HIGH CARBON FERROCHROMIUM OPERATIONAL MANAGEABILITY WHILE DIVERSIFYING PRODUCTS

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ABSTRACT

Conventional high carbon ferrochromium production basically is carried-out by carbothermic reactions as a result of reducing chrome oxides. In the alloy structure, carbon takes place as carbide forms. Depending on the concentration of carbon versus chromium in the alloy microstructure; tapping and post-tapping operations including casting, crushing and screening operations are influenced accordingly.

The study has experienced at Eti Krom Inc (Turkey), Vargön Alloys AB (Sweden) and Tikhvin Ferroalloy (Russia) smelters. Thus, at a large range of high carbon ferrochromium products (C%: 5 to 9), the study was fulfilled.

1 INTRODUCTION

Ferrochrome is mostly known as an alloy of chrome and iron, containing between 50% and 70% chrome. Depending on using a different chemical characteristics of chrome ore, each smelter has opportunities to diversify its ferrochrome quality. The main characteristic to be considered is the level of carbon in the alloy. International trade organisms divide ferrochrome production into three types of alloy.

I. High-carbon (HC) ferrochrome (C>4%),
II. Low- and medium-carbon (LC & MC) ferrochrome (C<4%),
III. Ferrochrome-silico-chrome (FeSiCr) [1].

Figure 1 shows that 95% of total ferrochrome production represent HC ferrochrome and Charge Cr.

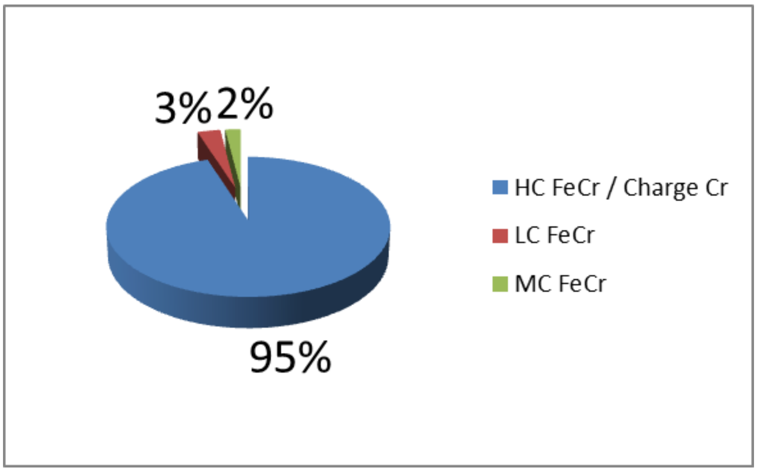

Figure 1: Global ferrochrome production share by type in 2013 [1]

Conventional high carbon ferrochromium production is basically carried-out by carbothermic method, using carbon based agents such as coal, metallurgical coke, anthracite. As a result of reduction reactions, reduced oxides generate metal alloy phase and unreduced oxides generate slag phase. Metal and slag flow from the tapping hole every 2-3 hours through tapping operations. Afterwards, post-tapping operations of which include casting and crushing-screening operations are managed. Depending on the concentration of carbon versus chromium in the alloy microstructure tapping and post-tapping operations are influenced accordingly.

This paper will assess operational cases considering conventional high carbon ferrochromium process.

2 PRODUCT DIVERSIFICATION PHENOMENA

2.1 Ore and Reductant Quality

Ore quality is the main phenomena of the product differentiation. EtiKrom Inc., Vargön Alloys AB and Tikhvin Ferroalloy diversify the products by using Kazakh and Turkish lumpy chromites from grade-30 to grade-46. Today, these three plants are producing approximately total 9 types of different products.

As it is called carbothermic process, reductant quality and size are also crucial to provide sufficient conductivity in the furnace charge for electrometallurgical operation. P% and S% of ferrochrome are controlled by reductant specifications.

2.2 Slag Composition

Unreduced oxides generate slag phase. The smelting point of the slag has to be higher than the metal smelting point, because metal is heated up by using slag liquid phase. The composition of ferrochrome slag could be controlled by blending of chrome ore, fluxes (quartz, bauxite) and SiO_2-MgO-Al_2O_3 ternary equilibrium (Figure 2) [4].

