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Characterization of Local Tensile Property of Dissimilar Metal Weld by Tensile and Automated Ball Indentation Tests

Jin-Weon Kim[a], Jong-Sun Park[a], Jong-Sung Kim[b], Tae-Eun Jin[b]
[a] *Department of Nuclear Engineering, Chosun University, 375 Seosuk-dong, Dong-gu, Gwangju, 501-759, Korea,* *jwkim@chosun.ac.kr*
[b] *Korea Power Engineering Company, 360-9 Mabuk-ri, Gusung-eup, Gyeonggi-do, 449-713, Korea*

1. Introduction

Dissimilar metal weld (DMW) using Alloy 82/182 filler wire is commonly employed in the joints between ferritic steel and austenitic stainless steel in the primary system of nuclear power plant (NPP). Recently, the concern has been raised on the integrity of this weld joint, because it is highly susceptible to cracking [1-4]. It is known that the cracking is mainly related to high residual stress and microstructural and mechanical heterogeneity across the weld joints [5]. Also, the significant variation in mechanical properties in DMW prohibits proper integrity assessment of weld joints. Thus, it is important to characterize the local mechanical properties of DMW to reliably assess the integrity of welded components. This study evaluates the local tensile properties of DMW region through tensile tests using small-size flat specimen and automated ball indentation (ABI) tests, and investigates the spatial variation in tensile properties of welded region.

2. Experiments

2.1 *Materials and Specimens*

The material used in this study is single V-grooved weld, which was prepared by joining two 150×300mm pieces (SA508 Gr.3 and TP316) of 40mm thick plate. It was produced by manual welding: GTAW using Alloy 82 filler metal for buttering and root passes and SMAW using Alloy 182 filler metal for other passes. Figs. 1 and 2 show the weld configuration and cross-section, respectively.

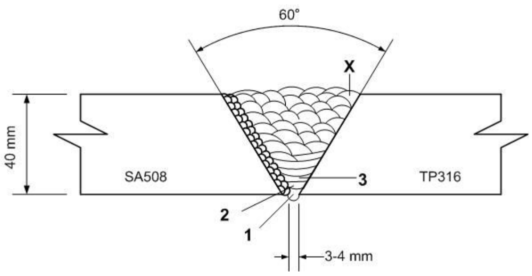

Fig. 1 Configuration of dissimilar metal weld

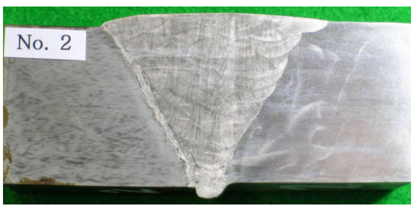

Fig. 2 Cross-section of weld prepared in this study

2.2 *Tensile Tests*

Small-size flat specimen with a cross-section of 0.5mm×2mm and gage length of 9mm was employed in tensile tests. As shown in Fig. 3, the specimens were machined along the weld direction from the various material zones of DMW: heat-affected-zone (HAZ), weld metal, buttering zone, SA508 Gr.3 and TP316 base metals. Four specimens were taken from each material zone (see Fig. 3). The tensile test was performed under quasi-static loading conditions using universal testing machine (Instron 4204) with load cell whose maximum capacity is 5kN.

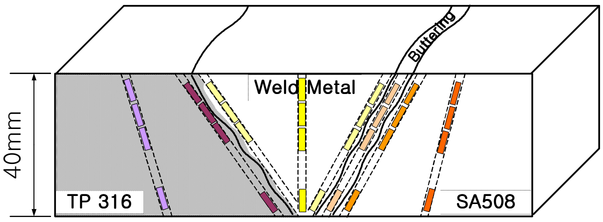

Fig. 3 Specimen locations in the weld area

2.3 *ABI Tests*

The local tensile properties of DMW was also evaluated by performing ABI test, which is a non-destructive test technique, across the weld region including base metals, HAZ, buttering, and weld metal. The test were performed on both surfaces, weld cross-section and top of weld, of a block specimen along the direction normal to the weld fusion line as shown in Fig. 4. The sufficient spacing between indentation points was considered to avoid plastic zone impingement of adjacent indentations. All tests were carried out at ambient temperature using a tungsten carbide ball indenter of 0.5 mm diameter. The surfaces of specimen were machined by milling and polished with #1200 emery paper to minimize the effect of surface roughness, and finally etched to make clear the interface of each material zone.

