§1. Comparison of Impact Property of Japanese and US Reference Heats of V-4Cr-4Ti after Gas-Tungsten-Arc Welding

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Development of welding technology is essential for vanadium alloys as fusion structural materials. NIFS-HEAT-1, a high-purity V-4Cr-4Ti alloy, has been developed as the reference low-activation vanadium alloy in Japanese universities. One of intentions to fabricate the heat was to verify the improvement in weldability by reducing interstitial impurities. The oxygen content of NIFS-HEAT-1, 181 wppm, is about half the US-DOE (Department of Energy) V-4Cr-4Ti large heats. The purposes of this study are to compare the welding properties of NIFS-HEAT-1 with that of a US large heat by DOE Fusion Program under the same condition, and to investigate the impurity effects on weldability.

Three kinds of V-4Cr-4Ti alloy, such as NIFS-HEAT-1, Heat 832665 by the US-DOE Fusion Program (US832665), and a high-purity model alloy (HP) melted by laboratory scale arc furnace were used in this study. Table 1 shows chemical compositions of the materials. The major difference is the concentrations of oxygen, such as about 180, 310 and 36 wppm in NIFS-HEAT-1, US832665 and HP, respectively. From HP alloy only wires were prepared because the melting scale was very small. The plates were 6.4-6.6 mm thick. Filler wires were 2.0-2.3 mm in diameter. Table 2 shows combinations of plates and wires in GTA welding performed in this study. For the welds designated as JGTA1 and GTA23, the plates and the wires were made from the same alloy, while in JGTA2 and JGTA3 wires were made from HP. GTA welds were made in a glove box installed in Oak Ridge National Laboratory. The box was evacuated and filled back with high purity argon. For all the welds oxygen gas and moisture levels were 0.7-0.8 wppm and 5.0-7.5 wppm, respectively. Six-pass welds were made on each butt joint. The current range at welds was 150-240 A at 8-9 V. 1/3-size Charpy specimens were prepared from the butt joints. A V-notch was located in the center of the weld metal so that crack propagated along the welding direction.

Figure 1 shows correlation between DBTT (Ductile-Brittle Transition Temperature) and oxygen content in weld metal, which was mixture of the melted plate and wire. In weld GTA23 oxygen content was estimated from that of base metal[1]. Fig. 1 reveals that Charpy impact property of NIFS-HEAT-1 (JGTA1) is superior to that of US832665 (GTA23), and that the use of HP wire leads to the further improvement of the impact property (JGTA2 and 3). This means that reduction of oxygen in V-4Cr-4Ti alloy is very effective to improve the weldability.

Table 1 Chemical composition of plates and wires for welding study.

	Cr*	Ti*	H	C	N	O
NIFS-HEAT-1						
Plate	4.41	4.10	18	68	88	181
Wire	4.43	4.22	3.7	60	107	179
US832665						
Plate	3.8	3.9		80	85	310
Wire	3.74	3.89	4.3	140	73	311
HP						
Wire	3.94	4.01	4.8	67	89	36

wppm, *wt%

Table 2 Combinations of plates and wires used in GTA welding.

ID	Plate	Wire
JGTA1	NIFS-HEAT-1	NIFS-HEAT-1
JGTA2	NIFS-HEAT-1	HP
JGTA3	US832665	HP
GTA23	US832665	US832665

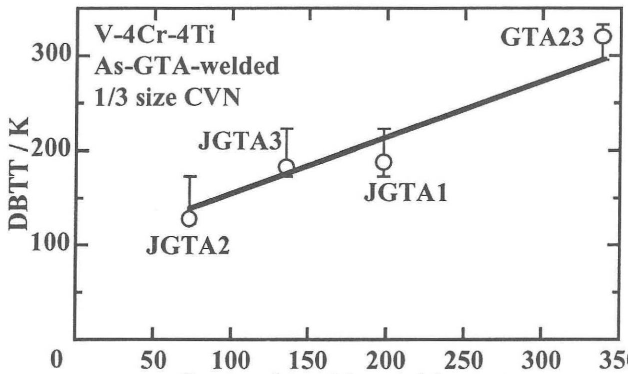

Fig. 1 Correlation between DBTT and oxygen content in weld metal. In weld GTA23 oxygen content was estimated from that of base metal[1].

In NIFS-HEAT-1 plate Ti-C-O precipitates have been identified before weliding. However, no Ti-C-O precipitates were observed in weld metal. Most of oxygen is expected to be in solid solution state in the weld metal. In the previous study on oxidation of V-Cr-Ti alloy, it has been demonstrated that oxygen in solid solution state should increase yield strength and decrease ductility more effectively than that in precipitation state. Degradation of the impact property of the weld joints possibly dues to both the strengthening and the ductility loss by solid solution oxygen.

[1] T. Nagasaka, M. L. Grossbeck, T. Muroga and J. F. King, Fusion Technol., 39 (2001) 664.