BENEFICIATION OF IRON ORE

A THESIS SUBMITTED IN PARTIAL FULLFILLMENT OF THE REQUIREMENTS FOR THE DEGREE OF

Bachelor of Technology

In

Mining Engineering

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Under the guidance of

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CERTIFICATE

This is to certify that the thesis entitled **"Beneficiation of Iron Ore"** submitted by Sri Sanjay Kumar Agarwal (Roll No. 110MN0569) and Sri Sudhanshu Kuamr (Roll No. 110MN0593) in partial fulfilment of the requirements for the award of Bachelor of Technology degree in Mining Engineering at the National Institute of Technology, Rourkela is an authentic work carried out by him under my supervision and guidance.

To the best of my knowledge, the matter embodied in the thesis has not been submitted to any other University/Institute for the award of any Degree or Diploma.

Date:

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Date: **SANJAY KUMAR AGARWAL**

SUDHANSHU KUMAR

ABSTRACT

Wide reserves of iron ore is found in India. Due to the high quality of iron ore available in India, large deposits of Banded Haematite Jasper (BHJ) are left unused because of the presence of silica in unwanted quantity.

ROM is put through washing to remove the clayey matter due to the presence of alumina and silica in iron ore leading to slime generation which are disposed of in tailing ponds. Slime in these tailing ponds contains iron values in the range of 45-60%. Appropriate beneficiation process has to be advanced to reduce the waste generation in mines and for the sustainable growth of the iron ore industry some.

Major reason for difficulty in beneficiation of BHJ is revealed from characterization studies which show the intergrowth of haematite and quartz. Presence of Kaolonite is proved with the aid of mineralogical studies. For the separation of alumina from iron ore Beneficiation studies have to be carried out.

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CHAPTER-1

INTRODUCTION

1. INTRODUCTION

1.1 ORIGIN OF THE PROBLEM:

Basic raw material for iron and steel industry is Iron ore which leads to our growing economy. India has huge reserves of quality iron ore which can fulfil the growing demand for domestic iron and steel industry as well as sustain large external trade.

The most important iron ore types found in India are hematite and magnetite. Nearly 61% of hematite ore deposits are found in the eastern part of India and 82% of magnetite ore deposits occur in southern part of India, especially in the state of Karnataka.

India possesses around hematite resources of 11,464 million tons of which 6,013 million tonnes are reserves and 5,442 million tonnes are residual resources .About 2,842 million tons (25.8%) are medium grade lumpy ore resources while 945 million tons (8.4%) are high-grade lumpy ore. Out of the fines resources about 2,543 million tons (22%) are medium grade ore, 39.9 million tonnes (1%) are high-grade and 17.7 million tons (1%) resources are of blue dust range. The residual are low grade, unclassified resources of lumps and fines or high, medium, low or unclassified grades of lumps and fines mixed.

The cut-off grade for estimating the hematite resources has been taken as 57% Fe. If the cut-off grade is reduced to say 43% Fe, the iron ore resources will increase considerably and thus bearable utilization of iron ore can be achieved.

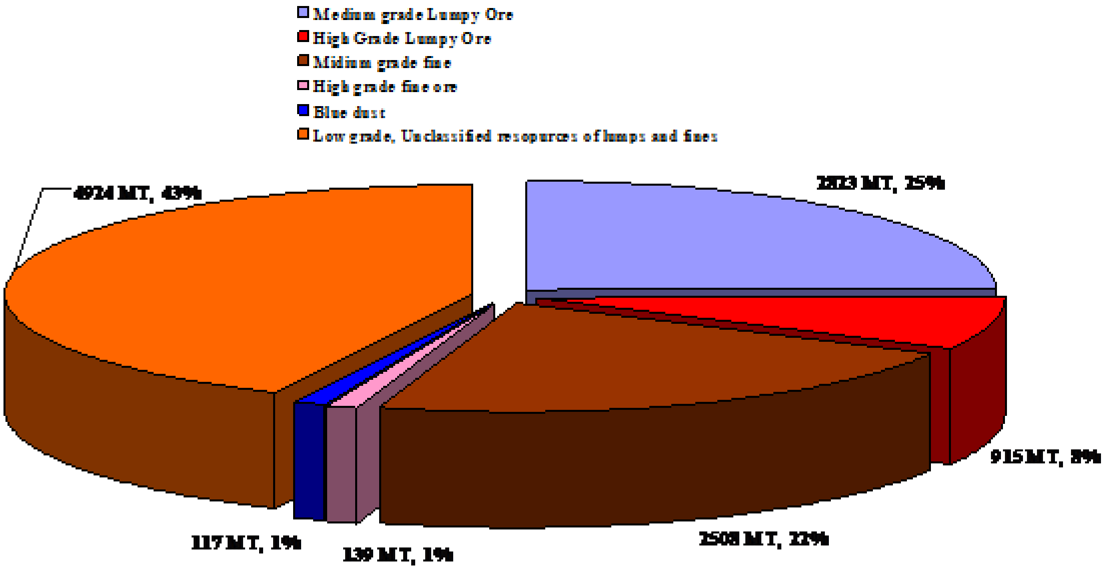

Fig 1.1 Graphical depiction of grade wise distribution of hematite ore

Major problem faced with the Indian iron ore is that though they are very rich in iron content they also have a high content of gangue material like silica and aluminium which obstruct the iron and steel production as the performance of the blast furnace lowers.

Iron ore sample found is a part of banded iron ore formation. Hematite and goethite are major constituents of iron ore samples. Hematite in the ore sample occurs as specularite with inter granular micro-pore spaces. Goethite is profuse and occurs as colloform product in cavities in addition with the weaker bedding planes. Hematite and goethite are very friable during mining and processing due to inter-granular pore spaces and voids along the weaker bedding planes. These friable particles break down and account for the iron content of the slime.

Ore samples, having magnetite and martite do not participate in the formation of the slime as they are very massive . Numerous cavities are contained in most of the bulk ore sample and are mainly occupied with clay in the form of kaolinite. Kaolinite is in greater concentration in the slime as it is friable, easily crumbles into ultrafine size during mining and processing actions.

Hematite and goethite in the ore sample are closely related with clay forming interlocking complex. This interlocking characteristic continues in the slime leading to considerable percentage of interlocked clay hematite/claygoethite.

Problems with slime is that they are usually very fine with considerable fraction in the220 micron range. In the present case this figure is 45%. It is very difficult to process such fine particles. This is replicated in the fact that though a pellet grade concentrate could be obtained the yield is a mere 27%.

1.2 Aim of the study:

The aim of this project is to propose methods for utilization of low grade iron ore especially Banded hematite Jasper (BHJ) and slimes. This is met by the following specific objectives:

- Study of field data collected from NIM(noamundi iron ore mines)
- Study the characterization data of BHJ and study the methods of up gradation by seeing to the characterization results.
- Proposal of methods for beneficiation of iron ore slimes.

CHAPTER-2

LITERATURE REVIEW

2. LITERATURE REVIEW

2.1 Main types of iron ores

Most prominent ore found in India are mainly hematite and magnetite. Among these, hematite is considered to be most important. Iron ore is used in production of pig iron which is further used in production of steel other uses of iron ore are like industrial finishes, polishing compounds and sponge iron industries. Iron ore belongs to Precambrian stage and its deposit is present in massive, laminated, friable and also in powdery form. Its major deposits are in Jharkhand, Orissa, Chhattisgarh, Karnataka and Goa States.

2.1.1 Hematite:

It is most important iron ore mineral main source for industries. Its composition is Iron Oxide and sometimes slight amount of titanium. Its name comes from the Greek word for blood, haima, because of its reddish colour. Crystals occurs in thin plates, as well as bundles of small micaceous plates, and in thin splinters. Most commonly massive, mammilary, botryoidal, reniform, oolitic, stalactitic, and radiating. Scalenohedral and rhombohedral crystals occur, although infrequently, and dendritic and rosette forms are also found. Hematite may also form as a pseudomorph of other minerals, especially as octahedral crystals of Magnetite. Striking features are reddish streak, hardness, crystal habits and Para magnetism. It becomes strongly magnetic when heated. Its specific gravity is 4.9 to 5.3 and luster is metallic to dull. Hematite is weakly magnetic, but it has a variety called magnetite which is found in many ore bodies in minute quantities having magnetic properties closely related to those of magnetite. The content of iron in the ore and physical characteristics vary from place to place in different types of ores.

2.1.2 Magnetite:

After hematite it is second most abundant Iron bearing ore. Black magnetic oxide of iron crystallizing in the isometric system with hardness of 5.5 to 6.5. Magnetite ore is of little value in its raw state, but it offers considerable advantages in its concentrated form. These include providing a viable iron-making commodity for premium quality steel production. By comparison, magnetite ore typically has much lower iron content when mined of between

25% and 40% Fe and in this form is unsuitable for steel making. The main iron mineral in magnetite ore is the ferrous iron oxide magnetite (Fe_3O_4). Magnetite ore requires complex processing to separate magnetite minerals from other minerals in the ore to produce an almost pure magnetite concentrate with an iron content of between 68% Fe and 70% Fe that is highly sought after by steel makers. It also occurs as a replacement product in sedimentary or metamorphic rocks. It is found as placer deposits as "black sand" in beach deposits and as banded layers in metamorphic and igneous rocks.

2.2 Resources/Reserves of iron ore deposit in India

The iron ore deposits of India can be broadly divided in to the following six groups on the basis of mode of occurrence and origin

- Banded Iron Formations(BIF) of Pre-Cambrian Age
- Sedimentary Iron Ore Deposits of Siderite and Limonitic Composition
- Lateritic Ores derived from the Sub-Aerial Alternations
- Apatite-Magnetite Rocks of Singhbhum Copper belt
- Fault and Fissure Filling Deposits
- Titanifereous and Vanadiferous Magnetites

Indian deposits of hematite belong to Pre-Cambrian Iron ore series and the ore is within the Banded Iron Ore Formations (BIF) occurring in massive, laminated, friable and also in powdery form. BIF mostly found in states of Jharkhand, Bihar, Orissa, Madhya Pradesh, Chattisgarh, Maharastra, Karnataka, Goa and Tamil Nadu. most common names used in India to designate BIF are Banded Hematite Jasper (BHJ) and Banded Hematite Quartzite (BHQ).

