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МАТЕМАТИЧКО МОДЕЛИРАЊЕ НА ХАЛКОПИРИТНА ФЛОТАЦИЈА ИЗРАЗЕНА ПРЕКУ РАВЕНКИТЕ НА КЛИМПЕЛ И АГАР

MATEMATICAL MODELLING OF THE CHALCOPYRITE FLOTATION EXPRESSED BY KLIMPEL AND AGAR EQUATIONS

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Introduction

The construction of the mineral processing plants, in this sense, the flotation plants as well, is carried out on the basis of large experimental studies in laboratory, semi-industrial and industrial conditions. This prolongs the time for the establishment of the optimum variation for the technical process and requires a lot of efforts. This classical step in the construction may be cut short in the period and made much more efficient by the application of certain mathematical modelling which allows preliminary qualitative and quantitative calculations and comparative analyses on several technical schemes before experimenting in real conditions.

The making of a mathematical model which is to reflect the dynamics of the flotation process in relation to the time, implies formalizing the kinetics process. In specialized literature a great number of kinetic equations are derived by an analytical way which describe the valuable component recovery with various accuracy in the function of flotation time. According to literatury date Climpel's and Agar's kinetic equations are very adequate in describing the flotation kinetics.

Climpel's kinetic equation is the following :

$$R_{(t)} = R_{max} \cdot \left\{1 - \left(\frac{1}{k \cdot t}\right) \cdot [1 - \exp(-k \cdot t)]\right\}$$

Agar's kinetic equation is the following:

$$R_{(t)} = R_{max} \cdot \{1 - \exp[-k \cdot (t + b)]\}$$

where:

$R_{(t)}$ - is the cumulative recovery of the valuable component for the time t in unit parts

R_{max} - is the maximum possible recovery of the valuable component in the concrete technical conditions at $t \rightarrow \infty$ (min) in unit parts.

k - is the kinetic constant which characterizes the flotation valocity of the valuable component (min^{-1}).

b - correction time of flotation

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These dependences can be applied to the analyses for the kinetics of the flotation process. It can easily be seen that the structure of models is very simple and contains only two parameters (R_{max} and k) - Klimpel's equation and only three parameters (R_{max}, k and b) - Agar's equation, which are subject to experimental determination. In this way the analysis of alternative flotation conditions and schemes reduces to the analysis of two or three components (R_{max} and k) or (R_{max}, k and b) but not to a simple comparison of the appropriate recoveries which may be subject to influence by some uncontrolled factors.

Various studies have shown that the kinetic flotation constant for a given mineral stage represents a much more delicate criterion for the evaluation of its kinetics behaviour compared to its recovery. The kinetic flotation constant depends, or rather more, is influenced by many factors like : the size of the mineral particles, the mineralogic as well as the chemical composition of their surfaces, together with the physical - chemical and hydrodynamic conditions in the flotation equipment.

Special Part

On the basis of all that we have said above we completed the modelling of the roughening flotation process of chalcopyrite minerals from "Bucim" - mine, Radovis Macedonia in laboratory conditions (Table 1).

Table 1

Time (sec)	Concentration mass (%)	Cu %
30	1.15	6.64
90	1.00	4.45
180	1.00	3.70
360	0.90	2.10
480	0.90	1.20
720	1.20	0.96
960	1.20	0.55
1170	0.80	0.50
1380	1.50	0.20
1560	2.60	0.12
1800	4.00	0.07
residue	83.75	0.02

When doing this, the parameters $R_{max\,i}$ and k_i (for Klimpel's equation) and $R_{max\,i}$, k_i and b_i (for Agar's equation) were determined for Copper i = 1 and gangue minerals i = 2, respectively. The parameters values were determined by the use of modified method of the sum of least squares (K. Gauss) when the following functions are successively minimized two times:

$$F_i = \sum_{j=1}^{11} \left\{ R_j(t) - \left[R_{max_i} \cdot \left(1 - \frac{1}{k_i \cdot t} \right) \cdot \left(1 - e^{-k_i \cdot t} \right) \right] \right\}^2 \rightarrow \min \quad \text{(for Klimpel's equation)}$$

$$F_i = \sum_{j=1}^{11} \left\{ R_j(t) - \left[R_{\max_i} \cdot \left(1 - e^{-k_i (t+b_i)} \right) \right] \right\}^2 \rightarrow \min \text{ (for Agar's equation)}$$

so that the value of the individual parameters $R_{max\ i}$, k_i and b_i are changed within:

