# ADJUSTMENT OF HIGH CARBON FERROCHROME COMPOSITION IN DC FURNACES

O. Privalov, Ye. Abdulabekov, Zh. Nurmukhanbetov, M. Kospanov, Zh. Mussabekov

"TNC "Kazchrome" JSC, 4A M. Mametovoi Str., Aktobe city, 030008, Republic of Kazakhstan
e-mail: Erzhan.Abdulabekov@kz.enrc.com

## ABSTRACT

*One of the main trends of carbon ferrochrome smelting development is implementation of DC furnaces enabling processing of fine chrome ore without preliminary pelletizing. At the present construction of a shop equipped with 72 MW DC furnaces will be soon completed at Aktobe Ferroalloy plant.*

*Usage of just fine chrome ore and change of heating and material recovery principles in DC furnace excludes the possibility of adjusting carbon and silica content by traditional methods. The mentioned circumstances can result in producing off-grade carbon and silica.*

*The paper basing on data of pilot tests performed in DC furnaces with a capacity of 3,2 MBA, conducted by Mintek (South Africa) research center considers readymade metal chemical composition adjusting aspects. In particular, basing upon process conditions and thermodynamic laws carbon and silica transferring into metal has been considered. The paper endeavors to evaluate results of ferrochrome production in DC furnaces and influence of smelting operational parameters onto metal quality and composition.*

*Basing on the conducted researches it can be said despite some restrictions, silica and carbon transfer into metal and so metal quality management in DC furnaces are potentially possible. For that firstly optimal slag and temperature mode of the process is to be maintained.*

***KEYWORDS:*** *DC furnace, high carbon ferrochrome.*

## INTRODUCTION

The majority of ferrochrome nowadays is being produced in AC thermal furnaces in which electrodes are immersed into lumpy charge materials in the form of chrome ore or pellets, reducers and flux metals. One of the main trends of carbon ferrochrome smelting development is implementation of DC furnaces enabling processing of fine chrome ore without preliminary pelletizing [1, 2]. At the present construction of a shop equipped with 72 MW DC furnaces will be completed soon at Aktobe Ferroalloy plant. Due to this Kazchrome company has conducted research on selection of tailored composition of charge materials, electrical, processing and slag modes using Donskoy Mine processing plant ores at Mintek pilot furnaces. Experiment results revealed first, stability and flexibility of ferrochrome production in DC furnaces, and secondly, enabled obtaining valuable data on chrome raw materials processing using this method [3].

In AC thermal furnace carbon and silica low content can be adjusted by selection of ore body having good density and thermal stability in bottom part of the furnace to provide required rate of chromium carbide oxidizing. However, usage of just fine chrome ore in DC furnace excludes the possibility of adjusting carbon and silica content by traditional methods. The mentioned circumstances can result in producing off-grade carbon and silica.

It is known, high carbon ferrochrome is used mainly for production of stainless steel. Silica and carbon content in these alloys is of big importance, especially during oxygen finishing of liquid steel.

Therefore, the paper basing on data of pilot tests conducted by Mintek research center [3], considers readymade metal chemical composition adjusting aspects. In particular, basing upon process conditions and thermodynamic laws carbon and silica transferring into metal has been considered. The paper endeavors to evaluate results of ferrochrome production in DC furnaces and influence of smelting operational parameters onto metal quality and composition.

## EXPERIMENTAL

Pilot tests on producing of high carbon ferrochrome from Donskoy Mining Processing plant chrome ore were executed in experiment DC furnace with a transformer capacity of 3,2 MBA at Mintek research center. Conducted tests comprised several stages presenting three main periods during of which it was planned to melt metal with three different capacity values (450 $kWT/m^2$, 500 $kWT/m^2$ и 550 $kWT/m^2$).

In the paper data obtained during pilot tests have been processed aiming to revealing pair relations on adjusting of metal chemical composition. Processing of results not divided into periods has not revealed any certain relations. Therefore processing of experimental data was conducted separately for each test stage, results of which are given at the figures and considered below.

## RESULTS AND DISCUSSIONS

### Influence of operational parameters onto carbon content

Carbon content is a main and very important ferrochrome characteristic specifying its brand, physical features and quality. Therefore, possibility of its content adjustment during smelting is one of the main tasks requiring special attention.