Different types of iron ore derived from banded hematite rocks met within the deposits of this group are

- Massive ore
- Laminated ore
- Blue dust.

The massive ores occur as massive bodies in which show non planar structures. The blue dust is a form of very fine-grained powdery ore which consists loose crystals of hematite and magnetite. The laminated ores though be mineralogicaly and chemically similar to massive ores, but have planar structures, which may be spaced closely. Occurring as pockets in harder ores it forms the major constituent at depth.

2.3 Processing of Iron ore in India

Iron processing depend mainly on the type of ROM ore feed and optimum product. Dry screening into lumps and fines is practised for high quality flaky ore and blue dust, because, if wet treatment is used, a substantial part of good quality material is rejected in the form of slimes. Another advantage of dry screening is dry screened fines also retain ultra-fines particle may later be used in sintering. Ore types having gangue material which strictly adhere to the useful metal surface are subjected to wet screening -> classification or scrubbing -> wet screening -> classification. Mineral processing plants at mines like Barsua, Bolani, Bailadila, Donamalai, Dalli, Gua, Kiriburu, Meghahatuburu, Noamundi and Rajhara use dry screening for direct ore mined from the face.

Except Rajhara and Gua all the other plants use wet screening - classification for ores that meet the cut off criteria. Scrubbers are being used in Barsua, Bolani, Dalli and Noamundi for better recovery. Noamundi mine have hydro cyclones , screw classifiers for better beneficiation process . Log washers are being used to produce better and stable quality lumps of iron ore in Sesa Goa mine. Various techniques and methods generally being used in the Indians iron ore processing are schematically shown in the figures below.

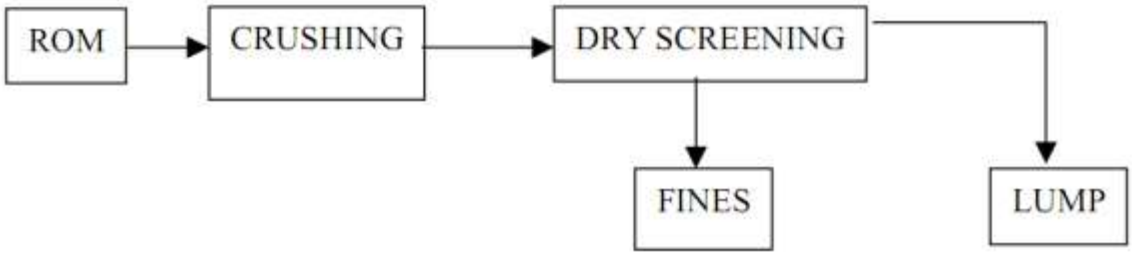

Fig 2.1 Dry screening process

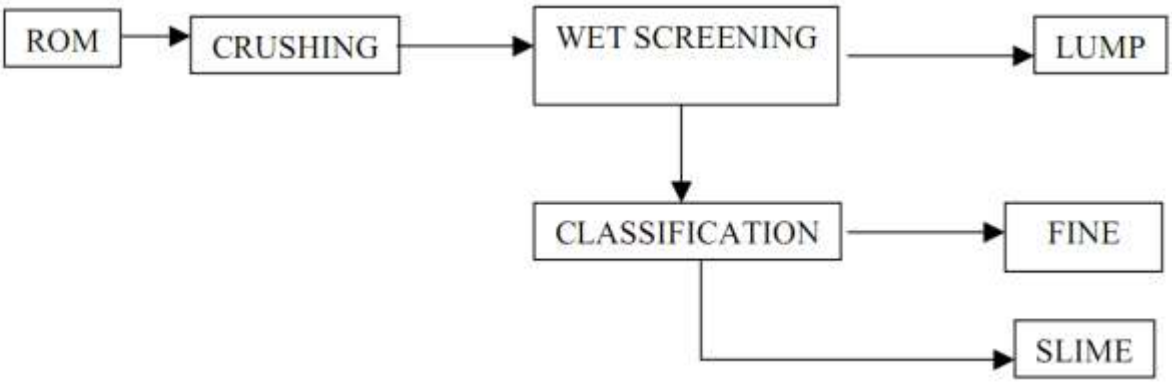

Fig 2.2 Wet screening classification

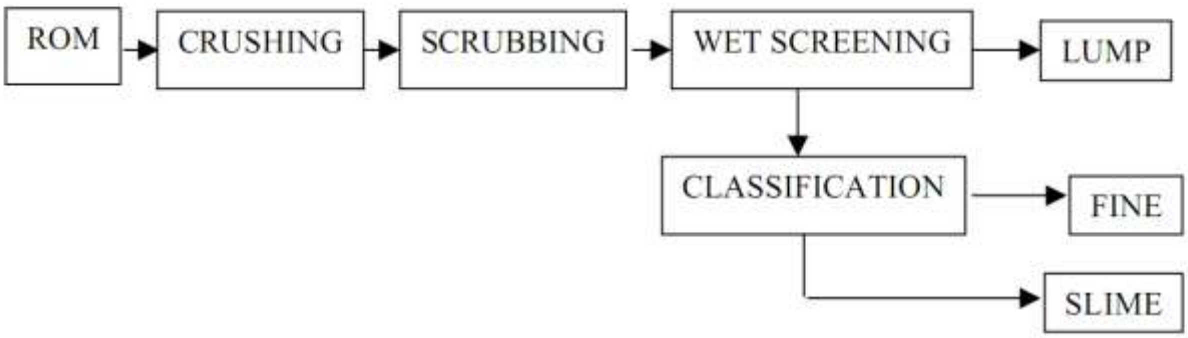

Fig 2.3 Scrubbing wet screening classification

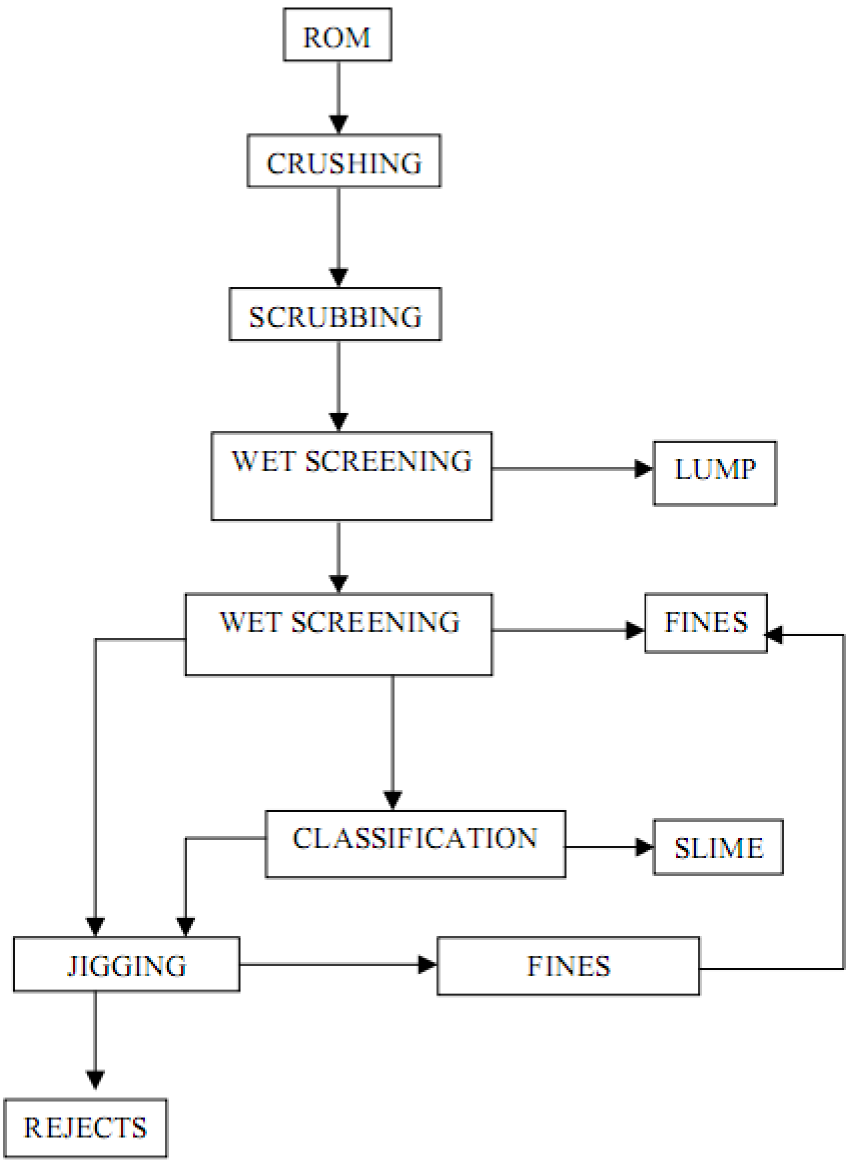

Fig. 2.4 Washing and gravity separation process

2.4 Slimes of Iron ore:

For improving quality and to reduce cost of production iron ore industries are demanding high grade raw minerals. However, the ore being a non-renewable natural resource, the reserve of good quality ore is depleting. Marginal to sub-marginal ore should be used to meet the present as well as future requirements and avoid environment related problems. The circumspect utilization of Iron ore can conserve high grade mineral resource. So today there is need of sustainable development in iron ore mining that is need of present without compromising the need of future generation. So it becomes vital to develop some technique for beneficiation of unutilized low grade ore and ultra-fine material i.e. slime. Washing plant data implies that generation of slime comprise of 30-35% of the total ore mined. Because of lack of technology and its complex nature, a significant quantity of slime remains unused. These slimes are dumped which causes environmental hazards. If pellets are produced directly from such fines, they become high in alumina which is undesirable in Blast furnace as high alumina content will adversely affect the pellet properties, typically measured by Reduction Degradation Index (DRI) and Reducibility Index (RI). A drop in alumina content can improve these properties and also reduce the coke consumption in Blast furnace. Tailings contain harmful material like iron sulphide which is primary source for acid mine drainage. Sedimentation test show that the tailings and the area required for tailing pond is around 3155 m^2 in comparison to 10,000 m^2 obtained from the use of an empirical equation. It is estimated that around 10 million tons of slimes are being generated every year in the processing of hematite ore and lost as tailings containing around 48-62% of Fe. It is also very difficult to evaluate the characteristics of these slimes where most of the particles are below 50 microns. The generation of iron ore slimes in India is estimated to be 10-25% by weight of the. Presently, because of lack of availability of efficient technology to process them and due to difficult nature of the fines and slimes, a large amount of it is left still unused. Base on the fact that iron ore production wills more than double and rise to at least 300 million tonnes soon, finding suitable methods of safe disposal/utilization of slimes is indeed urgent. If we look at the present quantity of the iron ore slimes that is being generated annually, amalgamation of quantity of slimes, over the years the fact that slimes are available in ground form and assaying that is reasonably high %Fe, it is natural that if beneficiated in a proper way, these slimes can be considered a national resource rather than a waste. The alumina content of the slimes, if brought to less than 2% Al_2O_3 in the beneficiated product will

- Lead to better utilization of national resources
- Achieve more mine output (enhanced production) with not much additional costs
- Reduce environmental issues associated with storage and disposal of slimes and
- Result in higher blast furnace and sinter plant productivity

In view of the above facts proper technology shall be adopted for processing of slimes to recover iron ore values from them, this will be a step forward for conservation of mineral in national interest. As particle size in slime is finer (<.15mm) so it will be easy to beneficiate the slime without the use of any combination process.