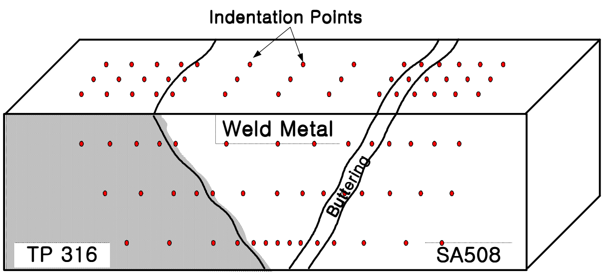

Fig. 4 Indentation locations across DMW joints

3. Results and Discussion

3.1 *Tensile Test Results*

From the tensile tests using small-size flat specimen, the stress-strain curves were obtained for each material zone of weld. The stress-strain curves exhibit relatively little variation within the same material zone, but large differences are observed between the different material zones. From the stress-strain curves, the yield stress (YS) and ultimate tensile stress (UTS) are obtained and presented in Fig. 5 as a function of position of material zone. First of all, it is confirmed that YS and UTS of weld metal and both base metals measured using small-size flat specimen are comparable with those measured using sub-size round bar specimen that was given by previous study [6]. As shown in Fig. 5, the YS values of weld metal (Alloy 82/182) are slightly higher than those of TP316 and smaller than those of SA508 Gr.3, and the UTS values of weld metal are similar as those of TP316 and SA508 Gr.3 base metals. YS and UTS of Alloy 82 buttering are nearly same as those of Alloy 82/182 weld metal. HAZ of SA508 Gr.3 and TP316 showed higher YS and UTS values than those of base metals. For SA508, especially, the increase in strength at HAZ is significant. Also, this implies that the gradient of mechanical properties near the HAZ of SA508 Gr.3 is considerable.

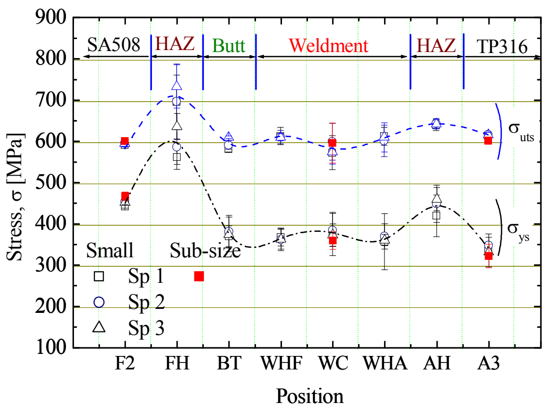

Fig. 5 Spatial variation of yield and ultimate tensile stresses across dissimilar metal weld joints.

3.2 *ABI Test Results*

Figure 6 presents YS and UTS measured by ABI tests at each material zone, together with the results of tensile test using small-size specimen. The values of YS and UTS measured by ABI test on the surface of weld cross-section agree well with those measured by tensile test at the same position, although the ABI test results give slightly higher YS for weld metal and lower UTS for both base metals. Also, the spatial variation in YS and UTS within local region is reasonably measured by ABI test results. The ABI test results obtained from the top of weld also show good agreement with those of tensile test in the overall range of material, expect that the stress peak at HAZ of TP316 is not clear. From these results, thus, it is indicated that the ABI test reasonably measures the local YS and UTS of DMW joints.

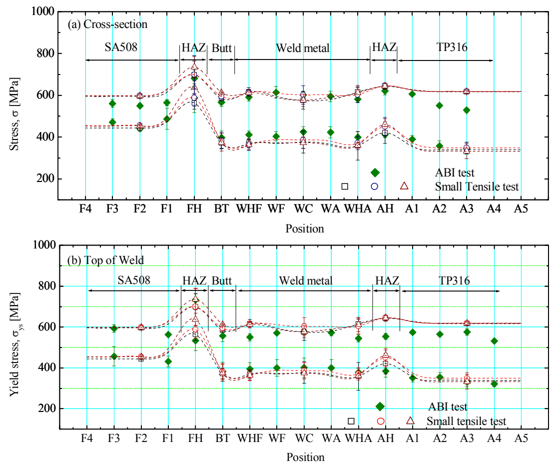

Fig. 6 Comparisons of yield and ultimate tensile stresses measured by ABI and tensile tests

4. Conclusions

In this study, the local tensile properties of dissimilar metal weld were evaluated by tensile tests using small-size flat specimen and automated ball indentation (ABI) tests, and the spatial variation of tensile properties were investigated.

1. YS of weld metal (Alloy 82/182) were slightly higher than those of TP316 and smaller than those of SA508 Gr.3, and UTS of weld metal were similar as those of TP316 and SA508 Gr.3 base metals.
2. The values of YS and UTS of Alloy 82 buttering were nearly same as those of Alloy 82/182 weld metal.
3. Heat-affected-zones (HAZs) showed higher YS and UTS values compared to base metals. Especially, the increase in strengths at HAZ was significant for SA508 Gr.3.
4. The ABI test reasonably measured the local YS and UTS values of dissimilar metal weld joints.

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