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Case Report

Fine Particle Processing of Some Indian Iron Ore Slimy Tails from Orissa and Karnataka

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Abstract: 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 slimy plant tails. The latter route was logically and scientifically attractive as pellet grade concentrates may be produced at low cost with a possibility of partial reclamation of tailing pond area and mitigating vexed tailing pond management problem. The fine particle of processing of slimy tails has 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 slimy tails spread across Orissa assaying 27% to 57% Fe, with 32 to 80% -10 microns slime content. The results indicate that it is possible to produce pellet grade concentrates and / or Cement grade concentrates with appreciable wt.% yield for different types of slimy tails varying in granulometry, silica, alumina and hydrated – anhydrous iron oxide content. In some cases, the above process also paved way for nil waste process where in the alumina rich tails produced may be used in local building material and pottery industry.

Keywords: WHIMS, Iron Ore Slimes, HGMS

1. Introduction

Indian Iron ore occurs mostly as oxides in nature. A substantial amount of this reserve is high grade hematite. India's total reserve is estimated to around 17880 million tones assaying on an average +58% Fe. The deposits are fairly well distributed in the states of Jharkhand, Chattisgarh, Orissa, Karnataka, Maharashtra, Goa and Andhra Pradesh [1, 2]. Indian iron ores 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, 2, 4] and need washing prior to industrial use or interfaced based eco sensitive processes like flocculation and flotation. [6-10] Alternatively, the iron ore mineals are liberated from gange 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 (-0.150 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 are deposited to tailing pond which assays about 45% Fe with 20 Wt% yield. The tails are classified as clayey tails based on alumina content [>5%] and siliceous tails based on silica content [>15%] and alumina [<3%]. Alternatively, the tails are classified as coarse jig tails [-10+1mm], sandy gravity spiral tails [-0.5+0.05mm], clayey slimy tails of cyclone overflow [-0.1mm] and fine slimy tails generated by grinding of soft iron ores [-0.05mm containing major amount of -0.01 mm] Around 32 million tons of hematite ore is washing every year, producing 24 million tons of lumps and fines for blast furnace operations. The balance of 8 million tons of mined ore is lost as tailing (slimes) containing around 52-63% Fe. The loss of iron ore thus amounting to 8 million tons per year is not a good proposition in a developing country like India. Besides, the slime disposal into tailing pond poses enormous environmental hazards and ecological problems. With an increase in iron ore production to 155 million tons per annum, the slime generation is expected to be above 10-12 million tons. Further, with the rapid increase in the projected iron and steel making capacity in India, utilization of these slimes as sources of iron values is imperative. Thus, safe disposal and utilization of such vast mineral wealth are posing big challenges to mineral engineers throughout the world and India is not an exception. Finding a viable solution to recover iron values from slimes is a great problem facing mineral technology. Further closing down iron ore mines due to environmental constraints, drop in concentrate prices spurred the iron ore beneficiation plants to recover the values from their slimy tail pond as it enables in production of pellet grade concentrates without raw material and grinding cost, besides reclaiming the tailing pond. Efforts have been made to recover iron values from slimes as enumerated by, selective dispersion – flocculation, inverse flotation and wet high intensity magnetic separation as enumerated by the works of CSIR labs, NMDC and IBM [1]. The Magnetic separaation route is gaining importance due to reduction in operating cost and environmental reasons [1]. The present paper summarizes a few case studies of fine particle processing of some iron ore beneficiation plant slimy tails spread across, Orissa, where most of iron ore and concentrates are produced from the soft friable aluminous ores by beneficiation employing grinding to liberate the values followed by gravity concentration.

