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Evaluation of Local Tensile Properties of Dissimilar Metal Weld Joint at Ambient and Operating Temperatures

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1. Introduction

Alloy 82/182 filler metal is commonly used in dissimilar metal weld joint between ferritic steel and austenitic stainless steel in primary system of nuclear power plant (NPP). Recently, a concern has been raised on the integrity of this weld, because it is susceptible to PWSCC [1~4]. However, the variation of mechanical properties of Alloy 82/182 weld joint was not properly investigated at operating temperature of NPP. Our previous study evaluated the local tensile properties of dissimilar metal weld between SA508 Gr.3 Cl.1 ferritic steel and Type 316 stainless steel at ambient temperature [5].

In this study, the local tensile properties of dissimilar metal weld joint between SA508 Gr.1a ferritic steel and Type 316 stainless steel are evaluated using small-size tensile specimen at ambient and operating temperature (320°C) of NPP. Also, the microstructure is examined at each local material zone.

2. Experimental Procedure

The material used in the experiment is single V-grooved weld, which was prepared by joining two pieces (SA508 Gr.1a and Type 316) of 37mm thick plate. The ferritic joint face was buttered with two layers of Alloy 82 filler metal, and the buttered SA508 Gr.1a was stress relieved by heat treatment at 610~620°C for 1.5 hrs. The weld joint between Type 316 and buttered SA508 Gr.1a steels was made using manual welding: GTAW using Alloy 82 filler wire for root passes and SMAW using Alloy 182 filler wire for additional passes. Fig. 1 shows as-welded plate specimen.

Fig. 1 As-welded plate specimen

Small-size flat specimen with a cross-section of 0.5mm×2mm and uniform length of 14 mm was employed in tensile tests (Fig. 2). As shown in Fig. 3, the specimens were machined along weld direction from the various material zones of dissimilar weld joint, such as heat-affected-zone (HAZ), weld metal, buttering zone, SA508 Gr.1a and Type 316 base metals. Three specimens were taken from each material zone: bottom, middle and top of specimen. The tests were conducted at ambient and operating temperature under quasi-static loading condition.

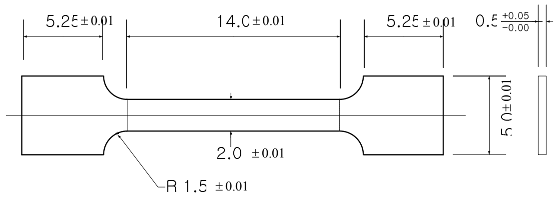

Fig. 2 Dimensions of small-size tensile specimen

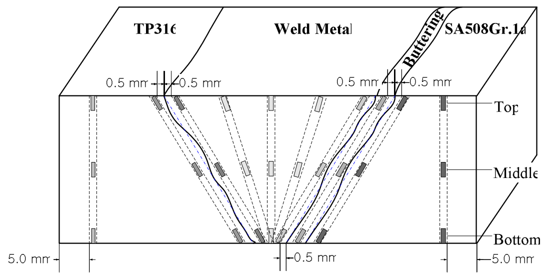

Fig. 3 Locations of tensile specimen extracted

3. Results and Discussion

Fig. 4 shows the spatial variations of yield stress (YS) and ultimate tensile stress (UTS) across the weld joint. YS of Alloy 82/182 weld metal was higher than that of both base metals. That is, the weld joint showed typical strength overmatching. The variation of YS within Alloy 82/182 weld metal including Alloy 82 buttering was less significant. However, the variations of YS across the weld joint were considerable. Especially, heat-affected-zones (HAZs) of SA508 Gr.1a and Type 316 showed higher YS compared to surrounding materials. Thus, the strength mismatching at near the HAZs was significant. The value of UTS at weld center region was lower about 80MPa compared to weld boundaries. Thus, the value UTS at weld center region was slightly lower than that of Type 316 base metal and higher than that of SA 508 Gr.1a base metal.

