2011 International Conference on Environment Science and Engineering
IPCBEE vol.8 (2011) © (2011) IACSIT Press, Singapore

Effects of size distribution on flotation kinetics of Chalcopyrite

Luo Xian-ping
College of Resource and Environmental Engineering
Jiangxi University of Science and Technology
Ganzhou , China
E-mail: lxp9491@163.com

Tang Xue-kun, He Li-ping, Luo Li-ying
College of Resource and Environmental Engineering
Jiangxi University of Science and Technology
Ganzhou , China
E-mail: yanqun8219893@163.com

***Abstract*—Four kinetic models are tested on batch flotation time-recovery profiles. A statistical analysis of data demonstrated that the flotation rate constant corresponded to a first-order model with rectangular distribution of floatabilities given by the equation：$\varepsilon=\varepsilon_\infty\{1-\frac{1}{kt}[1-e^{-kt}]\}$. The effect of size distribution on the flotation behaviour of chalcopyrite has been investigated in terms of kinetic parameters and maximum recovery.**

Keywords-Size distribution; Flotation models; Flotation rate constant; Chalcopyrite

At present, over ten billion tons of various ores are treated annually by flotation processes. Flotation processes are influenced by many factors such as the properties of ores、the effects of flotation reagent and the Characteristics of flotation machine and so on, The research about flotation theory includes flotation thermodynamics and flotation kinetics. The main purpose of the flotation kinetics is studying the rule of flotation rate constant, and analysing the effects of various parameters such as the properties of ores(particles, shapes, composition and so on), the system of flotation reagent and the Characteristics of flotation machine and so on[1-2]. Particle size plays important role in flotation processes, the liberation of ores and the detachment of particles, during which bubble coalescence are decided by it. There is an optimal particle size for a certain ore. If mineral size is too small,for their light weight and low momentum, it is difficult to overcome the barrier of bubble surface, and the possiblity of bubble collision and attachment are small, too. At the same time, as the weight is light, fine-grained will be mixed, then ore grade will be lowered, as mineral particles are small, their surficial area will be large. Then for the selective absorption of flotation reagent, it will increase consumption of Pharmacy, and small particles will also induse the energy increasing of the surface. The accelerate high rate of oxidation, so fine-grained minerals will decrease the possibility of flotation. But if mineral particle's size is too rough, then the required bubble which loads ore tablets will be too large, then the poor stability of it will decreases the possibility of flotation too. As Yang Song-rong proposed in the literature[3], many mineral processing scholars have examined the impaction of particles in flotation rate[4-8]. It shows that the biggest flotation rate exists in the middle of a particle size. And for different minerals, the optimal particle sizes are also different[9].

In order to study effects of size distribution on the flotation rate about a certain ore, an appropriate flotation model which describes the flotation kinetics must be found, then the flotation rate constant can be calculated. Subsequently, many flotation models have been proposed and published in the literature, as several flotation kinetic models have been concluded by O.Bayat et al [10] and X.M.Yuan et al[11], Luo Xian-ping et al[12] also evaluated several models in the literature. Some of these are summarised and commented as follows:

Classical first-order model

$$\varepsilon = \varepsilon_\infty\left[1-e^{-kt}\right] \tag{1}$$

First-order model with rectangular distribution of floatabilities

$$\varepsilon = \varepsilon_\infty\left\{1-\frac{1}{kt}\left[1-e^{-kt}\right]\right\} \tag{2}$$

Second-order kinetic model

$$\varepsilon = \frac{\varepsilon_\infty^{2}kt}{1+\varepsilon_\infty kt} \tag{3}$$

Second-order model with rectangular distribution of floatabilities

$$\varepsilon = \varepsilon_\infty\left\{1-\frac{1}{kt}\left[\ln(1+kt)\right]\right\} \tag{4}$$

In this study, The four flotation kinetic models described above were tested on batch flotation time-recovery profiles

This research was supported by the National Natural Science of Foundation of China (50704018).

for size distribution of Chalcopyrite. Understanding and interpreting changes in the values of ε_∞ and k are necessary. Changing any condition in a laboratory operation may lead to a obvious change in the value of k and ε_∞. The main purpose of this paper is to study effect of size distribution on flotation kinetics of chalcopyrite. Therefore, to determine kinetic parameters such as flotation rate constant(k) and the maximum recovery(ε_∞), a statistical programme MATLAB was usded to treat the data in the 'non-liner regression' model. Then the disciplinarian about the changes of flotation rate constant as the particle size distribution can be found so that the conclusions and the law about effects of size distribution on flotation kinetics of Chalcopyrite can be concluded.