2. Experimental, Results and Discussion

The iron ore wash plant slimes were collected from iron ore washing plants of study area. Mozley hydro cyclone [25, 50 and 75mm dia] test rig was used for desliming if needed. The particle size analysis was done by test sieves and beaker decantation method. Lab model WHIMS was used for carrying out lab tests while at the site VPWHIMS of LONGI make [LGS-EX 500] was used to confirm the findings. Initially, tests were carried out varying the %Solids [15-40], desliming [as it is and desliming 10 / 20 microns], intensity [6000 to 13000 gauss], matrix size [1.5 to 3mm], pulsation frequency /min [50-200] and rpm [2-3]. This was followed up with a cleaner and scavenger stage for improving the grade and recovery. The results indicated that (1) 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. (2) 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. (3) Increase in rpm insignificantly decreased the grade of concentrate and significantly increased the wt% yield and % Fe distribution of concentrate. (4) Like any other concentration desliming and split concentration of slimes and sand separately yielded good results. (5) The matrix size indicated that finer matrix size increased recovery of slimy values with a marginal drop in grade and depends on feed granulomentry (6) The %S indicated that dilute pulps yielded better quality concentrate at the loss of values. (7) 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%] (8)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%]. (9)Siliceous ore slimes responded well as compared with aluminous hydrated iron oxides.(10) Low grade tails may be used in cement pottery and local aerated bricks - tile industries. The findings are akin to works of Sridhar [5] on NMDC Donimalai slimes Table 1 gives the characteristic of slimy tails from beneficiation plant. The results indicate a lot of heterogeneity in iron ore wash plant tailings from different plants in different states as regard to physical, granulometry, chemistry and mineralogy. Table 2 shows the final process flow sheet comprising of Rougher WHIMS at ~0.8 to1.3 Tesla, Scavenging WHIMS of R tails at ~1 to 1.3 T, Cleaner WHIMS of Rougher concentrate at 0.7- 0.9T in counter circuit configuration with dewatering of recirculating loads [Cleaner tails and Scavenger concentrate] with feed slimes.

Table 1. *Characteristics of some Indian iron ore wash plant tails.*

Particulars	Orissa 1	Orissa 2	Orissa 3	Karnataka	Orissa LG tails
Characteristics of the sample					
Fe%	57.10	52.21	46.12	48.00	20.01
SiO_2%	5.60	7.88	12.02	15.97	66.80
Al_2O_3%	6.10	8.16	10.32	7.56	10.36
LOI%	6.00	8.21	9.40	8.40	8.07
Mineralogy					
Hematite	Major	Subordinate	Subordinate	Major	Sub ordinate
Goethite	Subordinate	Major	Major	Subordinate	Subordinate
Ferruginous clay	Subordinate	Subordinate	Subordinate	Subordinate	Subordinate
Quartz	Minor	Minor	Minor	Minor	Major
Silicates	Traces	Traces	Traces	Minor-traces	Minor
%-0.01mm	31.74	66.7	79.25	55.0	75.0
Colour	Brown yellow	Brown Yellow	Yellow	brown	Yellowish brown
Sp.Gr	4.0	3.6	3.6	3.4	3.2

***Table 2.** Results of some LONGI VPHGMS tests on slimes of some Indian iron ore beneficiation plant tails.*

Area	Process Conditions	Products	Wt% yield	%Fe Assay	%Fe Distn
Sample1Orissa Hematitic with little slimes gravity spiral tails	Rougher WHIMS 35% S, 2mm rod 8200 gauss and Scavenger WHIMS 25% S, 1.2 mm rod 10600 gauss 75mm Hydrocyclone, 50 psi pressure, 15% S, 5 mm VF, 3mm Apex for desliming the scavenger concentrate	R mag conc	53.0	63.13	58.6
		Deslimed Sc mag conc	25.0	58.75	25.7
		OF slime reject	22.0	40.74	15.7
		Head[Cal]	100.0	57.10	100.0
Sample 2 Orissa Goethitic slimy sample	1.5mm rod matrix, 25 %S feed pulp density, intensity of 13300 gauss, ring revolution of 3 rpm and pulsation of 75 strokes per minute.	R Mag Conc	46.0	61.17	54.9
		Non mag tails	54.0	44.59	45.1
		Head[Cal]	100.0	52.21	100.0
Sample 3 Orissa Goethitic slimy sample from beneficiation plant treating high LOI soft weathered ore	Rougher WHIMS at 1 Tesla, Scavenging WHIMS of R tails at 1.3T, Cleaner WHIMS at 0.7T 15% S in counter circuit. Sc mag and Cl Tails recirculates back to Rougher feed	Cl Mag Conc	51.7	60.00	67.2
		Sc Non mag tails	47.3	31.30	32.8
		Head Cal	100.0	46.12	100.0
		Sc mag + ICl Tail [Recirculating]	20.0	46.12	20.0
Sample 4Karnataka Slimy siliceous hematite tails from beneficiation plant	Rougher WHIMS at 1.3T, 1.5 mm rod, 25%S	Mag Conc	68.0	59.00	83.1
		Non mag tails	32.0	25.00	16.9
		Head Cal	100.0	48.00	100.0
Sample 5 Orissa LG Tails Slimy beneficiation plant tails with VPWHIMS	1.5mm rod matrix, 25 %S feed pulp density, intensity of 13300 gauss, ring revolution of 3 rpm and pulsation of 75 strokes per minute	Deslimed mag conc	22.2	55.00	61.1
		Non mag and slimy tails	81.8	9.76	39.9
		Head Cal	100.0	20.00	100.0

