Transactions of the Korean Nuclear Society Autumn Meeting
Gyeongju, Korea, October 24-25, 2013

A Study of Microstructural Changes by Thermal Aging in the Interface between Low Alloy Steel and Ni-base Alloy Filler Metal

Kyoung Joon Choi, Jong Jin Kim, Seung Chang Yoo, 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. The incidences of stress corrosion cracking (SCC) of Alloy 182 in pressurized water reactors (PWR) have been reported, and the initiation and growth of the SCC have been acknowledged in the Alloy 82/182 weld metal of DMWs. The corrosion resistance of welds made with filler metal may be inferior to that of properly annealed base metal because of microsegregation, precipitation, formation of unmixed zone and so on. In recently, in order to prevent the SCC incidences, Alloy 182 filer metal is replaced with Alloy 152 containing relatively higher Cr & Ni concentration.

There is no experience of SCC in DMW where Alloy 152 is used as filler metal in weld between Alloy 690 and A533Gr. B low alloy steel (LAS). However, it is believed that the current operational experience is not long enough to conclude that the high Cr Ni alloys are perfectly immune to SCC. Due to dilution effects, in the dilution zone and the fusion boundary (FB) region near the A533 Gr. B LAS, the reduced chromium and nickel contents tend to increase its corrosion and SCC susceptibility with respect to the bulk weld metal [1]. Moreover, as-welded condition at FB may not cause serious cracking issues, but thermal aging may change the local microstructure and decrease the cracking resistance and/or the strength. This study mainly focused on a potential microstructural change due to the thermal aging: Cr carbides formation at the low alloy steel side of FB region.

This study is focused on the characterization of FB region between Alloy 152 and A533 Gr. B LAS in order to take a kind of proactive approach rather than reactive one. And, such data will be important for assessing aging effects of structural components and evaluating the long-term operation of commercial power plants.

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.

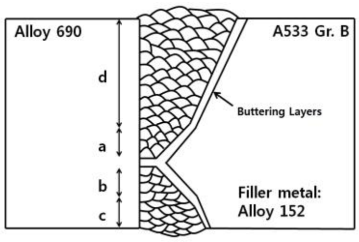


Fig. 1. Schematic diagram of dissimilar metal weldments

2. Experiments

In this section, some of the instruments used to characterize the effect of thermal aging on the microstructures of the DMW are described. It focuses on the interface between LAS and weldment in the DMW.

2.1 Materials

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-

Table. Ⅰ Chemical Composition (in wt. %) of dissimliar metal weld used in this study

Material	Composition													
	C	Al	Si	P	S	Cr	Mn	Fe	Co	Ni	Cu	Nb+Ta	Mo	Ti
Alloy 690	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	29.040	3.560	9.360	<0.01	55.25	<0.01	1.84	0.01	0.15
A533 Gr. B	0.220		0.19	0.010	0.012	0.18	1.28			0.51			0.48	

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.

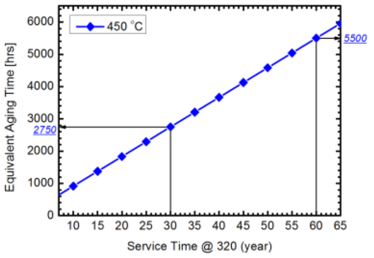


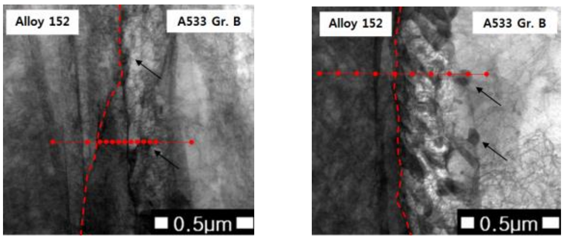
Fig. 2 Aging time equivalent to the service time at 320℃

2.2 Heat treatment

The condition was determined by using diffusion equation. Service time of 30 and 60 years at 320℃ is equivalent to aging time 2750 and 5500 hours at 450℃. For the activation energy of diffusion, Cr is considered as one of key elements because the formation of precipitates in interested region is mainly attributed to the diffusion of Cr in Alloy 152 across the FB to LAS during thermal aging process.

125 kJ/mol was used for the activation energy for Cr diffusion in the nickel weld metals having similar chemical composition with the region near the FB [4].

In order to simulate the aged DMW in LWR (320℃), during 30 and 60 years, the weld sample were aged in the accelerated temperature condition (450℃) during 2750 and 5500 hrs (Fig. 2).



(a) Aw-welded DMW (b) Aged DMW for 2750 hrs
Fig. 3. Precipitates in LAS near the FB

3. 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.

4. Conclusion

In order to investigate the effect of the thermal aging on the change of structure and chemistry in that region, the detail instrumental analysis in the fusion boundary region of A533 Gr. B-Alloy 152 DMW joint were performed. The following conclusions can be drawn from the study.

Firstly, while the microhardness in the FB region is decreased after the thermally aging heat treatment for 2,750-hrs, that is re-increased after the treatment for 5,500-hrs. It is believed that the changed microhardness could be caused by the microstructural change and the residual stress relief during the thermal aging heat treatment. Next, the distribution of Ni, Fe and Cr became relatively uniform in the dilution zone in the weld metal region of DMW, and the concentration of Fe is lower, but those of other elements are higher in A533 Gr. B near the FB region after aging heat treatment. And, the precipitates are mainly formed in the HAZ of A533Gr.B near the FB, and the increase in size and number density of the precipitates is observed after aging heat treatment. The thermal aging can promote the formation of carbides in the HAZ of A533 Gr. B near the FB region in DMW of A533 Gr. B - Alloy 152. Finally, the 3D APT analysis confirmed that the precipitates which were formed in the A533Gr. B near the FB are mainly carbides, and the ratio of chromium constituents in precipitates increases after aging heat treatment.

ACKNOWLEDGEMENT

This work was financially supported by the R&D Program of Korea Institute of Energy Technology Evaluation and Planning (KETEP) funded by the Korean Nuclear R&D program organized by the National Research Foundation (NRF) of Korea in support of the Ministry of Science, ICT and Future Planning (MSIP).

REFERENCES

[1] Q. Peng, T. Shoji, T. Sato and H.P. Seifert, "SCC behavior in the transition region of an alloy 182-SA 508 cl.2 dissimilar weld joint under simulated BWR-NWC conditions", Proceedings of the Twelfth International Conference on Environmental Degradation of Materials in Nuclear Power Systems-Water Reactors , pp. 589-599, 2005
[2] 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
[3] 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
[4] J.M. Boursier, F. Vaillant and B. Yrieix, "Weldability, thermal aging and PWSCC behavior of nickel weld metals containing 15 to 30% chromium", PVP, 490 pp. 109, 2004