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ALLOY DEVELOPMENT FOR IRRADIATION PERFORMANCE QUARTERLY PROGRESS REPORT FOR PERIOD ENDING JUNE 30,1980

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The handbook activity is progressing slower than desired with inputs. The primary delay seems to center around conflicting priorities between preparing for reactor experiments and preparing data sheets. A portion of the data sheets, those relating to fatigue crack growth and irmdiation creep, have been received and are being reviewed. To speed up the turn around time for these data sheets an alternate approach is being tried which involves placing more emphasis a the people working a projects since they have to be responsive to project needs in a timely manner.

No report this period.

Three-dimensional neutronic calculations are under way to follow the irradiation environment of the MFE-4A experiment, which has recently been loaded into the Oak Ridge Research Reactor (ORR), and are in progress to determine the response of the ORR to multiple tungsten core pieces that will be used during later irradiations to reduce the thermal flux levels seen by the nickel-containing alloys. Preliminary results indicate that two core pieces of 50% W or four core pieces of 25% W can be used simultaneously in the reactor. However, since additional fuet is required to maintain criticality, the core fuel loading exceeded the standard 6 kg ^{235}U by about 15%. In addition, one-dimensional neutronic calculations are being planned to determine the heating rates within these tungsten core pieces and within the experimental capsules.

The last in a series of tests demonstrating the prototypic fatigue machine has been successfully completed. An eight-specimen chain test was conducted at 425°C with one specimen being continuously monitored using the electrical potential method. Results were used to finalize precracking and loading conditions for the in-reactor test.

The 20%-cold-worked types 316 and 316 + Ti stainless steel were irradiated in HFIR at temperatures of 55 to 375°C to neutron fluences producing up to 13 dpa and 740 at. ppm He. Both steels offer similar mechanical properties at these irradiation temperatures as determined by postirradiation tensile testing. Both alloys are strengthened by irradiation, but the ductility of cold-worked 316 decreases while that of cold-worked 316 + Ti increases. The failure mode was ductile-transgranular for all irradiated specimens. Microstructural examination reveals cavities and dislocation loops at 285 and 375°C in both alloys. Both alloys swell less than 0.5% and even less at higher irradiation temperature. The titanium modified alloy swells slightly less.

Precipitation in thermally aged and neutron-irradiated samples of types 316 and 316 + Ti stainless steel is characterized by conventional transmission electron microscopy and by extraction and x-ray energy dispersive spectroscopy. Below 750°C, the major phases in the thermally aged alloys are eta, tau, Laves, sigma, and MC in 316 + Ti. Each phase has a unique and clearly distinguishable characteristic solubility for the alloy elements found in these steels. Particularly important to irradiation behavior is the fact that all the phase except MC and tau can concentrate Si, but only eta concentrates Ni. Relative to this baseline, these phases have nearly the same composition when produced by irradiation in HFIR. The phase MC is exceptional in that it is the only phase that is enhanced by irradiation and yet incorporates little or no Si or Ni.

The iron-base LRO alloys with compositions $(Fe,Ni)_3V$ are being developed for fusion energy applications. The alloys have excellent high-temperature strength and good ductility and fabricability in the ordered state. Studies of phase relations indicate that sigma phase precipitates from the disordered solid solution (gamma) at temperatures above the critical ordering temperature (T_c). Below T_c, atom ordering takes place in the alloys through the peritectoid reaction $\gamma + \sigma \rightarrow \gamma'$, where γ' is the cubic ordered phase ($L1_2$-type) formed on the face-centered cubic (fcc) lattice. The sigma phase region can be reduced or eliminated by adding small amounts of titanium. Tensile tests as a function of temperature indicate that the LRO alloys with base compositions show a ductility minimum around T_c. However, modifying the alloys with titanium significantly improves their ductility at elevated temperatures. The tensile properties of the base and titanium-modified alloys are not affected by long-term aging at 550°C. Preliminary evaluation of material prepared by using commercially produced ferrovanadium as feed material indicates this as a promising approach to towering the alloy production cost.

The unirradiated microstructure of $(Fe_{61}Ni_{39})_3V$ contains a relatively uniform distribution of small MC-type precipitate particles and large, widely scattered islands of sigma phase. Essentially the same alloy, except for a 0.4 wt % Ti addition, contained scattered inclusions with MC-type precipitate particles decorating the distocations at the inctusion-matrix interfaces.

