THE OPTIMIZATION AND MATHEMATICAL MODELS DETERMINATION OF COPPER RECOVERY – THE PRECONDITION FOR IMPROVEMENT OF RECOVERY IN BUCIM COPPER MINE

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ABSTRACT. The improvement in the chalcopyrite copper Bucim mine are gone forward to renewed reagent regime, including and involving new reagents for increase d recovery of copper and gold. The optimization and mathematical linear models using gradient method Box and Wilson are good example for improvement of industrial recoveries in flotation circuit. In this paper is shown optimization techniques, formatting the mathematical model and adequate model for carried out investigations. Tables and figures will show the optimal quantity in reagent regime (collectors), particle size, flotation time I rougher flotation, conditioning time etc.

KEYWORDS: investigation, mathematical, model, recovery, flotation, Bucim

INTRODUCTION

The previous carried out laboratory investigations with application of the new collectors CYTEC and frothers confirmed that there is possibility for significantly improvement of the gold recovery with same copper quality and decreasing of the CaO consumption. The investigations with reagents Aerophine 3404, Aero XD 5002 and frother OP-F49 in the previous period (2010) were very short because of the low quality and variations of the ores. Variations of the ore from 0.15-0.22%Cu, instability of the flotation and other problems in the flotation process. The combination of the Aerophine 3404, KEX:KBX= 1:1, NaIPX, SKIK Bz 2000, in the different points of the flotation process gave significantly better results that early. The process was prolonged with pH=10.5 and the point of addition of CaO was at the hydro cyclone (70%) and 30% in the flotation process. The conclusions of these investigations were very heavy for sure confirmation, bur the obtained results were close to the previous results by standard conditions (specially for Au), may be better but not significantly. The Au content in the ore was од 0,19-0,29 gr/t, in the concentrate 8-12,3 gr/t, with Au recovery from 45-55% (some appearances up to 60%), but the copper recovery in the standard interval. Considering these investigations in laboratory and industrial real conditions may be concluded that:

- The instability and relative short period of investigations in the real conditions have contributed for obtaining the technological parameters closed to the standard conditions,
- As a result of the good regrinding, it was very heavy to clean the rough concentrate Cu/Au,
- Using higher pH, higher than standard in the rougher flotation (elimination of pyrite flotation) by Aerophine 3404, it will be expected higher quality and content of Cu/Au,
- In the existing real conditions of flotation at pH 11,0-11,6 and consumption of Aerophine 3404 (AP3404) from 18-22 гр/т, together with change of adaptive changeable reagent regime by different collectors (the combination from Aerophine 3404, KEX:KBX, NaIPX),
- The prolonged changes of the reagent regime with contemporary addition of new reagents (Bz 2000 = 4-8 gr/t + KEX:KBX=1:1 = 8-4 gr/t, total 12 gr/t) in the grinding cycle, together with addition of NaIPX in the condiotioner with 8-10 gr/t, in the flotation process (rougher and controlled flotation) with 2-4 gr/t, or total addition of 14 gr/t NaIPX,

Full Factorial Plan of experiments for three factors in Bucim mine

The plan of experiments is carried out for existing regent regime in the flotation plant in Bucim mine. The obtained result are given in the following table 1 and table 2:

Tabl. 1 Tests with a plan experiments

Опит	X_o	X_1	X_2	X_3	I_1	I_2	$I_{Cu}\%_{sr}$
1	+	15	10	5	90,13	89,05	89.59
2	+	15	6	5	90,52	87,90	89.21
3	+	9	10	5	89,18	88,80	88.99
4	+	9	6	5	86,66	87,22	86.94
5	+	15	10	3	89,10	87,22	88.16
6	+	15	6	3	88,60	90,48	89.54
7	+	9	10	3	88,90	89,62	89.26
8	+	9	6	3	88,00	87,08	87.54

Tabl. 2 Tests with a plan experiments

Опит	X_o	X_1	X_2	X_3	I_1	I_2	$I_{Cu}\%_{sr}$	I[illegible]	ΔI
1	+	15	10	5	90,13	89,05	89.59	88,87	0,72
2	+	15	6	5	90,52	87,90	89.21	87,93	1,28
3	+	9	10	5	89,18	88,80	88.99	88,18	0,81
4	+	9	6	5	86,66	87,22	86.94	87,24	-0,30
5	+	15	10	3	89,10	87,22	88.16	90,06	-1,90
6	+	15	6	3	88,60	90,48	89.54	89,12	0,42
7	+	9	10	3	88,90	89,62	89.26	89,37	-0,11
8	+	9	6	3	88,00	87,08	87.54	88,43	-0,89

