TENSILE PROPERTIES OF 832665 AND 832864 HEATS OF V-4Cr-4Ti ALLOY AT HIGH TEMPERATURES* - H. Tsai, L. J. Nowicki, T. S. Bray, M. C. Billone, D. L. Smith (Argonne National Laboratory) and W. R. Johnson (General Atomics)

Summary

To explore the upper operating limit of vanadium-base alloys, SS-3 tensile specimens were prepared from the 832665 and 832864 heats of V-4Cr-4Ti alloy and tested at temperatures between 600 and 800°C. The results showed the behavior of the two heats to be similar (with the 832864 heat being slightly weaker) and the reduction of strengths with temperature insignificant at least up to 750°C. Ductility for both materials is good in the test temperature range. These findings are largely consistent with previously reported results on these two heats.

Objective

The objective of this task is to determine the high-temperature tensile properties of the 832665 and 832864 heats of V-4Cr-4Ti alloys. The 832665 heat[1] is the "500-kg" heat procured by the U.S. DOE and the 832864 heat[2] is the "1200-kg" heat procured by General Atomics (GA) for the DIII-D radiative divertor upgrade[3].

Background

Susceptibility of vanadium-base alloys to low-temperature embrittlement[4,5,6] during neutron irradiation may limit the application of these alloys in low-temperature (<≈400°C) regimes. To extend the service window, it is necessary to assess the performance of the materials in the high-temperature end, i.e., in the ≈700-800°C range. While the performance at high-temperature may be limited by many factors, including helium effects and creep, adequate tensile properties remain an important consideration.

The tensile properties for the GA's 832864 heat have been measured up to 380°C[7]. Those for the 832665 heat have been measured to 700°C and recently to 800°C[8,9].

Test Specimens

The test specimens for this study were prepared from the 832665 and 832864 heats of V-4Cr-4Ti alloys. The compositions of the two heats are shown in Table 1.

Table 1. Chemical composition of the two alloys investigated

Heat Number	Ingot Size (kg)	Nom. Composition (wt.%)	Interstitial Content (wppm) O	N	C	Si
832665	500	V-3.8Cr-3.9Ti	310	85	80	780
832864	1200	V-3.8Cr-3.8Ti	370	120	30	270

The specimens had nominal gauge dimensions of 0.76 (t) x 1.52 (w) x 7.6 (l) mm. The longitudinal direction was parallel to the final rolling direction of the sheets. The 832665 specimens were cut by electric-discharge machining (EDM) from a cold-rolled sheet with the appropriate thickness. For the 832864 heat, as sheets of the required thickness were not available, EDM was used to slice sheets of the correct thickness from a 4.8-mm-thick plate and then prepare the specimens from the sliced sheets. This method avoided rolling of the plate, thus

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preserving the plate's as-rolled microstructure. (4.8-mm-thick plate is a major product form for the DIII-D application.)

After the machining, all specimens were held in a Ti boat and annealed at 1000°C for 1 h in a vacuum better than 10^{-7} torr.

Experimental Procedure

The tests were performed with the specimens and the test train contained in a quartz tube purged with high-purity argon. An impurity getter made of Ti foil was used to protect the specimen at temperature. Heating was achieved with a radiant furnace and the specimen temperature was indirectly measured with a thermocouple attached to the lower specimen grip. As no extensometer was used, gauge section extension was determined from the crosshead displacement after the slack in the grip and the deformation of the load frame were subtracted. The strain rate for all tests was 1.09×10^{-3}/s, except one, which was conducted at 1.09×10^{-4}/s to investigate strain-rate effects.

Results and Discussion

The results of our tests are summarized in Table 2. For both materials, in the 600-800°C-test range, the maximum strength appears to occur at 700°C. All specimens display substantial ductility, with uniform elongation ranging from 7.4 to 12.3% and total elongation from 15.2 to 20.9%. In comparison, as has been seen before in lower-temperature tests[7], the 832864 heat appears to be slightly weaker than the 832665 heat. Not unexpectedly, the 832864 heat exhibits slightly greater ductility. Serrations in the load curve, due to dynamic strain aging, were observed in both materials only at 600°C. At higher test temperatures, serrations could not be identified. Strain-rate effects at 750°C appear to be slight.

Our results exhibit fairly good agreement against previously reported tensile data, as shown in Figs. 1 and 2. The overall database indicates that degradation of the tensile properties due to high temperatures appears not to be an issue, at least at temperature up to ≈750°C.

Table 2. Summary results of the high-temperature tensile tests

Heat/ Material	Specimen No.	Test Temp.(°C)	Strain Rate (s^{-1})	0.2% OS YS (MPa)	UTS (MPa)	UE (%)	TE (%)
832665	133	600	1.09×10^{-3}	227	413	9.8	18.6
(V-4Cr-4Ti)	134	700	1.09×10^{-3}	238	428	10.6	17.3
	135	750	1.09×10^{-3}	233	395	9.6	18.4
	137	750	1.09×10^{-4}	230	401	7.4	15.8
	136	800	1.09×10^{-3}	217	357	7.8	15.2
832864	114	600	1.09×10^{-3}	199	382	10.0	18.7
(V-4Cr-4Ti)	115	700	1.09×10^{-3}	223	398	12.3	20.9
	116	750	1.09×10^{-3}	174	388	11.5	16.3
	117	800	1.09×10^{-3}	173	350	10.5	16.3

Future Activities

The fracture surface of the specimens will be examined with scanning electron microscopy to delineate the fracture mode and to determine areal reduction.

