An Electrochemical Evaluation on the Corrosion of Weld Zone in Cold Arc Welding of the Cast Iron

Kyung Man Moon[1,†], Jin Gyeong Kim[2], Myung Hoon Lee[3], and Ki Joon Kim[3]

[1]*Department of Material Engineering, Korea Maritime University, Dongsam-2Dong youngdo-ku, Busan 606-791, Korea*
[2]*Korea Instritue of Marine and Fisheries Technology, yongdang-dong Nam-Ku, Busan, Korea*
[3]*Department of marine system Engineering, Korea Maritime University Dongsam-2Dong, youngdo-Ku, Busan 606-791, Korea*

Cold arc welding of cast iron has been widely used with repair welding of metal structures. However its welding is often resulted in the galvanic corrosion between weld metal zone and heat affected zone(HAZ) due to increasing of hardness. In this study, corrosion properties such as hardness, corrosion potential, surface microstructures, and variation of corrosion current density of welding zone with parameters of used electrodes for cast iron welding were investigated with an electrochemical evaluation. Hardness of HAZ showed the highest value compared to other welding zone regardless of kinds of used electrodes for cast iron welding. And its corrosion potential was also shifted to more negative direction than other welding zone. In addition, corrosion current density of WM in polarization curves was qualitatively smaller than that of HAZ. Therefore galvanic corrosion may be apparently observed at HAZ. However galvanic corrosion may be somewhat controlled by using an optimum welding electrode.

Keywords *: hardness, corrosion potential, heat affected zone, galvanic corrosion, cast iron*

1. Introduction

There are some kinds of welding methods such as SAW(Submerged Arc Welding), SMAW(Shielded Metal Arc Welding) and GMAW(Gas Metal Arc Welding) to manufacture ships, pressure vessel and structures etc. However cold arc welding of cast iron, one of GMAW is a repair welding irrespect of welding degree, root clearance and welding method. Therefore its welding technique is an important factor to get the good welding result.

When the cold arc welding of cast iron is carried out, increasing of hardness in the heat affected zone is often observed and galvanic corrosion due to their hardness difference between heat affected zone and weld metal zone is inevitably sometimes occurred, which may be finally resulted in cracking of the structures.

In this study, galvanic corrosion between heat affected zone and weld metal zone was investigated with electrochemical evaluation method such as corrosion potential, polarization curves, vickers hardness and micro structures.

2. Experimental

2.1 Welding method and kinds of electrodes

There are generally two methods for repair welding of cast iron, one is a hot arc welding maintaining constant temperature after preheating at high temperature, the other one is a cold arc welding without preheating. Cold arc welding is used in this experiment and six kinds of electrodes is also used to evaluate the effect to galvanic corrosion.

Table 1 shows the chemical composition and mechanical properties of cast iron and electrodes.

2.2 Electrochemical measurement

The electrochemical experiment in this investigation were carried out some parameters such as corrosion potential, polarization curves, vickers hardness and microstructures in natural sea water solution and 10% H_2SO_4 solution. Solution temperature was about 25℃. Fig. 1 shows the schematic view of welded cast iron and Fig. 2 shows the experimental apparatus.

† Corresponding author: lab@hhu.ac.kr

Table 1. Chemical composition and mechanical properties of cast iron and electrodes.

Electrode	Chemical composition (%)								Mechanical properties		
	C	Si	Mn	P	S	B	Cu	V	Tensile strenth (N/mm^2)	Elongation (%)	Hardness (HV)
Cast iron	3.2	1.1	0.8	0.4	0.1	0.04	1.5	0.22	245	0.3	180~230

