Priority Subjects — **Further Improvement of Facility Operations and Maintenance Technologies**

Evaluation of Components and Piping Integrity in LWRs

Background and Objective

This subject will contribute to stable operation by developing components and piping integrity evaluation methods as a part of maintenance technology for improvement of structural material reliability and aging prediction accuracy for LWRs, and for raising safety of maintenance and inspection personnel.

Main results

1 Evaluation of Tensile Properties of Safety-Conscious Rolled Steels for Building Structure (SN Steels) at High Temperature

Rolled steels for general structure (SS steels) are generally used for support structures in nuclear power plants. Meanwhile rolled steels for building structure (SN steels) could be alternative steels from their high weldability and toughness. To make the use of SN steels possible, comprehensive tensile properties up to 400°C were evaluated for the incorporation of SN steels into the JSME material code, and additional tensile properties up to 650°C were evaluated for the structural integrity assessment under severe accident conditions. The effect of temperature on the yield stress or tensile strength was similar in spite of the differences in material type or plate thickness, and the difference due to different charge*1 was limited (Fig. 1). Based on the results, the approximated equations of the trend curves both for design yield stress and design tensile strength at high temperature normalized at room temperature were derived, and these can be incorporated into the JSME material code (Q14006).

2 Verification of Pipe Wall Thinning Prediction Software, FALSET

Pipe wall thinning prediction software, FALSET, was verified for comparison with pipe wall thickness measurement data in Japanese LWRs. As a result of a comparison with FAC data in condensate and feedwater lines (water single-phase system) of 4 PWRs (980 data), where 1 PWR was newly added, FALSET demonstrated a prediction accuracy with an error margin of approximately 10% for residual wall thickness of elbow elements comparing to recent measurement thickness (Fig. 2). It was confirmed that management for pipe wall thinning with prediction by FALSET could be conducted conservatively for most piping elements except for those in low temperature conditions with low thinning rates.

3 Evaluation of Thermal Aging Embrittlement of Cast Austenitic Stainless Steel

Cast austenitic stainless steel (CASS), which is used for the pump casing and the primary coolant pipes in LWR, is susceptible to thermal aging embrittlement*2. In order to quantitatively evaluate the thermal embrittlement, CASS (JIS SCS16A) aged at 300-450°C for up to 15,000 hours was investigated using an elastic-plastic fracture toughness test and hardness test. As a result of the tests, it was found that the fracture toughness tended to decrease as aging time increased. On the other hand, the hardness of ferrite phase tended to increase as aging time increased (Fig. 3). Relatively good correlation was observed between the fracture toughness value and hardness of ferrite phase. This result suggested that the fracture toughness can be estimated from the hardness of ferrite phase.

4 Development of Dispersant Technology in LWR Primary Systems

Dispersant technology is considered to be promising in reducing the radiation intensity of LWRs. As a part of the dispersant technology development, radiolysis of PAA (polyacrylic acid) solution was investigated. After gamma-ray irradiation, the yields of carbon dioxide and acetate were highest in the carbon-containing products. But, the concentrations of carbon dioxide and acetate were much lower than the initial PAA concentration. The radiation chemical simulation of PAA solutions implied that scission of PAA radicals*3 is the major process in the radiolysis of PAA (Fig. 4). No radiolytic products harmful to structural materials in LWRs were found (Q14014).

*1 Molten steel extracted from particular ladle furnaces.
*2 Transition of material property with time when exposed to certain temperature conditions.
*3 PAA radical is polyacrylic acid molecule with unpaired electron(s).

