Fine particle processing of iron ore slimes from Orissa, India

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Abstract - *The fine particle of processing of slimy tails of iron ore wash plant tails have been addressed either by flotation or wet high intensity high gradient separation. This paper furnishes a few case studies of fine particle processing of some iron ore wash plant slimy tails spread across, Orissa. The results indicate that it is possible to produce concentrates assaying >60% Fe with 22 -78 wt.% yield depending on % -10 microns slime content, feed Fe value, granulometry, hydrated – anhydrous iron oxide content, ferruginous clay and tails generated may be used locally in pottery and bricks cottage industry leading to nil waste sustainable development.*

***Key Words*: Iron ore slime processing, Desliming, VPHGMS, WHIMS**

1. INTRODUCTION

Indian Iron ore occurs mostly as oxides in nature. The deposits are fairly well distributed in the states of Jharkhand, Chattisgarh, Orissa, Karnataka, Maharashtra, Goa and Andhra Pradesh [1&2]. The lack of consistency with respect to the ratio of Al_2O_3 to SiO_2 make these ores unsuitable for direct use in the blast furnace [1-3] and need washing prior to industrial use. Alternatively, the iron ore minerals are liberated from gangue minerals by ball mill grinding, followed by hydrocycloning, gravity concentration and WHIMS. During the preparation of ore as a feed to blast furnace a significant amount of slimes (-0.050 mm) are being generated [5]. The presence of alumina bearing clay and excessive generation of fines during mining, washing operations, material handling and ball mill grinding of very soft natured iron ore, are the main problems in the Iron ore industries. The tails assaying 30-55 %Fe are deposited to tailing pond.. The iron ore washing practices for reducing alumina have resulted in production of millions of tons of slimy tails stacked tail pond necessitating a suitable beneficiation process for recovering the iron values from the perspective of mineral conservation and effective space utilization of the tailing ponds and to enhance the life of the existing operating mines. Restriction in production of ore and closing down Iron ore mines, spurred the mines to look for alternative routes like processing of BHQ/BHJ waste rock or processing of iron ore wash plant tails. The latter route was logically and scientifically attractive as pellet grade concentrates may be produced with a possibility of partial reclamation of tailing pond area and mitigation of vexed tailing pond management problem. National steel policy envisaging the production of steel to beyond 200 million tons per annum, the onus is on the Iron ore mining industry to cater to the requirement of the raw material. Further, the processing of slimes does not have expensive mining and grinding operation making it a suitable alternative for green technology iron making by pelletization. The review of literature on processing of Indian iron slimes is enormous where in centrifugal concentration devices, selective dispersion – selective flocculation, inverse cationic column flotation, wet high intensity magnetic separation (WHIMS)/ High gradient magnetic separation (HGMS) have been used.[1-17] However the most of the work on industrial scale centers either on either inverse cationic column flotation or HGMS. Bonai Iron ore range of Orissa is the largest (34%) Indian iron ore resource and producer [1]. Keeping in view the large reserves, an attempt has been made to carry out the fine particle processing studies on iron ore wash plant tails from various plants spread across Orissa with an aim to produce pellet grade concentrates (Fe > 60%, $SiO_2 + Al_2O_3$ <6%)

2. MATERIAL AND METHODS

Four slime sample from tailing dams of washing plants spread across Orissa were collected and sub samples were drawn after homogenization followed by coning and quartering method. The sub samples drawn were subjected to physical, chemical and mineralogical characterization. The four slime samples were (1) High grade old plant slimes (Sample 1) (2) Medium grade old plant slimes (Sample 2) (3) Medium grade current plant slimes (Sample 3) and (4) Low grade current plant slimes (sample 4).Mozley hydro cyclone [10.25 and50 mm dia] test rig was used for desliming if needed. The particle size analysis was done by classical method. Lab model WHIMS was used for carrying out lab tests while Vertical pulsating wet high intensity magnetic separator [VPWHIMS] of LONGI make [LGS-EX 500] was used to confirm the findings. Initially tests were carried out varying the %Solids, desliming [as it is and desliming 10 microns], intensity, matrix rod size pulsation frequency /minand rpm.3]. This was followed up with a cleaner and scavenger stage for improving the grade and recovery. Fig 1 shows VPWHIMS/VPHGMS used.

