Corrosion and Hydrogen Pick-up Behaviors of Cladding and Structural Components in BWR High Burnup 9×9 Lead Use Assemblies

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Abstract

The high burnup BWR 9x9 lead use fuel assemblies, which have been designed for maximum assembly burnup of 55GWd/t in Japan, have been examined after irradiations to confirm the reliability of the current safety evaluation methodology, and to accumulate data to judge the adequacy to apply it to the future high burnup fuel.

After 3 cycle and 5 cycle irradiations, post irradiation examinations were performed for both 9x9 Type-A and Type-B fuel assemblies. The former has 74 fuel rods including 8 partial length rods and the latter has 72 fuel rods. Both Type LUAs utilize Zry-2 claddings, while there are deviation in the contents of impurity and alloying elements between Type-A and Type-B, especially in Fe and Si concentration. Fuel rods were supported by spacers composed of Zry-2 band (sheet) and cell (tube) in both Type-A and Type-B fuel, although Zry-4 sheet material was also used for band of some spacers in Type-B fuel for comparison between materials.

After visual inspection of fuel assemblies, the fuel assemblies were disassembled for subsequent PIEs on fuel rods and structural component such as spacers. Some fuel rods were selected for oxide thickness measurement by an eddy current method and some of them including the rod at the corner position were subsequently subjected to destructive examination.

Measured oxide thicknesses on fuel rods showed no significant difference between after 3 and 5 cycle irradiation except for some rods at corner position in Type B LUA. The axial profile of hydrogen concentration and oxide thickness for the corner rods in Type B LUA after 5 cycle irradiation had peaks at the second lowest span from the bottom. The metallographic observation indicated that the azimuthal variation in oxide thickness is strong only for the rods located at the corner. Its maximum oxide thickness is about 50 μm on the surface facing the bundle outside at the second lowest span and dense hydrides layer (Hydride rim) is observed in peripheral region of cladding showing unexpected high hydrogen concentration. The micro-vickers hardness at the sample of the corner rod is typical for irradiation hardened Zry-2. This indicates there are no recovery of the irradiation hardening due to the elevation of temperature. To compare thermal-hydraulic conditions between corner positions and others, coolant void and mass flux distribution in the fuel assembly was evaluated by subchannel code. The neutron flux was also calculated by continuous-energy Monte Carlo calculation code. The results show that the thermal neutron flux at the corner position was higher than the other position. On the other hand, the void fraction and the mass flux were relatively lower at the corner position.

The oxide thickness on spacer band and spacer cell of Zry-2 increases with increasing fuel burnup from 3 to 5 cycle irradiations. Spacer band of Zry-4 showed significantly thick oxide after 5 cycle irradiations but Hydrogen concentration was relatively small in contrast its obviously thick oxide in comparison with Zyr-2 spacer bands. The large increase in hydrogen concentration was measured in Zry-2 spacers after 5 cycle irradiations and the evaluated hydrogen pick-up rate also increased remarkably. The notably high hydrogen concentration in zircaloy component, seems to be an issue on which much attention should be paid with respect to the integrity of fuel during irradiation up to high burnup.