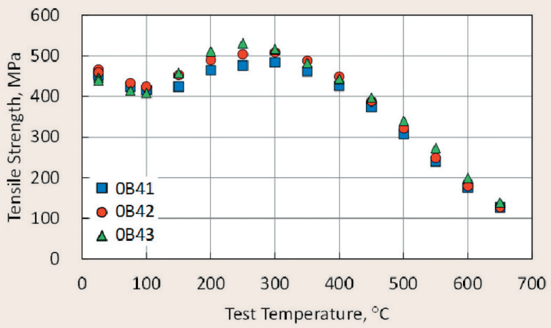

Fig. 1: Effect of test temperature on tensile strength for SN steel (SN400)

Tensile tests were conducted for 40 mm thickness SN400B steel with three different charges under strain rate condition compatible with the JIS standard (0.00007/s before yielding, 0.0014/s after yielding). Different charges gave similar tensile properties.

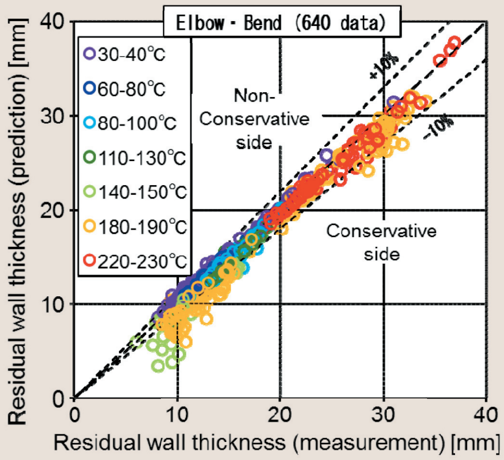

Fig. 2: Prediction accuracy for residual wall thickness of 4 PWRs' elbows by FALSET

Prediction accuracy for residual wall thickness was verified with FAC data of 640 elbows in condensate and feedwater lines of 4 PWRs, and more than 99% of the data could be predicted under +10% (non-conservative side) comparing to recent measurement thickness.

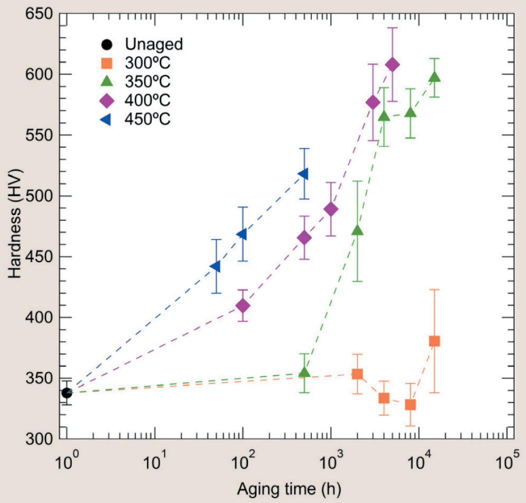

Fig. 3: Relationship between hardness of ferrite phase and aging condition

Hardening began at an earlier stage at high temperature. The change of hardness was obvious after 15,000 h in the specimen aged at 300°C.

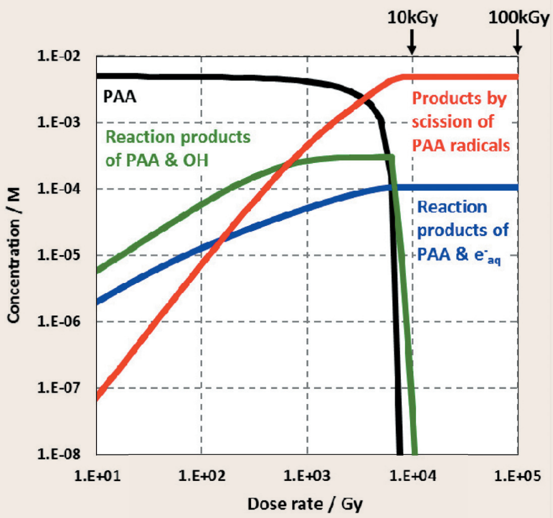

Fig. 4: Results of radiation chemical simulation of PAA solution (PAA 500 ppm, 300°C, neutral pH)

Scission of PAA radicals is the major process up to several kGy. PAA is consumed at about 5 kGy. It seems that disproportionation of PAA radical is dominant at higher absorption dose due to the fact that slow change in molecular weight of PAA was observed.