Comparison of Post-Irradiation Annealing Effects in Proton-Irradiated and Neutron-Irradiated 304 Stainless Steels

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The effectiveness of post-irradiation annealing (PIA) in removal of irradiated microstructure, irradiation hardening and irradiation-assisted stress corrosion cracking (IASCC) was examined in a neutron irradiated 304L SS and a proton irradiated 304SS. The 304L SS was irradiated to 5.9 dpa in the Barsebäck 1 BWR while the 304SS was irradiated to 5 dpa using 2 MeV protons at 360°C in a particle accelerator. PIA was conducted at temperatures of 500 to 600°C up to 10 hours. The irradiated microstructures before and after PIA, including dislocation loops and Ni/Si-rich clusters, were examined using transmission electron microscopy and atom probe tomography. Irradiation hardening was characterized using a Vickers micro-hardness indenter and IASCC susceptibility was examined by conducting CERT tests in a simulated BWR environment. Our results showed that the population of dislocation loops and the Ni/Si clusters was significantly reduced by PIA in both the proton-irradiated 304SS and the neutron-irradiated 304L SS. Similar trends were also observed in the removal of irradiation hardening, the degree of localized deformation in dislocation channels, and IASCC susceptibility. IASCC susceptibility was fully removed by PIA in both proton irradiated 304SS and in neutron irradiated 304L SS after PIA at 550°C for 1 hour. In general, great similarities of PIA effects were observed between proton- and neutron- irradiated stainless steels. Mitigation of IASCC susceptibility in both types of irradiation methods was linked to the reduction of the degree of localized deformation. The result provides additional evidence of the validity of proton irradiation in emulation of neutron irradiation effects in stainless steels and on the role of localized deformation in the IASCC process.