Irradiation of $(Fe_{61}Ni_{39})_3V$ at 525, 570, 625, and 680°C with 4-MeV (0.6-pJ) nickel ions to 70 dpa with the simultaneous injection of helium and hydrogen produced cavities, a high density of dislocation loops, and a redistribution of MC-type precipitate particles, The alloy remained ordered throughout the irradiation except at 680°C, which was above its critical ordering temperature of about 670°C. The irradiation also produced a high density of distocations in the titanium-modified alloy but only a few small cavities at 525 and 570°C. No cavities were observed at either 625 or 680°C. The MC-type particles precipitated in the modified alloy at all

Fracture toughness tests were performed a unirradiated 2.54 mm thick HT-9 specimens at 25, 149, 232, 315, 427 and 539°C. The electropotential technique was applied to develop single specimen method for J_{1c} determination. Rased on experimental data, a semi-emperical expression was obtained for a calibration curve which was used to measure continuous crack extension. With this continuous Δa measurement, it is possible to generate J versus Δa curves from single specimens at various temperatures successfully. Large specimens were also tested at 232°C to study the thickness of HT-9. The upper shelf fracture toughness of HT-9 is evaluated at temperatures ranging from room temperature to 539°C.

Calibration fatigue tests were conducted with HT-9 ferritic steel specimens at 755 K in a Plowing lithium environment. The procedure for strain control and strain measurement has been established. Several continuous cycle fatigue tests have been performed with gauge specimens of HT-9 alloy. The results are being analyzed to determine the strain-life relationship. Exposure of corrosion specimens of HT-9 steel with solid Li_2O, $LiAlO_2$, and Li_2SiO_3 breeding mterials at 873 K has been completed. Metallographic evaluation of the corrosion specimens is in progress.

Experimental hardware has been built and specimens have been fabricated for the AD-2 experiment. The loading of the specimens into the six uninstrumented B-7C capsules has been completed and these capsules have been shipped to Idaho Falls for insertion into ERR-11, Cycle 109.

Small heats of ferritic (martensitic) steels based a 12% Cr-1% Mo and 9% Cr-1% Mo were prepared containing about 0, 1, and 2% Ni. Additional heats were made with 2% Ni, in which the content of the ferrite-forming elements was adjusted to restore the net chromium equivalent to a value near that of the unmodified alloy. During irradiation in the High Flux Isotope Reactor (HFIR), transmutation of the ^{58}Ni will give helium concentrations approximating those *produced in such steels in fusion reactor service. Because the addition of nickel can affect the response to heat treatment, the microstructures of the alloys are being characterized.*

After normalizing, the alloys without nickel and those containing 1 and 2% Ni (but with no chromium equivalent adjustments) had microstructures that were entirely martensite. The 2% Ni addition towered the Ac_1 temperature, making it necessary to temper these alloys at temperatures no greater than 700°C. The normalized microstructure of the 2% Ni alloys oith adjusted chromium equivalent contained large mounts of a phase in addition to the predominant martensite. Work is in progress to determine if this phase is 6-ferrite or retained austenite.

The following bar charts show the schedule for all ADIP reactor irradiation experiments. Experiments are presently under way in the Oak Ridge Research Reactor (ORR) and the High Flux Isotope Reactor (HFIR), which are mixed spectrum reactors, and in the Experimental Breeder Reactor (EBR)-II, which is a fast reactor.

During the reporting period irradiation was begun for two irradiation experiments: ORR-MFE-4A in the ORR and HFIR-CTR-33 in the HFIR.

The Office of Fusion Energy has assigned program responsibility to ORNL for the establishment and operation of a central inventory of research materials to be used in the Fusion Reactor Materials research and development programs. The objective is to provide a common supply of materials for the Fusion Reactor Materials Program. This will minimize unintended materials variables cad provide for economy in procurement and for centralized record-keeping. Initially this inventory is to focus on materials related to first-wall and structural applications and related research, but various special purpose materials may be added in the future.

No report for this period. The next reporting of progress on this tusk will be at the end of the fourth quarter of FY-1980.