

크롬백주철의 기지조직 및 탄화물에 있어서 합금원소의 거동

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The Distribution Behavior of Alloying Elements in Matrices and Carbides of Chromium White Cast Iron

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초 록 0.5% C-25.0% Cr-1.0% Si(합금1), 0.5% C-5.0% Cr-1.0% Si(합금2) 및 2.0% C-5.0% Cr-1.0% Si(합금3)의 3종 류 크롬백주철에 있어서 기지조직 및 탄화물에 분포되는 Cr 및 Si의 거동을 연구하였다. 15kg 용량의 고주파 유도용해로에 선철, 고철, Fe-Cr, Fe-Si 등을 장입시켜 용해시킨 후 슬래그를 제거시키고 1550°C에서 펄스주형에 주입시킨후 실온까지 냉각시켜 SEM으로 응고조직을 관찰하였으며 EPMA 분석을 통하여 Cr 및 Si의 분포거동을 관찰하였다. 합금1의 경우 초정으로 δ 페라이트가 정출후 δ 페라이트와 용액의 입계에서 δ 페라이트와 M_7C_3 탄화물이 공정으로 정출하였으며 합금2의 경우 용액에서 초정으로 거의 δ 페라이트가 정출된 후 극히 일부분만이 δ 페라이트와 M_7C_3 탄화물의 공정으로 정출하였다. 반면 합금3의 경우 오스테나이트가 초정으로 정출된 후 오스테나이트와 M_3C 탄화물이 공정으로 정출하였다. Cr은 주로 M_7C_3 및 M_3C 탄화물에, 그리고 Si는 기지조직에 선택적으로 분배되었으며 Cr의 기지조직에 대한 분배계수는 0.56-0.68, 그리고 Si는 1.12-1.28의 범위에 걸쳐있었다. 또한 Cr의 기지조직에 대한 분배계수는 C함량이 2.0% 일때가 0.5%의 경우보다 낮았으며 M_7C_3 탄화물내의 Cr함량은 Cr함량이 25.0% 일때가 5.0%의 경우보다 높은값을 나타내었다.

Abstract Three different white cast irons alloyed with Cr and Si were prepared in order to study their distribution behavior in matrices and carbides. The specimens were produced using a 15kg-capacity high frequency induction furnace. Melts were super-heated to 1600°C, and poured at 1550°C into a pepset mold. Three combinations of the alloys were selected so as to observe the distribution behavior of Cr and Si: 0.5% C-25.0% Cr-1.0% Si (alloy No. 1), 0.5% C-5.0% Cr-1.0% Si (alloy No. 2) and 2.0% C-5.0% Cr-1.0% Si (alloy No. 3). Cellular M_7C_3 carbides- δ ferrite eutectic were developed at δ ferrite liquid interfaces in the alloy No. 1 while only traces of M_7C_3 carbides- δ ferrite eutectic were precipitated in the alloy No. 2. With the addition of 2.0% C and 5.0% Cr, ledeburitic M_3C carbides instead of cellular M_7C_3 carbides were precipitated in the alloy No. 3. Cr was distributed preferentially to the M_7C_3 carbides rather than to the matrix structure while more Si were partitioned in the matrix structure rather than the M_7C_3 carbides. K^m for Cr was ranged from 0.56 to 0.68 while that for Si was from 1.12 to 1.28. K^m for Cr had a lower value with increased carbon contents. The mass percent of Cr was higher in the M_7C_3 carbides with increased Cr contents.

Key words : white cast iron, distribution behavior, M_7C_3 , M_3C , matrix

1. Introduction

Chromium white cast irons have been used for abrasion wear resistant applications in steel making plant, cement industry, mining industry and thermal power plant.^{1~12)} Particularly, chromium white cast irons containing chromium from 5 to 30 mass% have high performance not only in abrasive and erosive wear resistance but also in corrosion and oxidation resistance owing to M_7C_3 and M_3C carbides, and matrix structures alloyed with chromium.

Properties such as abrasive and erosive wear

resistance, corrosion and oxidation resistance, surface roughening resistance and seizing or sticking resistance are essentially important to apply these chromium white cast irons for the rolls and other wear resistant parts of steel rolling and mineral pulverizing mills. These properties are reported to be dependent upon not only type, morphology, amount and distribution pattern of the precipitated carbides, but also the matrix structure, all of which are controlled by distribution behavior of alloying elements such as Cr, Si and Fe. Nevertheless, the distribution behavior of alloying elements in the matrices and carbides of these irons was little

researched systematically.