Electrode	C	Si	Mn	P	S	Ni	Fe	Tensile strenth (N/mm^2)	Hardness (HV)
1 (Ni)	0.86	0.28	0.30	0.002	0.002	Bal	1.85	440	-
2 (NiFe)	0.98	0.32	0.80	0.005	0.004	55.1	Bal	560	-
3 (Ni)	1.0	0.38	0.07	0.006	0.006	Bal	0.02	300	145
4 (NiFe)	0.94	0.69	0.67	0.005	0.005	53	Bal	460	210
5 (Ni)	0.5	-	-	-	-	Bal	2.0	460	140
6 (NiFe)	0.5	-	-	-	-	54	45	460	180

※ SR: 550℃ × 4H

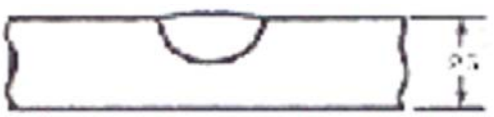

Fig. 1. Schematic view of welded cast iron.

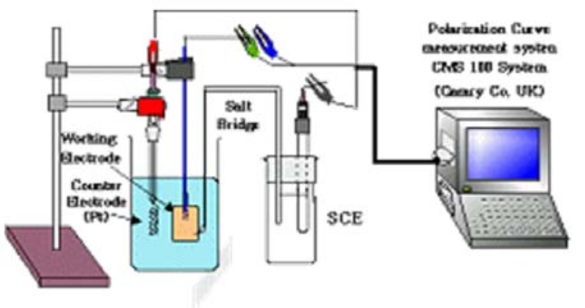

Fig. 2. Schematic diagram of experimental apparatus for polarization curves.

3. Results and discussion

Table 2 and Fig. 3, 4 shows the variation of corrosion potential and of hardness in each zone such as WM (Welded Metal), HAZ(Heat Affected Zone) and BM (Base Metal). As shown in Fig. 3, 4 the corrosion potential of WM was the most noble than other area and its potential of HAZ showed the most negative value. Especially the value of corrosion potential in all each zone measured in 10% H_2SO_4 solution showed negative value compared to sea water solution.

This is probably because corrosion rate in 10% H_2SO_4 solution is higher than sea water solution due to cathodic reaction such as oxygen reduction reaction ($O_2+4H^++4e \rightarrow 2H_2O$) as well as hydrogen generation reaction ($2H^++2e \rightarrow H_2$) in 10% H_2SO_4 solution compared to only oxygen reduction reaction ($O_2+2H_2O+4e \rightarrow 4OH^-$) in sea water solution. And Vickers hardness of HAZ showed consid-

Table 2. Relationship between hardness(HV) and corrosion potential(E_{cor}) in weld zone of cast iron.

Numbers of electrodes	WM (Welded Metal)		HAZ (Heat Affected Zone)		BM (Base Metal)		Remard
	HV	E_{cor}	HV	E_{cor}	HV	E_{cor}	
1 (Ni)	212	-281	712	-453	215	-430	Seawater
		-505		-690		-610	10% H_2SO_4
2 (NiFe)	228	-292	832	-441	218	-430	Seawater
		-464		-685		-610	10% H_2SO_4
3 (Ni)	217	-280	715	-442	214	-430	Seawater
		-543		-681		-610	10% H_2SO_4
4 (NiFe)	232	-263	722	-454	215	-430	Seawater
		-454		-673		-610	10% H_2SO_4
5 (Ni)	204	-252	694	-430	214	-430	Seawater
		-490		-613		-610	10% H_2SO_4
6 (NiFe)	252	-245	789	-435	219	-430	Seawater
		-528		-618		-610	10% H_2SO_4

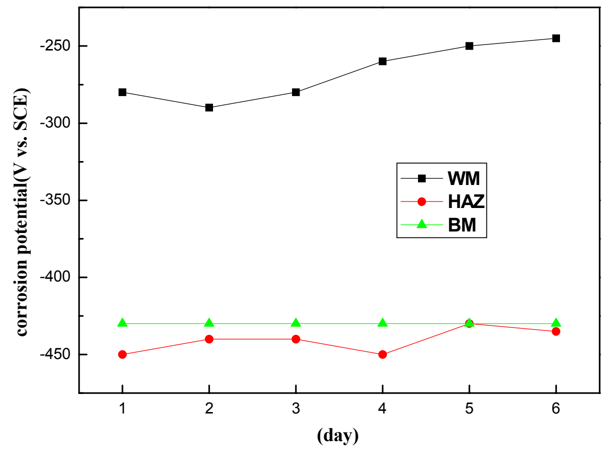

Fig. 3. Variation of corrosion potential in various area in natural sea water solution.

