Stress Corrosion Cracking in Light Water Reactors

Background and Objective

Stress corrosion cracking (SCC) is one of the major degradation events that occur on stainless steel components in light water reactors. Countermeasures against SCC are residual stress improvement, water chemistry improvement, application of alternative material and so on. In addition, Fitness-for-Service code of the Japan Society of Mechanical Engineers has been applied on some nuclear power plants. The code describes methods of inspection, evaluation and repair/replacement. Operation with remaining flaws is permitted if the detected flaw is evaluated as non-hazardous during the evaluation period. The evaluation method will be more accurate, if state of the art knowledge on SCC is reflected on the code.

Object of our research is to obtain SCC related data in order to update the code or develop a countermeasure technique. This project focuses on investigation of SCC initiation and propagation behavior of stainless steel, stainless steel weld joint, nickel base alloy and low alloy steel.

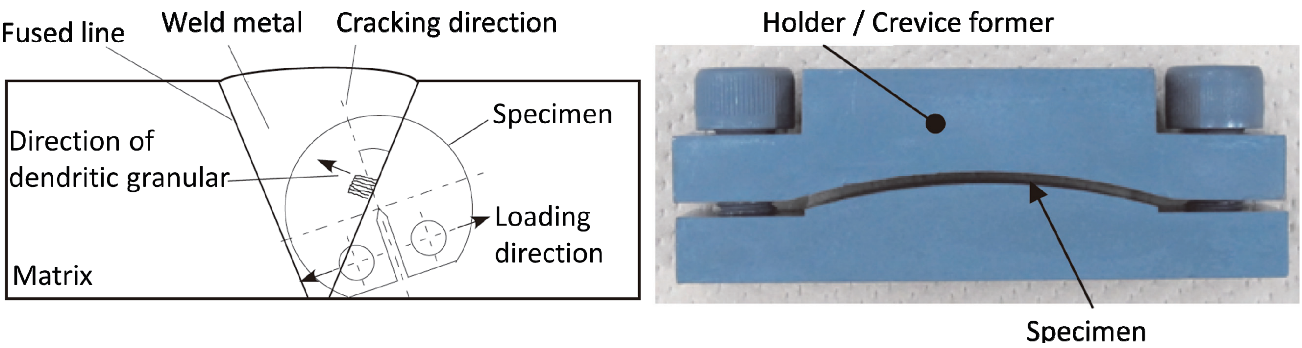
Main results

1. SCC propagation behavior around a weld joint of low carbon stainless steel

SCC propagation behavior from a base metal to a weld metal should be observed in detail. In order to clarify crack growth behavior, a specimen with pre-cracked notch in front of weld boundary was used in pure water at the same temperature of operating plant (Fig.1 a). Cross-sectional observation of the specimen reveals that number of ratio was less than 20% for individual crack of greater than 50um in length. Cracks greater than 50um only exist on the portion where austenitic grain boundary and dendritic boundary are linearly jointed; Type I (Fig.2 a). On the other hand, cracks less than 50um observed on the same portion of previous one also with the junction of both boundaries cranked; Type II (Fig.2 b) or the portion of tiny dendritic grain grew in random orientation; Type III (Fig.2 c). Ratio of each type in observed cases is 20%, 70% and 10% respectively. These results reveal that morphology of dendritic grains on fused boundary of weld rules SCC propagation. The fused boundary with certain structure plays a role as a barrier for SCC propagation [Q10001].

