

## Evaluation of Accelerated Graphitic Corrosion Test of Gray Cast Iron

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### 1. Introduction

In operating nuclear power plants, gray cast iron is commonly used as materials for various non-safety system components including pipes in fire water system, valve bodies, bonnets, and pump castings. In such locations, operating condition does not require alloy steels with excellent mechanical properties. But, a few corrosion related degradation, or graphitic corrosion is frequently occurred to gray cast iron during the long-term operation in nuclear power plant. Graphitic corrosion is selective leaching of iron from gray cast iron, where iron gets removed and graphite grains remain intact. In U.S.A., one-time visual inspection and hardness measurement are required from regulatory body to detect the graphitic corrosion for the life extension evaluation of the operating nuclear power plant [1]. In this study, experiments were conducted to make accelerated graphitic corrosion of gray cast iron using electrochemical method, and hardness was measured for the specimens to establish the correlation between degree of graphitic corrosion and surface hardness of gray cast iron.

### 2. Methods and Results

#### 2.1. Test material

To select proper cast iron grade for the test, several grades were obtained and compared. The tensile property of gray cast iron used in operating nuclear power plants corresponds to Class B, C of ASTM A-126 [2] (or Class 30, 40 of ASTM A-48/48M [3]), which are shown in Table 1. From the standard for gray cast irons used in Korea, or KS D-4301 shown in Table 2 [4], GC-250 shows equivalent properties and chosen as material for this study.

#### 2.2. Electrochemical test

Potentiodynamic polarization test was conducted to the gray cast iron and its elements – Fe and C(Graphite), to analyze the corrosion behavior of the material. The dimension of specimen for potentiodynamic polarization test was coupon type having 15mm diameter and 1.5mm thickness. Test was conducted by using potentiostat equipment and corrosion test cell. Fig. 1 shows the polarization diagram of (a) Gray cast iron, (b) Fe and (c) Graphite, respectively. Each material's exchange current density,  $i_o$  and corrosion potential,

$E_{corr}$  are listed in Table 3. Result shows the corrosion potential and corrosion current density of gray cast iron is somewhat similar to those of iron instead of graphite.

Table 1. Tensile requirements for gray cast iron

Specification A126 Class	Tensile Strength, min, ksi (MPa)	Equivalent Class (Specification A48/48M)		
		Under 0.50in. (12.7 mm)	0.51 to 1.00 in. (13.0 to 25.4 mm)	Over 1 in. (25.4 mm)
A	21 (145)	25A	20B	20C
B	31 (214)	35A	30B	30C
C	41 (283)	45A	40B	40C

Table 2. Specification KS D-4301 class

Class	Tensile Strength N/mm <sup>2</sup> (MPa)	Hardness HB
GC100	100<	201>
GC150	150<	212>
GC200	200<	223>
GC250	250<	241>
GC300	300<	262>
GC350	350<	277>

#### 2.3. Accelerated corrosion test

Graphitic corrosion is known to progress in relatively mild environments such as soft waters, waters having a slightly acidic pH, waters containing hydrogen sulfide, and brackish and other high-conductivity waters. In more aggressive environments, corrosion can be accelerated but may be manifested as general metal loss rather than as graphitic corrosion [5]. Considering these, several test conditions for accelerated graphitic corrosion experiments are chosen and shown in Table 4. For each condition, 40ml of test solution is prepared.

Fig. 2 shows the cross-sectional image of the test specimens obtained by optical microscope. At the surface, remaining C-rich layer was clearly revealed and the average thickness of this layer was recorded.

The EDS(Energy Dispersion Spectroscopy) images shown in Fig. 3 reveal the surface element change. There are only few Fe atoms in the leached layer but the carbon atoms are remaining unchanged. If general corrosion occurred at the surface, the oxygen atoms are shown in near-surface area, but the oxygen atoms are uniformly distributed. So it is thought the graphitic

corrosion is relatively dominant corrosion mechanism in this environment and condition.

