STUDY OF IN-REACTOR CREEP OF VANADIUM ALLOY IN THE HFIR RB-12J EXPERIMENT*

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SUMMARY

Biaxial creep specimens will be included in the HFIR RB-12J experiment to study in-reactor creep of the V-4Cr-4Ti alloy at ≈500°C and 5 dpa. These specimens were fabricated with the 500-kg heat (832665) material and pressurized to attain 0, 50, 100, 150, and 200 MPa mid-wall hoop stresses during the irradiation.

OBJECTIVE

The objective of this task was to investigate the in-reactor creep of the 832665 heat of V-4Cr-4Ti alloy at ≈500°C and 5 dpa. Comparable creep specimens were included in the ATR-A1 experiment at ≈200 and 300°C.

SPECIMEN DESIGN AND TEST MATRIX

The creep specimens are 0.180 in. OD x 0.160 in. ID x 1.0 in. long drawn tubes with welded end plugs. The construction of these creep specimens is identical to that used in the ATR-A1 experiment.

The design mid-wall hoop stresses are 0, 50, 100, 150, and 200 MPa at the target irradiation temperature of 500°C. These stresses will allow the determination of creep rates over a wide range with no undue risk of specimen failure. Furthermore, they permit a direct comparison with the lower-temperature ATR-A1 test data at 0, 100, 150, and 200 MPa.

FABRICATION OF CREEP SPECIMENS

The procedure used for fabricating the HFIR RB-12J creep specimens is essentially the same as that used for the ATR-A1 experiment.

- Perform X-ray radiography with machined defect standards to determine the condition of the as-drawn tubing.
- Produce 1-in.-long tube blanks from defect-free regions of the tubing.
- Measure the ID, OD, thickness, concentricity, and roundness of the tube blanks.
- Produce end plugs from 832665-heat plate stock with electrode discharging machining (EDM).
- Clean the machined end plugs with nitric acid to remove residual copper from the EDM brass wire. (Residual copper caused intergranular cracking in some qualification welds.)
- Clean all tube blanks and end plugs with a pickling solution (HF/HNO_3/lactic acid) and alcohol.
- Weld the top and bottom end plugs to the tube blanks with an electron-beam welder.
- Perform visual and radiographic inspections of the girth welds.
- Measure the diameters of the specimens with a laser profilometer at five axial locations (0.1, 0.3, 0.5, 0.7, 0.9 in.) and every 10° azimuthal.
- Anneal the specimens at 1000°C for 1.0 h in vacuum, with each specimen wrapped in a Ti getter foil.
- Pressurize the specimens with high-purity helium and seal the vent hole in the top end plug with a laser.
- Perform helium leak check, weighing, and length measurement of each specimen.
- Repeat the diameter measurements with the laser profilometer.
- Package the specimens for shipment.

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The required room-temperature pressurization of the specimens was determined with a PNNL-supplied computer program, "FILPRESS.BAS," which takes into account thermal expansion of the vanadium tube and helium compressibility. The design values and the actual pressure loading in the specimens are compared in Table 1. Dimensions of the pressurized specimens are shown in Table 2.

Six archival creep specimens (identical to the test specimens in every way except without pressurization) were produced and are in protective storage along with the qualification welds.

Table 1. Design and Actual Pressure Loading in Vanadium Alloy Creep Specimens for HFIR RB-12J Experiment

Specimen No.	Design Mid-Wall Hoop Stress (MPa)	Design Pressure Loading (psi)	Actual Pressure Loading (psi)
B1	0	3	8
B12	50	360	363
B11	100	720	727
B3	150	1082	1083
B9	150	1082	1086
B5	200	1448	1446

Table 2. Dimensions of Vanadium Alloy Creep Specimens for the HFIRRB-12J Experiment

	Azimuthally-Averaged Diameter (in.) at Axial Locations of					
Specimen No.	0.1 in.	0.3 in.	0.5 in.	0.7 in.	0.9 in.	Specimen Length (in.)
B1 (0 MPa)	0.18002	0.17997	0.18000	0.18000	0.18002	1.002
B12 (50 MPa)	0.17980	0.17979	0.17978	0.17979	0.17976	1.013
B11 (100 MPa)	0.17984	0.17982	0.17982	0.17981	0.17985	1.017
B3 (150 MPa)	0.17997	0.18000	0.18001	0.18001	0.18001	1.007
B9 (150 MPa)	0.17991	0.17989	0.17988	0.17987	0.17994	1.012
B5 (200 MPa)	0.17999	0.17995	0.17997	0.17997	0.17994	1.000

FUTURE ACTIVITIES

At ORNL, the specimens will be loaded in semisealed Zr getter enclosures before being placed in the RB-12J vehicle. The purpose of the getter enclosures is to prevent excessive impurity pickup from the flowing helium environment during irradiation. The locations in the vehicle selected for the specimens are such that all six specimens will receive approximately the same neutron and thermal exposure during irradiation.

The RB-12J irradiation is expected to produce ≈5 dpa neutron damage in the specimens. After irradiation, the specimens will be retrieved and the diameters will be measured again with the same profilometer and the same procedure. The creep rates will be determined from the measurements and compared with those of the ATR-A1 specimens irradiated at lower temperatures. Microstructural characterization will be performed to elucidate the observed creep behavior.