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HELIUM MEASUREMENTS FOR THE MFE-4 SPECTRAL TAILORING EXPERIMENT

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HELIUM MEASUREMENTS FOR THE MFE-4 SPECTRAL TAILORING EXPERIMENT - F. A. Garner (Pacific Northwest Laboratory)[a] and B. M. Oliver (Rockwell International)

OBJECTIVE

The objective of this effort is to determine the role of helium on microstructural development and changes in mechanical properties of model Fe-Cr-Ni alloys.

SUMMARY

Measurements of helium concentration have been made on Fe-15.1Cr-34.5Ni specimens irradiated at 330, 400, 500 and 600°C after irradiation in ORR to displacement levels ranging from 12.6 to 13.8 dpa. The measurements compare well to previously calculated values, being 4 to 8% lower. Minor differences in helium content were also observed between specimens from capsules that were assumed to have possessed identical spectral environments.

PROGRESS AND STATUS

Introduction

In a companion report on ^{59}Ni isotopic doping, it is shown that three simple Fe-Cr-Ni alloys irradiated in FFTF do not exhibit a significant difference in mechanical properties when exposed to both breeder-relevant and fusion-relevant helium/dpa ratios[1]. In another experiment conducted in ORR at much larger helium generation rates, however, a significant increase in yield strength was observed (see Figure 1) relative to that of a similar experiment in EBR-II.[2,3] In ORR these and several other Fe-Cr-Ni alloys were exposed to environments whose calculated He/dpa ratios ranged from 27 to 58 appm/dpa. This range reflects not only the neutron spectra but also the variation in nickel content (20 to 45 wt%). These values were calculated using dosimetry calculations and measurements provided in reference 4 for individual elements.

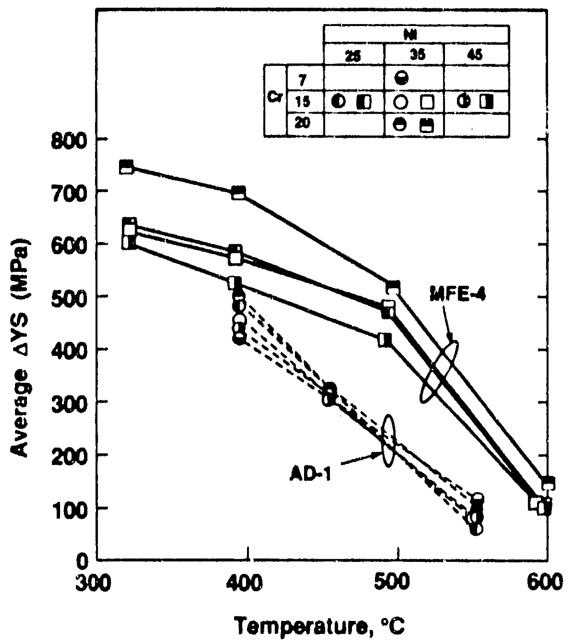

FIGURE 1. Comparison of Radiation-Induced Changes in Yield Strengths of Fe-15Cr-XNi and Fe-YCr-35Ni Alloys Irradiated in the AD-1 Experiment in EBR-II and the MFE-4 Experiment in ORR[2].

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Table 1 lists the displacement and helium levels reported earlier for the ORR portion of this experiment. Note that it was assumed that the 330 and 400°C irradiation sequences proceeded in the same spectral environment and also that the 500 and 600°C sequences were irradiated together. Detailed microstructural analyses of the ORR and EBR-II specimens are now in progress; the early results indicate that the larger than fusion-relevant levels of helium in the ORR experiment caused an extensive refinement of the microstructure, leading to suppression of swelling at the two lower irradiation temperatures and significant increases in hardening at all four irradiation temperatures.

Table 1

Calculated Displacement and Helium Levels[a] for the MFE-4 Experiment in ORR[2,3]

	330 and 400°C		500 and 600°C	
Composition, wt%	dpa	He, appm	dpa	He, appm
Fe-19.7Ni-14.7Cr	13.4	371	12.2	332
Fe-24.4Ni-14.9Cr	13.6	463	12.4	414
Fe-30.1Ni-15.1Cr	13.8	555	12.6	495
Fe-34.5Ni-15.1Cr	14.0	647	12.7	573
Fe-45.3Ni-15.0Cr	14.3	832	13.1	740

(a) These values were calculated for the maximum flux position using dosimetry calculations and measurements provided in reference 4 for individual elements. Note that the dpa levels increase with nickel content, reflecting the contributions of the ^{56}Fe recoil atom during helium production.

Further analysis requires confirmation of the calculated helium levels. Using standardized procedures at Rockwell International,[5,6] measurements were made on Fe-34.5Ni-15.1Cr specimens from each of the four irradiation temperatures. The specimens for analysis were cut from the gauge section of previously tested and broken tensile specimens.

Results

Table 2 lists the measured values of helium concentration for Fe-34.5Ni-15.1Cr at each irradiation temperature. When compared to the previously calculated values for the maximum flux position it is obvious that some small differences in neutron spectra and flux exist between the specimen locations in the 330 and 400°C capsules and also between the specimen locations in the 500 and 600°C capsules as well. The measured values are uniformly lower (4-8%) than the calculated values for all four of the irradiation capsules. These relatively small differences in concentration reflect the impact of small differences in position between the maximum flux position and that of the gauge sections of the tensile specimens.

CONCLUSIONS

Slight differences in helium generation rate occurred in the various canisters used in the MFE-4 spectral tailoring experiment. The helium concentrations measured for Fe-34.5Ni-15.1Cr are lower but within 4 to 8% of the previously reported values calculated from dosimetry results. These differences arose from slight differences in position between the specimens and the maximum flux position.

FUTURE WORK

This effort will continue, focusing on completion of the microscopy effort and on prediction of strength increases from measured microstructural densities.

Table 2

Helium Concentration in the Gauge Section of Fe-34.5Ni-15.1Cr Tensile Specimens

Specimen	Temperature °C	Specimen Mass[a] (mg)	^{4}He Measured (10^{15} atoms)	Helium Concentration (appm)[b] Measured	Average[c]	Calculated[d]
JN00-A	330	1.230	7.913	600.1	597	647
-B		2.089	13.30	593.9	±4	
JN09-A	400	1.736	11.47	616.3	611	647
-B		2.610	16.95	605.8	±7	
JN13-A	500	1.548	8.818	531.4	533	573
-B		2.157	12.38	535.4	±3	
JN19-A	600	1.461	8.722	556.9	552	573
-B		1.196	7.011	546.8	±7	

(a) Mass uncertainty is ±0.001 mg.
(b) Measured helium concentration in atomic parts per million (10^{-6} atom fraction) with respect to the calculated number of atoms in the specimen.
(c) Mean and 1σ standard deviation of duplicate analyses.
(d) From Table 1.

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