

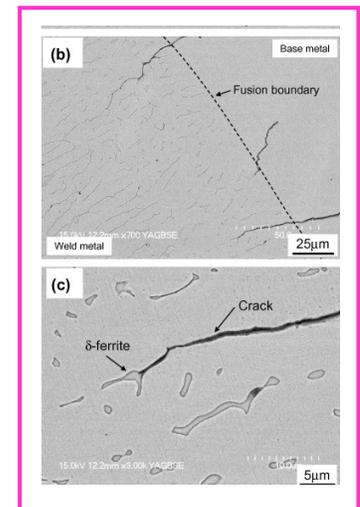
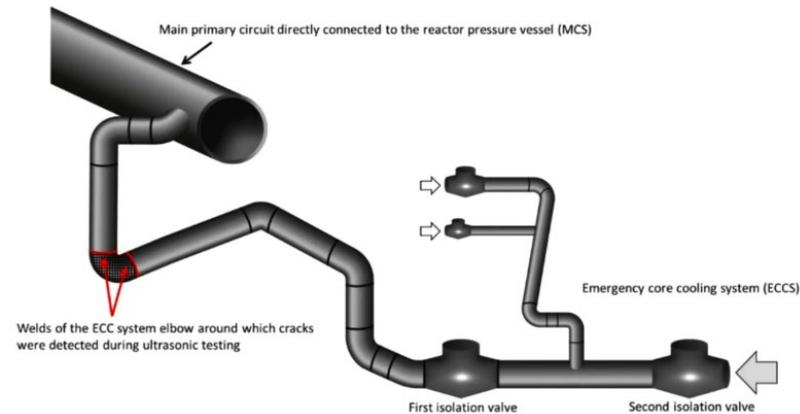
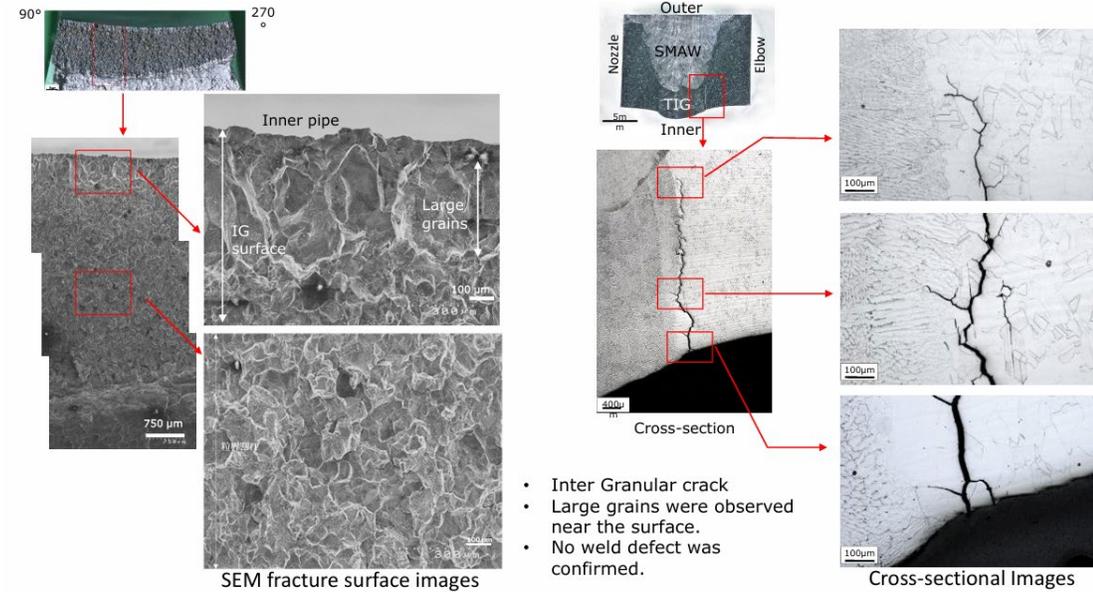
Inducing δ -ferrite in 316NG austenitic stainless steel without welding: Microstructure and SCC resistance in simulated BWR environment