In last twenty years importance is slowly tilting towards slime beneficiation and in addition to the traditional methods of processing, enhanced gravity separators (EGS) such as Falcon, Knelson concentrator are also being experimented with to beneficiate the Slimes. Now a day's novel method of beneficing iron ore slime is used via magnetic and gravity method of separation.

Two distinct mineral constituent of Alumina in Indian iron ore slimes are gibbsite (hydrated aluminium oxides) and kaolinite. Exact amount of alumina has not been quantified till date according to liberation studies a significant portion of alumina is present in the liberated form and so it is possible to separate them using physical methods.

Slag viscosity in blast furnace is increased due to high alumina content. This leads to increase in metal loss in slag, increase in thermal requirement and thus makes the Blast furnace operation more tough. To reduce alumina burden new technologies are adopted by steel industries. Using pellets can reduce this burden.

All around the world Iron ores are being beneficiated including Kudremukh in India. Several Methods such as

- Spiral
- Floatex density separators
- Jigs
- 3 multi-gravity separator

- Low and high intensity magnetic separator
- Conventional as well as column flotation
- Selective dispersion
- Flocculation is all part of current industrial practice.

Present advances include Batacjigs, packed flotation column, packed column jigs and centrifugal concentrators like Falcon Concentrator, Knelson Concentrator for the beneficiation of iron ore slimes. At present Processing of hematitic ores is done in India, however, does not involve any beneficiation except for rejection of silica for some alumina occurs during washing and classification of crushed ores.

Recently two beneficiation plants have been set up to process sinter fines for value addition. Essar is operating an 8 million tonnes per anum pellet plant in Visakhapatnam based on the slimes and fines being pumped from NMDC's Balladilla iron ore mine. The beneficiation includes gravity separation (spirals) of the coarser portion after desliming it and high intensity magnetic separation of the finer fraction.

Assay less than 2.5% by weight of added alumina and silica content is grounded to produce a feed acceptable for the pelletization circuit is produced by the concentrator.

A technological development programme needed to define the appropriate Beneficiation strategy for Indian iron ore deposits must include

(i) The mode of occurrence, alumina containing minerals association and liberation characteristics.

(ii) A comparison of the separation efficiency of different unit operations for both hematitegoethite/ kaolinite/gibbsite separation in view of recovery-grade plots (separation Characteristics) and as a function of particle size

(iii) Preliminary techno-economic valuation of the various technology options for a typical iron ore mine in the country.

CHAPTER-3

BENEFICIATION PLANT STUDY OF NOAMUNDI IRON ORE MINE

3. BENEFICIATION PLANT STUDY OF NOAMUNDI IRON ORE MINES

3.1 Mineral Processing

Noamundi processing plant processes ROM from Noamundi Iron Mine as well as from adjoining Katamati iron mine. A part of the ROM ore is beneficiated by Wet process while the other part of the ROM ore is beneficiated by the Dry process. In the Wet process, the feed constitutes **hard ore, soft ore and flaky or**e, which is fed in pre-determined proportion while in the Dry process; feed constitutes of **flaky ore and blue dust.** The secondary beneficiation plant is consists of two processes:-

- Dry Processing
- Wet Processing

The Primary beneficiation plant consists of only a Gyratory crusher and from there the material is transferred to the Secondary plant via conveyor belt method. The main objective of the Primary beneficiation plant is **the crushing of the ROM from the mines** while the main objective of the Secondary beneficiation plant is **screening, crushing and washing.**

3.2 Primary Beneficiation Plant

The Primary crushing system process produces iron ore of **170mm** (input feed material for secondary beneficiation system) with ROM quality scheduled by geological department. The ROM is dumped into primary crusher having a capacity of **1800 TPH (54 inch Gyratory crusher).** The crushed ore (-200mm) in size is then stored in two separate primary stockpiles. The crushed ore is then fed into two identical circuits for secondary processing.

3.2.1 Working of Primary Beneficiation Plant

ROM of **-1200mm size** is feed to primary crusher by Mining Department through 100T dumper, **-150mm size boulder gets screened through the grizzly, and the rest is being crushed in the crusher**. **Normally the crusher gap (open side setting) is being set to 150mm to avoid any oversize material going to secondary crushing system.** All crushed and grizzly-screened material goes directly through two apron feeders to C1 conveyor. C1 conveyor has integral tripper system for stocking the material in B & C primary surge pile during crushing to minimize the dust emission, dust suppression for which dust extraction system are installed. An overview of the basic steps involved in the processing of the ROM ore is produced below in the figure: -

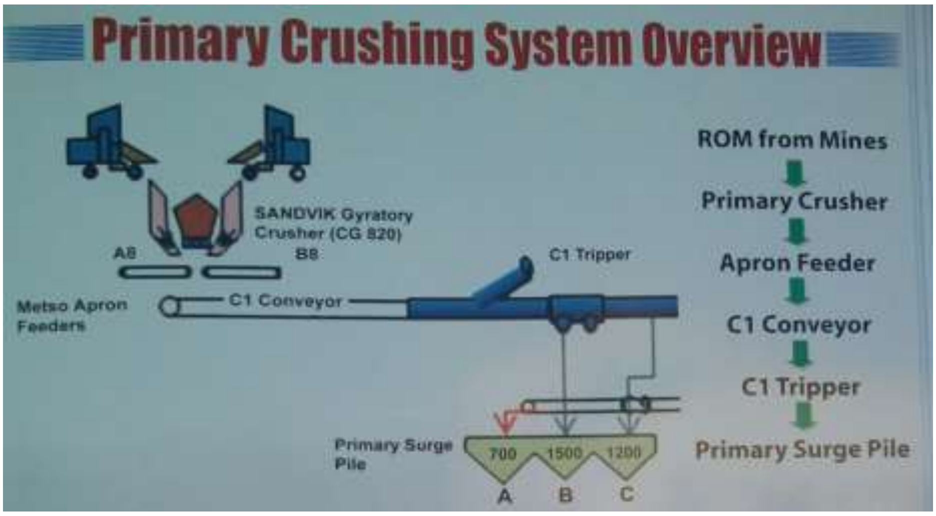

Fig 3.1 Overview of the main steps involve at primary crushing plant

Primary beneficiation mainly consists of following main components: -

Gyratory crusher: - Gyratory crushers are principally used in surface- crushing plants, although a few currently operated underground. The gyratory crusher consists essentially of a long spindle, carrying a hard steel conical grinding element, the head, seated in an eccentric sleeve. The spindle is suspended from a spider and as it rotates, normally between 85-150 rev/min**, it sweeps out conical path** within the fixed crushing chamber, or shell, due to the gyratory action of the eccentric. Generally in this model of **gyratory crusher being used ¾ of the material is passed while ¼ material has to be removed sometime with the help of crane or manually**. Korrobond 65 Epoxi-based dampningsmassa for stenkrossas is used for lining the core. The specification the Gyratory crusher used in the Primary beneficiation plant-Noamundi is given below: -

Table 3.1 Specification of Gyratory crusher (Primary crusher)

MODEL	CG-820
MAKE	SANDVIK

WEIGHT	262T
CAPACITY	1600-3500MTPH
MAX FEED SIZE	1200mm
LUMP SIZE	130-200mm
MOTOR CAPACITY	450KW
V-BELT SIZE	SPC 9500(16 NOs.)

Grizzly: **- Grizzlies are used for rough screening of coarse materials and often found in crushing circuits.** A grizzly is basically an inclined set of heavy bars set in a parallel manner. Coarse material slides on the inclined surface of the bars material finer than the spacing between the bars falls through. The Grizzlies can be vibrated to improve performance.

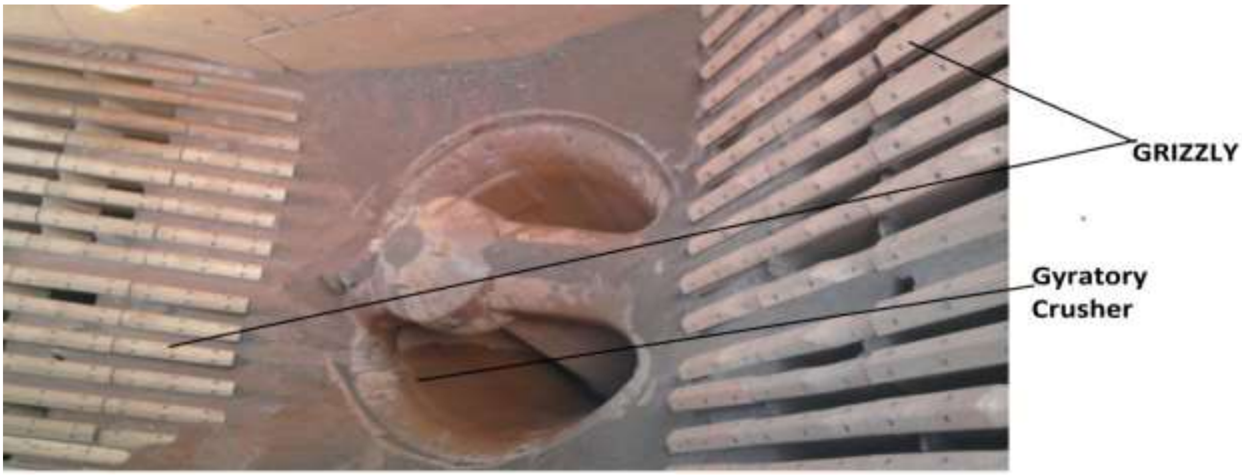

Fig 3.2 Figure showing the Grizzly and Gyratory crusher

Apron Feeder: - Apron feeder is used to transfer the material from the crusher to the belt conveyor. The crushed ore from the Gyratory crusher is no directly to the conveyor since it will have adverse impact on the belt and the belt might get damaged. Thus apron feeder is used as an intermediate to transfer the material to the belt thus preventing the belt from any damage. Specification of the Apron feeder is given in the table below: -

Table 3.2 Specification of the Apron feeder

MAKE	METSO
CAPACITY	**500-1200 TPH**
LUMP SIZE	200-250 mm
VELOCITY	0.12m/sec

WIDTH*DEPTH	1.83*0.84 M
MOTOR	55KW * 1500RPM ,VVVF DRIVE
GEAR BOX	BEVEL PLANETARY HELICAL REDUCTION GEAR UNIT RATIO-365.87:1
INPUT COUPLING	GEAR COUPLING , SIZE:-ED500

Hydro set Tank: - Hydro set tank is used to maintain the jack pressure.