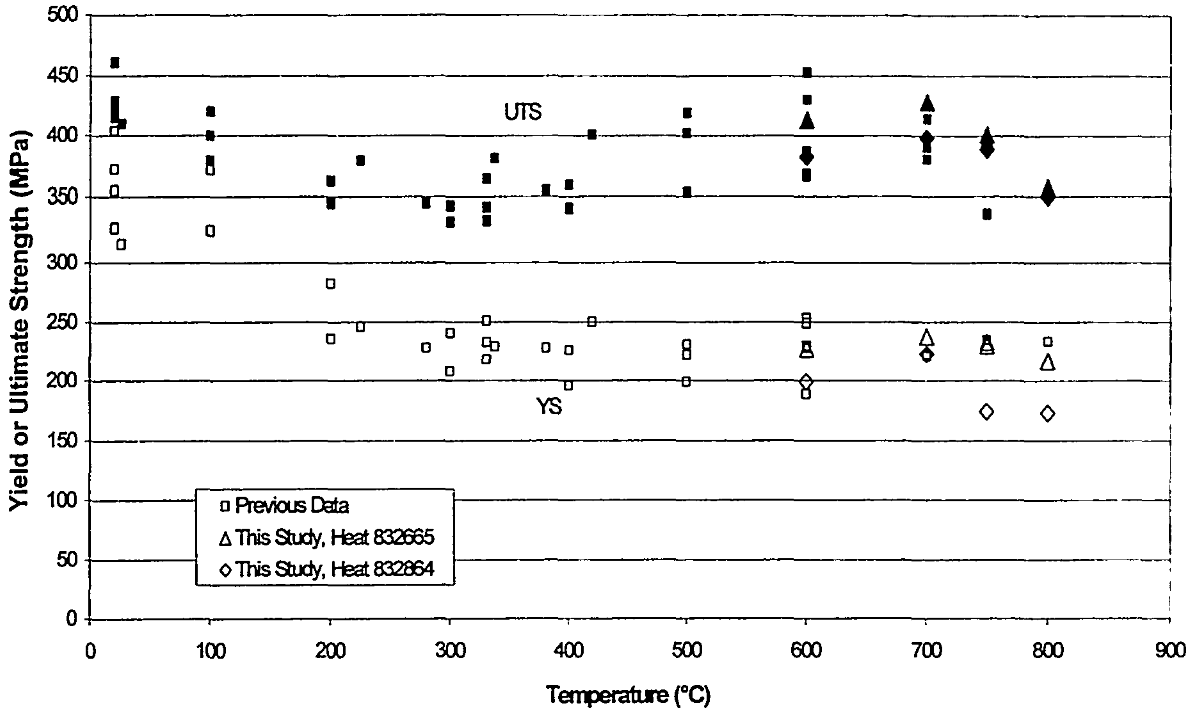

Fig. 1 Comparison of tensile strength of 832665 and 832864 heats with the existing database[7,8,9,10,11,12]. Filled symbols depict ultimate tensile strength and open symbols depict 0.2% offset yield strength.

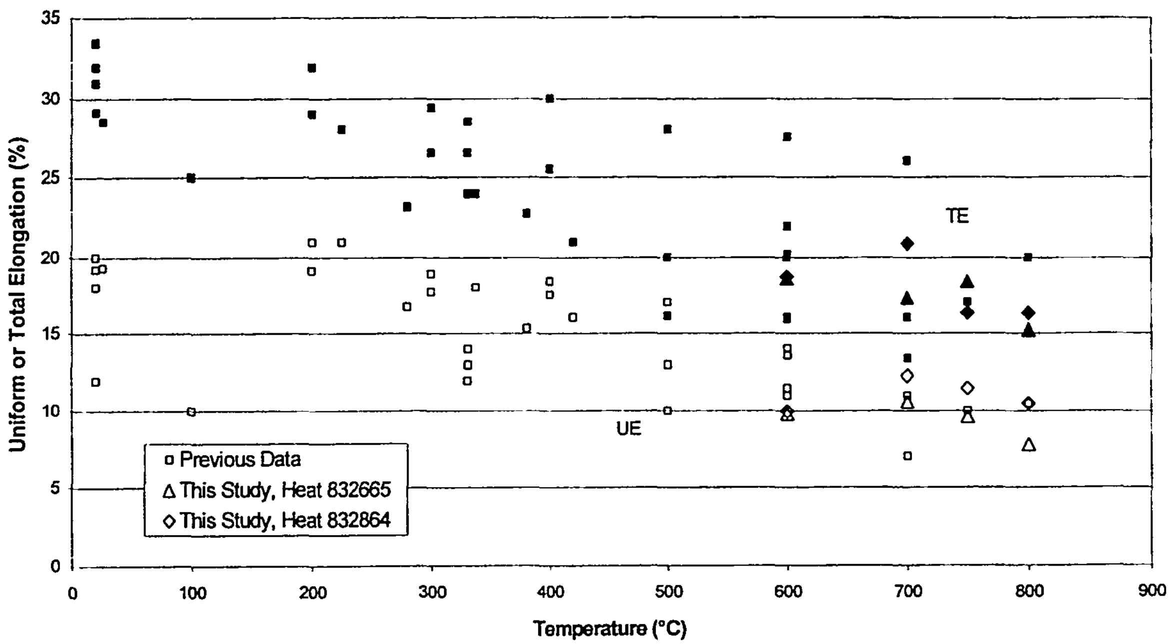

Fig. 2 Comparison of tensile elongation of 832665 and 832864 heats with the existing database[7,8,9,10,11,12]. Filled symbols depict total elongation and open symbols depict uniform elongation.

Acknowledgements

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