§11. The Hardness Changes and Microstructure of Laser Welded V-4Cr-4Ti Alloy after Neutron Irradiation

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1. Introduction

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 [1]. However, quite little is known to the neutron irradiation effect on the weldment. Our previous reports 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. And the effects of PHWT on weld metal are very effective at 563K. But higher irradiation temperature regions, formation of radiation induced Ti(CON) precipitates becomes prominent. Therefore, the present paper summarized the resent progress on microstructural evolution and hardness changes of laser welded V-4Cr-4Ti alloy during neutron irradiation at 673-873K.

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. 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 $5.18 \times 10^{24}/m^2$ (>1.0 MeV), which corresponds to 0.45 dpa.

3. Results

Fig. 1 shows hardness distribution around the bead centre before and after the irradiation at 723K. From the microstructural observations, the width of the weld metal was 1mm as indicated in the figure. In the figure, hardness changes due to the irradiation at 563K, are also shown for comparison [2]. At 563K, irradiation hardening of the weld metal was relatively larger than that of base metal. But increasing with irradiation temperatures, irradiation hardening of base metal became prominent. The PWHT at 1073K was very effective before and even after the irradiation at 563K. At 723K, Vickers hardness of base metal was almost comparable to that of weld metal.

Fig. 2 shows the corresponding microstructure after irradiation at 723K. In the right corner of each photo, void contrast images (s >> 0) taken by higher magnification are inserted. After the irradiation at 723K, PS and PF areas were also formed in weld metal without PWHT. But higher magnification of void contrast images revealed that precipitates were also existed in PF area in weld metal with and without PWHT.

4. Discussions

With increasing irradiation temperature, growth of Ti(CON) precipitates became prominent and the precipitate can be easily identified by their habit planes. At 673K irradiation, Ti(CON) precipitates were homogenously formed in weld metal and number density of Ti(CON) precipitates was about tree time 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 PHWT 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.

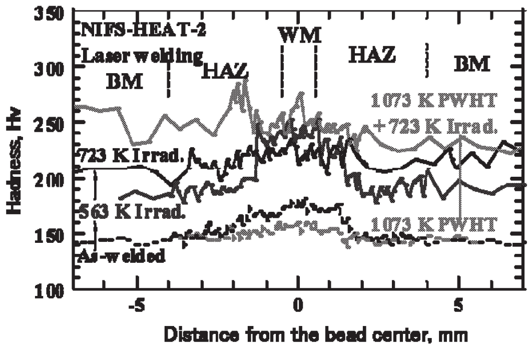

Fig.1 Hardness changes due to irradiation

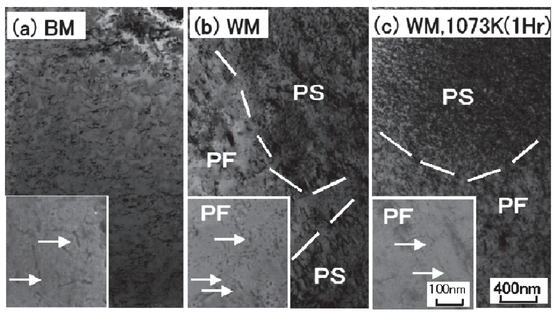

Fig.2 Microstructure at 723K

References

[1] Nam-Jin Heo, T. Nagasaka, T. Muroga, A. Nishimura, K. Sinozaki and H. Watanabe, Fusion Science and Technology, 44(2003)470.

[2] Nam-Jin Heo, T. Nagasaka, T. Muroga, A. Nishimura, K. Sinozaki and H. Watanabe, to be published in J. Nucl. Mater.