

UNIVERSITY OF BELGRADE
TECHNICAL FACULTY BOR

**52nd International October Conference on
Mining and Metallurgy**



PROCEEDINGS

Edited by

Saša Stojadinović

and

Dejan Petrović

November 29th – 30th 2021

Bor, Serbia

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COMPARATIVE RESULTS OF COPPER FLOTATION FROM SLAG BEFORE AND AFTER THE PROCESS OF MAGNETIC CONCENTRATION

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Abstract

Previous research on the possibility of valorization of useful components from smelters slag has shown that copper and precious metals can be economically justifiably valorized by flotation concentration. In addition to the basic useful components, smelters slag also contains other useful components (iron) whose valorization would improve the economic effects of processing this secondary raw material. This paper presents the results of testing the possibility of valorization of copper and iron from the new smelters slag of Mining and Smelting Combine Bor (RTB) Bor using magnetic and flotation concentration.

Keywords: smelter slag, magnetic concentration, flotation concentration.

1. INTRODUCTION

Smelters slag as a by-product of pyrometallurgical processing of copper concentrate, in terms of the content of useful components (copper, iron, precious metals, etc.), represents a very valuable^[1,2], and in terms of its physical and chemical characteristics a very complex, technogenic secondary raw material. From an environmental point of view, smelters slag is also a potentially hazardous waste.

Smelting (copper) slag is a complex raw material that consists mainly of silicates, sulfides, oxides and some metallic copper and iron, where copper minerals or their mixtures are present. The percentage share of major oxides in slag is in the following limits: Fe₂O₃: 35–60%, SiO₂: 25–40%, CaO: 2–10%, Al₂O₃: 3–15%, CuO: 0,3–2,1%, MgO: 0,7–3,5%. Oxides of iron, SiO₂, Al₂O₃, CaO and MgO make up more than 95% of the total oxides present in the slag^[3]. Various technologies and processes such as flotation^[3,4,5], magnetic concentration^[6,7], leaching^[8,9] and roasting^[10] are used for valorization of useful metals from smelters slag. Due to the high content of magnetite in smelting slag (35-60%), in recent years more attention has been paid to the valorization of iron using magnetic concentration. On the other hand, magnetite, due to its physical characteristics, negatively affects the characteristics of the pulp in the process of flotation concentration.

This paper presents the results of testing the possibility of valorization of copper and iron from new smelters slag using the process of flotation, i.e. magnetic and flotation concentration.

2. EXPERIMENTAL

For the purposes of research in this paper, sampling of hydro cyclone overflows from the second stage of classification (OF II) was performed, which represents the entrance to the process of rough flotation of new smelters slag in RTB Bor plants (now Serbia Zijin Copper) during 2017.

2.1 Magnetic separation

Laboratory testing of the magnetic concentration was performed on a Davis magnetic analyzer at different magnetic field intensity.

Considering the goal of the research, a chemical analysis of all obtained products was performed on the contents of iron (Fe), as well as copper (Cu) and sulfur (S).

2.2 Flotation concentration

Flotation concentration experiments were performed using a laboratory flotation machine type "DENVER DR 12", flotation cell volume 2.6 l, at a constant rotor speed of 1700 rpm. When performing flotation experiments, the following reagents were used: NaIPX collector 600 g/t and D250 frother 10 g/t. The conditioning time was 10 minutes, while the total flotation time was 20 minutes. Laboratory testing of flotation concentration was performed on the non-magnetic fraction obtained at a previously defined current, i.e. magnetic induction, on which the best results of experimental investigations of the magnetic concentration of iron are achieved.

3. RESULTS AND DISCUSSION

3.1 Results of granulometric and chemical composition analysis

The results of the chemical analysis of the hydrocyclone overflow of the second stage of classification (OF II) are given in Table 1.

Table 1 - Results of chemical analysis of hydrocyclone overflow (OF II) by size classes^[11]

Size class d (mm)	Mass share W (%)	Cu (%)	Fe (%)	S (%)	R _{Cu} (%)	R _{Fe} (%)	R _S (%)
+0.150	0.35	0.46	22.19	2.09	0.13	0.19	0.55
-0.150+0.106	1.25	0.51	35.25	1.02	0.53	1.08	0.96
-0.106+0.075	5.85	0.49	38.49	0.81	2.37	5.54	3.56
-0.075+0.040	22.95	0.74	38.15	1.35	14.05	21.54	23.28
-0.040+0	69.60	1.44	41.84	1.37	82.92	71.65	71.65
Σ	100.00	1.21	40.65	1.33	100.00	100.00	100.00

From Table 1 can be concluded that the average copper content in the hydrocyclone overflow (OF II) is 1.21% and is many times higher than the copper content in the primary copper ores (about 0.30%), which confirms that the slag is high-value secondary raw material. The average iron content in the overflow of the second stage hydrocyclone (OF II) is 40.65%, which indicates a significant share of this component, so that the tested raw material deserves serious research with the aim of valorization of copper and iron.

