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PE-16 swelling

Alloy Development for Irradiation Performance

Quarterly Progress Report

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The helium production to displacement per atom (He/dpa) ratio expected near or at the first wall of a fusion reactor for stainless steels and nickel-base alloys can be reasonably reproduced in "real" time in fission reactors as a result of the reactions $^{58}Ni(n,\gamma)^{59}Ni(n,\alpha)^{56}Fe$. The He/dpa ratio can be reproduced by intermittent modification of the thermal-to-fast neutron flux ratio since the He production will be dominated by the thermal flux and the fast flux will determine the dpa. This report summarizes neutronic calculations and experimental design considerations to determine: (1) the needed change in the thermal-to-fast ratio as a function of time, (2) the possibility of using the EBR-II in conjunction with the ORR, and (3) the configuration of the first experimental capsule.

Type 316 stainless steel cold-worked 20% has been preinjected with 200 at. ppm He and irradiated in EBR-II at 625°C to a neutron fluence of 1.6×10^{26} n/m^2 (>0.1 MeV). The preinjected helium results in 1.2×10^{22} cavities/m^3 that are 5 nm in diameter, while the uninjected material contains no cavities. The preinjected helium results in nearly an order of magnitude more cavities, and these cavities are slightly smaller than those produced by irradiation of the same material in HFIR. Preinjected helium appears to have no effect on the dislocation structure that develops during irradiation. However, all cavities produced by helium preinjection are attached to dislocations, as is observed after HFIR irradiation.

Tensile tests were performed on type 316 stainless steel, with and without 0.23 wt % Ti added, irradiated in the HFIR to simulate fusion reactor first-wall conditions. Both annealed and 20%-cold-worked materials were examined and hardened more rapidly than similar materials irradiated in EBR-II (containing only trace amounts of helium) but had comparable ductility for the fluences attained (2×10^{26} n/m^2, <0.1 MeV).

Swelling-tensile samples of Nimonic PE-16 were irradiated in HFIR at 55 to 700°C to produce simultaneously dpa levels from 2.2 to 16.7 and helium contents from 120 to 2960 at. ppm. These conditions resulted in <2% swelling. The maximum swelling, 1.92%, was found at 500°C in solution treated and aged material. The material solution treated only resisted swelling slightly more than aged material. Neither material showed very strong temperature dependence of swelling. There was no rapid, breakaway swelling above 600°C, as observed in type 316 stainless steel and alloy 600. The fluence dependence of the swelling suggests that an "incubation period" precedes significant swelling.

The irradiation of ORR-MFE-1 was completed June 28, 1978 with an irradiation of 72,698 MWh (261.71 TJ). The experiment has been disassembled, and the specimens are being examined. Irradiation of ORR-MFE-2 began September 1, 1978, and it has accumulated an exposure of 16,212 MWh (58.363 TJ).

Approximately 2 wt % N in lithium significantly enhanced the degradation of type 316 stainless steel, with the corrosion rate decreasing as a function of time. At 500°C, the corrosion was uniform, while at 600 and 700°C, grain boundary attack dominated. As-rolled type 316L stainless steel had worse corrosion resistance to nitrogen-contaminated lithium than fully annealed type 316. We do not know whether the decreased resistance is attributable to differences in microstructure or alloy composition. While the corrosion of type 316 stainless steel in Li–2% N is more severe than in relatively pure lithium, such effects are expected to be transient in a closed system.

Type 316 stainless steel thermal convection loops containing molten lithium are being used to investigate the effect of time on corrosion rates in lithium. Corrosion rates are initially time dependent, decreasing up to 2000 h, and constant after approximately 2000 h. Absolute weight losses among three loops were quite reproducible at short exposures (500 h) but diverged at longer times.

A type 316 stainless steel thermal convection loop recently began operation with the proposed tritium-processing salt LiF-LiCl-LiBr. Two additional thermal convection loops are being used to study the corrosion properties of Li_2BeF_4 and $NaNO_2$-KNO_3-$NaNO_3$.

The hydrogen dissolution and permeation characteristics of the 5621S alloy of titanium have been evaluated. This alloy was found to have a permeability of approximately 3000 times greater than that of conventional 300-series stainless steels. The observation of a pressure dependence somewhat greater than half-power was construed as evidence for a permeation process that is partially limited by surface impurity effects. Roughly determined values for the solubility of hydrogen in the 5621S alloy were in the range of those reported for Ti–6% Al–4% V. The surface condition and mechanical integrity of the 5621S membrane appeared to be unaffected by approximately 2000 h of hydrogen infiltration under typical power-reactor plasma-chamber conditions with respect to temperature, gas pressure, and gas composition.