Journal of Mining and Metallurgy, 44 A (1) (2008) 44 - 50

Journal of
Mining and
Metallurgy

WASTEFREE TECHNOLOGY FOR PROCESSING SMELTER SLAG FROM BOR COPPER MINE

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(Received 26 June 2008; accepted 1 December 2008)

Abstract

Smelter slag, a by-product of metallurgical processes, was made and dumped for over 100 years of ore exploitation in Bor Copper Mine. Smelter slag dumps with approximately 16.500.000 tons of slag and 700-1000 tons of daily produced slag in Bor Copper Mine smelting plant, represents a significant economic potential, as well as big ecological problem.

Researches have shown that it is possible to process smelter slag without residue, using so called "wastefree technology". This technology represents a complementary technology of several technological processes: flotation and leaching, utilized for recovery of copper from smelter slag, followed by magnetic concentration, where magnetic fraction can be used as suspensoid in heavy media separation processes and non-magnetic fraction that could be applied for infrastructure for roads production, construction or construction material industry.

All this signifies that technological process for processing smelter slag can be verified as technology without residue or wastefree technology.

Key words: *wastefree technology, smelter slag, copper, flotation, leaching, magnetic concentration.*

1. Introduction

The process of copper production is not considered to be clean, because during this process various kinds of waste materials, such as: overburden to mine, flotation tailings, slag, etc. are made [1]. All of those waste materials, beside the fact that they have negative influence on environment, also contain a respectable quantity of valuable metals that could be recovered.

In recent years many copper ore deposits became outworn. This fact

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enforced many countries to convert to alternative sources for copper production. Since, pyrometallurgical methods for copper extraction are not 100 % efficient [2] copper slag contains a considerable amount of cooper that could be utilized.

Smelter slag was made in Bor Copper Mine, since the beginning of smelting ore and copper concentrate, in early twenty century. All smelter slag made in different time periods and from different start materials, using various technologies, were dumped on existing dump.

Smelter slag dumps with approximately 16.500.000 tons of slag and also 700-1000 tons of daily produced slag in Bor Copper Mine smelting plant, represents a significant economic potential, as well as big ecological problem.

Examining the large number of samples, we have established that smelter slag contains approximately 0,7 - 0,8 % copper, 0,4 g/t gold and 7,5 g/t silver, as basic useful components.

Along with copper, gold and silver, smelter slag also contains other components, which could be recovered and used for different purposes. So, tendency is to create a technology for processing smelter slag that will utilize all useful components and reduce waste and residue production to a minimum.

2. Characterisation of material

The most important characteristic of material is its chemical content. This characteristic determinates if the material in question could be economically processed and what technology should be applied for its processing.

Chemical content of smelter slag integral sample is given in Table 1. As it can be seen the contents of copper, silver and gold are 0,79 %, 7,57 g/t and 0,40 g/t, respectively. Those contents are two times higher than contents of same basic useful components in primary copper ores exploited at the time in Bor Copper Mine.

Table 1. Chemical content of smelter slag integral sample

Element / Compound	Content, (%) (g/t)*
Cu	0,79
Fe	38,45
S	2,03
SiO_2	34,76
Al_2O_3	5,38
Au	0,40*
Ag	7,57*

Also, very important characteristic is a mineral content of material. Mineralogical content of smelter slag integral sample is given in Table 2.

Table 2. Mineral content of smelter slag integral sample

Mineral	Content, (%)
Faialite	60,00
Magnetite	30,00
Bornite	6,70
Chalcopyrite	1,60
Pure copper	0,50
Chalcosine	0,15
Coveline	0,05
Pyrite	0,10
Other minerals	0,90

3. Methods

Examining the characteristics of slag, we have determinated that flotation and leaching should be utilized for recovery of basic useful components, copper, silver and gold and magnetic concentration, for valorisation of iron minerals.

3.1. Flotation

The flotation tests were carried out in a laboratory flotation machine DENVER DR-12 with cell volume of 2.6 l. Dowfroth D-250 was used as the frother in amount of 15 g/t added in pulp during conditioning and 20 g/t into flotation cell. Conditioning time was 10 minutes and flotation time 20 minutes.

During researches, influences of following parameters on recovery of copper were investigated:

- collector type (KEX; KAX; KIBX; NaIPX; Selkol; Ž-96 and their mixture),
- collector dosage (30 g/t; 60 g/t; 90 g/t; 150 g/t),
- pH value of pulp (4-5; 9,5-10; 12),
- content of - 74 μm class (60 %; 70 %; 80 %),
- rotation speed of the impeller, n (rpm) (1200; 1400; 1600),
- content of solid phase in flotation pulp, Pm (%) (25; 30; 35; 40),
- aeration of the pulp, q_v (dm^3/min) (310; 360; 460; 510).