In this work, chromium white cast irons with three different chemical compositions were selected for the investigation of distribution behavior of Cr and Si in matrices and carbides in as-cast condition.

2. Experimental Procedure

Specimens were produced using a 15kg-capacity silica lined high frequency induction furnace. Initial charge materials were clean pig irons and steel scraps. Ferro-alloys such as Fe-60%Cr and Fe-75%Si were added to a slag-free molten iron so as to minimize the oxidation loss and the slag formation. The melt was subsequently super-heated to 1600°C and transferred into a preheated teapot ladle. After removal of any dross and slag, the melt was poured at 1550°C into a pepset mold containing a cylindrical bar of 30mm dia. x 200mm length. For the investigation of distribution behavior of alloying elements, three different compositions were selected so as to obtain the different type of matrices and carbides: 0.5%C-25.0%Cr-1.0%Si, 0.5%C-5.0%Cr-1.0%Si and 2.0%C-5.0%Cr-1.0%Si. The specimens were polished, etched and examined metallographically. The etching solution used was Murakami's etchant (10g of potassium ferricyanide, 10g of potassium hydroxides and 100ml of distilled water). The alloy concentrations in each phase were also analyzed by EPMA. Using a X-ray diffractometer, the amounts of retained austenite (V_r) in the matrix was measured from diffracting angle of 24 to 44 degree by employing Mo target, and simultaneously rotating and swinging sample stage in order to reduce the effect of texture structure. The relative intensity of peaks were monitored from (200) and (220) planes of ferrite and martensite, and (220) and (311) planes of austenite. The area under each peak was calculated by using image analyzer from which V_r was measured. The chemical analysis of the alloys are shown in Table 1.

3. Results and Discussion

A summary of the chemical analysis of the three alloys employed in this research is presented in Table 1.

The microstructures of the three alloys No. 1, No. 2 and No. 3, and their EPMA analysis of the matrix structure are shown in Fig. 1.

At the carbon level of 0.5%, cellular M_7C_3 carbides- δ ferrite eutectic are developed at δ ferrite liquid interfaces in the alloy No. 1 while only traces of M_7C_3 carbides- δ ferrite eutectic are precipitated in the alloy No. 2. Due to lower addition of carbon to melts, the carbide forma-

Table 1. Chemical composition of the three alloys employed in this research.

Alloy No.	Element(mass%)		
	C	Cr	Si
1	0.48	24.94	1.09
2	0.53	5.3	1.07
3	1.98	5.2	0.97

tion has been limited to small amounts, especially in the alloy No. 2 with 5.0% Cr. According to the Fe-Cr-C diagram¹³⁾, the alloy No. 1 solidifies with precipitation of δ ferrite followed by (M_7C_3 carbides + δ ferrite) eutectic reaction. On the other hand, most of the melts in the alloy No. 2 are solidified as δ ferrite with the remainder being transformed to M_7C_3 carbides- δ ferrite eutectic. The matrix structures of the alloys No. 1 and No. 2 were also identified with X-ray diffractometer, which revealed the existence of ferrite only as shown in Fig. 2.

With the addition of 2.0% C and 5.0% Cr, ledeburitic M_7C_3 carbides instead of cellular M_7C_3 carbides are precipitated as shown in Fig. 1. From the Fe-Cr-C diagram of the alloy No. 3, it can be known that austenite crystallizes from the melts as primary phase and followed by eutectic reaction of (M_7C_3 carbides + austenite). As shown in Fig. 2, the X-ray diffraction pattern of the alloy No. 3 is quite different when compared with that of the alloys No. 1 and No. 2 because it contains about 20% of austenite in the matrix structures.

In each alloy, three spots were taken and EPMA analyzed from the carbides and matrix structures to observe the distribution of Cr and Si, and the results are listed in Table 2.

In the alloy No. 1, it can be known that Cr is distributed preferentially to the M_7C_3 carbides rather than to the matrix structure while more Si are partitioned in the matrix structure rather than the M_7C_3 carbides. The distribution coefficient of primary matrix (K^m) is defined as C_m/C_l , where C_m is an alloy concentration in the primary phase and C_l in the melts. As calculated from Table 2, K^m for Cr is 0.56 (13.89/24.94), while that for Si is 1.12 (1.22/1.09). In the alloy No. 2, K^m for Cr is 0.68 (3.61/5.30), while that for Si is 1.14 (1.22/1.07). On the other hand, K^m for Cr is 0.62 (3.22/5.20), while that for Si is 1.28 (1.24/0.97). When compared the alloy No. 2 with the alloy No. 3, K^m for Cr has a lower value with increased carbon contents. This result is consistent with the fact that K^m for carbide stabilizers such as Cr, Mo and V becomes smaller with increase of carbon in the melts, while K^m for graphite stabilizers