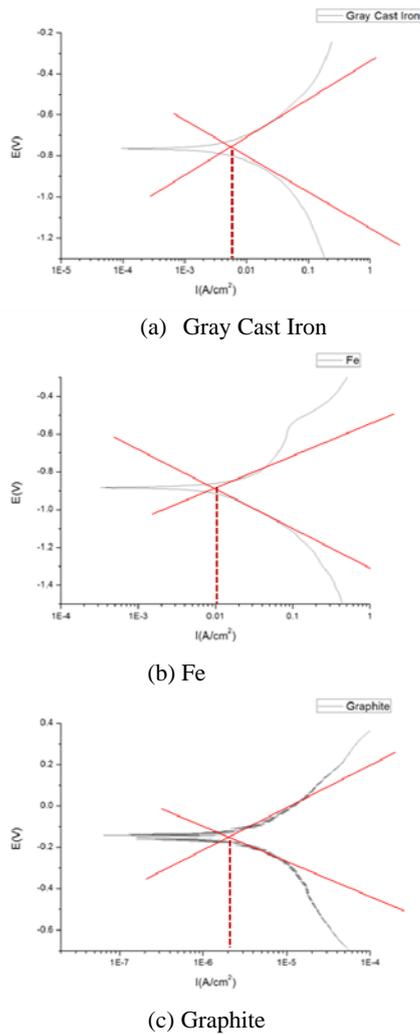


Fig. 1. Polarization curves

Table 3. Values of  $i_o$  and  $E_{corr}$

Material	$i_o$ (A/cm <sup>2</sup> )	$E_{corr}$ (V)
Gray Cast Iron	$6 \times 10^{-3}$	-0.78
Fe	$1 \times 10^{-2}$	-0.90
C(Graphite)	$2 \times 10^{-6}$	-0.18

### 3. Summary

The graphitic corrosion is very slow reaction, but it was confirmed that the thickness of leached layer can be controlled by the accelerated corrosion test with chemical solution using hydrogen sulfide environments. And through potentiodynamic polarization test, it was confirmed that the corrosion potential and corrosion current density of gray cast iron was somewhat similar to those of iron instead of graphite. Through the SEM and EDS analyses, formation of graphitic corrosion zone on the surface was confirmed.

### 4. Further Work

Using the specimens with varying depth of accelerated graphitic corrosion, hardness change due to should be measured. For this, several types of hardness test for graphitic corrosion would be tested. And the correlation between the degree of graphitic corrosion and the hardness should be established.

Table 4. Graphitic corrosion test result

No.	FeS (g)	HCl (ml)	Na <sub>2</sub> SO <sub>4</sub> (g)	Time (hour)	Temperature (°C)	Thickness (μm)
1	0.1	2	2	50	75	190
2	0.15	3	3	50	75	260
3	0.2	4	4	50	75	400
4	0.05	1	1	50	75	90
5	0.1	2	2	10	75	130
6	0.1	2	2	30	75	230
7	0.1	2	2	70	75	210
8	0.1	2	2	50	25	0
9	0.1	2	2	50	50	190
10	0.1	2	2	50	90	140

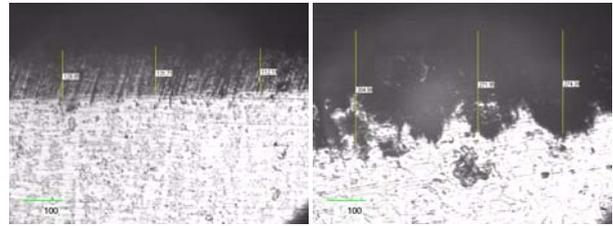


Fig. 2. Cross-sectional image (×100)

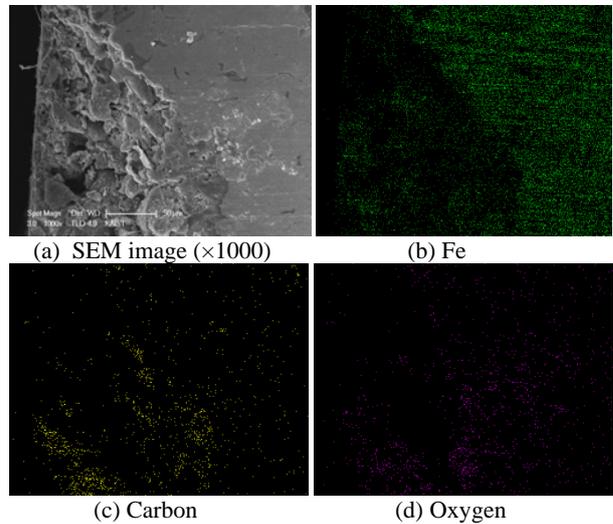


Fig. 3. SEM and EDS images

### REFERENCES

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