ISSN 0543-5846
METABK 63(2) 264-266 (2024)
UDC – UDK 622.762:669.168.26:622.781:539.26=111

# MELTING OF CALCINED PELLETS WITH PRODUCTION OF HIGH-CARBON FERROCHROME

Received – Primljeno: 2023-11-07
Accepted – Prihvaćeno: 2023-12-28
Preliminary Note – Prethodno priopćenje

The use of composite calcined pellets obtained according to a sequential scheme of chemical and gravitational beneficiation of dump sludge tailings of the Dubersay tailing dump as a part of a charge with factory chromium concentrate enabled to obtain high-carbon ferrochrome FeCr70C90Si4LP China Standard where the low phosphorus content is not more than 0,03 % and that of sulfur is not more than 0,1 %. The obtained samples of high-carbon ferrochrome and slag were studied. The maximum chromium content was 57,14 % at 1 750 °C, the charge sample included 50 % of experimental pellets and 50 % of factory concentrate and reducing agent 17 %, chromium recovery into the alloy was 80 %.

*Keywords*: sludge tailings, ferrochrome, melting, pellets alloy

## INTRODUCTION

World resources of chrome ores are estimated at 16 billion tons, including confirmed reserves of about 2,5 billion tons, of which 70 % are concentrated in South Africa, 12, 5 % are in Kazakhstan and 5,6 % in Zimbabwe. Thus, Kazakhstan is in the second place in terms of chrome ore reserves, and in first place in terms of their quality. [1,2].

The urgent question about the need to recycle the sludge tailings from the beneficiation of sludge tailings from the Donskoy Mining and Processing Plant (DMPP), also a part of TNC Kazchrome JSC, arises with the increase in the amount of processed raw materials [3, 4].

Fine beneficiation tailings are a waste product and are pumped to a sludge storage facility. For many years, researchers at various research institutes and factory laboratories have been conducting experimental work to increase the recovery of chromium from processed raw materials [5-8].

It is not possible to increase the recovery of chromium oxide into standard chromium concentrates significantly due to the complexity of the mineralogical composition of chromite ores, the small difference between chromite minerals and host rocks in density. Taking into account the huge mining and beneficiation amounts of chrome ores at DMPP, the disposal of sludge tailings is an urgent task, since they contain up to 25-35 % $Cr_2O_3$.

An increase in the dispersion of chromium concentrates during electric arc melting of raw materials in alternating current furnaces results in a decrease in the technical and economic indicators of the processes. Preliminary agglomeration of raw materials is required to solve this problem with the purpose to obtain a product for melting in electric arc furnaces [9, 10].

The thermal sulfatization of sludge tailings and the transfer of magnesium oxide into leaching solutions were studied in our published article [11], in order to weaken the bonds between chromium spinel and serpentinite minerals. A product beneficiated in chromium with $Cr_2O_3$ content of about 40 % was obtained as a result of chemical beneficiation, with the recovery of more than 98% of chromium oxide into a chromium-containing cake. A standard chromium concentrate was obtained as a result of the subsequent gravitational beneficiation of chromium-containing cake on concentration tables divided into size Classes -1,0 + 0,315 and -0,315 + 0,250. This concentrate contained more than 50 % $Cr_2O_3$ and total chromium recovery of 95 % or more.

The purpose of the work was experimental melting of pellets with the resulting chromium-containing concentrate and fluxes, studying the melting products for high-carbon ferrochrome.

## MATERIALS AND METHODS

The initial raw material for the production of pellets was finely dispersed chromium concentrate obtained under a sequential scheme of chemical and gravitational beneficiation. Chemical composition of chromite concentrate, wt / %: 51,06 $Cr_2O_3$; 12,14 $Fe_2O_3$; 17,2 $SiO_2$; 4,88 $Al_2O_3$; 0,62 CaO; 14,0 MgO; 0,007 P; 0,089 S.

Finely dispersed chromite concentrate must be agglomerated before metallurgical processing to use it. One of the more common methods to agglomerate fine ore is pelletizing. Modern pellet production consists of two stages - the formation of raw pellets and their subsequent roasting.

