# LECTURE NOTES

# ON

# MINERAL DRESSING

**Ghanshyam Dhurua**

**Sr. Lecturer(Mining)**

**Orissa School Of Mining Engineering, Keonjhar**

COURSE CONTENTS (Based on specific objectives)

**1. Introduction**

1.i. Describe the objective & scope of application of mineral dressing in surface & u/g mines.

**2. Unit operations**

2.i. Explain the principle of Blake & dodge jaw crushers, gyratory & cone crushers, roll crusher.

**3. Grinding**

3.ii. Explain the principle of ball mill operation, open circuit grinding, close circuit grinding, dry & wet grinding.

**4. Explain the procedure for size analysis & use of standard screen as also screening techniques employed.**

**5. Industrial screening**

5.i. Explain the principle of industrial screening, type of screening ( without calculation)

5.ii. Explain the operation of classifier & their application.

**6. Gravity concentration**

6.i. Explain the general principles of wilfly table & its operation.

6.ii. Develop elementary idea regarding the operation jigs.

**7. Heavy media separation**

7.i. Explain the fundamental principle of heavy media separation – Chance process.

**8. Floatation**

8.i. . Comprehend elementary principle of froth floatation, practical utility of frother, collection, modifiers & depressants.

8.ii. Describe & illustrate floatation cell.

**9. Magnetic & Electrostatic Separators**

8.i. Explain the principle of operation of magnetic & electrostatic separators.

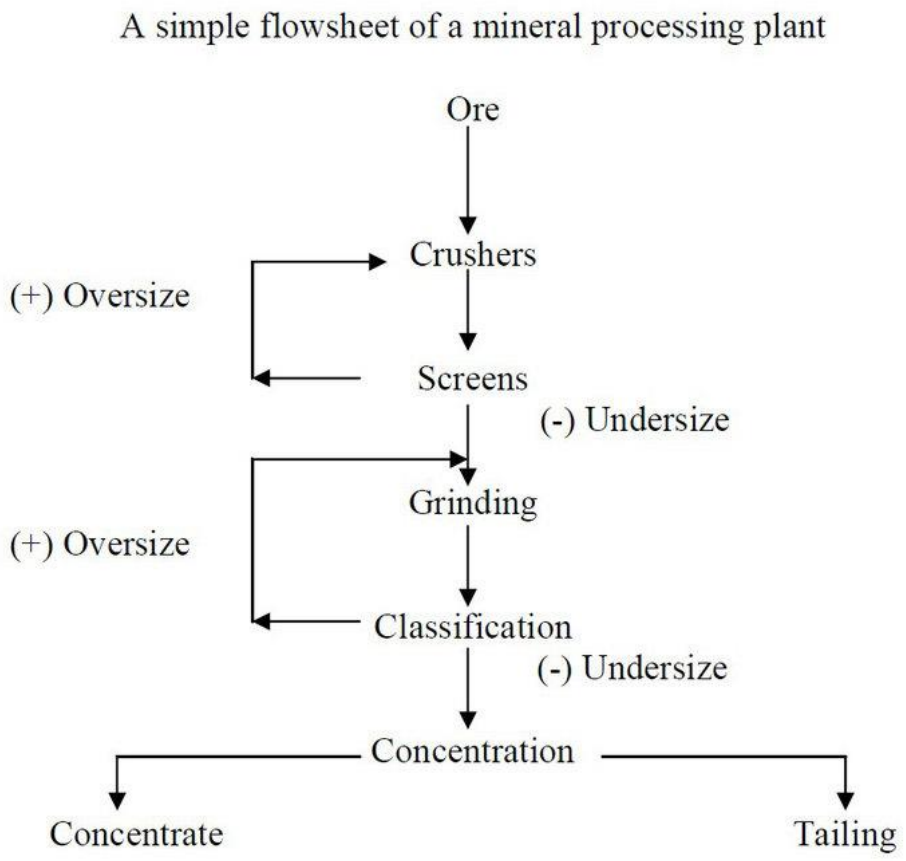
8.ii. Describe the application of separators in mineral dressing.

# CHAPTER-1

# INTRODUCTION

## INTRODUCTION.

- A metal extraction plant's working is conveniently represented by means of a flow sheet.
- Flow sheet is a combination of processes which are followed in the given plant to extract the metal(s) most economically. While analysing the flow sheet we come across certain unit processes and operations.




- The unit processes are usually characterized by certain chemical reactions such as roasting, leaching etc while unit operations are usually physical processes carried out discreetly on the ore.

These physical processes are usually represented by **crushing, grinding and similar such processes**.

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.**

So **mineral dressing or ore dressing is commonly** regarded as processing of raw ores to yield marketable products by such physical means those do not destroy the physical and chemical identity of the ore.

## 1.I. DESCRIBE THE OBJECTIVE & SCOPE OF APPLICATION OF MINERAL DRESSING IN SURFACE & U/G MINES.

## Objective of mineral dressing

**1. 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.

**2. To prepare ore from physical standpoint.**

This involves:

a. Reduction in size.

b. Separation of particles of dissimilar physical nature.

