§13. Overall Characterization of High Purity Reference Vanadium Alloys NIFS-HEATs

Satou, M., Abe, K., Hino, T. (Tohoku Univ.)
Nagasaka, T., Muroga, T.

Vanadium alloy is metallic and nonmagnetic material among the prime candidates for fusion rector first wall application, yet luck of industrial background that include large-heat productivity and fabricability was weakness form viewpoints of material developments. Successful production of high purity reference vanadium alloys known as NIFS-HEATs alloy demonstrates its capability for large production and provides an opportunity to carry out round-robin tests and full size industrial standard tests. Research activities in each organization were also utilized for overall characterization of the vanadium alloy for fusion applications. Basic physical properties, workability, weldability, interaction with gaseous elements, defects production after irradiation, mechanical properties, compatibility, joining or coating with ceramics materials, etc. were studied. Guideline for the alloy development was discussed in this collaboration study based on individual research results.

Since mechanical properties of the V-Cr-Ti type alloy depend on interstitial impurity levels, controlling the interstitial elements is a key for the alloy development. Initial impurity levels can be reduced by modification of melting process as NIFS-HEATs. Further modification of the high purity Vanadium alloy is possible by means of a small addition of chemically reactive elements such as yttrium. In this report, tensile and Charpy impact properties of a series of V-4Cr-4Ti-xY alloys are briefly described.

The alloys used in this work were V-4Cr-4Ti-0.1Y, V-4Cr-4Ti-0.2Y, V-4Cr-4Ti-0.3Y and V-4Cr-4Ti-0.5Y (nominal weight percentage) fabricated by levitation melting method. Miniaturized specimens annealed at 950 °C for 3.6ks were used. Tensile tests were carried out using an INSTRON-type machine with an external cooling bath at strain rates of $6.7x10^{-4}$ to $x10^{-2}s^{-1}$. Charpy impact tests were carried out using an instrumented machine at the Oarai Branch, Institute for Materials Research, Tohoku University. Test temperatures were from ambient and to liquid nitrogen temperature. After these testing, specimens were examined by scanning electron microscopy in order to characterize the fracture surface.

The alloys showed fairly good ductility and tensile strength even in liquid nitrogen temperature. Little dependence of the levels of yttrium contents on the tensile properties was shown. The only difference was reduction in area became the smallest and the size of dimples observed in the fracture surface became the largest in the V-4Cr-4Ti-0.5Y alloy tested with strain rate of $6.7x10^{-2}s^{-1}$ at liquid nitrogen temperature. From these results with higher strain rate deformation at low temperature, yttrium oxide that perhaps exists as inclusions might be starting point of the fracture.

Figure 1 shows the test temperature dependence of absorbed energy for the V-4Cr-4Ti-Y alloys measured by instrumented Charpy impact test. Absorbed energy, E, was normalized by size parameter of the specimen using a following equation:

$$E = E_{obs.} / Bb^2$$

, where $E_{obs.}$ is the observed value of absorbed energy, B is the width and b is the ligament size (= thickness - notch depth) of the specimen, respectively. The DBTTs of the alloys are as low as -150°C. The alloys of V-4Cr-4Ti-0.1Y and V-4Cr-4Ti-0.2Y show higher upper shelf energy (USE) compared to the alloys V-4Cr-4Ti-0.3Y and V-4Cr-4Ti-0.5Y. NIFS-HEATs showed a little higher USE than the V-4Cr-4Ti-0.1Y alloy as 0.5 J/mm^3 at -196°C. The dependence of the levels of yttrium contents on the USE may indicate heterogeneous distribution of yttrium as precipitates. To clarify and to control the distribution of yttrium is a key issue to understand the properties of the alloys even though the most of them considered to be distributed as nano-size precipitates.

The amount of yttrium contents has the optimum between 0.1 and 0.2 weight percents so far from the Charpy impact properties. The characterization of the alloys from other viewpoints such as irradiation behavior and weldability of the V-Cr-Ti type alloy with small addition of Si, Al and Y are under way compared to the NIFS-HEATs.

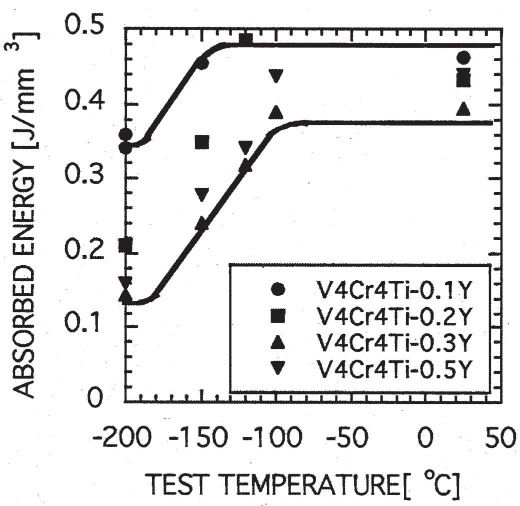

Fig. 1 Comparison of impact properties for the V-4Cr-4Ti-Y alloys, containing various levels of Y.