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Understanding Swelling-Related Embrittlement of AISI316 Stainless Steel Irradiated in Experimental Breeder Reactor II

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ABSTRACT:

The objective of this proposal is to investigate the swelling-related embrittlement behavior of AISI 316 stainless steels irradiated in Experimental Breeder Reactor II (EBR-II) at high neutron fluences. The mechanical response of high-dose neutron irradiated nuclear core structures is of vital interest to the development of advanced reactor materials. Austenitic AISI 316 stainless steel has been used for the structural materials of light-water-reactor core internals due to its stable ductile fracture behavior, while neutron irradiation can significantly harden the materials and render them less ductile than their unirradiated counterparts. At low irradiation temperatures (<360°C), neutron exposure causes very limited void swelling, but AISI 316 stainless steel can exhibit intergranular fracture due to the formation of defects, such as dislocation loops. At higher irradiation temperatures, severe embrittlement arises in AISI 316 stainless steels after neutron irradiation at 400°C to 130 dpa concurrent with ~ 10% swelling. Some efforts have been made to correlate such embrittlement with void swelling, while the formation of precipitates and grain boundary degradation (such as chemical redistribution along grain boundaries and formation of nanoscale H/He filled cavities at grain boundaries) may also cause the embrittlement of AISI 316 stainless steels irradiated at high temperatures. The basic fracture initiation and propagation mechanism of AISI 316 stainless steels under high-dose neutron irradiation is still unclear. This proposal is to 1) study the swelling-related fracture model of AISI 316 stainless steel at high neutron exposure, 2) establish the relationships among irradiation-induced microstructure, grain boundary chemistry, and fracture modes of AISI 316 stainless steels irradiated at high neutron fluences, and 3) develop an experimentally validated multi-scale/multi-physics model to predict the irradiation embrittlement behavior of nuclear core components.