ADDITIONAL CHARACTERIZATION OF V-4Cr-4Ti EXPOSED TO FLOWING Li – B. A. Pint (Oak Ridge National Laboratory)

OBJECTIVE

Characterize specimens exposed to flowing Li in a thermal gradient to evaluate the effects on V-4Cr-4Ti and a multi-layer electrically-insulating coating needed to reduce the magneto hydrodynamic (MHD) force in the first wall of a lithium cooled blanket.

SUMMARY

In order to clarify prior results, more Li-exposed V-4Cr-4Ti specimens were evaluated at 500°C in vacuum with a strain rate of $10^{-3}s^{-1}$. These specimens confirmed prior results that exposure in the loop increased strength and slightly decreased ductility. However, while the increase in strength decreased with exposure temperature, the ductility effect was minor and more variable. The specimens exposed at lower temperatures in the loop showed the highest tensile strength, lowest ductility and least dynamic strain aging. More microstructural characterization is needed to complete this study.

PROGRESS AND STATUS

Introduction

The previous report[1] covered 500°C tensile behavior of V-4Cr-4Ti after various exposures including flowing Li in a thermal convection loop with a peak temperature of 700°C for 2,355h.[2] Because of the unusual results from the loop exposed specimens, five additional loop-exposed V-4Cr-4Ti specimens were evaluated at 500°C under the same conditions to provide additional data for evaluation.

Experimental Procedure

Details of the thermal convection loop exposure have been presented previously.[2] The specimens consisted of miniature tensile specimens (type SS-3: 25 x 4 x 0.9mm), tab specimens and specimens with a dual layer MHD coating in a chain held together with V-4Cr-4Ti wire. The tensile specimens were annealed for 1h at 1050°C prior to exposure in Li. The exposure temperature for each specimen is estimated by using a linear extrapolation of the temperatures measured at the top and bottom of the each leg.[2] Tensile testing was conducted at 500°C in a vacuum with a base pressure of 10^{-6}Pa (10^{-8}Torr) and a strain rate of $10^{-3}s^{-1}$. No microstructural characterization of these V-4Cr-4Ti tensile specimens has been conducted at this time.

Results and Discussion

Table I summarizes the results from all of the tensile experiments conducted at 500°C [1] and the mass change that occurred during loop exposure for each of the specimens. The five additional tests are marked with an asterisk. Only the loop specimen near the top of the hot leg showed a mass loss. The other mass gains were attributed to uptake of C and N being greater than the loss of O to the flowing Li. Figure 1 shows the 500°C tensile properties as a function of calculated exposure temperature in the hot and cold legs of the loop. In general, all of the specimens showed an increase in ultimate tensile stress (UTS) compared to the unexposed specimens and some decrease in ductility, Table I. The increase in UTS decreased with exposure temperature while the decrease in ductility generally decreased with temperature but the effect was more scattered. As each specimen is not large enough to perform a chemical analysis, tab and tube specimens were used to measure chemistry changes. The analyses

Table 1. Summary of 500°C tensile data for V-4Cr-4Ti specimens with $10^{-3}s^{-1}$ strain rate.

Location	Mass Gain (mg/cm^2)	Yield Stress (MPa)	Ultimate Stress (MPa)	Uniform Elong. (%)	Total Elong. (%)
As-annealed	N/A	218	384	25.3	25.6
As-annealed	N/A	194	379	23.8	24.9
Top Hot Leg, 627°C	-0.13	185	388	21.0	23.2
*Mid. Hot Leg, 595°C	0.04	211	403	23.3	24.9
*Mid. Hot Leg, 501°C	0.08	293	436	19.0	20.6
Bottom Hot Leg, 459°C	0.02	306	465	18.6	20.6
Top Cold Leg, 562°C	0.06	234	392	22.5	23.5
*Mid. Cold Leg, 539°C	0.07	261	401	20.3	22.1
*Mid. Cold Leg, 516°C	0.06	273	405	20.9	21.8
*Mid. Cold Leg, 470°C	0.07	290	433	21.8	23.1
Bottom Cold Leg, 447°C	0.10	287	441	20.1	21.6
800°C Li capsule	-0.04	178	351	25.3	27.3
800°C Li capsule	-0.01	181	358	26.5	28.2
700°C anneal	0.01	220	371	21.9	23.6