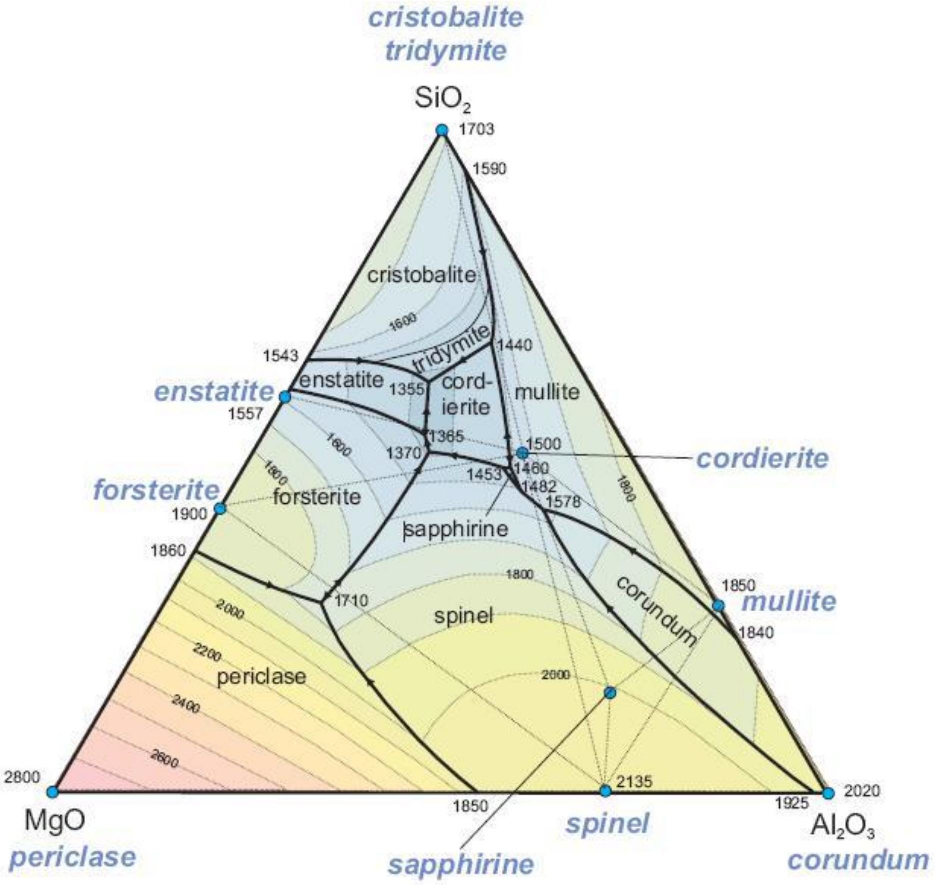

Figure 2: SiO_2-MgO-Al_2O_3 ternary equilibrium [5]

2.3 Chrome Carbide Generation

In high carbon ferrochrome alloy microstructure, carbon takes place as carbide forms. Mostly $Cr_{23}C_6$, Cr_7C_3 and Cr_3C_2 are dominated the carbide form. Likewise, iron and silicon are exposed to carburization as well. However, this paper approaches the cases solely according to Cr-C relationship [2,3].