Zhao-Wei Fu, Hiroshi Abe, Yutaka Watanabe

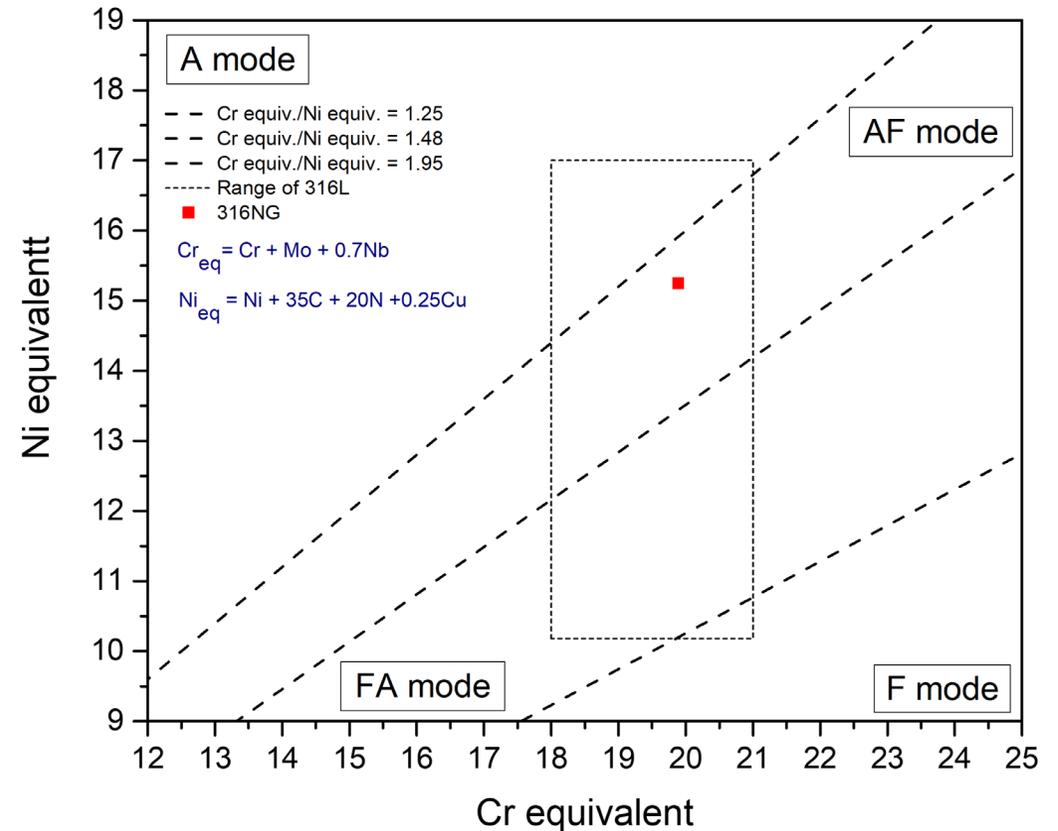
Department of Quantum Science and Energy Engineering,
Graduate School of Engineering, Tohoku University

Background & Purpose

- Stress corrosion cracking (SCC) has been reported in these low-carbon stainless steels since 2001, particularly in the core shrouds and primary loop recirculation (PLR) piping of several Japanese BWR plants.
- In recent years, similar degradation has also been observed in PWRs, where cracks have been identified in the heat-affected zones (HAZ) of 316L pipeline weld joints in both residual heat removal (RHR) systems and safety injection systems (SIS).
- After more than a decade of research, it has been widely recognized that δ -ferrite present at the fusion boundary exhibits a retardation effect on intergranular stress corrosion cracking (IGSCC) growth.

