HEAT TREATMENT EFFECTS ON TENSILE PROPERTIES OF V-(4-5) WT.% Cr-(4-5) WT.% Ti ALLOYS*

K. Natesan and W. K. Soppet (Argonne National Laboratory)

OBJECTIVE

The objectives of this task are to (a) examine the influence of thermomechanical treatments on microstructural development in V-Cr-Ti alloys and (b) assess the impact of changes in microstructures on the mechanical properties of these alloys.

SUMMARY

Effects of thermomechanical treatments on microstructures and mechanical properties are of interest for long term application of V-Cr-Ti alloys in fusion reactor systems. Influence of thermal annealing at 1050°C on stress/strain behavior, maximum engineering strength, and uniform and total elongation were evaluated. The results show that multiple annealing has minimal effect on the tensile properties of V-(4-5)Cr-(4-5)Ti alloys tested at room temperature and at 500°C.

EXPERIMENTAL PROGRAM

Thermomechanical treatments can have a significant effect on the development of microstructures that can lead to changes in the bulk mechanical properties of the materials, especially for refractory alloys such as V-base alloys. As a first step, we are evaluating the role of annealing in the development of microstructures and tensile properties. The heats of the vanadium alloy selected for the study had nominal compositions of V-5 wt.% Cr -5 wt.% Ti (designated BL-63) and V-4 wt.% Cr -4 wt.% Ti (designated BL-71). Sheet tensile specimens were fabricated according to ASTM Standard E8-69 specifications and had a gauge length of ≈19 mm and a gauge width of ≈4.5 mm. Specimens of the two alloys were wrapped in a tantalum foil and given an annealing cycle of heating up to 1050°C in $\approx 10^{-6}$ torr vacuum, a hold for 1 h at 1050°C, and slow-cooling in the furnace. The specimens were given either one, two, or three annealing cycles.

The annealed specimens were tensile-tested in air at room temperature and at 500°C. Crosshead speed in the Instron machine was set to yield a strain rate of $1.8 \times 10^{-4}\ s^{-1}$ for all tests. The specimens were loaded by means of pins that pass through holes in the grips and in enlarged end sections of the specimen, thus minimizing misalignment. Total elongation was measured with a vernier caliper and by using load/elongation chart records. The fracture surfaces and longitudinal and axial cross sections of tested specimens were examined by scanning electron microscopy (SEM). In addition, Vickers hardness and grain size of several of tested specimens are being measured.

RESULTS AND DISCUSSION

Engineering stress/engineering strain data for V-Cr-Ti alloys in as-rolled condition and after single anneal treatments were reported earlier [1,2]. Stress/strain behavior of the alloys showed that the as-rolled material possess high tensile strength and low tensile ductility at both test temperatures. Materials subjected to one anneal cycle at 1050°C exhibited substantial reduction in tensile strength with an improvement in tensile ductility. Figure 1 shows the engineering stress/engineering strain curves from tests at room temperature and 500°C, for V-4Cr-4Ti and V-5Cr-5Ti specimens subjected to either two or three anneal treatments. The effect of multiple annealing is negligible on the room temperature tensile properties of either of the alloys. At

*This work has been supported by the U.S. Department of Energy, Office of Fusion Energy Research, under Contract W-31-109-Eng-38.

500°C, the stress/strain curves for both alloys are similar up to the maximum stress value but the rupture strains are somewhat smaller for V-4Cr-4Ti when compared with those for V-5Cr-5Ti alloy. The test at 500°C normally takes about 2 hours of heat up/thermal equilibration in air during which time some oxidation of the alloys occurs. Since V-4Cr-4Ti exhibits a slightly higher oxidation rate than V-5Cr-5Ti alloy [3], this increased oxygen uptake may have contributed to lower values of total elongation for the V-4Cr-4Ti alloy.

The load-displacement curves were analyzed by drawing lines parallel to the initial portion of the loading curve at the points of maximum load and rupture load. The intersects of these lines with the displacement axis are used to calculate the uniform and total elongation for the specimens subjected to different annealing treatments. This approach accounts for the stiffness, or lack of it, in the loading fixture of the tensile machine and, as a result, yields elongation values that are more representative of the gauge section of the tensile specimen.

Figure 2 shows the variations in maximum engineering stress for specimens in as-rolled condition and after single and multiple annealing treatments and tested in air at room temperature and at 500°C. The data indicate that for a given alloy and temperature, multiple anneal has little effect on maximum stress values. The maximum stress values are consistently lower by ≈5-10% for both alloys as the temperature increases from room temperature to 500°C and number of anneals has negligible effect.

Figures 3 and 4 show the variations in uniform and total elongation for the two alloys in as-rolled condition and annealing treatments. Uniform and total elongation values are higher at room temperature than at 500°C, for both alloys used in this study. Multiple anneal has small effect on either uniform or total elongation of both the alloys. Measurements of grain size of V-4Cr-4Ti alloy with different annealing treatments showed virtually no grain growth, which is consistent with grain size data for the alloy up to 2000 h at 1000°C reported earlier[3].