3.2 Results of magnetic concentration

Laboratory testing of the magnetic concentration was performed on the overflow of hydro cyclone II smelters slag with the aim of testing the possibility of iron valorization and the introduction of the magnetic concentration process before the flotation concentration process. The results of the magnetic concentration are shown in Table 2.

Table 2 – Results of magnetic concentration^[11]

Current intensity I (A)	Magnetic induction B (T) x 10 ⁻⁴	Magnetic fraction (MF)				Non-magnetic fraction (NMF)			
		m (%)	Cu (%)	Fe (%)	S (%)	m (%)	Cu (%)	Fe (%)	S (%)
1	1.79	4.14	0.63	49.67	1.41	95.86	1.11	42.66	1.25
3	4.63	32.60	0.44	49.21	0.71	67.40	1.56	35.89	1.21
5	7.15	35.80	0.42	40.00	1.08	64.20	1.59	34.22	1.91
7	9.55	37.80	0.28	48.15	1.01	62.20	1.88	35.46	1.73

9	11.02	37.00	0.56	48.28	1.11	63.00	1.46	35.96	1.74
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From the table 2 it can be concluded that the best separation of the tested sample (OF II) into magnetic and non-magnetic fraction was achieved at a current of 7 A, or at an induction of a magnetic field of 9.55×10^{-4} T. Achieved results of mass recovery of a magnetic product of 37,80% with an iron content of 48.15% justify the introduction of the technological process of magnetic separation on the overflow of the second degree of hydrocyclone (OF II) before the process of flotation of smelters slag. The non-magnetic fraction obtained by this induction of the magnetic field in the mass of 62.20% and with a copper content of 1.88% is as such suitable for further treatment with flotation concentration, in order to utilize the basic useful component, copper.

3.3 Results of flotation concentration

Within this phase of the research, two flotation experiments were performed. The first experiment involved flotation of hydrocyclone II overflow to pH 7.83 (industrial conditions). In the second experiment, flotation of the non-magnetic fraction obtained by the process of magnetic concentration at a current of 7 A, at a pH of 7.83 and using a 600 g/t NaIPX collector and a 10 g/t D250 frother (industrial conditions) was performed. Figures 1 and 2 give comparative results.

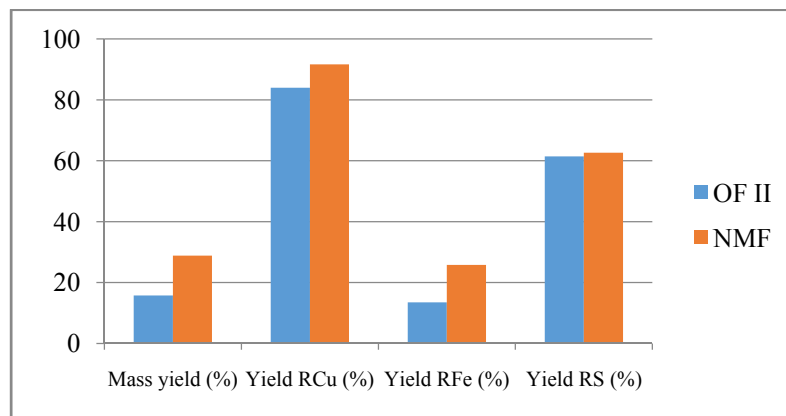


Figure 1 -Comparative results of mass and technological yield on the overflow of hydrocyclone (OF II) of smelters slag and on the non-magnetic fraction (NMF)^[11]

