EVALUATION OF COARSE PARTICLE FLOTATION PROCESSES [1]

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Abstract

Flotation is a very successfull concentration process, and is employed for many types of minerals (sulphides, oxides, etc.) as well as for diverse particle sizes. Previous works show that flotation can be applied successfully for particle sizes between 10 to 300µm. The flotation selectivity drops dramatically out of these size limits, as the system hydrodynamic conditions cannot keep at suitable levels for the flotability of these particles. Some flotation systems use a wide range of particle sizes, which can very often reduce the process selectivity due to distinct behaviors of the several size classes, and corresponding specific surface areas, hydrophobicity and weight. Along the course of this work a mechanical industrial flotation process for itabirite iron ore with high grade of coarse particles was evaluated. The results show low selectivity (Gaudin) for coarse (+0.500mm) and fine (-0.045 mm) size fractions. Positive results were obtained with 25% of particles greater than 0.150mm with the top size of 0.300mm and about 13% of particles smaller than 0.045mm. The available literature shows high probability of non-collection during flotation for coarse particles, thus requiring greater collector dosages aimed at increasing the hydrophobicity level for these particles. Bench scale flotation assays were conducted using a -1.0+0.15mm size fraction for an itabirite iron ore. The results showed the possibility to obtain a flotation concentration with SiO_2 degre below 1% and metalic recovery close to 90%. Additional tests must be carried out to confirm these results.

Key words: Flotation; Coarse particles; Selectivity.

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1 INTRODUCTION

As one of the major mineral concentration processes used today all over the world, flotation has been in use for approximately one hundred years in a large number of classes of minerals such as sulphides, oxides, phosphates, silicates, coal and soluble salts. The mineral industry owes its development to the discovery of flotation as other traditional physical processes for mineral concentration (gravity, magnetic and electrostatic) do not allow for the differentiating property (density, magnetic susceptibility or electric conductivity) to be either induced or modulated. A significant part of the world production of iron concentrates that are required to meet the current steel demand is only possible to be produced through the large scale use of flotation processes.

The selectivity of the flotation process is based on the hydrophobicity differential amongst the diverse mineral species that are to be separated. The hydrophobicity concept relates to the easiest way of using water to moisten minerals, with hydrophilic substances being chemically classified as polar and hydrophobic substances clasified as apolar, an affinity being present when both substances are either polar or apolar. Very few minerals are naturally hydophobic by nature (graphite, molibdenite, talcum, pyrophilite, some coals and silver-free natural gold). Minerals known to be polar show high values of surface-free energy, strongly reacting with water molecules, in addition to showing a null or near zero(1-3) contact angle.

One of the advantages of the flotation process is the possibility that the originally hydrophilic surface can become hydrophobic with respect to most mineral species. This process occurs with the use of surfactant reagents that adsorb on the surface of such minerals (mineral interface/solution). Adsorption is the process of concentrating chemical species (collectors, modifiers, foamers) in interfaces. Surfactants are type R-Z amphipathic molecules, that is, those which show an apolar portion R (R=hydrocarbon chain) that can be branched out, either linear or cyclic; Z constitutes the polar portion which can be composed by one ore more functional groups. R constitutes the apolar.(4)

The main components of the itabirite iron ore – hematite and quartz – can be separated by using cathionic collectors such as alkyl ether acetate amine. Therefore, the selectivity is attained using starch as an iron mineral depressor, which is conditioned on the ore pulp prior to adding the collector. The cation alkyl ether amine preferably adsorbs in the quartz/solution interface so as to turn its surface into a hydrophobic surface while the starch ensures the hydrophilic character of the hematite/solution interface.

A very simplified flotation model can be described in terms of the collection of particles that result of a likely occurrence of the following events: 1. collision between particles and air bubbles (P_c); 2. Adherence between particles and bubbles (P_a); 3. Detachment of the particle which adhered to the bubble (P_d); 4. Retention of the particle on the foam during the required time for the transportation and removal of the flotation system (P_r). Equation 1 shows the result of these probabilities during the collection of particles in the flotation process.

$$P = P_c \times P_a \times P_r \times (1 - P_d) \qquad (1)$$

Coarse particles show high levels of collision and low likelihood of adherence and retention (high level of non-collection), thereby justifying the difficulty in collecting these particles in the flotation process.

Hewitt et al.(6) have shown that there is an increased likelihood of adherence with an increased particle size and increased level of hydrophobicity, the latter being achievable with higher collector dosages.

