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The Influence of Post Weld Heat Treatment in Alloy 82/182 Dissimilar Metal Weld between Low Alloy Steel and 316L Stainless Steel

Sunghoon Hong[a], Jong-Dae Hong[a], Changheui Jang[a*], Kyoung Soo Lee[b]
[a]*Department of Nuclear and Quantum Engineering, Korea Advanced Institute of Science and Technology*
[b]*Central Research Institute, Korea Hydro and Nuclear Power Co. Ltd.*
[*]*Corresponding author: chjang@kaist.ac.kr*

1. Introduction

Dissimilar metal welds (DMWs) using an Alloy 82/182 are widely used to join low alloy steel components and stainless steel pipes in pressurized water reactors (PWRs). It has been reported that tensile residual stress would be generated within DMWs during the welding processes [1]. It is thought as main reason for primary water stress corrosion cracking (PWSCC) resulting in deterioration of long-term integrity [2]. The application of post weld heat treatment (PWHT) has been considered to reduce the tensile residual stress after welding process [3]. Meanwhile, the PWHT could affect the changes in microstructure, mechanical properties, and corrosion resistance [1, 4]. Therefore, in this study, the effects of PWHT on the microstructure, mechanical properties and corrosion behaviors of (1) base metals of low alloy steel and stainless steel and (2) welding materials of Alloy 82/182 are evaluated.

2. Materials and Experiment

2.1 Materials

The materials used in this study are commercial grade of SA 508 class 3 (low alloy steel), 316L SS (stainless steel), and Alloy 82/182 (welding material). For the welding process, manual gas-tungsten arc welding and shielded-metal arc welding are used. The schematic design of the weld is shown in Fig. 1.

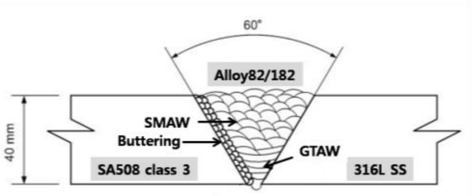

Fig. 1. Schematics of the DMW.

2.2 Post Weld Heat treatment

The PWHT is conducted on the welding blocks following the NESC-III project [5]. It is carried out at 575 °C and 600 °C to minimize the sensitization of stainless steel [6]. Fig. 2 shows the thermal history (temperature versus exposure time) of specimens during the PWHT process. The PWHT procedure is as follows; the specimens are heated to the 350 °C with the heat-up rate of 300 °C/h. Then, those are heated to the target temperature of 575 °C and 600 °C with the heat-up rate of 38 °C/h. It is maintained at those target temperatures for 10 h. The specimens are cooled in furnace down to 350 °C and then air cooled.

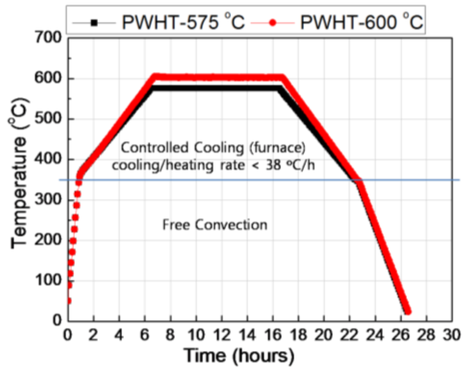

Fig. 2. Thermal history of the PWHT process.

2.3 Mechanical properties test

To investigate the mechanical properties of the DMW after PWHT, micro-hardness and tensile tests are performed. The micro-hardness value is obtained by averaging at least 10 measurements. The Micro-Vicker's hardness is measured with a load of 100 g for 10 s. Tensile tests in room temperature air are performed by using round bar tensile specimens with a strain rate of $5x10^{-4}$ /s following the procedures of ASTM E8/E8M-13a.

2.4 Potentio-dynamic test

To observe corrosion behaviors of DWM in PWR environment following PWHT, potentio-dynamic test is conducted. In electrochemical cell, carbon rod is used as the counter electrode. Test solution is 1200 ppm H_3BO_3 + 2.2 ppm LiOH. The test after PWHT is conducted following the ASTM G5. Specimens are potentio-dynamically polarized using a potentiostat at 1 mV/sec scan rate and are exposed to at a potential of E_{corr}-500 mV for 5 min to remove air-formed surface oxide before the polarization.