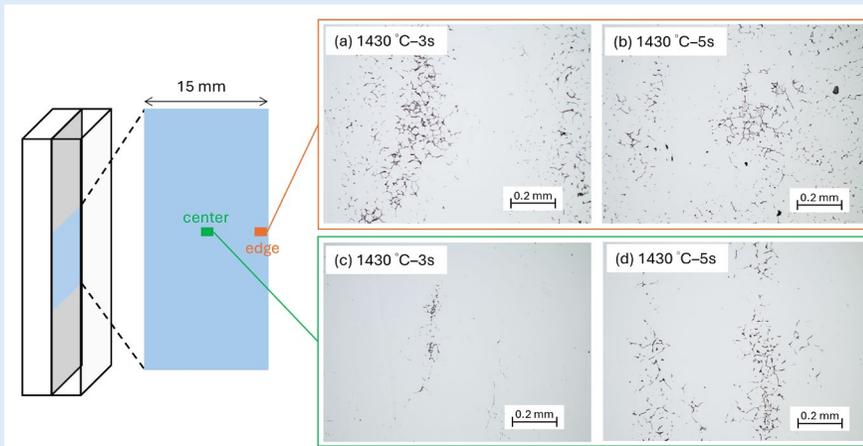
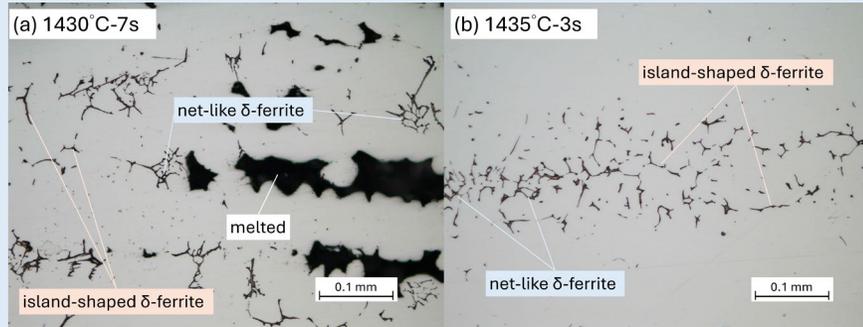
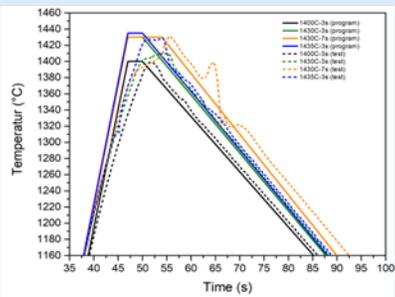
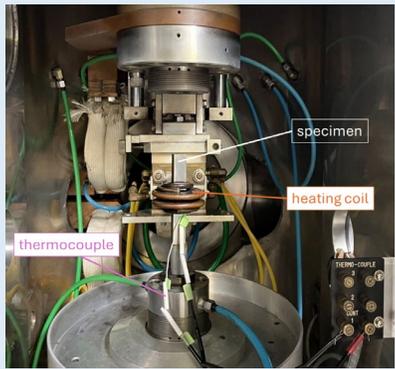


- The ease of δ -ferrite formation is closely related to the solidification mode, which is directly governed by the chemical composition of the materials.
- However, studies investigating the relationship between solidification mode and corrosion susceptibility in austenitic stainless steels remain limited.
- This study aims to uniformly introduce δ -ferrite into the material through a controlled heat-treatment process (induction heating) and to evaluate whether its crack-retardation effect is comparable to that of δ -ferrite formed during welding.

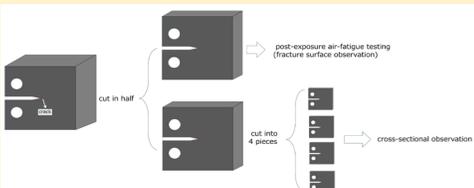
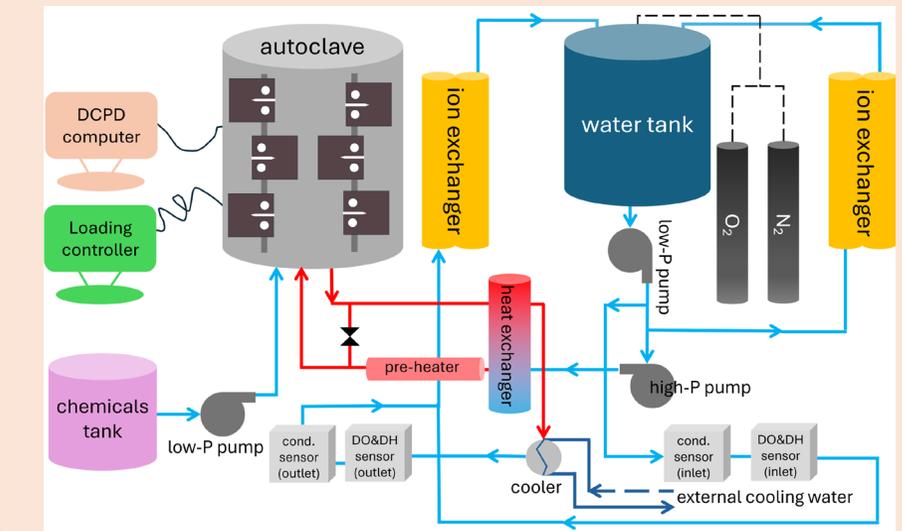
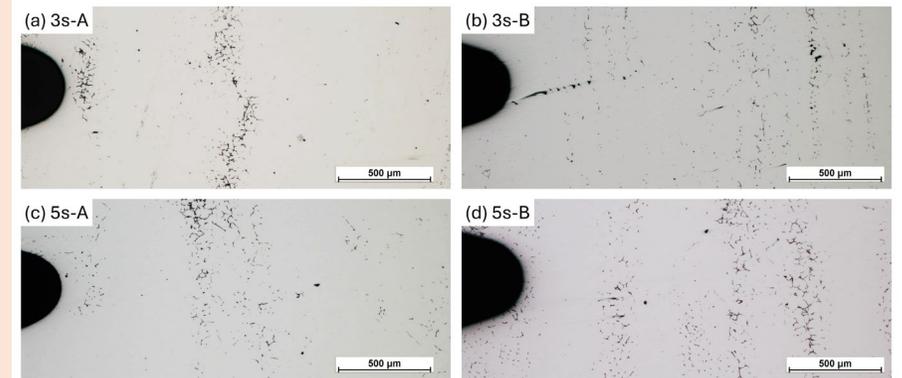