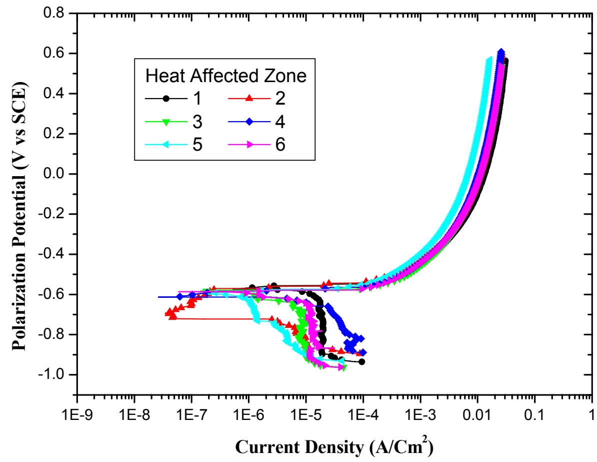

Fig. 5. Polarization curves of HAZ in sea water solution.

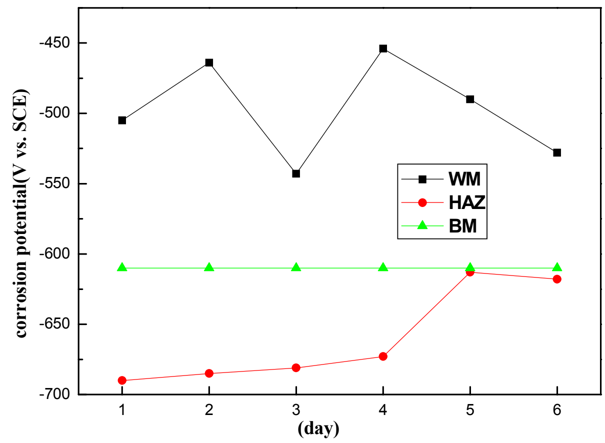

Fig. 4. Variation of corrosion potential in various area in 10% H_2SO_4 solution.

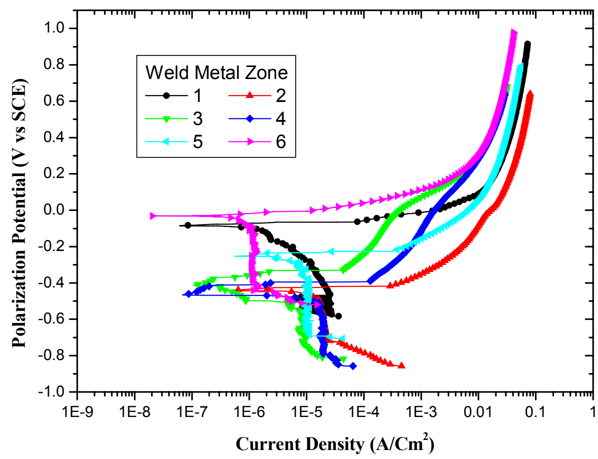

Fig. 6. Polarization curves of WM in case of various electrodes in sea water solution.

erably the highest value than other zone such as WM and BM. However in case of No. 5 electrode(Ni), their values of HAZ, BM and WM were the lowest compared to among those other electrodes.

And in case of Ni series electrodes(No. 1, 3 and 5) Vickers hardness shows slightly the lower value in various area than NiFe series electrodes(No. 2, 4 and 6). Fig. 5 shows the variation of polarization curves of HAZ in sea water solution, cathodic polarization curves are considerably different phenomenon each other, however anodic polarization curves are almost the same morphology.