3.2. Leaching

The apparatus used for leaching tests was consisted of a 600 ml reaction flask into which 100 ml of sulphuric acid solution was placed. Reaction flask was supplied with a magnetic stirrer. The solution was heated to the desired temperature, which was kept constant. Slag sample of 100 g was added to the sulphuric acid solution and then stirring was started.

Researches were conducted in order to determine the influence of following parameters on recovery of copper:

- sulphuric acid concentration (0,1 M; 0,5 M; 1 M),
- stirring speed (400 min^{-1}; 600 min^{-1}; 800 min^{-1}),
- solid-liquid ratio (1:1; 1:2; 1:4),

- temperature of the pulp (20°C; 40°C; 60°C; 80°C),
- type of oxidant (iron (III) sulphate, iron (III) chloride, H_2O_2),
- dosage of iron (III) chloride (1 g/dm^3 Fe^{3+}; 5 g/dm^3 $Fe^{3+;}$ 10 g/dm^3 Fe^{3+}),
- dosage of H_2O_2 (on 100 ml of solution, 10 g/dm^3 Fe^{3+}),
- temperature of the pulp combined with oxidants.

3.3. Magnetic concentration

Preliminary research was executed on Davis magnetic analyser. Sample of leaching solid residue in amount of 100 g was passed through different magnetic field intensities (4,625 x 10^{-4} T; 7,150 x 10^{-4} T; 9,555 x 10^{-4} T; 12,510 x 10^{-4} T) in order to determine which intensity provides the best results.

4. Results and discussions

4.1. Flotation

Flotation tests were carried out in order to determine the best conditions for utilizing this process. Experiments have shown following optimal values of investigated parameters:
- as while as type of collector is concerned the best results were obtained with mixture of collectors KAX and Ž-96 in dosage of 90 g/t KAX + 30 g/t Ž-96,
- pH value of pulp 12 provides the best technological indexes of the process,
- with 60 % class – 74 μm and 30 % solid phase in flotation pulp the copper recovery rate was the highest
- also, when rotation speed of the impeller was 1600 rpm and 460 dm^3/min of air was introduced in the pulp the best results were obtained.

Utilizing the flotation under these optimal conditions the following results shown in Table 4 were achieved.

Table 4. Results of smelter slag flotation under optimal conditions

Product	Mass, m (%)	Cu content (%)	Distribution (%)
Concentrate C	8,06	5,89	75,23
Tailing T	91,94	0,17	24,77
Feed F	100,00	0,63	100,00

As while as flotation is concerned, both chemical and mineral contents, were signifying that good recovery results could be expected. Results of laboratory researches show that by optimising flotation process and choosing appropriate reagents, recovery of copper is approxi-mately 75 % along with copper content in basic copper concentrate of 5,89 %.

4.2. Leaching

Analysing the tailing of copper flotation from smelter slag, it was noted that there is a significant copper content in it. Copper content of 0,24 %, which represents approximately 25 % of all copper positioned in optimally liberated particles, signified that it was justified investigating possibilities for additional recovery of copper from flotation tailing.

Table 5. Results of leaching smelter slag flotation tailing under optimal leaching conditions

Optimal leaching conditions		Rate of copper leaching (%)
Concentration of H_2SO_4	1 M H_2SO_4	
Stirring speed	600 rpm	
Solid-liquid ratio	1 : 4	
Temperature of the pulp	40 °C	45,80
Type of oxidant	iron (III) chloride	
Dosage of iron (III) chloride	10 g Fe^{3+}	
Leaching time	3 hours	

Results of investigating the possibilities for additional recovery of copper from flotation tailing show that under optimal leaching conditions given in Table 5, copper recovery of 45,80 % could be obtained. This additional recovery of copper, related to the 25 % of this useful component left after flotation, will increase the total recovery for approximately 11 %.

Total recovery of copper of 86 %, without any doubt signifies that it is possible to successfully recover this useful component utilizing the combination of smelter slag flotation with leaching of copper from flotation tailing.

4.3. Magnetic concentration

Suitable granulation of smelter slag residue after flotation and leaching, as well as dominant content of ferrosilicate component, were referring to possibility of utilizing magnetic concentration for recovery of magnetic minerals. Magnetic fraction abstracted on right intensity of magnetic field, could represent a product suitable for further metallurgical processing in purpose of producing raw iron, or could be used as suspensoid in heavy media separation processes.

Results of investigations executed on Davis magnetic analyser, are shown in Table 6.

