§7. The Microstructure of Laser Welded V-4Cr-4Ti Alloy after Neutron Irradiation

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1. Introduction

It is recognized that welding procedure is one of the key technologies for use of V-4Cr-4Ti alloys as a large component [1]. Recently, laser welding technology for the alloys was developed by NIFS (National Institute for Fusion Science) by controlling the flow rate of high purity argon gas [2]. However, quite little is known to the neutron irradiation effect on the weldment. Nagasaka et al. [3] revealed that weld metal showed larger irradiation hardening than that of the base metal after neutron irradiation at 563K. The Irradiation hardening at 563K was mainly controlled by very high density of dislocation loops. But higher irradiation temperature regions, formation of radiation induced Ti(CON) precipitates becomes prominent. Therefore, the present paper summarized the recent progress on microstructural evolution of laser welded V-4Cr-4Ti alloy during neutron irradiation at higher irradiation temperature regions.

2. Experimental Procedure

Welded joints used in this study were prepared from high purity V-4Cr-4Ti alloy, which was designated as NIFS-HEAT-2 [1]. Before the YAG laser welding (bead-on-plate welding) in a high purity argon atmosphere, the samples were annealed in a vacuum at 1273K for 2hr. Oxygen concentrations of the sample before welding, and weld metal are 139 and 158 wt ppm, respectively. The PWHT was carried out in a vacuum of about 1×10^{-5} Pa at 1023K for 1 or 100hr. Fission neutron irradiation was carried out in JMTR under improved temperature control condition at 673, 723 and 873K in the same irradiation cycle (namely, JMTR 03M-69U). The total neutron dose of irradiation was $5.18 \times 10^{24}/\text{m}^2$ (>1.0 MeV), which corresponds to 0.45 dpa.

3. Results

Microstructure of laser welded NIFS-HEAT-2 was strongly depended on irradiation temperature. Upper part of fig. 1 shows the TEM images of base metal (a) and weld metal (b) after irradiation at 673K, respectively. In the figure, corresponding images of base metal (c) and weld metal (c) with annealed at 1073K for 100 hour are also shown. The figure shows that the radiation enhanced formation of Ti(CON) precipitates with {100} habit planes and dislocations. Ti(CON) precipitates were homogeneously formed in weld metal. In weld metal, number density of Ti(CON) precipitates was higher than that in base metal. Measured number density of precipitates in base metal and weld metal were 1.4×10^{21} and $4.3 \times 10^{21}/\text{m}^3$, respectively. And average precipitates size of base metal and weld metal were 43.5 and 17.7 (nm), respectively. From our previous results, tiny Ti(CON) precipitates were heterogeneously

formed in weld metal and segregated during the PWHT at 1073K. Namely, after the annealing, the microstructure of weld metal was divided into two regions, precipitate-segregation (PS) and precipitate-free (PF) areas. As shown in fig.1 (d), after the irradiation at 673K, relatively larger Ti(CON) precipitates were observed in PS area and small precipitates of about 40 (nm) (shown by arrows in the figure) were also observed in PF area of the weld metal. At 873K PS and PF areas were also observed in weld metal without the PWHT at 1073K. With increasing irradiation temperature, growth of Ti(CON) precipitates became prominent and the precipitate can be easily identified by their habit planes.

3. Discussion

And as shown in fig.1, at 673K irradiation, Ti(CON) precipitates were homogeneously formed in weld metal and number density of Ti(CON) precipitates was about three times higher than that of base metal. At temperature above 723K, formation of Ti(CON) precipitates were not formed uniformly. Namely, precipitate – segregation (PS) and precipitate-free (PF) area, which were commonly observed after the PWHT at 1073K, were appeared in weld metal. At 873K, large Ti(CON) precipitates were commonly observed in PF area in weld metal. It is important to note that the absorbed energy of welded sample increased significantly, when microstructure is divided into PS and PF areas. But once, plate like precipitates with typical orientation are formed, the absorbed energy of welded sample drops drastically. Therefore, the effects of PWHT on weld metal, which are useful for unirradiated and lower temperature irradiations, are not effective or very limited at higher irradiation temperatures where plate like Ti(CON) precipitates were formed.

References

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