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The Flotation Device Designed to Treat Phosphate Rock

Z. Q. Zhang, Y. Zhang, D. L. Li

***Abstract*—**To overcome the some shortcomings associated with traditional flotation machines and columns in collophanite flotation, a flotation device was designed and fabricated in the laboratory. A multi-impeller pump with same function as a mechanical cell was used instead of the injection sparger and circulation pump in column flotation unit. The influence of main operational parameters of the device like feed flow rate, air flow rate and impellers' speed on collophanite flotation was analyzed. Experiment results indicate that the influence of the operational parameters were significant on flotation recovery and grade of phosphate concentrate. The best operating conditions of the device were: feed flow rate 0.62 L/min, air flow rate 6.67 L/min and impellers speed 900 rpm. At these conditions, a phosphate concentrate assaying about 30.5% P_2O_5 and 1% MgO with a P_2O_5 recovery of about 81% was obtained from a Yuan'an phosphate ore sample containing about 22.30% P_2O_5 and 3.2% MgO.

***Keywords*—**Collophanite flotation, flotation columns, flotation machines, multi-impeller pump.

I. Introduction

FLOTATION machine with a mechanically driven impeller is mainly equipment on phosphate flotation now in use. The impeller in a mechanical flotation cell achieves four functional objectives: (1) keeping the mineral pulp suspended, (2) shearing the incoming air into bubbles, (3) providing sufficient turbulent energy for bubbles dispersing in the pulp and attaching the hydrophobic particles to form mineralized bubbles, (4) providing a quiescent fluid environment for mineralized bubbles to rise into the froth products [1]-[3]. However, large quantities of fine particles are generated during the grinding in order to liberate mineral particles from the ore for collophanite flotation and they are usually difficult to be recovered by flotation due to their low mass and inertia that leads to low probability of particles colliding with bubbles [4], [5]. When mechanical flotation machine is used in collophanite flotation, the mineralization of bubbles requires high stirring kinetic energy to form a turbulent fluid environment for efficient collisions of fine particles with bubbles, while at same time the separation of minerals generally requires low stirring kinetic energy to maintain a quiescent fluid environment for mineralized bubbles to rise into the froth product [6], [7]. So this is a contradictory problem with no solution for a conventional mechanical cell [8]. Compared with mechanical cells, flotation columns are believed to be mechanically simpler and more suitable for fine particle flotation with a good quiescent separation environment and small bubble diameter [9], [10]. A flotation column is composed mainly of a reaction zone and a separation zone. In the reaction zone, bubbles are brought in attaching hydrophobic particles. In the separation zone, bubble/particle aggregates rise achieving separation [11]-[13]. Generally an injection sparger is installed at the bottom of column connected with a circulation pump to recycle middling pulp and inhale air to generate small bubbles [14]. The main problem for columns used in phosphate flotation is sparger plugging caused by scaling of calcium dissolve in the pulp. The operation and maintenance costs for columns also tend to be higher than mechanical cells due to the sparger system [15]. To develop the equipment more suitable for collophanite flotation, a combined flotation device of mechanical and column cell was designed and tested in terms of lab-scale performance.

Z.Q.Zhang, Y. Zhang, and D.L. Li are with School of Resources and Civil Engineering, Wuhan Institute of Technology, Wuhan 430073, China (e-mail: zzqgxn@hotmail.com.cn, 21601334@qq.com, ldl5469@163.com).

II. Design of Flotation Device

Instead of the injection sparger and circulation pump used in column flotation unit, a multi-impeller pump similar to a multistage pump was connected with the column as shown in Fig. 1. The multi-impeller pump with same function as a mechanical cell has the following advantages when combining with column: (1) Without injection sparger and solving the plugging problem, (2) with small bubbles and a high turbulent environment for efficient collisions of fine particles with bubbles, (3) overcoming the contradiction in single mechanical cell through providing high turbulent mineralization environment in the pump and quiescent separation environment in the column, (4) increasing the collection zone in the pump.

III. Experimental

A. Materials

The test ore sample is marine sedimentary phosphate rock from Yuanan, Hubei province, China, in which the phosphate minerals are mainly present as amorphous and microcrystalline carbonate fluoro-apatite. The main gangue minerals in the ore are quartz, calcite, dolomite, water mica, sericite, kaolinite, pyrite and glauconite. The chemistry of the sample is shown in Table I. Usually, in order to obtain the qualified concentrate, direct-reverse flotation or double reverse flotation are applied to the phosphate ore [16].

B. Experimental Set up

A laboratory flotation device used in this work is shown in Fig. 2. Its column was made of plexiglass with an inner diameter of 60 mm and a height of 1200 mm. The top 200 mm of the column protrudes into the froth recovery section. The multi-impeller pump is placed at the bottom 200 mm of the column. A mixing tank is available upstream to mix reagents with feed slurry. The feed slurry and air are introduced in multi-impeller pump by the pumping action of the impellers permitting the transfer of intermediate flows without other pumps. A conical section is attached to the bottom of the column for tailings recovery. Wash water was introduced through a perforated 10 mm copper tubing ring placed above the column.