During coal reducing process of chromite alloys production carbon content is mostly determined by silica content. Many research workers [4] had been considering matters of quantitave relation between carbon and silica in chromite alloys. The mentioned relation is stipulated by the fact that silica is closer to chrome rather than carbon therefore silica content increase causes carbon content decrease.

Similar results have been obtained upon carbon ferrochrome smelting in DC furnace. Data on different work stages prove that the higher silica content the lower carbon content in metal. This is as stated above can be explained by carbon solvency decreasing and silica content increase (figure 1). However, silica content increase in metal cannot be used as an adjustment tool of carbon content, since in compliance with effective standards silica content as per high carbon ferrochrome is limited by 2%.

Slag content can serve as an indirect indicator of the process, and considerably effect temperature and electrical mode of smelting process. As it will be shown below, slag content has significant effect onto carbon content in metal.

As it was proven practically, reducer excessive content while ferrochrome smelting can be estimated by residual concentration of $Cr_2O_3$ in slag. Concentration of the mentioned oxide in slag is one of the important smelting indicators as well as chrome extraction rate, metal quality etc. There is interrelation between $Cr_2O_3$ content in slag and carbon content in metal represented by diagram 2. As it can be seen, chrome oxide content increase causes carbon content decrease in metal.

This can be explained by refining process way by reaction owing to reacting agents activity increase.

