§14. High Temperature Creep Properties of Ultra-Fine Grained, Particle Dispersed V-V-W-TiC Alloys

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Ultra-fined, particle dispersed vanadium (V) alloys exhibited good resistance against neutron irradiation, however, they also exhibited significant decrease in high temperature strength due to grain boundary sliding (GBS). In order to mitigate the detrimental effect of GBS, the authors developed many kinds of nanostructured, solution/dispersion hardened V alloys and found that a V-1.6Y-8W-0.8TiC (wt%) alloy exhibits higher strength up to around 1273K than solution hardened V-4Cr-4Ti alloys. Since the detrimental effect of GBS depends on grain size and may occur more significantly in long-time creep tests than in short-time tensile tests, it is important to study the effects of grain size on the long-time creep behavior of the V-1.6Y-8W-0.8TiC alloy. However, to the authors' knowledge, there are no reports on the creep properties of nanostructured V alloys.

In this study V-1.6Y-8W-0.8TiC specimens with four different grain sizes between 580 and 2160nm were prepared and creep tested at 1073K and 250MPa in a vacuum. It is shown that the creep resistance of V-1.6Y-8W-0.8TiC is significantly improved with increasing grain size. .

An alloy with the composition of V-1.6Y-8W-0.8TiC and relative density of 99.7% was fabricated from commercially available powders of pure V, Y, W and TiC utilizing mechanical alloying (MA) and HIP. The MA treatment was conducted by three mutually perpendicular directions agitation ball milling with vessels and balls made of TZM (Mo-0.5%Ti-0.1%Zr) for 50h in a purified H_2 atmosphere. The MA processed powders were HIPed at 1273K and 200MPa for 3h and the HIPed compact was machined to prepare specimens for transmission electron microscopy (TEM) observations, X-ray diffraction (XRD) analyses and creep tests: The dimensions of the creep specimens were 16mm x 4mmx 0.5mm with the gauge section of 5mm x 1.2mm x 0.5mm. All of the specimens were annealed at 1473, 1573, 1673 and 1773K for 1h in a vacuum. The creep tests were performed at 1073K and 250MPa. It should be noted that the specimens used are in the as-HIPed and annealed states without any plastic working after HIP. The main results obtained are as follows.

1) Dissolution of added W into the V matrix required annealing at and above 1573K. Dispersoids of Y_2O_3, YN and V_2C were newly formed by reaction of solute impurities of O and N with dissolved Y and by reaction of V atoms with solute carbon atoms decomposed from added TiC. The average diameters of grains and size and number density of dispersoids are listed in Table I.

Table I. Average diameters of grains and size and number density of dispersoids for V-1.6Y-8W-0.8TiC.

Anneal temp. (K)	Grain size (nm)	Particle size (nm)	Number density (m^{-3})
1473	583	56	2×10^{22}
1573	898	83	3×10^{21}
1673	1445	91	2×10^{21}
1773	2156	95	8×10^{20}

2) The creep resistance of V-1.6Y-8W-0.8TiC depends strongly on grain size and increases with increasing grain size. The specimen with 1.5 μm in grain size exhibits a creep life of 34-64 hours, which is approximately one order higher than that with 583nm in grain size (Fig.1). The creep life is also significantly higher than that of V-4Cr-4Ti (NIFS-Heat 2; 17.8μm), 0.5h.

3) The transient behavior occurs from the short, initially high strain rate region towards the long, minimum strain rate region. The initial strain rates increases with increasing grain size, suggesting that the creep in the initial region occurs by dislocation glide. The initial creep by the dislocation glide ceases by strain hardening and the creep deformation resumes by GBS prior to the steady state creep region.

4) The steady state creep rate decreases with increasing grain size and tends to saturate as the grain size exceeds around 1.0 μm. The steady state length and creep life monotonically increase with grain size.

5) The steady state creep of V-1.6Y-8W-0.8TiC mainly occurs by GBS, whereas that of V-4Cr-4Ti occurs mainly by dislocation glide with much higher creep rates. This can be attributed to less hardening by solutioning and dispersioning in V-4Cr-4Ti than in V-1.6Y-8W-0.8TiC.

6) The microstructures of V-1.6Y-8W-0.8TiC with solute W and dispersoids of Y_2O_3, YN and TiC and grain size exceeding 1.0~1.5μm are sufficiently capable of suppressing creep deformation by dislocation glide and GBS at 1073K and 250MPa.

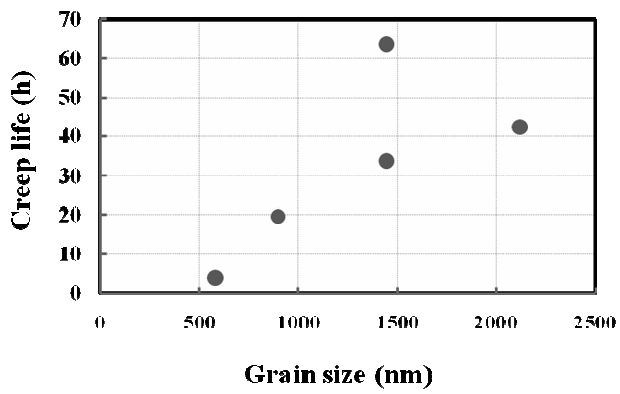

Fig.1 Grain size dependence of creep life for V-1.6Y-8W-0.8TiC tested at 1073K and 250MPa.