THE EFFECT OF ALUMINA ON THE FLOTATION OF SOME IRON ORES

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ABSTRACT

The flotation behaviour of some iron ores is, in many instances, strongly affected by the presence of aluminium containing species, analysed as alumina. This paper presents the results of a laboratory investigation with samples collected in a mine in full operation. Bench scale flotation tests and a criterious chemical and mineralogical characterisation were performed. The alumina distribution in all samples presents a similar pattern. Alumina content decreases from particles size 150μm to a minimum at 30μm and increases sharply to a maximum at 9μm. Poor flotation performances are a consequence of high contents of slimes.

The major aluminium bearing minerals identified were caolinite and gibbsite. These minerals are usually associated with hydrated iron species (mainly goethite), but associations with microporous hematite were also observed. Poor flotation performances (high silica content in the concentrate) are caused by high caolinite contents. Gibbsite does not seem to impair the reverse cationic flotation process.

INTRODUCTION

The Pico project implemented by Minerações Brasileiras Reunidas S.A. - MBR - in 1994. The major difference between this concentrator and the existing MBR plants (Águas Claras and Mutuca) is the column flotation section, designed for the concentration of fines (<150μm). The need for flotation concentration of the fines of an ore predominantely constituted of hematite arises from the characteristics of the deposit, presenting a high degree of intergrowth between the hematite and itabirite ore bodies. This phenomenon causes major variations in the silica content of the fines fraction that feeds the flotation circuit.

The presence of alumina renders the relatively simple technique of silica removal by column flotation much more complex, bringing difficulties to the production of Pellet Feed Fines (PFF) within the current specifications.(Silva, 1999)

The origin (association) and nature of alumina present in the feed of the quartz cationic reverse flotation performed at Pico's concentrator was investigated, aiming at understanding and minimising its harmful influence on the process.The minerals responsible for the presence of alumina are goethite, caolinite and gibbsite, occurring either as free particles or associated particles.

MATERIALS AND METHODS

The selection of ore types for the experiments was based on the industrial flotation responce to feeding the plant with these ore types. Some clay types, considered as waste rock, were included in the selection because they, sometimes, feed the flotation plant due to the close association with the ore.

The ore types and their chemical characteristics are presented in Table I. The samples were collected by channel sampling on the bench face.

The tests were performed with the same reagents and dosages utilised in the industrial plant at the beginning of the investigation:

collector: EDA B, an etheramine manufactured by Clariant, with 50% neutralisation degree with acetic acid - dosage = 70g/t;

depressant: gelatinised corn starch (weight ratio starch:NaOH = 4:1), locally known as "fubá", manufactured by Ceval, dosage = 830g/t.

RESULTS AND DISCUSSION

Its worth observing that the alumina distribution by narrow size range is similar for all samples (Figure 1). It is higher for the fractions retained in 105μm and 44μm, decreases to a minimum at approximately 30μm and increases again to a maximum below 9μm.

The alumina remotion in the desliming stage was higher than 50% for all samples even in the cases of lower alumina percentage in the fraction <150μm.

Regarding slimes remotion (the fraction <9μm taken as reference), the desliming performance was adequate, providing a remotion degree higher than 80% for all samples. The results of the desliming stage are presented in Table II.

It is observed that some ore samples and all waste samples present alumina content in the deslimed fraction above 1.0%, due to the high initial slimes content in the sample and also to the limited capacity of slimes removal in the desliming stage.

The most relevant results of the bench scale flotation tests are presented in Table III. In general, even the waste samples presented a good response to the flotation process. Outstanding results were achieved with sample CS10, regarding chemical quality of the concentrates, metallurgical recovery, efficiency evaluation indices and selectivity. It may be considered as a performance reference. The flotation performance of samples containing gibbsite does not seem to be impaired by the presence of alumina. It is important to notice that this sample had de lowest alumina content and 100% of the slimes was removed at de desliming stage.