$$[Cr_7C_3] + (Cr_2O_3) = 9\ [Cr] + 3\ \{CO\}$$

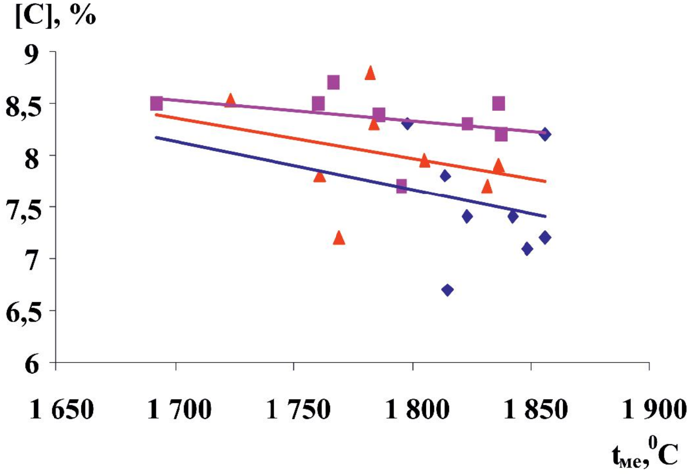


**Figure 1:** Influence of metal temperature onto [C] content

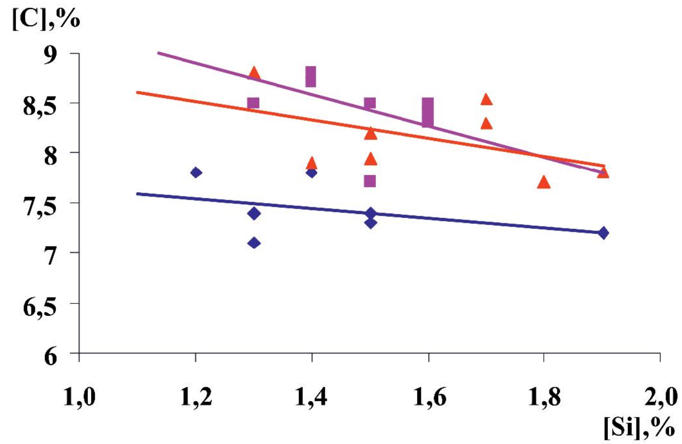


**Figure 2:** Influence of silica in metal onto [C] content

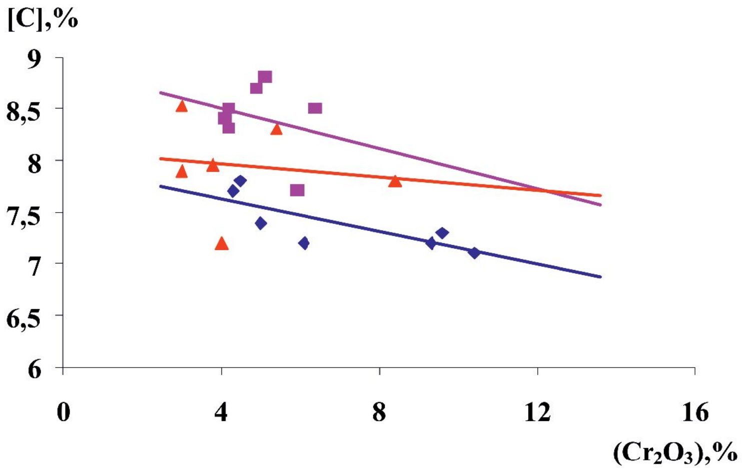


**Figure 3:** Slag concentration of ($Cr_2O_3$) influence onto [C] content

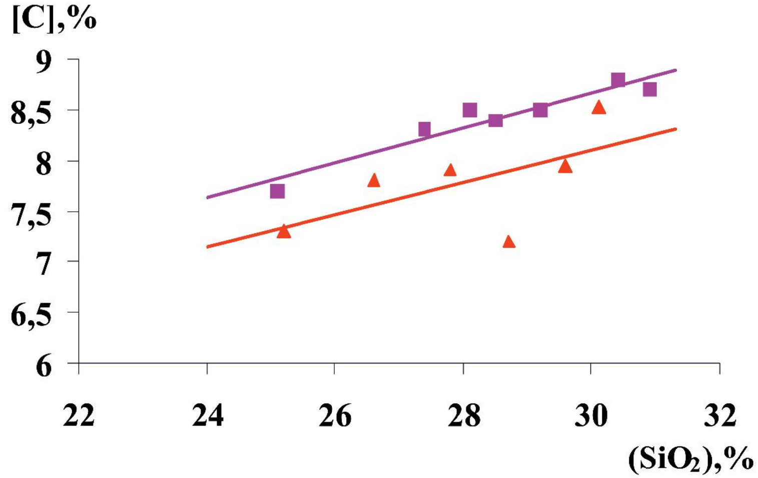


**Figure 4:** Slag concentration of ($SiO_2$) influence onto [C] content

This method is being used nowadays during carbon ferrochrome smelting in AC furnaces, when sufficient amount of lumpy ore required for creating of ore layer in furnace bath is missing. Technologists artificially create light insufficiency of reducing agent enabling to achieve carbon content reduce up to certain level.

As it was stated above, the only way of reducing chrome oxide in slag and carbon content in metal up to limited values in DC furnace is increasing system temperature in the furnace. Figure 1 shows that increase of metal temperature reduces carbon content all over three experiment stages which can be explained by reduction of chromium carbide consistency and carbon solvency in ferrochrome under high temperatures. Basing on this industrial operation requires maintaining metal temperature not less than 1850-1900ºC enabling to produce low carbon metal.

Slag composition is a main factor determining process temperature in AC and DC furnaces. Composition change shall indirectly effect carbon content in metal accordingly. Figures 4 and 5 prove the fact that silica and aluminum oxide affect carbon leaving metal. This is connected, as is was stated above, with slag composition effect onto metal temperature. It is known, increase of silica and aluminum oxide content in high carbon ferrochrome magnesia slag results in smelting temperature reduction and the complete process accordingly. And as it was stated above (figure1) temperature reduction is characterized by carbon concentration increase in metal.

**Influence of operational parameters onto silica content**

Silica concentration in ferrochrome is not less important characteristic specifying its brand and quality. Therefore, possibility of its adjustment during smelting process is one of the main aspects requiring special attention, since its concentration exceeding by 2% is not acceptable in compliance with effective standards, metal with such silica concentration will be in lower demand. As it was stated above, the only way of reducing silica and carbon concentration in metal up to limited values is increasing of complete system temperature in a furnace. As it can be seen from figure 6 silica concentration is being increased upon metal temperature increase during all main test stages. Thus, temperature increase is not characterized by intense metal purification of silica as with carbon. This is connected with silica recovery process intensification under high temperatures.

This factor is to be taken into consideration while adjusting carbon concentration by process temperature. Therefore, process temperature exceeding is to be limited by upper limits-not more than 1850-1900°C, otherwise there will be a high risk of producing non standard metal in regards to silica content.

