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Response of process parameters for processing of iron ore slime using column flotation

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ABSTRACT

Iron ore slimes of India contain high alumina and silica that reduce the grade and pose difficulty in processing. This investigation addresses the interactive effect of process parameters on the processing of Indian iron ore slimes by using column flotation. The iron ore slime containing 58.7% Fe, 5.2% SiO_2 and 4.9% Al_2O_3 was used for this investigation. The subsequent size analysis, chemical characterisation, desliming and column flotation tests were performed targeting the effect of process parameters on the flotation behaviour of the slimes. A factorial design of experimental approach was followed using three variables at two levels namely froth height, superficial air velocity, and collector dosage. The dosages of frother and depressant were held constant. Froth height plays a significant role on recovery and Fe-grade in the concentrate. The interaction effects of the variable factors on recovery and Fe grade of concentrate were studied. The relationship between the residence time of air in froth zone and recovery was also established. Increased residence time demands more collector dosage for high recovery of the concentrate. Recovery of the concentrate could be improved to 63% (54.6% overall recovery) with a grade of 64.3% Fe, 1.9% silica and 2.2% alumina.

1. Introduction

The Indian iron ore industry is one of the fastest growing iron ore processing industries in the world. It is estimated that about 200 million tonnes of iron ores is produced every year in the Indian subcontinent (Mineral Year Book, 2008). Indian iron ore should be able to sustain the projected domestic steel demand for over 200 years (FIMI, 2008). The high grade resources of iron ore in India are depleting at an alarming rate. Now approaches are made by the researchers to overcome such challenges by utilizing the low grade resources of iron ore, i.e. fines and slimes. In Indian scenario, the iron ore slime is a material generated during the washing and sizing of sized ore. This generated slime with a size of less than 200 to 150 μm is simply discarded into the tailing pond. According to an estimation, around 15 to 20 million tonnes of slimes is generated every year during the processing of iron ores (Pradip, 2006). The slime tailing ponds are creating problems by covering huge agricultural and forest lands. In the current scenario processing of Indian Iron ore slime is important for ecological and economical benefits. Indian iron ore slime contains a high iron value with gangues like silica and alumina. The alumina rich iron ore slime contains 8–10% alumina, 54–56% Fe with the subsequent amount of silica (~6%). The abovesaid impurities are undesirable characteristic of an iron ore as they are detrimental to the subsequent blast furnace operation in iron making. The beneficiated iron ore slime can be utilized as pellet feed for iron making industries by adopting an effective beneficiation strategy.

Processing of iron ore slime in an Indian scenario is a challenging task as it contains a significant amount of silicates and different types of aluminates as gangue minerals. Research carried out on Indian iron ore slime (Bhaskar Raju and Prabhakar, 2002; Das et al., 2005; Pani et al., 2010; Dey et al., 2012) indicated that the silica and alumina contents can be minimized to the cut-off limit by selective flotation of iron minerals. The flotation routes of iron ore can be classified into five major groups, i.e. cationic flotation of iron oxide, cationic flotation of quartz, anionic flotation of iron oxide, anionic flotation of quartz and their combination (Clemmer, 1947). Theoretically, iron oxides should be easy to separate from quartz in direct flotation. In reverse flotation, starch is added to depress the iron particles. As in the reverse flotation, the starch added for the depression of iron particles carries surface charge onto the particles and makes them hydrophilic and thus makes pellet making difficult. Therefore, the direct flotation of iron oxides appears to be more preferable for processing of low grade iron ores containing large quantity of silica and alumina.

In any froth flotation process the hydrophobic particles are carried out from pulp zone to froth zone by means of true flotation, but undesirable gangue minerals also report to the concentrate through entrainment and entrapment rather than true flotation. In the case of iron ore flotation, the hydrophilic silica and quartz minerals report to the concentrate by means of entrainment and entrapment. The important

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Table 1
Chemical analysis of feed sample.

