§1. Development of Manufacturing Technology for High Purity Low Activation Vanadium Alloys

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Vanadium alloys are promising candidate fusion structural materials because of their low activation properties, high temperature strength, good resistance against neutron irradiation and excellent compatibility with liquid Li. However, establishment of industrial infrastructure is remaining to be a critical issue for vanadium alloys, because of lack of other large scale commercial application. Recent studies on vanadium alloys showed that the increase in interstitial impurities such as carbon, nitrogen and oxygen results in loss of workability, degradation of weldability and enhanced radiation embrittlement at relatively low temperature. Thus, in the development of technology for large-scale production of vanadium alloys, suppression of the impurity levels is essential. National Institute for Fusion Science (NIFS) is promoting a program for large scale manufacturing of a V-4Cr-4Ti alloy by collaboration with Japanese industry. This paper is an overview of the results obtained in the program.

In this program, carbon and nitrogen levels of the present commercial metal vanadium were reduced by improving the manufacturing processes. Particular efforts were made for inhibiting nitrogen pick-up during the calcination and the aluminothermic reduction in the processes. By this improvement, carbon and nitrogen levels were reduced from ~300 to ~100ppm and from 400-700ppm to ~100ppm, respectively.

Alloying technologies were investigated and improvements were made in the present Vacuum Arc Remelting (VAR) technique for further reduction of the impurity introduction during the alloying. A 30kg V-4Cr-4Ti ingot was made by the VAR technique, whose impurity levels were ~60ppm C, ~100ppm N and ~180ppm O. The alloy ingot was designated as NIFS-HEAT-1.

The ingot was canned into a case of 304 stainless steel followed by hot forging, hot rolling and cold rolling. The geometry of the case, especially the thickness of the edge part, was carefully designed so as not to break during the deformation. Plates of 6.6 and 4.0 mm thick were made out of the ingot. The increase in the impurity level was small during the fabrication. The resulting plates will be used for Round-Robin tests by Japanese universities and international collaboration partners.

US-DOE had a program of fabricating large V-4Cr-4Ti ingots[1]. The nitrogen and oxygen contents of metal vanadium, V-4Cr-4Ti ingot and plates fabricated from the ingot are plotted in Fig. 1 for the present and the US-DOE fabrications. The nitrogen and oxygen levels of the products of the present study are comparable to and almost half of those of the US-DOE program, respectively. In the US-DOE program, the rolling into plates was carried out at around 400C. The fact that the rolling into plates were possible at room temperature for the present alloy, which would simplify significantly the manufacturing processes, will be due to its low impurity levels.

By this study, technology for fabricating large V-4Cr-4Ti alloy products with <100ppm C, ~100ppm N and <200ppm O was demonstrated.

[1] W. R. Johnson and J. P. Smith, J. Nucl. Mater., 258-263 (1998) 1425-1430

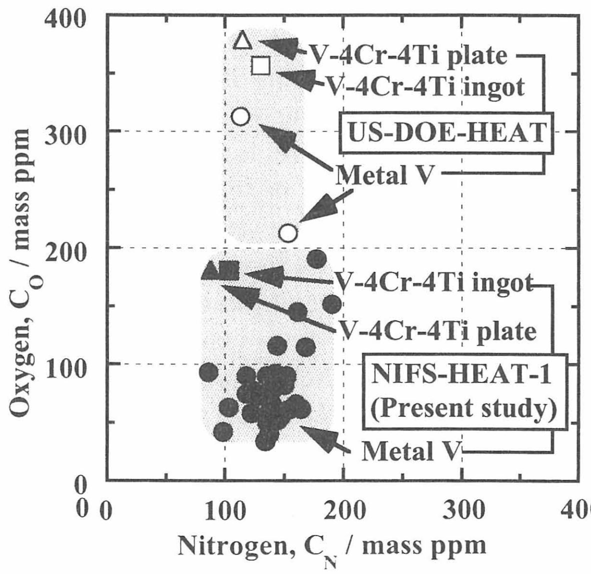

Fig.1 Impurity levels of metal vanadium, V-4Cr-4Ti alloy ingot and plates fabricated from the ingot in the present study and in the US-DOE program