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COMPARATIVE ESTIMATION OF THE EFFICIENCY OF VARIOUS MATERIALS IN THE REDUCTION OF MAGNETITE IN SLAG MELT

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Abstract. Magnetite is an indispensable component of all liquid products of smelting in the pyrometallurgical method of copper production. Dissolving in matte and slag, it significantly impairs their physicochemical properties and has a negative effect on their further processing. The recovery of magnetite from these melts can significantly improve the technical and economic indicators of copper production in general. A comparative assessment of the efficiency of various materials in the reduction of magnetite in a slag melt is presented.

Keywords. metallurgical slag, magnetite, copper losses, reduction, zinc plant clinker, reducing agent.

I. Introduction.

Currently, it is a generally accepted statement that magnetite, which is an obligatory component of all metallurgical melts in the production of copper, has a significant negative impact on the technology and technical and economic indicators of metal production, in general [1,2].

The preliminary reduction of magnetite can have a positive effect on the processes of obtaining matte and its further processing [3,4].

It is known from the theory of pyrometallurgical processes and the practice of metallurgical enterprises that magnetite in a slag melt can be reduced by the following reactions [5,6,7].

$$Fe_3O_4 + C = 3FeO + CO \quad (1)$$

$$Fe_3O_4 + CO = 3FeO + CO_2 \quad (2)$$

$$Fe_3O_4 + Fe = 4FeO \quad (3)$$

To assess the effectiveness of various reducing agents, special studies have been carried out. The experiments were carried out according to a previously published technique [8]. For research, a synthetic slag was prepared, which is close in composition to converter slag, in contrast to the earlier work [9], composition, %: 25 SiO_2; 55 FeO and 20 Fe_3O_4. Graphite, iron, and cast iron were used as reducing agents. The results of the studies are presented in table 1 and fig. 1.

Table 1

Effect of reducing agent material on kinetics reduction of magnetite in slag of the original composition, % (by mass):25 SiO_2, 20 Fe_3O_4, 55 FeO

Materials	Time	In the composition of the slag by chemical analysis,% by weight	Reduction rate Fe_3O_4, %

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	Min.	Fe_3O_4	
Iron disc	5	11,90	40,50
	10	9,46	52,70
	15	7,78	61,1
	20	6,62	66,9
	25	4,98	75,1
	30	3,70	81,5
	35	2,96	85,2
Graphite disc	5	14,1	29,5
	10	11,8	41,2
	15	9,9	50,6
	20	8,36	58,2
	25	6,76	66,2
	30	5,50	72,5
	35	4,26	78,7
Cast iron	5	5,78	71,1
	10	3,82	80,9
	15	2,96	85,2
	20	1,1	94,5
	25	1,24	93,8
	30	0,16	99,2
	35	0,36	98,9

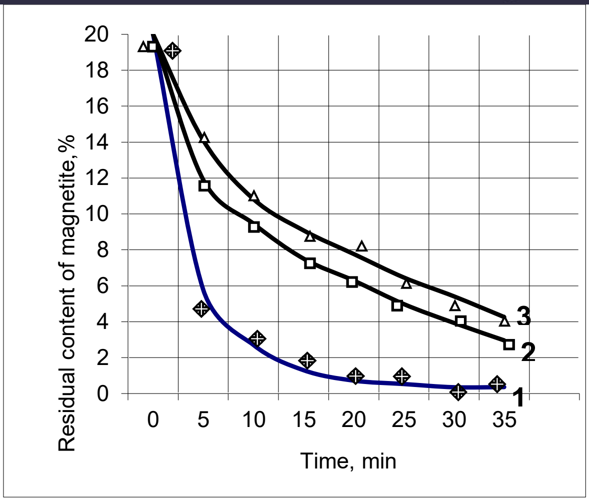

Fig. 1. Change in the residual content of magnetite over time when using various materials, temperature – 1300 °C.

1-cast iron; 2- iron disc; 3- graphite disc

As can be seen from the above results, cast iron turned out to be the most effective reducing agent in this case. The reducing capacity of solid carbon and iron is approximately the same [10].

The study of a deeper degree of reduction of magnetite to wustite and to flesh before the appearance of metallic iron in time is of certain scientific and practical interest [11]. For this purpose, according to the previously described method [12], studies were carried out on the reduction of magnetite with a solid reductant in the slag melt. The studied slag had the following composition, %: 20 Fe_3O_4, 25 SiO_2, 55% FeO. The experiments were carried out at temperatures of 1250, 1350 ° C. The experimental results were monitored by X-ray microanalysis [13].

Mineralogical analysis of a vertical section of a graphite-slag sample taken 45 min and 60 min after the start of the experiment at 1250 °C showed that the graphite did not undergo any noticeable changes [14]. The bulk of the slag contains relatively large (0.05 - 0.1 x 0.5 - 2.0. 10^{-3} m) fayalite crystals, in the intervals between which glass, magnetite and fine-grained fayalite are located. The magnetite

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content as a whole over the entire slag section plane is about 2% at 45 min, 1% at 60 min. In the horizontal section from the graphite to the crucible wall, there is no noticeable difference in the Fe_3O_4 concentration. On the border with graphite, in some places there are areas of one fayalite and sour glass. There is no metallic iron in the sample [15,16,17,18].

