Effects of postweld heat treatment on the dissimilar weldments of SA508 Gr. 4N Ni-Mo-Cr low alloy steels

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1. Introduction

Low alloy steels are generally employed in reactor pressure vessels (RPVs) of nuclear power plants. SA508 Gr.4N Ni-Mo-Cr low alloy steel has been studied as candidate materials for RPVs because it has excellent mechanical properties such as strength and toughness due to higher Ni and Cr contents compared with SA508 Gr.3 commercial RPV steel.

In order to improve corrosion resistance of inner-wall of RPV, it is necessary to be coated by clad-welding with austenitic stainless steels such as 308L and 309L. PWHT of such dissimilar weldments results in the formation of a soft region near the weld interface on the low Cr side, and hard zone on the high Cr side of the weldment [1]. The hardness change of weldments by formation of these characteristic zones affected overall safety margin and integrity property of RPV.

In this study, effects of post-weld heat treatment (PWHT) on the microstructural and mechanical properties of dissimilar weldment between SA508 Gr.4N steel and austenitic stainless steel have been studied. The changes in microstructure, hardness and composition profiles across the weld interface were studied in detail. And, those results were compared with weldment in SA508 Gr.3 steel.

2. Experimental Procedure

SA508 Gr.4N and SA508 Gr.3 low alloy steels were used as base metal and submerged arc welding process was employed in cladding process using austenitic stainless steels, 308L and 309L, as filler metals. First layers were used in 309L and second layers were used in 308L. The compositions of those steels are given in table 1 and the detailed welding conditions are given in Table 2. The PWHT of welded specimens were carried out at 610K for 30h.

The specimens were polished and etched with nital solution for base metal and oxalic acid for weld metal. And then, overall microstructure was observed by an optical microscope (OM). Transmission electron microscope (TEM) was used to investigate the type and morphology of carbides precipitated in heat treated sample. The concentration profiles of carbon, chromium and nickel were analyzed using an electron probe microanalyzer (EPMA) to determine the elemental redistribution across the weld interface. In order to evaluate the changes of mechanical property in weldments, microhardness of the specimens was evaluated by using Vickers's hardness tester with 100g load.

Table 1. Chemical composition of the base metals and filler metal (wt%).

	C	Mn	P	Ni	Cr	Mo	Fe
SA508 Gr.3	0.19	1.40	0.007	0.84	0.15	0.50	Bal.
SA508 Gr.4N	0.19	0.30	0.007	3.54	1.82	0.49	Bal.
ER309L(4mm)	0.01	1.61	0.023	13.80	23.07	0.14	Bal.
ER308L(4mm)	0.02	1.90	0.025	9.72	19.75	0.15	Bal.

Table 2. Welding conditions

Method	Current(A)	Voltage(V)	Speed(cm/min)	Heat input(kJ/cm)
SAW	400	25	40	15

3. Results and Discussion

Fig. 1 shows the microstructures of the dissimilar weldments of (a) SA508 Gr.3 and (b) SA 508Gr.4N. The heat affected zones (HAZ) of both steels showed martensite structure. Lightly etched band commonly referred as unmixed zones on the fusion line **[1].**

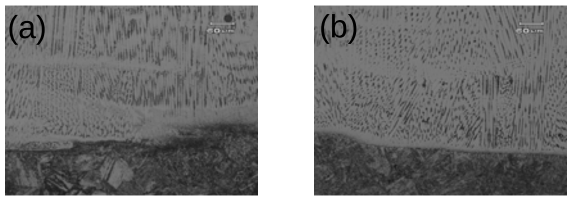

Fig. 1 Optical micrographs of as-welded specimen (a) SA508 Gr.3, (b) SA 508Gr.4N

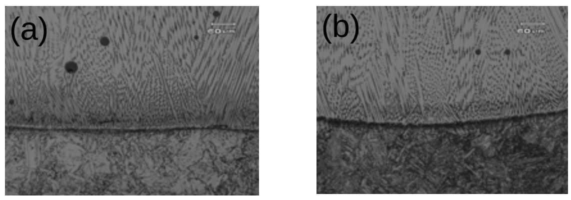

Fig. 2 Optical micrographs of PWHT specimen (a) SA508 Gr.3, (b) SA508 Gr.4N.