I. EXPERIMENTAL

A. Preparation of experimental sample

The test material was ore from HuiLi Lead-Zine Mine. According to hand-selected, milling, cradle and vacuum drying. The experimental sample with grade of 33.29 percent and purity of 96.32 percent was received. Five discrete size fraction for pure Chalcopyrite ore are used to investigate the effect of size distribution on flotation kinetics, -0.125+0.098 mm, -0.098+0.074 mm, -0.074+0.063 mm, -0.063+0.054 mm, -0.054+0.039 mm. The mineral surface was cleaned by ultrasonic cleaning.

B. Flotation

Flotation test were operated in a laboratory flotation cell with 50 milliliter cell volume. In a typical flotation test, the weight of a representative sample is 5 g. They followed the flow sheet in Figure 1. Pulp density was adjusted to 10% solids by volume at each test. All reagents were of technical grade. The frother was a pine-oil, the collector was butylxanthate, the pulp pH was not adjusted. The rotate speed of flotation machine is 4000 r/min. Distilled water was used throughout the experiments. In the same amount of flotation reagents, batch flotation was done on a different kind of particle.

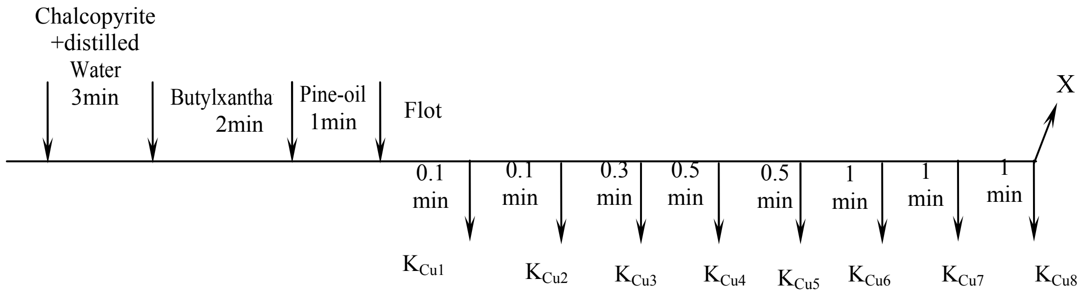

Figure.1 Flow sheet for laboratory tests

II. RESULTS AND DISCUSSION

Batch flotation was done on five different size fractions for pure Chalcopyrite ore,i.e. -0.125+0.098 mm, -0.098+0.074 mm, -0.074+0.063 mm, -0.063+0.054 mm, -0.054+0.039 mm. As for the test sample was pure chalcopyrite minerals, the recovery was accounted with test weight directly. The results of test were fitted by statistical program MATLAB. MATLAB software is a mathematical software which was introduced in the mid-1980s. At present, MATLAB is the best language in scientifical computing and engineering calculation. It can be used for technical computing and graphics. It covers the higher mathematics, matrix theory, numerical and mathematical statistics, optimization, neural networks, control theory and mathematical modeling, simulation, and many other classical and modern mathematical problems[13-15]. In this study, the fractional recoveries after 0.1, 0.2, 0.5, 1.0, 1.5, 2.5, 3.5, 4.5 minutes of flotation time were fitted to the models given previously.To determine the kinetic parameters such as the rate constant and the maximum recovery, the statistical program MATLAB was used to treat the data in the mode "non-linear regression." At last, the relationship between flotation rate constant and particle size was fitted by Origin software.

The different model epuations were drawn on a time-recovery graph, which is shown in Figure 2-6. The regression results from each model are given in Table 1. The relationship between flotation rate constant and the particle size is shown in Figure 7.

