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SHADOW CORROSION EVALUATION IN THE STUDSVIK R2 REACTOR

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Abstract

Post-irradiation examination has shown that increased corrosion occurs when zirconium alloys are in contact with or in proximity to other metallic objects. The observations indicate an influence of irradiation from the adjacent component as the enhanced corrosion occurs as a 'shadow' of the metallic object on the zirconium surface. This phenomenon could ultimately limit the lifetime of certain zirconium alloy components in the reactor. The Studsvik R2 materials test reactor has an IN-Core Autoclave (INCA) test facility especially designed for water chemistry and materials research. The INCA facility has been evaluated and found suitable for shadow corrosion studies. The R2 reactor core containing the INCA facility was modeled with the Monte Carlo N-Particle (MCNP) code in order to evaluate the electron deposition in various materials and to develop a hypothesis of the shadow corrosion mechanism.

Method

The INCA facility consists of two major parts: the external water supply and analysis system as well as the in-core rig. In the external INCA system, degassed and de-ionized high purity water is pumped into the rig at various flow rates. Injections of additives and impurities, which is called the injection flow, can be fed into the rig either before the water enters the rig or just above the in-core section of the rig. The specimen rod is installed in the rig tube to serve as a carrier for the test specimens.

The INCA facility was modeled in the MCNP code in order to evaluate the electron deposition and to analyze a hypothesis of the shadow corrosion. MCNP is a three-dimensional, continuous-energy, coupled neutron-photon-electron transport code. The principle behind MCNP is to track a particle from birth to death. MCNP was used to calculate the electron deposition arising from neutron-photon-electron transport. The case modeled represents the cladding specimen surrounded by the Inconel spacer cell in the INCA facility and is shown in Figure 1.

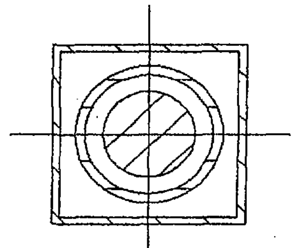

Figure 1. Outline of the INCA model. Everything unmarked in the pictures is water.

Discussion & Results

The electron depositions and the corresponding currents calculated by MCNP show that the spacer becomes negative charged relative to the cladding. This will enhance the corrosion of the cladding in close vicinity of the spacer, since the electric field between spacer and cladding will promote the diffusion of oxygen ions through the zirconium oxide to the zirconium metal. At the same time, positive hydrogen ions will be pulled away from the oxide/metal interface thus decreasing the normally observed level of hydrogen uptake. The estimated electron current density at the Zircaloy surface is of the same order of magnitude as the corrosion current density for the observed oxide thickness assuming that all the current had to be provided by an external source (in this case the electrons were redistributed by the gamma irradiation).

Conclusions

In-pile testing of spacer, shadow corrosion using the INCA facility in the Studsvik R2 reactor showed that the same type of shadow corrosion was obtained in the INCA rig as in a real BWR-reactor. To further develop a hypothesis regarding currents involved in the process of shadow corrosion MCNP modelling was used to obtain rates of electron deposition in the components involved. The MCNP model shows that electrons are redistributed within the INCA facility. Voltage differences are built up between the various components. The resulting polarity of the electric field between the cladding and the spacer is such as to promote oxidation of the cladding and to reduce hydrogen uptake as has been observed in many practical cases of shadow corrosion on fuel rods.