Effects of Loading and Dendrite Growth Directions on Crack Growth Behavior near Fusion Line in Low Carbon Stainless Steel Weld Joints

Background

The results of a field investigation on cracked PLR pipes suggested that cracks which initiated in the inner surface of pipes near the weld root are arrested or considerably decelerated around the weld fusion line. It is known that SCC in weld metal propagate in the dendrite boundary *1 with high grain-orientation, therefore, the SCC propagation direction in base metal and angle between crack propagation direction and weld fusion line might affect the crack propagation behavior near the fusion line. Meanwhile, only a few studies have focused on the crack growth behavior near the fusion line.

Objectives

The purpose of this study is to clarify the effects of loading and dendrite growth directions on the SCC growth behavior near the weld fusion line.

Principal Results

SCC growth tests were conducted on the specimens obtained from SMAW *2 and GTAW *3 weld joints of low-carbon 316L stainless steel under simulated BWR coolant conditions. The specimens were machined out from the weld joints with various angles (θ) between neutral line of the specimen and weld fusion line to change the angles between crack growth direction and dendrite growth direction. The following results were obtained.

(1) IGSCCs *4 from precrack tips in the base metal propagated toward the weld metal while branching to form secondary cracks, then, the cracks changed direction to avoid the weld metal and propagated along the fusion line.
A stronger tendency of crack behavior to avoid weld metal was observed in specimens with a smaller angle between the neutral line of the specimen and the fusion line.

(2) The propagation of large IDSCC *5 into the weld metal was only observed in a specimen with the crack propagation direction perpendicular to the fusion line (θ =90 °).

(3) The result of measuring the length of 63 secondary cracks that propagated into weld metal showed that 80% of cracks propagated less than 50 mm from the fusion line, and two cracks with a propagation length of greater than 150 mm were observed in the specimens with the neutral line perpendicular to the fusion line (θ =90 °).

These results suggested that cracks tend to be arrested or decelerated near the fusion boundary in most cases except when the crack propagates perpendicular to the fusion line and tensile stress applies perpendicularly to the dendrite boundary.

Future Developments

To clarify the root cause that the IGSCC tend to avoid the fusion line and propagate along the fusion line and to investigate the possibility of crack propagating into the weld metal in the actual pipe joints considering the residual stress distributions.

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Reference

Taku Arai, et al., “Effect of Loading Direction on Crack Growth Behavior near Fusion Line in Low Carbon Stainless Steel Weld Joints”, CRIEPI Report No. Q08020 (in Japanese) March, 2009.

*1：Dendrite is the specific microstructure of weld metal which has columnar shape and usually grows perpendicular to the weld fusion line near the fusion line.
*2：Shield Metal Arc Weld
*3：Tungsten Inert Gas
*4：Intergranular Stress Corrosion Cracking
*5：Interdendric Stress Corrosion Cracking

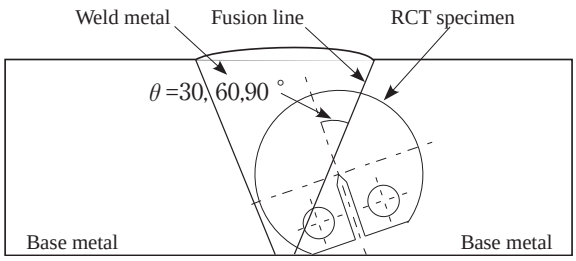

Fig.1 Specimen sampling method.

Three specimen sampling orientations were chosen to evaluate the effect of the relationships between expected crack growth orientation (parallel to the specimen neutral line) and the dendrite growth orientation (perpendicular to the fusion line) on the crack growth behavior near the fusion line.

