LECTURE NOTES

On

Mineral Processing

ORISSA SCHOOL OF MINING ENGINEERING
Governnnent of Odisha
ଓଡିଶା ଖଣି ଯାନ୍ତ୍ରିକ ବିଦ୍ୟାଳୟ, କେଓଁଝର

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CHAPTER :1

VARIOUS MINERAL RESOURCES OF INDIA

MINERALS	DEPOSITS	
Chromite	Orissa, Karnataka, Maharashtra, Jharkhand, Madhya Pradesh, Chhattisgarh, Tamil Nadu and Manipur.	
Bauxite	Orissa, Andhra Pradesh, Chhattisgarh, Gujarat, Maharashtra and Jharkhand.	
Copper	Singhbhum (Jharkhand), Balaghat (Madhya Pradesh) and Jhunjhunu and Alwar (Rajasthan).	
Iron Ore	1.Haematite resources are located in Orissa,Jharkhand, Chhattisgarh, Karnataka, Goa, Maharashtra, Andhra Pradesh and Rajasthan. 2.Magnetite resources are located in Karnataka, Andhra Pradesh, Goa, Kerala, Jharkhand, Rajasthan and Tamil Nadu.	
Lead Zinc	Rajasthan, West Bengal, Andhra Pradesh, Gujarat, Madhya Pradesh, Uttar Pradesh, Orissa, Maharashtra, Meghalaya, Tamil Nadu and Sikkim.	
Manganese	Main reserves fall in Karnataka, followed by Orissa, Madhya Pradesh, Maharashtra and Goa. Minor occurrences of manganese are in Andhra Pradesh, Jharkhand, Gujarat, Rajasthan and West Bengal.	
Tungsten	The main reserves are at Degana, Rajasthan. It also occurs in Maharashtra, Haryana, West Bengal and Andhra Pradesh.	
Dolomite	Madhya Pradesh, Chhattisgarh, Orissa, Gujarat, Karnataka, West Bengal, Uttar Pradesh and Maharashtra.	
Gypsum	Production of gypsum is confined to Rajasthan, Tamil Nadu, Jammu and Kashmir, and Gujarat. Rajasthan is the main producer of gypsum followed by Jammu and Kashmir.	
Graphite	Andhra Pradesh" Jharkhand, Gujarat, Karnataka, Kerala, Madhya Pradesh, Maharashtra, Orissa, Rajasthan and Tamil Nadu.	
Limestone	Madhya Pradesh, Chhattisgarh, Andhra Pradesh, and Gujarat: Rajasthan, Karnataka, Tamil Nadu, Maharashtra, Himachal Pradesh, Orissa, Bihar, Uttaranchal and Uttar Pradesh.	
Magnesite	Uttaranchal, Tamil Nadu and Rajasthan while minor deposits are in Jammu and Kashmir, Karnataka, Himachal Pradesh and Kerala.	

CHAPTER :- 2

UNIT OPERATIONS (ORE DRESSING)

Distinction between Mineral and Ore

MINERAL	ORE
● Minerals are naturally occurring inorganic solid compound with crystalline structure and a definite range of chemical. ● All Minerals are not ore. ● Clay is a mineral of aluminum.	● Ore is the rock form which the metal is extracted in a convenient and economically way. ● All ores are mineral. ● Bauxite is the main ore of aluminum.

★Explain the scope and objective of Ore dressing

■ORE DRESSING OR ORE BENEFICIATION

From metallurgical engineering point of view any physical operation carried out on the ore to enhance its quality and make it more suitable for subsequent operations will be termed as Ore Dressing or Mineral Beneficiation.

■ECONOMIC JUSTIFICATION OF MINERAL DRESSING

•To purify and upgrade the ore.

• Making smelting practice easier.

• Savings on Freight.

• Reduced losses of metal at the smelter.

• Reduction of the total smelting cost.

• Enhancing the efficiency of unit processes.

■ Scope of Ore Beneficiation:

1. It helps in eliminating unwanted chemical species from the bulk of the ore.

2. It helps in eliminating particles improper size and physical structure which may adversely affect the working of smelters, roasters etc.

•To eliminate unwanted chemical species:

To prepare the ore particle from chemical stand point, primarily involving the following steps:

a. Liberation of dissimilar particles from each other appearing in the bulk ore.

b. Separation of chemically dissimilar particles.

•**To prepare ore from physical standpoint,This involves:**

a. Reduction in size.

b. Separation of particles of dissimilar physical nature.

So the first step in ore beneficiation is size reduction causing libration. This is followed by separation of liberated particles as the second step in the process. These two steps are made to alternate to accomplish the desired end product most economically.

COMMINUTION AND LIBERATION

Comminution:- It is a size reduction process,it can be accomplished in both dry and wet conditions.

Liberation:- The process in which the mineral composition distribution in particles changes due to breakages is called liberation.

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CHAPTER : 3

CRUSHING

Gangue:-Unwanted particles or worthless portion of ore is known as gangue.

Comminution of any ore is carried out in several stages using different crushing equipments. So the objective crushing is to reduce the large lumps in to smaller sizes. Depending upon the feed and product particle size, the crushing operation can be classified as follows:

1. Primary crushing: The feed material is usually the run of mine.

2. Intermediate crushing or secondary crushing: The feed material is usually product of a jaw crusher.

3. Fine crushing or coarse grinding: The feed material is usually comes from the secondary crushers.

4. Fine Grinding: The objective of fine grinding is to produce ultrafine material less than one micron.

■ **Mechanism of Size Reduction:** Crushing is a mechanical operation in which a force of large magnitude is applied to a relatively brittle solid material in such a direction that its failure takes place. The theory of size reduction for solids is quite complex, but can be attributed to the action of following forces acting on the particle:

1. A huge compressive force exceeding the ultimate strength of the material may be responsible for size reduction as actually happens in case of jaw, gyratory and roll crushers.

2. A sufficiently high impact force may be responsible for size reduction. Impact force is largely utilized in hammer & ball mills.

3. Attrition, rubbing action or frictional forces may be utilized for size reduction. Such action is largely responsible for crushing in attrition mill, tube and pebble mills.

4. Cutting force is utilized in knife edge mills to reduce the size of fibrous materials like mica, asbestos.

Basic Requirements of Crushing Equipments:

An ideal crusher or grinder should have the following characteristics:

a. It should have a large capacity.

b. It should require a small (energy) input per unit weight of production.

c. It should yield a product of uniform size or in the required size range.

Classification of the Size Reduction Equipments:

(In The Order Of Finer Size Product)

A. Primary Crushers:

1. Jaw crusher.

2. Gyratory crusher.

B. Intermediate crushers:

1. Crushing rolls.

2. Cone crusher.

3. Disc crusher.

C. Fine crushers or Coarse Grinders:

1. Ball Mill.

D. Fine Grinders:

1. Rod mill.

2. Pebble mill.

3. Tube mill.

4. Hammer mill with internal classifier.

● **Primary crushers are of two types:**

1. Jaw crusher.

2. Gyratory crusher.

Classification of Jaw Crushers:

From capacity and working mechanism point of view jaw crushers are three types such as:

1. Blake crusher.

2. Dodge crusher.

3. Universal crusher.

The functional figure of different jaw crushers are as shown

schematically in the figure.

BLAKE JAW CRUSHER

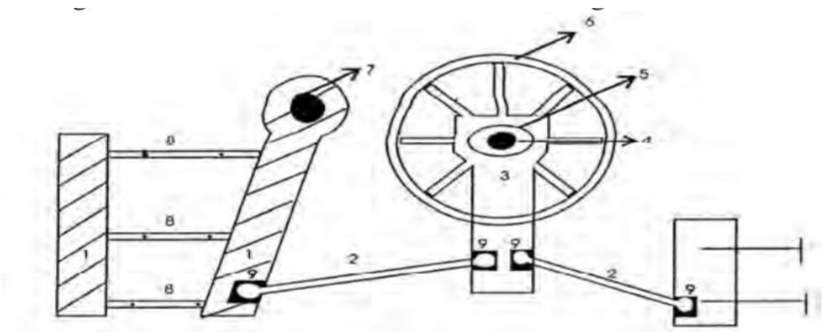
It is a primary crusher used most widely. It has its moving jaw pivoted (hinged).Though the working principles of Blake and Dodge crushers may be different from constructional point of view they are almost identical excepting two notable differences which will be discussed afterward. The Blake crusher may be classified as single toggle or double toggle type.

Application of Blake Jaw Crusher

It is used for reducing run-of-mine ore or coal to a size small enough to be taken by the next crusher in the series during the first stage of crushing.

Technical Specifications

1. Toggle Type: Single or double toggle



1. Jaw Plates 2. Toggles 3. Pitman 4.Main Shaft
5. Eccentric 6. Flywheel 7. Top hinge 8. Check P
9. Bearings
[Blake Jaw Crusher]

2. Feed size: 100 mm

3. Product Size: (5-15) mm

4. Capacity: 20-30 kg/hr.

5. Jaw Type: One fixed jaw and one movable jaw with Mn steel Liner. Provisions for output gap adjustment is available.

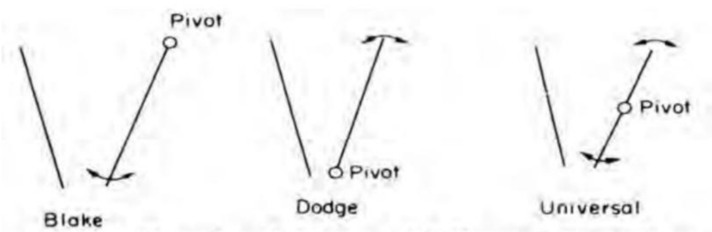


Fig-- Functional figures of different jaw crushers.

6. Feed materials: Coal, iron ore, Mn ore, Chromite ore, Rock, Mg ore,Aluminium ore etc.

7. Motor capacity: Preferably with (415-440) V/3Ph/50Hz electric supply,and onsite isolator switch

Comparison between Blake & Dodge Crusher:

BLAKE JAW CRUSHER	**DODGE JAW CRUSHER**
1.It has got two toggles.	1. It has one toggle in the form of a llever
2. It has no pitman	2. It has no pitman
3.The movable jaw is pivoted at the top,so has a variable product discharge opening while feed receiving opening is fixed.	3. The movable jaw is pivoted at the bottom so the discharge opening is fixed. The set is fixed, while the feed receiving opening varies. This results in almost uniform sized product.
4.No choking takes place here as it has variable discharge. It operates on principle of forced feed.	4. Choking is a very common problem as the set is quite small compared to receiving opening.
5.This crusher is mechanically more balanced and has fewer breakdowns.Further it is built for much larger capacity.	5. Mechanically the design of this crusher is inferior. So it is built only to lower capacity. This machine has more breakdowns as compared to the other.
6. Product size distribution is large & produces more fines.	6. Product size distribution is more uniform.
7. Blake is preferred at large industrial setups where elaborate screening facility is available along with other comminution machines.	7. A dodge is preferred where jaw crusher is to be used as the only comminution equipment.
8. This machine is of higher cost for same output.	8. This machine is cheaper for same output.
9. Because of forced feed lubrication it yields a coarser product.	9. As choke feeding is possible, it can yield a much finer product.

GYRATORY CRUSHER:

Classification of Gyratory Crusher: Gyratory crushers have been developed recently in order to supply a machine with a larger capacity than jaw crushers.The best known gyratory crushers are:

1. Suspended spindle gyratory crusher.

2. Parallel Pinch or Telsmith gyratory crushers.

Of late the suspended spindle gyratory has been obsolete and only the parallel pinch gyratory is used widely. Theoretically the parallel pinch is not a gyratory crusher since the crushing head rotates eccentrically instead of gyrating.

It consists of two substantially vertical truncated conical shells. The outer shell has its apex pointing down while the inner cone has its apex pointing up. The outer conical shell is fixed rigidly to the main frame while the inner cone or the crushing cone is mounted on a heavy central shaft also known as spindle.

