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Tensile and Fracture Toughness Properties Variation in Inconel 82/182 Dissimilar Metal Welds

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1. Introduction

Dissimilar metal welds between ferritic steel and austenitic steel tubing and piping are commonly employed in nuclear power plants. Such transition joints are necessary because of the corrosion resistance of stainless steel, while ferritic steels are commercially more attractive [1]. The concern and interest in the integrity of dissimilar welds have been raised because of the incident in V.C. Summer plant [2]. It has been thought that the repair welding during the construction caused significant residual stress on the inner surface of the weld. For the integrity analysis of the dissimilar welds, it is essential to have enough materials property database. In this paper, the spatial variations of the mechanical properties of dissimilar metal weld were investigated.

2. Test materials and welding

Base materials used to construct dissimilar metal welds are SA508 Gr.3 low alloy steel and TP316 stainless steel which are the types of material used for constructing nuclear pressure vessels and pipes in Korea. These metals are provided as forged and heat treated, and prepared as 40 mm thick plate before welding procedure. Using inconel electrode 182 and filler metal 82, dissimilar metal welds are fabricated. These procedures were followed by manual which is used for the nozzle to pipe welding in OPR1000. The schematics of welding procedure are shown in Figure 1.

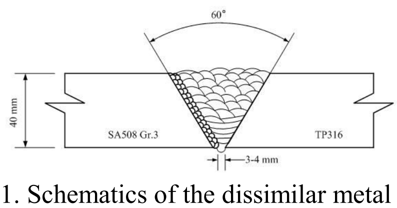


Figure 1. Schematics of the dissimilar metal weld of single V-grooved design.

3. Test method

3.1 Tensile test

Round bar tensile specimens were machined from the welded plates [3]. As shown in Figure 2, specimens were taken from SA508 low alloy steel region, inconel 82/182 weld region, and TP316 stainless steel region along the welding direction. The specimens were tested at strain rate of $5x10^{-4}$/sec. Test temperature was room temperature and 320°C, and temperature variation of test was less than 1°C. These specimens are made and tested by ASTM E8M-01.

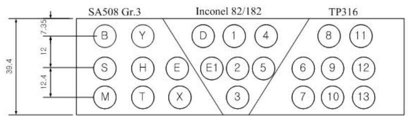


Figure 2. Locations for round bar tensile specimen.

2.2 Fracture toughness test

Fracture tests were performed on precracked compact tension (CT) specimens that had a width (W) of 38.1 mm and thickness (B) of 12.7 mm. All specimens had 20 percent side grooves. Inconel weld specimens were tested in the transverse orientation, with the notch normal to the welding direction as shown in Figure 3. Specimens were tested in room temperature and 320°C using direct current potential drop (DCPD) system that was operated in displacement control. Loading rate for the test was 0.2 mm/min. Fracture toughness was followed by ASTM E1737-96 and E1820-05a.

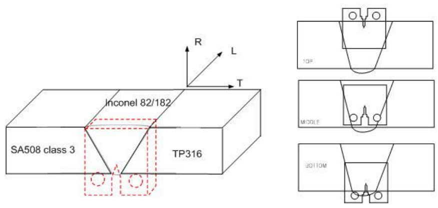
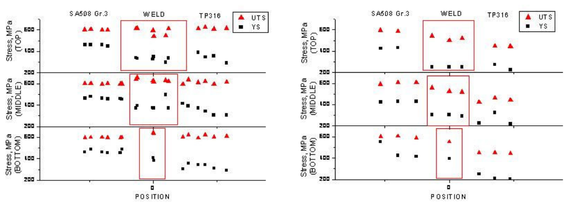


Figure 3. The orientation and position of the specimens.

4. Results and Discussion

4.1 Tensile Properties

The tensile properties of test materials in air room temperatures and 320°C are summarized in Figure 4. Test results show a little different property depending on the test position. In the case of the room temperature, SA508 Gr.3 base metals show higher yield strength than inconel 82/182 weld and TP316 base metals. However UTS values are similar in both of base metals and inconel weld metal. Within the weld, a quite large tensile property variation is present, such that the yield strength and UTS are larger at the bottom of the weld than at the top of the weld. In the case of the 320°C, SA508 Gr.3 had the highest value of UTS, and inconel 82/182 has higher values of UTS than those of TP316. As a whole, the yield strength was decreased as the temperature was increased at the all materials. The ultimate tensile strength of SA508 was not changed as the temperature was increased. However, in the case of inconel 82/182 and TP316, the ultimate tensile strength was decreased as the temperature was increased.

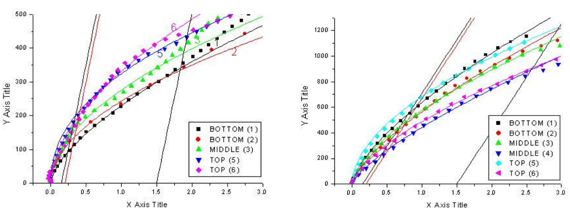


(a) (b)

Figure 4. Tensile properties variation across the dissimilar metal welds (a) room temp. (b) 320°C

4.2 Fracture Toughness

The fracture toughness test results of the inconel welds are shown in Figure 5. In the case of the room temperature, for the specimens taken at the same location, the J-R curves are similar. The J-R curves of the specimens taken at the top of weld are much greater than those at the bottom of weld. However, in the case of the 320°C, the J-R curves are not depending on the location. Because of large number of welding pass and repeated heat cycles during the welding process, the mechanical properties can not be uniform within the weld. Through the fracture surface observation, the relation between the fracture toughness and fracture modes can be demonstrated. So the SEM observation is being observed.



(a) (b)

Figure 5. Fracture toughness variation across the inconel 82/182 welds (a) room temp. (b) 320°C

4.3 Fracture Surface Observation

From the fracture surface observation of the compact tension specimens in the case of the room temperature, ductile fracture modes are observed. Representative fracture-surface morphologies of welds are shown in Figure 6. The dominant fracture mechanisms are different depending on the location within the weld. In the bottom of the weld (Fig. 6(a)), primary microvoid coalescences are dominantly observed. In the middle of the weld (Fig. 6(b)), shear-stretch features are observed and primary dimples are also partially observed. In the top of the weld (Fig. 6(c,d)), shear-stretch features are dominantly observed, and the size of shear-stretch region are larger than the size in the middle part [4].

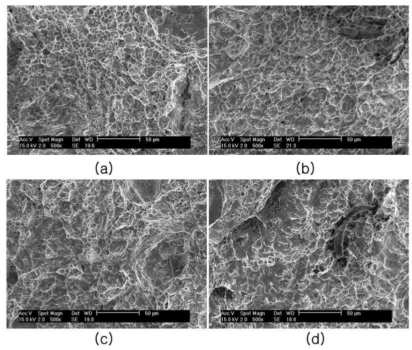


Figure 6. Fracture surface morphology for Inconel 82/182 welds

In the case of 320°C, the specimens are being prepared for SEM observation.

5. Conclusion

The dissimilar welds joining the low alloy steel and stainless steel were fabricated and the spatial variations in mechanical properties were investigated.

1. Inconel 82/182 weld showed a quite large tensile property variation. The YS and UTS values are larger at the bottom of the weld than at the top of the weld. And these strengths were decreased as the temperature was increased.
2. At room temperature, fracture toughness at the top of weld is much higher than at the bottom of weld.
3. Fracture toughness of room temperature was depending on the ductile fracture modes. The ductile fracture behavior in inconel 82/182 welds involves a combination of microvoid coalescence, void-sheet, and shear-stretch formation.

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