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Crack Growth Behaviors of Alloy 600/182 Weld Metals in a Simulated PWR Environment

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1. Introduction

Recently, corrosion damages due to a primary stress corrosion cracking (PWSCC) in the reactor pressure vessel (RPV) head penetration nozzles and the welded parts around them at pressurized water reactors have been found throughout the world [1]. Alloy 600 is an austenitic Ni-16wt%Cr-8wt%Fe alloy that has been extensively used for structural components, including the RPV head penetration nozzles, in nuclear power plants. In the present work, the crack growth rate and the PWSCC properties of the Alloy 600 base metal and Alloy 182 fusion zone were studied by observing the fracture surfaces of the compact tension (CT) specimens after the test. After that, the PWSCC behaviors of the alloys were explained in terms of their microstructures.

2. Experimental

Alloy 600 was from an air melt, and cold worked at 30% by a cross rolling. The test specimens were taken from the welds, which were made by filling a machined groove in an Alloy 600 plate with a filler metal of Alloy 182. The PWSCC test was conducted under a simulated primary water condition, in a 1200 ppm B + 2 ppm Li solution at 325 ℃. The CT specimens were machined from the weldment with several orientations. There is no standard terminology for the orientation of weld specimens, so the ASTM standard for plates [2] has been adapted. In the present experiment, the direction of the Alloy 182 weld has been used in a similar fashion to the rolling direction of the Alloy 600 plate, and this is shown in Fig. 1.

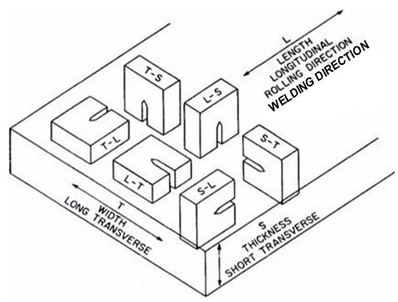
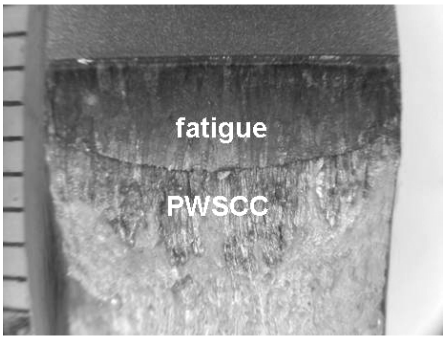


Fig. 1 Terminology used for orientations of cracking planes in the test specimens with respect to the rolling and welding.

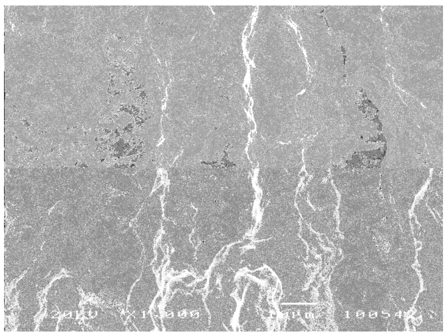
3. Results and Discussion

3.1 PWSCC morphologies

Fig. 2(a) shows an overall fracture surface of the Alloy 182 weld CT specimen with the T-S orientation of Fig. 1. In the figure, the pre-fatigue and the PWSCC areas could be identified. Fig. 2(b) is the high magnified view of the part denoted as 'PWSCC' in Fig. 2(a). From the figure, it can be seen that the cracks were propagated along the inter-dendritic interfaces, therefore, the cracking mode in the Alloy 182 weld was inter-dendritic.



(a)



(b)

Fig. 2 (a) Fracture surface of the Alloy 182 weld CT specimen with the T-S orientation, and (b) high magnified view of a part denoted as 'PWSCC' in (a).

On the other hand, as shown in Fig. 3, the fracture morphologies of Alloy 600 showed that the cracks grew along the grain boundaries. Therefore, it is confirmed that the cracking mode was completely intergranular in this case. The predominant failure mode of Alloy 600 is well known to be intergranular in the primary and secondary water environment [3]. Since the Alloy 600 base metal was heavily cold rolled, the grains were elongated along the rolling direction, as shown in Fig. 3.

The average grain size in the heat affected zone was smaller than that in the unaffected base metal. This result was due to the fact that new grains were nucleated and grew on the pre-existing grain boundaries during a welding process.

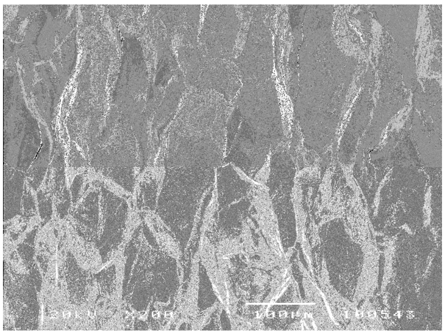


Fig. 3 Fracture surface of the Alloy 600 base metal

3.2 Crack growth rates

Fig. 4 shows the crack growth rates of the Alloy 182 fusion zone, depending on the orientation of CT specimens. As shown the Figure, The crack growth rates of the Alloy 182 weld were found to be very high when the orientations of the cracking planes were T-S, T-L-L-S, and L-T in Fig. 1. When the cracking planes were S-T and S-L, however, PWSCC cracks were rarely found under the same test conditions. These results originate from the fact that the crack propagation direction was along the dendrites. The cracking planes of the S-T, and S-L specimens were perpendicular to the dendrites, therefore, the cracks could not be easily propagated in these circumstances. The cracking planes of the rest were more or less parallel to the dendrites.

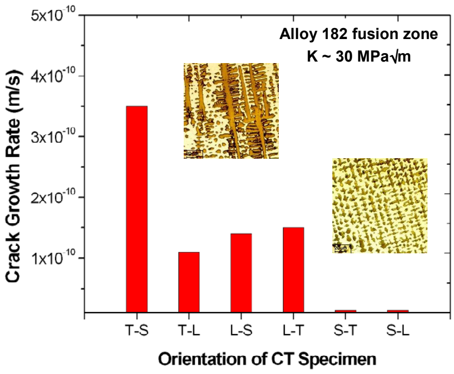


Fig. 5 Crack growth rates of the Alloy 182 fusion zone, depending on the orientation of CT specimens.

4. Conclusions

The PWSCC mode was an intergranular cracking in the Alloy 600 base metal and the heat affected zone. On the other hand, it was inter-dendritic in the Alloy 182 fusion zone. The crack growth rate had a maximum value when the cracking plane was parallel to the primary dendrites.

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[3] G.S. Was, Corrosion, 1990, 46, 319.