IRRADIATION CREEP IN AUSTENITIC AND FERRITIC STEELS IRRADIATED IN A TAILORED NEUTRON SPECTRUM TO INDUCE FUSION REACTOR LEVELS OF HELIUM –

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Extended Abstract

Six austenitic stainless steels and two ferritic alloys were irradiated sequentially in two research reactors where the neutron spectrum was tailored to produce a He production rate typical of a fusion device. Irradiation began in the Oak Ridge Research Reactor where an atomic displacement level of 7.4 dpa was achieved and was then transferred to the High Flux Isotope Reactor for the remainder of the irradiation to a total displacement level of 19 dpa. Temperatures of 60 and 330°C are reported on. At 330°C irradiation creep was found to be linear in stress and fluence with rates in the range of $1.7 - 5.5 \times 10^{-4}$% MPa^{-1} dpa^{-1}. Annealed and cold-worked materials exhibited similar creep rates. There is some indication that austenitic alloys with TiC or TiO precipitates had a slightly higher irradiation creep rate than those without. The ferritic alloys HT-9 and Fe-16Cr had irradiation creep rates about 0.5×10^{-4}% MPa^{-1} dpa^{-1}. No meaningful data could be obtained from the tubes irradiated at 60°C because of damage to the tubes.

The irradiation creep rates are provided in Table 1. From the table, it can be seen that there is little difference in the average deformation between 7.4 and 19 dpa. This indicates that the observed creep does not result from the initial microstructural transient. Most differences between the two fluence levels are attributed to errors in measurements, especially with the lower exposure values. It is clear that the ferritic alloys have lower levels of irradiation creep by about a factor of 5 to 6. This is consistent with previous determinations of irradiation creep in this class of alloys. It is also apparent from the table that the alloys containing titanium have a higher irradiation creep rate than the other alloys. Both of these alloys have precipitates of TiC or TiO. It is suggested that the interfacial misfit due to the volume expansion upon formation of the precipitates results in a sink for vacancies. The correspondingly higher concentration of interstitials in the matrix could than give rise to higher levels of irradiation creep as predicted by the SIPA or climb-assisted-glide mechanisms.

Several effects observed in the austenitic alloys are illustrated by the PCA data plotted in Fig. 1. The linear dependence of irradiation creep on stress is clear from the graphs. It as also evident that cold-worked material creeps at the same rate as annealed material. Although creep rate is predicted to be linear in dislocation density, in the sink-dominated regime, the interstitial concentration is inversely proportional to the dislocation density which cancels its effect on irradiation creep.

Table 1. Irradiation Creep Rate for 330°C
Normalized with Respect to Stress and Displacements

Alloy	Creep Rate (% MPa^{-1} dpa^{-1} $\times 10^{-4}$)	
	7.4 dpa*	19 dpa*
USPCA 25% CW	23 ± .1	2.7 ± .08
JPCA SA	1.6 ± .7	2.7
J316 20% CW	1.3 ± .1	2.1 ± .4
Fe-13.5 Cr-15 Ni	1.4 ± .7	0.8 ± 2**
Fe-13.5 Cr-35 Ni	3.0 ± .2	3.4 ± .4
Fe-13.5 C4-15 Ni--.18 Ti	5.1 ± .8	5.5 ± .6
Ht-9	0.44 ± .09	0.43 ± .08
Fe-16 Cr	0.8 ± .3	0.5 ± .2

*standard errors in curve fitting only
**scatter in data does not permit an accurate creep rate to be determined

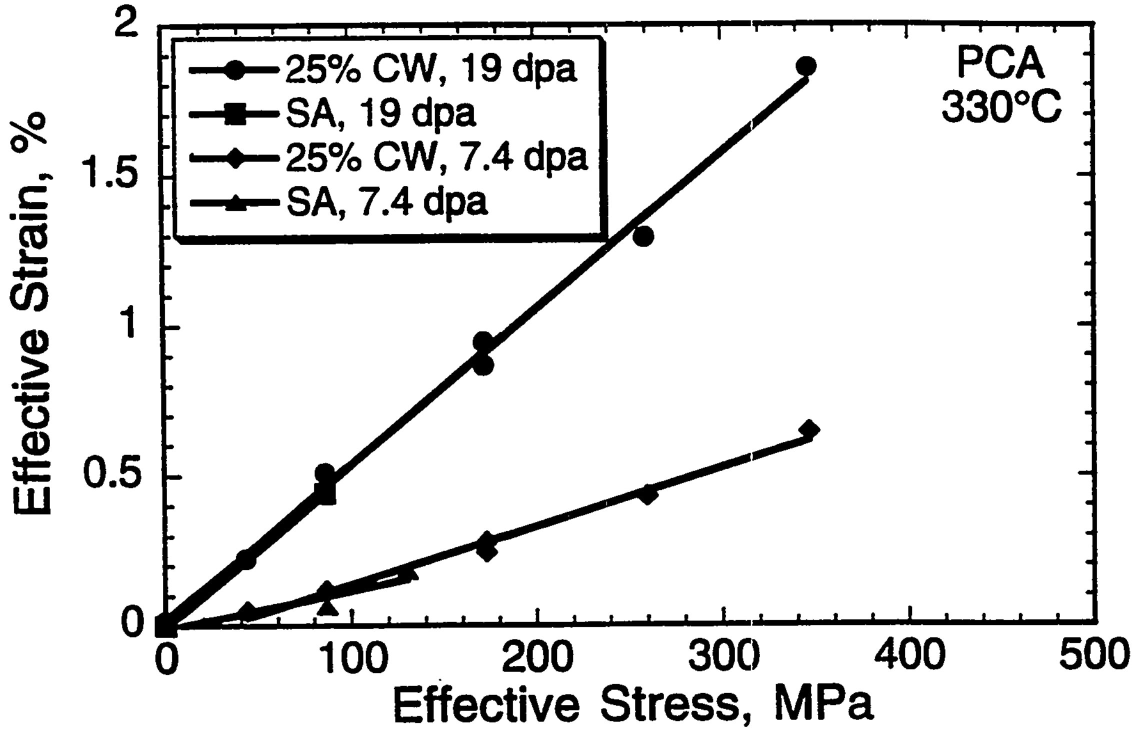

Fig. 1. Effective uniaxial strain vs. effective stress for the austenitic stainless steel PCA in the 25% cold-worked state from the U.S. Fusion Program and annealed PCA from the Japanese Fusion Program.