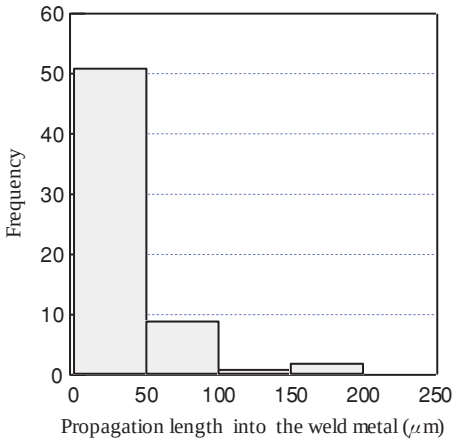

Fig.3 Histogram of propagation length into the weld metal for cracks that reached the fusion line

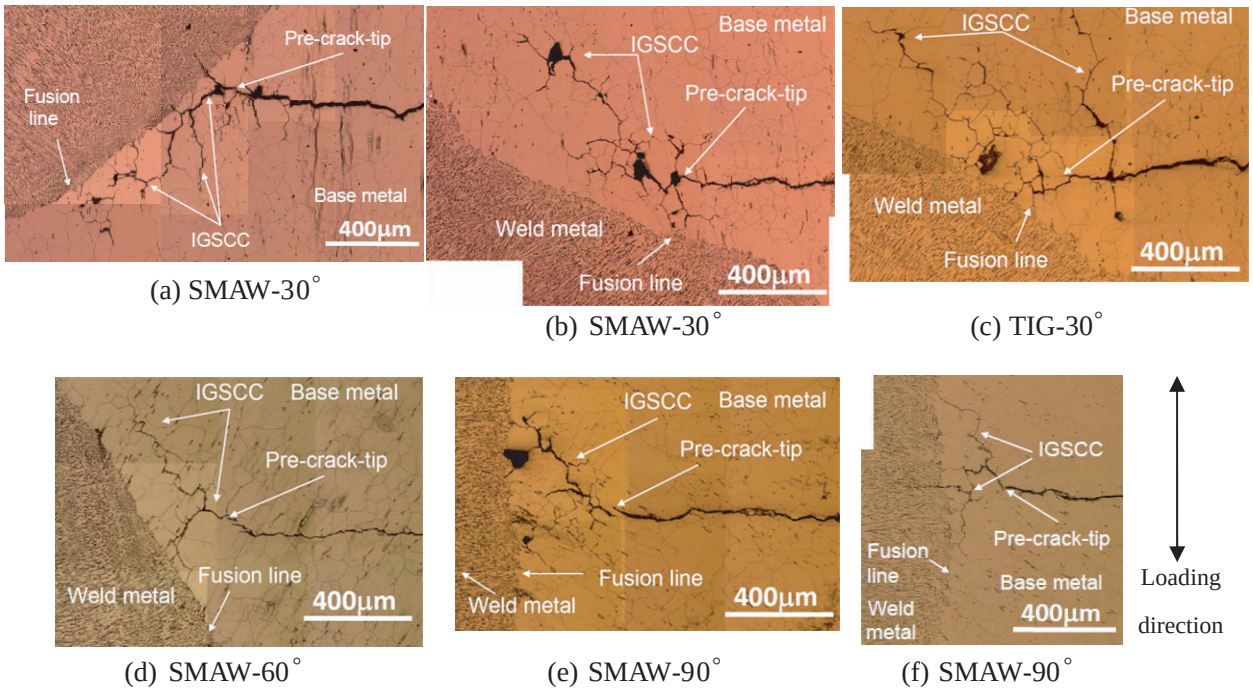

Fig.2 Examples of cracking morphologies near weld fusion line.

IGSCCs[*4] from precrack tips in the base metal propagated toward the weld metal, then, the cracks changed direction to avoid the weld metal and propagated along the fusion line. A stronger tendency of crack behavior to avoid weld metal was observed in specimens with a smaller angle between the neutral line of the specimen and the fusion line ((a) – (e)). Meanwhile, a crack reached to the fusion line perpendicularly, then, propagated into the weld metal in the specimen of θ =90°(f).