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Applicability of Ferritic/Martensitic Steels for Spallation Applications: Comparison of Performance in Fission, Fusion to Spallation Systems

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Ferritic/Martensitic (F/M) steels have become the lead material for a number of applications in extreme neutron and ion irradiation environments due to their robust resistance to irradiation effects and, in some cases, low activation. In the range from ~400 to 650℃, these materials exhibit low or no swelling in fission irradiation environments while maintaining excellent mechanical properties. For applications in more fusion neutron or spallation proton environments, the production or implantation of helium and hydrogen becomes a significant additional challenge.

We have conducted a large study on fission neutron irradiation effects on large numbers of Fe-Cr-base model alloys for their dimensional stability and resilient mechanical properties performance. This work is based on microstructural evolution during irradiation over a range of temperatures from 300℃ to nearly 600℃ to doses up to 10 dpa. The work also includes mechanical properties measurements of these irradiated materials where changes in properties can be associated with irradiation-induced microstructural changes. Unique to our program is the use of a synchrotron x-ray source to monitor in sit deformation processes.

The results of our work can be related to other work on F/M alloys from the spallation irradiation structures and mechanical properties which have been exposed to similar doses over the same range of temperatures. One relevant finding from our work is that the early evolution of defect structures and low dpa levels produces significant hardening or strengthening even at temperatures above 450℃. This behavior is tied directly to the dislocation loop structures and their evolution with dose. At higher doses, the growth of these loop structures diminishes their effect on mechanical properties, but the evolution of irradiation-induced precipitate structures, particularly the G-phase and alpha-prime at higher Cr levels, produce other hardening and strengthening effects. This talk will compare the irradiation performance of our alloy systems to the results for available spallation systems studies.

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