EFFECT OF TIME AND TEMPERATURE ON GRAIN SIZE OF V AND V-Cr-Ti ALLOYS*

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OBJECTIVE

The objectives of this task are to evaluate the effect of temperature and exposure time on grain growth kinetics and associated microstructural changes in V, V-4 wt.%Cr-4 wt.%Ti, and V-5 wt.%Cr-5 wt.%Ti alloys and to correlate the information with the long-term mechanical properties of the materials.

SUMMARY

Grain growth studies were conducted to evaluate the effect of time and temperature on the grain size of pure V, V-4 wt.%Cr-4 wt.%Ti, and V-5 wt.%Cr-5 wt.%Ti alloys. The temperatures used in the study were 500, 650, 800, and 1000°C, and exposure times ranged between 100 and ≈5000 h. All three materials exhibited negligible grain growth at 500, 650, and 800°C, even after ≈5000 h. At 1000°C, pure V showed substantial grain growth after only 100 h, and V-4Cr-4Ti showed growth after 2000 h, while V-5Cr-5Ti showed no grain growth after exposure for up to 2000 h.

EXPERIMENTAL PROGRAM

The materials selected for the evaluation included pure V, V-5 wt.%Cr -5 wt.%Ti (designated as BL-63), and V-4 wt.%Cr-4 wt.%Ti (designated as BL-71). Sheet samples of the materials were annealed for 1 h at 1050°C prior to their use in grain growth studies. Coupon specimens measuring ≈15 x 7.5 x 1 mm were enclosed in Vycor capsules in vacuum and exposed at temperatures of 500, 650, 800, and 1000°C for several time periods in the range of 100-5000 h. After exposure, specimen surfaces and cross sections were examined by scanning electron microscopy. The aged specimens were analyzed for grain size with the ASTM/E-112 Intercept procedure.

RESULTS AND DISCUSSION

The grain size of a material and the grain growth rate for the material as a function of temperature and exposure time can influence the mechanical properties of the material, as well as the transport of interstitial elements such as O, C, N, and H. A finer grain size can lead to increased diffusion of interstitials via grain boundaries, with a resultant increase in total concentration of the interstitial elements. On the other hand, grain boundary diffusion of these elements can also result in a fine precipitates of second-phase particles that can pin the grain boundaries and thereby stabilize the microstructure over extended periods of time at temperature.

Figures 1-3 show measured grain size values as a function of exposure time for V, V-4 wt.%Cr-4 wt.%Ti, and V-5 wt.%Cr-5 wt.%Ti alloys after exposure at 500, 650, 800, and 1000°C. The results in Fig. 1 indicate that the initial grain size of the V specimens was ≈120-140 µm and that the grain growth in pure V is negligible at 500, 650, and 800°C for times up to ≈5000 h. The specimen exhibits a substantial grain growth at 1000°C even after 100 h exposure. Even though many grains were examined by the line-intercept method, a significant variation in grain size was noted in the specimens exposed at 1000°C. This is indicative that at some locations, the larger grains gave very few intercepts while in other locations with smaller grains a large number of intercepts was noted. This also reveals the dynamic nature of grain growth at 1000°C, which involves time-dependent dissolution of smaller grains and growth of a few larger grains.

Grain size measurements on the V-4 wt.%Cr-4 wt.%Ti alloy (see Fig. 2) showed virtual absence of grain growth at 500, 650, and 800°C after ≈5000 h. The initial grain size of the alloy was in the range of 18-20 µm and changed little with exposure. At 1000°C, the alloy showed no grain growth after 100 and 600 h but showed an increase to 62-84 µm after 2000 h. Similar measurements made on V-5 wt.%Cr -5 wt.%Ti alloy showed virtually no grain growth under all conditions tested. The specimens are presently being examined by several electron-optical techniques to examine the grain boundary precipitate phases.

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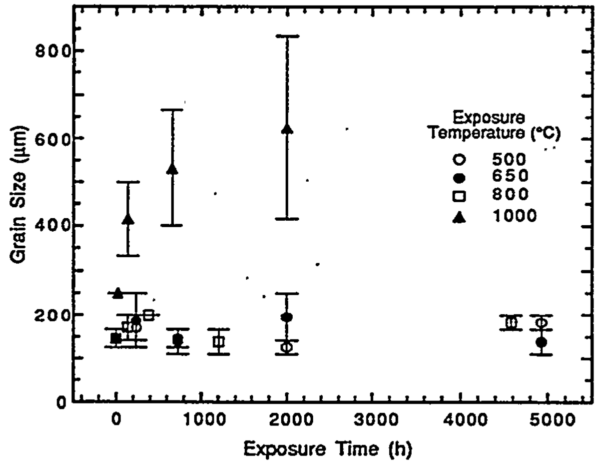

Fig. 1. Grain size variation in pure V as a function of time and temperature

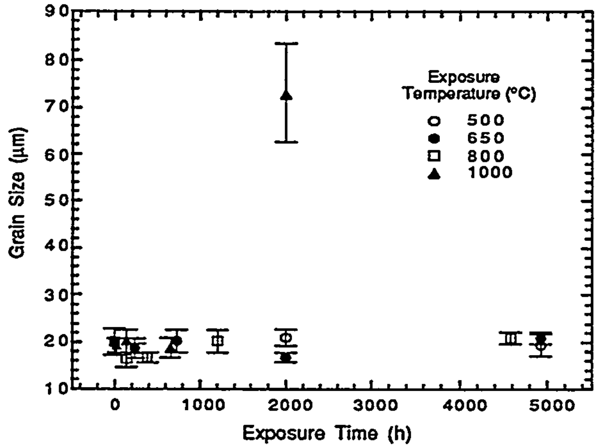

Fig. 2. Grain size variation in V-4 wt.%Cr-4 wt.%Ti alloy as a function of time and temperature

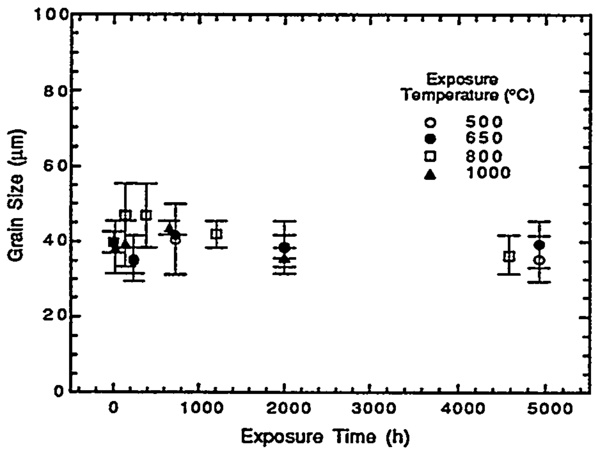

Fig. 3. Grain size variation in V-5 wt.%Cr-5 wt.%Ti alloy as a function of time and temperature