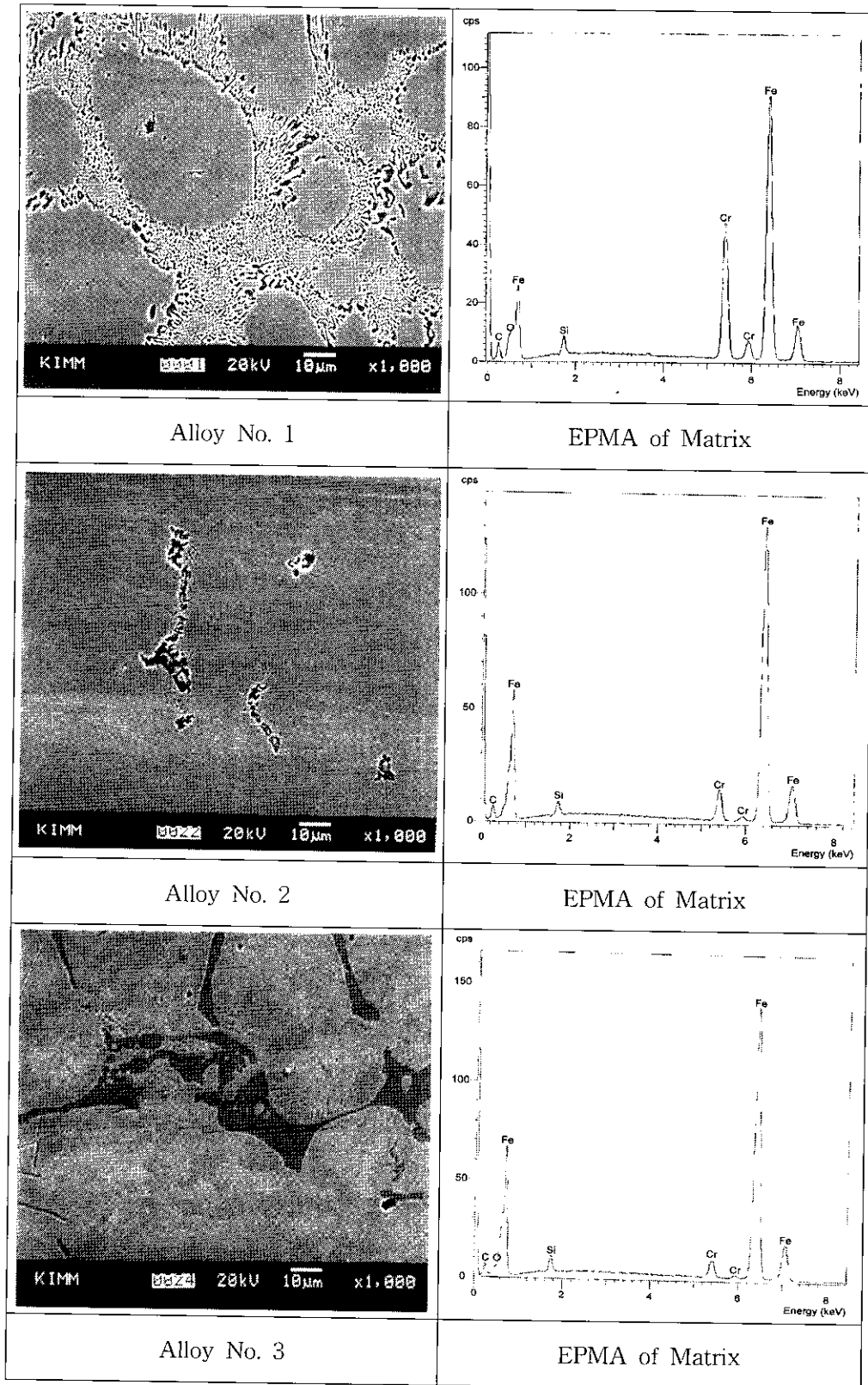


Fig. 1. Microstructures and EPMA analysis of matrix structures in the alloys No. 1, No. 2 and No. 3.

such as Si and Ni becomes larger with the addition of carbon to the melts.¹⁴⁾ It is also noted from Table 2 that

the mass percent of Cr is higher in the M_7C_3 carbides as the Cr content is increased.

