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ISSN 0543-5846
METABK 53(3) 343-345 (2014)
UDC – UDK 669.3:666.88:66.094.1:669.041=111

A STUDY ON REDUCTION OF COPPER SLAG FROM THE FLASH FURNACE WITH THE USE OF ANTHRACITE DUST

Received – Prispjelo: 2013-05-22
Accepted – Prihvaćeno: 2013-12-29
Preliminary Note – Prethodno priopćenje

In the paper, results of a study on reduction of blister copper flash smelting slag with the use of anthracite dust are presented. The material, following proper preparation, can be used for slag processing as a substitute for currently applied coke breeze.

Keywords: copper, slag, reduction, flash furnace, anthracite

INTRODUCTION

A disadvantageous process that can considerably limit metal production until the mid-century is reduction of natural resources, including both metal ores and energy reserves. Not only are their available deposits poorer than those currently exploited but most of them are found at very deep locations. Therefore, their mining costs will be probably far higher than the present ones. To ensure continuous production in the metallurgy branch, there are many activities aimed at even wider use of metalliferous wastes and scraps as well as alternative carboniferrous materials. The last example refers to application of coal-enrichment, coke production or chemical industry wastes as substitutes for coke and coke breeze. As already demonstrated, fine-grained carboniferous wastes can be potentially used in blast-furnace processes as well as during acid-lead accumulator scrap processing and steel dust treatment [1 - 8]. In the paper, results of a study on reduction of blister copper flash smelting slag with the use of anthracite dust are presented. The material, following proper preparation, can be used for slag processing as a substitute for currently applied coke breeze.

TECHNOLOGY OF FLASH SMELTING SLAG PROCESSING

Slag that is generated in a flash smelting furnace during Polish copper concentrate processing shows a high copper fraction of 12 – 16 % mass. The material also contains lead (2 – 4 % mass), iron (4 – 8 % mass), CaO, MgO, SiO_2 and Al_2O_3. Its processing is conducted in the electric furnace and main stages of this process include:

– Pouring of flash smelting and converter slags as well as charging of some limestone ($CaCO_3$) and coke
– Reduction of metal (copper, lead and iron) oxides and deposition of the Cu-Pb-Fe alloy
– Tapping of decopperised slag and Cu-Pb-Fe.

The main product of the process is the Cu-Pb-Fe alloy that contains 70 - 84 % mass copper. Moreover, dusts that contain 35 - 45 % mass lead and waste slag, containing up to 0,8 % mass copper, are generated. In Figure 1, a demonstrative schematic diagram of phases in the electric furnace during a process of reductive flash slag melting is presented.

Reduction of slag metal (copper, lead and iron) oxides occurs with coke breeze that is a component of the charge material.

These reactions can be described by the following general chemical equation:

$$Me_xO_y + y\ CO = x\ Me + y\ CO_2 \qquad (1)$$

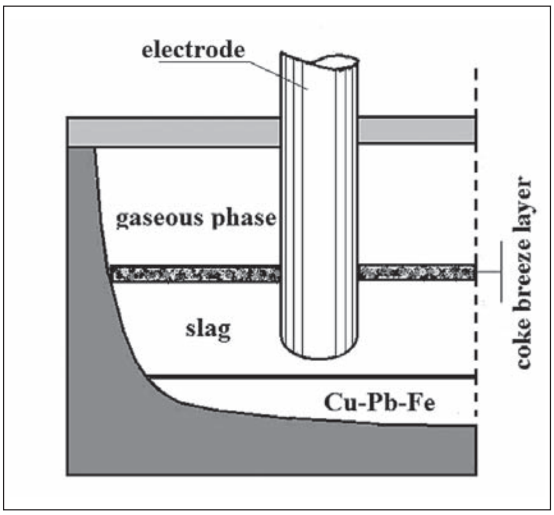

Figure 1 A demonstrative schematic diagram of phases in the electric furnace during a process of flash slag melting

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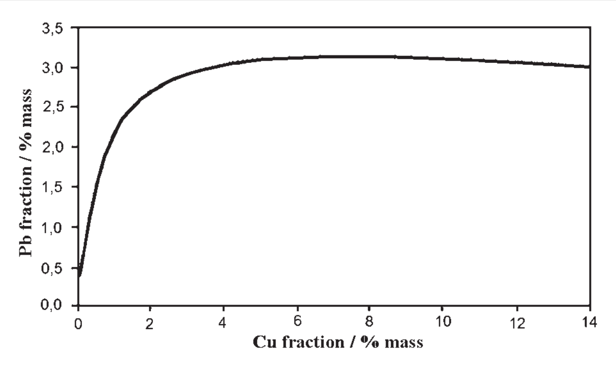

