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Interaction of corrosion-induced hydrogen with nascent nanodefects in steel under neutron irradiation

Evgenii Krasikov
National Research Centre “Kurchatov Institute”, Russia

As the service life of an operating nuclear power plant (NPP) increases, the potential misunderstanding of the degradation of aging components must receive more attention. Integrity assurance analysis contributes to the effective maintenance of adequate plant safety margins.

In essence, the reactor pressure vessel (RPV) is the key structural component of the NPP that determines the lifetime of nuclear power plants. Environmentally induced cracking in the stainless steel corrosion-preventing cladding of RPV’s has been recognized to be one of the technical problems in the maintenance of light-water reactors. Therefore, in the case of cladding failure, the problem arises of hydrogen (as a corrosion product) embrittlement of irradiated RPV steel because of exposure to the coolant.

The effects of neutron fluence and irradiation temperature on steel/hydrogen interactions (adsorption, desorption, diffusion, mechanical properties at different loading velocities, post-irradiation annealing) were studied. Experiments clearly reveal that the higher the neutron fluence and the lower the irradiation temperature, the more hydrogen-radiation defects occur, with corresponding effects on the RPV steel mechanical properties. Hydrogen accumulation analyses and thermal desorption investigations were performed to prove the evidence of hydrogen trapping at irradiation defects. Extremely high susceptibility to hydrogen embrittlement was observed with specimens which had been irradiated at relatively low temperature. However, the susceptibility decreases with increasing irradiation temperature. To evaluate methods for the RPV’s residual lifetime evaluation and prediction, more work should be done on the irradiated metal–hydrogen interaction in order to monitor more reliably the status of RPV materials.