3. Results and Discussion

3.1 Microstructure

The microstructure of the as-welded and PWHTed DMW is shown in Fig. 3. The weld cross-section is distinguished by etching as SA 508 class 3, 316L SS, and Alloy 182. SA 508 is typically composed of tempered bainite structure. 316L SS consists of austenitic grains with a few residual stringer type ferrites in which grain boundary carbides are not observed due to low carbon content (0.03 wt.%) and short exposure time [7]. The microstructures of two base metals are similar to as-welded regardless of the PWHT conditions. In the case of Alloy 182, dendritic structure is typically observed in all test conditions. In PWHT-575 ^{o}C and PWHT-600 ^{o}C conditions, however, grain boundaries are covered with a large quantity of film-like continuous Cr-rich $M_{23}C_6$ carbides.

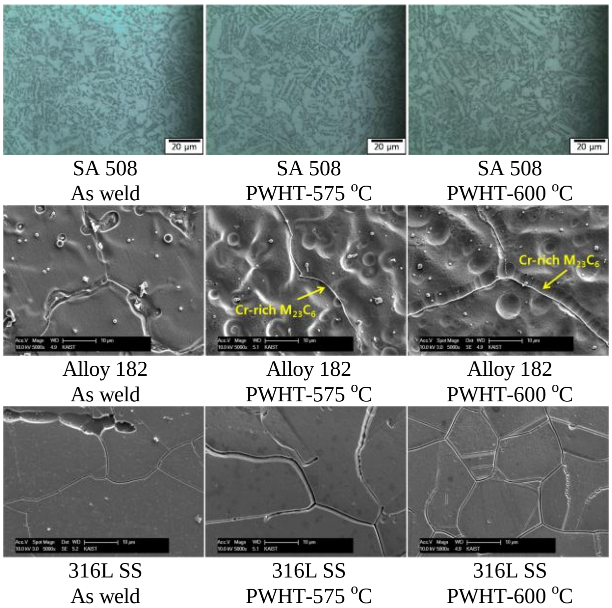

Fig. 3. Microstructure of DMW after PWHT.

3.2 Micro-Vicker's hardness and tensile properties

The results of Micro-Vicker's hardness test are shown in Fig. 4. In PWHT-575 ^{o}C and PWHT-600 ^{o}C, a general tendency of micro-hardness is similar to as-welded. Though some changes in micro-hardness are observed for all test materials, the effects of PWHT on mechanical property are not clearly present.

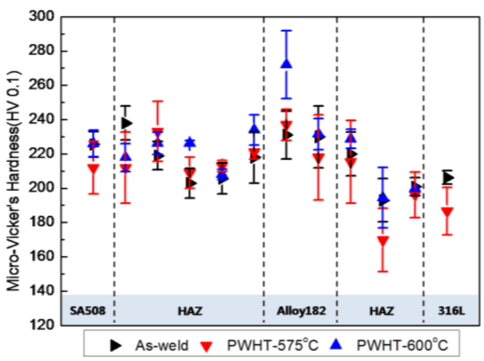

Fig. 4. Result of Micro-Vicker's hardness after PWHT.

3.3 Tensile properties

The results of tensile test are shown in Fig. 5. For all test materials, the differences of tensile strength and elongation are not significant before and after PWHT process. It indicates that exposure to PWHT temperature (575 ^{o}C and 600 ^{o}C) for 10 h would not affect mechanical properties. For the Alloy 182, grain boundary carbides are formed after PWHT, but it seems that would not significantly alter mechanical properties.

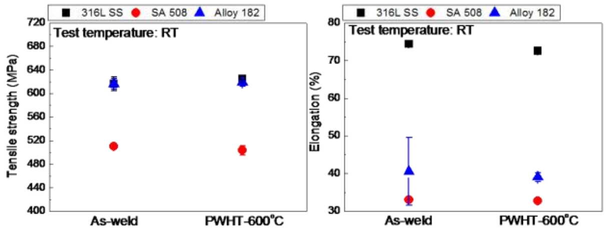

Fig. 5. Result of tensile test after PWHT.

4. Conclusions

The influence of PWHT in DMW has been investigated. SA 508 and 316L SS exhibited tempered bainite and austenitic grains with a few residual stringer type ferrite. Grain boundary carbides are not precipitated owing to low carbon and insufficient exposure time in 316L SS. The change of mechanicals properties in base metals is not observed. In case of Alloy 182, after PWHT, grain boundaries are covered with film-like continuous Cr-rich carbides. However, it seems that would not affect mechanical properties. To evaluate the corrosion resistance, potentio-dynamic test is currently underway.

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