§4. Mechanical Property of Highly-purified Vanadium Alloys at High Temperatures

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Vanadium alloys are candidate materials for fusion reactor blanket structural materials because of their potentially high operation temperatures. However the knowledge about the mechanical property of vanadium alloys at high temperatures is limited and there are uncertainties that may have influenced the results such as the interstitial impurity content of specimens. The first objective of this study is to investigate the creep properties of the high-purified V-4Cr-4Ti alloys, NIFS-HEAT1 [1]. The second objective is to investigate the effect of chromium addition and impurity effect for creep property by using V-10Cr-5Ti alloys and high purification method due to Zr-treatment.

The V-4Cr-4Ti alloy used in this study was produced by NIFS and Taiyo Koko Co. and designated as the NIFS-HEAT1 [1]. The interstitial impurity concentrations in this alloy were approximately 180 wppm O, 70 wppm N and 60 wppm C. An ingot of V-10Cr-5Ti was prepared by the arc-melting and the impurity levels are 450 wppm O, 18 wppm N and 6 wppm C. The annealing conditions are 1000°C for 2 hrs and 1100°C for 2hrs, for NIFS-Heat1 and V-10Cr-5Ti, respectively. In order to reduce impurity concentration in vanadium alloys, a zirconium foil gettering treatment (Zr-treatment) was employed. The sheet of a specimen with a thickness of about 1 mm was wrapped with zirconium foils and rolled together at one time passing in roll. The specimen was stuck with zirconium foils tightly. The sandwiched specimens between zirconium were annealed at 1100°C for 2hrs in vacuum. After annealing, the layer of zirconium was removed by chemical polishing. The tensile specimens were punched out from the sheet and annealed at 600°C in 1hr in order to remove incursion of hydrogen during chemical polishing [2]. A study of the uniaxial thermal creep property of V-4Cr-4Ti is being performed using miniature-sized tensile specimens, 16x4x0.25mm. Specimens are being tested at 700, 750 and 800°C with stress levels ranging from 150 to 200 MPa in a high vacuum furnace, $<1x10^{-5}$Pa. The minimum creep strain rate and rupture time are obtained from the creep tests. After the creep rupture, the microstructural and fractographic analyses are done using TEM and SEM.

Creep test data of NIFS-HEAT1 showed a power-law creep behavior with a stress exponent of 5.5-8 and activation energy of 185-211kJ/mol. TEM observations of creep specimens were performed. Sub-boundaries and cell structures were seen from an early stage of steady-state creep regime and developed into larger cell structures as creep time increases. It is suggested that the deformation mode of creep is dislocation glide creep of pure metals.

Figure 1 shows the stress dependence of creep strain rate for NIFS-Heat1 and V-10Cr-5Ti alloys with or without Zr-treatment. Compared the creep behavior of NIFS-Heat1 with that of V-10Cr-5Ti alloys at a same creep condition; the creep strain rate of V-10Cr-5Ti alloy is lower than that of the NIFS-Heat1. The chromium addition in V-Ti alloys is significantly effective for the increase of creep strength. On the contrary, the highly-purified NIFS-Heat1 and V-10Cr-5Ti alloys by Zr-treatment show the higher creep strain rate than the alloys treated by the conventional heat treatment. From the TEM observation, the precipitates of titanium oxides disappeared in the matrix and on grain boundaries in the highly-purified V-10Cr-5Ti alloys. And also, the serration behaviors on the plastic flow of stress-strain curves during the tensile tests at the temperature regime from 500 to 700°C were eliminated in the highly-purified NIFS-Heat1. It is very difficult to form the precipitates in V-Cr-Ti alloys with the impurity levels of a few ten wppm, and even the impurity atoms in solution do not play a role as hardeners for the highly-purified V-Cr-Ti alloys. In order to improve the creep property in V-Cr-Ti alloys, not only the chromium addition into bulk but also the reduction of impurity from bulk materials should be considered at a time. From the result of Larson-Miller plot for NIFS-Heat1 and V-10Cr-5Ti alloys, the same understandings are also obtained that the reduction of impurity level makes the creep properties of the V-Cr-Ti alloys worsened and the high chromium addition makes them strengthened. It is necessary to find out the optimum composition of both the chromium addition levels and impurity contents in V-Cr-Ti alloys in order to improve both the mechanical properties at elevated temperatures and the irradiation enbrittlement at low temperatures.

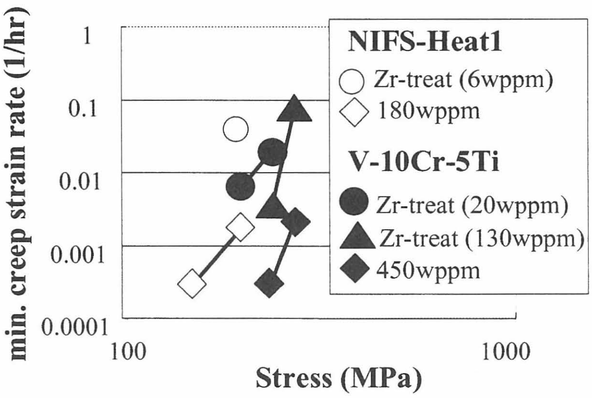

Fig.1: Stress dependence of creep strain rate in the NIFS-Heat1 and V-10Cr-15Ti alloys tested at 800°C.

Reference

[1] Muroga,T., et al., J. Nucl. Mater. 283-287 (2000) 711

[2] Fukumoto, K., et al., J. Nucl. Mater. 283-287 (2000) 535