Balancing cylinder: - Balancing cylinder consists of NO_2 gas. The main function of the balancing cylinder is to control the jack movement thus preventing any damage. Also id helps in clearing the material that stuck into the crusher bottom opening.

C1 conveyor: - It is used to transport the material from the primary beneficiation plant to the secondary plant. It is a centrally driven two drive arrangement.

Dust Collector: - It is used to collect the dust produced at the Apron feeder in the Primary crushing system and then discharge it into the atmosphere.

3.3 Secondary Beneficiation Plant

Secondary Plant is consisting of mainly three parts in which the beneficiation of the sized ore is done. In secondary plant the material is transported from the primary plant with the help of C1 conveyor and is stored in primary surge-pile of capacities **700ton, 1500ton, 1200ton** respectively for A, B, C surge pile. **Out of which Primary surge-pile A is used as input for the production of LD and is dry circuit,** while surge-pile B, C is wet circuit input feed. The output of the three circuits is stored in three secondary surge-bins after processing from the Jig and Hydro-cyclone plant. There are three secondary surge-bins of capacities 2000ton, 3000ton, 3000ton, respectively for circuits A, B, C. The main three parts of the secondary beneficiation plant is: -

- Wet Processing
- Dry Processing
- Jig and Hydro-cyclone Plant

3.3.1Wet Processing

“““‘Sized ore (-200mm) from the primary plant is stocked into two primary stockpiles of capacity (1500ton and 1200ton) and then fed into two identical circuits for secondary processing. Each secondary processing circuit consists of one secondary crusher which crushes the material to -40mm size. The crushed product is then screened on a double deck screen, with the top deck at +40mm and the lower deck at -10mm. The oversize (i.e. +40mm) product from each of the secondary circuits is stored in a surge-pile from where it is fed to a tertiary crusher arranged in a closed loop, to ensure minimum generation of oversize in the sized ore. The -40mm +10mm fraction is recovered as sized ore. The -10mm fraction from the secondary crushed product is sent to screw classifiers. The -10mm fraction of the tertiary crushed product is recovered as Fines. In the screw classifier, the -10mm fraction from the secondary crushed product is classified to yield two products viz. -10mm +0.15mm (as underflow) and -0.15mm (as overflow). The coarser fraction (i.e. -10mm +0.15mm) is then sent to a dewatering screen to drain off the excess moisture in the fines. The dewatering screens have a 1mm aperture, where the coarser fraction of the screw classifier (+0.15mm) is screened. **The +1mm product after screening is sent for jigging while the finer fraction (i.e. -1mm) collected from each of the three circuits along with the classifier overflow is sent to the hydro-cyclones**.’**””**

In wet following are the main components: -

- Cone Crusher [Shot head cone crusher for circuit A and Standard cone crusher for circuit B, C]
- Screw Classifier
- Scrubber
- Rinse Screen
- Dewatering Screen
- Conveyor

Table 3.3 Specification of C-4 conveyor

Conveyor	Width-1000mm Specification-1000*800/4 , 9mm/2.5mm Length-27 mtrs
Gear Box	Make: Jones Model: 105DHC Power: 11kw RPM :1450
Motor	Make : KIRLOSKAR Frame; KAA44/02-63
Coupling	C-1.5/C-2.5

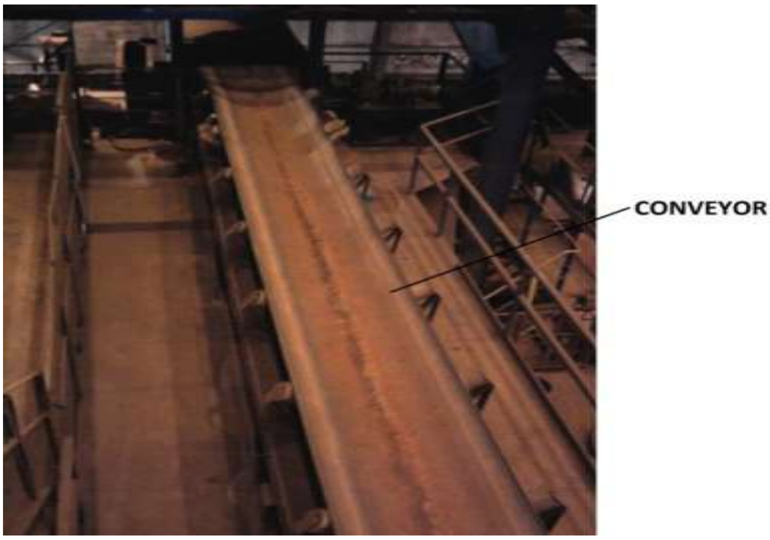

Fig.3.3 Conveyor at Secondary beneficiation plant

Fig.3.4 Screw Classifier

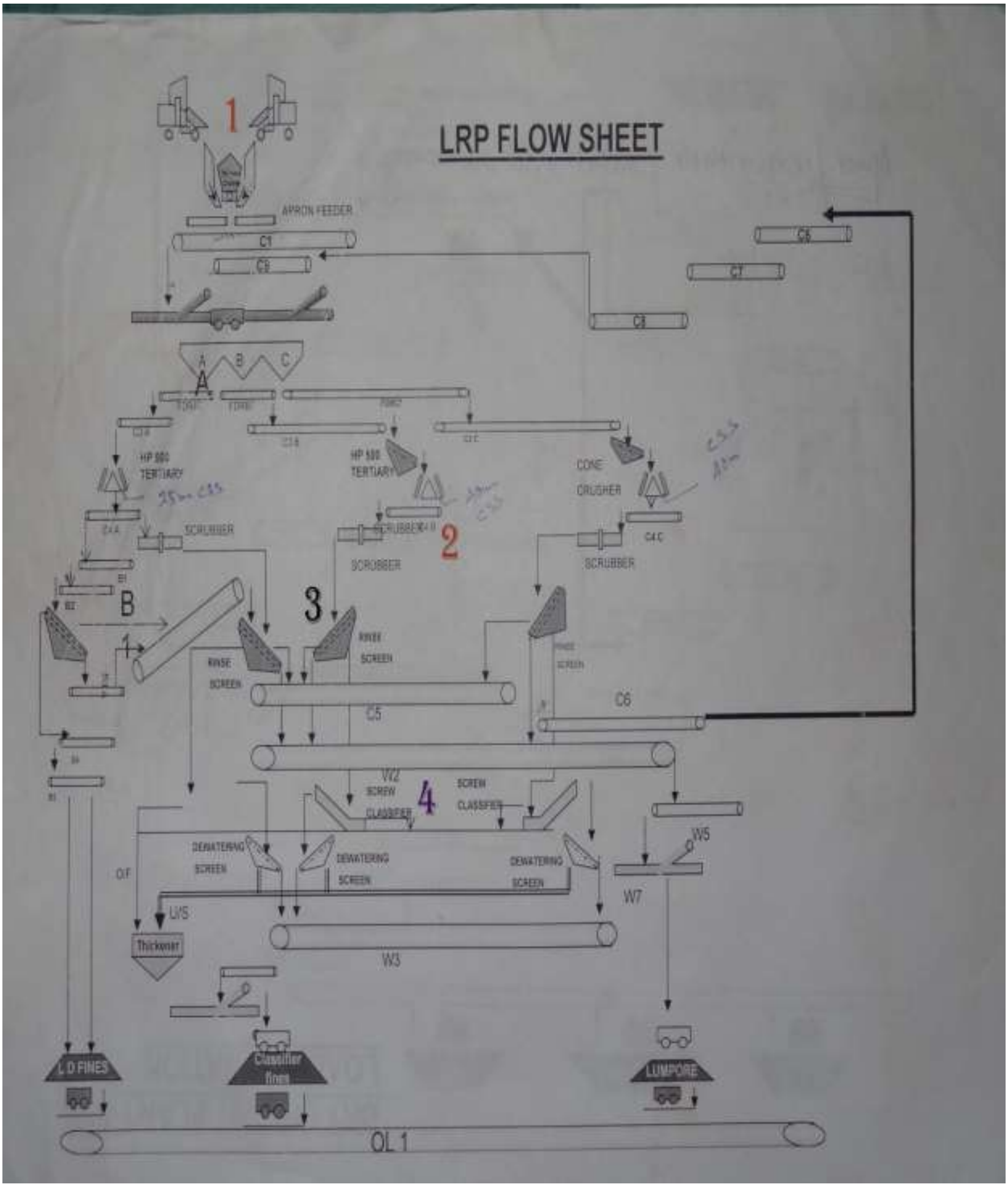

Fig 3.5 Overview of secondary beneficiation plant

Fig 3.6 Scrubber

Fig.3.7 Rinse Screen

Table 3.4 Specification of Rinse Screen

MAKE	TRF
TYPE	TE-13 ELLIPTEX SCREEN
M/C SERIAL NO	6758
SIZE	8’ * 16’
STROKE	5/8”