The study of flotation has been the target of a number of studies,(7,8) the results of which showing that the same forces driving the collision and aggregation between particles and bubbles can also be responsible for disrupting the aggregate's stability, consequently causing the non-collection. In general, the efficacy of collision and collection drops dramatically in the case of particles greater than 300µm. It can be stated that the likelihood of non-collection is higher for larger-size particles albeit these also show increased collision probability.

Leppinen et al.(9) have developed a flotation process for coarse particles named SIF (Separation in Froth) through which pulps with 60% to 80% solids by weight are directed to the flotation reactor from the foam area (upper part), thus presenting higher particle-buble contact. The studies (bench scale and pilot) were conducted with particles of apatite, calcite, silicates and diamond of up to 3.0mm in size.

In the foam-based separation process (SIF), hydrophobic mineral particles are removed by the air bubbles immediately after being fed into the flotation reactor, while the hydrophilic particles travel all the way down in this equipment. Figure 1 illustrates operational principle of the SIF process.

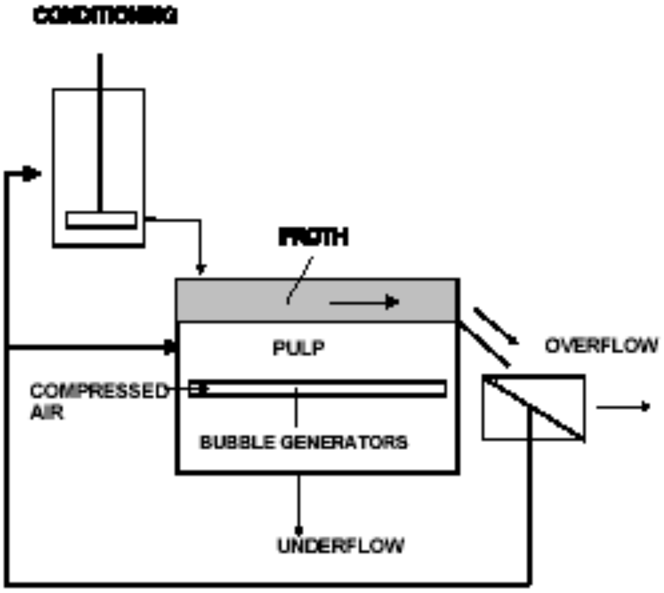

Figure 1 – SIF process principle. This configuration was used for lab tests (Leppinem et al, 2003)

2 MATERIALS AND METHODS

This work is divided into two tasks:

1- Evaluation of an industrial flotation process through mechanical cells for an itabirite iron ore. The evaluation has been carried out taking into account a feed with a distinct size distribution. Feed size analyses were also carried out in performing this evaluation. The flotation circuit comprises of rougher, cleaner, recleaner and the scavenger steps.
2- Bench scale tests for the SIF process were carried out using a pre-sized -1.0+0.150mm itabirite ore sample. These tests were preliminarily made in

order to evaluate SIF's potential with respect to coarse particles. The tests were executed with varied dosages of both reagents (collector and depressor) and pH values. The resulting products were characterized using size and chemical analyses.

3 RESULTS AND DISCUSSION

The evaluation of the industrial mechanical cell process was carried out taking into account two feed size distributions. Table 1 shows the feed size distribution for the first industrial evaluation.

Table 1 – Size distribution for the first industrial evaluation

Size (mm)	% Retained	Cumulative % Retained	Cumulative % Passing	Fe (%)	SiO_2 (%)
0.300	9.62	9.62	90.38	53.02	20.56
0.200	12.93	22.55	77.45	39.17	41.05
0.150	22.59	45.14	54.86	28.48	56.14
0.105	10.48	55.62	44.38	27.21	58.09
0.075	13.41	69.03	30.97	31.27	49.97
0.053	8.26	77.29	22.71	41.21	34.20
0.045	6.70	83.99	16.01	55.54	16.36
-0.045	16.01	100.00	0.00	65.76	5.44
Total	**16.01**	**xx**	**xx**	**41.30**	**37.55**

Table 1 shows that in the first industrial evaluation the mechanical cells were fed with approximately 45% particles greater than 0.150mm, whereas this percentage is usually on the average of 8% in current industrial practice. The size distribution in Table 1 also shows 9.62% of particles greater than 0.300mm and 16% particles smaller than 0.045mm. Table 2 and Figure 2 show the flotation process performance during this first evaluation, pointing to a low selectivity level (Gaudin) for the extreme size fractions (+0.500mm and -0.045mm). A higher collector dosage constituted an attempt to collect coarse quartz (+0.150mm), but this was not achieved, as shown in Table 2, with 33.1% of particles +0.150mm in the concentrate.