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Table 1 **Chemical composition of the initial products involved in the melts**

| Material | Element content / % | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | $Cr_2O_3$ | $SiO_2$ | $Al_2O_3$ | FeO | $SO_3$ | $P_2O_5$ | MgO | CaO |
| Developmental composite pellets | 48,06 | 7,243 | 5,086 | 13,46 | 0,012 | 0,01 | 16,06 | 0,157 |
| Factory chrome concentrate of current arrival | 56,63 | 6,1 | 7,6 | 12,8 | - | - | 18,3 | 0,27 |

Table 2 **Weight characteristics of experimental melts for ferrochrome**

| Melts | Charge g | | | | Weight of crucible with a sample | Crucible weight after the melt | Weight of the slag | Melt weight |
|---|---|---|---|---|---|---|---|---|
| | Sludge concentrate | Compositional pellets | Factory chrome concentrate | Coke | | | | |
| 1 | 200 | - | - | 38 | 663,84 | 606,66 | 68,24 | 120,55 |
| 2 | - | 100 | 100 | 38 | 654,87 | 563,83 | 59,96 | 66,1 |

Previously, our colleges published articles on the production of pellets from chromium concentrate obtained from the sludge of the Dubersay tailings [3, 4, 7, 8].

Melting tests of calcined complex pellets were conducted on a high-temperature Tamman furnace of a vertical type in the metallurgy laboratory of the experimental workshop of the Aktobe Ferroalloy Plant of TNC Kazchrome JSC, Aktobe [12]. Table 1 shows the compositions of experimental composite pellets and current production chromium concentrate. The weight of one melt was 200 g of chrome raw materials and 38 g of coke. A graphite crucible containing the charge material was lowered into the working zone of the furnace heated to a given melting temperature. The behavior of the charge was assessed visually through the upper inspection hole. The condition of the samples was observed with the use of a molybdenum rod.

Experimental composite pellets, factory chromium concentrate of the current supply were used as the main charge material, and coal coke from the Gubakha deposit, used at the Aktobe Ferroalloy Plant for smelting high-carbon ferrochrome was used as a reducing agent.

The required amount of coke was calculated by stoichiometry for the reduction of iron and chromium oxides in the charge. Melting temperature: heating up to 1 750, °C heating rate 10 degrees/min. the exposure was 30 minutes, cooling in the furnace to 1 000 °C. After cooling to room temperature, the crucibles were broken and the slag was separated from the resulting alloy, the resulting products were weighed to calculate the material balance. Two experimental melts were performed. A summary of the experimental weight data of the initial charge, the resulting alloys and slags is specified in Table 2.

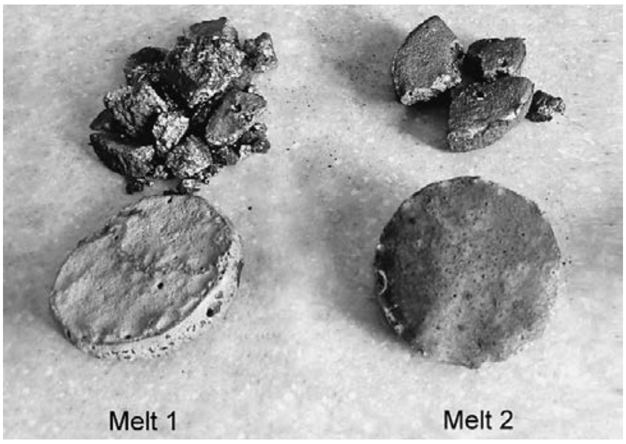


**Figure 1** Developmental samples of the obtained ferrochrome and slag alloys

Figure 1 shows prototypes of the resulting ferrochrome alloys and the corresponding slags from two melts.

Tables 3 and 4 show the chemical compositions of the resulting ferrochrome alloys and the corresponding slags.

The resulting alloys correspond to standard grades of high-carbon ferrochrome in terms of the content of the main components: chromium, carbon, iron and silicon, as well as the impurity elements phosphorus and sulfur. A higher chromium content of 57,14 % was obtained by melting a charge consisting of 50 % composite pellets and 50 % current production chromium concentrate.

