1.2 Irradiation Creep Behavior of F82H IEA Heat and B-Doped F82H Irradiated at 573 and 673K up to 5dpa — M. Ando, T. Nozawa, T. Hirose, H. Tanigawa, and E. Wakai (Japan Atomic Energy Agency), R. E. Stoller and Janie Myers (Oak Ridge National Laboratory)

OBJECTIVE

This report is a result of creep tube measurements for F82H IEA heat and Boron-doped F82H irradiated at 573 and 673 K in HFIR MFE-RB-15J capsule. The objectives of this work are to obtain irradiation creep data of F82H and to investigate the effect of helium on irradiation creep behavior.

SUMMARY

The 34 pressurized tubes irradiated in MFE-RB15J capsule have been measured by a laser profilometer in hot cell. The irradiation creep of F82H IEA and ^{10}BN-F82H exhibited similar behavior below 573 K up to 5dpa. The irradiation creep strain in F82H irradiated at 573K and 673 K was almost linearly dependent on the Hoop stress level for stresses below 300 MPa and 200 MPa, respectively. The creep strain of ^{10}BN-F82H was similar to that of F82H IEA at each Hoop stress level except 340 MPa at 573 K irradiation.

PROGRESS AND STATUS

Introduction

Reduced activation ferritic/martensitic steels (RAFM) are the most promising candidates for blanket structural materials for fusion reactors. Irradiation creep has been recognized as one of the most important properties for engineering data due to the blanket structural design. Several researchers have reported on irradiation creep and void swelling behavior of austenitic stainless steels and ferritic steels irradiated above 673 K in FFTF, HFIR, and other fission reactors [1-3]. In addition, some results of irradiation creep experiments on RAFM (F82H and JLF-1) above 663 K have been reported by the Japan/US collaboration program for fusion materials [4]. For fusion reactors, it is anticipated that irradiation creep of RAFM at lower temperatures could be also significant, and this would have a large impact on the life expectancy of a water-cooled solid breeder blanket system. However, irradiation creep behavior of RAFM at temperatures below 673 K has scarcely been reported [5]. In a fusion reactor, some transmutations (mainly helium) are produced by high-energy neutrons in the first wall. The effect of helium on irradiation creep behavior has not been reported in F82H.

The objectives of this work are to provide irradiation creep data of F82H IEA heat for blanket structural materials database. The effects of helium on irradiation creep behavior are also reported using BN-F82H.

Experimental

The materials studied were F82H IEA heat and Boron-doped F82H provided by Japan Atomic Energy Agency. The chemical compositions of these materials are given in Table 1. Boron-doped F82H steels were provided to investigate the effect of helium on irradiation creep. In this experiment, two types of Boron-doped F82H were prepared by a co-doping of Boron and Nitrogen in F82H steel [6, 7]. One is ^{10}BN-F82H which produced helium atoms by the reaction ^{10}B (n, a) ^{7}Li during irradiation. The other is ^{11}BN-F82H which did not produce helium. These BN co-doped

F82H steels show that mechanical properties were improved by a suppression of boron localization.

Table 1. Chemical composition of F82H and B-doped F82H (mass%).

	C	Cr	W	V	Ta	Mn	Si	P	S	N	B
F82H EA heat	0.090	7.71	1.95	0.16	0.020	0.16	0.11	0.002	0.0020	0.006	0.0002
^{10}BN-F82H	0.099	8.09	2.10	0.30	0.039	0.10	0.10	0.006	0.0008	0.020	0.0059
^{11}BN-F82H	0.088	8.08	2.09	0.31	0.043	0.10	0.11	0.006	0.0010	0.020	0.0053

The tube specimens had dimensions of 4.57 mm outside diameter and 25.4 mm length with a 0.25 mm wall thickness as shown in Fig. 1. The hoop stresses ranged from 0 to 380 MPa at the each irradiation temperature. The diameter of these tubes was measured by a non-contacting laser profilometer system (Beta Lasermike Model162) at Oak Ridge National Laboratory (ORNL) prior to irradiation.

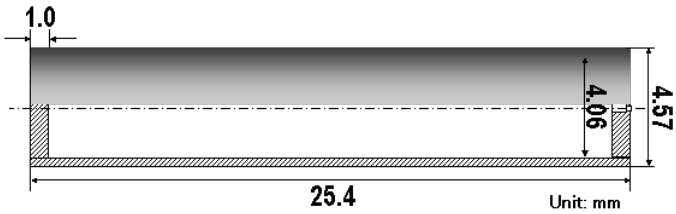

Fig. 1. Geometry of the pressurized tube specimen.

Irradiation was performed in High Flux Isotope Reactor (HFIR) to atomic displacement levels up to 5 dpa in the RB-15J capsule [8]. Nominal irradiation temperatures were 573 and 673 K in this experiment.

The tubes were measured with a laser profilometer system capable of a precision of ±250 nm. Each tube was measured three times after irradiation. The average diameter of the central three-fifths of each tube was used in the analysis of the data. A creep strain was calculated from tube diameter measured before and after irradiation.

Results and Discussion

Table 2 shows results of irradiation creep measurements for pressurized tube specimens irradiated at 573 and 673 K.

Table 2. Results of creep tube measurements for RB15J.