Figure 2 Slag lead concentration vs slag copper level at equilibrium [5]

Based on a thermodynamic analysis, the equilibrium concentration of copper oxide in the slag is approx. 0,003 % mass, i.e. it is markedly lower than its final level in the slag that is a product of a technological process. The thermodynamic analysis has showed that at equilibrium, the slag PbO reduction practically begins when the copper (as Cu_2O) level in the slag is lower than 3 % mass. In Figure 2, the slag lead concentration versus the slag copper level at equilibrium is presented [9].

As shown in the [10], the process rate is mainly determined by Cu_2O mass transfer to surfaces where reduction reactions occur as well as coalescence of metal particles and transfer of formed metal drops to liquid alloy in the furnace heath.

EXPERIMENTAL PART

In Table 1, a composition of flash smelting slag that was used in all the experiments is presented. The technological additives were: coke breeze (15 mm sized grains), anthracite dust and limestone.

Table 1 **Chemical composition of the investigated slag**

Component	Cu	Pb	Fe	Zn
Content /%mass	11,6	3,25	10,63	1,31
Component	CaO	Si O_2	MgO	Al_2O_3
Content /%mass	13,28	31,84	5,08	8,95

In Figure 3, a schematic diagram of the measurement system used for all the experiments is presented. Its main component was a PT 40 electric resistance furnace.

The study included two series of measurements with various reducer types. Basic parameters of the experiments are presented in Table 2.

The amounts of charge material additives (reducers and limestone) corresponded to the proportions used in industrial processes. After each test, the slag and post-cast alloy were subjected to a chemical analysis.

STUDY RESULTS AND DISCUSSION

In Table 3, values of post-reduction copper fractions in the Cu-Pb-Fe alloy as well as copper fractions in the slag are presented.

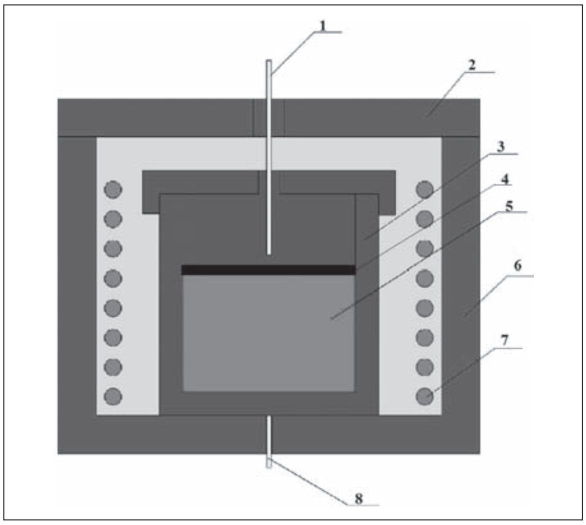

Figure 3 A schematic diagram of the slag reduction system: 1-thermocouple, 2-furnace cover, 3-melting pot, 4-coke breeze, 5-charge material, 6-furnace chamber, 7-heating elements, 8-thermocouple

Based on the experimental results, a slag decopperisation level was estimated by means of the following equation:

$$S_{Cu} = (C^0_{Cu} - C^t_{Cu}) / C^0_{Cu} \quad (2)$$

where:

C^0_{Cu}; C^t_{Cu} - initial copper fraction in the slag and copper fraction after time 't', respectively.

In Figure 4, a slag decopperisation level change versus reduction time is presented. Based on the results, very high values of this parameter for all the experiments were observed.