Specimens of graphite, after 30 min stay in the slag at 1350 °C, underwent severe corrosion, and drops of cast iron accumulated in abundance on their surface. In the horizontal and vertical sections of the section of the thin section, graphite is slag, magnetite is absent [19].

The data obtained are in good agreement with the data in table 1 regarding the reduction of magnetite from a slag melt with a graphite disk [20].

Based on the studies carried out on the comparative assessment of the effectiveness of various materials, it is necessary to select a relatively cheap reducing agent, preferably produced in our Republic, since imports are very problematic due to the high cost of material, transportation costs, taxes, etc. In the absence of a reducing agent in Uzbekistan, it is possible to use its substitute in the form of a carbon-containing or iron-containing intermediate product of metallurgical and chemical industries [21].

In this regard, a search was made for an alternative source of reducing agents. This material turned out to be clinker of zinc production, which is a technogenic raw material in the form of middlings from the Waelz zinc cakes. Hundreds of thousands of tons of this material have accumulated in special storage facilities and they can be used without special preliminary preparation [22].

Studies were carried out on the use of clinker for the recovery of magnetite, which is in the composition of the slag melt [23].

Converter slags and clinker were used as objects of research, the compositions of which are shown in table 2.

Table 2

Composition of starting materials,%

Name of the original materials / Elements	Cu	Pb	Zn	SiO_2	S	C	F_{total}	Au	Ag
Converter slag of copper production	3,5	-	-	25,00	1,16	-	47,47	-	-
Clinker	1,51	0,32	1,95	20,16	3,24	24,80	25,00	2,3 g/t	185,0g/t

The experiments were carried out according to the previously described method [24] of the first work. Considering that the recovery of magnetite is not an end in itself, but it is considered only in the context of a decrease in the copper content in slags and a decrease in its irrecoverable losses, the experiment studied the effect of settling time on the depletion indicators of converter slags. The effect of the time of natural settling on the degree of depletion of converter slags with and without clinker was evaluated. It was found that at 1250 °C mixing of melts without adding clinker followed by settling for 5 minutes (the maximum possible option for industrial implementation of the converter slag depletion process) is ineffective. The experimental results are shown in table 3.

Table 3

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The composition of the resulting converter slag after blowing it in place with clinker and without it at a temperature of 1250 °C

№	Clinker additive , %	Standing time	Cu	Extraction of Cu,%	Fe_{total} %	S %
1.	-	5	2,90	16,9	46,42	2,63
2.	-	10	2,49	28,8	47,15	2,32
3.	-	15	2,29	34,6	47,25	2,69
4.	-	20	2,03	42,0	46,07	2,63
5.	5	5	1,24	64,4	47,56	2,71
6.	5	10	1,12	67,8	46,62	2,82
7.	5	15	0,89	74,5	46,30	2,67
8.	5	20	0,81	76,7	47,60	2,77

With the addition of 5% clinker by weight of the charge, the extraction of copper from the slag during this period increases from 16.9 to 64.4%. The concentration of magnetite in the crystallized slag was halved. Some of the results of these studies are shown in Fig. 2.

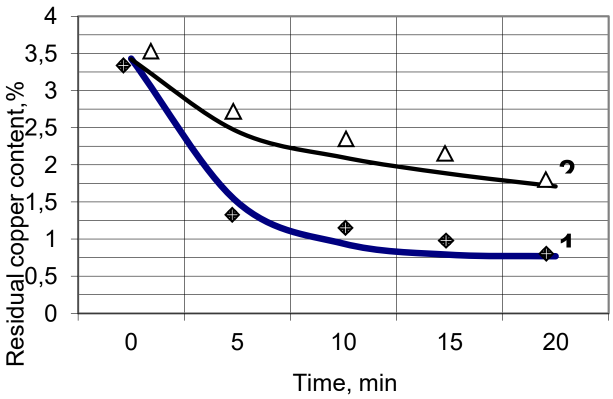

Figure: 2. Change in the residual copper content in the converter slag over time during treatment with clinker (1) and without it (2) with stirring with argon

From the results presented in Fig. 2 it can be seen that the concentration of copper in the converter slag decreases by almost three times from its original content [25]. At the same time, the ballast turnover of copper between the main smelter and the converter is significantly reduced. In addition, slags with such a low copper content and, with its unchanged extraction in a reverberant furnace, will make it possible to obtain slags with a copper content of no more than 0.23-0.35% in the smelting unit, which will allow organizing a waste-free environmental technology.

Findings:

1. A comparative assessment of the effectiveness of various materials in the reduction of magnetite in the slag melt in the pyrometallurgical method of copper production is presented.

2. It is shown that the most acceptable indicators for the degree of recovery were obtained when using cast iron as a reagent.

3. The results of slag reduction using the most accessible material in the conditions of Uzbekistan - zinc clinker are presented.

4. It has been established that the recovery of converter slag magnetite will allow, during its further processing, to increase the complexity coefficient of the use of raw materials and organize a waste-free environmental technology.

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