

EXTRACTION OF A FINELY DISPERSED LOW- GRADE IRON ORE BY FROTH FLOTATION

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ABSTRACT: The gradual depletion of high-grade iron ores due to extensive utilization has necessitated the exploitation of low-grade iron ore reserves of India. Extraction of low-grade iron ore is required to make it suitable for industrial usage. The low-grade iron ore mined from Gua mines contains 57.6% Fe. Mineralogical Studies revealed that liberation of gangue from iron-bearing mineral at coarser sizes is limited, thereby necessitating the samples to be ground to finer sizes below 150 microns for better liberation. The ground material is de-slimed using a hydro-cyclone and the underflow product was subjected to reverse flotation. In the flotation experimentation, the main variables investigated were collector dosage, pH, per cent solids, depressant concentration and frother concentration. Results of these studies show that froth flotation can be used for the beneficiation of low-grade iron ore to produce a concentrate suitable as pellet feed for iron making.

Keywords: Low-grade iron ore, Mineral extraction, Desliming, Reverse flotation.

INTRODUCTION

The current world production of iron ore is dominated by supply from massive hematite deposits. World resources of crude iron ore are estimated to exceed 160 billion tonnes (as per Indian Mineral Year Book, 2011) containing more than 28 billion tonnes of iron^[1]. In India, as per the UNFC system, the total reserve of hematitic iron ore is 17.882 billion tonnes and the annual production was 218.7 million tonnes in 2009-10 and expected to achieve a production target of near 350-400 million tonne by 2020. The annual consumption within the country is expected to reach nearly 300 million tonnes by 2020. Although India is blessed with high-grade iron ores, it is estimated that proved metallurgical grade iron ore is going to sustain the production and consumption for another 30-35 years only^[2]. The high-grade iron ore is depleting due to the increasing demand for iron. In India substantial quantity of low grade, iron ore deposits are present. Hence, to increase the iron ore resources to meet the ever-increasing demand for iron and steel, the use of the abundant low-grade iron ore is inevitable.

Due to the depletion of good grade iron ores, more complex ores have to be mined and to be processed. Because of the finely disseminated impurities in the iron ore matrix, the ore must be ground to a specific size to have a good liberation from the gangue. Froth flotation process is used for beneficiation of both magnetite and hematite ore. Very fine size material has an adverse effect in flotation and also consumes more reagents. This problem is minimized by employing a desliming step before flotation. Iron ores usually contain a huge amount of silicates and its presence has been found to harm the quality of the iron and also it complicates the process for the production of iron. Thus, the silicate content of the enriched iron mineral must be reduced as much as possible.

Essentially, iron ore flotation employs two types of collectors: anionic and cationic, the difference between them is related to which mineral wants to be floated. By employing anionic collectors, fine-sized iron oxide mineral is recovered away from siliceous mineral particles. In the other case, using cationic collectors, the siliceous mineral is floated depressing iron minerals. In the latter case, the sink contains iron minerals. In this case, a reverse flotation process is employed wherein the silica is floated from the iron oxide by using a cationic collector.

EXPERIMENT

Material

Low-grade iron ore sourced from Gua mines located in Jharkhand–Orissa region is used for the experimental studies. ROM is stage crushed to -1.68mm and then the material is ground to -105 μm in a Denver make pulverizer.

Methods

Size analysis of crushed material is done by FRITSCH vibratory sieve (wet screening) in size range of +90micron to -32 micron. Because of the presence of fines screening is done using water as a medium. The ground material is deslimed in Mozley's 2" hydro cyclone classifier. The condition for desliming operation is as follows: Apex: 3mm, vortex finder: 14.3 mm, pressure: 10 psi. The underflow (concentrate) is subjected to froth flotation for further enrichment in iron content.

Chemicals used

All chemical used is of AR grade. Reagents used in froth flotation are as follows: Starch (depressant), Dodecyl trimethyl ammonium bromide (collector), Hydrochloric acid, NaOH, Methyl Isobutyl Carbinol (frother), Sodium silicate (dispersant).

Reverse flotation

A Fragergen flotation cell is used for experimental work. By varying different parameters e.g. collector concentration, pH, depressant concentration, solid content in the feed, frother concentration, variation in Fe content is observed.

The feed material was taken in a flotation vessel with a constant volume of water. The pH of the pulp was maintained by adding HCl or NaOH. Starch, Sodium silicate, Dodecyl trimethyl ammonium bromide and MIBC were used as a depressant, dispersant, cationic

collector and frother respectively and were conditioned sequentially. After the addition of reagents, the air was allowed to pass and froth was collected at regular interval. In reverse flotation, gangue is floated and concentrate accumulates at the bottom.