As it can be seen from figure 7 metal purification of silica by chromite oxide is possible in slag. This is proved by observed on the picture inverse relation of silica concentration and chromite oxide concentration in slag. Upon chromite oxide concentration increase in slag ferrochrome desiliconization will take place. This can be achieved by creating slight insufficiency of reducer in the furnace, but it will cause decrease of chromite extraction rate.

Thus, it is arising necessity of searching for ways of carbon decrease under high temperatures meanwhile preventing silica concentration increase. To achieve that, a matter on possibility of silica recovery without reducing temperature of the process is to be solved. So, it is required to minimize silica recovery process, as it deteriorates metal quality and requires additional power and reducer consumption.

Silica recovery and oxidation during production of carbon ferrochrome as during any other slag process is closely connected with slag and its composition and features. Silica recovery of slag during carbothermic process is performed according to reaction

$$(SiO_2) + 2C = [Si] + \{2CO\}$$

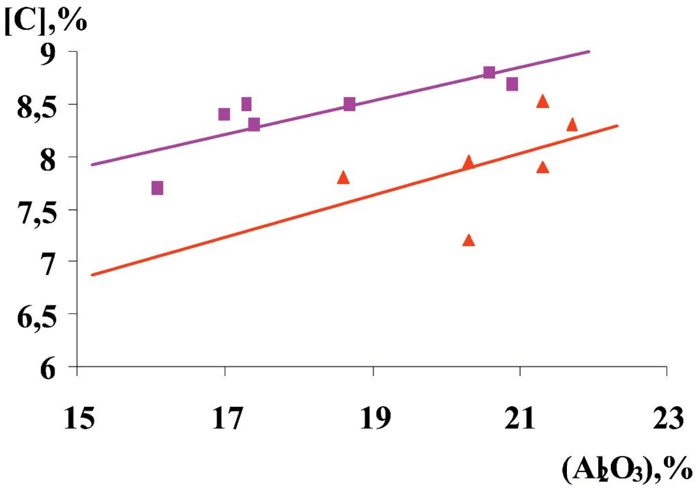


**Figure 5:** Influence of ($Al_2O_3$) in slag concentration onto C content

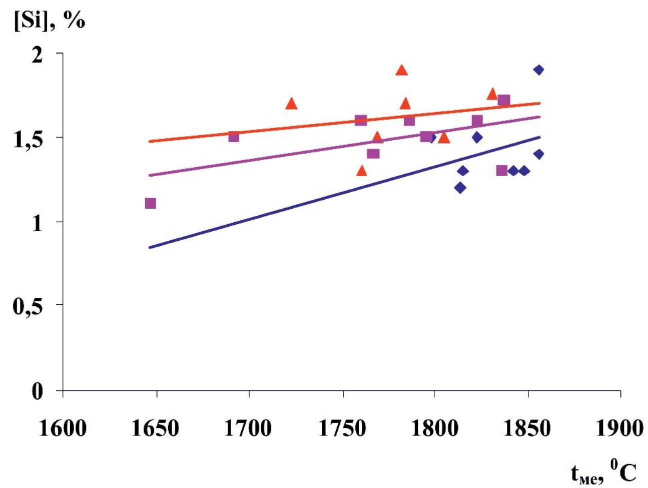


**Figure 6:** Influence of temperature onto Si content

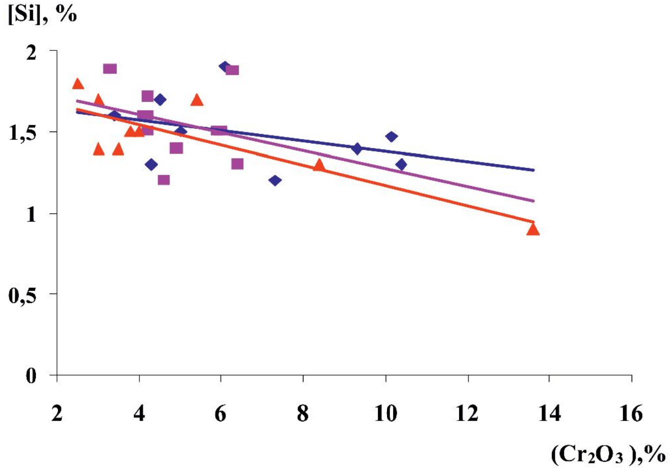


**Figure 7:** Influence of ($Cr_2O_3$) in slag concentration onto [Si]

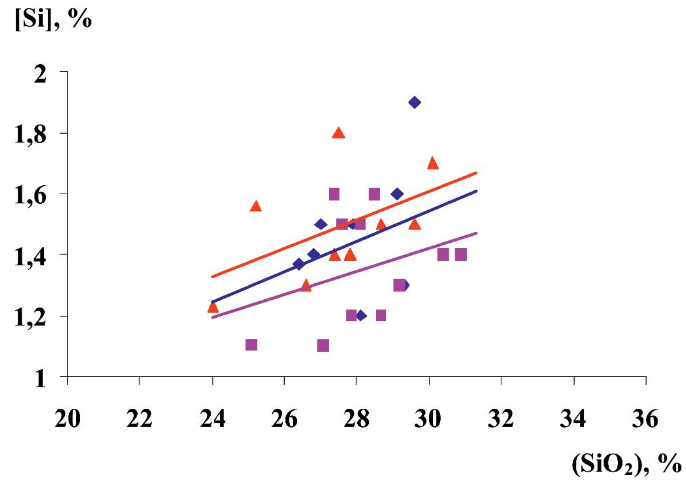


**Figure 8**: Influence of ($SiO_2$) in slag concentration onto [Si]

K-value of the reaction is presented as follows: $K_p = \frac{a_{[Si]} \cdot p_{CO}^2}{a_{(SiO_2)} \cdot a_C^2}$

According to reaction constant formula, to achieve silica recovery process minimization it is required to reduce silica activity in slag and reducer amount in charge. The latter can be achieved by reducer insufficiency in charge, and as it was stated above, can result in increasing of chromite oxide in slag and reducting of chromite extraction rate accordingly.

Thus, to reduce silica concentration in metal it is required to reduce activity and silica concentration in slag. This assumption is proved by research results shown on figure 8.

