Transactions of the Korean Nuclear Society Autumn Meeting
Gyeongju, Korea, October 25-26, 2012

Effect of thermal aging to microstructure of the interface of Low Alloy Steel and Ni-based Alloy filler metal of Dissimilar Weld Metal

Kyoung Joon Choi, Sang Hoon Shin, Jong Jin Kim, Sang Il Choi, Ji Hyun Kim*
Ulsan National Institute of Science and Technology(UNIST)
100 Banyeon-ri, Eonyang-eup, Ulju-gun, Ulsan, Republic of Korea 689-798
**Corresponding author: kimjh@unist.ac.kr, kjchoi@unist.ac.kr*

1. Introduction

Dissimilar Metal Welds (DMWs) is generally applied to nuclear power plants for manufacturing and machining in structural components such as reactor pressure vessels and pressurizer nozzles. Alloy 152 is used frequently as filler metal in the manufacture of the DMW in light water reactors to join the low alloy steel pressure vessel nozzles and steam generator nozzles to nickel-based wrought alloy or austenitic stainless steel components. However, in recent years cracking phenomena has been observed in the welded joints. Additionally, the number of long-term aged nuclear power plants is increasing. Concerns have been raised to the integrity and reliability in the joint transition zone due to the high susceptibility of the heat affected zone (HAZ) and the fusion boundary (FB) to stress corrosion cracking in combination with thermal aging [1].

Since the material microstructure and chemical composition are key parameters affecting the stress corrosion cracking, improving the understanding of stress corrosion cracking at the FB region requires fundamental understanding of the unique microstructure of the FB region in DMW. Despite the potential degradation and consequent risk in the DMW [1, 2], there is still a lack of the fundamental understanding of microstructure in the FB region, in particular the region containing unidentified band structures near the FB.

As the life of nuclear power plants becomes long cycle, concerns have been raised to the integrity and reliability in the region after getting thermal aging effect. The long term exposure of this kind of material could experience the thermal aging which can form the chromium carbides near the FB by promoting the diffusion of C content at the service temperature [3, 4].

Therefore, the current study is aiming at the investigation of the thermal effect on the interface between Alloy 152 filler metal and A533 Gr. B. The used tools are Vickers hardness tester and Scanning Electron Microscope (SEM).

2. Experiment

2.1. Materials and Specimens

2.1.1. Material

A representative dissimilar weld mock-up made of Alloy 690/Alloy 152/Alloy 533 Gr. B was fabricated in Argonne National Laboratory. The welding procedures have been qualified per ASME Section IX. A post-weld heat treatment was performed after the LAS block was buttered with Alloy 152. Then Alloy 690 and buttered LAS blocks were joined by Alloy 152 fillers. Figure 1 shows the dissimilar metal Chemical compositions of both metals were shown in table 1. There are two different aging conditions of samples including as-welded and heat treated one at temperature of 450°C for 1375hrs. The objective of the heat treatment is to simulate the 15y-aged DMW. As it can be seen at Fig.2, the heat treatment condition was got from the diffusion activation energy equation for chromium.

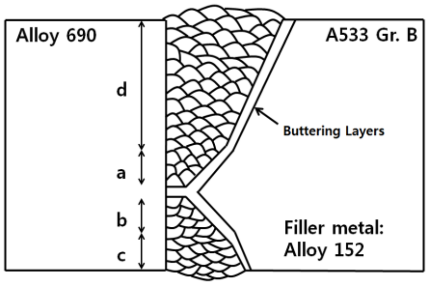


Fig. 1. Schematic diagram of dissimilar metal weldment (DMW)

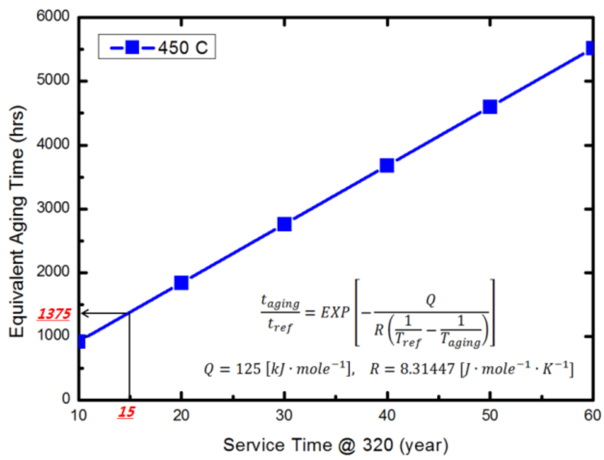
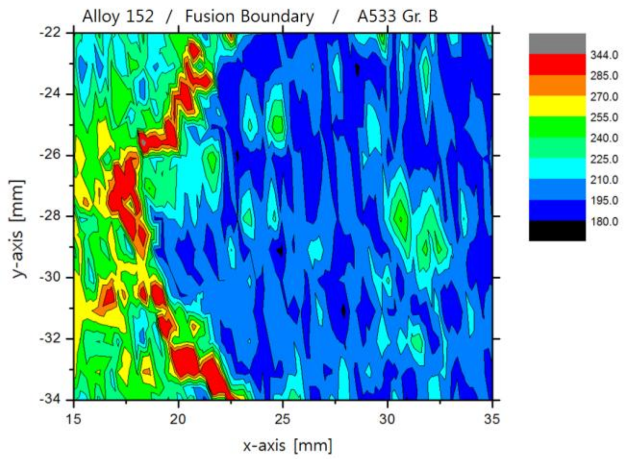