RESULTS AND DISCUSSION

Characterization

Optical microscopy of low-grade iron ore sample shows mostly hematitic, however, it has a considerable amount of goethitic/limonitic component in it. The major impurities present are quartz and clay.

Particle size distribution

By screen analysis, it was observed that the ground sample consists of 68.5% of -32 μ m particles with 55.33% Fe. The low value of iron is an indicator of the presence of goethite in that size class. The result of the size analysis is given in Table-1.

Table-1: Result of wet screening of low-grade iron ore in a vibratory sieve

Size (μ m)	Wt %	Fe %
+90	0.5	60.82
+63	10.5	63.51
+45	11.3	61.83
+32	9.2	61.83
-32	68.5	55.33
	100.0	57.55

As indicated by Table-1, the ground sample contains a large proportion of very fine particles which may interfere in the flotation process and hence, a de-sliming operation was conducted on the ground sample using a 2" Mozley's Hydrocyclone unit.

Desliming

In the de-sliming operation, a significant increase in Fe % from 57.6 to 61.7% was observed. The result of the de-sliming operation is given in Table-2. 31.8% slime material was removed containing 48.74% Fe by hydro cyclone operation.

Table-2: Result of de-sliming low-grade iron ore sample in hydro cyclone

Product	Wt%	Fe%
Cyclone underflow	68.2	61.7
Cyclone overflow	31.8	48.74
Feed (Calc.)	100	57.60

Froth flotation of de-slimed feed

The de-slimed material obtained from hydrocyclone operation was further enriched using flotation and the results are given in this section.

Effect of collector concentration

Collector concentration was varied from 0.5 to 1.25kg/t and other parameters were kept constant viz. pH: 8.5; starch concentration: 1 kg/t; sodium silicate: 1 kg/t and frother concentration: 0.029 kg/t. After the depression of the iron minerals by starch, the silica is floated by a cationic collector. Fig. 1 shows variation in yield and Fe% with different concentration of cationic collector. By increasing collector concentration from 0.5 kg/t to 1.25 kg/t, yield of concentrate decreases from 52.5% to 18.7%. However, Fe% increases from 64.03 to 64.5 with increase in collector concentration from 0.5 to 0.75kg/t but decreases beyond 0.75kg/t. At 0.75 kg/t collector concentration optimum value of yield (50%) and Fe% (64.5%) was obtained. The yield is mentioned to the original which means 50% of the material of low-grade iron ore, concentrate can be obtained with 64.5 Fe.

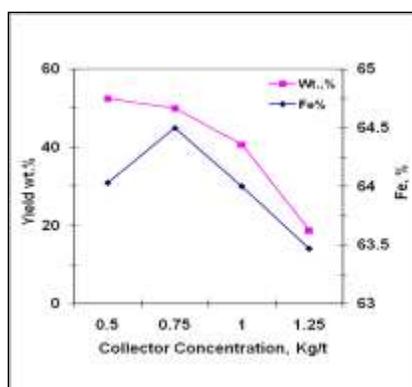


Fig.1: Yield and Fe% of iron ore concentrate as a function of collector concentration.

Effect of depressant concentration

Depressant concentration was varied from 0.5 to 2kg/t while other parameters were kept constant viz. pH : 8.5;sodium silicate:1kg/t; cationic collector concentration: 0.75kg/t and frother concentration:0.029kg/t. By varying starch concentration from 0.5 to 1 kg/t, concentrate yield increases from 49% to 50.6% while further increase in the depressant concentration does not have much effect on its yield. On the other hand, iron content decreases slightly from 64.6 to 64.4 on increasing the starch concentration from 0.5 to 2 kg/t (Fig- 2). Starch mainly consists of amylose and amylopectin. Starch strongly interacts with hematite compared to that of quartz^[3]. At 1.0 kg/t of starch concentration, an optimum value of both yields per cent and Fe% was found and hence was maintained in further experiments.

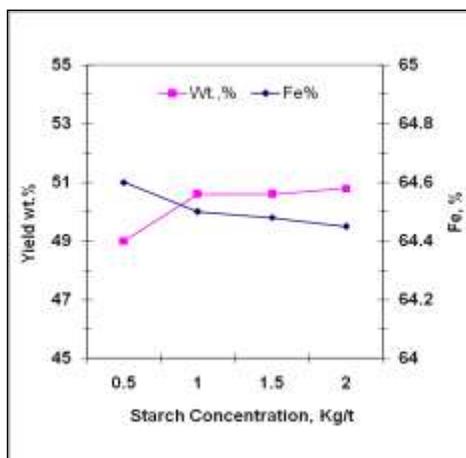


Fig. 2: Yield and Fe% of iron ore concentrate as a function of starch concentration.

