NEUTRON IRRADIATION EFFECTS ON THE DUCTILE-BRITTLE TRANSITION OF FERRITIC/ MARTENSITIC STEELS—R. L. Klueh and D. J. Alexander (Oak Ridge National Laboratory)

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EXTENDED ABSTRACT

Ferritic/martensitic steels such as the conventional 9Cr-1MoVNb (Fe-9Cr-1Mo-0.25V-0.06Nb-0.1C) and 12Cr-1MoVW (Fe-12Cr-1Mo-0.25V-0.5W-0.5Ni-0.2C) steels have been considered potential structural materials for future fusion power plants. The major obstacle to their use is embrittlement caused by neutron irradiation. Observations on this irradiation embrittlement is reviewed.

Below 425-450°C, neutron irradiation hardens the steels. Hardening reduces ductility, but the major effect is an increase in the ductile-brittle transition temperature (DBTT) and a decrease in the upper-shelf energy, as measured by a Charpy impact test. After irradiation, DBTT values can increase to well above room temperature, thus increasing the chances of brittle rather than ductile fracture.

Neutron irradiation of the conventional 9Cr-1MoVNb and 12Cr-1MoVW steels in a fast reactor over the temperature range 365-550°C has shown that these steels harden below ≈425°C; at higher temperatures there is little change in strength. The steels show an increase in the DBTT and decrease in the USE at the temperatures where the hardening occurs. Increases in DBTT of 54°C for the 9Cr-1MoVNb steel and 124-144°C for the 12Cr-1MoVW steel were observed when the steels were irradiated in a fast reactor. In addition to irradiation hardening, neutrons from the fusion reaction will produce large amounts of helium in the steels used to construct fusion power plant components. Little helium is produced in fast reactor irradiation, but tests to simulate the fusion environment indicate that helium can also affect the toughness.

Irradiation of a structural steel by neutrons generated in the fusion reaction will activate (transmute to radioactive isotopes) elements of the steel. Reduced-activation steels that contain elements that transmute to short-lived isotopes are being developed, thus simplifying the disposal of the radioactive structure after its service lifetime. Common alloying elements that must be eliminated or minimized in reduced-activation steels include Mo, Ni, Nb, Cu, and N. A reduced-activation 9Cr-2WVTa steel was developed that had a much lower DBTT than the conventional steels and showed a shift in DBTT that was about half that of the best conventional steels after fast reactor irradiation.