Specimen ID	Strain %	Hoop Stress MPa	Tempreture K	Dose dpa	Material
0XP0	0.56106	380	573	3.7	F82H IEA
0XP2	0.19426	340	573	4.2	F82H IEA
0XP3	0.10199	300	573	3.7	F82H IEA
0VP1	0.07804	250	573	4.2	F82H IEA
0ZP4	0.04084	250	573	3.7	F82H IEA
0XP6	0.09114	200	573	4.2	F82H IEA
0XP7	0.08823	200	573	4.2	F82H IEA
0XP9	0.02406	150	573	3.7	F82H IEA
0ZP0	-0.03977	150	573	4.2	F82H IEA
0ZP1	0.00583	100	573	4.2	F82H IEA
0WP1	0.07638	100	573	4.2	F82H IEA
0XP5	0.02926	0	573	3.7	F82H IEA
0YP3	0.34470	250	673	5.7	F82H IEA
0ZP2	0.24479	250	673	5.7	F82H IEA
0YP5	0.15722	200	673	5.7	F82H IEA
0XP8	0.12050	200	673	5.7	F82H IEA
0XP1	0.15132	170	673	5.7	F82H IEA
0YP9	0.05398	150	673	5.7	F82H IEA
0WP0	0.07321	100	673	5.7	F82H IEA
0YPB	-0.14052	100	673	5.7	F82H IEA
0XPA	-0.00791	0	673	5.7	F82H IEA
DXP0	0.28687	340	573	3.7	^{10}BN-F82H
DXP1	0.09482	250	573	3.7	^{10}BN-F82H
DXP2	0.06477	200	573	4.2	^{10}BN-F82H
DXP3	0.06543	150	573	4.2	^{10}BN-F82H
DZP2	0.02269	0	573	3.7	^{10}BN-F82H
DYP6	0.28239	250	673	5.8	^{10}BN-F82H
DYP7	0.11017	200	673	5.8	^{10}BN-F82H
DYP8	0.10329	150	673	5.8	^{10}BN-F82H
DYP9	0.04431	0	673	5.8	^{10}BN-F82H
EYP8	0.20079	250	673	5.8	^{11}BN-F82H
EYP9	0.10608	200	673	5.8	^{11}BN-F82H
EZP0	0.07613	150	673	5.8	^{11}BN-F82H
EXP0	-0.00260	0	673	5.8	^{11}BN-F82H

In this experiment, a total of 34 tubes were measured in the hot cell. A creep strain is calculated from the change in the outer diameter of tube following irradiation. Using the measured diameters, a creep strain is calculated by the following expression:

$$\varepsilon = 1.15 \times \frac{\Delta D}{D_o}$$

where ΔD is the change in the tube's outer diameter before and after irradiation, D_o is the outer diameter before irradiation. The outer diameter strain is converted to the mid-wall strain by a factor of 1.15 [9].

Fig. 2 (a) shows the relationship between the creep strain (e) and the Hoop stress (s_{Hoop}) in F82H IEA and BN-F82H irradiated at 573 K. F82H IEA and BN-F82H exhibit similar irradiation creep behavior at 573 K up to 5dpa.

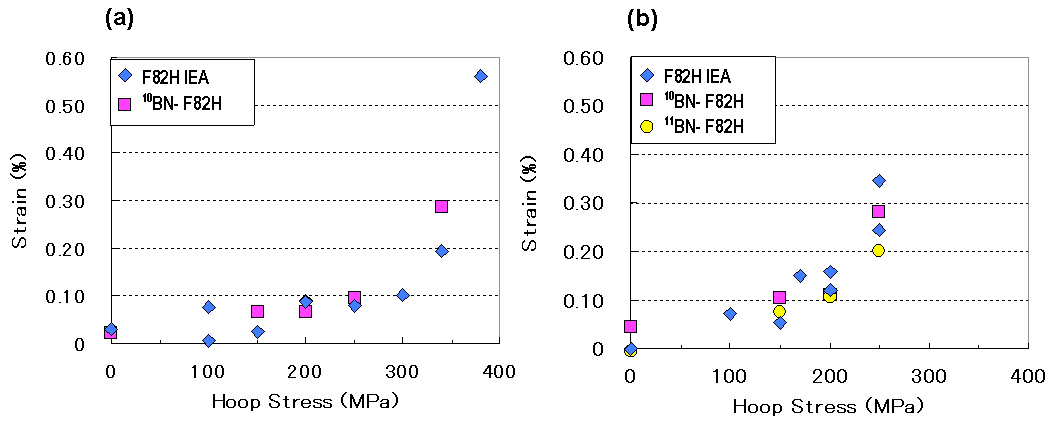

Fig. 2. Hoop stress dependence of irradiation creep at (a) 573 K and (b) 673 K.

The irradiation creep strain in F82H is nearly linearly dependent on the Hoop stress level for stress levels below 300 MPa. However, the creep strain becomes nonlinear at higher stress levels. Fig. 2 (b) shows the results of 673 K irradiation. In this case, the irradiation creep strain of F82H is linearly below 200 MPa. At higher stress levels, the creep strain increased in F82H IEA because thermal creep gradually had also occurred during irradiation.

In this experiment, stress-free tubes were included to monitor swelling. For 573 K irradiation, the data from each stress-free tube show that swelling is very small in this condition, below 0.02 %.

The effect of helium on irradiation creep of F82H was also examined using ^{10}BN and ^{11}BN-F82H. Helium production after irradiation was estimated to be about 300 appm and was controlled using a thermal neutron shielded capsule. The creep strain of ^{10}BN-F82H was similar to that of F82H IEA at each Hoop stress level except 340 MPa at 573 K irradiation. For 673 K irradiation, the creep strain of some ^{10}BN-F82H tubes was larger than that of F82H IEA tubes (including stress free tube). It is suggested that a swelling caused in each ^{10}BN-F82H because small helium babbles might be produced by a reaction of ^{10}B(n, a)^{7}Li.

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