The upper end-of the shaft is held in a flexible bearing while the lower end is driven by an eccentric so as to describe a circle. Because of this eccentric rotation, the inner cone thus rotates inside the outer cone alternately approaching and receding from all the points on the inner periphery of the outer shell.The solids caught in the V-shaped space between the crushing heads are broken repeatedly until they pass at the bottom. The crushing action takes place all over the cone surface.

The gyration speed varies from 125-425 r.p.m. As the gyratory crusher operates continuously, for an equivalent size of the crushing heads,the capacity per unit area of grinding surface of the gyratory crusher is much larger than that of Blake jaw crusher. As the crushing action is

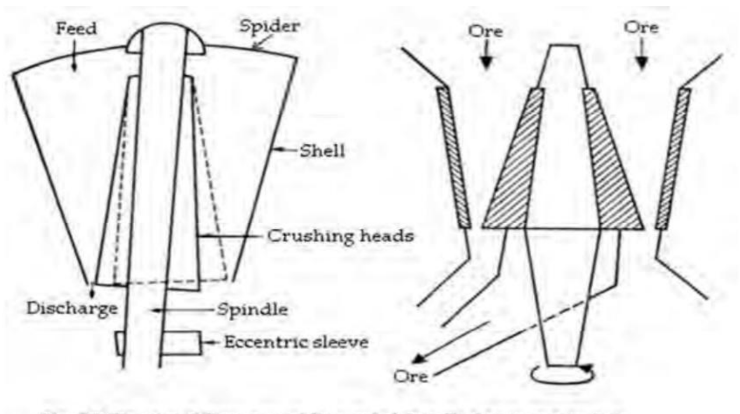


Fig. 2.5. Functional Elements of Suspended Spindle Gyratory Crusher.

continuous,the fluctuating stresses on machine members are minimized and it consumes less power. Thus it has a better efficiency compared to jaw crusher. The product from gyratory crusher is much more uniform compared to the jaw crusher. Because of the high capital cost, the crusher is most suitable for very large output.

Characteristics of Gyratory Crusher:

1. At any cross section there are in effect two sets of jaws opening and closing alternatively like a conventional jaw crusher. Hence gyratory crusher can be regarded as a series combination of infinitely large number of jaw crushers of infinitely small width. Hence the capacity of the gyratory crusher is much greater than that of a jaw crusher having equivalent gape size.

2. It has more regular power draft due to continuous crushing action.

3. With respect to the reduction ratio, at fixed power consumption and equivalent capacity, both jaw and gyratory crusher are at par4. The rule of installing a gyratory crushers or jaw crusher is given by Taggart as follows:

If the hourly tonnage to be crushed divided by square of gape expressed in inches yields a

JAW CRUSHER	GYRATORY CRUSHER
1.The loading on machine components is intermittent and the power draft irregular.	1.Uniform loading on the machine components with regular power draft.
2.Crushing action isintermittent.	2. Crushing action is almost continuous.
3. For a particular gape size the capacity is less compared to gyratory crusher.	3. For the same gape size the capacity is much larger
4. Its feed acceptance size is much larger compared to gyratory crusher.	4.Its feed acceptance size is much less compared tojaw crusher for the some capacity.
5. Product particle size distribution varies widely &it has a reduction ratio less than that of the gyratory crusher.	5.More uniform sized product is obtained with a larger r.r.
6. Power consumption is higher for jaw crusher for a particular r.r.& capacity.	6. With the same r.r.& capacity, the gyratory crusherrequires less power.
7. The crusher is less efficient compared to gyratory crusher It has an efficiency of10 -20%.	7.Ithas an efficiency of 30 - 50%.
8. The wear on the jaw plates is not uniform which causes heavy wear on the jaw plates at certain areas.The jaw plates are replaced frequently.	8.The wear on the crushing cone is quite uniform. If the bottom opening changes, the inner cone can be lifted up by the variable bearing toreduce the gap. So the heads can serve for a longer time.
9.Not much variation can be obtained with regards to product particle size.	9. Wide variation in product size can be obtained by varying the setting of the central shaft. The set can be varied as per requirement.
10. It has a low cost of installation.	10. It has a high cost of installation.
11. It is better for lower production rates.	11. It is better for higher production rates.

quotient less than 0.115 than use a jaw crusher or else use a gyratory crusher.

Comparison between Jaw & Gyratory Crusher

Mathematically:

$$\text{If, } \frac{T}{Gape^2} > 0.115, \textit{select Gyratory crusher.}$$

$$\text{And, } \frac{T}{Gape^2} < 0.115, \textit{select Jaw crusher},$$

Where, T is expressed in tons per hour and *gape* is expressed in inches.

Intermidiate Crusher:-Generally products from the jaw crusher or gyratory crusher are not fine enough for the complete liberation of mineral grains and needs further size reduction. The product is charged into either cone crusher or crushing rolls for further size reduction. Cone crushers and crushing rolls are the equipments for intermediate range crushing.

Cone Crusher: This type crusher is a newer development. They have gained wide popularity because of their economical operation in the intermediate range. The general types are: Simon's Cone Crusher and TelsmithGyrosphere.

- The product of Primary crusher is the input of Intermediate Crusher .

  There are 2 types of cone crusher

  1. SIMON'S CONE CRUSHER

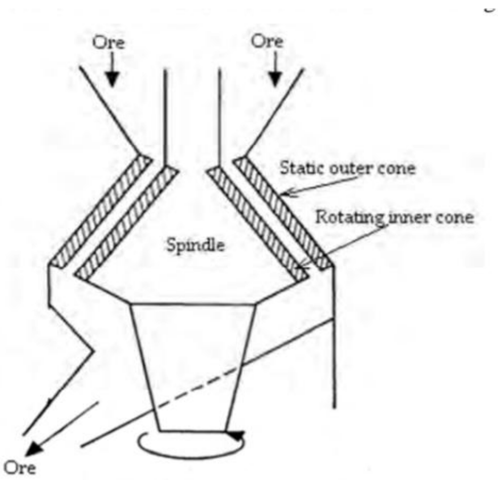


Fig.2.6. Sectional view of a Cone Crusher.

2. TELSMITH GYROSPHERE

CONSTRUCTION OF CONE CRUSHER:-

- The construction of this cone crusher is much similar to gyratory Crusher, though the feed size is much smaller and the product is much finer.
- There are two cone inside cone crusher

I.FIXED OUT CONE

II.ROTATING INNER CONE

- Inner cone is connected to shaft which rotates eccentrically.
- Crushing heads are made of hardfield Manganese steel.
- Depending on the set materials can have different sizes.
- Compared to crushing rolls it has better capacity and low reduction ratio.
- Normally dry feed is used,wet feed is not used because it lags the system.

LIMITATIONS:

1. It operates only on closely sized brittle material.

2. It has a low reduction ratio.

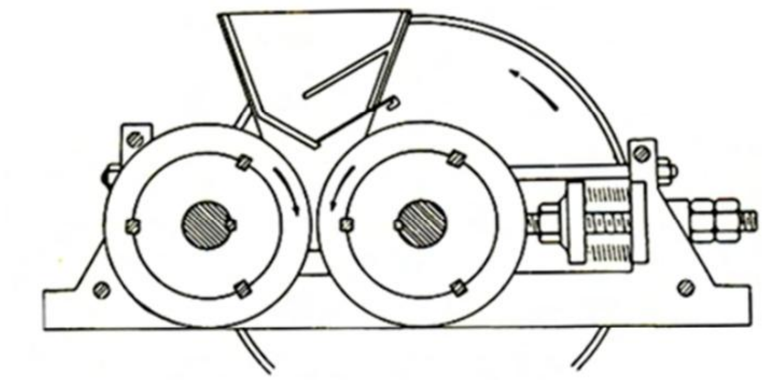
3. It needs extensive lubrication of all its moving part regularly.

4. It operates best in closed circuit grinding.

Crushing Rolls:

- Consist at two heavy cylindrical roll revolving /rotating towardseach other
- Rolls are made of wear resisting cast hadfield manganese steel
- Roll centers are at the same height separated by a distance.
- Crushing occur by compressive force.
- Rolls turn towards each other at same speed to avoid slip.
- Rolls are 300mm diameter and 600mm long.
- Roll speed is 50-300rpm
- Feed size 12-75mm
- Product size 12-20mm.

CRUSHING ROLL



ANGLE NIP OF A CRUSHER

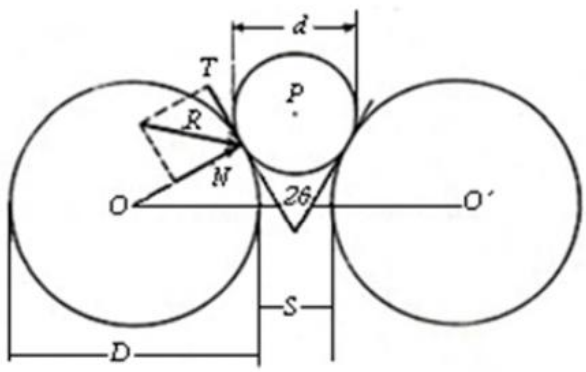
It is defined as the angle subtended between the two tangents drawn at the points of contact of the rolls and the particle to be crushed.

1. Roll diameter (D).

2. Particle diameter (d).

3. Inter roll distance (S). Assuming the particle to be spherical.

4. Friction factor between the roll & the mineral (μ).



Characteristics of the Crushing Rolls:

1. It has a reduction ratio (r.r) is around 3 - 4 only which is very low compared to other size reduction equipments.

2. It yields a uniform sized product.

3. The product of the crushing rolls contains fewer fines as the mastification time is limited and no repeated crushing takes place.

4. Capacity:

Capacity of the roll crusher depends on the following factors:

i. Speed of revolution (N).

ii. Width of the faces (W).

iii. Diameter of the rolls (D).

iv. Set (S), the inter roll distance

v. Specific gravity of rock (ρ) lb /in3

6. Rolls can be operated either wet or dry. Dry crushing has a lower output but causes lesser wear of the rolls.

5. It is best operated on choke feeding for maximum output. In open feeding the output is less.

Uses:

The rolls are most suitable in effecting only a smaller size reduction in a single operation. Therefore, it is common to employ a number of pair of rolls in series to achieve higher reduction ration. Crushing rolls are extensively used in crushing oil seeds, gun powder and coal because of lower residence time of the feed as lower residence time reduces the effect of heat on the feed material.