2. Detailed analysis on SCC initiation behavior of low carbon stainless steel

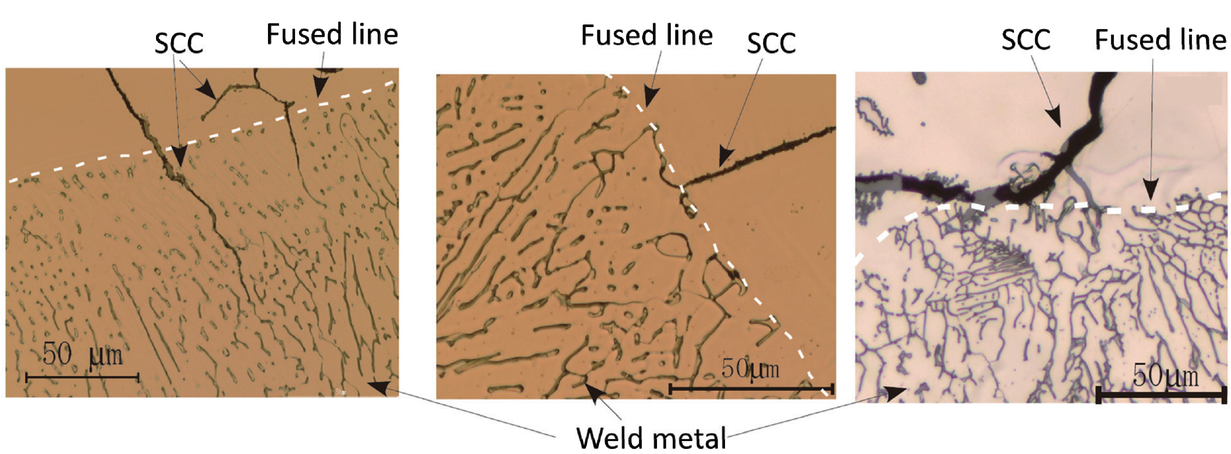
SCC initiation and propagation behavior in sensitized type 304 stainless steel (SS) is reported as follows: firstly, micro-cracks of less than 50 um in depth initiate and they do not easily propagate by themselves; secondly, some micro-cracks coalesce into single cracks and then the coalescent cracks propagate over 50 um in depth. However, SCC initiation and propagation behavior in low carbon SS has not yet been reported. In this study, SCC behaviors in type 316L SS (one of low carbon SSs) under a simulated coolant condition of boiling water reactor were investigated. The results were obtained as follows: (1) only micro-cracks with depth of less than 50 um were observed until 250 h, cracks with depth of more than 50 um were observed after 500 h and the incidence of micro-cracking (rate of new crack formation) decreased after 500 h as shown in Figure 3, (2) maximum crack depth increases with increase of test duration as shown in Figure 4. These results indicate that SCC initiation and propagation in low carbon SSs shows similar behavior to that in sensitized type 304 SS [Q10024].



(a) Shape of the specimen and weld joint
The weld joint is a mock-up of PLR piping.

(b) The specimen holder and the specimen
Tensile strain is applied by bend. Crevice on the specimen promotes cracking.

Fig.1 Specimens for SCC test



(a) An example where SCC direction and dendritic granule direction coincide

(b) An example where SCC direction and dendritic granule direction are mismatched

(c) Dendritic granule is small and direction of the granule is randomly grown

Fig. 2 Some examples of SCC growth properties around fused line
SCC tips were observed on a cross section of the specimen by optical microscope.

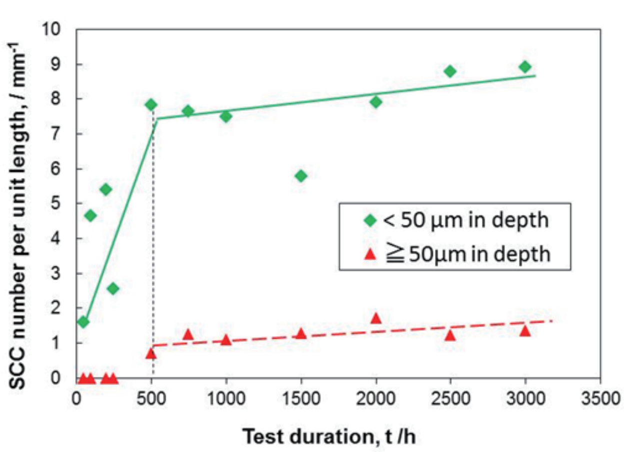


Fig. 3 Relationship between test duration and SCC number per unit length

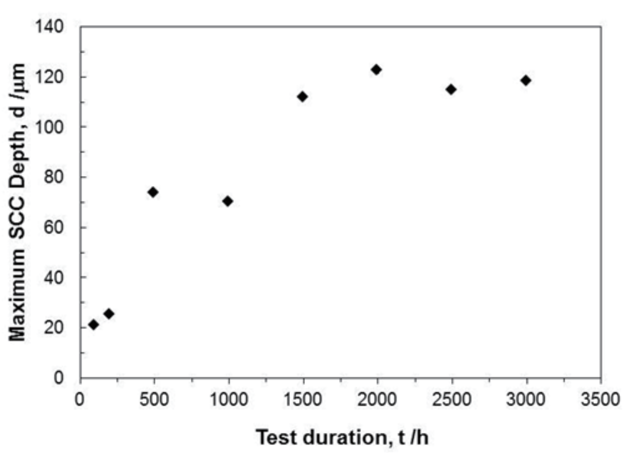


Fig. 4 Relationship between test duration and maximum SCC depth