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

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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, that include irradiation 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 properties after neutron irradiation of a series of V-4Cr-4Ti-Si-Al-Y alloys are briefly described.

The alloys used in this work were V-4Cr-4Ti-0.1Si-0.1Al-0.1Y alloy and V-4Cr-4Ti-0.1Si-0.1Al-0.3Y alloy (nominal weight percentage) fabricated by a levitation melting method and V-4Cr-4Ti alloy (NIFS-HEAT). Miniaturized tensile specimens annealed at 900 ^{o}C for 3.6ks were used. Tensile tests at ambient temperature were carried out using an Instron-type machine with strain rate of $6.7 x 10^{-4} s^{-1}$ at the Oarai Branch, Institute for Materials Research, Tohoku University. The specimens were irradiated in MNTR capsules with purified sodium bond at JOYO. Irradiation temperature was 450 ^{o}C. Neutron fluences were $2.5 \times 10^{21} n/cm^2$ and $1.1 x 10^{22}$ n/cm^2 corresponding to 1.7 and 7.4 dpa(displacements per atom) for vanadium, respectively.

Figure 1 shows typical stress-strain curves of the specimens after irradiation. All of the specimen show fairly good ductility. In case of V-4Cr-4Ti-Si-Al-Y type alloys, the uniform elongation of the specimens irradiated to 1.7 and 7.4 dpa were 15 and 13.8 %, respectively.

The yield stress of the V-4Cr-4Ti-Si-Al-Y type alloys was about 530MPa, while that of the V-4Cr-4Ti alloy was 625MPa at the lower fluence irradiation condition. Work hardening rate of the V-4Cr-4Ti-Si-Al-Y type alloys was larger than that of the V-4Cr-4Ti alloy. The differences probably represent the scavenging effects of the interstitial impurities by small amounts of the additives.

The difference of the yield stress became negligible at the higher fluence condition. The ultimate tensile strength of the V-4Cr-4Ti-0.1Si-0.1Al-0.1Y alloy was the largest 730MPa, while the others were about 700MPa. It is possible that the differences correspond to microstructure evolution during irradiation, such as irradiation enhanced precipitates.

The amount of yttrium contents had the optimum between 0.1 and 0.2 weight percents so far from the Charpy impact properties before neutron irradiation. The present results of the irradiation behavior of the V-Cr-Ti type alloy may lead slightly different optimum composition from previously reported. More detailed examination including the Charpy impact test after neutron irradiation and microstructure observation will soon be carried out.

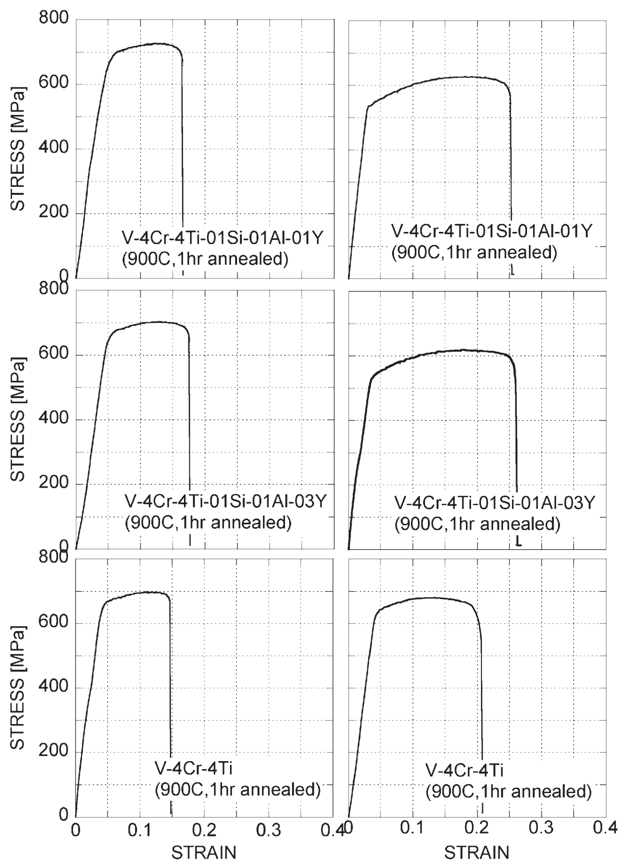

Fig. 1 Typical stress-strain curves for the V-4Cr-4Ti-type alloys after neutron irradiation at 450^{o}C to the fluences of $1.1 x 10^{22}$ (left column) and $2.5 x 10^{21}$ (right column) (n/cm^2, En>0.1MeV).