Development of Fabrication Technology for Low Activation Vanadium Alloys as Fusion Blanket Structural Materials

High purity vanadium alloy products including laser weld joints and pressurized creep tubes were fabricated from the reference high-purity V-4Cr-4Ti ingots designated as NIFS-HEAT. Control of impurities such as C, N, O was the key to maintaining the good mechanical properties of the products.

Vanadium alloys are promising candidates for fusion blanket structural materials, because of their low activation property, high temperature strength and high resistance to neutron irradiation. In the development of the alloy for fusion blanket application, joining and tubing are the key necessary technologies. Joining and tubing technologies are also crucial for fabricating Pressurized Creep Tubes (PCTs), which are the only available means to evaluate creep deformation during irradiation. Coating with W is thought to be necessary for application to fusion first wall for the purpose of protecting the wall of vanadium alloy from heat and particle loadings originated from the core plasma. Japanese Universities and National Institute for Fusion Science (NIFS) have a collaboration program for producing high purity reference heat of V-4Cr-4Ti alloy (NIFS-HEAT) [1]. After production of the ingot, collaboration activities were promoted for fabricating various products and characterizing the alloys and the products including irradiation tests. In this program, plates, sheets, wires and tubes were fabricated. Also carried out was the production of W-coating, laser weld joints and pressurized creep tubes. The products were exhibited in Fig. 1. Part of the achievement of this program was reported in Ref. [2].

The common key issue in the fabrications is the control of impurities such as C, N and O. The increase in the level of C, N and O is known to degrade the ductility of the alloy. The mechanical properties of the products were improved significantly not only by reducing the impurity levels of C, N and O, but also by controlling density, size and distribution of the Ti-C, N, O precipitates. In the laser weld joining, atmospheric control of the welding area was essential. Also important was the post-weld heat treatment, which can cause redistribution of the impurities introduced during the welding and the Ti-C, N, O precipitates. For the tubing, vacuum level and prior surface cleaning at the intermediate heat treatments were crucial.

Because the size, density and distribution of Ti-C, N, O precipitates influence strongly the mechanical properties, efforts were made to increase the high temperature strength by distributing high density of fine Ti-C, N, O precipitates in the matrix by series of controlled heat treatments. In addition to the increase in the Yield and Ultimate Tensile Strength, increase in thermal creep resistance was derived by the fine precipitation.

Through the production of PCTs, technology for small scale welding with controlling the grain size was enhanced [3]. The PCTs fabricated are being used for characterizing thermal and irradiation creep properties in JOYO and HFIR reactors. Recent results showed that the consistency of the data was much better than those obtained using the PCTs fabricated previously.

The present achievements enhanced coordination for promoting international collaboration on developing vanadium alloy-based test blanket modules to be installed into International Thermonuclear Experimental Reactor (ITER).

References

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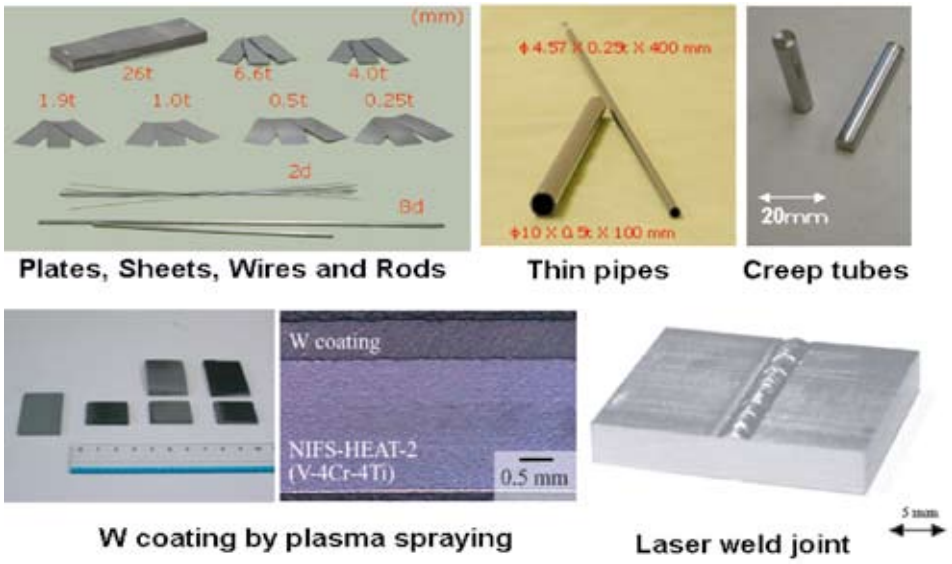

Fig. 1 Collection of the products of high purity V-4Cr-4Ti alloy.