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1/4

Optimisation of a Production System in the Process of Remelting of Post-Reduction Slag by Applying New Physical and Chemical Conditions

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Abstract

Production processes at KGHM are complex and require from customers products of constantly higher quality at relatively lowest prices. Such situation results in an increase of the importance of optimisation of processes. As products and technologies change rapidly, technologists at the plant in Głogów have less time to achieve optimisation basing on own experiences. Analysing a particular process, we can e.g. detect occurring disturbances, find factors having an influence on quality problems, select optimal settings or compare various production procedures. Analysis of the course of production process is the basis of process optimisation. One optimisation in case of the process of decopperisation of flash slag can be a change of a technological additive to a less energy-consuming one, and its final result can be an improvement of the productivity index, a change of the relation between final effects and born expenditures, as well as optimisation of production costs.

Keywords: Product Development, Quality Management, Decopperisation, Flash smelting slag, Optimisation

1. Introduction

A production system is a specially designed and organised system of materials, energy, and information, exploited by human and used for production of particular products (goods or services) in order to meet various needs of consumers. In the process of slag decopperisation, we can distinguish the following parameters of the production process that have a direct influence on the quality of the whole process: temperature, technological additives, composition of slag, pressure. Figure 1 presents the production system used in Glogów II Copper Mill.

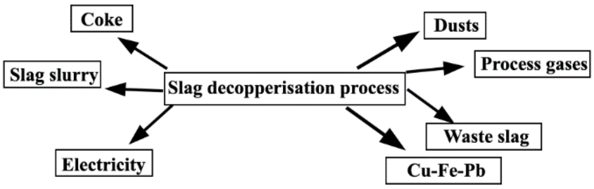


Fig. 1. The production system of the slurry slag process

The paper presents an innovative method enabling effective recovery of copper from slag from a flash furnace. It is proposed to use various additives, other than before. The method of conducting the pauses intensifies the reduction reactions and affects the viscosity. The carbides and carbide metals are used, which promotes the reduction of oxides and the emergence of the Cu-Pb-Fe metal phase [1]. Coagulation processes are accelerated by the use of additives reducing the interfacial surface tension. During the process the crystallization of the metallic phase is looped. The analyzes of the impact of cooling rates and simulations of the sampling process were also conducted [2,3]. The whole proposed new production system includes several independent stages:

Stage 1 – change of a part of technological additives – new physical and chemical conditions in the electric furnace,

Stage 2 – change of the way of introduction of technological additives,

Stage 3 – modernisation of the work of the electric furnace,

Stage 4 – change of the ways of work in the system of anode furnaces and convectors.

The presented article discusses mainly chief principle of stage 1 - change of a part of technological additives - new physical and chemical conditions in the electric furnace.

Metallurgical slag used in introduction of processing processes should meet specific quality criteria. Qualitative criteria were partially presented in BAT reference documents (for the industry of non-ferrous metals). The document lists e.g. criteria such as:

I – criterion of selection of proper chemical composition of slag,

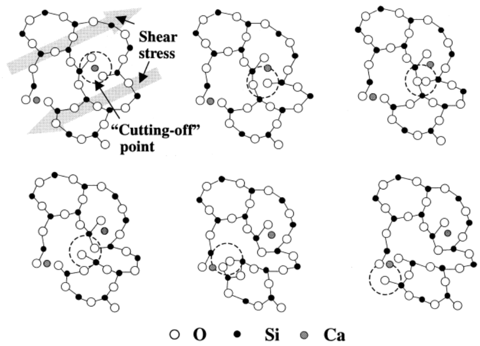
II – criterion of environmental protection, including protection against emitted technological gases during melting and reduction of slag,

III – criterion of consumption of electric power during melting of slag.

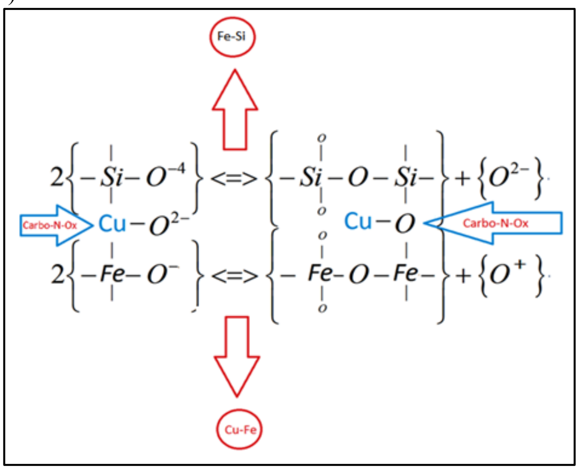
2. New physical and chemical conditions

A new mean for recovery of copper from metallurgical slags, based on the concept of CARBO-N-OX [4], promoted by the authors, is used at presence of known coal reducers and oxygen, halide, and phosphate fluxes. It is characterised by the fact that it includes carbides and/or cyanamides, disintegrated to granulation of 0,1 – 100 mm, in the amount of 0,5 – 15 % of the mass of slag, phosphides of metals or semimetals and/or alloys of phosphorus with metals or semimetals in the amount corresponding to 0,0001 – 3% of phosphorus in relation to the amount of copper in slags.

