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Radiation Stability of Structural Steel in the Presence of Hydrogen

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Abstract : 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 determining the NPP lifetime. 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 and development of light-water reactors. Extensive cracking leading to failure of the cladding was found after 13000 net hours of operation in JPDR (Japan Power Demonstration Reactor). Some of the cracks have reached the base metal and further penetrated into the RPV in the form of localized corrosion. Failures of reactor internal components in both boiling water reactors and pressurized water reactors have increased after the accumulation of relatively high neutron fluences (5´1020 cm–2, E>0,5MeV). 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. At present when notable progress in plasma physics has been obtained practical energy utilization from fusion reactors (FR) is determined by the state of material science problems. The last includes not only the routine problems of nuclear engineering but also a number of entirely new problems connected with extreme conditions of materials operation – irradiation environment, hydrogenation, thermocycling, etc. Limiting data suggest that the combined effect of these factors is more severe than any one of them alone. To clarify the possible influence of the in-service synergistic phenomena on the FR structural materials properties we have studied hydrogen-irradiated steel interaction including alternating hydrogenation and heat treatment (annealing). Available information indicates that the life of the first wall could be expanded by means of periodic in-place annealing. 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 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 irradiated materials.

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