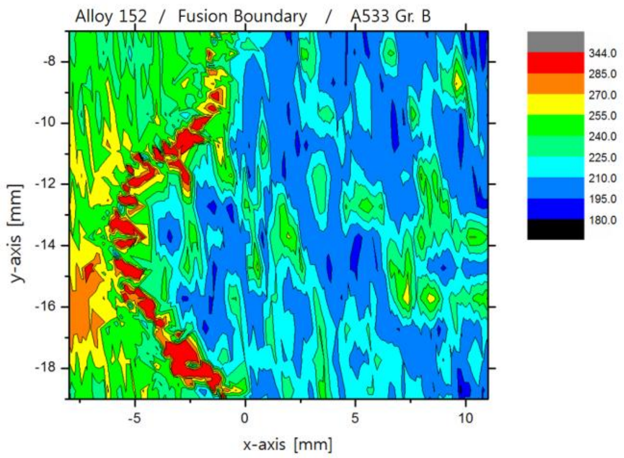
Fig. 2. Aging time equivalent to the service time at 320℃ with the activation energy for Cr diffusion.

Table 1. Chemical Composition

Material	C	Al	Si	P	S	Cr	Mn	Fe	Co	Ni	Cu	Nb+Ta	Mo	Ti
Alloy690	0.03		0.07		<0.001	29.5	0.20	9.9		59.5	0.01			
Alloy 152	0.040	0.240	0.460	<0.003	<0.001	29.04	3.560	9.360	<0.01	55.25	<0.01	1.84	0.01	0.15
A533B	0.220		0.19	0.010	0.012	0.18	1.28			0.51			0.48	



(a)



(b)

Fig. 3. Distribution of Vickers hardness in as-welded DMW (a) and aged DMW (b)

2.1.2. Specimen

For Vickers hardness test, the specimens were prepared by polishing (~0.05um). And by using vibrator polisher, the residual stress of the specimens was removed. The specimens for SEM were prepared by polishing the sample with ~0.05um colloidal silica and etching with 3% nital solution. After polishing (~0.05um) and lightly etching, the specimens for TEM and 3D APT were prepared by using FIB. TEM specimens were deposited with carbon, cut and thinned with gallium ion by Quanta 3D FEG Focused Ion Beam. 3D APT specimens were prepared by doing deposition of platinum and carbon, milling with gallium ion in Helios Nanolab 600 Dual –beam Focused Ion Beam.

2.2. Analyses

For Vickers microhardness measurement, the condition is test load 2.94N and dwell time 15sec. The distance between horizontal and vertical point lines are 0.2 mm. The hardness analysis was performed at the rooter region including the interface between Alloy 152 and A533 Gr. B in the DMWs having different heat treatment condition. In the same region with the hardness analysis area, the microstructure was characterized by SEM. Chemical composition in FB region was analyzed by (Nano nova 230 SEM) energy-dispersive X-ray spectroscopy.

3. Result

Fig. 3 shows the result of 2-dimensional distribution of measured Vickers hardness values in the rooter region including the weld metal Alloy 152, A533 Gr. B and the FB. Fig. 3(a) shows the hardness distribution of as-welded DMW. Fig. 3(b) presents the distribution of aged DMW. As a concomitant of as-welded and 15 year aged ones, it is observed that the microhardness in the Alloy 152 weld is generally larger than that of the A533 Gr. B base metal. In comparison with the two DMWs, the hardness value of aged DMW is higher than as-welded one.

The results are shown that the root region of the DMWs get the thermal aging effect. And further studies on the area are in progress.

4. Discussion

This study is focused on the investigation of the thermal aging effect on the weld root area including the FB. The thermal aging can form the chromium carbides near the FB by promoting the diffusion of C content at the service temperature. The effect can induce the local loss of ductility near the FB. It is considered to be more problematic in terms of structural integrity. From the results described in the previous section, it’s observed that the microhardness in the Alloy 152 weld is generally larger than that of the A533 Gr. B base metal. Since there is possibility for the weld rooter region to be degraded, further studies on the interface are in progress.

5. Summary

Through the Vickers hardness measurement, it’s observed that the thermal aging effect can harden the root region containing Alloy 152 and heat affected zone of A533 Gr. B.

REFERENCES

[1] J. Hou, Q.J. Peng, Y. Takeda, J. Kuniya, T. Shoji, J.Q. Wang, E.H. Han and W. Ke, “Microstructure and mechanical property of the fusion boundary region in an Alloy 182-low alloy steel dissimilar weld joint,”J. Mater. Sci., vol. 45, pp. 5332 (2010)

[2] T.W. Nelson, J.C. Lippold and M.J. Mills, “Nature and Evolution of the Fusion Boundary in Ferritic-Austenitic Dissimilar Metal Welds —Part 2: On-Cooling Transformations,” J. Weld, vol. 79, pp. 267 (2000)

[3] J.D. Parker and G.C. Stratford, “Characterization of microstructures in nickel based transition joints”, J. Mater. Sci., vol. 35, pp. 4099 (2000)

[4] J.D. Dupont and R. E. Mizia, “Review of Dissimilar Metal Welding for the NGNP Helical-Coil Steam Generator,” INL/EXT-10-18459, Idaho National Laboratory (2010)