The presented method of conducting the pauses uses the interaction of strong carbides as reducers instead of carbon. This is a factor of originality. Currently, coal or iron is used as a reducer. The second new element is the use of fluxes and additives that promote coagulation other than calcium carbonate. The previous experience of the authors indicates the adverse impact of calcium carbonate. This is: firstly, an oxidizing agent, and secondly a very energy-consuming one. Both of these aspects are not conducive to the correct reduction and affect a significant, about 30%, energy consumption on the melting of the charge.



a)



$$2\{-Si-O^{-4}\} <=> \{-Si-O-Si-\} + \{O^{2-}\}$$

$$Cu-O^{2-} \quad Cu-O$$

$$2\{-Fe-O^{-}\} <=> \{-Fe-O-Fe-\} + \{O^{+}\}$$

b)

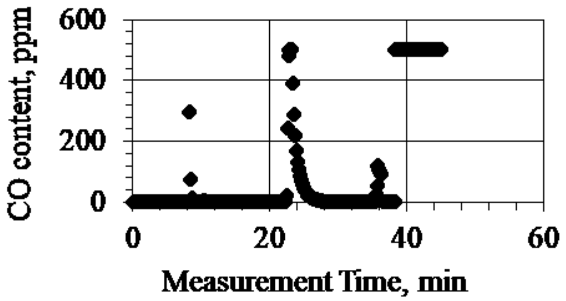
Fig 2. a) Mechanism of breaking silicon-oxygen anions according to Tanaka [5], b) Proposed reaction scheme for slag suspension–reagents of Carbo-N-Ox system [4]

Coal reacts mainly with the atmosphere and not with oxides. this has been confirmed by the long-term research of A. W Bydałek in reference to the refining processes of copper alloys. The use of carbon ions $\{C^{2+}\}$ and $\{C^{4+}\}$ originating from carbide dissociation is used in technology. Nitrogen, phosphate and fluorite compounds are also proposed as fluxes. All these substances influence the reduction of oxides and, over the next period, the coagulation of the Cu-Pb-Fe metal phase formed.

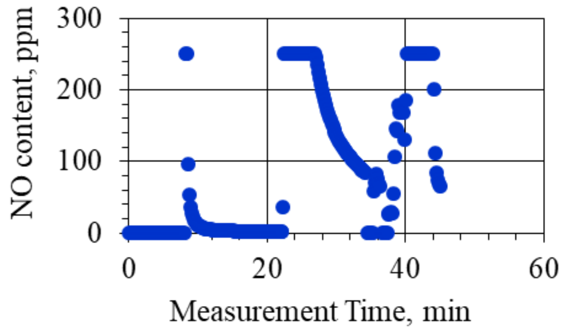
Among all possible used technological substitutes of calcium carbonate (FeO, CaF_2, Na_2O, CaO, and above mentioned phosphates), it seems that CaF_2 is the most optimal technological additive, what results mainly from is physical and chemical characteristics. According to the theory of discrete anions [6], it is the type of polyanion that is decisive on viscous flow, not the type of metal oxide present in slag. Calcium fluoride has two fluoride ions that accelerate the process of breaking silicon - oxide chains in the structure of slag. Similarly as Ca^{+} ion, F^{-} anion can destruct network bridges.

3. Research results

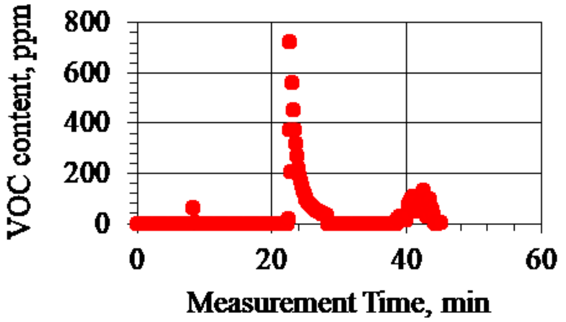
3.1. Analysis of atmosphere



a)



b)



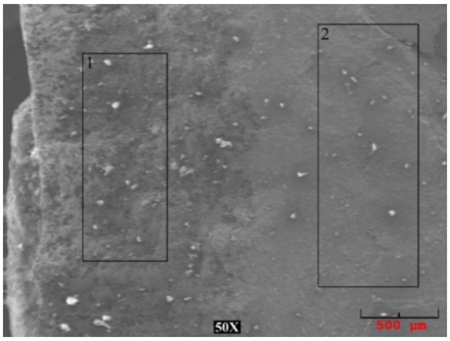
c)

Fig. 3. a,b and c are analysis of gases emissions during reduction processes using Carbo-N-Ox reactants
a) Analysis of carbon monoxide during reduction processes using Carbo-N-Ox reactants, b) Analysis of nitrogen (I) oxide during reduction processes using Carbo-N-Ox reactants, c) Analysis of volatile organic compounds during reduction processes using Carbo-N-Ox reactants

Apart from analyses of the chemical composition indicating the level of decopperisation, also the composition of arousing atmosphere was analysed. The used tool was MultiRAE with a group of multi-gas detectors, combining capabilities of constant monitoring of volatile organic compounds (VOC), toxic gases, and explosive gases.

