24P047-P

Study on Dissimilar Metal Joint of Reduced Activation Ferritic/Martensitic Steel and Austenitic Stainless Steel by Electron Beam Welding
電子ビーム溶接による低放射化フェライト鋼とオーステナイトステンレス鋼の異種金属接合に関する研究

Masahiro Waki, Shuhei Nogami, Takuya Nagasaka, Akira Hasegawa, Takeo Muroga
和氣昌弘 [1], 野上修平 [1], 長坂琢也 [2], 長谷川晃 [1], 室賀健夫 [2]

[1] *Tohoku University, 6-6-01-2, Aramaki-aza-Aoba, Aoba-ku, Sendai, 980-8578, Japan*
[1] 東北大学　〒980-8579　仙台市青葉区荒巻字青葉 6-6-01-2
[2] *National Institute for Fusion Science, 322-6, Oroshi, Toki, Gifu, 509-5292, Japan*
[2] 核融合科学研究所　〒509-5292　岐阜県土岐市下石町 322-6

The dissimilar metal joint of reduced activation ferritic/martensitic (RAFM) steel and austenitic stainless steel by electron beam welding (EBW) was investigated. The EBW joint was categorized into five regions: the base metal of F82H (F82H-BM), the heat-affected zone of F82H (F82H-HAZ), the interlayer at the edge of F82H-HAZ (IL), the weld metal (WM), and the base metal of SUS316L (SUS316L-BM). No hardening due to welding and no significant change in hardness due to the post-welding heat treatment (PWHT) above 640ºC were observed in the F82H-BM, SUS316L-BM, and the WM. On the other hand, a significantly higher hardness due to welding and a significant reduction of hardness due to the PWHT above 640ºC was observed in the F82H-HAZ and IL.

1. Introduction

Reduced activation ferritic/martensitic (RAFM) steel and austenitic stainless steel are considered to be applied as a structural material and the peripheral equipment material of fusion reactor blanket, respectively [1]. Therefore, it is necessary to develop the dissimilar metal jointing technique of these materials for the fabrication of fusion reactor. The authors have been studying the dissimilar metal jointing of RAFM steel, F82H, and austenitic stainless steel, SUS316L, by the electron beam welding (EBW), and suggested the necessity of the optimization of post-weld heat treatment (PWHT) to improve mechanical property of the joint [2]. The objective of this study is to investigate the effect of PWHT temperature on mechanical and metallographical properties of dissimilar metal EBW joint of F82H and SUS316L steels.

2. Experimental

Materials used in this study are the F82H IEA-heat and the SUS316L steels. Electron beam butt-welding was carried out using flat plates measuring 50 mm × 50 mm × 7 mm. The acceleration voltage, beam current, and welding speed were 150 kV, 20 mA, and 1000 mm/min, respectively. The electron beam was shifted by 0.2 mm on the SUS316L side, which was optimized in the previous study [2]. PWHT was performed in a vacuum at temperatures ranging from 640ºC to 750ºC for 1 h.

Vickers hardness measurement of the cross-sectional surface of the weld joint was conducted using a Vickers hardness tester. Metallographical analysis was performed by using an optical microscope, scanning electron microscope (SEM) with an energy-dispersive spectroscopy (EDS) system, and a field-emission electron probe micro-analysis system (FE-EPMA).

3. Result and Discussion

The EBW joint was categorized into five regions: the base metal of F82H (F82H-BM), the heat-affected zone of F82H (F82H-HAZ), the interlayer at the edge of F82H-HAZ (IL), the weld metal (WM), and the base metal of SUS316L (SUS316L-BM). Fig. 1 shows the cross-sectional Vickers hardness distribution in the as-welded and post-welding heat treated EBW joints. PWHT was not confirmed to have any influence on the hardness of the F82H-BM and SUS316L-BM at PWHT temperatures between 640ºC and 720ºC.

Although a much higher hardness (Hv420) was observed in the as-welded F82H-HAZ, a significant reduction of hardness occurred due to the PWHT above 640ºC. Similar to the F82H-BM, a martensitic phase was observed in the F82H-HAZ, and a more complex metallographical appearance was observed in the as-welded F82H-HAZ than in the as-welded F82H-BM. Thus, the higher hardness of the as-welded F82H-HAZ was considered to be a result of the higher density of the lath in the martensitic structure formed by cooling after the welding.