Table 2 – Performance of the mechanical flotation process in the first industrial evaluation with high collector dosage

Parameter	Feed	Concentrate (Underflow)	Tailings (Froth flow)
Rec. Mass	100.00	37.18	62.82
Rec. Fe (%)	100.00	57.65	42.35
Rec. Sio_2 (%)	100.00	5.29	94.71
Fe (%)	41.30	64.04	27.84
Sio_2 (%)	37.55	5.35	56.60
% + 0.300 mm	9.62	22.25	2.15
% + 0.150 mm	45.14	65.44	33.13
% - 0.150 mm	54.86	34.56	66.87
% - 0.045 mm	16.81	2.14	24.32
Selectivity (Gaudin)		5	
Collector (g/t_{SiO2})		386	
Depressor (g/t_{alim})		500	

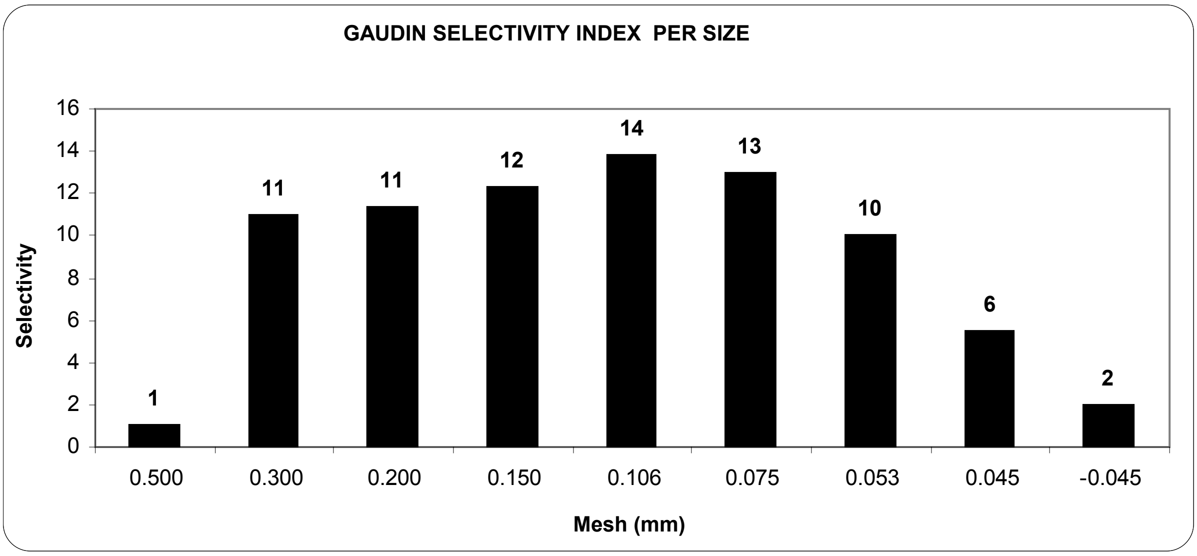

Figure 2 – Selectivity index (Gaudin) per size fraction for the mechanical flotation process in the first industrial evaluation.

The aforementioned results show the likelihood of quartz particle collection with up to 0.300mm size (selectivity=11), and due attention shall be given to the fact that particles smaller than 0.045mm show a low selectivity level, which can be construed as follows: the higher collector dosage was not enough to increase the probability of collection of coarse quartz. At the same time, this surplus in reagent might have contributed to the collection of fine hematite particles.

Over the course of the second industrial evaluation, an attempt was made towards reducing both the feed top size and the percentage of fine particles (-0,045mm). Table 3 shows the feed size distribution and Table 4 shows the performance of the mechanical industrial cells during the second industrial evaluation.

