Dependence of Steady-state swelling rate of 0.1C-16Cr-15Ni-3Mo-1Mn austenitic steel on DPA rate AND irradiation temperature

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In order to predict void swelling under high dose neutron irradiation for fission and fusion spectra it is needed to describe both the onset (transient duration) of steady-state swelling as well as the steady-state rate. One current conception is that the steady-state swelling rate of austenitic alloys is $\sim 1 \%$/dpa, independent of dpa rate and temperature over a rather broad range of typical irradiation conditions. The objective of the paper is to explore the behavior of the steady-state swelling rate with temperature and damage rate, using $\sim 1800$ swelling measurements made on 0.1C-16Cr-15Ni-3Mo-1Mn austenitic steel used as fuel cladding at 370-600°C in the BN-600 fast reactor. These data were analyzed over 10°C increments and the steady-state rate was determined for swelling levels above 10% for each increment. The steady-state swelling rate was found to be relatively invariant at somewhat less than 1%/dpa over most of the temperature range but to climb strongly to levels in excess of 2%/dpa at the highest temperatures.

A quantitative model of point defect migration in austenitic steels to sinks generated under irradiation was developed using statistical thermodynamics of solid bodies. Vacancy and interstitial fluxes to voids, dislocations and precipitates developed in this steel were calculated using earlier experimentally derived descriptions of temperature dependencies of void integral surfaces for this steel. The model was calibrated to fit the derived temperature dependence at $10^{-6}$ dpa/s characteristic of BN-600. The model was then used to explore the dependence of the steady-state swelling rate on dpa rate over a very wide range. Over most of the reactor-relevant temperature range the predicted steady-state rate is independent of dpa rate. At the highest temperatures with higher steady-state swelling rates, the swelling rate is shown to be independent of dpa rate over a much smaller range of dpa rates typical of fusion, but tending to decrease for both lower LWR-relevant and higher ion simulation study rates.