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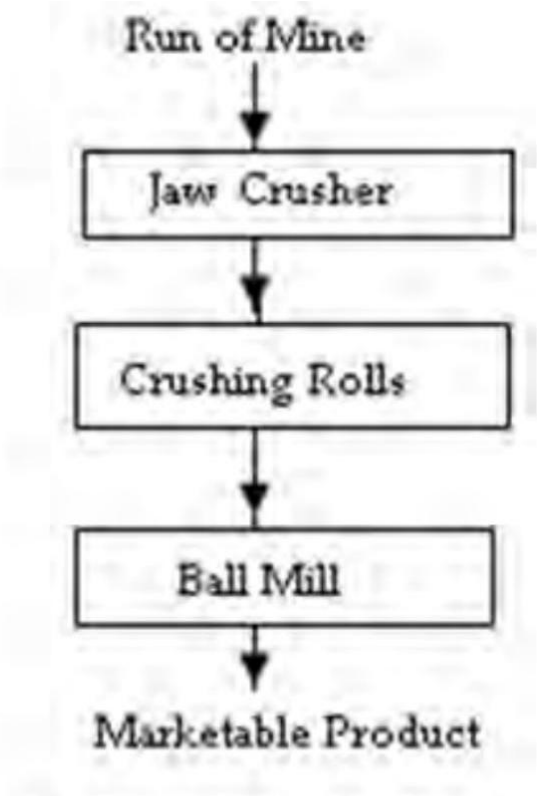
CHAPTER :-4

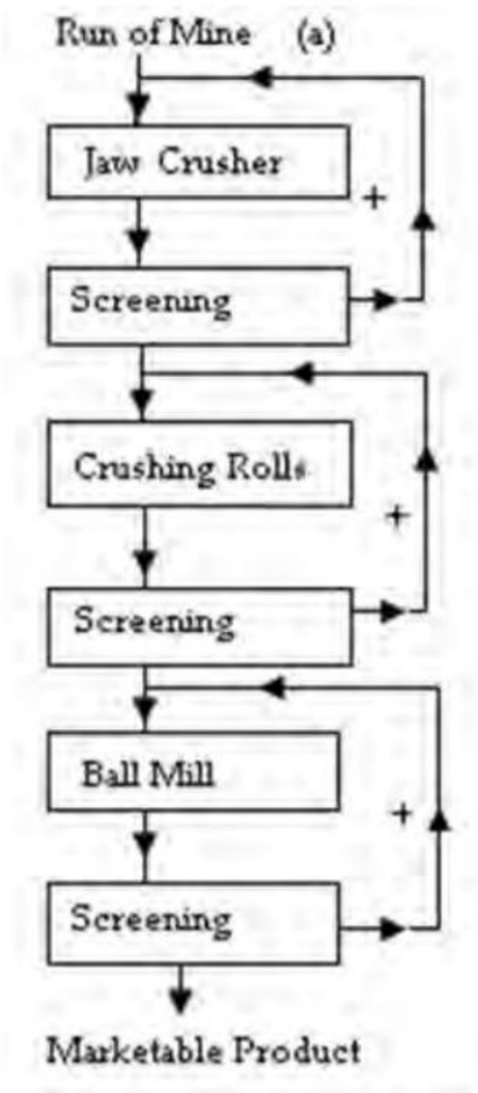
GRINDING

Open Circuit Grinding Operations: The usual meaning of grinding here is comminution and has nothing to do the product particle size. In many mills the feed is broken into particles of satisfactory size by passing it once through the mill. When no attempt is made to return the over sized particles in the product once again to the crusher for further size reduction the product simply passes-off to the next stage of size reduction.

Such a method of size reduction at various stages till the desired product is obtained is termed as open circuit grinding. A bright example is dodge crusher operating on choke feeding. This grinding may require excessive amount of power and much of the energy is wasted in regrinding the particles that are already fine enough.



Close Circuit Grinding Operation: In another method the partially crushed material is screened and the oversized material is returned back to the crusher for further crushing and the undersized product is given as the feed to the next machine for further size reduction. If such a method is followed in all successive crushers till the desired product is obtained it is termed as closed circuit grinding. This method of grinding operation is generally adopted as such a process has been found to be economical making full capacity utilization of all equipments efficiently. This process avoids unnecessaryregrinding.



BALL MILL

Classification of Ball Mills:

Ball mills can be classified according to the

a. Shape of the mill.

b. Methods of discharge of the ground ore.

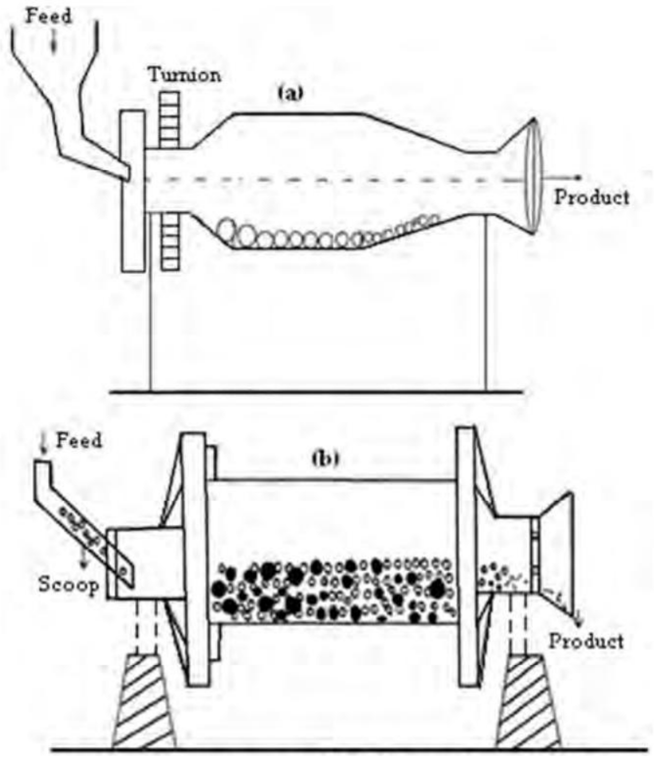
c. Weather the grinding is conducted dry or wet.

Shape of the Mills:

According to the shape the mills are classified as:

1. Cylindro-conical mills: Harding mill (where feed & discharge ends are fixed).

2. Cylindrical mills. This represents the usual ball mills.



2. Method of Discharge:

Cylindrical mills are also classified according to the mode of product discharge taking place from the mill. According to the discharge method mills are classified as:

a. Peripheral discharge mill: Discharge of the ground product takes place through meshed cylindrical shell.

b. Grate mill: Discharge of the ground product takes place through a screen extending as a diaphragm across the full section of the mill at the discharge end.

c. Overflow mill: Discharge of the ground product takes place by free overflow from the axis of the mill.

GRINDING MILLS 273

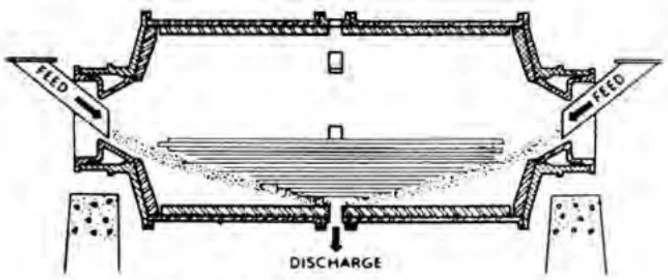


FIG. 7.16. Central peripheral discharge mill.

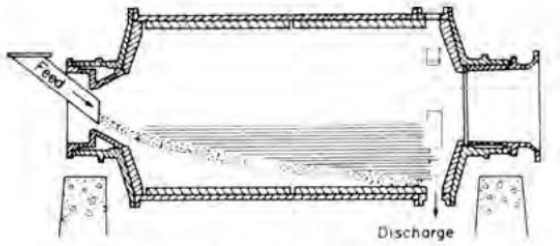


FIG. 7.17. End peripheral discharge mill.

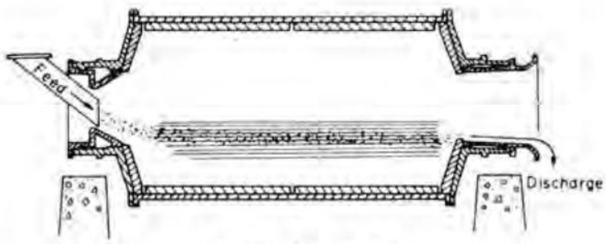


FIG. 7.18. Overflow mill.

<u>Theory of Ball Mill Operation:</u>

Ball mills may be continuous or batch type in which grinding media and the ore to be ground are rotated around the axis of the mill. Due to the friction between the liners–balls & liners–ore lumps, both the ore and balls are carried up along the inner wall of the shell nearly to the top from where the grinding media fall down on the ore particles below creating a heavy impact on them. This usually happens at the toe of the ball mill.

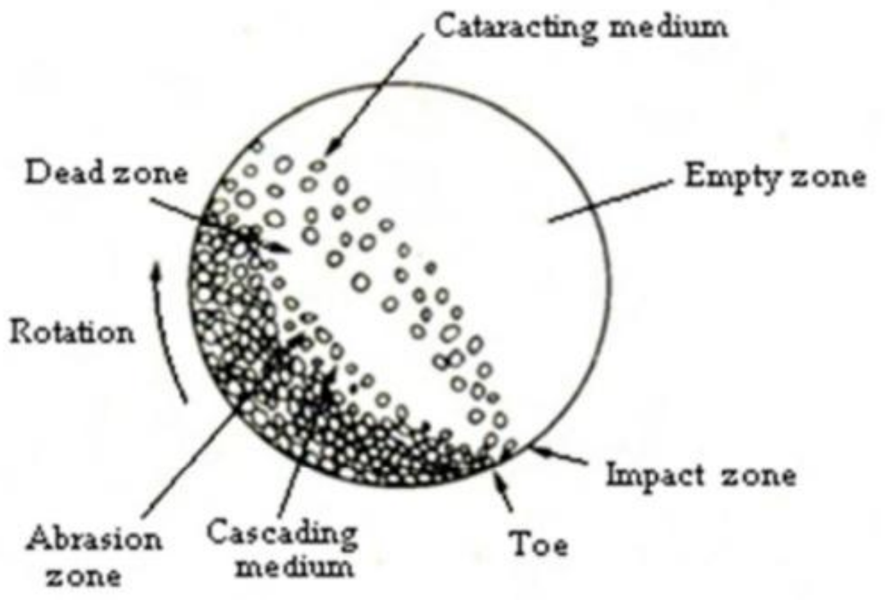
The energy expanded in the lifting up the grinding media is thus utilized in reducing the size of the particles as the rotation of the mill is continued. In fact the grinding process is attributed to three different stages of ball mill working. They are:

a. Cascading (attrition between the balls and particles).

b. Cataracting (impact of the ball on the particles).

c. Centrifuging.

All these stages of working are shown schematically in below



CASCADING:- Grinding occurs due to attrition,and balls will not be carried up along the inner wall to a greater height,they roll over each other or slip.

CATARACTING:-If speed increases then balls will be raised to a greater height and fall down and create a large impact, This impact is largely responsible for most of the grinding.

CENTRIFUGING:-If the speed of rotation becomes too high, the balls are carried over and over again all along the inner lining as if they are sticking to the inner wall and there is hardly any grinding. This condition is known as centrifuging of the mill.

CHAPTER :-5

LABORATORY SIZING TECHNIQUE

Introduction

Size analysis of various products of a crushing mill constitutes a fundamental part of the laboratory testing procedure.particle size has a great role to playduring reactions between solid - liquid or solid-gas.So the product from the crushing equipment is to be analysed for its size for all practical purposes. Further the size analysis of the product is required to evaluate the energy consumption and the size reduction process it may require for further size reduction.

Particle size and shape

The size of a spherical particle can be defined uniquely by its diameter. However, there is no unique dimension by which the size of an irregular particle can be described. The term most often used to describe an irregular particle is the equivalent diameter ($\overline{)}$). There can be various shapes to describe a particle as discussed below:

1. Accicular: Needle like particles.
2. Angular: Sharp edged polyhedrons.
3. Crystalline: Particles of regular geometric shapes.
4. Fibrous: Regular or irregular thread like particles.
5. Dendritic: Particles having branched crystalline structure.
6. Flaky: Plate like particles.
7. Granular: Equidimensional irregular shaped particles.
8. Irregular: Lack of any symmetry in the particles.
9. Nodular: Particles having rounded irregular shape.

Particle Size:

The crushed ore particles are generally irregular in shape and it is quite difficult to define the size of the particle uniquely. In case of spherical particles, the diameter is the size. For cubes the edges, the long diameter or diameter of a sphere of equal volume may be considered as the size. But for totally irregular particles there is no such standard method. So it is impossible to define what is meant by size of the particle.

Common Methods of Size Analysis:

Particle size is usually defined as the narrowest regular aperture through which mineral particle passes through. Through this definition is applicable to polyhedrons it is not valid for rod shaped narrow particles. Particle size can be determined by various methods as described below table;

Methods	**Approximate size range (microns) (1 μm = 10^{-6} m)**
Sieve analysis	100000 -10
Elutriation	40 – 5.0
Optical microscopy	50 – 0.25
Sedimentation(gravity)	40 – 1.0
Sedimentation(centrifugal)	5 – 0.05
Electron microscopy	1 – 0.005

Microscopic Measurement: For measuring the particle size under microscope, it is customary to sprinkle them on a slide and to measure their diameter in random directions or in any two perpendicular axes within the plane of vision. In both the cases the smallest dimension is neglected. For number of particles the dimension +is measured and tabulated as follows:

Number of observations	x_i
1	x_1
2	x_2
n-1	x_{n-1}
N	x_n

Now average size, $\bar{x} = \frac{x_1+x_2+x_3+x_{n-1}+x_n}{n}$

2. Elutriation: Elutriation is based on the fact that a particle will just be sustained in an upward rising current of water or any other fluid if the velocity of the water current is equal to that which the particle would attain when falling in still water. This works on the principle of Stoke's law of settling.