In accordance with traditional technology of carbon ferrochrome smelting using Donskoy Ore Mining Processing plant, silica concentration in final slag should be 30-32%. Temperature of such slag smelting is 1750-1800°C,which provides optimal temperature and electrical smelting mode. Therefore, reduction of silica concentration in slag by less than 30% can result in having refractory slag, metal overheating, power overconsumption, slag viscosity increase and increase of chrome with slag losses. For this reason, to adjust slag temperature characteristics, other types of fluxes apart form silica are to be provided.

As an example aluminum oxide can be considered. To maintain the same smelting temperature and reduce silica concentration slag content shifting into spinel cristalization area option can be proposed. For that slag quartzite part is to be replaced with bauxite. According to numerous research workers this is supposed to have positive effect onto slag mode of carbon ferrochrome production, since domestic chromite ores of Donskoy Ore Mining Processing plant are distinguished by high magnesian gangue.

## CONCLUSION

As it was proved by conducted researches, silica and carbon transfer into metal is being a multifactorial process and will depend on progress of recovery and purification furnace processes. Unlike submerge arc furnace where metal purification happens due to produced metal drops filtering through viscous slag layer enriched with chromite oxide, in open arc furnace the majority of purification processes takes place at metal-slag margin which considerably limits purification processes progress. Limiting factors in this case will be surface area and interaction duration, also temperature.

Basing on the conducted researches it can be said despite some restrictions, silica and carbon transfer into metal and so metal quality management in DC furnaces are potentially possible. For that firstly optimal slag and temperature mode of the process is to be maintained.

## REFERENCES

[1] Abdulabekov Ye.E., Kaskin K.K. Teoriya i technologiya proizvodstva chromistykh splavov– Aktobe: RIO AGU imeni K. Zhubanov, 2010. – 273 s.

[2] Basson J., Curr T.R. and Gericke W. A. South Africa's ferro alloys industry - present status and future outlook // INFACON XI, New Delhi, 2007. – s. 3-24.

[3] Hockaday L., Sooful N. Otchet № 4954 «Opytno-promyshlennye ispytaniya po vyplavke vysokouglerodistogo ferrochrome iz kazakhstanskoy chromovoy rudy v dugovoy dvukhelectrodnoy pechi postoyannogo toka» - Mintek, UAR, 2008. – 118 s.

[4] Lyakishev N.P., Gasik M.I. Mettallurgiaya chroma. – M.:ELIZ. 1999. –582 s.