Constituents	Fe (T)	SiO_2	Al_2O_3	LOI
%	58.71	5.25	4.88	6.26

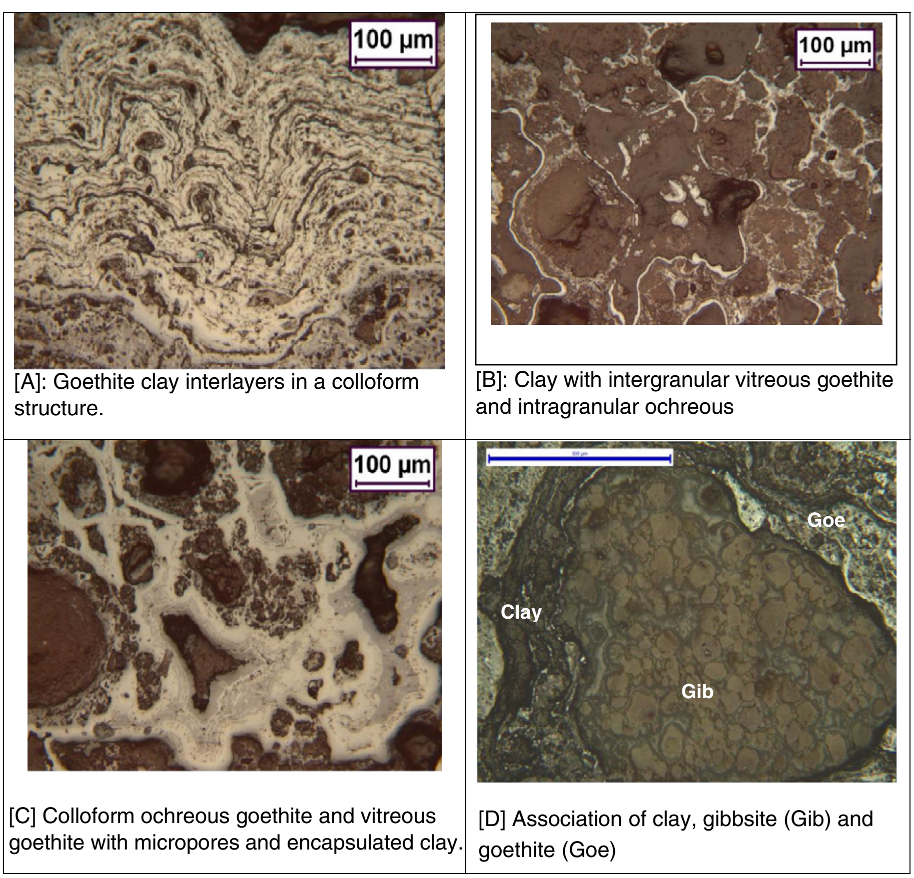
Table 2
Distribution of particles and Fe grade in different fractions of feed sample.

Size (μm)	Wt.%, retained	Fe%	Fe % distribution
−150 + 100	28.70	61.42	30.4
−100 + 74	17.38	62.27	18.7
−74 + 63	12.70	62.19	13.6
−63 + 45	10.74	61.83	11.4
−45 + 25	14.58	59.72	15.0
−25	16.0	39.6	10.9

factors affecting the recovery of entrained gangue are water recovery and particle characteristics in the ore. Water flow is the medium whereby gangue is transported by mechanical entrainment (Harris et al., 1963; Jowett, 1966; Sadler, 1973; Engelbrecht and Woodbum, 1975; Bisshop and White, 1976; Trahar, 1981). Mechanical entrainment is a non-selective process and independent of particle surface (Livshits and Bezrodnaya, 1961; Jowett, 1966; Johnson et al., 1974). The momentum and low settling velocity of the lighter particles also account for mechanical entrainment. The low momentum of the particle required for reducing the entrainment can be achieved by increasing the residence time of mineral carrier (i.e. air) in the froth zone. The settling velocity of particle depends upon the size, shape, specific gravity of the particle and slurry density. Higher slurry density lowers the settling velocity. The silicates having a lesser density will have a lower settling velocity than a high density particle (iron ore). To overcome this problem the froth height is maintained at certain levels so that the particle residence time in froth phase can be increased, resulting in a drop back of gangue particles from the froth to the pulp phase.

The abovesaid problems can be solved using column flotation by replacing the mechanical flotation cell. The column flotation process has a substantial advantage over the mechanical batch flotation process for achieving higher grades with reduced maintenance cost as well as better control on the froth depth (Wheeler, 1985; Finch and Dobby, 1990; Sastri, 1998; Bhaskar Raju and Prabhakar, 2002). An investigation carried out by Trahar (1981) shows the relationship between particle size and collection efficiency in flotation. In summary, the collision efficiency increases with particle size whereas the adhesion efficiency increases with the degree of hydrophobicity and decreases with the particle size. A study carried out by Sivamohan (1990) also stated that the low flotation rate of ultrafine particles may be improved by increasing the collision rate and the moment of inertia. The particle size in iron ore slimes is in micron levels so it is believed that the factors responsible for the collection and adhesion need to be studied. The flotation rate may be increased by enhanced aggregation, keeping smaller bubbles, increasing the residence time in the machine and providing counter current flows of particles and bubbles. This can be effectively studied using column flotation. The processing of iron ore slime by mechanical flotation has been extensively studied but it was less understood with the column flotation. So in order to achieve the grade and recovery of iron values from slimes of Indian iron ore, rich in alumina and silicate minerals, the effects of process parameters need to be explored.

The froth flotation is a complex phenomenon as all the process parameters are dependent on each other. The present study aims to highlight the effect of process parameters like collector dosage, superficial air velocity, froth height and their interactive effect on recovery of



[A]: Goethite clay interlayers in a colloform structure.
[B]: Clay with intergranular vitreous goethite and intragranular ochreous
[C] Colloform ochreous goethite and vitreous goethite with micropores and encapsulated clay.
[D] Association of clay, gibbsite (Gib) and goethite (Goe)

Fig. 1. Photomicrographs showing the mineralogical characteristics under optical microscope.