Table 3 **Chemical composition of the obtained ferrochrome alloys**

| Sample no. of alloys | Chemical composition wt / % | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Cr | Si | Al | Fe | S | P | Mg | Ti | Ni | C | other |
| 1 | 50,47 | 1,10 | 0,18 | 25,5 | 0,02 | 0,011 | 0,74 | 0,29 | 0,28 | 8,98 | 1,65 |
| 2 | 57,14 | 0,45 | 0,072 | 17,34 | 0,015 | 0,010 | 0,201 | 0,199 | 0,341 | 9,0 | 1,24 |

Table 4 **Chemical composition of the resulting slags**

| No. of slags | Element content / % | | | | | | | | $\frac{MgO}{Al_2O_3}$ |
|---|---|---|---|---|---|---|---|---|---|
| | $Cr_2O_3$ | $SiO_2$ | $Al_2O_3$ | $Fe_2O_3$ | $SO_3$ | $P_2O_5$ | MgO | CaO | |
| 3 | 0,62 | 19,006 | 16,95 | 0,462 | 0,885 | 0,008 | 36,24 | 0,76 | 2,13 |
| 4 | 2,07 | 22,144 | 17,278 | 0,405 | 0,715 | 0,003 | 37,494 | 2,18 | 2,17 |

Table 5 **Phase analysis of ferrochromium alloy 2**

| Material name | Chemical formula | / % |
|---|---|---|
| Chromium Carbide | $C_3Cr_7$ | 65,8 |
| Chromium Iron Carbide | $(Cr,Fe)_7C_3$ | 21,3 |
| Tongbaite | $Cr_3C_2$ | 13,0 |

The actually obtained alloys corresponds to the Chinese standard (ISO 5448-81) for high-carbon ferrochrome FeCr-C90LSLP in terms of the content of main elements (Cr 45≤75; C >8-10; Si≤ 1,5; P≤0,03; S ≤ 0,05 in %). It can be noted that more than 50 % of the high-carbon ferrochrome produced by the enterprises of TNC Kazchrome JSC is exported to China.

The obtained results of large-scale laboratory tests conducted in the experimental workshop for the pre-mixing of chromium concentrate and coke used in the production of the main workshops of the Aktobe Ferroalloy Plant (TNC Kazchrome JSC) indicate that the proposed composition of composite pellets from fine chromite concentrate obtained by chemical-gravity beneficiation of sludge tailings enable to reduce chromium oxide up to 80% during the melting process of the test charge. The achieved recovery degree corresponds to high performance when chromite raw materials are melted and confirms the optimal composition of the proposed mixture of composite pellets.

X-ray phase analysis of the obtained ferrochrome alloys was studied on a D8 ADVANCE diffractometer “Bruker Elemental GmbH”, Cu –Kα radiation). Table 5 shows the phase analysis of alloy 2.

## CONCLUSIONS

Tests intended to melt calcined complex pellets to produce high-carbon ferrochrome were conducted based on the experimental workshop of the AFP of TNC Kazchrome JSC in Aktobe. The optimal temperature regime for melting was determined - heating up to 1 750 $^{o}$C, heating rate 10 degrees/min, holding time 30 minutes. The following starting materials were used for testing - chromium concentrate obtained by chemical and gravitational beneficiation, calcined chromium pellets and factory-made chromium concentrate.

The carbon content in alloys 1 and 2 ranges from 8,9 to 9,2 %, respectively. This carbon content is acceptable for high-carbon ferrochrome. The maximum chromium content is 57,14 % in alloy 3 at a melting temperature of 1 750 °C; this alloy can be classified as ferrochrome grade - FeCr60C90LP China Standard where the low phosphorus content is not more than 0,03 % and sulfur is not more than 0,1 %. The charge samples were experimental pellets 50 % and factory concentrate 50 % and reducing agent 17 %, chromium recovery into the alloy was 80 %.

Structural lines were established based on X-ray phase analysis that indicate the presence of a γ-phase with a tetragonal crystal lattice and the formation of complex iron and chromium carbides with the $C_3Cr_7$, $(Cr, Fe)_7C_3$ и $Cr_3C_2$ formulas. The presence of weak reflections in the region of 3,38304 indicates the presence of traces of α-quartz that are similar in composition.

## Acknowledgments

This research was funded by the Science Committee of the Ministry of Science and Higher Education of the Republic of Kazakhstan (Grant No AP09259594).

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**Note:** The responsible for English language is A. Kurash, Almaty, Kazakhstan