§ 5. Metallurgical and Mechanical Properties of Laser Weldment for Low Activation V-4Cr-4Ti Alloy

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V-4Cr-4Ti alloys are attractive candidate low activation structural materials for fusion reactors, due to their low induced radioactivity, good resistance to neutron radiation damage and good elevated-temperature strength. Two major issues remain for manufacturing vanadium alloy components for fusion reactors. One is the technology for production of large heat vanadium alloys with impurity control. Some large heats were fabricated by the US-DOE program and, recently, high purity V-4Cr-4Ti alloys (NIFS-HEAT-1 and 2) were fabricated by the National Institute for Fusion Science (NIFS) in Japan. The other issue is the development of joint technology, which is the key requisite for fabricating structures.

The YAG laser welding is a promising technique because of its flexibility for field, lenient requirement for atmospheric control and capability of deep penetration with less input. In the previous study, we have developed the laser welding technology for unalloyed vanadium eliminating the contamination by means of controlling the flow rate of environmental argon gas.

To optimize the welding parameters for vanadium alloys, it is necessary to characterize the properties of the HAZ as well as the weld metal. The impurity redistribution in the weld metal and the HAZ should be investigated for mechanistic understanding of the change of the properties. The purpose of this study is to investigate the microstructure and the impurity behavior of the laser weldment for low activation V-4Cr-4Ti and to find an optimized laser welding conditions, based of the characterization of the weld metal and the HAZ.

In this study, high-purity V-4Cr-4Ti alloy (NIFS-HEAT-2) fabricated by the National Institute for Fusion Science was used for the specimen, and prepared by annealing at 1273 K for 2 hours before the welding. Bead-on-plate welds were produced on the 4 mm-thick plate, using 2.0 kW YAG laser. Welding parameters such as average power, laser wave mode, traveling speed, etc. were controlled to obtain the optimum welding conditions for 4 mm-thick plate.

Hardness measurement in the weld metal and the HAZ and microstructural observations by optical microscope and scanning electron microscope (SEM) were carried out. Impact absorption energy was also estimated by one third size V-notch charpy impact test from 77 K to 298 K. The notch was machined from a weld metal, which was orientated parallel to the welding direction.

Fig. 1 shows the positional difference of microstructure and hardness. Hardening occurred in the weld metal and the HAZ. In the authors' previous study, the banded-structure precipitates and the fine spherical precipitates were observed in the base metal. The former were formed during the hot extrusion, hot forging and hot rolling processes, and the latter were formed by final annealing at 1273 K for two hours. The hardness of the weld metal and the HAZ, shown in Fig. 1, is thought to relate with the impurity behavior. It is well known that, in unalloyed vanadium and its alloys, increase in the impurity level results in increase in hardness.

The banded-structure precipitates, which were observed in the base metal before welding, were dissolved in the weld metal and in the inner region of the HAZ. Thus, the HAZ is divided into two regions; region (1) and (2). Region (1) in the HAZ was designated from the weld line to the boundary of the resolution of the banded-structure precipitates.

SEM observation shows that the banded-structure precipitates in the weld metal and in region (1) disappeared during laser welding. In the previous study, the fine precipitates disappeared by annealing up to 1373 K for an hour, but the banded-structure precipitates did not. Since the resolution of the fine precipitates resulted in hardening, it is expected that the hardening in the weld metal and in region (1) is due to the increase of impurity levels driven by the resolution of the banded-structure precipitates and the fine precipitates and the hardening in region (2) by the fine precipitates only.

Hardness decreased gradually with the distance from the bead center, probably due to the decrease in the amount of precipitates dissolved into the matrix. Hardness in the weld metal and in region (1) is higher than that of region (2), because only the fine spherical precipitates were dissolved in region (2).

From this study, YAG laser welding technology controlling the welding atmosphere makes it possible to obtain the bead-on-plate weld zone reducing contamination of impurities. The hardening in the weld metal and the HAZ is due to the increase in the impurity level induced by the resolution of precipitates. Impact absorption energy for the weld metal was similar to that of the base metal. Grain size and the width of HAZ were increased with increasing the power and decreasing the traveling speed. To improve the welding properties, it is desirable that the welding procedure should be carried out with low introduced energy per unit bead length.

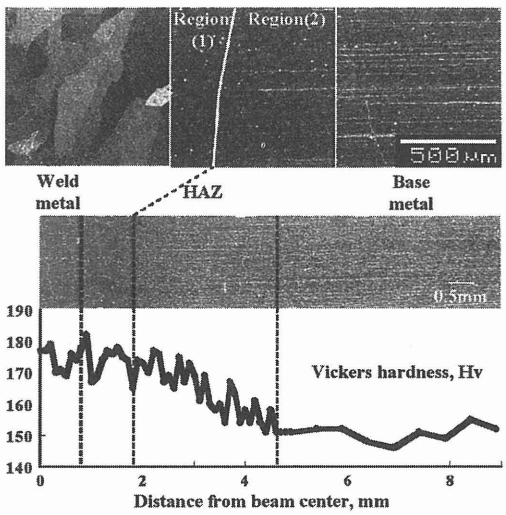

Fig. 1 Positional difference of microstructure and hardness.