Experimental Method

1st:
Inducing δ -ferrite into the matrix.
Method: Induction Heating

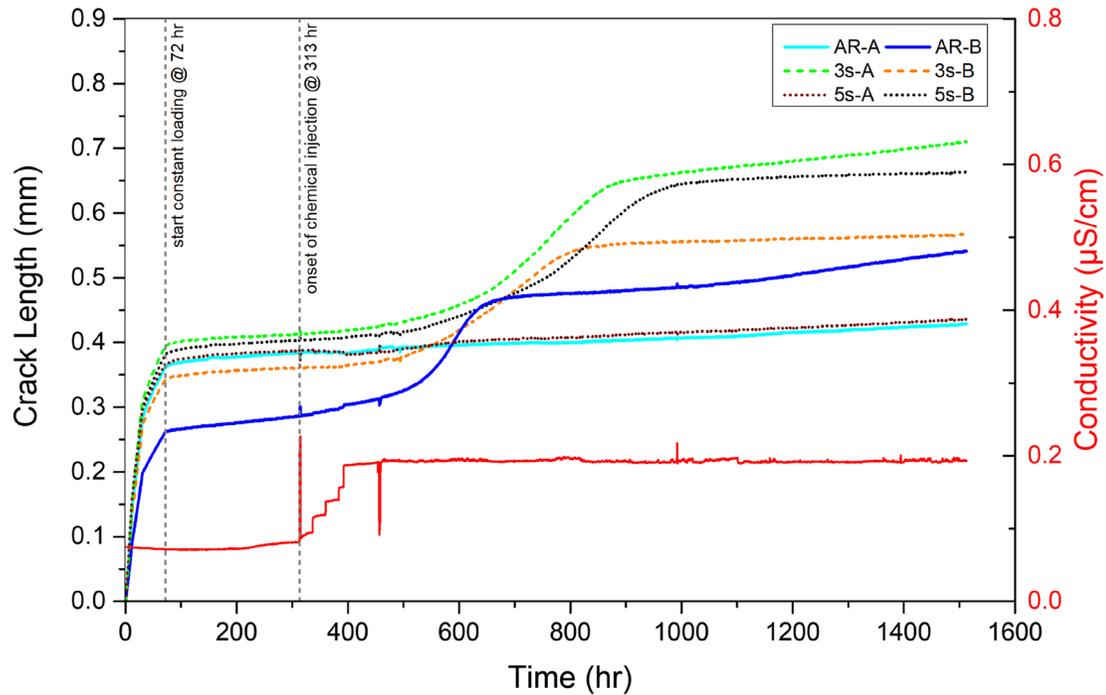


2nd:
SCC CGR test:
4 specimens with δ -ferrite vs. 2 specimens w/o δ -ferrite

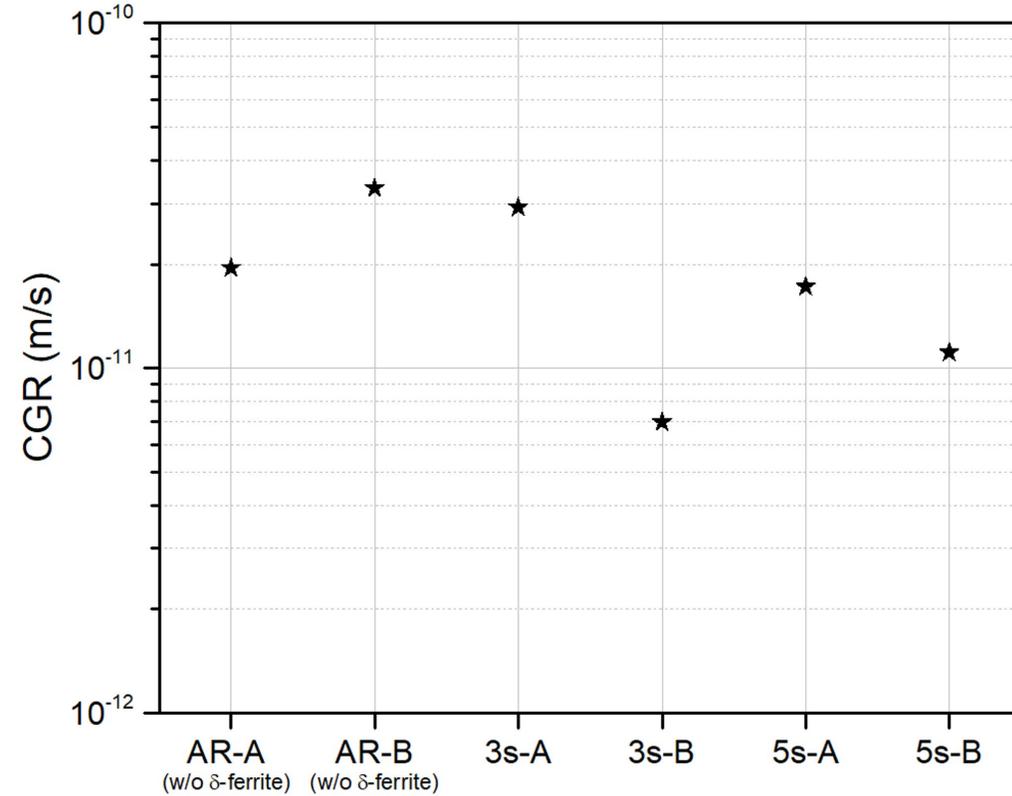


3rd:
Post-analysis
Observation of fracture surface and cross-section

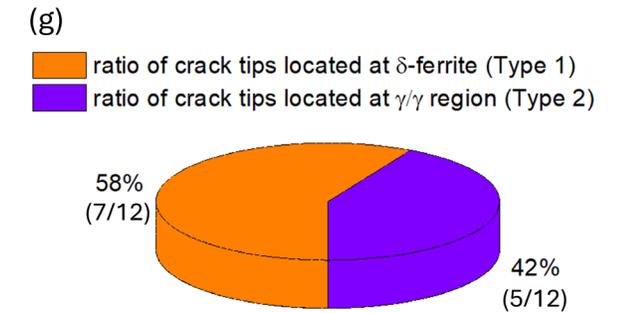
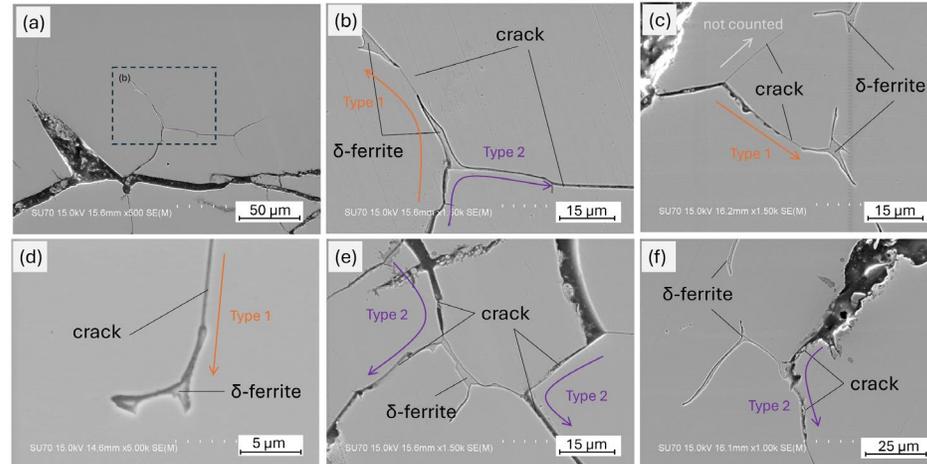
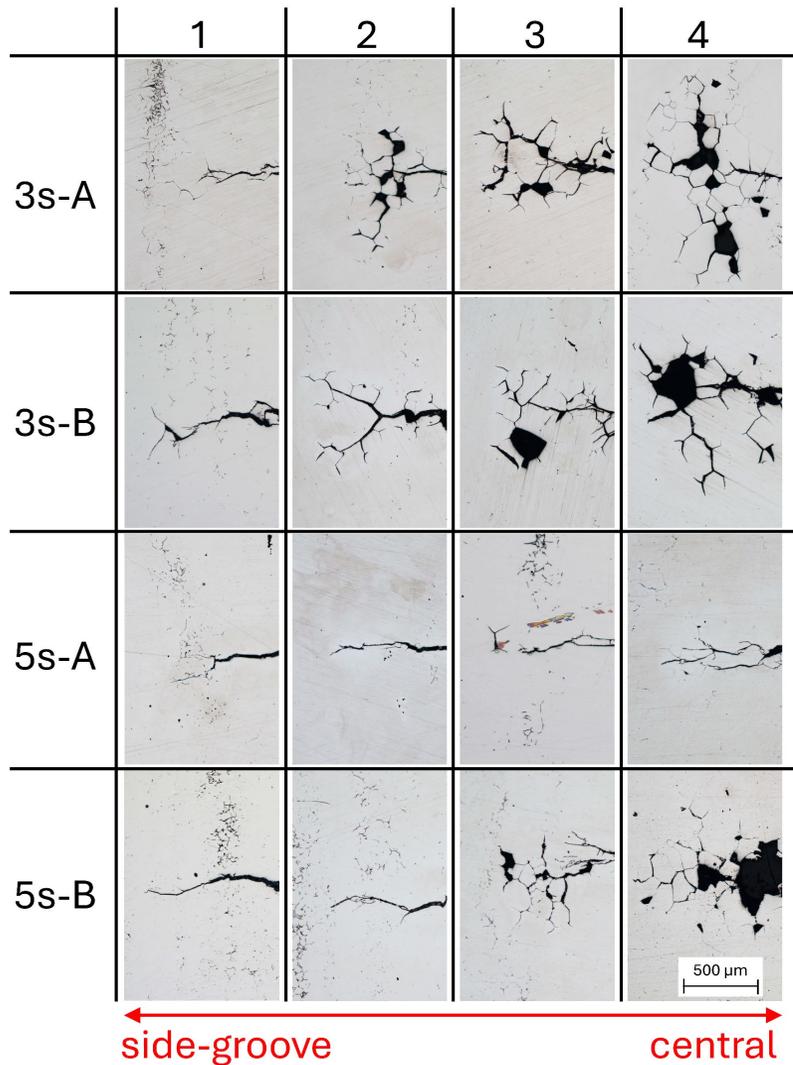
DCPD results



CGR evaluation



It is difficult to tell the retardation effect of δ -ferrite on SCC propagation because the four specimens with ferrite did not show noticeably lower CGR.



- However, the investigation of all secondary cracks observed in the cross sections that encountered δ ferrite revealed that, although the volume fraction of δ -ferrite along the total crack length was extremely small, >50 % of the crack tips were located at δ -ferrite. This result suggests that δ -ferrite possesses resistance to crack propagation.

=> retardation effect was occurred at localized region.

- Island-shaped δ ferrite can be introduced along some grain boundaries in 316NG base metal.
- The effect of the δ -ferrite phase on the SCC crack growth rate was not clear. This was attributed to the low crack growth rate and the insufficient distribution of δ -ferrite along the crack propagation path. Cross-sectional observations confirmed that the main SCC cracks encountered δ -ferrite only in very limited cases.
- Although the volume fraction of δ -ferrite along the total crack length was extremely small, >50 % of the crack tips were located at δ -ferrite. This result suggests that δ -ferrite possesses resistance to crack propagation.