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Neutron Irradiated Austenitic Stainless Steels: An Applied Methodology for Nanoindentation and Transmission Electron Microscopy Studies

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Abstract : Neutron radiation-induced microstructural changes cause degradation of mechanical properties and the lifetime reduction of reactor internals during nuclear power plant operation. Investigating the effects of neutron irradiation on mechanical properties of the irradiated material (hardening, embrittlement) is challenging and time-consuming. Although the fast neutron spectrum has the major influence on microstructural properties, the thermal neutron effect is widely investigated owing to Irradiation-Assisted Stress Corrosion Cracking firstly observed in BWR stainless steels. In this study, 300-series austenitic stainless steels used as material for NPP's internals were examined after neutron irradiation at ~ 15 dpa. Although several nanoindentation experimental publications are available to determine the mechanical properties of ion irradiated materials, less is available on neutron irradiated materials at high dpa tested in hot-cells. In this work, we present particular methodology developed to determine the mechanical properties of neutron irradiated steels by nanoindentation technique. Furthermore, radiation-induced damage in the specimens was investigated by High Resolution - Transmission Electron Microscopy (HR-TEM) that showed the defect features, particularly Frank loops, cavity microstructure, radiation-induced precipitates and radiation-induced segregation. The results of nanoindentation measurements and associated nanoscale defect features showed the effect of irradiation-induced hardening. We also propose methodologies to optimized sample preparation for nanoindentation and microscotructural studies.

Keywords : nanoindentation, thermal neutrons, radiation hardening, transmission electron microscopy
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