§13. Tensile and Impact Properties of High-Chromium V-$_x$Cr-4Ti-0.15Y Alloys

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V-4Cr-4Ti-0.15Y alloy has exhibited a reduction of irradiation hardening and an improvement of ductility in tensile tests after neutron irradiation around 400 °C [1]. However, V-4Cr-4Ti-0.15Y alloy has also exhibited a reduction of high-temperature strength due to the reduction in interstitial impurities by the scavenging effect of Y [2]. Increasing Cr content relative to V-4Cr-4Ti-0.15Y alloy is considered to be an effective method in order to compensate for the reduction of high-temperature strength. However, excess Cr addition can lead to loss of ductility and degradation of workability [3]. The influence of the interstitial impurities on the Cr effects is not known. In this study, V-*x*Cr-4Ti-0.15Y alloys with high-Cr contents are fabricated in order to improve the impact properties of V-*x*Cr-4Ti alloys without degrading the high-temperature strength. A combined effect of purification and Y addition is investigated by the evaluation of tensile properties and impact properties.

Figures 1 shows the dependence of tensile strength on test temperatures. Tensile strength for V-*x*Cr-4Ti-0.15Y alloys increased with increasing Cr content. Between 600 to 700 °C, UTS for V-4Cr-4Ti alloy remained almost constant, while that for V-*x*Cr-4Ti-0.15Y alloys decreased. V-10Cr-4Ti-0.15Y alloy has UTS at 700 °C approximately equal to that of V-4Cr-4Ti alloy.

Figure 2 shows absorbed energies from -196 °C to room temperature (RT). These energies are normalized by specimen width (B = 1.5 mm) and 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 of the upper-shelf energy (USE). DBTTs for V-4Cr-4Ti and V-4Cr-4Ti-0.15Y alloys were below -196 °C. DBTTs for V-6Cr-4Ti-0.15Y and V-10Cr-4Ti-0.15Y alloys were estimated as -194 and -130 °C, respectively. Figure 3 summarizes the dependence of DBTT for V-*x*Cr-(4-5)Ti and V-*x*Cr-4Ti-0.15Y alloys on Cr content [3, 4]. V-10Cr-4Ti-0.15Y alloy has lower DBTT than those of V-*x*Cr-(4-5)Ti alloys with x > 9 wt.%. It seems that the factors contributing to DBTT are not only the solution hardening of Cr but also the difference in precipitation behavior. Sakai et al. [3] clarified that high DBTTs of V-*x*Cr-4Ti alloys with x > 10 wt.% were caused by high flow stress due to solution hardening of Cr, and by initiation of crack formation due to the large Ti-rich precipitates. The contamination of gaseous impurities such as O may result in the formation of the large Ti-rich precipitates to act as crack initiation sites. Therefore, the reasons for favorable impact properties of V-10Cr-4Ti-0.15Y alloy are considered to be as follows: (1) The purification could suppress the formation of the large Ti-rich precipitates because V-*x*Cr-4Ti-0.15Y alloys examined in this study have low level of C, O and N content. (2) The formation of Y_2O_3 inclusions during the melting process could further reduce O content in the matrix, and then suppress the formation of the large Ti-rich precipitates.

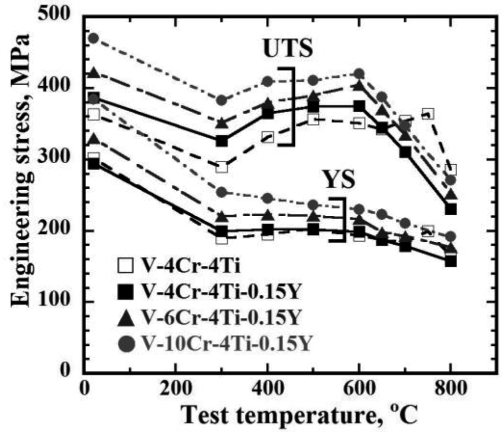

Fig. 1. Dependence of yield stress (YS) and ultimate tensile strength (UTS) on test temperatures.

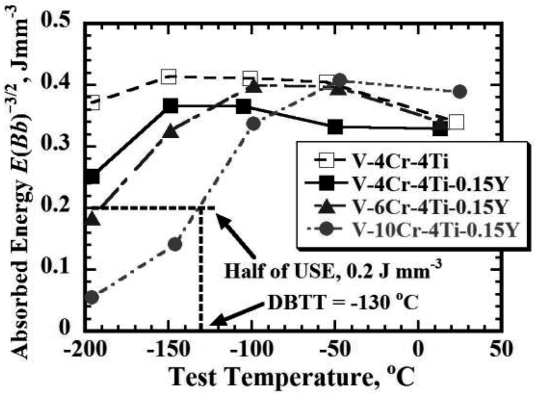

Fig. 2. Absorbed energies in the Charpy impact tests.

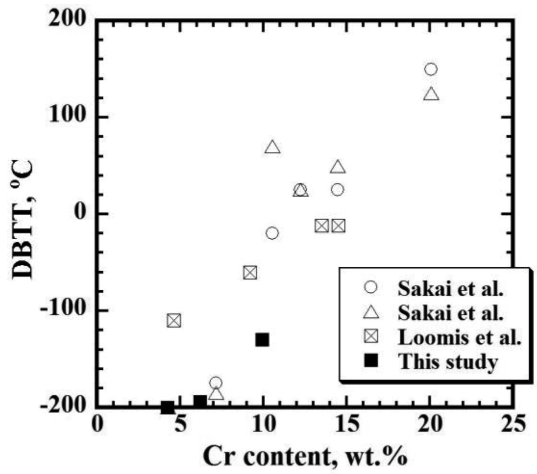

Fig. 3. Dependence of DBTT for V-*x*Cr-(4-5)Ti and V-*x*Cr-4Ti-0.15Y alloys on Cr content. Open circles and triangles represent V-*x*Cr-4Ti alloys annealed to obtain a mean grain size of 17 μm, and at 950 °C, respectively [3]. Open squares with cross represent V-*x*Cr-5Ti alloys annealed at 1125 °C [4]. Closed squares represent V-*x*Cr-4Ti-0.15Y alloys annealed at 950 °C (this study).

1) Satou, M. et al: J. Nucl. Mater. **283** (2000) 367.
2) Miyazawa, T. et al.: J. Nucl. Mater. **442** (2013) S341.
3) Sakai, K. et al.: J. Nucl. Mater. **329** (2004) 457.
4) Loomis, B.A. et al.: J. Nucl. Mater. **212** (1994) 799.