3. Sieve Analysis: This is the most important method of sizing the mineral particles. This is widely used to determine the efficiency of size reduction operations and also used as a yardstick for assessing the fineness of a ground product. As sieve analysis has been the most important method of size analysis it has become pertinent to discuss about the standard screens British Standard Sieves:

British standard sieves :-

In the British system a screen is designated with a number called mesh number and the aperture of screen opening is termed as mesh size. Mesh number is defined as the number of square openings available per linear inch length on the screen surface. If the screen has 4 openings per linear inch length of the screen surface then the mesh number of the screen is 4. Likewise we have screens of 20, 40 … 200, 270and 400 mesh number. When mesh number increases aperture of the screen opening decreases and vice versa. or sieves used worldwide for the purpose.

ASTM Standard Sieve Series:

Mesh Number	Aperture (in mm)	Mesh Number	Aperture (in mm)
3	6.680	35	0.417
4	4.699	48	0.295
6	3.362	65	0.208
8	2.362	100	0.147
10	1.651	150	0.104
14	1.168	200	0.074
20	0.833	270	0.052
28	0.589	400	0.037

<u>Screen Analysis Equipment:</u> For sieve analysis, screening is usually carried out in a mechanised sieve shaker called Ro-tap sieve shaker. Ro-Tap Sieve Shaker: Figure3.2.shows the Ro-tap machine schematically. It consists of a movable cage with a base a and a top plate b between which 13 half height or 7 full height sieves with pan and cover lid can be mounted. 55 The mounted sieves are subjected to rotary shifting motion while at the same time the lever c strikes the top plate once per revolution. This striking vibrates the screen cloth for better screening. A timer switch with the motor is used to control the time duration of screening. The machine is so designed that it performs the most ideal screening operation within the specified time period.

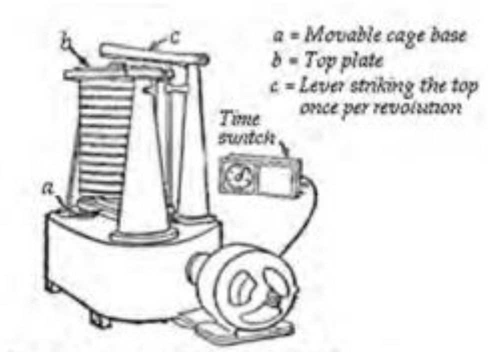


Fig 3.2. Rotap Sieve Shaker

CHAPTER:06

INDUSTRIAL SCREENING

a. Properly sized or the required sized material is charged into the next comminution equipments for further size reduction. Proper feed size reduces the overloading on the subsequent size reduction machines and increases the overall efficiency of the comminution.

b. Properly sized material can be charged into the process reactors such as smelters, roasters or calcinators making the process more efficient.

Till now screening has only been discussed on a laboratory scale but for industrial need, the screening has to be carried out in a much larger scale. Thus large scale screening is termed as industrial screening which differs from the laboratory screening practices in many ways. It is important to know the methods those are available and also the factors which affect the process of industrial screening.

Purposes of Screening:

1. To prevent the entry of undersized material to the crushing machines so as to increase the capacity and efficiency of comminution.

2. To prevent oversized material from passing to the next stage in closed circuit crushing or grinding.

3. To prepare closely sized feed for next stage of unit operation such as gravity concentration.

4. To prepare closely sized end product as per specification and requirement.

Mechanism of Screening:

When a crushed product is kept on a screen something would pass through &something would be retained on it. The material passing through screen openings is known as under flow or under sized while the material retained is known as over flow or over sized. So the basic fact attached to screening is the passage of under sized material through the screen. There are several factors affecting this passage.

The factors are

1. The absolute size of the screen openings.

2. The relative size of the particle to that of the screen aperture.

3. The percentage of open area available on the screening surface.

4. The angle at which particle strikes the screening surface.

5. The speed with which the particle strikes the screening surface.

6. The moisture content of the material to be screened.

7. The opportunity offered to each particle to hit the screening surface that is the probability that a particle will hit the screening surface before it is taken away by overflow.

Effect of Screen Opening Size: The passage of undersized particles though each opening is inversely proportional to the screen aperture. This leads to the fundamental conclusion that the other conditions remaining unchanged the capacity of a screen given in tons per hour per sq. foot per millimeter screen aperture increases with increase in screen opening size.

Effect of Relative Particle Size: The relative size of the particle and the aperture size control the passage of the particles through the screen. Larger sized particles with larger aperture get screened easily as compared to smaller sized particles on finer screens

Percentage of Open Area on the Total Screening Surface: If the total surface area is one square meter and there are only few openings on it then the quantity of screened material will also be quite less.

Angle at Which the Particle Strikes Screening Surface:

The crushed particles are always irregular in size and shape. Hence, the angle at which the particles hit the screen surface is extremely important. Most efficient results are obtained, when the particles hit the screen surface at angle in the range of o 45−60 Degree .

Screening Surfaces: Screening surfaces are the surfaces through which screening takes place. Screening surfaces are categorised according to the mode of their manufacturing classified as follows:

Parallel Rods: Such a surface is usually made-up-of steel bars, rails, channels and etc. It can also be made from wood and bamboo

Punched Plates: The surfaces are punched steel sheets or plates of various patterns. The openings are normally circular, rectangular, hexagonal and slot like.

Woven Wires: The screening surfaces are woven carefully by gauged wires. These wires are generally made up of steel, bronze, copper & monels.

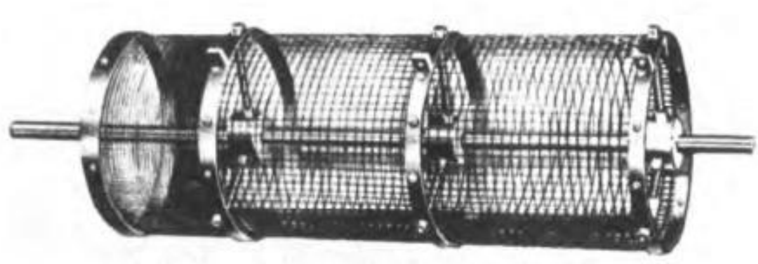
Types of Screens: The screens are classified as

1. Stationary.

2. Moving**.**

Stationary screens:

These screens are of limited use but are not totally obsolete. These screens are grizzlies. They consist of parallel rods, bars or woven wire mesh set at an angle to the ground. They have heavy screening surfaces. The bars are usually held together at right angles to their length and are spaced at the desired distance sleeves on the bolts. They are usually employed in case of coarse crushing. A slope is generally provided so that the material fed onto the screen surface would roll down facilitating better screening.The major disadvantage of this type of screen is clogging. Rails are used under severe service conditions with openings greater than five (5) inches .



Moving Screens

1. Moving grizzlies.

2. Trommels or Revolving screens

3. Shaking screens.

4. Vibrating screens.

Moving Grizzlies: The grizzly is made up of rods and bars but have movements as compared to stationary grizzly. 61 In moving grizzlies alternate bars or rods alternatively rise and subside, so that the feed material move forward gently with sufficient turning over. There are different grizzlies such as:

a. Moving-bar grizzly.

b. Chain grizzly.

c. Travelling grizzly.

d. Disc or Roller type grizzly.

e. Vibrating grizzly.

f. Shaking grizzly

Advantages of Grizzlies

a. Low floor space is required for installation.

b. They act as feeders to intermediate crushers.

c. Result in better screening than stationary screens.

TROMMELS (REVOLVING SCREENS-REELS) .

- They are rotating cylindrical shells of screen material(punched sheet).
- They are 3-4 ft in dia and 5-10 ft long.
- The material to be screened flows into the shell.
- The shell rotates.
- The shell is kept in an inclined position.
- The particles move towards the discharge (lower) end.
- The undersize particles are collected at the bottom.

Two types of operation.

1. Cylinders are in one line-finest screen first, coarsest last.The first cylinder is fed with the crushed ore. Very fine particles are separated. The coarse oversize is fed to the next screen and the process continues.

2. Compound (concentric) trommel. Screens are made to rotate on a single shaft. The coarsest screen is the innermost and the finest screen is the outer most.

Advantages of Trommels:

- It requires smaller floor space
- It has a larger capacity per unit screening area.
- It is cheap to operate.
- Several fractions are obtained in one go.
- Screening operation is quite efficient, can utilize both wet and dry screening.

Vibrating Screens: Vibrating screens are recent development and have made most of the other screening practices obsolete. It is essentially a flat plane screening surface made from punched plates or wire woven which is secured rigidly on a steel frame. This frame is attached to certain mechanical device which imparts a reciprocating up and down motion to the screen in the direction either normal to the screen surface or at a high angle to the screen surface. These screens can be driven electrically or mechanically. The particles passing through the screen is the under flow and particles retained on it are discharged as overflow continuously at the other end.

Multi Deck Vibrating Screens: When only one screen is used in the vibrating setup it is called single deck vibrating screen. But similar to compound trommel, multiple numbers of screens can be used in the set up. Then it will be called a multideck vibrating screen. In case of multideck vibrating screen a number of screens are used one over the other, fixed rigidly to the main frame. The coarsest screen is at the upper most position and the finest screen is at the bottom most position. So by using this technique we get number of over sized material fractions on each screen. Sometimes the vibrating screens are placed in an inclined fashion so as to facilitate automatic discharge utilizing the natural force of gravity.

Advantages of Multideck Screens:

- It requires minimum floor space.
- It operates continuously.
- The problem of screen blinding in this screen is less.
- The screen surface can be repaired easily compared to trommels

Disadvantage of Multideck Screens:

There is heavy wear of screen cloth or material in vibratory screens.

Comparison between Shaking & Vibrating Screens:

- Shaking screens have number of advantages over most of the vibrating screens in terms of cost of operation& installation.
- Shaking screens can be set almost flat during operation.
- But they are more prone to heavy wear and require more frequent and expensive repairs compared to vibrating screens.

Different types of classifiers and their applications :-

Classifiers:

Classifiers are broadly classified into three categories:

- Sorting classifier: It uses a relatively dense aqueous suspension as the fluid medium for classification.
- Sizing classifier: It uses a relatively dilute aqueous suspension as the fluid medium for classification.
- Sizing classifiers: It uses air as the fluid medium for classification.

Sorting Classifiers: Hindered settling takes place in sorting classifiers. The separation achieved by sorting is a sizing operation modified by specific gravity & shape of the particle. It is usually applied to coarser products. A dense suspension of 40 - 70% solids by weight is used depending on specific gravity, size of the particles to be sorted. The usual types of sorting classifiers are:

a. A simple launder classifier or Evans' classifier.

b. Richard's hinder settling classifier.
c. Richard's pulsator classifier.
d. Hydrotator classifier.

Evans Classifier: Evans' classifier consists of a sloping launder, A. Opening to this launder several rectangular boxes BC are attached. To the rectangular boxes spigots, O are fitted which are capable of discharging out. Pipes are suspended from a main water pipeline into the rectangular boxes. Water is introduced into the boxes through these pipes and the flow is controlled by valve, F.