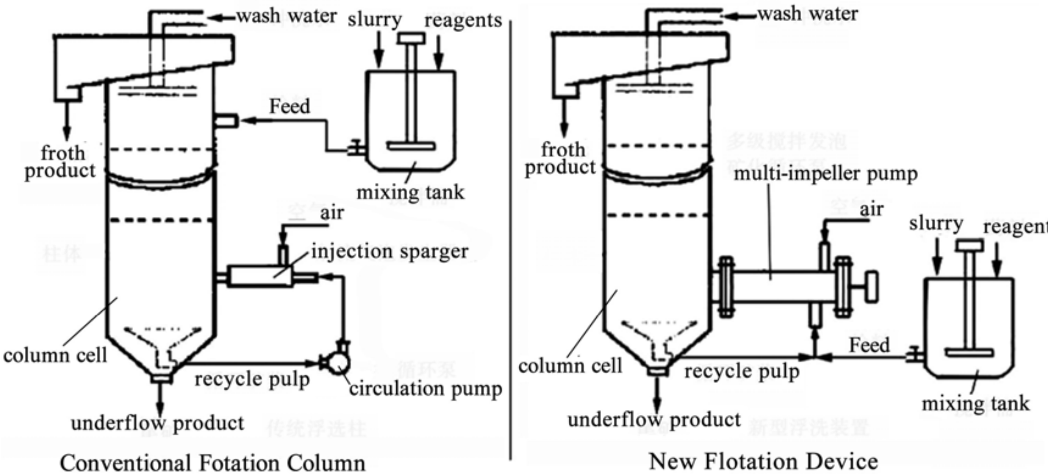

Fig. 1 Schematic diagram of improved flotation device

TABLE I
CHEMICAL ANALYSIS RESULT OF SAMPLE / (Ω, %)

P_2O_5	MgO	CaO	SiO_2	Al_2O_3	Fe_2O_3	F	K_2O	TiO_2	LOI
22.16	3.15	29.85	25.41	7.39	1.69	0.74	2.31	0.63	11.51

Fig. 2 Improved flotation device

C. Experimental Methods

In each experiment 1500 g of ore sample were ground wetly in a rod mill to a 98.5% passing size of 0.074 mm. Then direct flotation was applied to the phosphate ore separation. Chemicals used in flotation tests were DS-1 (a mixture of fatty acid and non-ionic surfactant) as phosphate collector, sodium silicate as silica depressor, calcium lignosulfonate as magnesium depressor, and sodium carbonate as pH modifier. The temperature of flotation pulp was kept at 25±1 °C. The flowsheet included a one-stage rougher and one-stage cleaner. After 15 min flotation, froth product was collected as phosphate concentrate and the slurry left in the column and pump were collected as flotation tailing, which were filtered, washed, dried, weighed and chemically analyzed. The conditioning and flotation parameters in Table II were kept constant during the test. The effects of some main operational parameters as feed flow rate, air flow rate, and impellers speed on phosphate flotation were tested and comparative test results were got at the better operational parameters.

TABLE II
CONSTANT PARAMETERS OF CONDITIONING AND FLOTATION

Conditioning		Flotation	
Parameter	value	Parameter	value
Solids /%	30	Flotation time /min	20
Conditioning time/min	10	Collector dosage/(g/t)	1000
pH	10.5	Sodium carbonate dosage/(g/t)	2000
Solids charge/g	1500	Sodium silicate dosage/(g/t)	2000
Water type	Tap water	Calcium lignosulfonate dosage/(g/t)	1500

IV. RESULTS AND DISCUSSION

A. The Effect of Feed Flow Rate on Phosphate Flotation

Fig. 3 depicts the effect of feed flow rate on flotation results. The results indicate that as feed flow rate increases from 0.44 to 0.62 L/min, P_2O_5 recovery increases from 66.34% to 80.22% and P_2O_5 content increases from 26.23% to

28.69%. When feed flow rate exceeds 0.62 L/min, P_2O_5 recovery and content decreases gradually. The higher feed flow rate may increase the probability of collision between particles and air bubbles and in turn will increase the number of particle-bubble aggregates. However, it is bad for phosphate separation when feed flow rate is too fast to reduce the flotation time.

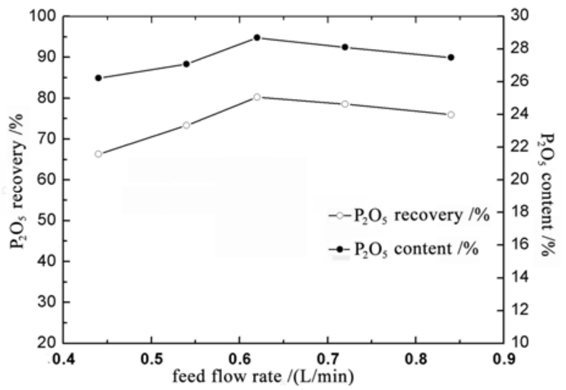

Fig. 3 Effect of feed flow rate on phosphate flotation

B. The Effect of Air Flow Rate on Phosphate Flotation

Fig. 4 shows the effect of air flow rate on phosphate flotation. The results indicate that as air flow rate increases from 3.35 to 9.16 L/min, P_2O_5 recovery increases from 51.96% to 80.33%. Meanwhile, the P_2O_5 content decreases from 29.80% to 27.48%. It is known that the higher air flow rate increases the probability of collision between particles and air bubbles and the number of mineralized bubbles. However, the bubble size is linearly related to the applied air flow rate [17]. The higher air flow rate produces bubbles of larger diameter which, in turn, provides a lower total surface area. Consequently, the air flow rate of 6.67 L/min with the higher separation efficiency is appropriate.