$R_{max\ 1} \in [80.0;99.9]$, $R_{max\ 2} \in [5.0;20.0]$

$k_1 \in [0.001;5]$, $k_2 \in [0.001;5]$

$b_1 \in [-100; 100]$, $b_2 \in [-100;100]$

The constructed optimizing assignment in this way is solved by computer programme which gave the following results:

CUMULATIVE GRADE RECOVERY DATE

Time (sec)	R-Cu (%)	Cu (%)	R-Gangue (%)
30.00	33.12	6.66	0.96
90.00	51.85	5.65	1.84
180.00	67.42	5.04	2.74
360.00	75.36	4.39	3.59
480.00	79.90	3.81	4.46
720.00	84.75	3.26	5.64
960.00	87.52	2.82	6.82
1170.00	89.20	2.59	7.62
1380.00	90.46	2.22	9.12
1560.00	91.77	1.78	11.72
1800.00	92.95	1.36	15.74

Parameters of Klimpel's equation:

Parameters	Cu, i = 1	Gangue, i = 2
Kinetic constant of flotation k_i (min^{-1})	0.02327495	0.001206447
Maximum Recovery $R_{(max)i}$ (%)	91.45	19.93
Acheived minimum of function F_{min}	3.6087395	1.5597226

Parameters of Agar's equation:

Parameters	Cu, i = 1	Gangue, i = 2
Kinetic constant of flotation k_i (min^{-1})	0.004601057	0.00100000
Maximum Recovery $R_{(max)i}$ (%)	89.72	16.49
Corection time b_i (sec)	82.67	0.093
Acheived minimum of function F_{min}	2.8151582	2.3448239

On the basis of the obtained results we made comparation between the experimental cumulative recovery and the calculated cumulative recovery for Cu, and gangue minerals for Klimpel's and Agar's equation respectively shown in the Table 2 and Table 3.

Table 2 - Klimpel's equation

Flotation time, sec	30	90	180	360	480	720	960	1170	1380	1560	1800
Experimental cumulative recovery Cu, (%)	33.12	51.85	67.42	75.36	79.90	84.75	87.52	89.20	90.46	91.77	92.95
Calculated cumulative recovery Cu, (%)	25.63	53.17	69.95	80.54	83.26	85.99	87.36	88.10	88.60	88.93	89.27
Experimental cumulative recovery Gangue, (%)	0.96	1.84	2.74	3.59	4.46	5.64	6.82	7.62	9.12	11.72	15.74
Calculated cumulative recovery Gangue, (%)	0.36	1.04	2.01	3.76	4.80	6.61	8.25	9.25	10.22	10.95	11.80

Table 3 - Agar's equation

Flotation time, sec	30	90	180	360	480	720	960	1170	1380	1560	1800
Experimental cumulative recovery Cu, (%)	33.12	51.85	67.42	75.36	79.90	84.75	87.52	89.20	90.46	91.77	92.95
Calculated cumulative recovery Cu, (%)	36.29	49.80	62.93	78.01	82.98	87.47	88.98	89.44	89.61	89.67	89.70
Experimental cumulative recovery Gangue, (%)	0.96	1.84	2.74	3.59	4.46	5.64	6.82	7.62	9.12	11.72	15.74
Calculated cumulative recovery Gangue, (%)	0.50	1.43	2.73	4.99	6.29	8.47	10.18	11.38	12.34	13.03	13.77

Graphics presentation of obtained rezults are shown on Figure 1 and Figure 2.