Table 2 **Basic parameters of the experiments (temperature of the process – 1 573 K)**

Charge material	Mass of the charge material component / g			Process duration / h
	slag	red.	$CaCO_3$	
Slag + breeze coke	1 000	30	-	1
Slag + breeze coke	1 000	30	-	2
Slag + breeze coke	1 000	30	-	3
Slag + breeze coke	1 000	30	-	5
Slag + anthracite dust	1 000	30	-	1
Slag + anthracite dust	1 000	30	-	2
Slag + anthracite dust	1 000	30	-	3
Slag + anthracite dust	1 000	30	-	5
Slag + coke breeze + limestone	1 000	30	70	1
Slag + coke breeze + limestone	1 000	30	70	2
Slag + coke breeze + limestone	1 000	30	70	3
Slag + coke breeze + limestone	1 000	30	70	5
Slag + anthracite + limestone	1 000	30	70	1
Slag + anthracite + limestone	1 000	30	70	2
Slag + anthracite + limestone	1 000	30	70	3
Slag + anthracite + limestone	1 000	30	70	5

Table 3 **Chemical composition of plumbiferous sludge**

Charge material	Process duration / h	Cu fraction in the alloy / %mass	Cu fractions in the slag / % mass
		Cu	Cu
Slag + breeze coke	1	69,9	1,4
Slag + breeze coke	2	77,1	1,1
Slag + breeze coke	3	81,2	0,7
Slag + breeze coke	5	81,0	0,11
Slag + anthracite dust	1	67,1	1,29
Slag + anthracite dust	2	65,0	0,99
Slag + anthracite dust	3	76,2	0,64
Slag + anthracite dust	5	80,1	0,23
Slag + coke breeze + limestone	1	73,6	0,98
Slag + coke breeze + limestone	2	66,5	0,67
Slag + coke breeze + limestone	3	78,8	0,17
Slag + coke breeze + limestone	5	78,6	0,12
Slag + anthracite + limestone	1	69,9	1,23
Slag + anthracite + limestone	2	72,8	0,53
Slag + anthracite + limestone	3	80,1	0,18
Slag + anthracite + limestone	5	77,3	0,21

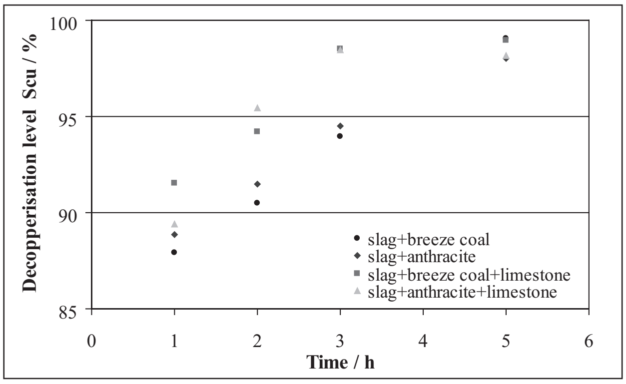

Figure 4 Slag decopperisation level change versus reduction time

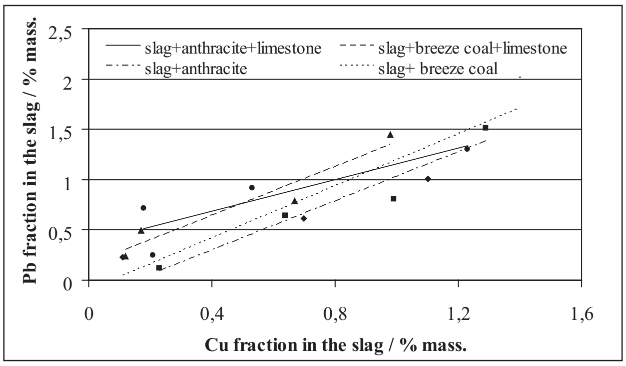

Figure 5 Post-reduction slag lead concentration versus slag copper level

In Figure 5, the slag lead concentration versus the slag copper level is presented. The figure shows that content reduction of copper in the slag is accompanied by enhanced reduction of lead oxides.

SUMMARY

In the paper, results of the study on reduction of the slag generated during blister copper flash smelting, with the use of coke breeze and anthracite dust as reducers, are presented. The last-mentioned material can be a substitute for the currently used coke. For all the experiments, a high level of the slag decopperisation was observed (over 88 %). A copper fraction in the Cu-Pb-Fe alloy resulting from the reduction reaction was 65 – 81 % mass regardless of the reducer applied. It should be noted that for all the tests regarding the post-processing waste slag, the copper fraction below 0,7 % mass was observed as early as at 2 hours of the reduction time. Summing up, the findings suggest a potential for application of anthracite dust as a carbon reducer alternative to coke breeze in the technology of high-copper flash smelting slag processing. It should be confirmed by reduction tests in the electric arc furnace.

Acknowledgements

The study was conducted under the Research Project No. PBS1/A1/21/2012, financed by the National Research and Development Center – Poland.

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Note: Nowak P. is responsible for English language, Katowice, Poland