A much higher hardness under the as-welded condition and a significant reduction of hardness due to the PWHT were also observed in the IL. A further increase in the PWHT temperature caused a lower hardness of the IL than that of the BMs. No martensitic phase was observed in the IL, and EDS and EF-EPMA analyses showed no significant diffusion of major elements such as Fe, Cr, and Ni, and minor elements such as C. Based upon the phase diagram of the Fe-Cr binary system, the formation of δ-ferrite occurs above approximately 1300°C or so. Therefore, δ-ferrite was considered to be one of the possible phases of the IL. During welding, the IL region might be transformed into the δ-ferrite phase, and then remain as the δ-ferrite phase as a result of rapid cooling.

No hardening due to welding was observed in the WM of the as-welded joint. An austenitic phase was observed in the WM, which was attributed to the electron beam being shifted by 0.2 mm on the SUS316L side [2]. Therefore, the hardness of the WM was considered to be relatively stable, similar to SUS316L-BM under PWHT temperatures between 640ºC and 750ºC.

4. Conclusions

The effects of PWHT on the mechanical and metallographical properties of a dissimilar metal EBW joint of F82H IEA-heat and SUS316L steels were investigated to support in the development of dissimilar metal welding techniques for RAFM and austenitic stainless steel. The results of this study are summarized as follows;

1) The EBW joint was categorized into five regions: the base metal of F82H (F82H-BM), the heat-affected zone of F82H (F82H-HAZ), the interlayer at the edge of F82H-HAZ (IL), the weld metal (WM), and the base metal of SUS316L (SUS316L-BM).
2) No hardening resulting from welding and no significant change in hardness resulting from PWHT above 640ºC were observed in the F82H-BM, SUS316L-BM, and WM. On the other hand, a significantly higher hardness was observed in the as-welded F82H-HAZ and IL than in the other region, and a significant reduction of hardness occurred in the F82H-HAZ and IL caused by PWHT above 640ºC.

References

[1] Y. Nomoto, S. Suzuki, K. Ezato, T. Hirose, D. Tsuru, H. Tanigawa, T. Hatano, M. Enoeda, M. Akiba: Fus. Eng. Des. **81** (2006) 719.

[2] N. Hara, S. Nogami, T. Nagasaka, A. Hasegawa, H. Tanigawa and T. Muroga: Fus. Sci. Tech. **56-1** (2009) 318.

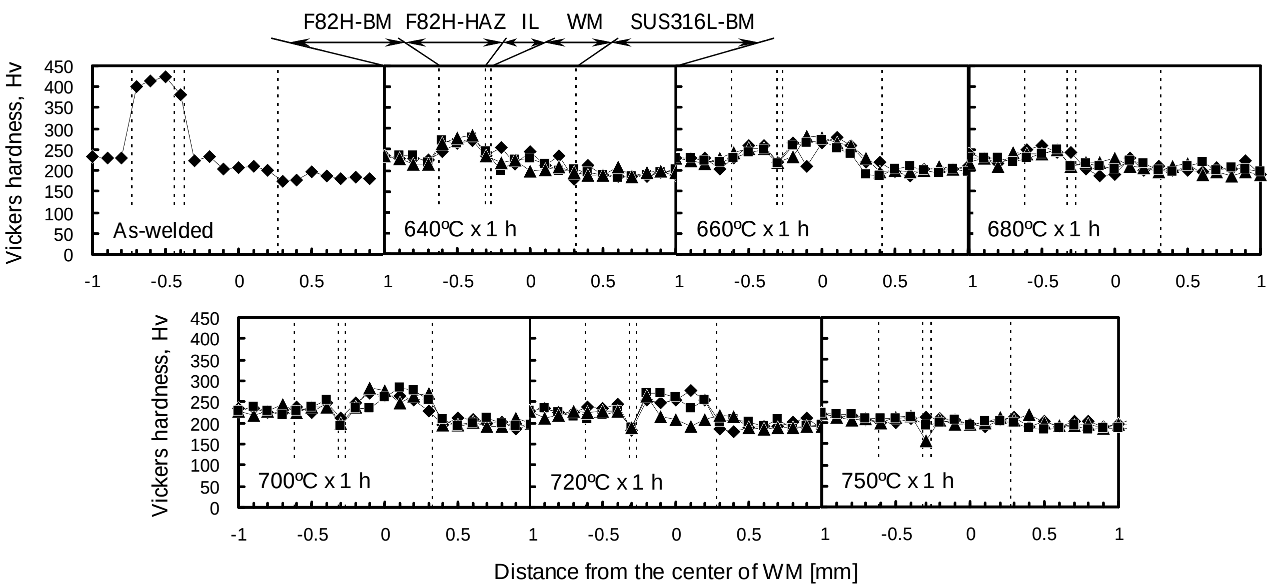

Fig. 1. Cross-sectional Vickers hardness distribution in the as-welded and post-welding heat treated F82H/SUS316L EBW joints (PWHT temperatures: 640, 660, 680, 700, 720, 750ºC)