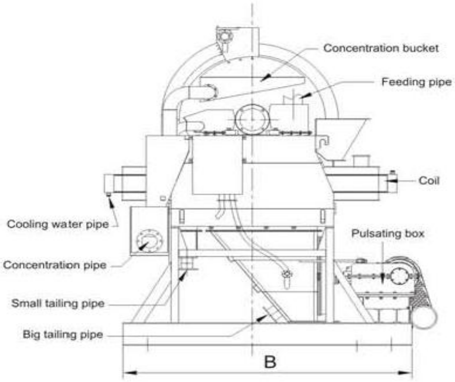

Fig -1: Vertical ring Pulsating Wet High Gradient Magnetic Separator (VPHGMS)

3. RESULTS AND DISCUSSION

The experimental comprises of characterization studies of four different iron ore slimes samples followed by the effect of desliming and other machine parameters of VPHGMS for one sample. The effect of scavenging, cleaner stage operations were also investigated.

3.1 Characterization studies

The representative samples were subjected to chemical analysis by classical methods, the mineralogical studies , particle size analysis by classical fine sieve and sub sieve analysis methods. The results of characterization studies are given in Table 1. The characterization indicate that the process refractoriness to amenability study increases with increase in slime content, hydrated iron oxide content and tenor. Samples 1 and 2 which are high – medium grade old wash plant tails are easily amenable to processing while sample 4 which is very low grade ferruginous clayey slimes appears not to be amenable to processing concurrent to previous findings[18].

Table -1: Characterization Data of slime samples

Particulars	Orissa 1	Orissa 2	Orissa 3	Orissa 4
Chemical				
Fe%	57.10	52.21	46.12	20.01
SiO_2%	5.60	7.88	12.02	66.80
Al_2O_3%	6.10	8.16	10.32	10.36
LOI%	6.00	8.21	9.40	8.07
Minealogy				
Hematite	Major	Sub ordinate	Subordinate	Subordinate
Goethite	Sub ordinate	Major	Major	Subordinate
Ferruginous clay	Subordinate	Subordinate	Sub ordinate	Subordinate
Quartz	Minor	Minor	Minor	Major
Silicates	Traces	Traces	Traces	Minor
%-0.01mm	31.74	66.7	79.25	75.0
Colour	Brown yellow	Brown Yellow	Yellow	Yellowish brown
Sp.Gr	4.0	3.6	3.6	3.2
Amenability	Yes	Yes	No	No
HLS - DHGMS	Yes	Yes	No	No

3.2 Effect of Desliming

De-sliming studies were carried out in a laboratory Mozley cyclone test rig with 25mm hydro cyclone by varying the vortex finder and spigot dia. The tests were carried out at feed consistency of around 12% solids and inlet pressure of around 25psi. Products of each test were collected and analyzed for grade and yield. The results obtained are shown in Table – 2. From the results it was observed that about 18 -22% of the slimes report to overflow with 4% up-gradation in under flow for samples 1 and 2. The samples 3 and 4 were not amenable to particle size refining by desliming as most of the sample reported to over flow with little up-gradation in under flow, as these feed slimes samples contained more than 75 % < 10 microns. Similar observations were made by earlier investigators on desliming of iron ore slimes. [7,11-15]. Desliming of high grade old wash plant tails (sample 1) yielded pellet grade concentrates by desliming alone owing to coarse granulometry and major amount of anhydrous iron oxide mineral content.

Table-2: Results of De sliming tests

Sample No.	Products	Wt.%	% Fe	
			Assay	Distn.
1 Coarser HG old wash plant tails	Cyclone O/F	18.0	31.20	9.8
	Cyclone U/F	82.0	62.92	90.2
	Head Cal.	100.0	57.20	100.0
2 Medium grade old wash plant tails	Cyclone O/F	22.0	35.59	15.0
	Cyclone U/F	78.0	56.88	85.0
	Head Cal.	100.0	52.20	100.0