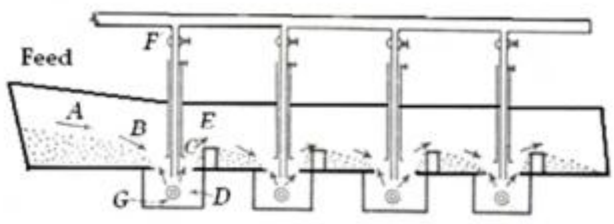
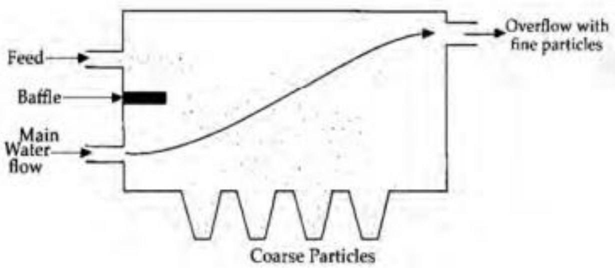


Fig.5.3. Evans Classifier.

The working of this classifier is quite simple. As water is introduced into the boxes, faster settling particles are discharged out through the spigot and slower settling particles overflow at E, to the next box in the launder. Baffles, E are fitted to the launder to restrict the return of particles to the same box from where they have been taken away as overflow. Depending upon the number of rectangular boxes & spigot attached to the launder several products are obtained. Water flow rate in each successive pipe is reduced as the sizes of the particles settling get reduced successively.

Richards Hindered Setting Classifier:

It is a modified version of Evans classifier. In this classifier, cylindrical sorting columns replace the boxes of the Evans classifier. More interestingly water is introduced into the cylindrical sorting column from below through radial or tangential ports. Richards Pulsator classifier is characterized by the use of an intermittent or pulsating upward current of water designed to make settling totally hindered.



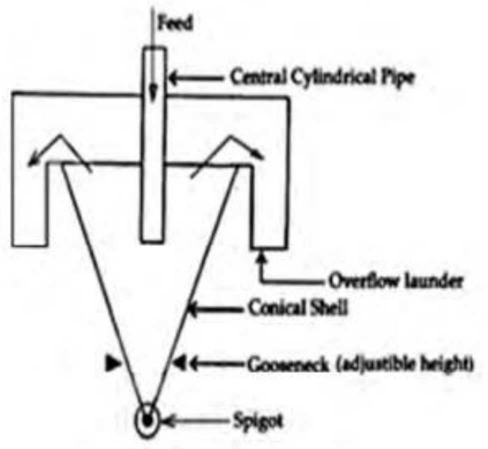
RICHARDS HINDERED SETTLER

Sizing Classifiers: Sizing classifiers utilize free settling conditions to effect sizing as much as possible being unaffected by specific gravity & shape of the particles. These classifiers do not require any additional water besides that is present in the suspension undergoing classification. Sizing classifier may be subdivided into

1. Settling cones having no moving parts
2. Mechanical classifiers having moving parts.

They may use water or air as classifying medium. Classifier using air is known as pneumatic classifier where the settling speed is around 100 times faster as compared to the settling speeds in water classifiers.

Settling Cones: Settling coned are conical sheet metal shells with apex at the bottom and a peripheral overflow launder at the top. Feed is charged through the central cylindrical bottomless pipe as shown in the below figure to prevent the bypassing of the feed to the overflow. Spigot at the bottom of the conical shell discharges the sediment. A gooseneck pipe of adjustable height is provided to guide the sediment away from the tank.



Settling Cone

CHAPTER:7

GRAVITY CONCENTRATION

Flowing Film Concentration:-

Before discussing the principles of flowing films concentration, it is important to have an idea of fluid flow. Fluid flow can be classified into three categories:

a. Laminar or streamline flow.
b. Turbulent flow or erratic flow.
c. Mixed flow

A combination of laminar and turbulent flow. All these fluid flow conditions are determined quantitatively by studying about the dimensionless quantity Reynolds number (Re).

Mathematically:

$R_e = \frac{VD}{\eta}$, where,

D = Diameter of the pipe in centimeters.

V = Average velocity of fluid in the pipe, centimeter/sec.

η = is a term defined as *Viscosity* of the fluid.

The flow pattern can be determined theoretically from the numerical value of the Reynolds R_e number for that flow.

a. If $R_e \leq 2100$ then such a flow is termed as laminar flow.

b. If $R_e > 4000$ then such a flow is termed as turbulent flow or erratic flow.

c. If the condition is such that $2100 < R_e \leq 4000$ then such a flow is termed as mixed flow.

Viscosity of Fluids (η):

Viscosity is defined as the internal fiction of fluid which resists the shear force acting on the fluid. This is an intrinsic property of the fluid at particular temperature & pressure. For liquids a rise in temperature lowers the viscosity η and for gases rise in temperature increases the viscosity η. Both viscosity and kinematic viscosity are interrelated with a factor i.e., the specific gravity of the fluid.

Mathematically:

$$\gamma = \frac{\eta}{\rho}$$

γ = Kinematic viscosity of the fluid.

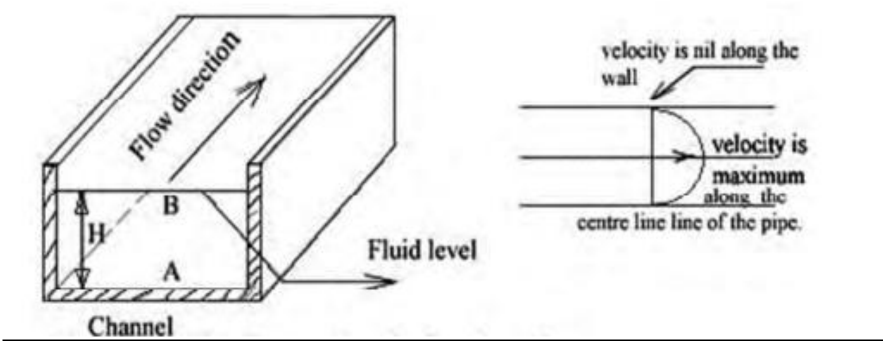
η = Viscosity of the fluid

ρ = Specific gravity of the fluid

Units:

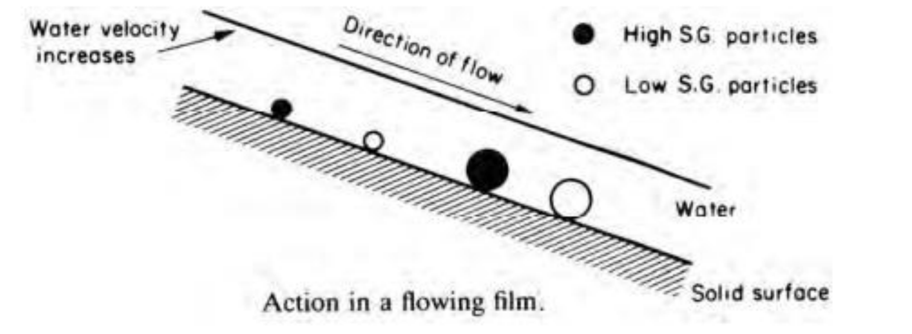
1. Viscosity unit is poise = 1 dyne .sec /cm^2
2. Kinematic viscosity unit is Stoke.

<u>Flowing Film Concentration:</u> Liquid films under laminar flow have specific mechanical property that can be easily adopted to separate the minerals according their specific gravities. The specific mechanical property is that, the velocity of the fluid is not the same at all depths of the film. Lets us imagine the fluid is flowing in rectangular open channels as shown schematically in the below figure. In this case the velocity at the bottom of the depth A is nil and is maximum at the top B.



Similarly in case of a pipe, the flow rate is highest along the central axis and nil at the inner periphery of the pipe. This property in turn depends upon the viscosity of the fluid.

This physical sense of speed difference during fluid flow at different depths can be exploited industrially to result in mineral beneficiation. The flowing fluid film can effectively separate coarse light particles from the dense smaller particles. The action of a flowing fluid film on the mineral grains is shown schematically in the below figure.



<u>Action in a Flowing Film</u>

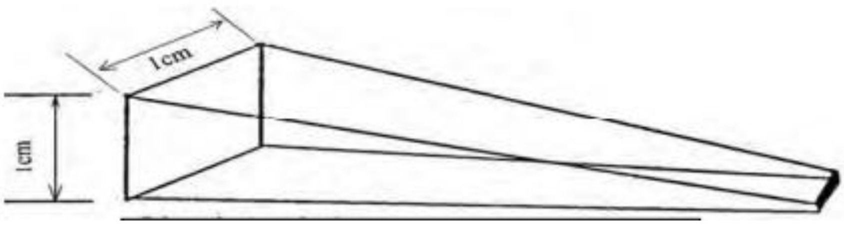
Mineral beneficiation carried out by the above principle is known as Tabling. The experimental facts regarding particle classification utilizing the principle of flowing film concentration can be summarized as follows where the down slope sequence of particles is:

1. Fine-heavy particles.
2. Coarse -heavy and fine light particles.
3. Coarse - light particles.

WILFLEY TABLE

Principle of Wilfley Table

- The velocity of the fluid is not the same at all depths of the fluid film.
- The variation in fluid velocity happens due to the viscosity o the fluids.
- Flowing fluid film can effectively separate coarse light particles from the heavy small particles.
- During tabling larger spherical particles move faster than the fixe irregular particles down the strem during tabling.
- Tabling takes place on an inclined shaking table which is known as wilfley table.
- Flat plane surface is called DECK.
- Table is shaken asymmetrically .
- The lighter gangue materials are thrown into the suspension and are discharged out over the edge of the table opposite to the feed box by the wash water.
- Speed of the table (200 – 300) strokes\min.
- Stroke Length (12 – 15)mm
- Finer feed material ➔ Higher speed ➔ Smaller stroke length.



- 2/3rd of total surface area of table is cleated/ riffled and rest 1/3rd portion is unriffled.
-

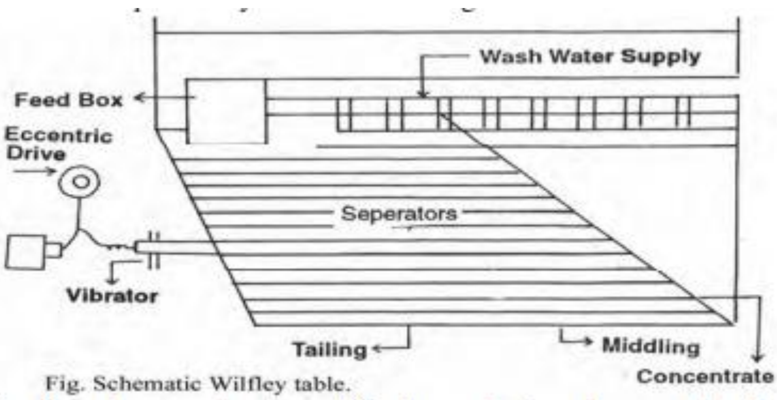


Fig. Schematic Wilfley table.

- The normal inclination in both the directions is limited to 0-3 degrees. For majority of ores a slope of 0.75-1.25 degrees is used.

Cost of Operation.

- Power 0.5 ---------- 0.8 Kw/hr
- Repairing, cost of cleats & deck as and when required.

Important Use of Wilfley Table:

- It is widely used to concentrate cassiterite or tin ore.
- It is widely used to concentrate free milled gold ores.
- It is widely used for beneficiation of nonmetallics like glass and sand.
- It is widely used for beneficiation chromite and tungsten ores.
- It is widely used to recover the part of galena and sphalerite in coarse aggregate of lead-zinc ores. 5. It is widely used for cleaning fine coal.
- It is widely used for beneficiation of some iron ores.
- It is adopted as a pilot and guide to flotation plants.

JIGGING :-

Jigging is one of the most ancient methods of ore concentration. It is a special form of hindered settling resulting in stratification of particles into layers of different specific gravities followed by removal of the stratified layers. The stratification is achieved by repeatedly affording an opportunity to a very thick suspension of mixed particles to settle for a short time.

Principles of Jigging: The three physical factors responsible for stratifications of particles during jigging are:

a. Hindered settling classification.
b. Differential acceleration at the beginning of the fall.
c. Consolidation trickling at the end of the fall.