## Scope Of Application Of Mineral Dressing.

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.

Of the above scopes, first one is more important and is considered to be the extent or working sphere of ore dressing. The second one is also equally important for proper smelting operation.

## GENERAL OPERATIONS INVOLVED IN ORE DRESSING:

### 1. Comminution:

Comminution or size reduction can be accomplished dry or wet.

### 2. Sizing:

This is the separation of product material into various fractions depending on their size parameter.

### 3. Concentrating:

Concentration of valuable portion of the ore is obtained by the various means which generally involve physical characteristics of the ore particles.

Sizing, jigging, tabling, classification, magnetic & electrostatic separation are few such examples. We may exploit an entirely different set of physio-chemical properties for concentrating the ore as it happens during froth flotation.

### 4. De -Watering:

Where aqueous medium is involved, water is to be removed before smelting can take place. This involves:

a) Removal of most of the water by the use of the thickener.

b) Then use of filter presses to prepare a damp cake of the concentrated ore.

c) Then drying the cake in a furnace

# CHAPTER-2

# UNIT OPERATION

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

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.

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

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

## Size Parameter for Different Comminution Processes:

Suitable parameters of feed and product material for different crushing operations are shown in the table.

| | Process Feed Size | Product size |
|---|---|---|
| 1. Coarse Crushing | ROM( 150-4cms) | 5.0- 0.5 cm |
| 2. Intermediate crushing. | 5.0 - 0.5cm | 0.5 -0.0 I cm |
| 3.Coarse grinding | 0.5.0 - 0.2cm | About 75 microns |
| 4. Fine Grinding (Special type) | ( 0.02 cm) | 0.01 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.

At least one or a combination of the above forces is always involved in size reduction in any crushing equipment.

## 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.

A classification of the size reduction equipments can be made on the basis of feed and product size as follow:

## Classification of the Size Reduction Equipments

### 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:

- Crushers are slow speed machines for coarse size reduction of large quantities of solids. The major types of crushers are: Jaw, Gyratory, Roll & Toothed roll crushers.
- The first three types operate on compressive force and can crush very hard & brittle rocks.
- The toothed roll crusher tears the feed apart as well as crushes it.
- It works best on softer materials like coal, bone and soft slate.
- These are the crushers which operate on the run of the mine (rom).

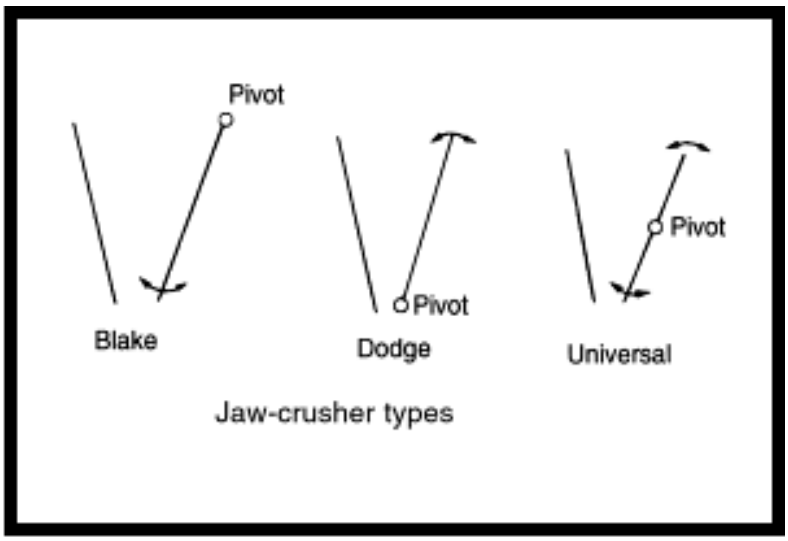
### Classification of Jaw Crushers:

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

1. Blake crusher.

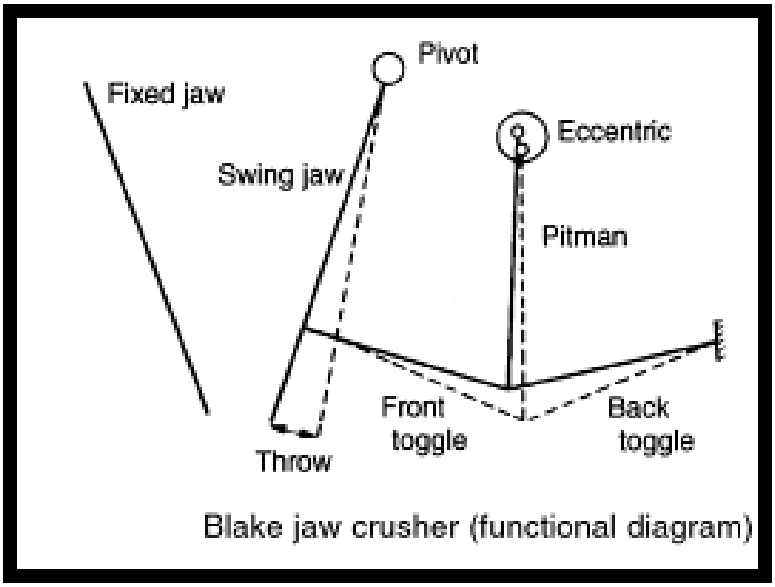
2. Dodge crusher.