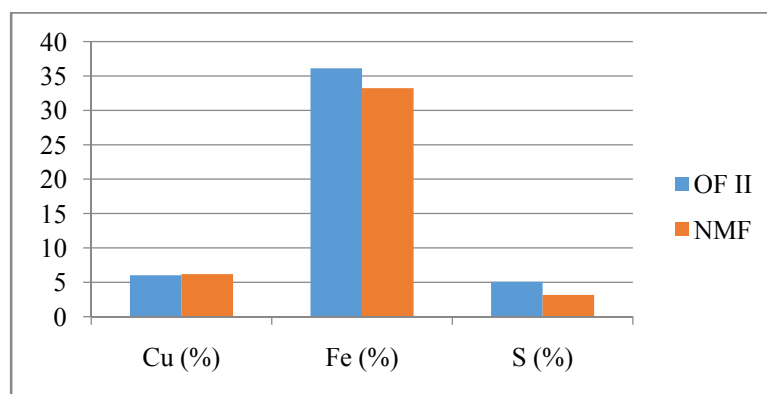


Figure 2 -Comparative results of Cu, Fe and S content on the overflow of hydrocyclone (OF II) of smelters slag and on the non-magnetic fraction (NMF)^[11]

Analyzing and comparing the results of flotation of the tested sample of smelters slag and flotation of non-magnetic fraction (NMF) obtained at a current of 7 A, it can be concluded that

better technological results are achieved by flotation of non-magnetic fraction (NMF) which justifies the introduction of magnetic concentration before flotation.

By flotation of the non-magnetic fraction (NMF) at pH 7.83, a high technological yield of copper is achieved, which amounts to 91.62%, while flotation of the overflow sample of hydrocyclone II of smelters slag achieves a lower technological yield of copper by about 8% and amounts to 83.99%. The total mass yield obtained by flotation of the non-magnetic fraction (NMF) at pH 7.83 is for 13.10% higher in relation to the flotation of the tested smelters slag sample and it amounts to 28.85%. Comparing the quality of the concentrate, it can be concluded that the highest copper content in the concentrate of 6.20% was obtained by floating a sample of non-magnetic fraction (NMF) at pH 7.83. The highest sulfur content in the concentrate of 5.07% was obtained by flotation of the overflow sample of hydrocyclone II of smelters slag, in contrast to the flotation experiment of the non-magnetic fraction obtained at a current of 7 A, where the sulfur content in the concentrate was 3.17%.

4. CONCLUSION

The results of the research of the possibility of valorization of iron from the overflow of hydrocyclone II smelters slag showed that iron, under the examined conditions, can be successfully separated by magnetic separation. The best separation of the tested sample into magnetic (MF) and non-magnetic fraction (NMF) is achieved at a current of 7 A, or at an induction of a magnetic field of 9.55×10^{-4} T. Achieved results of mass yield of the magnetic product of 37.80% with an iron content of 48.15% justify the introduction of a magnetic concentration process before the flotation process. By flotation of the non-magnetic fraction (NMF) at pH 7.83, a high technological yield of copper of 91.62% is achieved, compared to the flotation of the overflow sample of hydrocyclone II of smelters slag, whereby the technological yield of copper of 83.99% is obtained. Better quality of the rough flotation concentrate and higher copper content in the concentrate was achieved by flotation of the sample of non-magnetic fraction (NMF) and amounts to 6.20%. The obtained results fully confirm and justify the possibility of introducing the process of magnetic concentration before the process of flotation of smelters slag.

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REFERENCES

- [1] B. Gorai, R. Jana, K. Premchand., Conservation and Recycling., 39 (2003) 299-313.
- [2] H. Shen, E. Forssberg., Waste Management., 23 (10) (2003) 933-949.
- [3] A. Sarrafi, B. Rahmati, H.R. Hassani, H.H.A. Shirazi., Minerals Engineering., 17 (4) (2004) 457-459.
- [4] W.J. Bruckard, M. Somerville, F. Hao., Minerals Engineering., 17 (4) (2004) 495-504.
- [5] Z.M. Stirbanovic, Z.S. Markovic., Separation Science and Technology., 46 (16) (2011) 2496-2500.
- [6] K.Q. Li, S. Ping, H.Y. Wang, W. Ni., Intern. J. of Minerals, Metallurgy and Materials., 20 (11) (2013) 1035-1041.
- [7] B. Kim, S. Jo, D. Shin, S. Jeong., Intern. J. of Mineral Processing., 124 (2013) 124-127.
- [8] I. Mihajlovic, N. Strbac, P. Dordevic, A. Mitovski, D. Nikolic, Z. Zivkovic., Environment protection engineering., 38 (4) (2012) 171-184.
- [9] Y. Li, I. Perederiyi, V. Papangelakis., J. of Hazardous Materials., 152 (2) (2008) 607-615.
- [10] H.S. Altundogan, F. Tumen, Hydrometallurgy., 44 (1997) 261-267.
- [11] I. Strainovic, Graduation thesis, Technical Faculty in Bor, Bor, 2018.

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