Hindered settling classification:

The essential difference in hindered settling in jigs and classifiers is that in jigging the solid -fluid mixture is very thick and it approximates to a loosely packed bed of solids with interstitial fluid flowing through the particles rather than fluid carrying the solid particles with it happens in the case of classifiers. The thick solid-fluid suspension used in jigs cannot be maintained for a long length of time and also doesn't allow sufficient play between the particles for their complete rearrangement. As the jigs produce a fluidized bed for few seconds, it offers an open bed alternatively and particle rearrangement takes place during that time period only. Other parameters remaining same higher settling ratios are obtainable in jigs compared to classifiers.

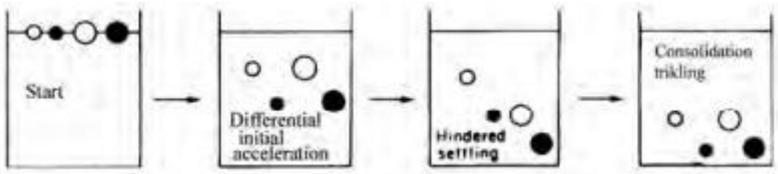
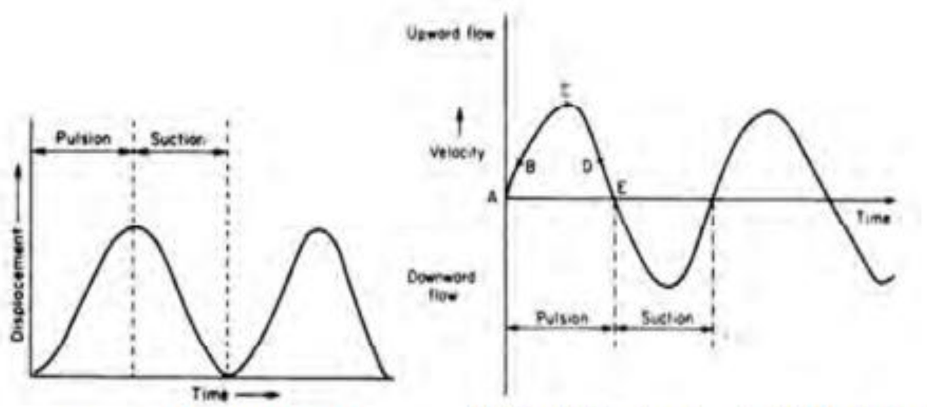


Fig.7.1. Effect of Hindered Settling During Jigging.

Jigging Cycles: Short falls are to be realized in jigs for stratification to occur. This is obtained by pulsation and suction of water or any other fluid through a bed of ground ore held on a perforated grate or sieve. During pulsation & suction the fluid moves up and downward respectively with reference to a stationary point. Fig.7.3. Consolidation Trickling. 99 During pulsation the ore bed expands while during suction the bed gets compacted. Most jigs use bath pulsation & suction, but in same jigs the suction is avoided. The plot of fluid velocity with respect to time describing a full cycle of pulsation and suction is termed as jigging cycle.



(a) Movement of the piston in a jig.

(b) Speed of flow through ore bed during the jigging.

Fig.7.4. A Schematic Jigging Cycle.

Different jigging cycles:

Jigging cycle is said to consist of pulsation and suction.Below figure shows several jigging cycles schematically.

- Type A & B use pulsation only.
- Type C & D use pulsation and suction both being symmetrical.
- Type E asymmetrical pulsation and suction.
- Type F symmetric but unequal suction and pulsation.

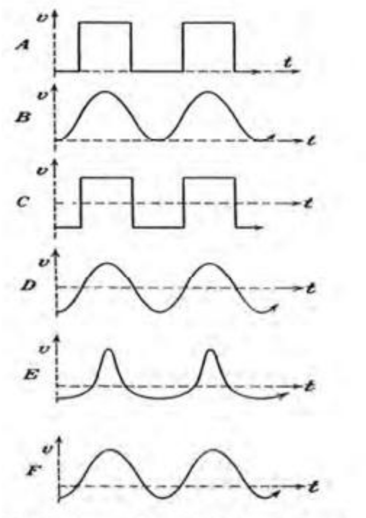


Fig.7.5. Several Idealized Jigging Cycles.

Classification of Jigs

Jigs are classified to two types:

a. Hand jig.
b. Mechanical jig.

Hand jig:

This is the simplest of all jigs which consists of a framed sieve held by hands and is actuated by the operator with a reciprocating vertical motion. In general a perforated cylindrical shape container is used. After filling up the vessel with minerals up to the desired level it is closed tightly. With a rope and pulley arrangement it is made to move up and down in a water tank to attain the condition of pulsation and suction of water in the mineral bed. As the process is continued or repeated for several times complete stratification takes place. This jig is mainly used in the laboratory to demonstrate the effect of jigging operation.

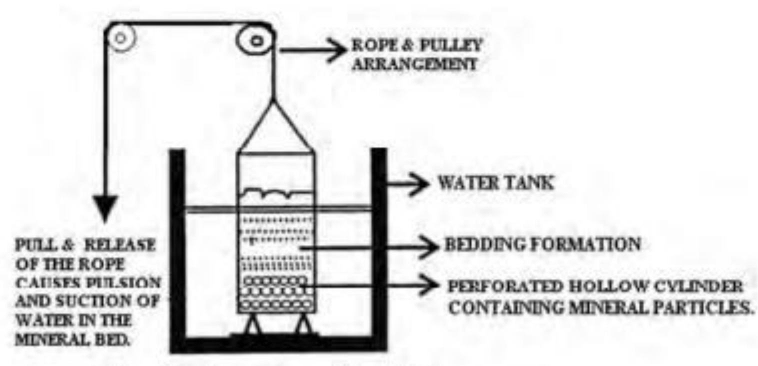


Fig. Laboratory Hand Jig.

Mechanical jigs:

Mechanical Jigs are of various types. But regardless of type they are essentially composed of:

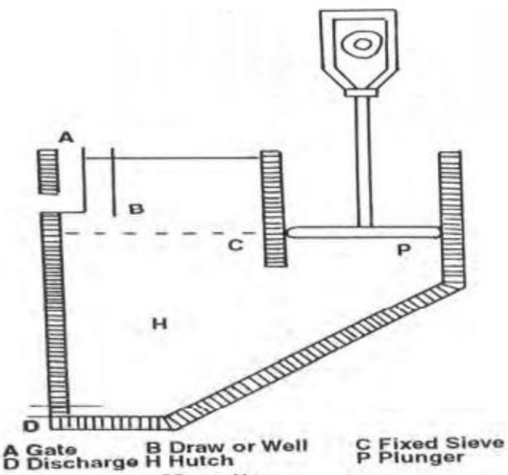
i. shallow open tank containing a screen-bottom on which ore is supported.
ii. A A hydraulic water chamber or hutch.
iii. A reciprocating system for pulsation and suction of water through the screen.

<u>Typical Mechanical Jig:</u>

There are different mechanical jigs such as:

1. Fixed sieve plunger jig.
2. Fixed sieve Pulsator jig.
3. Pneumatic or Baum jig.

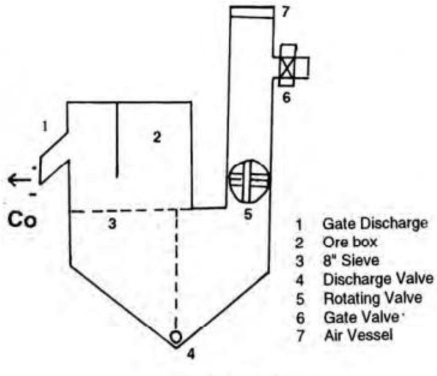
<u>Fixed Sieve Plunger Jig (Harz Jig):</u> The harz jig has a fixed sieve. The jigging motion is obtained by plunger, P reciprocating in a compartment adjoining the sieve compartment, C. The bottom layer (usually the concentrate) is removed through the gate, A. The upper layer (usually tailings) is discharged at the end away from the feed. Working: The crushed & graded ore is held on the sieve, C. Water is held in the hutch, when the plunger is pushed down water rushes up and when the plunger is moved up, water rushes down through the mineral bed held on the screen. 104 When water moves up it imparts a pulsation and when water moves down it imparts suction to the mineral bed. So both pulsation and suction takes place alternatively resulting in jigging. Jigging duration ranges from 0.2 to 0.6 sec (100-300 cycles per minute).



Harz jig

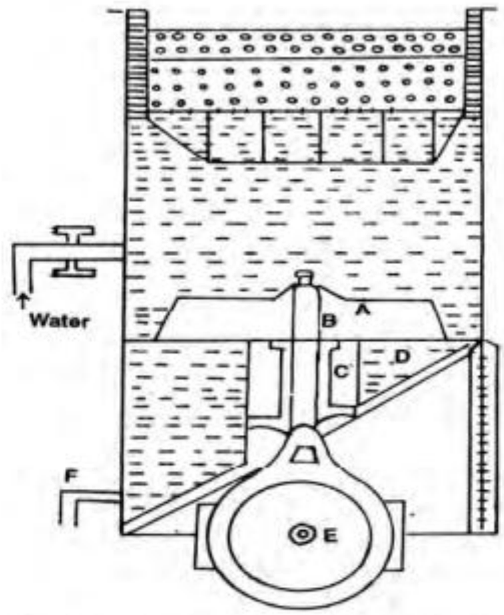
<u>2. Plunger Jig:</u> The plunger jig consists of ore box of size: 24''x8''x6'' fitted to one half of the tank and then plunger is fixed in the other half. The plunger is made to move up and down by mechanical arrangement. The bifurcation board between the jigging and plunger section at the centre extend sufficiently below the jigging sieve to ensure even arrival of water impulses at the sieve. Sieve plays an important role in jigging. Different types of jigs are used for different materials. Smaller materials use woven wire sieves, average sized material use punch plates while larger sized materials need barred grates.

<u>3. Pulsator jigs:</u> In this class of jigs there no suction stroke. The jigging is due to impulses of water flowing under pressure from the water service point. These impulses are obtained by placing a rotating device in the water service line. The number of impulses is around 200/minute. This type of jig can handle around 100tons/sq.foot/day.



Pulsator Jig

4. Diaphragm Jigs: Bendelari diaphragm jig is the most popular diaphragm jig used worldwide. This jig is an improved version of Harz type jig. In this case a diaphragm is used in place of plunger to produce pulsion and suction of water in the ore bed held on the sieve. The mineral separation is rapid compared to Harz jig. Constructional features of this jig are shown schematically in the figure.



A Movable Plunger with Rubber Diaphragm
B Driving rod through a Sealed Opening (C)
D Hutch Compartment
E Eccentric Arrangement
F Hutch Discharge

Fig. Bendelari Jig

In this case the plunger is sealed to the frame by a rubber diaphragm; hence there is no water leakage around the plunger which is a frequent problem in harz jig. Further the jigging surface is more accessible in this case as the actuating mechanism is placed at the bottom.

This results in an appreciable saving in floor space and weight. 107 Compared to the Harz jig, the Bendelari jig has a more open bed, larger capacity consumes less water and requires less maintenance. The jigging cycles range from 0.2-0.8 seconds, i.e.100-160 strokes per minute.

<u>5. Pneumatic or Baum Jigs:</u> Baum jig resembles the plunger jig in construction but differs in the working principle. With little modification it has been in use for the last 150 years. Presently it is extremely popular in coal washing. In this case air under pressure is forced in& out of a large air chamber on one side of the jig vessel causing pulsion and suction to the jig water. This in turn causes pulsion and suction through the crushed coal bed held on the screen. Thus stratification is caused finally. Baum jig has the advantage of handling wide range of sizes with high capacity.

