A numerical component to evaluate the iodine corrosion in a nuclear fuel accounting for chemisorption mechanisms Zirconia layer impact on SCC.

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In PWR plants, nuclear fuel pellets (cylinders 1.2 cm length, 0.84 cm diameter) are piled in nuclear fuel rods placed in assemblies, each containing 265 fuel rods. the fuel rod is a tube manufactured in a zirconium alloyed material. Fuel cylinders are piled to form a fuel stack shorter than the overall tube length to maintain a remaining upper volume called plenum, able to allow fuel stack elongation and accommodation of the gaseous and volatile fission products released during operation. The fuel stack (3.6-4 m depending on the design) is typically maintained during handling operation by a spring placed in the plenum. The fuel rod is closed at both ends by sealed end plugs after filling dead volumes with a neutral gas (helium) with a pressure ranging from 1 to 34.5 bars. The cladding insures the first confinement barrier against radionuclides dispersion. During severe power transients some fission products, like iodine, are expected to assist cracks initiation and propagation at the inner surface of the cladding. Our major concern here aims improving understanding the involved mechanisms, accounting for the zirconia layer able to develop as soon as a closed contact is locally established between the pellet fragments and the cladding inner surface.

In this work, we extend a specific numerical component, developed by EDF, coupling two numerical software codes [1]. The first one aims simulating the evolution of the fuel isotopic composition and the second one aims evaluating the fuel dioxide chemistry. The growth of the zirconia layer has been modelled and integrated in the numerical tool [2]. The scenario of Stress Corrosion Cracking (SCC) previously defined has been improved to consider the full impact of the zirconia layer on SCC. The role of the zirconia layer can be mechanical, thermal or even chemical. Assumptions and coupling of the phenomenon are discussed.

To make demonstration, a sensitivity analysis is performed. This study considers several zirconia layer thickness for two cases: a high burn-up fuel rod operated in normal PWR conditions, and a fuel rod segment pre-irradiated in a power plant and then submitted to an incidental power transient simulation in a MTR. The results demonstrated a protective effect of the zirconia layer. As a consequence, the corrosive attack of the clad is delayed. The logarithm function of the iodine chemisorption kinetic appears to be proportional to the zirconia thickness. The simulation analysis validates the extension of the SCC scenario. The results are in good agreement with experimental observations.

REFERENCES

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