Micromechanical testing of unirradiated and helium ion irradiated SA508 reactor pressure vessel steels: Nanoindentation vs in-situ microtensile testing

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Abstract:
In this paper, microtensile testing is demonstrated to be a viable technique for measuring irradiation hardening and reduction of ductility of ion irradiated hot isostatic pressed SA508 ferritic/bainitic steel. Ion irradiation with He2+ was used as a surrogate for neutron irradiation to reach a damage level of 0.6 dpa (Kinchin-Pease). The mechanical properties of four unirradiated microtensile steel specimens were measured and compared to the bulk properties: when averaged the 0.2% proof stress was 501.6 ± 56.0 MPa, in good agreement with the macrotensile 0.2% proof stress of 456.2 ± 1.7 MPa. On the basis of the agreement between microtensile and standard tensile 0.2% proof stress in the unirradiated material, it was possible to directly measure irradiation induced hardening from ion irradiation performed with He2+ ions to a dose of 0.6 dpa. Microtensile testing of the ion irradiated steel revealed an increase in 0.2% proof stress of approximately 730 MPa. The irradiation hardening measured by nanoindentation was 3.22 ± 0.29 GPa. Irradiation hardening was higher than that previously observed in neutron irradiated low alloy steels exposed to similar doses at low temperatures (<100 °C). The reason for the higher hardening was related to the presence of fine helium bubbles implanted in the irradiated layer that, alone, was calculated to produce a 707 ± 99 MPa increase in yield stress.