Table 6. Results of investigating the possibilities for magnetic concentration of magnetic minerals from solid residue after leaching

Magnetic field intensity (T) x 10^{-4}	Mass, m (%)		Fe content, (%)	
	Magnetic fraction	Non-magnetic fraction	Magnetic fraction	Non-magnetic fraction
4,625	38,16	61,84	39,45	32,79
7,150	60,55	39,45	36,88	30,89
9,555	72,46	27,54	37,97	26,44
12,510	75,40	24,60	37,91	26,33

Non-magnetic fraction, due to its physical, chemical and mineral characteristics, could be used in infrastructure for roads production, in construction industry or in construction material industry where it can be utilized for cement production [3, 4].

5. Wastefree technology

After all investigations were completed and all results were known, it become clear that wastefree technology (Fig. 1) consisted of flotation, leaching and magnetic concentration could be used for recovery of all useful components present in smelter slag. This technology not only that provides recovery of all useful components but also is ecologically acceptable because the production of residues is decreased to a minimum.

Besides, smelter slag represents a waste material with negative influences on environment when dumped and by processing and removing it from dumps we give contributes to ecology.

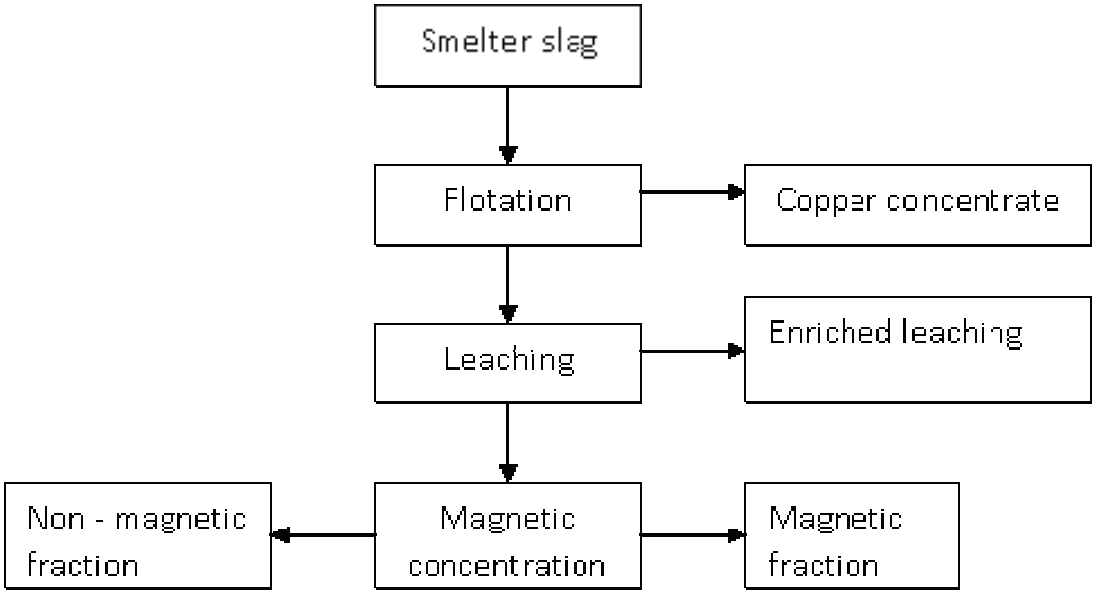

Fig. 1. Wastefree technology for processing smelter slag

Suggested flow sheet for processing smelter slag, wastefree technology, Fig. 1, represents a complementary technology of several technological processes: flotation, leaching and magnetic concentration, that provides economically justified and ecologically acceptable valorisation of useful components.

6. Conclusions

Smelter slag from Bor Copper Mine contains a considerable amount of basic useful components, copper, gold and silver.

In order to find a technology for its economically justified and ecologically

acceptable processing, a large number of experiments were conducted.

Copper flotation from smelter slag showed that it is possible to recover 75 % of copper by utilizing this process.

Recovery rate of copper gain by leaching smelter slag flotation tailing was 45,8 %, or transferred to 25 % of copper that was not recovered by flotation, approximately 11 %.

Magnetic concentration utilized on solid residue after leaching was applied for separating magnetic from non-magnetic fraction. Magnetic fraction obtained that way could be used as suspensoid in heavy media separation processes. Non-magnetic fraction could be used in infrastructure, in construction industry or in construction material industry.

Flotation, leaching and magnetic concentration applied, in that same order, for processing smelter slag represent wastefree technology, that provides successful recovery of all components, specially copper, gold and silver.

Beside economic effects industrial implementation of wastefree technology could give a significant contributes to preserving life environment.

7. Acknowledgements

This research has been financed by the Ministry of Science and Technological Development of Republic of Serbia as part of projects TR 17016.

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