*experiments during this period

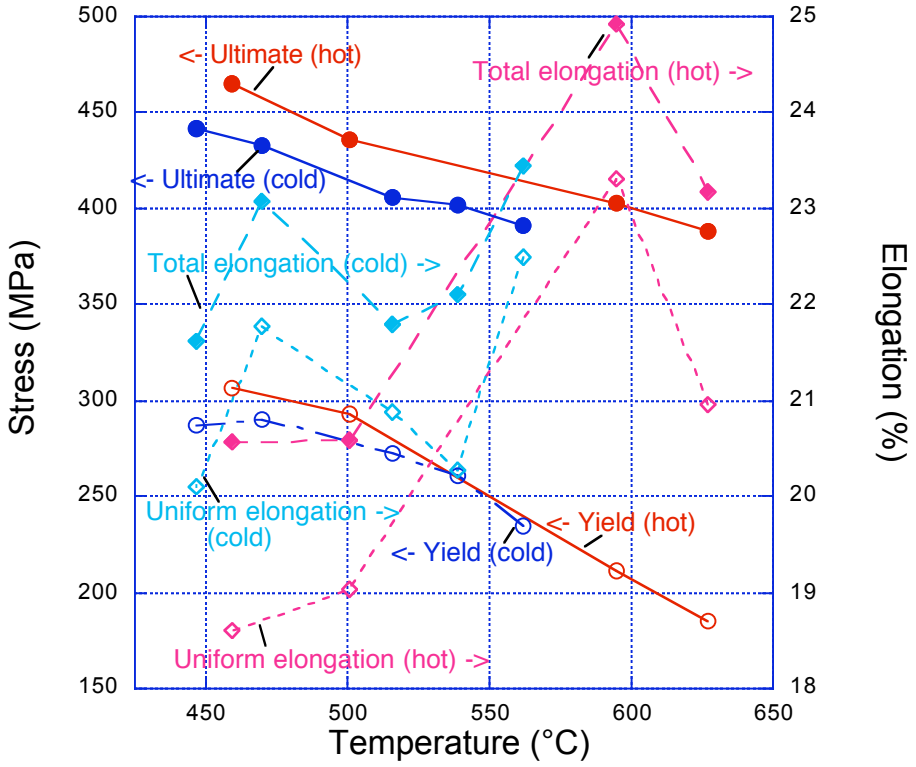

Figure 1. Tensile properties measured at 500°C for the loop-exposed specimens as a function of the calculated average exposure temperature for each specimen.

consistently showed a decrease in the O content and an increase in the C and N contents.[1-4] These changes in interstitial content are expected based on Li thermodynamics of gettering O, but low affinity, compared to vanadium, for C and N. Characterization work is needed to determine how the decrease in O and increase in C and N affected the precipitate composition and distribution.

Prior work with Li exposures at 700° and 800°C conducted in an Ar-filled glove box, nominally allowing some degree of Li contamination during the exposure, showed a much larger decrease in ductility measured at 500°C with exposures as long as 1000h.[5] As a further comparison with this work, Figure 2 shows the effect of loop location on the serrations in the stress-strain curve due to dynamic strain aging (DSA).[6,7] The conventional explanation for DSA is the interaction of dislocations with solute interstitials. Interpreting these results is complicated by the competing reduction in O with the increase in C and N observed in the loop. A complete characterization of the microstructure of these specimens is needed to understand the mechanism.