RPM	800
NO OF DECKS	2
PANEL APERTURE SIZE	TOP DECK: 40mm BOTTOM DECK:10mm
CAPACITY	700 TPH
VIBRATING UNIT BEARING	SKF22326 EXPLOR SERIES
MOTOR DETAILS	POWER: 45KW SPEED: 1480 RPM

3.3.2Dry Processing

The mineral beneficiation in the dry circuit consists of a Hooper in which DCM ROM is dumped. The material is screened in grizzly screen on a 100mm screen. The oversize (+100mm) is sent to the primary crusher. The crushed product (-140mm) along with the undersize from the grizzly screen (i.e. -100mm) is sent to the double deck screen via apron feeder where oversize (+40mm, -140mm) goes to secondary crusher. The crushed product (-40mm) along with the undersize from the double deck screen (i.e. -40mm) is sent to surge bins of 2000tonn capacity. The -40mm material is further screen and the oversize (+32mm, -40mm) is sent to tertiary crusher and the undersize (-32mm) is again screen on double deck

Screen and from there size (-8mm) sent to the product DCM fines surge piles while size (+8mm) to the tertiary crusher to produce desired DCM fines. The crushed product of tertiary crusher (+8mm, -14mm) is screened and after screening undersize (-8mm) sent to the product DCM fines surge piles and the oversize (+8mm, -14mm) again sent to the tertiary crusher for further crushing. The sized ore from the wet circuit and the DCM sized ore together constitute the sized ore. The DCM fines from the DRY circuit are blended with the Improved Quality Fines of the Wet circuit to form the Blended Fines.

Jig and Hydro-cyclone Plant

In the jigging plant, the coarser fraction of the fines (+1mm) is further beneficiated to yield Improved Quality Fines while the tailings are collected as solid rejects. In the hydro-cyclones, the finer fraction (i.e. -1mm) is beneficiated to yield Improved Quality Fines with an improved recovery, while the remaining slurry is sent to the thickeners. The slurry is thickened in the thickener and pumped to the slime dam about 80% of the water is recovered and recirculated in the system.

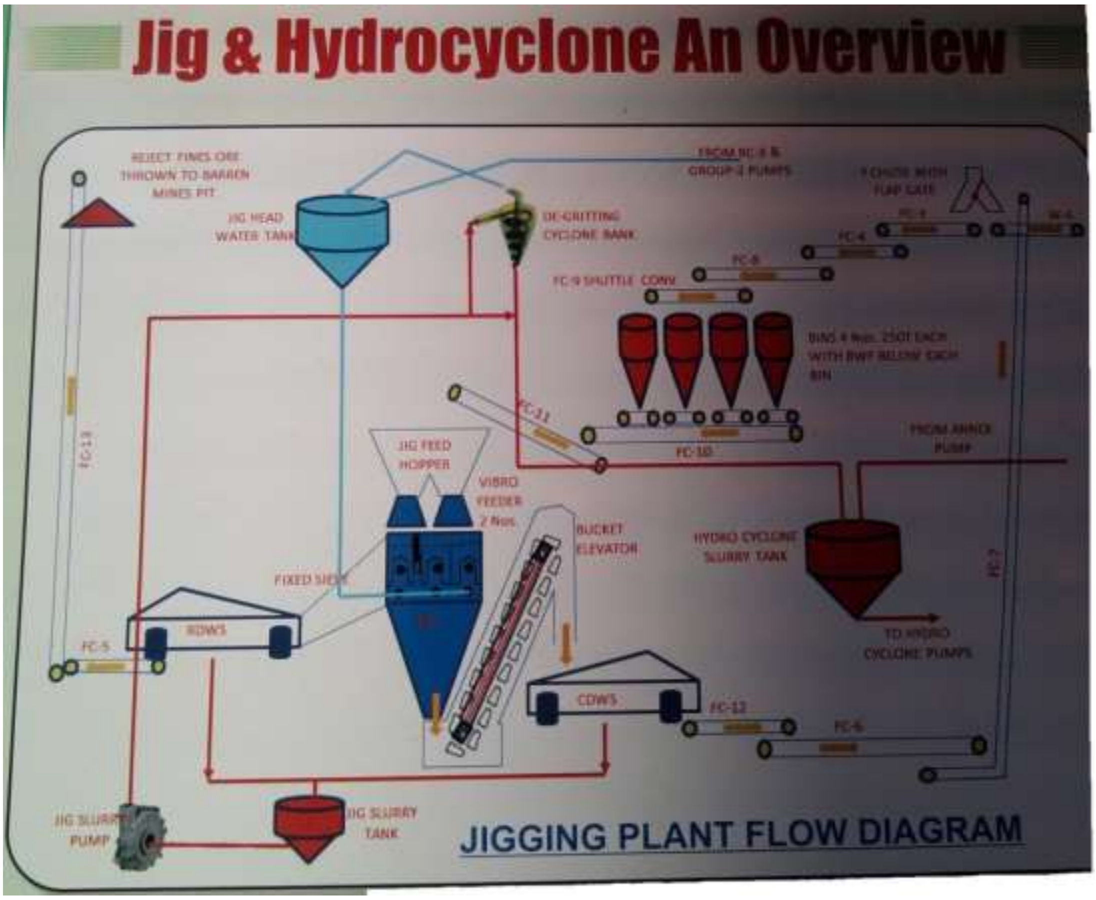

Fig 3.8 An overview of Jigging and Hydro-cyclone Plant

Table 3.5 Specification of Batac Jig

Make	Humboldt Wedag (Germany)
Main Dimensions : L*W	4250 mm * 4200 mm
Overall construction Length	4000mm
Jigging bed Width	4000 mm
Jigging area	12sqrmtr.

No. of Chamber	3
TPH	280(nominal) 300(maximum)
Length & width Of Jigging chamber	4000mm *1000 mm
Arrangement of Discharges	After the 2nd chamber
No. of Discharge boxes with gate	3
No. of supersonic pick up sensing devices	3
No. of hydraulic pack	3
Operating Air Requirement	90cumtr/min at 1.6 bar abs pressure
Control Air requirement	4.5cumtr/min at 7.5 bar abs pressure
Under Water requirement	1050cumtr/hr. at 1.8 bar abs pressure

3.4 Process Description

The jigging process produces iron ore concentrate (-10mm) with **Fe>64% and Al2O3 = 2.25%,** Jig tailings and slimes. Classifier fine ore is conveyed by Belt conveyor to Jig Bins, From Jig Bins by belt weigh feeders, FC 10, FC 11 conveyors to feed to the compartmentalized Jig feed Hopper in the Batac Jigging plant. Classifier Fine is fed to the Batac Jig through two nos. electro-mechanically operated Vibrating Feeder (VF-1& VF-2). The Batac Jig sink product (sinter feed concentrate) is discharged from the jig via the Jig Hopper into the **de-watering Bucket Elevator which is built as an integral part of Jig hutch & concentrate recovery system from the Batac Jig.**

Concentrate form de-watering Bucket is further de-watered by a linear motion Vibrating screen with 0.3mm slit aperture SS wedge wire decks; solid concentrate is transported through Belt conveyor (FC-12). Belt conveyor (FC-12) discharges to FC-6. Belo conveyor (FC-6) discharges to FC-7. Belt conveyor (FC-7) discharges to W-6. Belt conveyor (W-6) discharges to fines surge pile. From there fines go to loading plant for dispatch.

The Batac float product (Rejects/tailings) swims with flowing water out of Batac Jig and passes through one inclined De-watering fixed sieves before feeding to Vibrating de-watering screen for final de-watering of rejects and conveyed by a cross belt conveyor (FC-5). Belt conveyor (FC-5) discharges rejects onto FC-13 for subsequent conveying and disposal of rejects. Fixed de-watering sieve and vibrating screen is provided with 0.5mm slit aperture SS wedge wire decks.

Slurried water with fines solid (particle size<0.5mm) from the fixed de-watering sieve and of vibrating de-watering screen(s) both for rejects and concentrate is collected in a slurry sup. Centrifugal Slurry pump is pump slurry from the slurry sump of De-gritting cyclone. De-gritting cyclone recovers the coarser particle from Jig slurry and overflow water of these cyclones foes to Jig overhead tank for use in the Jig. Under flow of de-gritting cyclone goes to hydro-cyclone to prevent the coarser particles going to Thickeners. Underflow of hydro-cyclone goes to slow speed classifier for de-watering then it mix with jig rejects through FC-14 conveyor.

Jigging air is supplied from Rotary Roots Blower (RRB 1 & 2, 1operating and 1standby) installed at the Jigging plant. Compressed air for operation of the Batac jig valves, electro-pnematically operated cut off valves below Jig head water tank and other requirement within Batac Jigging plant like purging, flushing etc. is supplied from Screw compressor (SC-1& 2, 1operating and 1standby) and 3000 Ltrs. Capacity Air receiver tank.

Batac Jig underwater is supplied from a Jig water tank installed above the Jigging plant, Re circulating water from the existing Thickener in requisite quantities and with maximum permissible solid concentrate is supplied directly to the Jig head water tank through RC pump#3 or Group 2 pump house, pump as per requirement. A make up water tank also installed adjacent to the Jig head water tank to supply requisite quantities of make up water directly to the Jig head water tank to ensure appropriate pressure head for operation of the Batac Jig, a constant overflow of water from the Jig head water tank back to the existing Thickeners/Thickener clarified water tank is needed.

JIG: - It is an ore beneficiation machine in which the feed material is stratified according to its density. It works on gravity separation method

The Batch jig present in Noamundi Iron ore mine stratified High alumina fines Ore to the alumina concentrate by stratification according to its density by the pulsating motion of water**. It is an air pulsated jig which uses blower air at 0.39 bar pulsation of the jig**

bed.The thickness of the material layers stratified by specific gravity is sensed with the aid of a float equipped with a suitable linkage. The system provides a controlled withdrawal of the heavy fraction over a discharge device. Jigging of great width is equipped with independently operating discharge devices fitted with separate sensor and hydraulic units. Jig Plant is mainly composed of following parts: -

- **Pulse Generators**: - Magnitude and kind of kinetic energy, admitted to the beneficiation process are of decisive importance for successful separation. Therefore, special attention has should be given to the development of pulse generator for the controlled admission of compressed air. Disk valves are used for standard and square-wave, pulsation in BITAC jigs. They are actuated by compressed air.