In case of Fig. 6, cathodic and anodic polarization curves of WM shows the complicated phenomenon compared to HAZ because chemical composition of WM is different with used electrodes.

Fig. 7 shows the variation of polarization curves between WM and HAZ in cast of used No. 6 electrodes

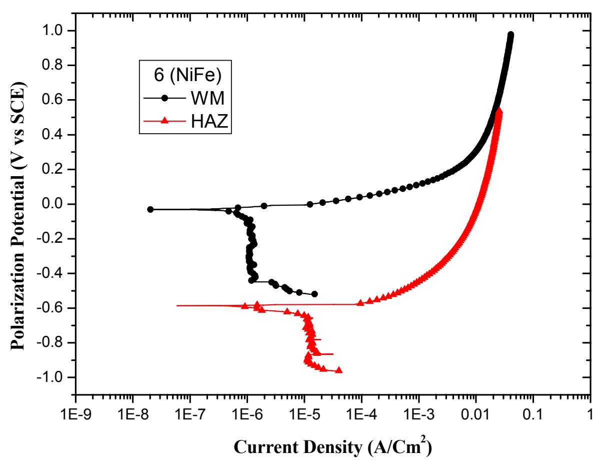

Fig. 7. Polarization curves of WM and HAZ in sea water solution.

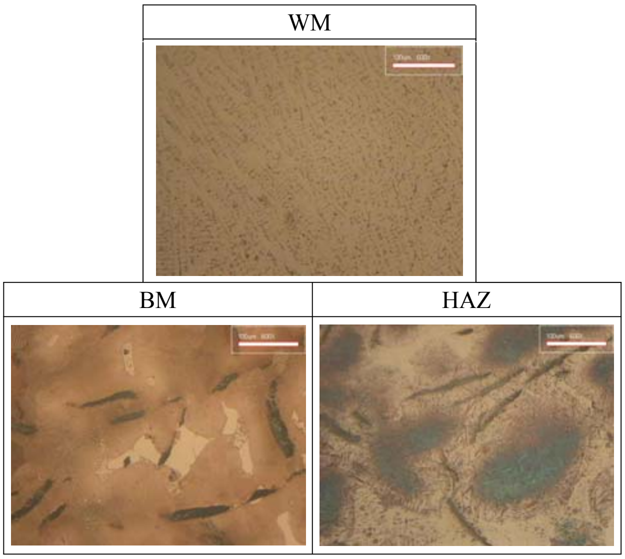

Fig. 8. Optical microstructures of HAZ, BM and WM (×600)

(NiFe) The corrosion potential of WM is nobler than that of HAZ, furthermore corrosion current density of WM is also qualitatively smaller than that of HAZ. These results mentioned above were apparently observed at all kinds of used electrodes. Therefore it is considered that galvanic corrosion can be occured between HAZ and WM.

Fig. 8 shows the microstructures of each zone such as WM, HAZ and BM. As shown in Fig. 8, the long size with black color in HAZ and BM is a graphite and was also mixed with white cast iron and gray cast iron. Especially mottled cast iron was observed at HAZ. And cementite and martensite were observed at WM.

And the morphology of WM was strongly different compared to those of BM and HAZ. Because Chemical composition of WM is quitely different with BM and HAZ materials with the cast iron.

4. Conclusions

In case of cold arc welding of cast iron, galvanic corrosion due to difference of hardness between HAZ and WM as well as difference of chemical composition between HAZ and WM may be easy to happen in severe corrosive environment.

The hardness of HAZ was higher than that of WM and BM, however their hardness values were some what different with used electrodes.

In case of Ni electrodes, hardness of 3 part such as HAZ, BM and WM was slightly lower than that of NiFe electrodes. Corrosion potential of WM was nobler than that of HAZ and also corrosion current density of WM was smaller than that HAZ.

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