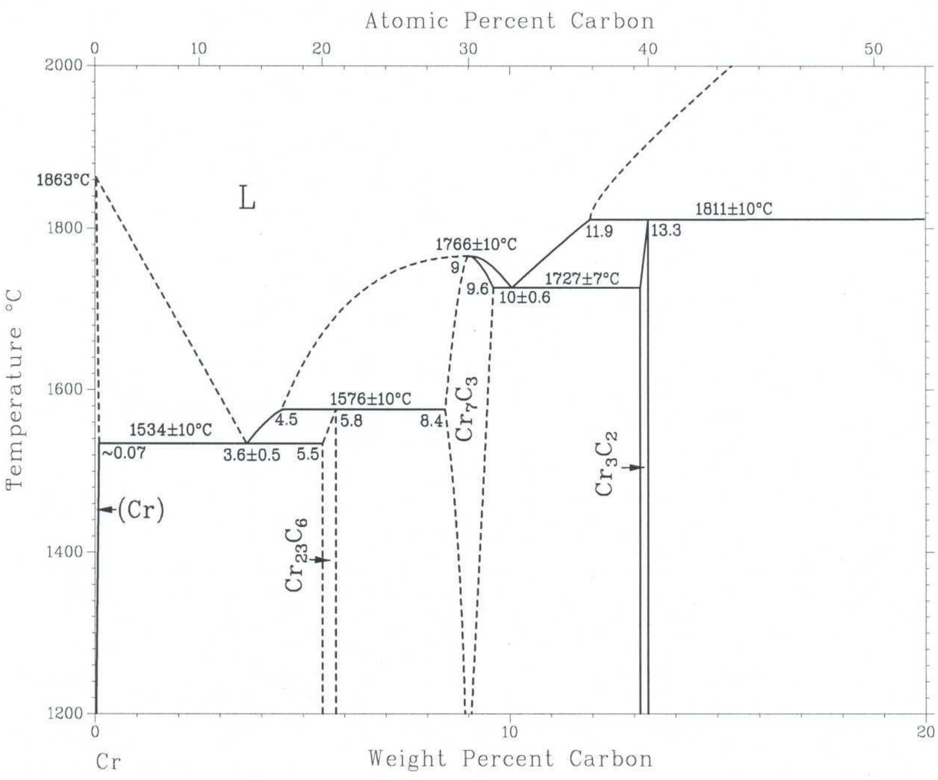

Figure 3: Cr-C Phase Equilibrium

When the temperature is reached at 1500 ^{0}C, reaction (1) starts

$<Cr_2O_3> + 13/3 <C> = 2/3 <Cr_3C_2> + 3(CO)$ (1)

When the temperature is reached at 1600 ^{0}C, reaction (2) starts

$<Cr_2O_3> + 27/5 <Cr_3C_2> = 13/5 <Cr_7C_3> + 3 (CO)$ (2)

When the temperature is reached at 1700 ^{0}C, reaction (3) starts

$<Cr_2O_3> + 3 <Cr_7C_3> = <Cr_{23}C_6> + 3(CO)$ (3)

Cr_3C_2 , Cr_7C_3 and $Cr_{23}C_6$ carbides are generated in this order [2]. As long as temperature rises, carburization continues unless insufficient quantity of Cr_2O_3 or carbon agents in the reaction zone. Accordingly, the rate of carbon in the alloy goes down and chromium rate goes up.

Moreover, other than chemical considerations, physical properties of furnace charge are also a crucial factor for the carburization. During conventional smelting in AC furnaces, of course there may be an optimum size of ore for per product or furnace. However, lumpy/fine ratio of ore is influenced reaction surface as well as production efficiency. If rate of fine reaches an excessive amount, carburization occurs at lower temperature.

3 OPERATIONAL MANAGEABILITY DURING FERROCHROMIUM DIVERSIFICATION

3.1 Tapping Operations

Tapping is actually an important portion for submerged arc furnace operations. Figure 3 shows melting temperature of carbides as following. [2,3]

- $Cr_{23}C_6$: ~1576 ^{0}C
- Cr_7C_3: ~1766 ^{0}C
- Cr_3C_2: ~1811 ^{0}C

It means that initially Cr_3C_2 starts to be solidified. Afterwards, Cr_7C_3 and $Cr_{23}C_6$. Therefore, as long as carbon content increases in the ferrochrome, metal tapping is getting harder due to lower Cr/C ratio dominates the carbide structure. Case study also shows that tapping operations for 9% C containing FeCr at Tikhvin Ferroalloy is more difficult than 5% C containing FeCr at Vargön Alloys.

3.1.1. Tapping hole problems

Tapping hole refractory lining life time depends on metal alloy temperature and of course C content of the product. Lower carbon containing high carbon ferrochrome shorten the refractory life time.

(a) (b)

Figure 4 – (a) Tapping hole lining maintenance, Vargön Alloys AB ,Sweden
(b) Tapping hole lining maintenance, Eti Krom Inc., Turkey

Similar tapping hole refractory lining was applied at Eti Krom and Vargön Alloys. Due to lower percentage of C containing products (5-6%), Vargön Alloys AB at least once in a year needs to repair tapping holes. On the other hand, due to higher C content (7-8%), Eti Krom's tapping hole lasts longer about 2 years.

3.2 Post-Tapping Operations

3.2.1 Casting operations

During post-tapping operations, liquid ferrochrome is casted in moulds. Depending on carbon content of the ferrochrome, slow cooling or fast cooling may occur.

