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MATHEMATICAL MODELLING OF THE FLOTATION PROCES

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INTRODUCTION

Nowadays, engineers especially investigators and constructors try to solve many issues related to various tasks in the technological processes of their work. As a rule, the problems have no unique solution. When you determine the important industrial indices, which give the production amount and the costs, the selection of the right solution and the permissible error are of great importance. For these reasons the complete, objective and heterogenous analysis for the available information is necessary. This requires a new style of engineering work which implies the application of computer technology, mathematics and kibernetics. An important segment in the application of up to date mathematical methods is the adequate assignment, the precise formulation and formation of the problems.

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 kinetic equation is very adequate in describing the flotation kinetics.

Climpel's kinetic equation is the following :

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

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 $t \to \infty$ (min) in unit parts.

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

These dependences can be applied to the analyses for the kinetics of the flotation process. It can easily be seen that the structure of model is very simple and contains only two parameters (R_{max} and k) which are subject to experimental determination. In this way the analysis of alternative flotation conditions and schemes reduces to the analysis of two components (R_{max} and k) 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 process of lead minerals in the lead - zinc ore from "Zletovo" - mine, Probistip Macedonia in laboratory conditions (Table 1).

Table 1

Time (sec)	Concentration mass (%)	Pb %	Zn %
30	3.88	57.76	2.20
60	3.19	49.56	3.29
90	2.07	42.07	3.97
120	1.21	33.95	4.97
240	1.93	21.79	6.40
360	1.46	9.11	7.38
480	1.42	4.30	7.50
600	1.74	2.66	6.22
840	3.30	1.30	4.53
residue	79.70	0.18	1.30

When doing this, the parameters $R_{max\ i}$ and k_i were determined for lead i = 1, zinc i = 2 and gangue minerals i = 3, respectively. The parameters values were determined by the use of modified method of the sum of least squares (K. Gauss) when the following function is successively minimized three times:

$$F_i = \sum_{i=1}^{9} \left\{ R_i(t) - \left[R_{max_i} \cdot \left(1 - \frac{1}{k_i \cdot t}\right) \cdot \left(1 - e^{-k_i \cdot t}\right) \right] \right\}^2 \rightarrow \min$$

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

$R_{max\,1} \in [0.976;0.999]$, $R_{max\,2} \in [0.4739;0.60]$, $R_{max\,3} \in [0.1457;0.30]$,

$k_1 \in [0.01;10]$, $k_2 \in [0.001;5]$, $k_3 \in [0.001;5]$

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

CUMULATIVE GRADE RECOVERY DATE

Time (sec)	R-Pb (%)	Pb (%)	R-Zn (%)	Zn (%)	R-Rest of minerals (%)
30.00	37.55	57.76	4.34	2.20	1.39
60.00	64.02	54.06	9.68	2.69	2.86
90.00	78.61	51.35	13.86	2.98	4.00
120.00	85.80	49.23	17.05	3.22	4.83
240.00	92.84	44.94	23.34	3.73	6.38
360.00	95.08	41.13	28.83	4.11	7.79
480.00	96.10	37.69	34.27	4.43	9.25
600.00	96.88	34.09	39.78	4.61	11.07
840.00	97.60	28.75	47.39	4.60	14.57

Parameters	Pb, i = 1	Zn, i = 2	Rest of minerals, i = 3
Kinetic constant of flotation k_i (min^{-1})	0.043665	0.004787	0.003585
Maximum Recovery $R_{(max)i}$ (%)	99.98	59.80	19.68
Acheived minimum of function F_{min}	0.009032	0.003436	0.000682

On the basis of the obtained results we made comparation between the experimental cumulative recovery and the calculated cumulative recovery for Pb, Zn and rest of minerals shown in the Table 2.

Table 2

Flotation time, sec	30	60	90	120	240	360	480	600	840
Experimental cumulative recovery Pb, (%)	37.55	64.02	78.61	85.80	92.84	95.08	96.10	96.88	97.60
Calculated cumulative recovery Pb, (%)	44.25	64.60	75.04	81.00	90.44	93.62	95.21	96.16	97.25
Experimental cumulative recovery Zn, (%)	4.34	9.68	13.86	17.05	23.34	28.83	34.27	39.78	47.39
Calculated cumulative recovery Zn, (%)	4.10	7.82	11.22	14.31	24.25	31.29	36.39	40.16	45.20
Experimental cumulative recovery RM, (%)	1.39	2.86	4.00	4.83	6.38	7.79	9.25	11.07	14.57
Calculated cumulative recovery RM, (%)	1.03	1.97	2.86	3.69	6.48	8.62	10.29	11.59	13.47

CONCLUSION

The calculated values of the kinetic parameters "k" and R_{max} for Pb, Zn and the rest of 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 consideration 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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