The above tables clearly indicates that (1) Concentrate grade depends on the mineralogical nature. Anhydrous iron oxides yielding better grades as compared to hydrated iron oxides (2) The grade and % Fe distribution in concentrate depends on % LOI, % Hydrated iron oxides and more so % of -0.01mm slime content. (3) It is difficult to produce pellet grade concentrates >63% while processing slimes (4) High intensity, high gradient in scavenging and cleaning / very fine desliming of scavenger magnetic concentrates improves the grade. The recirculation of Cl tails and Sc. Mag. increases the % Fe distribution reducing the tail losses. (5) The scavenger magnetic tails has low iron with high amounts of clay and LOI, having potential in local pottery, aerated bricks and tiles cottage industry. Nil waste process in case of LG tails of Orissa, reclamation of the tailing ponds is possible (6)Reduction of silica and alumina by inverse flotation method is recommended on the concentrates produced..

In the conventional horizontal WHIMS, the magnetic flux is transverse to the flow of pulp and fluids. The mechanical non-magnetic gangue entrapment with magnetic and matrix clogging due to concentric side tube type enlargement around matrix is shown in Fig 1. Further vertical pulp pulsation similar to jigging is carried out to minimize gangue entrapment. Also magnetic matrix rotates. vertically The combination of parallel pulp and high gradient matrix, vertical pulsation during feeding and vertical rotation of matrix to discharge magnetics counter current to loading direction flow revolutionized magnetic separation of paramagnetic slimes [3]. Longi magnetics subsequently concentrated on reducing the cost of operation by saving the energy for energizing the coils. Hitherto the conventional WHIMS or VPWHGMS had used low voltage and high current for energizing the coils. The coils are tubes with low wire space factor of 40%, low cross sectional area and long water pass. Longi used high voltage, low current for energizing coils. The coils are small dia solid wires with high wire space factor of 60%, low cross sectional area and short water pass length. Under identical conditions of field, coil shape and material, energizing power is inversely proportional to coil space factor. The ratio of power to Longi WHGMS and other WHIMS/WHGMS is inversely proportional to ratios of coil space factors of WHIMS and Longi WHGMS which is 60% [4]. Thus there is an energy saving of 40% without drop in applied intensity and gradient. The results indicated that, > 80% of the iron ore mineral particles <10 microns were concentrated, indicating the efficiency of fine particle processing of LONGI VPHGMS.

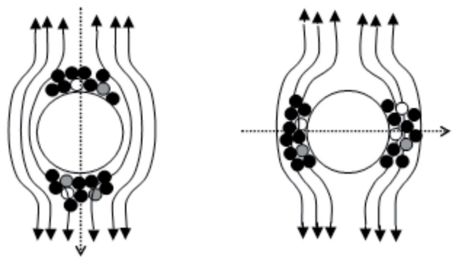

***Fig. 1.** Comparative Loading and discharge In VPHGMS and conventional WHIMS.*

3. Conclusions

This paper furnishes a few case studies of fine particle processing of some iron ore benficiation plant slimy tails from Orissa and Karnataka employing grinding, concentration of iron ore minerals.. The results indicate that it is possible to produce blend-able low grade pellet grade concentrates [~60%] with appreciable wt.% yield for different types of slimy tails varying in granulometry, silica, alumina and hydrated – anhydrous iron oxide content employing the generic process comprising of Rougher WHIMS at ~0.8 to1 Tesla, Scavenging HGMS of R tails at ~1 to 1.3 T, Cleaner WHIMS of Rougher concentrate at 0.7-0.9T in counter circuit configuration with dewatering of recirculating loads by a thickener. In some cases, the above process repetition of beneficiation plant tails also paved way for nil waste process where in the tails produced rich in alumina may be used in local building material and pottery industry, while the secondary concentrate may be either used in cement industry or blended with high grade pellet concentrate obtained in the primary beneficiation plant. More than 80% of Iron valuable particles < 10 microns were concentrated indicating the efficient fine particle processing of the equipment.

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