Considering the obtained results will be carried out analysis of the obtained linear model, establishing his adequate. As the model is obtained on the basis of the mean values of recoveries, then the productivity error for the mean values will be:

$$\overline{S}^2_{rIsr.} = \frac{\left[\begin{array}{l}(90{,}13-89{,}05)^2+(90{,}52-87{,}90)^2+(89{,}18-88{,}80)^2+(86{,}66-87{,}22)^2\\ +(89{,}10-87{,}22)^2+(88{,}60-90{,}48)^2+(88{,}90-89{,}62)^2+(88{,}00-87{,}08)^2\end{array}\right]}{64}$$

$$\overline{S}^2_{rIsr.} = 0{,}264;\ \overline{S}_{rIsr.} = \sqrt{0{,}264} = 0{,}514$$

Adequate model checking

After the estimation of the investigated model, it's needed to calculate the mean result of each test, and instead x_j in the mentioned model we'll put appropriate conditioned units of the test (±1):

$I_{pres.1}$ = 88,65 +0,346 (+1) + 0,47 (+1) – 0,596 (+1) = 88,87

$I_{pres.2}$ = 88,65 +0,346 (+1) + 0,47 (-1) – 0,596 (+1) = 87,93

$I_{pres.3}$ = 88,65 +0,346 (-1) + 0,47 (+1) – 0,596 (+1) = 88,18

$I_{pres.4}$ = 88,65 +0,346 (-1) + 0,47 (-1) – 0,596 (+1) = 87,24

$I_{pres.5}$ = 88,65 +0,346 (+1) + 0,47 (+1) – 0,596 (-1) = 90,06

$I_{pres.6}$ = 88,65 +0,346 (+1) + 0,47 (-1) – 0,596 (-1) = 89,12

$I_{pres.7}$ = 88,65 +0,346 (-1) + 0,47 (+1) – 0,596 (-1) = 89,37

$I_{pres.8}$ = 88,65 +0,346 (-1) + 0,47 (-1) – 0,596 (-1) = 88,43

In the above table are given errors $\Delta I = I_{sr.} - I_{pres.}$, and the model adequate may be checked by Fischer criteria:

$$F = \frac{\left[\sum_{i=1}^{N} I_{sr.i}^2 - N \cdot \sum_{i=0}^{k} b_i^2 \right]}{(N-k-1) \cdot S_{rIsr.}}$$

Where: k – number of linear members in the mentioned model. In our case we'll have:

F = [89,59^2 + 89,21^2 + 88,99^2 + 86,94^2 + 88,16^2 + 89,54^2 + 89,26^2 + 87,54^2] – 8[88,65^2 + (0,346)^2 + 0,47^2 + (0,03)^2 + (-0,596)^2 + 0,26^2 + 0,24^2 + 0,18^2] / 5 * 0,514 ;

F = 2,157

For f_b = 8–2–1 = 5 and f_r = 8(2–1) = 8, for confidential level p = 95%=3,69, andStudent = 2,306, Fischer criteria:

F^* = f_r + p + t = 8 + 3,69 + 2,306 = 13,996.

As F << F^*, the model is adequate. It means that investigated process is correct described by means of the first order pollinom and the difference which is appeared between experimented and estimated results is accidental

The determination of the obtained linear model gradient for reagent regime in the flotation plant in Bucim mine

The gradient method is based on the fact that biggest degree of improvement for a function is achieved if the progressive by the length of the gradient. As this direction is direction of the steeper gradient, then we're talking about for maximum, or the direction of the steeper fall. In fact, the gradient is vector for a point of the n-dimensional space. This one is determined by the determination of the first derivations of the aim function in the relationship of their changeable factors. It's important to note that the gradient direction is a local, not a global property. If we suppose that the function y(x_1, x_2,) which has had continuous partial derivations, then there is the point (x_1, x_2), around which for a little small change in the every one direction will be obtained the following estimation.