Table III - Results of laboratory scale flotation tests

sample	E%	SI	SC%
CS05	66.95	8.96	80.78
CS07	15.71	6.25	46.43
CS08	42.99	4.93	64.77
CS09	59.42	9.12	73.87
CS10	89.69	37.11	94.62
CS14	56.24	6.42	70.68
CS15	60.17	7.77	75.41
CS16	40.56	3.34	48.83
CS17	15.58	1.41	17.10

SI = selectivity index = $[(R_{Fe} \times R_{SiO2})/(100-R_{Fe})(100-R_{SiO2})]^{1/2}$

SC = separation coefficient = $(R_{Fe} + R_{SiO2}) - 100$

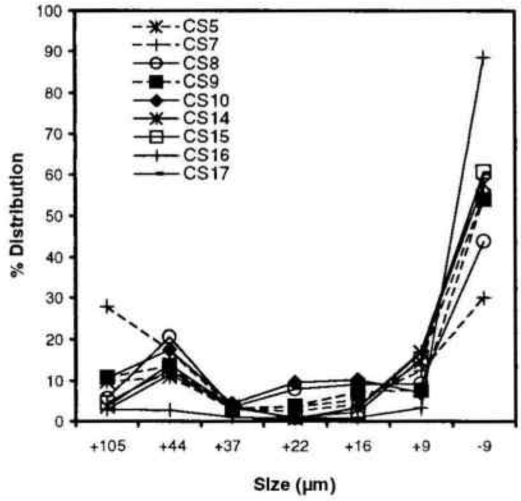
E = reduced efficiency = $100(R_{Fe}-RM)/(100-Gf)$

R_{Fe} = iron recovery in the concentrate

R_{SiO2} = silica recovery in the tailings

RM = mass recovery

Gf = $\%Fe_2O_3$ in the feed



Higher figures for metallurgical recovery (>90%) are associated with lower levels of entrainment of the iron bearing mineral.

Referring to Table II, it is noticeable that some samples present alumina content slightly higher than 0.8%, but the slimes content in this material is also low (<1.0%). These tests are not prone to performance problems due to the presence of slimes.

Samples CS 14, 15, 16, and 17, on the other hand, presented higher slimes content, that certainly interfered with the minerals separation selectivity.

The slimes mineralogical characterisation was performed by X-rays diffraction. The results are presented in Table IV. Due to the intrinsic inefficiency of the desliming stage, the alumina bearing minerals present in the slimes are likely to contaminate the flotation feed. The most abundant mineral species in the slimes are hematite and caolinite. Some samples present the predominance of goethite (CS 05, 07, 08, and 09).

Reflected light optical microscopy was the basic tool employed in the mineralogical characterisation. Scanning electron microscopy was utilised in the case of the earthy samples.

The mineralogy suggests that higher alumina contents are usually associated with high goethite grades, but may also correlate with the presence of gibbsite and caolinite (earthy materials) in some cases. These correlations are illustrated in Table VI. That explains the reason for washed material (throughout deslimed particles) presented high alumina content.

Considering the lower and variable content of alumina in the mineral goethite, it is expected that its contribution towards increasing the alumina grade in the sample require large percentages of the mineral. On the other hand, the contribution of alumina from aluminium bearing minerals, such as gibbsite and caolinite, is significant even for small amounts of the mineral.

The mineralogical investigation of the fraction in the size range -150μm +105μm showed a high liberation degree of quartz particles and also a few relevant aspects listed next:

i. the mineral phases observed are hematite, goethite, gibbsite, caolinite, and quartz;

ii. the presence, at larger or lower extent, of earthy material and goethite cementing fine hematite grains or coating laminar grains of coarser hematite was observed for almost all samples. This earthy phase consists predominantly of caolinite and gibbsite, with some iron in its composition;

iii. the content of impurities such as Al_2O_3 and SiO_2 in the goethites is variable and reflects on the earth like aspect of the sample;

iv. the hematites may present impurities such as Al_2O_3 and SiO_2, either associated with hematite as mixed particles, or in the grain boundaries or even filling pores. (Brandão, 1997)

CONCLUSIONS

The samples under investigation presented distinct behaviours. The performance of the deslimimg and flotation stages is strongly affected by the slimes removal capacity in the desliming stage. The proportion of the fraction <9μm is critical regarding the desliming efficiency.