The values of UTS at HAZs were almost same to those of near the weld metal, although they were higher than those at base metals. Therefore, the mismatching of UTS at near HAZs was insignificant.

According to the examination of microstructure, the strength increment at HAZ of SA508 Gr.1a was associated with a transformation of microstructure due to heating and rapid cooling during the welding process. For HAZ of Type 316 stainless steel, the strength increment was related to increasing content of ferrite phase in austenite matrix.

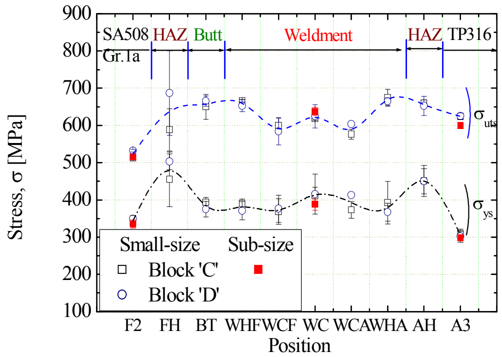

Fig. 4 Spatial variations of yield stress and ultimate tensile stress at ambient temperature

As shown Fig. 5, regardless of material zones, the value of YS decreased with increasing test temperature, and thus at operating temperature the spatial variation of YS across weld joint was nearly identical to that at ambient temperature. UTS values of Alloy 82/182 weld metal and Type 316 and its HAZ decreased more than 100MPa with increasing temperature up to 320°C, whereas the values of UTS at SA508Gr.1a and its HAZ slightly increased at 320°C compared to ambient temperature. At operating temperature, therefore, the spatial variation of UTS across the weld joint was different from that observed at ambient temperature. The value of UTS of Alloy 82/182 weld metal was nearly same to that of SA508 Gr.1a base metal and higher than that of Type 316 base metal. Also, UTS value at HAZ of SA508 Gr.1a was higher about 100MPa than that at surrounding materials.

The decrease in YS and UTS with increasing test temperature is a nature of material properties. However, the values of UTS at SA508Gr.1a and its HAZ were slightly increased with increasing temperature. This is associated with dynamic strain aging effect that is typically observed in ferritic steels [6].

4. Conclusions

In this study, the local tensile properties of dissimilar weld joint between SA508 Gr.1a and Type 316 stainless steels with Alloy 82/182 weld metal were evaluated using small-size tensile specimen at ambient and operating temperatures of nuclear power plant. From these results, the spatial variations of yield stress and ultimate tensile stress were examined. Also, the examination of microstructure was conducted to understand the local variations of tensile properties.

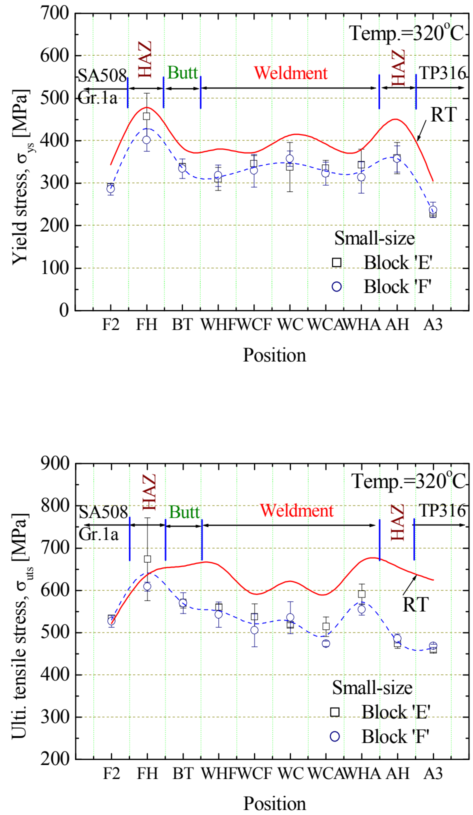

Fig. 5 Spatial variations of yield stress and ultimate tensile stress at operating temperature of NPP

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