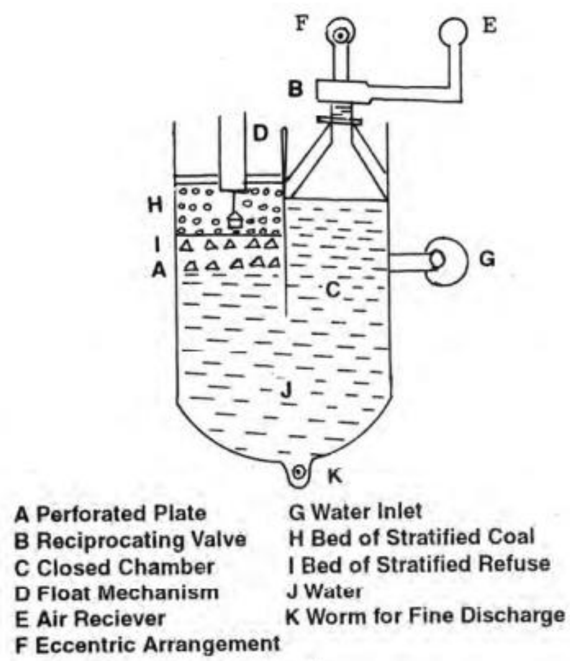


Fig. Baum Jig

<u>Advantages of Jigs:</u>

1. Jigs are primarily used to concentrate coarse-minerals. In coal washing, up to 4 - 5inches coal pieces can be washed in Jigs. In case of ores, pieces up to I inch size can be treated. Hydraulic jigs can wash coal up to 1/8 inch & minerals as fine as 20#. Pneumatic jigs can treat minerals as fine 65# mesh and as coarse as 1-1.5 inches but not in a wider size range.
2. Excluding washing of coal it is used widely to beneficiate non magnetic iron ores.
3. Jigs are cheap to operate and substantially foolproof and offers an easy access for inspection.

Limitations of Jigs:

- Jigs are obsolete for sulphide ores.
- It requires large amount of water during ore beneficiation.
- Fines cannot be treated in jigs. Jigging is applicable to the ore that is too coarse for complete liberation.
- Jigs do not provide a complete solution to any mineral beneficiation problem.

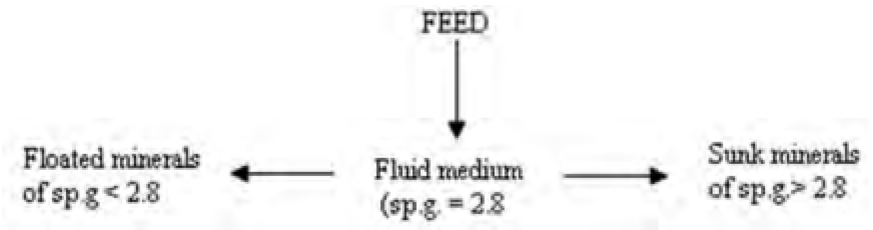
CHAPTER:- 8

HEAVY MEDIA SEPARATION

Introduction:

If a fluid is available whose specific gravity is intermediate between two solids which are to be to separated, then one of the simplest process will be to suspend the mixed mass in that fluid. As per law of buoyancy, one of the solids will float at the top of fluid level while the other one will sink to the bottom of the vessel. Then a mechanical arrangement will be required to draw 85 out different products from the top and bottom of the vessel. A typical example can be the separation of wood chips from gravel or sand using water medium.

Principle of Heavy Media Separation: The basic principle involved in the gravity concentration process is the 'Float and Sink'. This is carried out by using a fluid whose specific gravity is in between the specific gravities of the two mixed up minerals particles in the crushed ore. Since most of the minerals are heavier than water, water is not a suitable fluid medium for practicing 'float and sink' method of separation. For this process to be effective fluids heavier than water are required. The below figure explains the basic principle involved in HMS.



Laboratory Grade Heavy Fluids: Most of the heavy organic liquids are used as heavy fluids and can be used only on a laboratory scale to assess the optimum separation obtainable by gravity concentration. One of the most useful heavy fluids is acetylene tetra bromide whose specific gravity is 2.96. This fluid can be diluted with carbon tetra chloride with sp.8 of 1.59 to yield a series of fluids with a sp.g varying from 2.96 to 1.59. Another group of useful fluids of low specific gravity is the aqueous solution of zinc chloride ($ZnCl2$) and calcium chloride ($CaCl2$). High cost of laboratory heavy fluids precludes their employment in industrial applications.

Industrial Grade Heavy Fluids: For industrial application pseudo liquids can be prepared by suspending solids in water. These fluids can be used almost like true liquids provided the particles to be separated are coarser compared to the size of particles used to prepare the medium. This medium is continuously agitated to prevent settling of particles used to form the pseudo fluid but the agitation allows the settling of heavy particles in the crushed ore to be separated. Finely divided quartz, magnetite, galena or ferrosilicon is used for making up the suspension. The above figure Scheme of heavy Media Separation. 86 range of specific gravity for fluids of commercial interest is 1.3-2. Such fluids are mainly used to separate coal from clay. Pseudo fluids are much cheaper than organic liquids of high specific gravity, so the cost of fluid loss is not significant. But on the other hand, the use of pseudo fluids is not as simple as that of true fluids.

Heavy Media Separation Circuit: A simple heavy media separation circuit would essentially consist of the followings:

i.A separating vessel in which heavy suspension is kept with a provision for introducing the feed and withdrawing the product continuously.

ii. Means to clean the product separated, recover the media and recirculate it to the vessel for further utilization.

Specific Industrial Processes Using Heavy Liquids:

Three different processes have been developed until now using true heavy liquids. The processes are:

1. Lessing Process.
2. Bertrand Process.
3. Du Pont Process.

Lessing Process:

Lessing process is used to clean coal in a solution of calcium chloride having an approximate specific gravity of 1.4. It is most useful in separating coal from clay & slate.

Lessing's Settling Tank: Settling takes place in a cylindrical tank of 30 ft height & 6-10 ft. diameter with a conical bottom as shown schematically in the figure6.2. Graded raw coal freed from dust and fines is introduced into the tank through a central pipe to mix up with the separating solution thoroughly. As per "float & sink" principle cleaned coal floats up and is removed from the tank by a chain scrapper or any such mechanical arrangement. The slate, shale and sand drop to the 'conical bottom and are removed by the help of a bucket conveyor. Both cleaned coal and slate are delivered to the draining towers.

After draining, they are washed clean of the $CaCl_2$ solution. The wash liquor is returned to the concentration tank for recalculation $CaCl_2$ solution to the settling tank.

320 liters of CaCI2 1iquor is withdrawn from the separating tank after each ton of raw coal cleaned. During cleaning of coal the specific gravity of the parting solution drops to 1.2 from 1.4 due to addition of wash water and inherent moisture in the coal. 320 liters of parting liquid withdrawn from the tank is made-up to 640 titers and concentrated to a volume to yield $CaCl_2$ 87 solution of specific gravity 1.4. Subsequently the solution is recirculated to the separating tank for further cleaning of coal.

CHAPTER – 9

FLOTATION

Introduction:

Flotation is the most widely used method of wet concentration of ores for separating the valuable constituent of the ore from the worthless gangue. The process is primarily a surface phenomena based on the adhesion of some mineral particles to air and simultaneous adhesion of other particles to water in the pulp. It is the most efficient but is the most complex of all ore beneficiation processes. A In this process adhesion is made between air bubbles and small mineral particles in such a way that they rise in that pulp. The floating mineralized froth is then skimmed off while the other minerals are retained in the pulp. The above fact is known as flotation proper. There is another term called skin flotation.

In general flotation depends on a number of interrelated physico-chemical factors. After treatment with reagents, the air bubbles attach it to the mineral particles and lift them up to the surface of water. The mineral is usually transferred to the froth leaving behind the gangue in the pulp. This is termed as direct flotation. However, during reverse flotation the gangue is separated into the float fraction while the valuable mineral is retained in the pulp.

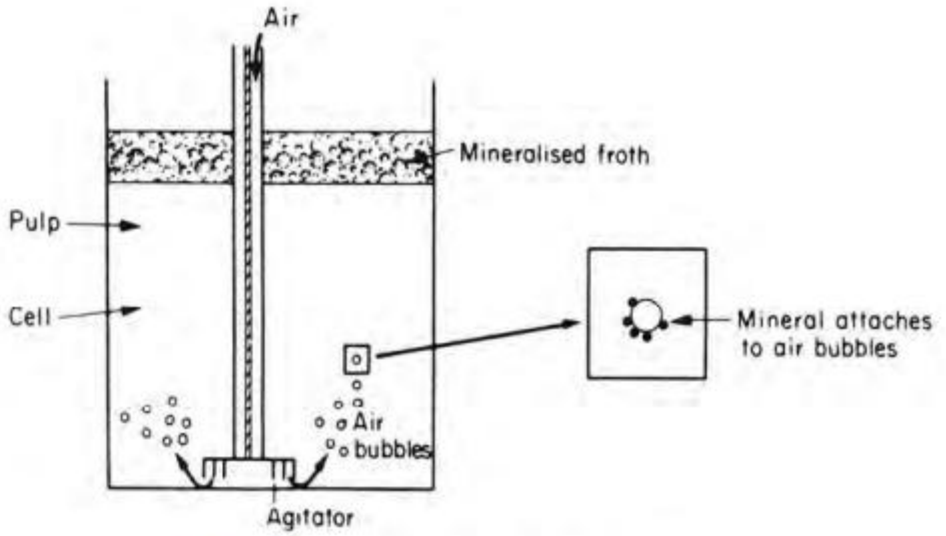


Fig.9.1. Basic Principles of Flotation.

Physico-Chemical Principles of Flotation: Physico-chemical principles of flotation can be explained in terms of surface energy & surface tension, contact angle, polarity and adsorption.

Flotation Reagents:

Froth flotation being a physico-chemical process requires a number of chemical reagents for its successful operation. Broadly the flotation reagents can be classified under following categories:

1. Frothers
2. Collectors
3. Modifiers.

Frothers: Frothers are heteropolar surface active organic reagents, capable of being adsorbed on the air-water interface. The adsorption of frothers at the bubble-water interface reduces the surface tension and stabilizes the air bubble. In the froth bubble, the non-polar group is oriented towards the water phase providing the necessary water repellency to the froth as required. A typical froth bubble is shown schematically in the below figure .

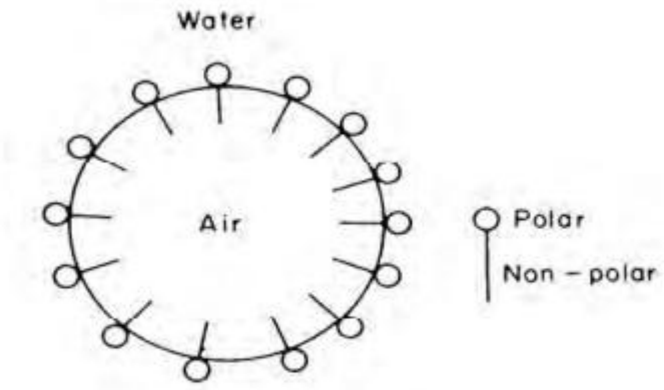


Fig.9.4. Schematic Froth Bubble.

The frothers practically have no effect on the floatability of the mineral particle in the pulp. Production of persistent froth of desired selectivity and durability is of prime importance in successful flotation. The froth should be strong and stable enough to support the weight of the desired mineral attached to it and permits it’s separation from pulp. On the other hand, the froth should break down readily after its removal from the flotation cell. Most widely used frothers are pine oil, isobutyl carbinol (MIBC), turpineol, aliphatic alcohols & cresol (cresylic acid).

Collectors:

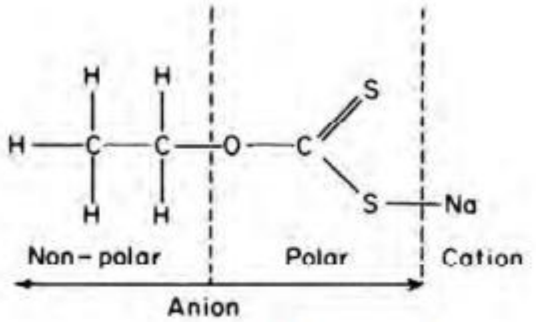
The collector is said to be the most important reagent in flotation. Each collector molecule contains a polar and a non-polar group. It gets adsorbed on the mineral surface and forms a continuous heteropolar film all around the particle.

