Project Research — **Further Improvement of Facility Operations and Maintenance Technologies**

Stress Corrosion Cracking in Light-water Reactors

Background and Objective

Stress corrosion cracking (SCC) is one of the degradation events that occur on structural materials in light-water reactors. Countermeasures against SCC are residual stress improvement, water chemistry improvement, the application of alternative material, and so on. In addition, methods of repair, replacement and crack growth evaluation, based on the fitness-for-service code of the Japan Society of Mechanical Engineers, are established. Although such countermeasures are well prepared, the continuous activities regarding the clarification of SCC properties, the development of countermeasures, and the improvement of codes/standards are necessary.

One of our research objectives is to clarify the SCC initiation mechanism and condition in order to develop a crack initiation model. The other objective is to clarify the SCC growth rate and growth conditions in order to introduce such clarifications into the current fitness-for-service code.

Main results

1 Clarifying the SCC Behavior of Low-alloy Steel

The welded parts of the reactor pressure vessel (RPV) penetration and the attachment of core internals, consisting of nickel-based metal, are susceptible to SCC. The possibility that SCC initiated in Ni weld metal reaches the RPV (low-alloy steel) is not fully excluded. Clarifying the SCC behavior regarding low-alloy steel is thus necessary. SCC growth tests were therefore conducted to investigate SCC behavior in this study. The SCC growth rate showed greater value at the earlier stage of the tests. Then, the SCC growth rate decreased with time (Fig. 1) (Q11023). The SCC growth rates obtained at constant K conditions were about 1/1,000th of those obtained during increasing K conditions (Fig. 2) (Q11023). This suggests that the use of growth rates corresponding to K distributions (K rates) is necessary to establish the precise evaluation of the actual components.

2 Clarifying the SCC Initiation Behavior of Low-carbon Stainless Steel

Several BWR plants have experienced stress corrosion cracking on the hardened surface of low-carbon stainless steel in a primary coolant environment. The hardened layer is induced with surface machining. The machining also causes tensile residual stress and plastic strain. It is thus possible that plastic strain distribution and stress distribution affect SCC initiation behavior. Our study using original specimens with cyclic plastic strain distribution introduced by face milling showed that SCC was preferentially initiated in areas with a large plastic strain gradient (Q10024). In addition, stress measurement using X-ray diffraction clarified that stress distribution on the specimen was negatively correlated with hardness corresponding to plastic strain distribution (Fig. 3). As a result of these studies, it was suggested that SCC tended to be initiated in areas with a stress and hardness gradient (Fig. 4) (Q11008).

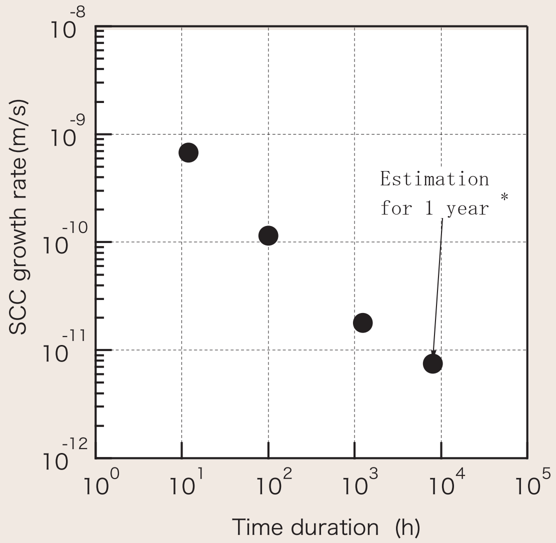

Fig. 1: Relationship between the SCC growth rate and time duration

The SCC growth rate decreased with time duration. The average SCC growth rate for one year is estimated to be about 1×10^{-11} m/s. (*The estimated value for one year is a weighted average of the growth rates by 100 h and after 100 h.)

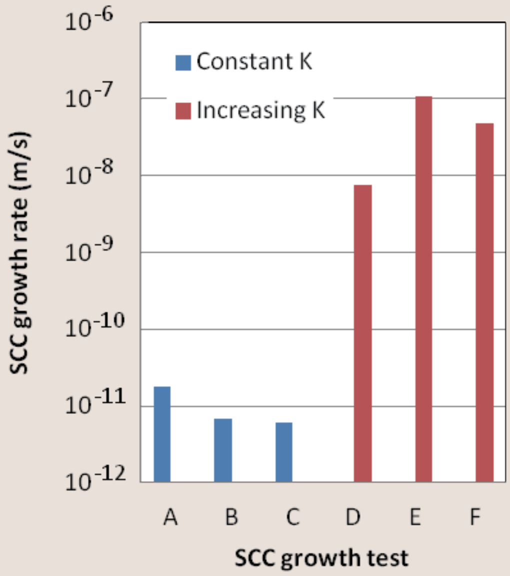

Fig. 2: Results of SCC growth tests

The SCC growth rates obtained at a constant K condition were about 1/1,000th of those obtained during increasing K conditions.

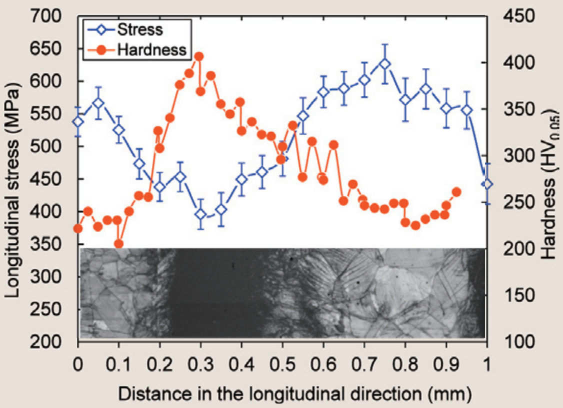

Fig. 3: Strain and stress distribution on the specimen surface

The contrast indicates the distribution of plastic strain, with the dark area having a high degree of plastic strain. The high plastic strain area has high hardness and a low degree of longitudinal stress.

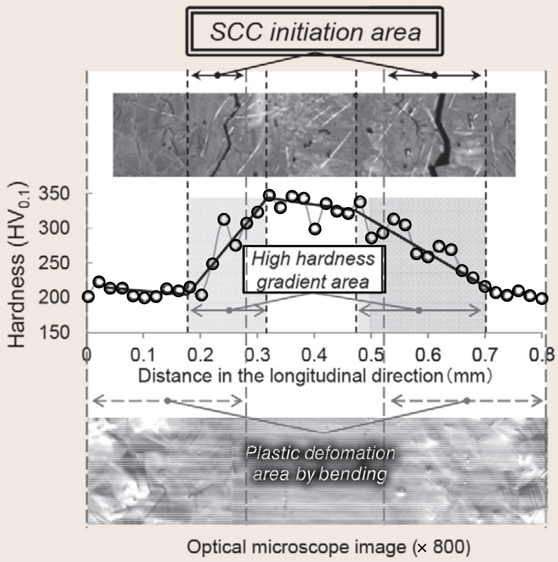

Fig. 4: SCC initiation area on the specimen surface

The hardness value indicates the amount of plastic strain in this figure. SCC cracks were preferentially observed in the areas that have steep plastic strain gradients and stress gradients as shown in Fig. 3.