- **Rotatory-flap valves**: - It is used for standard and square-wave pulsation. They are actuated by compressed air. The quantities of jigging air are controlled by electronically both for disk valves and rotary-flap valves. They can be set individually by means of decade switches. An identical pulsation frequency (40-120 pulsation/min.) is set for all jigging chambers. The specific pulsation of every chamber is generated from additional time cards. The operating pressure is matched to the specific operating condition from a PID controller operating on micro-processor basis. The nominal pressure has been stored in the controller. The operating pressure can be automatically matched to changed operating conditions be measuring the raw material feed rate (weigh feeder).

- **Discharge Devices: -** In case of both coarse- and fine grain jigs of great width several discharge devices have been distributed over the machine width. They operate independently by their own hydraulic system. The hydraulic units are actuated indirectly by float sensors.

    - **Coarse-grain discharge device**: - Refuse and middling’s are taken to the discharge shafts over movable jig beds of maximum 3.0m width. Depending on the quantity of heavy, fraction that has accumulated, the movable jig beds are opened up to 350 mm. The shaft walls have been protected against wear by ceramic tiles or wear plates.

- **Fine-grain discharge devices**: - The refuse and middling products are discharged into the bucket elevator over bottom outlets fitted with gates. The design of these discharge devices focused on aspects of wear and therefore the bottom outlets are easily replaceable insert boxes made of 15 mm thick stainless steel. The shafts are 440 mm deep and dew pending on the jig width their opening measures between 115*1000mm and a maximum of 2000 mm. The design concept was to keep a size able reserve layer (buffer) inside the shaft not only to prevent eddying but also to reduce the flow velocity of the material to be discharged.The lower part of the gate (run-off plate) has been separated from the gate body and has been rigidly welded to the insert box. The gate pro (1 er now only consists of the 15mm thick stainless plate which is moved and guided vertically with the aid of two flats made of stainless steel). Existing machines can be retrofitted with this modified discharge gate. Every discharge gate is equipped with its own hydraulic cylinder mounted vertically above the discharge gate and joined directly to it i.e. without interposing a shaft. This arrangement results in the following benefits*:* -
  - Extended longevity due to use of stainless steel
  - No wear occurring at the jig walls proper
  - Reduced machining of mechanical components
  - Lubrication of bearings is not necessary because of the absence of a shaft
  - Rapid replacement of gates and insert box

- **Discharge Control Loop**: - The thickness of the material layers stratified by specified gravity is sensed with the aid of a float equipped with a suitable linkage. Formerly employed induced current metering units are today replaced by analog displacement measuring system operating at ultrasonic velocity (2800 m/sec.). The basic float setting (separating density) is done by additional weights. The layer thickness is adjusted with a set point potentiometer. The hydraulic system of the discharge gates are actuated from PID controllers which operate on the basis of microprocessors. The measurement is made with the float in lowest position. This will preclude false measurements due to stroke influences. The new system are highlighted by improved measuring and control accuracy and their insensitive to impact and vibrations.

Discharge control loop:-

- Chassis
- Float
- Float guide rod
- Guide rolls
- Rubber buffer
- Indicator dial
- Weight disk
- Display panel-layer thickness
- Adjustable receptacle for displacement sensors
- Ultrasonic control bed level
- Reflector
- Converter
- Controller
- External set point input
- Ultrasonic control is charge opening
- Reflector
- Hydraulic unit
- Discharge shaft
- Gate
- Overflow weir
- Set point layer thickness

Control Cabinet: -

- OPERATING INDICATOR FOR AIR CONTROL
- LCD display with key board for adjustment of valve control(air in/out).
- Operating indication of discharge gates.
- LCD display with keyboard for entering various parameters.
- LED’s for general status.
- Hour meter
- Push, buttons with signal lamps for manual operation.

CHAPTER-4

DATA ASSIMILATION, EXPERIMENTATION AND ANALYSIS

4. DATA ASSIMILATION, EXPERIMENTATION AND ANALYSIS

4.1 Ground data (Noamundi Iron ore mines)

Table 4.1 : Data from Noamundi iron ore mines

Sl. No.	Description	Nature Of sample	$Fe_2\,O_3$ (%)	$Al_2\,O_3$ (%)	SiO_2 (%)
1.	22/03/2014 A Shift	Fines	60.01		
	22/03/2014 A Shift	Lumps	57.36	5.43	2.63
2.	22/03/2014 B Shift	Fines	61.34		
	22/03/2014 B Shift	Lumps	60.28	4.22	3.22
3.	22/03/2014 C Shift	Fines	60.36		
	22/03/2014 C Shift	Lumps	59.24	4.76	3.48
4.	23/03/2014 A Shift	Fines	63.49		
	23/03/2014 A Shift	Lumps	61.28	3.11	2.11
5.	23/03/2014 B Shift	Fines	59.38		
	23/03/2014 B Shift	Lumps	60.08	3.45	2.32
6.	23/03/2014 C Shift	Fines	56.21		
	23/03/2014 C Shift	Lumps	54.55	4.78	3.23

7.	29/03/2014 A Shift 29/03/2014 A Shift	Fines Lumps	60.12 59.01	4.47	2.77
8.	29/03/2014 B Shift 29/03/2014 B Shift	Fines Lumps	63.46 64.58	3.02	1.47
9.	29/03/2014 C Shift 29/03/2014 C Shift	Fines Lumps	62.37 61.49	3.58	1.67
10.	30/03/2014 A Shift 30/03/2014 A Shift	Fines Lumps	64.33 67.38	2.87	2.03
11.	30/03/2014 B Shift 30/03/2014 B Shift	Fines Lumps	63.34 61.47	3.58	2.67
12.	30/03/2014 C Shift 30/03/2014 C Shift	Fines Lumps	64.57 63.76	4.22	3.01
13.	05/04/2014 A Shift 05/04/2014 A Shift	Fines Lumps	63.40 64.48	3.11	1.87
14.	05/04/2014 B Shift 05/04/2014 B Shift	Fines Lumps	66.30 65.38	1.87	1.96
15.	05/04/2014 C Shift 05/04/2014 C Shift	Fines Lumps	63.69 62.51	3.46	1.44
16.	06/04/2014 A Shift 06/04/2014 A Shift	Fines Lumps	62.87 61.46	4.32	1.75
17.	06/04/2014 B Shift 06/04/2014 B Shift	Fines Lumps	62.98 61.47	3.27	2.45

18.	06/04/2014 C Shift 06/04/2014 C Shift	Fines Lumps	63.44 64.77	3.67	2.56
19.	12/04/2014 A Shift 12/04/2014 A Shift	Fines Lumps	54.32 53.48	2.96	2.08
20.	12/04/2014 B Shift 12/04/2014 B Shift	Fines Lumps	57.26 53.26	3.46	3.01
21.	12/04/2014 C Shift 12/04/2014 C Shift	Fines Lumps	58.25 52.29	4.48	2.67
22.	13/04/2014 A Shift 13/04/2014 A Shift	Fines Lumps	56.46 54.56	4.67	2.75
23.	13/04/2014 B Shift 13/04/2014 B Shift	Fines Lumps	58.48 55.78	3.56	2.45
24.	13/04/2014 C Shift 13/04/2014 C Shift	Fines Lumps	57.32 58.76	5.01	4.22
25.	19/04/2014 A Shift 19/04/2014 A Shift	Fines Lumps	61.68 63.46	3.21	2.33
26.	19/04/2014 B Shift 19/04/2014 B Shift	Fines Lumps	64.05 65.87	2.93	1.47
27.	19/04/2014 C Shift 19/04/2014 C Shift	Fines Lumps	63.49 65.68	3.69	1.12
28.	20/04/2014 A Shift 20/04/2014 A Shift	Fines Lumps	62.09 65.00	3.47	1.23

29.	20/04/2014 B Shift 20/04/2014 B Shift	Fines Lumps	61.98 62.24	 4.01	 3.51
30.	20/04/2014 C Shift 20/04/2014 C Shift	Fines Lumps	63.11 64.63	 3.87	 2.34

4.2 Experimentation for Beneficiation of Banded Haematite Jasper (BHJ)

The major minerals present in the ROM sample of BHJ is hematite and quartz in which approximately 98% are hematite and quartz and the rest 2% are other undesirable minerals like Goethite, kaolinite and limonite etc. If the average analysis of a given sample is done it may show that hematite accounts for around 60-65% and quartz accounts for up to 35-40%.The minerals are grouped into iron ore minerals consisting Hematite, Goethite and gangue minerals consisting rest of the minerals. The iron ore minerals contained in ROM sample are 1.3 times more than gangue minerals. Hematite mass% is high at lower sized fractions than ROM sample. Concentration of goethite is increased with decrease in size. The concentration of Hematite is considerably higher than Quartz. The ratio between iron oreminerals and gangue minerals has been significantly increased which specifies that enrichment of iron ore is possible at lower sized fractions over gangue minerals.Following are the results of Textural Relationship observed in BHJ are as follows

1) Alternate banding between Quartz and Hematite of variable thickness

Fig 4.1 Alternate thick bands of quartz and thin bands of hematite.