The flotability (silica recovery by narrow size range) of quartz, in bench scale flotation experiments, is high for most of the samples under investigation.

The origin of alumina in the product Pellet Feed Fines is the presence of the minerals goethite, gibbsite, and caolinite, which occur either as individual particles or cementing hematite grains.

Ore samples with high proportion of fines should constitute a small percentage of the plant feed in order that the desliming capacity is not impaired.

Waste material samples, if processed with the ore even in small amounts, are harmful to the flotation performance, contributing to an increase in the slimes content and increasing the amount of contaminants in the product Pellet Feed Fines.

REFERENCES

1. Silva, R.V.G., Effect of alumina on the flotation of a mixed hematite-iatabirite ore from Pico mine, M.Sc. thesis, UFMG, Belo Horizonte, 174 p. (1999) (in Portuguese)

2. Brandão, P.R.G.; Santos, L.D., Mineralogical characterisation of iron ores from Pico mine, Internal Report, Fundação Christiano Otoni, (1997) (in Portuguese)

Table I - Identification and chemical characteristics of the raw samples as collected in the mine

Sample	Identification	%Fe	%SiO_2	%Al_2O_3
CS05	soft clay itabirite	64.0	4.45	1.47
CS07	medium-soft laterised amphibolitic itabirite	64.3	1.24	0.92
CS08	medium hematite	67.8	1.08	0.66
CS09	soft itabirite with limonite	61.5	6.15	2.39
CS10	low clay medium-soft itabirite	64.4	5.98	0.94
CS14	clay itabirite	59.6	4.69	4.53
CS15	yellowish dolomitic phyllite	62.0	4.78	3.46
CS16	itabirite tectonic breccia	60.7	5.76	4.42
CS17	dolomitic phyllite	41.8	11.80	13.40

Table II - Results of the desliming tests

Sample	Al_2O_3 % grade		% removal		% -9μm		
	-150μm	Deslimed	Al_2O_3	mass	-150μm	Deslimed	% removal
CS05	2.33	0.98	63.4	13.1	11.8	1.0	92.6
CS07	0.72	0.39	51.3	9.6	7.3	0.3	96.3
CS08	0.76	0.41	50.4	5.8	9.8	0.2	98.1
CS09	2.19	1.17	51.1	8.5	11.0	0.2	98.3
CS10	0.45	0.22	52.4	2.5	10.6	0.0	100.0
CS14	4.37	4.18	66.4	30.0	30.7	7.0	85.4
CS15	2.96	2.83	63.6	18.6	18.8	3.1	86.6
CS16	4.93	2.57	77.1	56.0	15.2	4.7	86.4
CS17	14.03	10.34	76.1	67.6	53.8	28.3	83.0

Table III - Results of laboratory scale flotation tests

sample	Feed			Mass	Fe	Concentrate			Tailings	
	% Al_2O_3	% SiO_2	%-9μm	% rec.	% rec.	% Fe	% SiO_2	% Al_2O_3	% Fe	SiO_2% rec.
CS05	0.98	8.48	1.0	76.30	86.94	68.2	0.68	0.55	42.0	93.88
CS07	0.39	1.91	0.3	96.56	97.61	66.0	1.01	0.34	45.3	48.82
CS08	0.41	1.42	0.2	87.01	88.05	69.1	0.38	0.35	62.8	76.72
CS09	1.17	12.58	0.2	68.30	77.94	66.9	0.75	1.09	40.8	95.93
CS10	0.22	11.07	0.2	86.07	96.72	69.3	0.27	0.20	14.5	97.90
CS14	4.18	5.65	7.0	83.85	91.62	65.9	1.41	1.61	31.3	79.06
CS15	2.83	6.30	3.1	85.42	92.62	66.8	1.27	1.22	31.2	82.79
CS16	2.57	4.49	4.7	84.04	87.54	66.6	2.07	1.76	49.9	61.29
CS17	10.34	11.06	28.3	50.57	55.37	53.0	8.37	8.29	43.7	61.73

