§18. Effect of Yttrium Addition on Mechanical Properties of V-4Cr-4Ti Alloys Contaminated with Oxygen

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Mechanical behavior of V-4Cr-4Ti alloys is strongly influenced by solid solution hardening due to the interstitial oxygen (O) impurities, which are possible contaminant during the fabrication process and under the operation condition. Reduction of interstitial O content improves mechanical properties of V-4Cr-4Ti alloys. It has been clarified that yttrium (Y) addition is effective for the reduction in O content by Y_2O_3 slag-out on the melting ingot surface.[1] The present study seeks the effect of Y addition on mechanical properties of V-4Cr-4Ti alloys contaminated with O.

Figure 1 shows the dependence of yield stress (YS) and ultimate tensile strength (UTS) on O content. YS and UTS for pure vanadium were also plotted for comparison.[2] D.L. Harrod and R.E. Gold have reported that YS and UTS for pure vanadium linearly increased with increasing O content in this range. The hardening coefficient per unit O content was 1900 MPa/mass%. Because precipitates due to O doping were not observed in microstructure for pure vanadium, the hardening for pure vanadium was caused by solid solution hardening by interstitial O. The dependence of YS and UTS for V-4Cr-4Ti alloys on O content indicated similar to that for V-4Cr-4Ti-Y alloys. There was little effect of Y addition on YS and UTS of V-4Cr-4Ti alloys. YS and UTS for the vanadium alloys linearly increased with increasing O content up to 0.1 mass%. The hardening coefficient was 680 MPa/mass%, which was much smaller than that for the pure vanadium. YS and UTS for the vanadium alloys did not increase above 0.1 mass% in O content because Ti precipitates are increased with increasing it regardless of Y addition.[3]

Figure 2 plots absorbed energy at the temperatures from -196 °C to RT. The energy is normalized by the specimen width (B = 1.5 mm) and the ligament size (b = 1.2 mm). In the present study, ductile-to-brittle transition temperature (DBTT) is defined as the temperature where the absorbed energy is half the upper-shelf energy (USE). DBTTs for the alloys except for V-4Cr-4Ti-0.12O alloy were below -196 °C. The data for V-4Cr-4Ti-0.12O alloy were not enough to determine USE for the alloy. Assuming the USE is similar to the other alloys, 0.4 J/mm^3, DBTT for V-4Cr-4Ti-0.12O alloy was around -50 °C. Fig.3 shows load-displacement curves at around -50 °C for V-4Cr-4Ti-Y-0.27O and V-4Cr-4Ti-0.12O alloys. There was no difference between YS at around -50 °C for these alloys. Crack initiation for V-4Cr-4Ti-Y-0.27O alloy occurred at 4 mm in displacement, while that for V-4Cr-4Ti-0.12O alloy occurred at 2 mm. In these alloys doped with high O, the displacement for the crack initiation was increased by Y addition.

The increase in YS and UTS for vanadium alloys was saturated above 0.1 mass% in O content, because Ti precipitates are increased with increasing O content regardless of Y addition. There was little effect of Y addition on YS and UTS of V-4Cr-4Ti alloys. On the other hand, Y addition improved impact properties of the alloys highly doped with O. Y addition did not suppress the hardening due to O doping, but increased the deformation for the crack initiation.

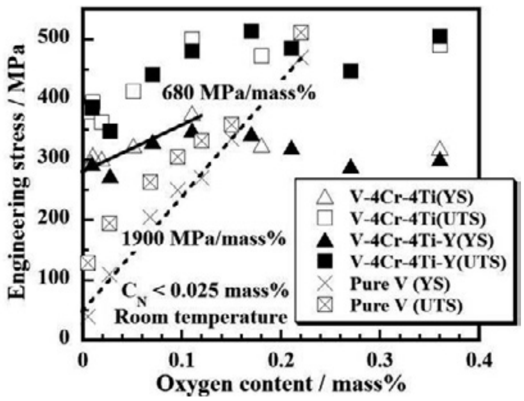

Fig. 1. Dependence of YS and UTS on O content.

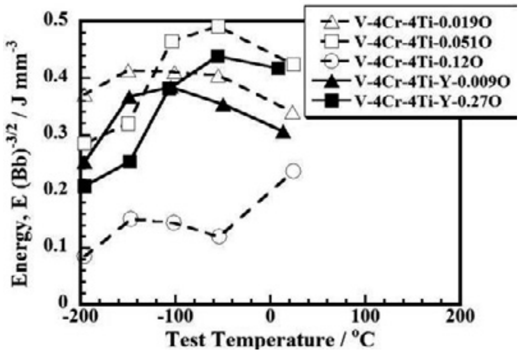

Fig. 2. Absorbed energy in the Charpy impact tests.

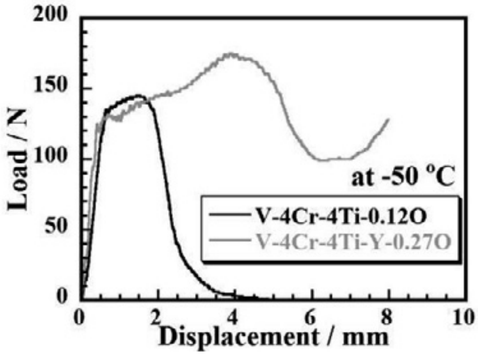

Fig. 3. Load-displacement curves at around -50 °C for V-4Cr-4Ti-Y-0.27O and V-4Cr-4Ti-0.12O alloys.

1) Nagasaka, T. et al. : J. Nucl. Mater., **367** (2007) 823.
2) Harrod, D.L. et al. : International Metals Reviews, **25** (1980) 163.
3) Miyazawa, T. et al. : J. Nucl. Mater., (2013).