2) Presence of veins of Quartz in micron to mm scale cutting across all bands and across massive bodies

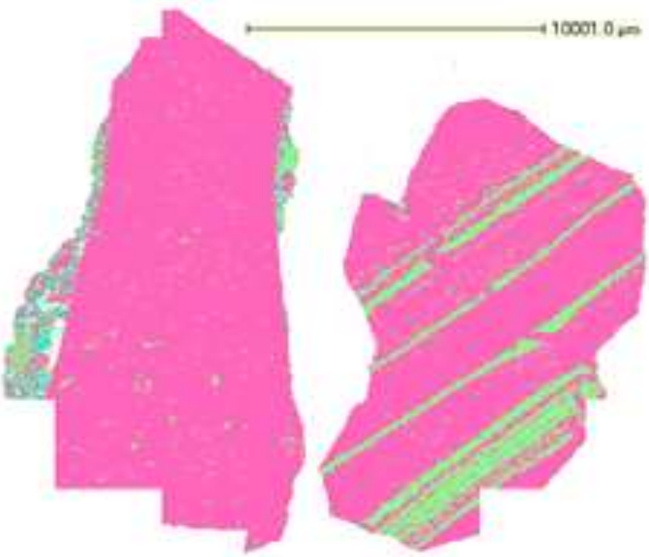

Fig 4.2 vein of quartz cut across all bands

3) Massive Bodies of Hematite and Quartz without banding

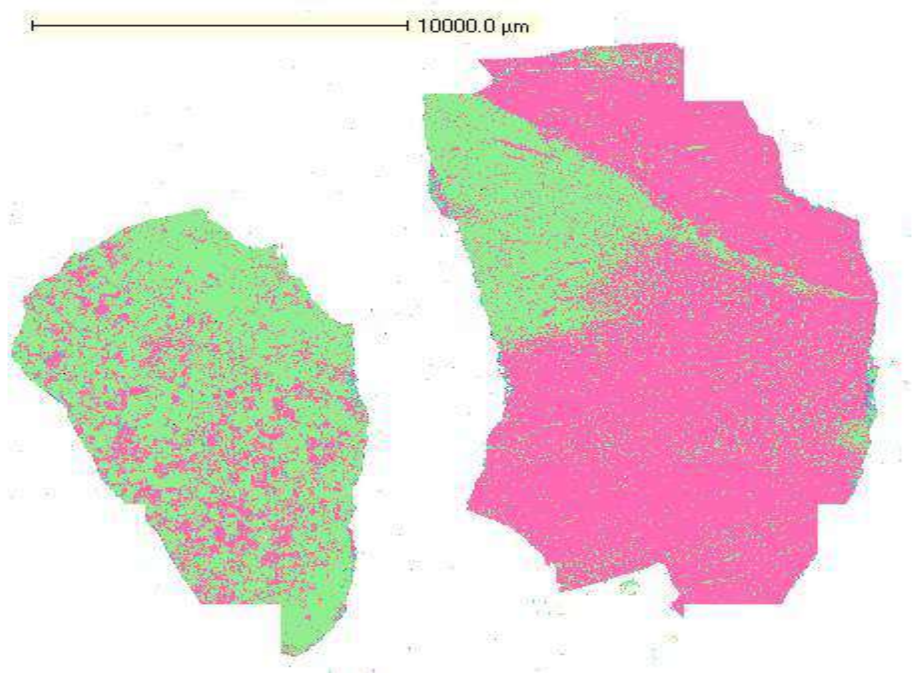

Fig 4.3 Massive quartz and sporadic quartz

4) Presence of Quartz inclusions within ore mineral bands and vice-versa.

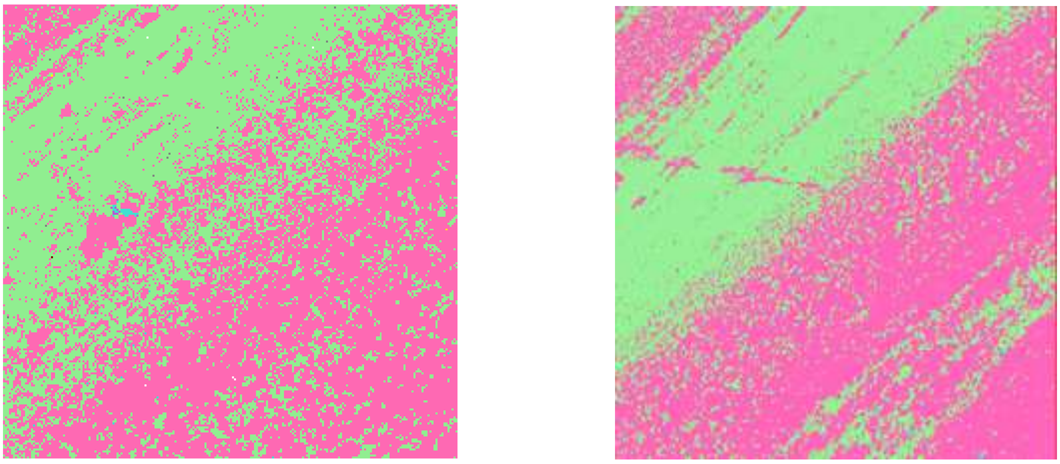

Fig 4.4 Sporadic hematite is present in quartz bands and vice versa

4.3 Results and discussions

BHJ sample is suitable for beneficiation for further sink and float analysis carried out. By using pre concentrator 30-40 % wt. of BHJ sample and 70-75 % silica gangue can be separated. Final concentrate yields up to 50-60% of Fe content and around 10-13% silica and this could be achieved by separation using gravity without grinding.

Size reduction is needed for further up gradation. It is indicative from the ratio of Iron ore minerals to gangue minerals.

4.4 Experimentation on iron ore slimes

Physical and Chemical Characterization Studies : the sample was collected from noamundi iron ore mine and brought for suitable sieving techniques in the mineral processing laboratory of mining engineering department to know average particle of sample. Sieve analysis of the sample is shown in the table given below.

Table 4.2 Sieve Analysis

SIZE FRACTION	(SIEVE MESH)	CONTENT (%)
-20		2.59
20	-40	3.0
40	-60	2.12
60	-100	3.1
100	-140	3.12
140	-200	3.78
200	-325	4.30
-325		77.91

Table 4.3 Chemical Analysis

Fe_2O_3%	Si_2O_3%	Al_2O_3%
62.55	2.35	3.46

Grinding test: for improving the grade of iron ore and for emancipation of iron values from associated particles, sample was gone through wet grinding test. Experiment was carried out in mineral processing laboratory, mining department using standard ball mill. Weights of balls were taken on the basis of bond index. The bond ball mill index test is a measure of the resistance of the material to crushing and grinding. Before arriving at different options for beneficiation grinding study is carried out. The objective was to achieve the maximum liberation of the Iron particles from the associated gangues due to reduction in size. So, the sample was put for the grinding study to produce samples for further investigations and to establish grinding parameters. At around 50 % solid consistency in ball mill all grinding studies were carried out.

4.5 Mineralogical Studies:

mineralogical characterization and Micro-morphological studies were carried out using SEM (scanning electron microscope). The study was done to analyse mineralogical content, micro morphology of individual particle and also to analyse constitution elements of slime. The results were integrated in the form of microanalysis tables and photo-micrographs. SEM study was carried out to know the content of Si, Al along with some Mn. Kaolinite is the main source of Alumina in Slime, which is most abundant in slime. Some of the manganese minerals like pyrolusite and others occur in association with iron bearing elements. These minerals don’t get separated during beneficiation and remain in final concentrate but there concentration is low. Most important problem with slime is there size is less than 20 microns so processing of such fines are always difficult task. This is reflected in the fact that although pellet grade concentrate can be obtained, the yield will be less. So it becomes necessary to remove ultra-fines for proper palletisation of ore.

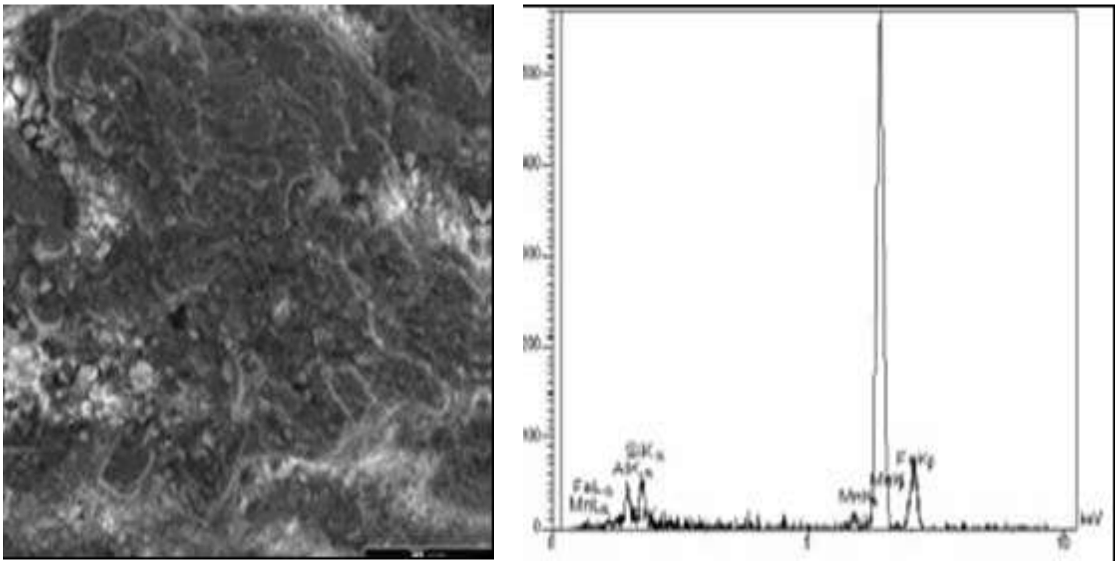

Fig 4.5 A typical SEM output of Iron ore slime with high Al content

4.6 ANALYSIS OF THE DATA ADAPTED FROM DIFFERENT MODES OF EXPERIMENTATION

1. From the sieve analysis of the slime sample it is clear that 77.91% of the slime is below 325 microns size

2. Presence of silica, aluminium in gauge sample was found by doing chemical analysis.

3. To liberate iron values from the interlocked gangue elements grinding study was carried out.

4. To study the extent of interlocking of different elemental constituents of the sample SEM study was carried out .by this study we know the presence of Al and Si. Al in the form of Kaolinite is the most abundant among the other constituents Manganese minerals such as Pyrolusite etc occur in association with iron bearing minerals. They generally don't get separated during processing and remain in the final concentrate. However, their yields are very low.

5. Through above studies it is clearly indicated that presence of Al and Si are there, so it need to be removed using proper beneficiation process.

CHAPTER-5

SUMMARY AND CONCLUSION

5. SUMMARY AND CONCLUSION

By looking at results indicated by characterization of the BHJ sample tests may be done using 2 Fundamental principles of separation namely:

- Magnetic separation
- Gravity Separation

Floatex gravity slime table is used for garavity separation and Wet high Intensity magnetic separator (WHIMS)is used for carrying out magnetic separation.

Drawback in using WHIMS technology is that the grains of jasper may concentrate at high intensities of gauss. Due to this problem separation by gravity using gravity spirals seems a more feasible and better option. Prior to gravity separation the sample may have to be subjected to pre concentration using wash waterless spirals. Different feed rates, pulp densities and splitter positions are used for conducting tests.

