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Tensile Property Evaluation of Dissimilar Metal Welds Containing Alloy 82/182 Fusion Weld using Miniature Specimen

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1. Introduction

Recently, the concern has been raised on the integrity of the dissimilar welds because of the incident in V.C. Summer plant [1]. In case of the dissimilar metal welds which consist of different types of materials, in part due to the chemical composition gradient and the mixing of filler metals and base metals, the spatial variation and scatter in material properties could be significant. Therefore, it is important to know the variation of the mechanical properties in dissimilar weld area to properly analyze the integrity of the nozzles. However, even though there has been several attempts to measure the mechanical properties of alloy 82/182 welds [2,3,4], the variation of mechanical properties were not properly investigated. In this paper, the spatial variations of the mechanical properties of experimental heat of dissimilar metal weld were investigated.

2. Materials and Experiments

2.1 Materials and Welding.

The materials used in welding are SA508 Class 3, TP316, and Alloy82/182 filler wire. Both base metals are provided as forged and heat treated condition and prepared as 40 mm thick plate before the welding procedure. The plates are welded manually, closely simulating the welding procedures used for the real nozzle to pipe welding in OPR1000. The schematic design of the weld are shown in Figure 1.

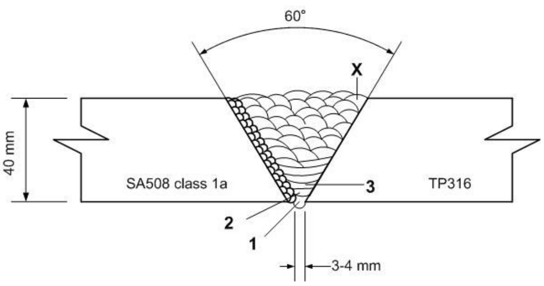
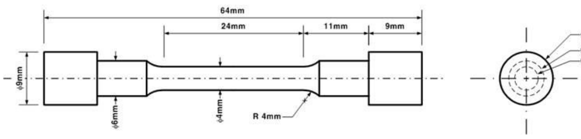


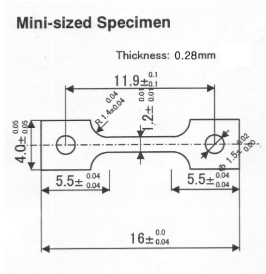
Figure 2. Schematics of the dissimilar metal weld of single V-groove design.

2.2 Tensile Test

Small size round bar tensile specimens and mini-sized sheet type tensile specimens shown in Figure 2 were machined from the welded plates. Specimens were taken from SA508 low alloy steel (LAS) region, Inconel weld region, and stainless steel (SS) regions along the welding direction. Additionally, 6 small size specimens were taken along the transverse direction. The specimens were tested at room temperature at strain rate of $5x10^{-4}$/sec.



a) small size specimen



b) mini size specimen

Figure 2. Small size round bar specimen for tensile test

3. Results and Discussion

3.1 Microstructure.

The cross section of the finished weld is shown in Figure 3. The distinctive region of DMW, such as, LAS base, buttering, fusion weld, and SS base are clearly visible after proper etching application. The microstructures of several regions of DMW are shown in Figure 3. SA508 is composed of tempered bainite structure, and SS316 is composed of austenitic grains with a few ferritic stringers. In the weld, the dendritic microstructure is clear in inconel weld and buttering area. Along the fusion boundary between inconel weld and SS base, partially melted zone is also visible, where the carbide structures which are made by mixing of them [5]. The region between Alloy 82 buttering and SA508 class3 shows a heat affected zone, but the zone size is small because of buttering process.

3.2 Standard Tensile Results

The round bar tensile test results are analyzed. As a whole, SA508 base metals showed higher yield strength and UTS than alloy 82/182 weld and TP316. On the average, the YS values of SA508 are about 450 MPa, but those of alloy 82/182 are about 350 MPa, far lower than base metals. However, the UTS values of alloy 82/182 welds are similar as those of SA508 and SS316 base metals.