The heteropolar film is so formed that the polar part is attached to the mineral surface and the non-polar group is projected outwardly providing hydrophobicity to the mineral surface. This results in attachment of mineral particles to the air bubbles available in the pulp and ultimately results in flotation. Collectors are broadly classified according to the chemical nature of the nonpolar part available in them as follows:

1. Anionic collectors

2. Cationic collectors.

Anionic Collectors: These are the most widely used collectors in froth flotation. If the nonpolar part of the collector, which imparts water repellency to the mineral surface, carries a negative charge on it, it is termed as an anionic collector. The structure of an anionic collector is shown schematically in the below figure.



9.5. Structure of an Anionic Collector: Sodium Ethyl Xanthate.

Some typical anionic collectors are:

1. Potassium or sodium ethyl xanthate (Xanthogenates),
2. Dithiophosphates (Aerofloats),
3. Thiocarbamates,
4. Fatty acids
5. Sulphonates.

Xanthates, thiocarbamates & dithiophosphates are primarily used to float sulphide minerals while fatty acids and sulphonates are used for nonsulphide minerals.

Cationic Collectors: The characteristic property of this group of collectors is that the nonpolar water repellant group has a positive charge in place of a negative charge as in the case of anionic collectors. The schematic molecular structure of the cationic collector is shown in the figure,

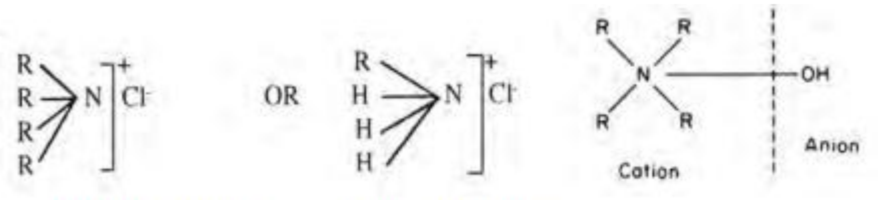


Fig.9.6. Structure of Cationic Collector.

The most general cationic collector is the fatty amine acetate. Cationic collectors are very sensitive to the pH of the pulp. They are most efficient in slightly acidic solutions but inactive in strongly alkaline or acidic media. They are specifically used to float oxides, carbonates and silicate minerals.

4. **Modifiers or Regulators:**

Sometimes it may be necessary to use a modifier before any collector can be made to function effectively. By means of a modifier, it is possible to accomplish the followings:

a. Utilize collectors under optimum conditions
b. Prevent or control mutual mineral interaction.
c. Prevent or control action of atmospheric air or aquatic ingredients at the mineral surfaces.
d. Modify favourably or adversely the ability of some minerals to acquire floatability.

Due to the actions of the diverse chemical reagents tremendous flexibility is achieved with regards to the floatability of the minerals. This is one of the two major reasons behind the success of froth flotation and the other being the applicability of flotation to particles of much finer size on which no other processes can be applied so successfully. Fig.9.6. Structure of Cationic Collector.

According to their function the modifying agents may be classed into one of the following categories:

i. pH regulator.
ii. ii. Activator.
iii. Depressant or Depressor.
iv. iv. Dispersant.

i. pH Regulator:

In the modern froth flotation, alkaline circuits are used almost exclusively for sulphide ores. For any particular ore there is a definite range of pH (7 to 13) at which optimum results are obtained. For this reason proper pH control of the pulp is of great importance: The reagents commonly used to control pH & obtain the desired alkalinity are lime, soda ash and sulfuric acid. But use of sulphuric acid has been highly restricted in the present days.

ii. Activator:

It is not only difficult but also impossible to float certain minerals with collectors and frothers alone. Some times xanthates are found ineffective in floating sphalerite and under such condition an activator is used to obtain the desired floatability of sphalerite. The activator ions are adsorbed at the mineral surfaces and enhance adsorption of collectors at the same surface thereafter. The outstanding example of this type of reagent is copper sulphate ($CuSO_4$) which is used to activate sphalerite. Hydrogen sulphide (H_2S) or sodium sulphide may be used for galena. Copper carbonate or lead nitrate is used to improve the floatability of various non-metallic minerals with fatty acid type collectors.

iii. Depressant or Depressor:

In some cases to induce selective flotation, it is required to prevent or suppress the flotation of a mineral over another. To achieve such a selective flotation, a class of reagents is added to the pulp called depressant or depressor. Depressing agents are used only to assist separation of a mineral from another. The basic mechanism of this activity is that the depressant gets adsorbed at the mineral surfaces and subsequently inhibit the adsorption of collectors. Beside lime, which works both as a pH controller & depressant the other widely used depressant is sodium cyanide. Sodium cyanide along with zinc sulphate is a depressant for sphalerite. Dichromate salts are used to depress the flotation of galena.

iv. Dispersant:

Sometimes the gangue may have the nature of flocculating along with the minerals. The extent of flocculation may be such that it interferes with the efficient flotation of the desired minerals. Then it becomes imperative to use a dispersant or deflocculator. Sodium silicate is used as a dispersant. Starch, casein and glue are used to disperse both gangue and carbonaceous materials associated with metallic minerals.

CHAPTER-10

MAGNETIC AND ELECTROSTATIC SEPARATOR

Magnetic Separation:-

1.It is the separation of valuable mineral from of the gangue.

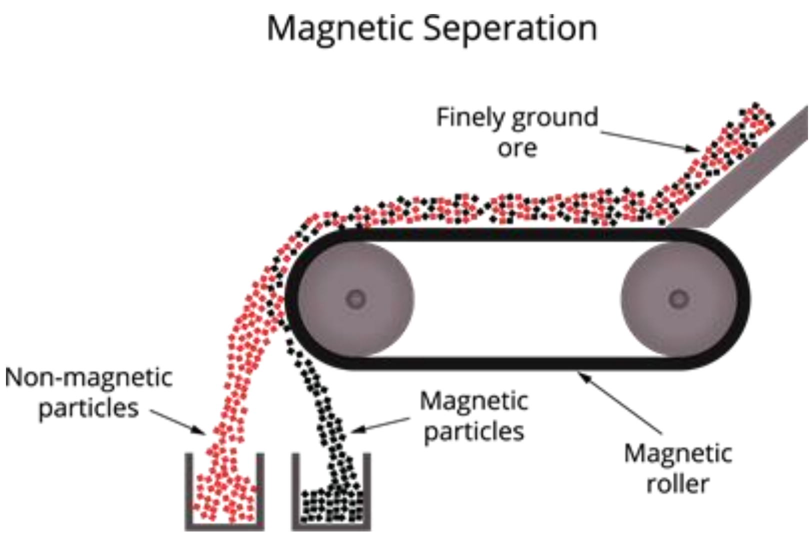
2.It is the separation of one mineral from another essentially based on the difference in the value of magnetic attractability of the minerals.

3.The ore is magnetic but the gangue is non magnetic .

4.The ore is passed over the conveyor belt that runs over 2 roller,one of which is magnetic.

5.The non magnetic particles drop down first due to the gravity.

6.The magnetic particles will stay on the belt for a little longer time and drop down little later.



Magnetic separation is the process of separating components of mixtures by using a magnet to attract magnetic substances. The process that is used for magnetic separation separates non-magnetic substances from those which are magnetic. This technique is useful for the select few minerals which are ferromagnetic (iron-, nickel-, and cobalt-containing minerals) and paramagnetic. Most metals, including gold, silver and aluminum, are nonmagnetic.

A large diversity of mechanical means are used to separate magnetic materials. During magnetic separation, magnets are situated inside two separator drums which bear liquids. Due to the magnets, magnetic particles are being drifted by the movement of the drums. This can create a magnetic concentrate (e.g. an ore concentrate).

Elements in Designing Magnetic Separators:

The following facts are essential and to be considered during the designing of a magnetic separator:

1. Production of a suitably converging magnetic field.

2. Easy regulation of magnetic field intensity.
3. Even feeding of ore particle as a stream or ribbon.
4. Controlling the passage speed of ore particles through the magnetic feed.
5. Avoidance of nonmagnetic materials within magnetic field as occlusion.
6. Suitable means to dispose the products.
7. Provision for production of a middlings.
8. Elimination or reduction of moving parts to a minimum.

Applications of Magnetic Separation:

1. For removal of tramp iron in coarse and intermediate crushing circuits as a protection to the crushing machineries.
2. To concentrate magnetite ore.
3. To concentrate ores other than magnetite after converting iron ores to magnetite by magnetic roasting.
4. To remove small quantities of iron or iron minerals from the ceramic raw materials

ELECTROSTATIC SEPARATOR

An electrostatic separator is a device for separating particles by mass in a low energy charged beam. An example is the electrostatic precipitator used in coal-fired power plants to treat exhaust gas, removing small particles that cause air pollution.

Electrostatic separation is a method of concentrating or separating minerals from each other on the basis of their differences in electrical conductivities. The basic principle of electrostatic separation is the coulomb's law which implies like charges repel and unlike charges attract. It was first used to separate zinc ore from lead sulphide ore. However, it was abandoned after introduction of froth flotation. But recently it has got a new lease of life for separating nonmetallics. Electrical concentration can be broadly classified into:

- Electrostatic separation.
- 2.High tension separation.

Theory:

It works on the principle of mutual attraction of unlike charges and mutual repulsion of like charges (Coulomb's law). On the basis of electrostatic charge, a body is said to be positively charged if it is deficient in electrons and is said to be negatively charged if it has excess of electrons. From the electrostatic point, materials can be classified as:

a. Conductor: When electrons are highly mobile in them (Metals).

b. Insulators: No mobility of electrons in them (plastics, rubber).

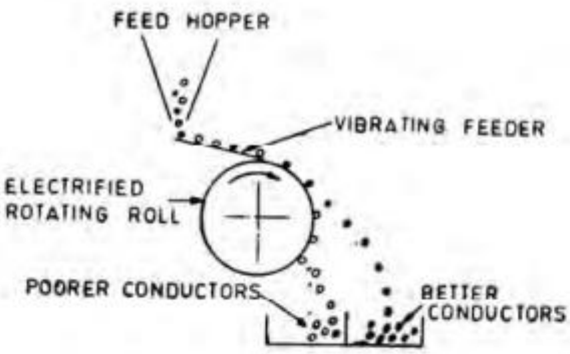
c. Semi-conductor: Higher mobility of electrons in them as compared to insulators but much less conductivity compared to conductors.

Electron mobility increases in all materials when they are placed inside an electrical field. Almost all the metallic ores and minerals gain electron mobility and develop excess electrical charges when they are placed or brought near a strong electrical field. This is due to electrostatic induction. However, the extent of induction will vary over a large range depending on the material. Depending on the extent of induction ore particles can be classified as:

a. Better conductors.

b. Poor conductors.

Electrostatic Separator Setup: In electrostatic separation the feed material is brought near a revolving roll which is either permanently electrified or electrified by means of induction. When the feed material touches the roll or comes near the electrified roll it develops an electrostatic charge on its surface by induction, conduction or by friction from charged drum surface. According to the principle of mutual repulsion of similar electrical charges, better conducting materials are repelled away from the roll surface and fall with a trajectory determined by the size & shape of the particle and the speed of the rotating electrified drum. The poor conducting particles move along the roll surface and have a free fall under the force of gravity. The working of an electrostatic separator is shown schematically in the figure.



Electrostatic separator.

Requirements for the Proper Working of an Electrostatic Separator:

1. For electrostatic separation, feed materials must be dried prior to separation.

2. For effective separation dry minerals grains are to be fed as a layer of one particle deep at the top of the rotating electrified roll. This is achieved by using a vibrating feeder.

3. For effective high tension separation, feed must be closely sized in the range of 1.0 - 0.1 mm free from fines. Quite often the feed material the feed material is to be heated above room temperature for effective separation.

Use

1. It is employed to separate conducting ores and minerals from non-conducting materials in ceramic industries.

2. This is applied for beneficiating rutile beach sands from non-conducting silica sand in rare earth plants. *