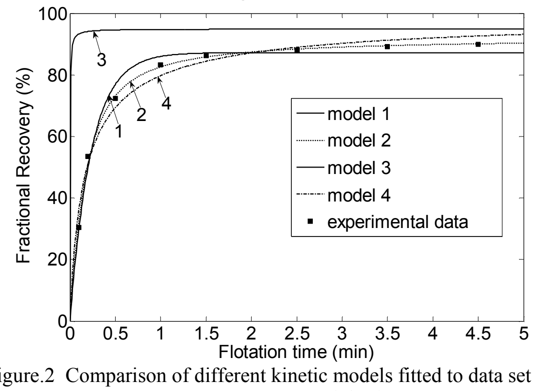

Figure.2 Comparison of different kinetic models fitted to data set for -0.125+0.098 mm particle size

It was observed that only very small differences occurred amongst the tested models at the beginning of flotation (up to 0.5 min flotation time). However, after this period, model 2 was considered to be the best fit and the most suitable for understanding the Cu flotation process to any size distrubution, i.e. -0.125+0.098 mm, -0.098+0.074 mm, -0.074+0.063 mm, -0.063+0.054 mm, -0.054+0.039 mm. Smiliar findings were also observed for a simple porphyry copper ore and a complex sulphide ore[16]. This finding basically agrees with Chen Zi-ming[17] who indicated that if minerals were classified to a very narrow range of particle size and minerals were purified rigorously, a first-order model

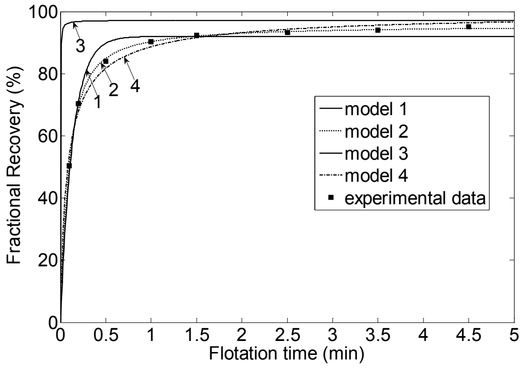

Figure.3 Comparison of different kinetic models fitted to data set for -0.098+0.074 mm particle size

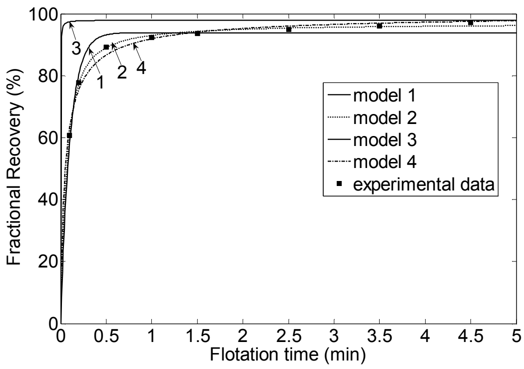

Figure.4 Comparison of different kinetic models fitted to data set for -0.074+0.063 mm particle size

gives a best fit to the data. So, We can believe that, chalcopyrite pure mineral flotation can be described with First-order model with rectangular distribution of floatabilities, $\varepsilon = \varepsilon_\infty\left\{1-\frac{1}{kt}\left[1-e^{-kt}\right]\right\}$.

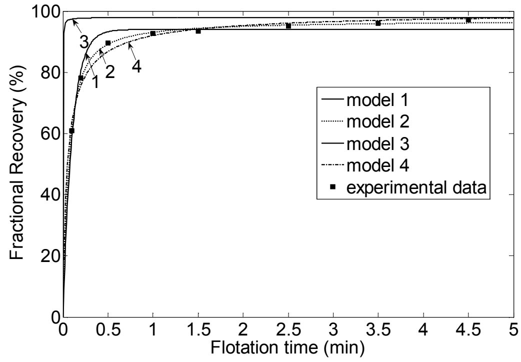

Figure.5 Comparison of different kinetic models fitted to data set for -0.063+0.054 mm particle size

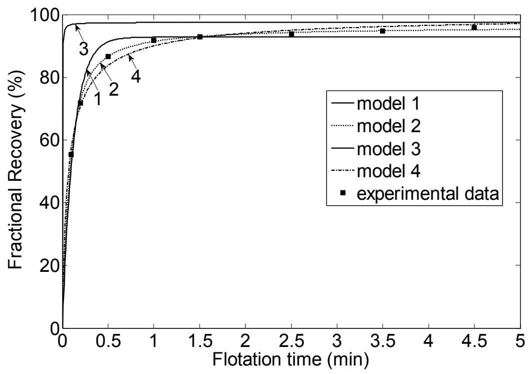

Figure.6 Comparison of different kinetic models fitted to data set for -0.054+0.039 mm particle size

