Shadow Corrosion: experiments and modeling

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1. Problem to be solved

- Shadow corrosion has long been an issue in BWRs: the use of Ni-based grids in close connection to Zry-2 cladding induces locally an accelerated corrosion.
- It is a galvanic coupling phenomenon, which cannot be reproduced without irradiation. Under (neutron) irradiation and at reactor temperature, several parameters are not known accurately (electrical conductivity of the coolant and of the oxide, or the Open Circuit Voltage and current of the metal parts). The role of the contact point between the grid and the cladding is also poorly understood.

> need of experiments and modeling

2. Experimental study

- A photoelectrochemical cell, simulating the conditions of Light Water Reactors was designed, developed and validated.
- Out of pile experiments with or without UV light were performed to measure the OCV, the exchange current densities as well as the Tafel slopes of Ni- and Zr-electrodes.

The influence of the irradiation flux allowed extrapolations in order to assess what could happen under neutron irradiation.

4. Results

- Electrochemical potential differences between Zry-2 and 718 specimens exposed in 280 °C/80 bar water containing different concentrations of O₂ and H₂O₂.

- Impact of the UV light power on the galvanic current density when the Zry-2 and 718 specimens were coupled through a ZRA in 280 °C/80 bar water containing 200 ppb of O₂.

3. Modeling

- A COMSOL finite element modelling based on the Butler-Volmer equation allowed to take simultaneously into account the thermal and galvanic corrosion.

\[ i_a = i_0 \exp \left( - \frac{E_a}{RT} \right) \exp \left( \frac{\alpha_a F (V - V_a)}{RT} \right) \]

Parametric study conducted

Under neutron irradiation, the following order of magnitude for parameters difficult to measure can be proposed:
- Oxide conductivity: 3 to 10⁻⁴ S/m
- Exchange current for the Ni-base alloy: 40 10⁻⁴ A/m² or higher
- Transfer coefficient for the anodic reaction: 0.5
- Rest potential difference between Zr and Ni-base alloy: about 500 mV

5. Conclusion

Galvanic coupling through the contact point; decoupling occurs due to spring relaxation; order of magnitude of several parameters determined.

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