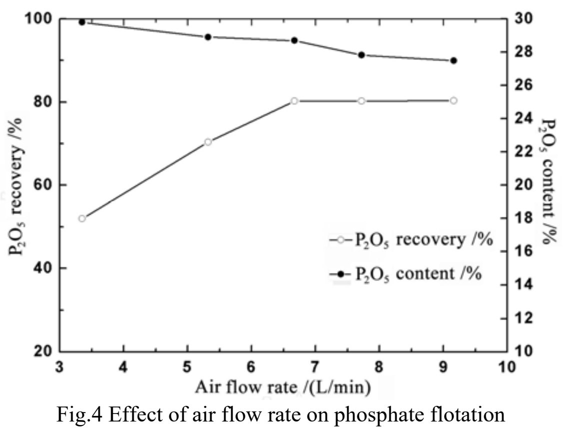

Fig.4 Effect of air flow rate on phosphate flotation

C. The Effect of Impellers Speed on Phosphate Flotation

The results in Fig. 5 indicate that both P_2O_5 content and recovery of concentrates were affected by the impellers speed. Increasing the impellers speed from 600 to 900 rpm increases the P_2O_5 content from 27.91% to 30.52% while P_2O_5 recovery increases from 63.83% to 81.66%. However, the increase of P_2O_5 content and recovery is not obvious when the impellers' speed is over 900 rpm. It is expected that bubbles size will decrease and collision energy between particles and air bubbles will increase with increasing impellers speed. But at the same time higher impellers speed results in higher energy consumption and cost. So the impellers speed of 900 rpm was selected for all the experiments.

D. The Effect of Impellers Speed on Phosphate Flotation

Based on the above experimental results, the better conditions for phosphate flotation with the new flotation device were: Feed flow rate 0.62 L/min, air flow rate 6.67 L/min and impellers speed 900 rpm. The comprehensive flotation tests were carried out under these conditions, and the results were shown in Table III. The results indicate that the qualified phosphate concentrates can be obtained by simple direct flotation.

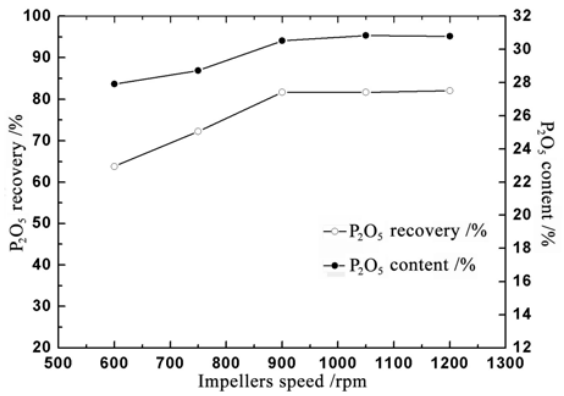

Fig. 5 Effect of impellers speed on phosphate flotation

TABLE III
THE COMPREHENSIVE FLOTATION RESULTS OF YUAN'AN PHOSPHATE ORE

Exp No.	products	Yield	P_2O_5		MgO	
			Content	Recovery	Content	Recovery
1	Concentration	59.22	30.52	81.01	1.02	19.18
	Tailing	40.78	10.40	18.99	6.24	80.82
	Feed	100.0	22.31	100.0	3.15	100.0
2	Concentration	59.38	30.45	81.19	1.04	19.79
	Tailing	40.62	10.31	18.81	6.16	80.21
	Feed	100.0	22.27	100.0	3.12	100.0

V. CONCLUSION

1. The performance of flotation cell and column cell can be effectively combined by using a multi-impeller pump instead of the injection sparger and circulation pump in column flotation unit.
2. The new designed flotation device can simplify the structure of the traditional flotation column, and solve the problems existing in the flotation of phosphate rock by traditional flotation column or flotation machine.
3. The influence of main operational parameters such as feed flow rate, air flow rate and impellers speed on

collophanite flotation was significant on flotation recovery and concentrate grade.

4. Under the optimum operational conditions, the qualified phosphate concentrates can be obtained by simple direct flotation.

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Z.Q.Zhang was born in August 1961 in Kunming China and received Ph.D from China University of Geosciences in 2009. His main research interest is Comprehensive utilization of solid waste.He is the technical committee members of Chinese chemical mining association.Since 1997 He has been the professor of Wuhan Institute of Technology (WIT) and engaged in teaching and scientific research work in mineral processing and mineral materials.