3.2. Analyses of compositions of slag

The analysis of slags was performed using ARL QUANT'X EDXRF tool by Thermo Fisher Scientific company. Each of analysed elements (Cu, Fe, Si, Al, Ca, Pb, Zn) was introduced into a calibration curve in measurement conditions optimal for it (atmosphere of helium or air), using a proper filter located between a detector and a sample, optimising the detection of the energy of photons. Before exposure, samples of slags were grinded in a ring-cylindrical grinder to the size of grain below 0.5 mm, and next averaged. Next, they were pressed with 10% content of cellulose as binder at the pressure of 125 tonnes to the form of cylindrical discs. Using MRX technique, structural observations and analysis of micro-composition of sediments arousing on the bottom of slag were conducted (Fig. 4).



Elt.	Line	Intensity (c/s)	Atomic %	Conc	Units	Error 2-sig	MDL 3-sig
O	Ka	9,53	12,604	4,689	wt.%	0,277	0,193
Mg	Ka	6,93	3,659	2,068	wt.%	0,143	0,172
Al	Ka	14,52	5,505	3,454	wt.%	0,166	0,164
Si	Ka	45,10	14,063	9,184	wt.%	0,250	0,153
P	Ka	1,98	0,545	0,392	wt.%	0,051	0,135
S	Ka	6,17	1,402	1,045	wt.%	0,077	0,122
Ca	Ka	27,68	4,891	4,558	wt.%	0,158	0,121
V	Ka	2,36	0,419	0,496	wt.%	0,059	0,146
Cr	Ka	6,24	1,102	1,333	wt.%	0,097	0,146
Fe	Ka	192,59	54,128	70,292	wt.%	0,925	0,265
Cu	Ka	3,67	1,683	2,487	wt.%	0,237	0,342
			100,000	100,000	wt.%		

Elt.	Line	Intensity (c/s)	Atomic %	Conc	Units	Error 2-sig	MDL 3-sig
Mg	Ka	3,27	0,962	0,436	wt.%	0,062	0,187
Al	Ka	4,67	0,955	0,481	wt.%	0,057	0,172
Si	Ka	22,71	3,636	1,906	wt.%	0,102	0,151
P	Ka	17,56	2,300	1,329	wt.%	0,081	0,133
S	Ka	10,03	1,097	0,656	wt.%	0,053	0,126
Ca	Ka	11,00	0,899	0,672	wt.%	0,052	0,112
Fe	Ka	638,40	86,189	89,820	wt.%	0,911	0,222
Cu	Ka	17,49	3,963	4,699	wt.%	0,288	0,331
			100,000	100,000	wt.%		

Fig. 4. Structural observationa and analyses of micro-composition of sediments arousing at the bottom of slag

3.3. Studies on leachability of slags

The assessment of the possibility of storing the slags after the dispensing process using the proposed method showed a reduction in the content of metals in the obtained filtrates in landfills. In the samples (filtrate) obtained from the slag of the existing technology, there were numerous surpluses in relation to the acceptable level for a given landfill. 12x more lead was found, 10x more antimony, 12x more copper and 2x more molybdenum. However, after discoursing such as lead (12x), antimony (10x), copper (12x), molybdenum (2x). Both slags after dispatching according to the case (two technological variants were used), there were also surpluses in filtrates, but also smaller and only for lead (3x) and antiman (10x). The tests carried out on the leaching of slags showed that:

– slag before and after decopperisation, regardless of technology, meet the criteria applicable to landfills and hazardous waste.
– new and previously applied technology affects the assessment of ecological assessment of received products.
– slags can be safely used in various branches of industry and the economy.

4. Summary and conclusions

This article presents results of studies on multicriteria optimisation in the decopperisation process of flash smelting slags coming from the process of decopperisation at the "Głogów II" Copper Smelter. The efficiency of optimisation of the process course depends not only on an accepted criterion of the quality of controlling, a type of technological parameters, but also, to large extent, on characteristics and features of these parameters. $CaCO_3$ currently added to the process of decopperisation efficiently decreases viscosity of flash slag, at the same time has influence on an increase of the yield of copper in alloy, but on the other hand, it increases the mass of slag, artificially under representing concentration of this metal.

The main advantage of the new concept of process optimization is the simultaneous interaction of the Carbo-N-Ox reagent with the slag mass where the surface-active phosphorus or fluorite describes the feathering of this reagent. They result in the following benefits:

– increased metal yield in the unveiling process (up to 0.3%), with simultaneous shortening of the process time by 10 - 20%,
– the costs of all the allowances are kept at the same level,
– reduction of the amount of added additives - from 20 - 35%,
– reduction of energy costs by 10%,
– use of post-process slag in other industries.

Acknowledgements

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