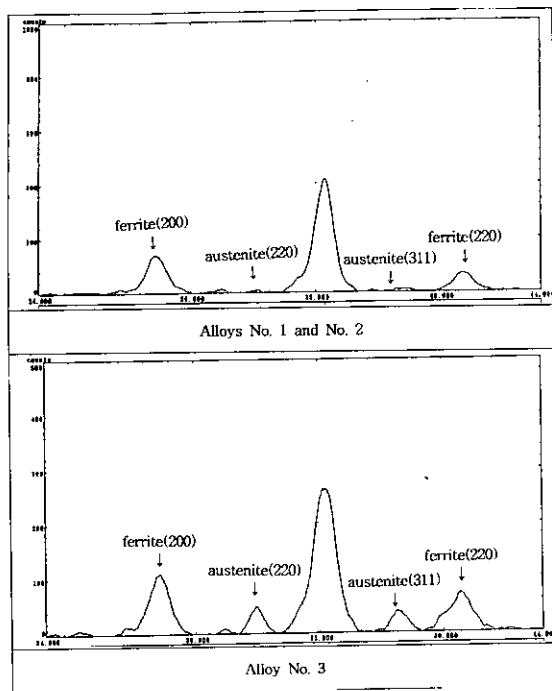


Fig. 2. X-ray diffraction patterns of the alloys No. 1, No. 2 and No. 3 in as-cast state.

Table 2. Averaged alloy concentrations in each carbide and matrix structures.

Alloy No.	Phase	Element(mass %)		
		Si	Cr	Fe
1	M_7C_3	0.87	54.58	44.55
	Matrix	1.22	13.89	84.89
2	M_7C_3	0.85	16.54	82.61
	Matrix	1.22	3.61	95.17
3	M_3C	0.87	18.30	80.83
	Matrix	1.24	3.22	95.54

4. Conclusion

Distribution behavior of alloying elements in matrices and carbides of chromium white cast iron has been studied. The results are summarized as follows:

1) At the carbon level of 0.5%, cellular M_7C_3 carbides- δ ferrite eutectic are developed at δ ferrite liquid interfaces in the alloy No. 1 while only traces of M_7C_3 carbides- δ ferrite eutectic are precipitated in the alloy No. 2.

2) With the addition of 2.0% C and 5.0% Cr, ledeburitic M_3C carbides are precipitated instead of cellular M_7C_3 carbides.

3) Cr is distributed preferentially to the M_7C_3 carbides rather than to the matrix structure while more Si are partitioned in the matrix structure rather than the M_7C_3 carbides.

4) K^m for Cr is ranged from 0.56 to 0.68 while that for Si is ranged from 1.12 to 1.28.

5) K^m for Cr has a lower value with increased carbon contents.

6) The mass percent of Cr is higher in the M_7C_3 carbides with increased Cr contents.

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References

1. W.A. Fairhurst and K. Rohrig, Foundry Trade Journal, **136**, 685, (1974).
2. J.D. Watson, P.J. Mutton and I.R. Sare, Metals Forum, **3**, 74, (1980).
3. K. Yamaguchi and Y. Matsubara, J. of Japan Foundry Eng. Society, **62**, 43, (1990).
4. S.K. Yu and Y. Matsubara, Proc. of 3rd Asian Foundry Congress, **3**, 128, (1995).
5. Y. Matsubara, N. Sasaguri and M. Hashimoto, Proc. of 4th Asian Foundry Congress, **4**, 251, (1996).
6. K. Shimizu, N. Sasaguri and Y. Matsubara, Proc. of 4th Asian Foundry Congress, **4**, 283, (1996).
7. Y. Matsubara and N. Sasaguri, J. of Japan Foundry Eng. Society, **68**, 1099, (1996).
8. Y. Honda and Y. Matsubara, Proc. of 5th Asian Foundry Congress, **5**, 162, (1997).
9. S.K. Yu and Y. Matsubara, Proc. of 4th Asian Foundry Congress, **4**, 291, (1996).
10. K.H. Zum Gahr and G.T. Eldis, Wear, **86**, 175, (1980).
11. J.T.H. Pearce : AFS Trans., **92**, 599, (1984).
12. S.K. Yu, N. Sasaguri and Y. Matsubara, International Journal of Cast Metals Research, **11**, 561, (1999).
13. R.S. Jackson: J. Iron Steel Inst., **208**, 163, (1970).
14. C.R. Loper : AFS Trans., **97**, 1001, (1989).