References

[1] B. A. Pint, DOE/ER-0313/45 (2008) 11.
[2] B. A. Pint, et al., J. Nucl. Mater. 386-388 (2009) 712.
[3] B. A. Pint, et al., DOE/ER-0313/43 (2007) 2.
[4] B. A. Pint, DOE/ER-0313/44 (2008) 10.
[5] M. M. Li, D. T. Hoelzer and M. L. Grossbeck, J. Nucl. Mater. 392 (2009) 364.
[6] T. Nagasaka, T. Muroga, M. M. Li, D. T. Hoelzer, S. J. Zinkle, M. L. Grossbeck and H. Matsui, Fus. Eng. Des., 81 (2006) 307.
[7] A. F. Rowcliffe, S. J. Zinkle and D. T. Hoelzer, J. Nucl. Mater. 283-287 (2000) 508.

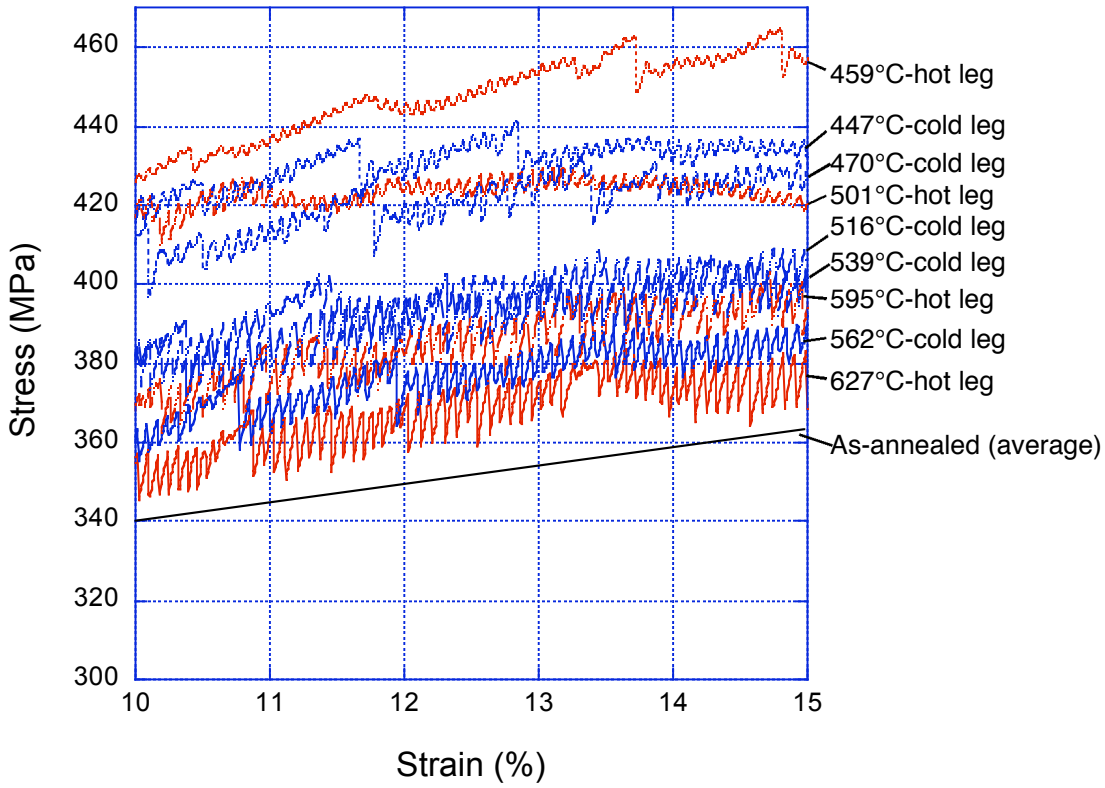

Figure 2. Expanded stress-strain curves of V-4Cr-4Ti specimens evaluated at 500°C in vacuum with a strain rate of $10^{-3}s^{-1}$ to show the dynamic strain aging behavior.