REFERENCES

1. K. Natesan and W. K. Soppet, "Effect of Oxygen and Oxidation on Tensile Behavior of V-5Cr-5Ti," Fusion Reactor Materials Semiannual Progress Report for Period Ending December 31, 1995, Argonne National Laboratory, DOE/ER-0313/19, p. 50, April 1996.

2. K. Natesan and W. K. Soppet, "Tensile properties of V-Cr-Ti alloys after exposure in helium and low-partial-pressure oxygen environments," Fusion Reactor Materials Semiannual Progress Report for Period Ending December 31, 1996, Argonne National Laboratory, DOE/ER-0313/21, p. 40, April 1997.

3. K. Natesan, W. K. Soppet, M. Uz, and T, Ulie, "Corrosion Compatibility," Presented at the Workshop on Vanadium Alloy Development, Argonne National Laboratory, March 11-13, 1997.

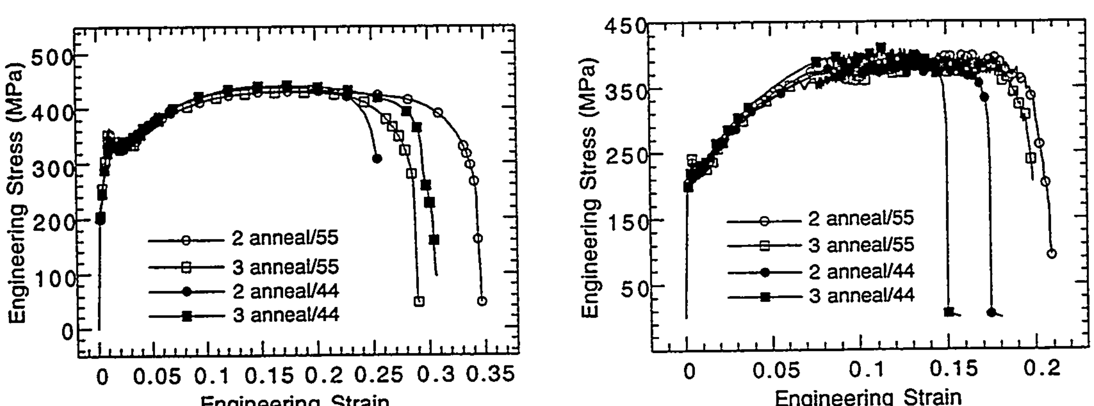

Figure 1. Stress/strain behavior of multiple-annealed V-4Cr-4Ti and V-5Cr-5Ti alloys tested at (left) room temperature and (right) 500°C, in air at a strain rate of 1.8×10^{-4} s^{-1}

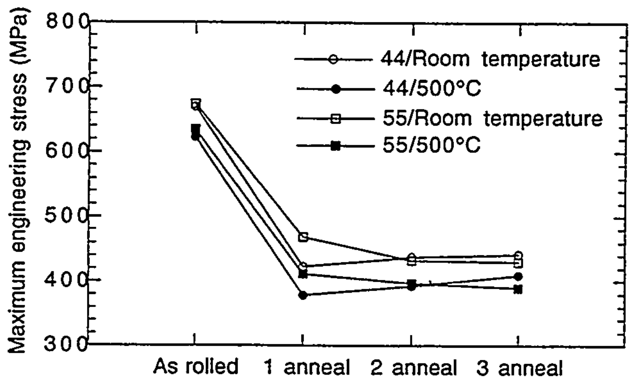

Figure 2. Maximum tensile stress for V-4Cr-4Ti and V-5Cr-5Ti alloys in as-rolled condition and after annealing treatments

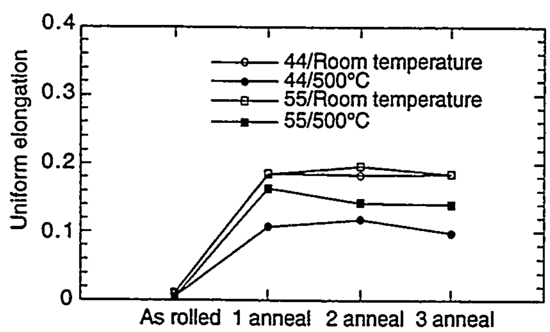

Figure 3. Uniform elongation for V-4Cr-4Ti and V-5Cr-5Ti alloys in as-rolled condition and after annealing treatments

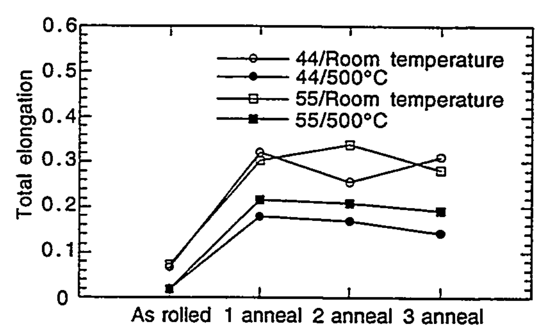

Figure 4. Total elongation for V-4Cr-4Ti and V-5Cr-5Ti alloys in as-rolled condition and after annealing treatments.