Table 3 – Size distribution of the second industrial evaluation

Size (mm)	% Retained	% Retained accumulated	% Passing accumulated	Fe (%)	SiO_2 (%)
0.300	3.58	3.58	96.42	33.10	52.48
0.200	8.65	12.23	87.77	36.05	47.55
0.150	12.25	24.48	75.52	35.13	48.91
0.105	15.80	40.28	59.72	45.15	35.00
0.075	22.46	62.74	37.26	43.12	38.05
0.053	12.45	75.19	24.81	51.25	25.80
0.045	11.44	86.63	13.37	57.80	15.50
-0.045	13.37	100.00	0.00	59.63	12.16
Global	**100.00**	**xx**	**xx**	**46.39**	**32.67**

Table 4 – Performance of the mechanical flotation process during the second industrial evaluation

Parameter	Feed	Concentrate Underflow	Tailings Froth
Rec. Mass	100.00	61.94	38.06
Rec. Fe (%)	100.00	88.92	11.08
Rec. Sio_2 (%)	100.00	2.70	97.30
Fe (%)	46.39	66.60	13.50
Sio_2 (%)	32.67	1.50	77.10
% + 0.300 mm	3.58	1.30	7.29
% + 0.150 mm	24.48	15.60	38.93
% - 0.150 mm	75.52	84.40	61.07
% - 0.045 mm	13.37	18.40	5.18
Selectivity (Gaudin)		17	
Collector (g/t_{SiO2})		200	
Depressor (g/t_{alim})		500	

The second industrial evaluation showed a metallic recovery of 89%, a Gaudin selectivity of 17%, a 1.5% grade of SiO_2 in the concentrate and 13.5% of iron in the tailings with the collector dosage adjusted to 200 g/t_{SiO2}. The feed contains roughly 4% of particles +0.300mm, 25% +0.150mm and 13% -0,045mm. The comparatively good results were obtained limiting the feed top size to 0.300mm and reducing the percentage of fine (-0.045mm) to values near 13%.

Table 5 below shows the feed size distribution used for the preliminary bench flotation tests with short residence time, based on SIF process.

Table 5 – Feed flotation size distribution for preliminary SIF bench scale tests.

Size (mm)	% Retained	% Retained accumulated	% Passing accumulated	Fe (%)	SiO_2 (%)
1.000	1.09	1.09	98.91	63.37	7.27
0.600	5.16	6.25	93.75	59.13	13.16
0.300	21.30	27.55	72.45	49.32	28.35
0.150	49.51	77.06	22.94	44.80	35.22
-0.150	22.64	100.00	0.00	58.31	15.75
Global	**100.00**	**xx**	**xx**	**49.80**	**27.85**

Table 6 below shows the analysis of the preliminary test aimed at coarse particle flotation with short residence time..

Table 6 – Results of the coarse particle preliminary SIF flotation test

Parameter	Feed	Concentrate Underflow	Tailings Froth
Rec. Mass	100.00	66.76	33.24
Rec. Fe (%)	100.00	96.18	3.82
Rec. Sio_2 (%)	100.00	2.05	97.95
Fe (%)	47.73	68.77	5.48
Sio_2 (%)	28.40	0.87	84.05
% + 0.300 mm	27.55	27.63	20.55
% + 0.150 mm	77.06	70.87	84.63
% - 0.150 mm	22.94	29.13	15.37
% - 0.045 mm	2.50	1.50	4.51
Selectivity (Gaudin)		35	
Collector (g/t_{SiO2})		400	
Depressor (g/t_{alim})		500	

Table 6 above points to the likelihood of coarse particle flotation (nearly 1.0mm) using a process through which the pulp is fed straight onto the foam layer with short residence time. Complementary tests will be performed to confirm the results and to evaluate pilot and industrial scale processes.

4 CONCLUSION

The evaluation of a mechanical industrial cells has shown low selectivity levels for particles greater than 0.500m and smaller than 0.045mm, thus pointing to great difficulty in handling the flotation of such class of particle sizes. A flotation feed with 0.500mm top size containing 45% of particles greater than 0.150mm and 15% smaller than 0.045mm has shown a clow Gaudin selectivity index at a higher collector dosage.

This flotation performed significantly better when the top size of the feed was adjusted to 0.300mm and with 25% particles greater than 0.150mm. For this size fraction, the consumption of collector was on the average 50% lower, whereas metallic recovery was 89% afor a Gaudin selectivity index of 17.

Preliminary bench scale tests of Itabirite iron ore pulp fed directly onto the foam layer with short residence time has demonstrated the possibility of flotation with particles between 1.0mm and 0.150mm. Complementary tests will be performed to confirm these results.

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