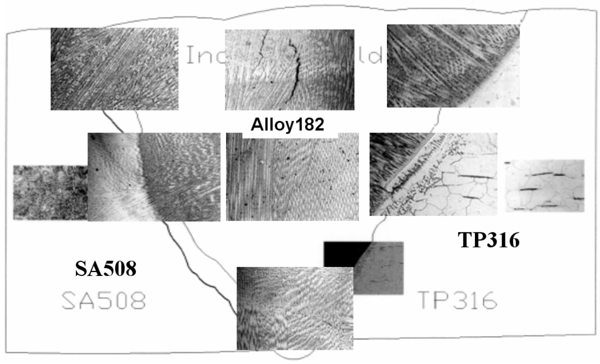
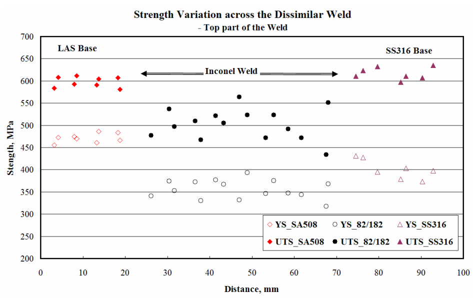


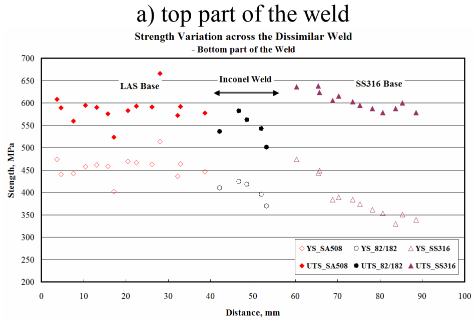
Figure 3. Typical cross section of dissimilar metal weld with details of the microstructure

2.3 Small Specimen Tensile Test

The mini tensile test results are shown in Figure 4. First of all, it is shown in the figure that the overall values of tensile properties measured using mini specimens are compatible with those measured using round bar specimens. The differences are greater at the top part of the weld and become smaller at the bottom part of the weld near weld root pass. The implication of softer alloy 82/182 weld than those of surrounding base metals is such that there would be the preferential deformation and failure in alloy 82/182 weld when subjected to external loading during operation. As shown in Figure 4, the SS316 specimen taken near the fusion boundary showed significantly higher strength than the base metal away from the fusion zone. This behavior could have been the results of the partially melted zone and formation of carbide during the welding process [5].



a) top part of the weld



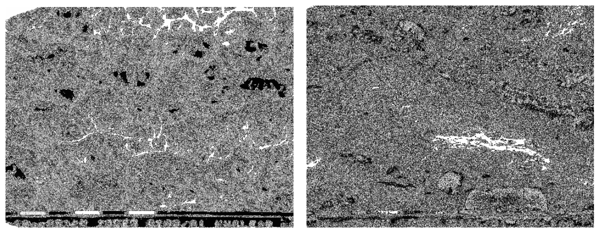
b) bottom part of the weld

Figure 4. Tensile properties variation across dissimilar metal welds. Using miniature specimens

2.4 Fracture Surface Observation

The fracture surfaces of round bar tensile specimens were observed under scanning electron microscope. As shown in Figure 5-a), the fracture surface shows the typical ductile dimple fracture surface. In some of the microvoids, the secondary particles are visible at the center. From the microstructural features, it is postulated that the interdendritic core with severe segregation or secondary particles would have been the microvoid initiation sites.

However, in certain location of the weld, the failure mode is not fully ductile dimple mode as shown in Figure 5-b). As shown in the figure, the fracture surface containing regions with virtually no microvoids. Instead, shear marks are shown on the rather large area extending up to 100 mm. However, the causes of such morphology are not clear and need further investigation.



a) fully ductile dimple b) location of shear mark

Figure 5. Fracture surfaces of tensile specimen of ally 82/182 weld

3. Conclusions

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

1. The dendritic structures are well developed and clearly visible in alloy 82/182 weld. Also, within the inter-dendritic cores, significant segregation and defect-like boundaries were observed.
2. Alloy 82/182 weld showed lower strength than the adjacent base metals. The differences in strength are greater at the top part of the weld and become smaller at the bottom part of the weld.
3. The fracture surface of tensile specimen showed typical ductile dimple fracture mode. However, in certain location of the weld, the fracture surface containing regions of large shear marks with virtually no microvoids.

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