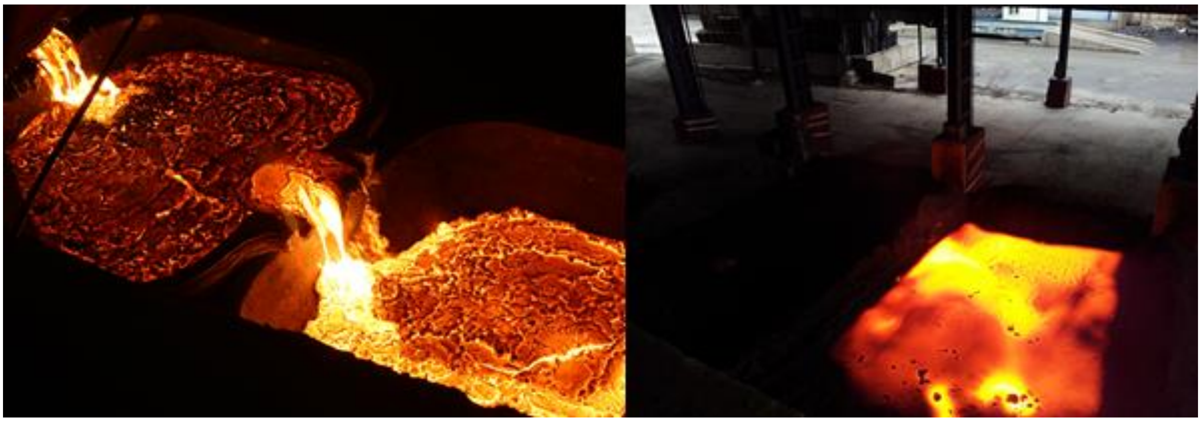

Figure 5: Ferrochrome cooling after casting, Tikhvin Ferroalloy (left) and Eti Krom (right)

In Figure 5, the photo on the left side represents a ferrochrome containing 8,5% of C and the photo on the right side represents a ferrochrome containing 7% of C. In the study, it was observed that 8,5% C containing metal was cooled faster and spreaded slightly in the mould.

Ladle Erosion Problems

While casting, metal is aggressive to consume the ladles. Figure 6 shows that obviously. It was occurred when the carbon content was 6%.

Figure 6: Metal ladles after casting, EtiKrom Inc.,Turkey

3.2.2. Crushing and screening operations

When metal is cooled totally, it is transported to the crushing and screening unit. Depending on the product chemical specifications, crushing-screening under size output is influenced. Higher carbon percentage makes the metal easily crushed.

Figure 7 shows the relation between carbon content of the product and crushing-screening operations undersize (-10mm). This study was fulfilled with 5 different products while sizing to 10-50 mm at Eti Krom, Vargön Alloys and Tikhvin Ferroalloy.

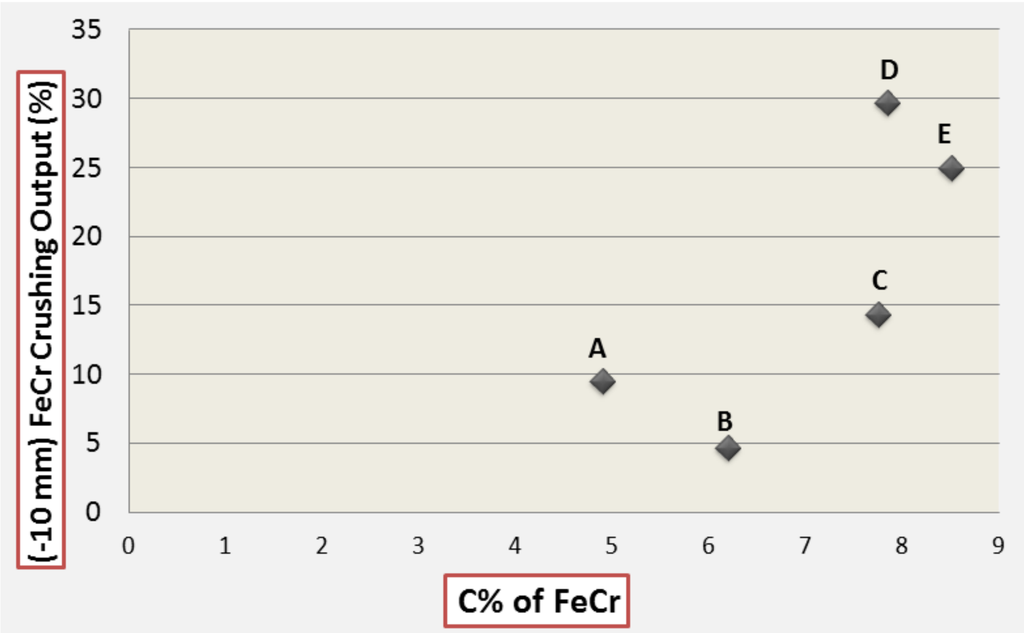

Figure 7: Carbon content of the product vs. crushing-screening under size

4 CONCLUSIONS

According to domination of various carbide forms and diversified carbon content in the alloy, operational circumstances are influenced simultaneously. Therefore in the field of high carbon ferrochromium production, this paper provides some practical clues to have a better understanding about operational manageability while diversifying products.

5 REFERENCES

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