TABLE Ⅰ Non-linear regression results for all models investigated

Number		**1**	**2**	**3**	**4**	**5**
Size distribution /mm		-0.125+0.098	-0.098+0.074	-0.074+0.063	-0.063+0.054	-0.054+0.039
Model 1	ε_∞	0.8723	0.9201	0.9389	0.9398	0.9282
	k	4.2593	7.4242	9.6855	9.7585	8.1926
Model 2	ε_∞	0.9226	0.9571	0.9693	0.9699	0.9622
	k	9.5552	17.7216	24.5505	24.8172	20.0962
Model 3	ε_∞	0.9493	0.9720	0.9793	0.9796	0.9750
	k	6.1662	12.1768	17.7816	18.0315	14.0840
Model 4	ε_∞	0.9937	0.9998	0.9999	0.9999	0.9998
	k	13.5824	30.5095	48.1351	49.0061	36.3687

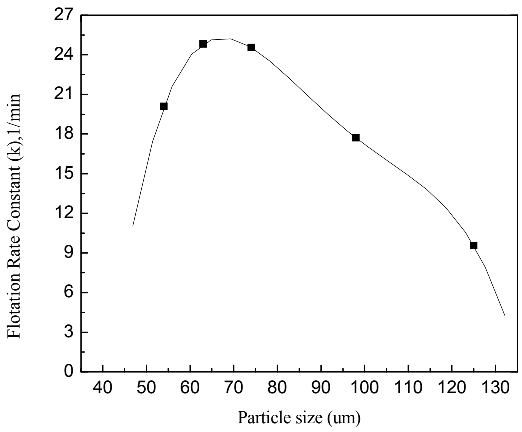

Figure.7 The relationship between flotation rate constant and particle size

The effects of size distribution on flotation kinetics of Chalcopyrite can be seen from the changes of k value in Table 1 and Figure 7. For instance, in model 2, as the size fraction is -0.125+0.098 mm, the value of flotation rate constant k is 9.5552; as the size fraction is -0.098+0.074 mm, the value of flotation rate constant k is 17.7216; as the size fraction is -0.074+0.063 mm and -0.063+0.054 mm, the value of flotation rate constant k is similar, at the same time they also reached the largest, the value of flotation rate constant k is 24.5505 and 24.8172 respectively; as the size fraction is -0.054+0.039 mm, the value of flotation rate constant k reduced to 20.0962.

In Table 1, it shows that there are also significant impact of size distribution on maximum recovery ε_∞. And it is similar to the changes of flotation rate constant. For example,in model 2, as the size fraction is -0.125+0.098 mm, maximum recovery ε_∞ is 0.9226; as the size fraction is -0.098+0.074 mm, maximum recovery ε_∞ is 0.9571; as the size fraction is -0.074+0.063 mm and -0.063+0.054 mm, maximum recovery ε_∞ is similar, at the same time they also reached the largest, maximum recovery ε_∞ is 0.9693 and 0.9699 respectively; as the size fraction is -0.054+0.039 mm, maximum recovery ε_∞ reduced to 0.9622.

The reason of the flotation rate constant changes with size distribution is: there are marked impact of size distribution on required induction time of bubble collision and attachment with ore, If the induction time is too long, the bubbles and mineral tablets is difficult to form aggregates,the flotation rate will decrease, And induction time grow rapidly with the increase of size, therefore, the flotation rate of coarse-grained decline soon. Any minerals can arrive the largest flotation rate in the middle of a particle size, When the size is less than the best value, with the increase in size, the possibility of the collision of air bubbles and mineral will increase,and it will be easy to form bubbles - mine tablets aggregation, so the flotation rate constant will also increase. But when the particle size is greater than the best value, though the impact of particle size on the probability of collision of air bubbles and mineral is little, the inertia will increase as size increases, then bubbles and mineral tablets aggregation will separate before arriving the foam of the surface of flotation, so the flotation rate constant will decrease.

III. CONCLUSION

1） A first-order kinetic model incorporating a rectangular distribution of floatabilities gave the best fit for experimental data, $\varepsilon = \varepsilon_\infty \left\{ 1 - \frac{1}{kt}\left[1 - e^{-kt}\right] \right\}$.

2） Particle size has an important effect on the flotation rate constant of Chalcopyrite,the optimum feed size for Chalcopyrite is -0.074+0.054 mm.

3） The effect of particle size on maximum recovery of Chalcopyrite is similar to the effect on flotation rate constant. The value of maximum recovery reached greatest as particle size in -0.074+0.054 mm.

ACKNOWLEDGMENT

This research was supported by The financial support for this work from the National Natural Science of Foundation of China(Grant No. 50704018) is acknowledged.

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