§18. The Effect of Yttrium Addition on Deformation Behavior of V-4Cr-4Ti

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V-4Cr-4Ti alloy is recognized as attractive blanket structural materials for fusion reactor systems because it exhibits low neutron-induced activation, high-temperature strength and high-thermal stress factor required for high-temperature system. The mechanical behavior of the V-4Cr-4Ti alloy and of BCC alloys is strongly influenced by interstitial carbon (C), nitrogen (N) and oxygen (O).[1)] It is widely recognized that reduction of these impurities is essential for maintaining workability and weldability.[2)] It has been reported that small addition of yttrium (Y) was effective to reduce interstitial O and improve ductility after neutron irradiation without degradation of low-temperature impact properties.[3)] While Y addition moderates the hardening induced by O impurity, it can also degrade high-temperature strength.[4)] The deformation behavior of V-4Cr-4Ti alloy during tensile test typically at temperatures ranging from 300 to 750 °C was shown to exhibit dynamic strain aging (DSA), which is manifested by oscillations in the flow stress on stress-strain curve (serrations). The formation of solute atmosphere (Cottrell atmospheres) composed of interstitial C, N and O at locked dislocations results in DSA. DSA, therefore, maintains material strength at high temperature. From 700 °C, Y addition suppressed DSA and started to reduce ultimate tensile strength.[4)] The purpose of this study is to obtain the mechanism of Y influence on DSA by systematic characterization of the tensile properties and microstructures, and kinetic analyses.

Figure 1 shows diagrams for DSA regime for V-4Cr-4Ti-0.019O and V-4Cr-4Ti-Y-0.009O as a function of strain rate and temperature. Serrations were observed at a moderate temperature and a certain strain rate region, where temperature and strain rate can correspond to the diffusion speed of solute atoms, v_i, and dislocation velocity, v_d, respectively. When $v_i > v_d$, solute atoms can interact with dislocations and then serrations appear in the work hardening regimes of the stress-strain curves which is indicated as DSA regime in the diagram. In low-temperature and high-strain rate region, serrations did not appear because $v_i < v_d$. Serrations disappeared at high-temperature region because solute atoms cannot exist around dislocation due to thermal detrapping.

It must be noted that there is a difference in DSA regime between V-4Cr-4Ti-0.019O and V-4Cr-4Ti-Y-0.009O for high-temperature limit where serrations disappear. Serrations for V-4Cr-4Ti-0.019O appeared at higher temperature than those for V-4Cr-4Ti-Y-0.009O. DSA regime was narrowed by Y addition.

Dynamic strain aging is induced by the diffusion of solute atoms, especially interstitial O in vanadium,[5)] to dislocations to form Cottrell atmospheres that become barriers to dislocation migration during plastic deformation. The reduction of interstitial O weakens DSA effect so is considered to narrow DSA regime. Figure 1 shows the reduction of DSA regime by Y addition. In the case of V-4Cr-4Ti-Y-0.009O, the formation of Y-oxide (Y_2O_3) decreases interstitial O further due to stronger affinity between Y and O. Therefore, DSA regime was narrowed.

Dynamic strain aging regime was narrowed by Y addition. Serrations were suppressed due to the reduction in interstitial oxygen content in the matrix caused by the enhanced precipitation.

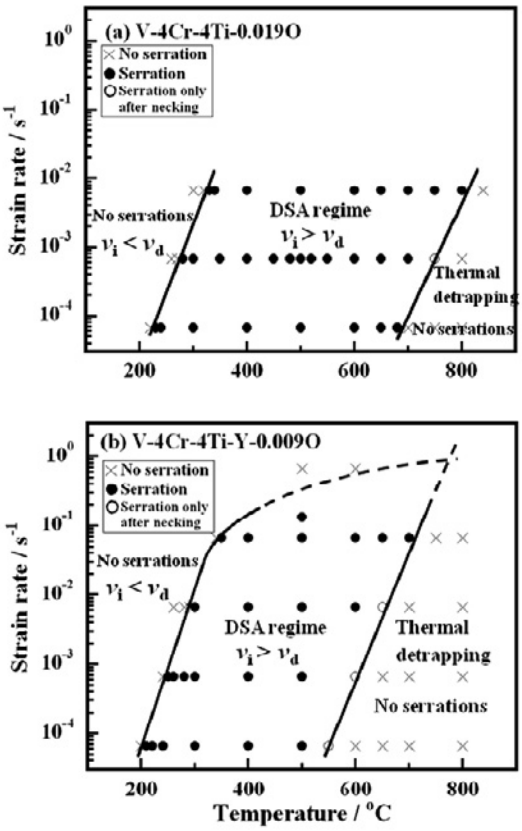

Fig. 1. DSA regime for (a) V-4Cr-4Ti-0.019O and (b) V-4Cr-4Ti-Y-0.009O. Crosses show data of smooth curve which has no serrations. Closed circles show data of serrated curve which has serrations. Open circles show data of serrated curve which has serrations only after necking.

1) Nagasaka, T. et al. : J. Nucl. Mater., **283-287** (2000) 816.

2) Grossbeck, M.L. et al. : J. Nucl. Mater., **258-263** (1998) 1369.

3) Satou, M. et al. : J. Nucl. Mater., **283-287** (2000) 367.

4) Miyazawa, T. et al. : Fusion Sci. Technol., **60** (2011) 407.

5) Koyama, M. et al. : J. Nucl. Mater., **329-333** (2004) 442.