Table VI - Correlation between alumina content and the presence of goethite and earthy material (washed fraction <150μm >105μm from the ROM)

Sample	Al_2O_3%		mineralogy	
	<150μm >105μm	PFF	% goethite	% earthy material
CS05	0.83	0.55	2.0	3.2
CS07	0.44	0.34	17.0	1.5
CS08	0.35	0.35	1.5	1.0
CS09	1.32	1.09	74.5*	1.7
CS10	0.20	0.20	1.5	0.5
CS14	3.12	1.61	0.5	0.5
CS15	2.48	1.22	0.6	5.5
CS16	2.10	1.76	0.2	0.7
CS17	13.90	8.29	9.4	1.2

Table IV - Results of the mineralogical characterisation (X-rays diffraction) of the slimes fraction from bench scale desliming

sample	chemical analyses %						mineralogical analyses %			
	Al_2O_3	Fe	Mn	P	LOI	SiO_2	A	M	L	T
CS05	11.25	43.4	1.26	0.47	13.57	9.63	K, Go	H	-	Gb
CS07	3.88	56.9	0.23	0.16	11.41	2.05	Go	H	Gb, Q	-
CS08	6.79	53.3	0.76	0.58	10.93	2.38	H, Go	K, Gb	Q	Mg
CS09	13.21	44.8	0.31	0.21	12.19	7.33	Go, H	GB, K	Q	-
CS10	9.44	48.7	0.10	0.74	11.63	5.12	H, K	Go	Gb	-
CS14	14.71	37.7	1.84	0.72	12.08	14.45	K	Go, H	Q	-
CS15	21.63	25.5	1.35	0.47	13.22	22.72	K	Go, H	Q	-
CS16	6.78	56.9	0.01	0.03	2.76	8.61	H	K	Gb, Q	-
CS17	15.80	35.6	2.79	0.44	10.83	16.03	H, K	Go, Gb	Q	-

A - predominantly abundant; M - moderately abundant; L - less abundant; T - traces

H - hematite; Go - goethite; K - kaolinite; Gb - gibbsite; Q - quartz; Mg – magnetite

* mixed hematite/goethite particles with magnetite relicts

Table V - Results of the mineralogical characterisation (volumetric mineralogical analysys) of the fraction <150μm >105μm of the ROM

sample	Chemical analyses %						mineralogy					
	Al_2O_3	Fe	Mn	P	LOI	SiO_2	hematite		G	M	Q	E.M.
							lam.	mart.				
CS05	0.83	60.2	0.214	0.036	0.54	12.12	3.8	76.0	2.0	-	15.0	3.2-
CS07	0.44	64.9	0.078	0.046	4.24	2.07	-	65.5	17.0	15.0	1.5	1.0
CS08	0.35	67.4	0.035	0.042	0.55	2.41	10.0	83.0	1.5	0.8	3.0	1.7
CS09	1.32	49.8	0.039	0.027	2.14	24.5	-	74.5[1]	2.0	-	23.0	0.5
CS09[2]	1.26	66.8	0.044	0.034	2.44	0.90	-	77.5	11.5	9.0	-	2.0
CS10	0.20	47.0	0.005	0.015	0.29	31.63	22.0	53.0	1.5	-	23.0	0.5
CS14	3.12	62.1	0.107	0.045	2.09	4.98	-	92.0	0.5	-	2.0	5.5
CS15	2.48	61.4	0.065	0.048	1.45	8.21	9.0	84.0	0.6	0.2	5.5	0.7
CS16	2.10	60.8	0.005	0.024	1.09	10.10	6.6	83.0	0.2	-	9.0	1.2
CS17	13.90	42.7	0.846	0.216	7.58	13.70	-	59.6	9.4	-	1.0	30.0

[1] mixed hematite/goethite particles with magnetite relicts

[2] CS09 concentrate

lam. = lammelar; mart. = martite

G = goethite; M = magnetite; Q = quartz; E.M. = earthy material