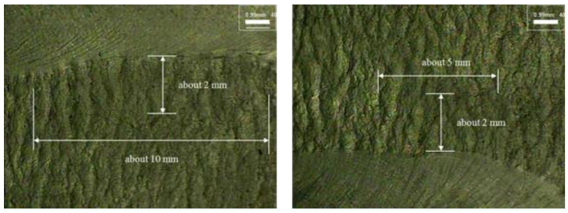

Fig. 9 Endoscopy (X40) results of specimen 2

from the welding bead. So the crack in the specimen 2 was regarded that it was induced by tensile residual stress and it was stress corrosion crack.

4. Conclusion

The stress corrosion crack was manufactured in AISI 304 stainless steel in simulated the nuclear power plant's reactor coolant system. And the crack was generated when the low inner pressure had an effect on specimen in severe corrosive environment. The tensile residual stress could be induced the stress corrosion crack near the weld bead when the welding heat input was enough.

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