3.3 Beneficiation studies with vertical ring pulsating high gradient magnetic separator:

The development of vertical ring pulsating high gradient magnetic separator (VPHGMS) has been proving to be a boon to the iron ore industry. It was observed that with increasing intensity, the magnetic separators tend to give better yield with a reduced grade. The selectivity is improved by the pulsating mechanism and parallel magnetic flux with gravitating feed leading to beard formation averting clogging and entrapment of non-magnetics in the concentrate [16]. Tests were carried out in batch mode using deslimed feed on sample 2, employing LGS-EX 500 with 1.5mm rod matrix by varying intensity [10700 to 15200 gauss], pulsations frequencies [75 to 225 strokes/minute] and ring rpm [2.5 to 3]. The results are given below.

3.3.1 Effect of field intensity: Tests were carried out by varying the intensities at 10,700, 13,300 and 15,200 gauss at a constant ring speed of 3 rpm, 25%S and frequency of 75 cycles /min. The results are shown in Fig 2. The results indicate that an increase in intensity increases the wt% yield and % Fe distribution of concentrate, but decreases the grade of concentrate. The tails value decreases significantly with increase in intensity. The magnetic intensity of 13,300 gauss was found to be optimum, as grade of tails is minimum, wt% yield and % Fe distribution reaches saturation. At intensities > 13,000 gauss the dilution of grade occurs due to concentration of ferruginous clayey impurities. The results are concordant with previous works [7 & 9]

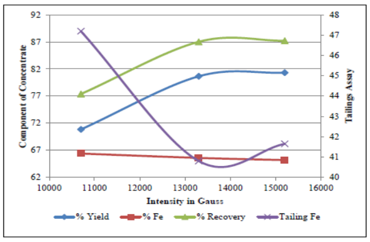

Fig- 2: Effect of intensity on sample 2

3.3.2 Effect of frequency of pulsation: VPHGMS tests were conducted by varying the frequencies at 75, 150 and 225 cycles / minute at 15,200 gauss, 2.5 rpm of ring and 25%S. The results are depicted graphically in Fig. 3. The results indicate that an increase in frequency decreases the wt% yield, % Fe distribution and increases the grade of concentrate. Also the % Fe grade of tail losses increases significantly if the frequency value increases more than 75. The results are akin to previous findings [11-14 , 15 & 17]

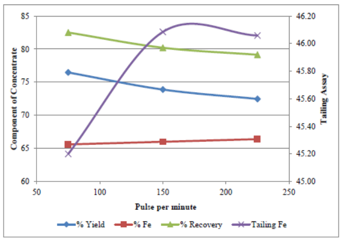

Fig -3: Effect of frequency of pulsation on sample 2.

3.3.3 Effect of rpm of ring: The rpm of the ring was varied between 2.5 and 3 keeping frequency at 75, intensity at 15,200 gauss and 25%S. The results are graphically shown in Fig 4. The results, similar to previous findings [15]. The results indicated that an increase in rpm insignificantly decreased the grade of concentrate and significantly increased the wt% yield and % Fe distribution of concentrate. The %Fe in tails decreased with increase in the rpm from 2.5.