Fig. 2 shows the microstructure of the dissimilar weldments of the SA508 Gr.3 and SA508 Gr.4N after PWHT. In the heat treated weldments, microstructural changes were observed on the weld metal side. It was observed dark region of 50-60 ㎛ scale which is estimated as 'hard zone' with precipitates-rich.

In order to evaluate the changes of microstructure and the formation of hard zone and soft zone during PWHT, the microhardness profile across the weldments were analyzed in Fig. 3. HAZ of as-welded SA508 Gr.4N showed higher hardness than that of SA508 Gr.3. Because of tempering effects, HAZ of both steels showed lower hardness after PWHT. But significantly high hardness was indicated in the regions near the fusion line of both steels. It may be the hard zone known as precipitates rich band. And a lightly etched band may be the soft zone near the fusion line on the HAZ, since it is characterized by the lowest hardness and the absence of precipitation. This is attributed to the migration of carbon form low Cr side to high Cr side as a consequence of the difference in the activities of carbon of the two steels **[2-5].**

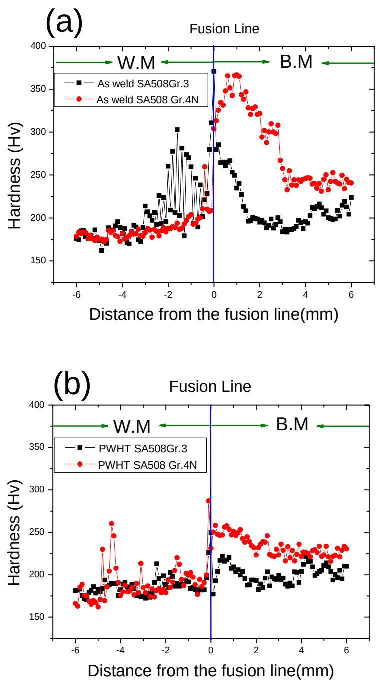

Fig. 3 The microhardness of (a) as-welded specimen and (b) PWHT specimen

The line scanning was performed across the weld interface of SA508 Gr.4N to determine the redistribution of C after PWHT using EPMA. The results are shown in Fig. 4. It was found that there is an increase in the concentration of C on the weld metal side of the interface after PWHT, while concentration of C on the base metal side after PWHT was decreased. Therefore, it was concluded that the hard zone with precipitate rich and the soft zone with precipitate free were formed on weld metal side and base metal side, respectively.

4. Summary

Microstructural and mechanical properties after PWHT were evaluated in dissimilar weldment of SA508 Gr.3 and SA508 Gr.4N steel. In the results of microhardness tests, hardness was high in the weld

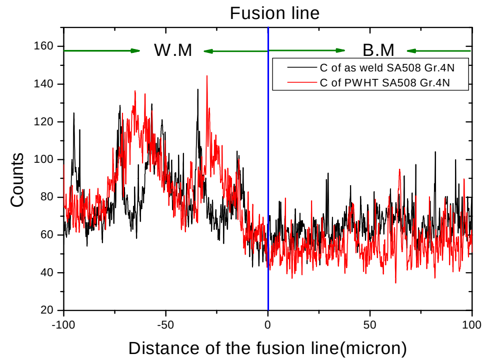

Fig. 4 EPMA data of as-welded SA508 Gr.4N and PWHT SA508 Gr.4N

metal side, while the lowest hardness was observed in the base metal side near the fusion line of both steels. It was found that hard zone and soft zone were C-rich state and C-depletion state, respectively, in the analysis of line scanning using EPMA. It was concluded that the hard zone with precipitate rich and the soft zone with precipitate free were formed on weld metal side and base metal side.

Acknowledgement

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