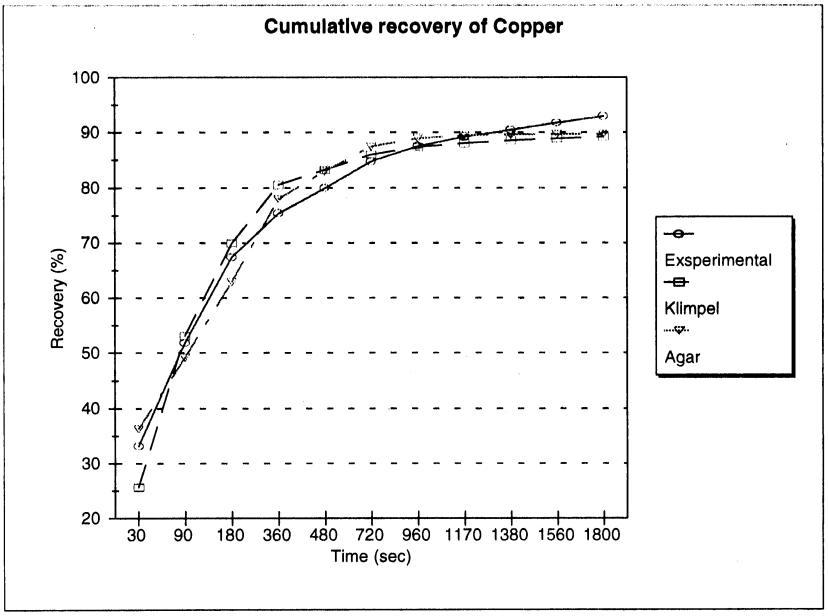

Figure 1

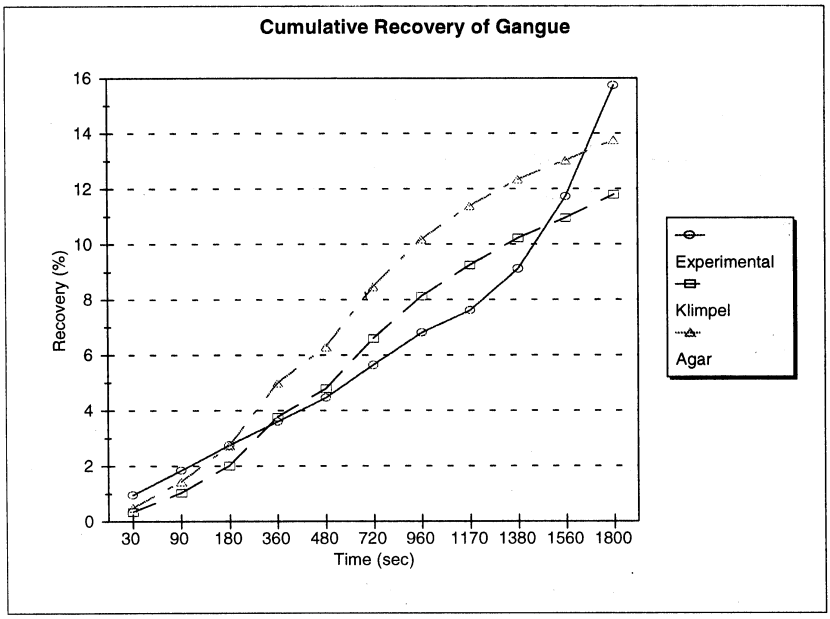

Figure 2

Conclusion

The calculated values of the kinetic parameters "k", R_{max} and "b" for Cu, and the gangue minerals are of great use in the following stage of the investigation work - the construction of the optimum flotation scheme which will supply the most efficient economic date. The application of computer simulation modelling to various technological configurations, including enrichment operations (rough, control and cleaning flotation), the reseacher can,

very shortly, select the most adequate scheme which will satisfy these requirements as well as the quality of the final flotation products.

At the same time, some technological, technical - economic and other criteria and some other limiting conditions can be utilized and on the basis of them the optimum construction solution can be acheived.

The simulation method itself is based on the imperative approach, taking in consicleration the hydrodynamic conditions in the enrichment as well as the distribution of the particles, respectively:

a) according to the retaining time in the flotation cell;

b) according to flotability.

In the cases with multidisperse material (with granulometric analysis carried out for all products) the estimation of the kinetic parameters from individual granulometric particle sizes helps the complete study and defining.

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