Iron ore slimes

The occurrence of Kaolinite causes high alumina content in the slime. Advancement in the field of beneficiation methods based on the principle of froth floatation/selective dispersion gravity separation, magnetic separation, and bio beneficiation can be used for the up gradation of iron ore slimes in India. The enhanced low alumina ore can then be used in the main stream industry for sintering and pelletization.

The waste management can be carried out using suitable techniques like, thermal conversion to iron and glass ceramics semi dry disposal, iron rich cements. Certain test need to be carried out to validate the effectiveness of the above techniques. Based on the results of the tests a suitable flow chart can be developed for the beneficiation of slime. The tests comprise floatation and WHIMS (Wet high intensity magnetic separator), hydrocyclone, spiral.

Hydrocyclone

For the upgradation of Iron values as well as for de-sliming of slime particles present in the sample Hydrocyclone can be used. Samples contain large amount of slime materials Containing of particles falling in the sub micron size category, de-sliming has to be carried out prior to flotation. The underflow and overflow constituents of the cyclone have to be collected at a steady state for a fixed time, dried, weighed and analysed for the desired Iron and other constituents. Further analysis of overflow & underflow samples collected at finest operating conditions should be done.

Spiral

To enrich the Iron content of the classified sample (hydrocyclone underflow) a spiral concentrator of 100 mm diameter can be used. Advantage of using spiral is that it is an energy saving gravity equipment where large quantities of sample can be served for pre concentrations. Iron ore sample has to be fed to the centrifugal pump at the requisite solids consistency and the slurry has to be kept re-circulating for a predetermined time in the spiral study. Complete concentrate and tailings are then to be collected after attaining the steady state. All the products thus achieved were dried, weighed and examined.

Wet High Intensity Magnetic Separation

The high gradient magnetic separator (HGMS) and wet high intensity magnetic separator (WHIMS) has to be used at various magnetic field intensities to recuperate the fine Iron values from the hydrocyclone over flow or spiral tailings. Different magnetic groves of width and matrix with movable currents to provide different magnetic intensities are provisions of both the separators .A desired concentration of solids has to be passed through the magnetic separator after this. Many a times the magnetic products have to be cleaned in second stage to enhance the superiority of the product from first stage separation.

Flotation

To select either direct or reverse flotation method to optimize reagent mixture and to generate the number of stages in the operations, batch flotation studies have to be carried out. Subaeration flotation machine needs to be used for the batch flotation studies Suitable frothing agent and Cationic and anionic reagents have to be used as collectors. To get good grade concentrate with high recoveries flotation condition needs to be optimised.

After this column flotation studies have to be carried out by using glass column of appropriate diameter. At nominal capacity of 15kg approximately of Iron ore fines per hour with the help of a peristaltic pump the column has to be operated. After attaining the steady state and analysed for Iron content both the concentrate and tailings are then to be collected separately.

After the validation of the above mentioned tests a general flowchart for removal of alumina can be generated .The procedure may vary from place to place subject on the nature of ore, its alumina content and the beneficiation methods have to be adopted according to it.

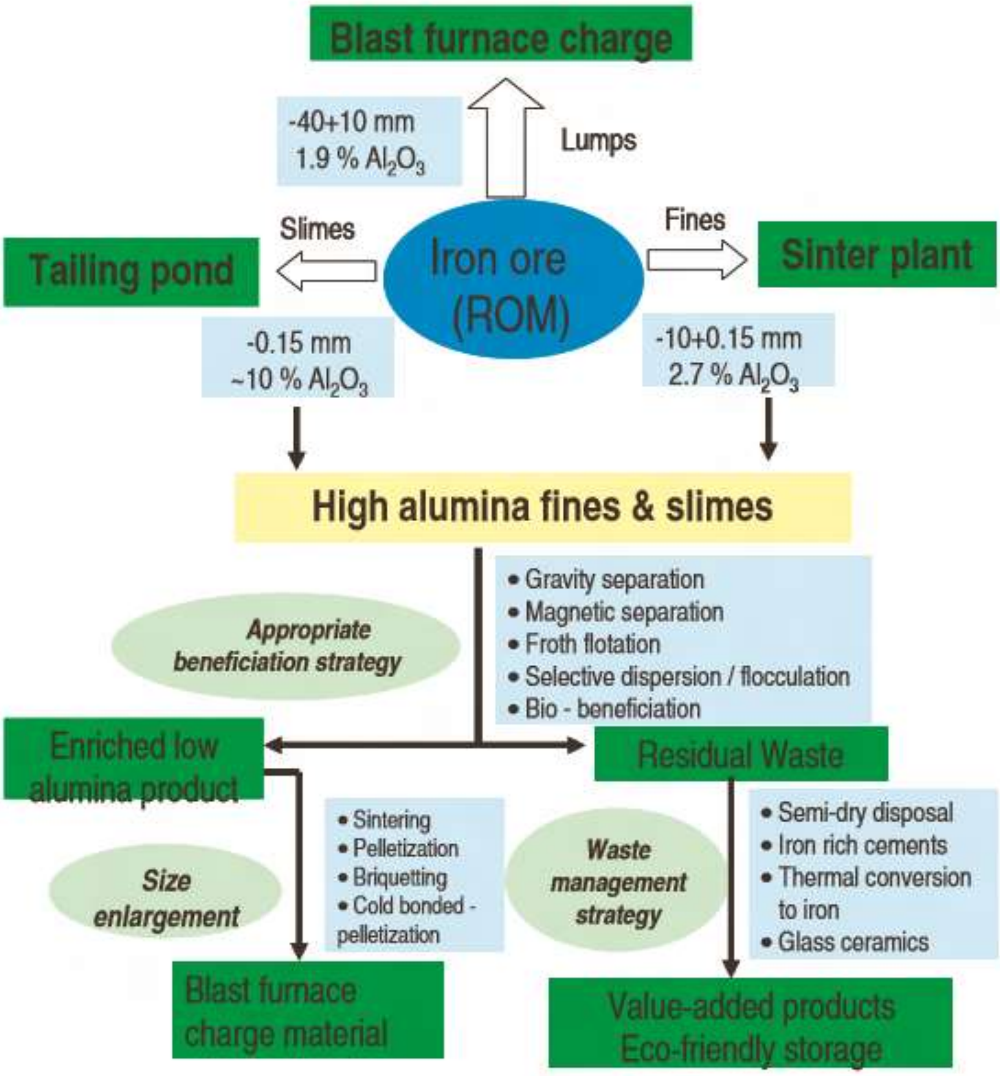

Fig 5.1: An integrated approach to removal of alumina from slime

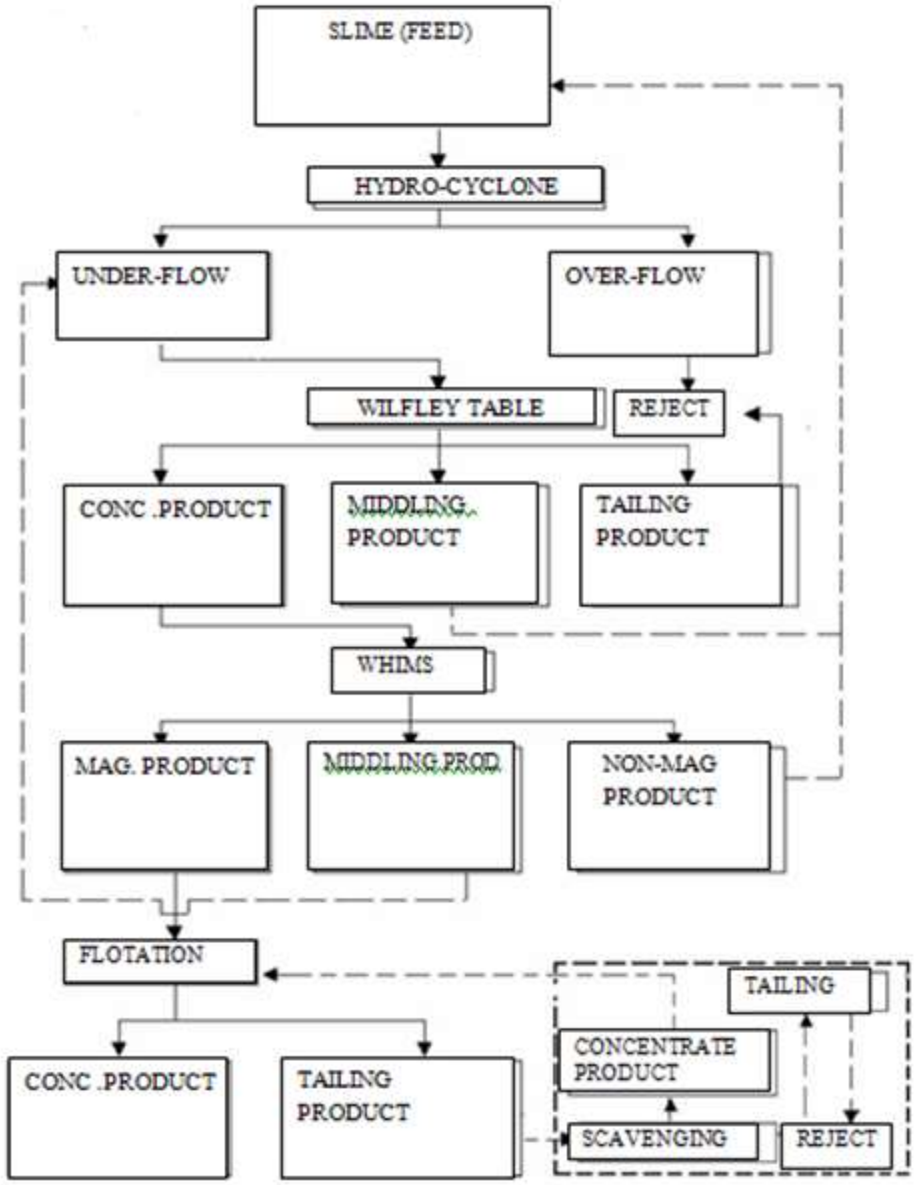

Fig 5.2: Flowchart for beneficiation of iron ore slime

CHAPTER-6

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6. REFERENCES

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