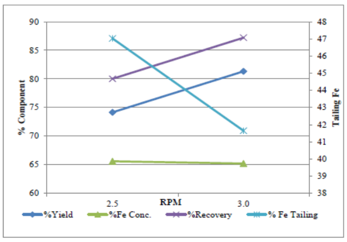

Fig -4: Effect of ring rotation on sample 2

The above results indicated that (1) High grade coarse granular siliceous anhydrous iron oxide wash plant tails is amenable to desliming, gravity and VPHGMS. (2) An increase in intensity increases the wt% yield and % Fe distribution of concentrate, but decreases the grade of concentrate. The tails value decreases significantly with increase in intensity. (3) An increase in frequency decreases the wt% yield, % Fe recovery and increases the grade of concentrate. But low frequency produces concentrates with low grade and recovery. Optimum values lie at medium levels and is dependent on granulometry of material.(4) An increase in rpm insignificantly decreased the grade of concentrate and significantly increased the wt% yield and % Fe distribution of concentrate. (5) Like any other concentration desliming and split concentration of slimes and sand separately yielded good results. (6) The matrix size indicated that finer matrix size increased recovery of slimy values with a marginal drop in grade and depends on feed granulomentry (7) The %S indicated that dilute pulps yielded better quality concentrate at the loss of values. (8) Scavenging tests at very high intensity of 13000 gauss, 35%S,1-1.5mm rod matrix low rpm, low pulsation rate yielded high recoveries and low Fe values in non magnetic tails, though the grade of concentrate was close to cement grade [Fe~50%, Free silica <15%] (9) Cleaner tests on rougher concentrates at moderate intensity of 6000 -8000 gauss,10-15% S, 2 mm dia rod matrix, high rpm, high pulsation rate yields high grade concentrates meeting pellet specifications[Fe >63%]. (10) Siliceous ore slimes responded well as compared with aluminous hydrated iron oxides. (11) Low grade slimes yielded cement grade concentrate only.

3.4 Amenability of samples to final process

The final process flow sheet comprising of Rougher WHIMS at 10000 gauss, Scavenging WHIMS of R tails at 13000 gauss, Cleaner WHIMS of Rougher concentrate at 8000 gauss in counter circuit configuration with dewatering of recirculating loads[Cl. tails and Scavenger concentrate with feed slimes]. The results are given in Table 3 for all the four samples. The above table indicates that various tails when subjected to a process comprising of Rougher WHIMS at 10000 gauss, Scavenging WHIMS of R tails at 13000 gauss, Cleaner WHIMS of Rougher concentrate at 8000 gauss in counter circuit configuration with dewatering of recirculating loads[Cl. tails and Scavenger concentrate with feed slimes] indicated that

(1) Coarser HG old wash plant tails and Medium old wash plant tails yielded pellet grade concentrates, wt% yield depending on % -10 microns slime content and % anhydrous iron oxide content

(2) Slimy tails (from WHIMS non mag) could yield only cement grade concentrates. The non mag tails may find use in either pottery or brick manufacture.

Table – 3: Amenability of sample to VPHGMS locked test

Sample	Products	Wt.%	% Fe	
			Assay	Distn.
Sample1 Coarser HG old wash plant tails	Cl. Mag. Conc.	78.0	65.15	89.0
	Sc. N.M. Tails .	22.0	28.55	11.0
	Head Cal	100.0	57.10	100.0
Sample2 Medium grade old wash plant tails	Cl. Mag. Conc.	45.5	63.00	54.9
	Sc. N.M. Tails .	54.5	43.20	45.1
	Head Cal	100.0	52.21	100.0
Sample3 Medium grade current WHIMS plant tails	Cl. Mag. Conc.	51.7	60.00	67.2
	Sc. N.M. Tails .	47.3	31.30	32.8
	Head Cal	100.0	46.12	100.0
Sample4 Low grade current HGMS Reprocessed tails from plant tails	Cl. Mag. Conc.	22.2	55.00	61.1
	Sc. N.M. Tails .	81.8	9.76	39.9
	Head Cal	100.0	20.00	100.0

4. CONCLUSIONS

Four iron ore beneficiation plant tails sample comprising of
(1) Sample1 - Coarser HG old wash plant tails
(2)Sample2-Medium grade old wash plant tails
(3) Sample3- Medium grade current WHIMS plant tails
(4) Sample4-Low grade current HGMS Reprocessed tails from plant tails were subjected to the beneficiation process. The beneficiation process comprised of Rougher WHIMS at 10000 gauss, Scavenging WHIMS of R tails at 13000 gauss, Cleaner WHIMS of Rougher concentrate at 8000 gauss in counter circuit configuration with dewatering of recirculating loads [Cl. tails and Scavenger concentrate with feed slimes]. The results indicated that:

(1) Coarser HG ols wash plant tails is amenable to desliming, gravity process also producing pellet grade concentrate.
(2) Coarser HG old wash plant tails and Medium old wash plant tails yielded pellet grade concentrates, wt% yield depending on % -10 microns slime content and % anhydrous iron oxide content.
(3) Current plant Slimy tails (from WHIMS/HGMS non mag) could yield only cement grade concentrates.
(4) The non mag. tails from above process may find use in either pottery or brick manufacture leading to a possibility of nil waste processing of old plant tails.

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