Effect of pH

Result of pH variation on yield and Fe% is shown in Fig. 3. pH value was varied from 1.9 to 9.2 while other parameters were kept constant viz. starch concentration:1.0 kg/t; sodium silicate:1kg/t; cationic collector concentration: 0.75kg/t and frother concentration:0.029kg/t.

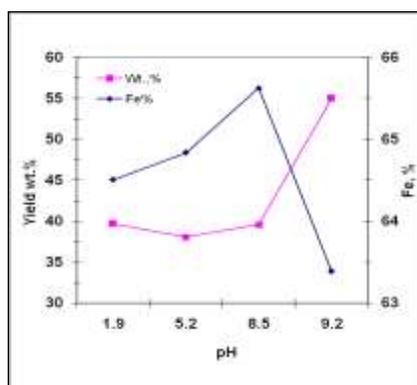


Fig. 3: Yield and Fe % of concentrate with pH variation

With an increase in pH from 1.9 to 8.5, the Fe content increases from 64.5 to 65.6%, while a further increase in pH decreases the Fe content to 63.39. However, with an increase in pH, there is not much change in the yield up to 8.5 and beyond pH 8.5 the yield increases rapidly (55%) as expected. At low pH, silicates having negative charge^[4] interact electrostatically with positively charged cationic collector ions. As a result, the yield of concentrate decreases enriching the iron content. But, at high pH silicates become less negative and correspondingly interaction with cationic collector gets reduced.

Effect of solid concentration

The solid concentration of feed was varied from 10 to 40% while other parameters were kept constant viz. pH : 8.5;Starch: 1kg/t; sodium silicate:1.0kg/t; cationic collector concentration:0.75kg/t and frother concentration:0.029kg/t. With low pulp density, the yield is high as shown in Fig. 4. Variation in solid concentration of feed shows a good effect on concentrate yield as it decreases from 54.5% to 43.2% as solid content increases from 10 to 40%. For the Fe%, a better enrichment of Fe takes place however at the cost of the yield.

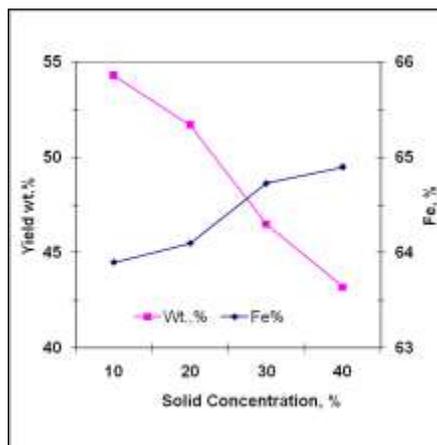


Fig. 4: Yield and Fe% as a function of %, solid concentration.

Effect of frother concentration

Frother (MIBC) concentration was varied from 0.0146 to 0.0584 kg/t while other parameters were kept constant viz. pH:8.5;starch:1.0kg/t; sodium silicate:1kg/t and cationic collector:0.75kg/t. Variation in MIBC i.e. frother does not show a significant effect on yield as well as Fe%. As shown in Fig. 5 yield curve is almost straight though the Fe% curve shows a little bit of variation. 0.029kg/t of frother concentration is optimum in both yield at 51.7% and Fe, % at 64.1. The frother affects the particle bubble adhesion kinetics; rendering the relaxation time shorter than the contact time^[5].

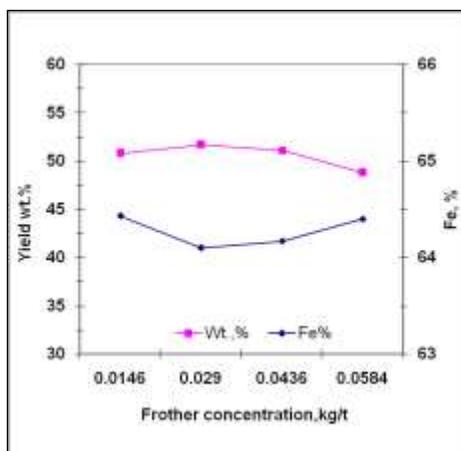


Fig. 5: Yield and Fe% concerning frother concentration.

CONCLUSIONS:

1. From the mineralogical analysis it was concluded that low-grade iron ore contains hematite and goethite as minerals and quartz and clay as impurities.
2. It was observed; by increasing collector dose and pulp density yield of concentrate decreases while Fe, % increases.
3. It is concluded that the yield of concentrate decreases and Fe % increases with an increase in pH value up to 8.5 and beyond this pH yield increases and Fe% decreases.
4. Best operating conditions are as follows: 0.75kg/t for collector concentration, 1.0kg/t for depressant concentration, 8.5 for pH, 20% solid content in pulp and 0.029kg/t for frother concentration at which 51.7% yield and 64.5% Fe content was obtained.
5. It is concluded that pellet feed grade can be achieved by froth flotation.

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