$$\frac{df}{dx_1}(x_1, x_2) = \frac{df(88.65 + 0.346\,x_1 + 0.47x_2 - 0.596x_1x_2)}{dx_1} = -4{,}422$$

$$\frac{df}{dx_2}(x_1, x_2) = \frac{df(88.65 + 0.346\,x_1 + 0.47x_2 - 0.596x_1x_2)}{dx_2} = -6{,}682$$

$$m_1 = \frac{\frac{df}{dx_1}(x_1,)}{\sqrt{(\frac{df(x)}{dx_1})^2 + (\frac{df(x)}{dx_2})^2}} = \frac{-4{,}422}{8{,}012} = -0.55$$

$$m_2 = \frac{\frac{df}{dx_1}(x_2,)}{\sqrt{(\frac{df(x)}{dx_1})^2 + (\frac{df(x)}{dx_2})^2}} = \frac{-6{,}682}{8{,}012} = -0{,}83$$

The moving direction will be shown as a vector φ marked with n numbers (m_1, m_2 . . . m_n).

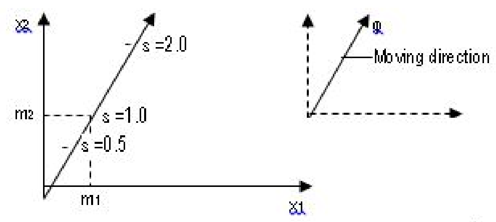

Fig. 1. Direction of search

$$\frac{m_1}{m_2} = \frac{-0{,}55}{-0{,}83} = 0{,}663$$

$$m_1 \cdot \Delta x_1 = -0{,}55 \cdot 3 = -1{,}65$$

$$m_2 \cdot \Delta x_2 = -0{,}83 \cdot 2 = -1{,}66$$

It's evident that gradient direction is exact, and$x_1$and$x_2$has had to be adjuste, because the coefficient of interaction $b_{12}$with his sign show this action. Standard deviation **$\sigma = \sqrt{\frac{\sum \Delta I^2}{7}}$ = 1.03.**

By the analysis of the linear model of the first order polinom for copper recovery from the chalcopyrite ore, above mentioned equations for carried out investigations by decreasing of the collector (x_1–NaIPX) and with increasing of the (x_2–KEX:KBX=1:1), we'll be obtained following results in table 4.

Tabl. 3 Tests with a plan experiments

I_1	I_2	$I_{Cu}\%_{sr}$	I_{pres}	ΔI	ΔI^2	$\Delta I^2/7$
90,13	89,05	89.59	88,87	0,72	0,52	
90,52	87,90	89.21	87,93	1,28	1,64	
89,18	88,80	88.99	88,18	0,81	0,65	
86,66	87,22	86.94	87,24	-0,30	0,09	**1,07**
89,10	87,22	88.16	90,06	-1,90	3,61	
88,60	90,48	89.54	89,12	0,42	0,17	
88,90	89,62	89.26	89,37	-0,11	0,01	
88,00	87,08	87,54	88,43	-0,89	0,79	

Tabl.4 Tests with a plan experiments

Опит	X_1	X_2	I_1	I_2	$I_{Cu}\%_{sr}$
1	11.5	10.5	90.0	89.2	89.6
2	11.5	9.5	90.4	90.0	90.2
3	9.5	10.5	90.1	89.3	89.7
4	9.5	9.5	89.7	89.3	89.5
5	11.5	10.5	89.2	89.2	89.2
6	11.5	9.5	89.2	90.0	89.6
7	10	10.5	90.4	90.2	90.2
8	9.5	9.5	88.7	88.3	88.5

The other working parameters (pH=11.72, 55÷60% - 0,074 mm, flotation time 12 min and time of conditioning 6 min and X_3 = 4÷6 gr/t) are standard as in the real industrial conditions. The copper recovery in the $I_{Cu}\%_{sr}$ is optimal or need minimum decreasing of collector consumption of NaIPX = 10-11.5, and increasing of KBX:KEX=1:1 = 9.5÷10.5 gr/t, according to the influence of the feed ore quality, bigger content of copper in the feed, bigger consumption of the collectors.

CONCLUSION

In this paper is shown optimization techniques with formatting the mathematical model and adequate model for carried out investigations. Obtained tabular results and figures will show the optimal quantity in reagent regime (collectors), particle size, flotation time for rougher flotation, conditioning time etc.

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