3. Universal crusher.

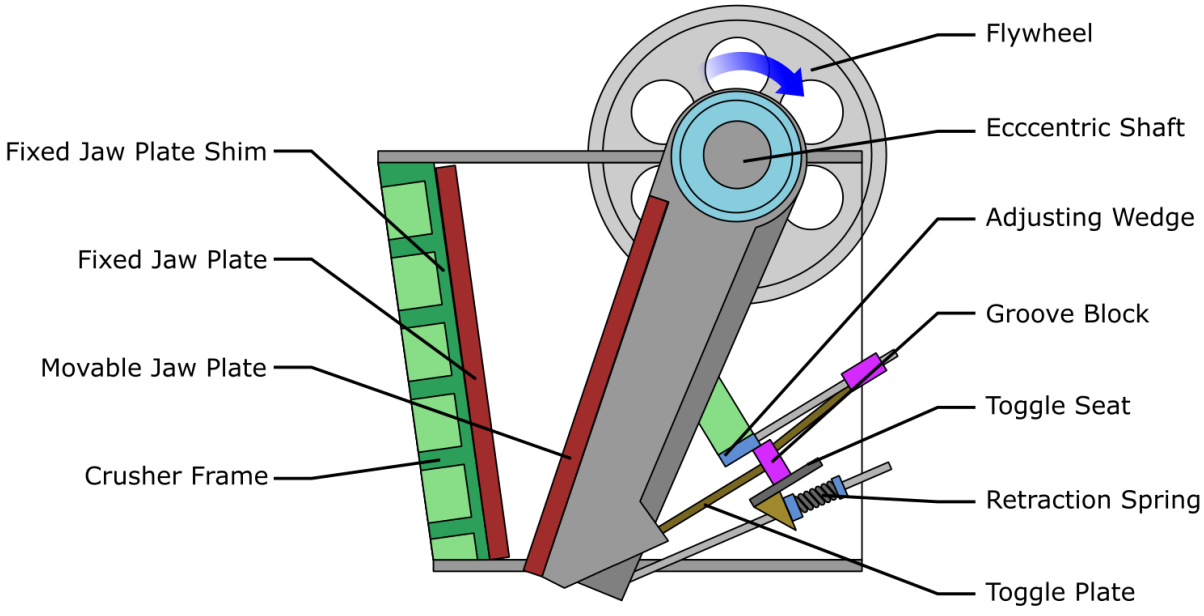


## Blake Jaw Crusher:

- It is a primary crusher used most widely. It has its moving jaw pivoted (hinged) at the top as in the figure.
- 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.

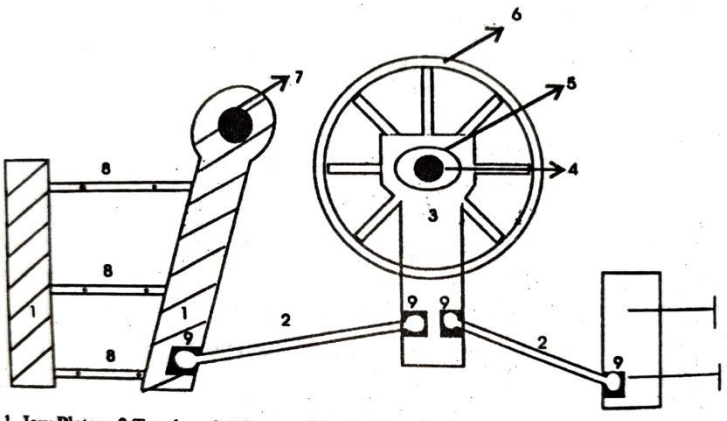


Blake jaw crusher (functional diagram)



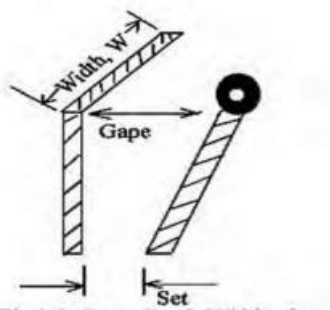
## Constructional Features:

1. As the name suggests a **jaw crusher has two jaws set to form a V-shape** at the top through which feed is admitted into the jaw space.
2. One of the jaws is fixed to the main frame of the crusher almost vertically while the other one is movable.
3. The swinging jaw, driven by an eccentric, reciprocates in a horizontal plane and makes an angle of 20- 30 degrees with the stationary jaw.
4. It applies a huge compressive force on the ore lumps caught between the jaws.
5. On the jaws, replaceable crushing faces are fixed by nut & bolt arrangement.
6. The crushing faces are made of hadfield manganese steels. When extensive wear is observed on any of the faces it is replaced with a new one. The crushing faces are rarely flat.
7. They are usually wavy surfaces or may carry shallow grooves on them. The jaw running speed vary from 100-400 rpm.



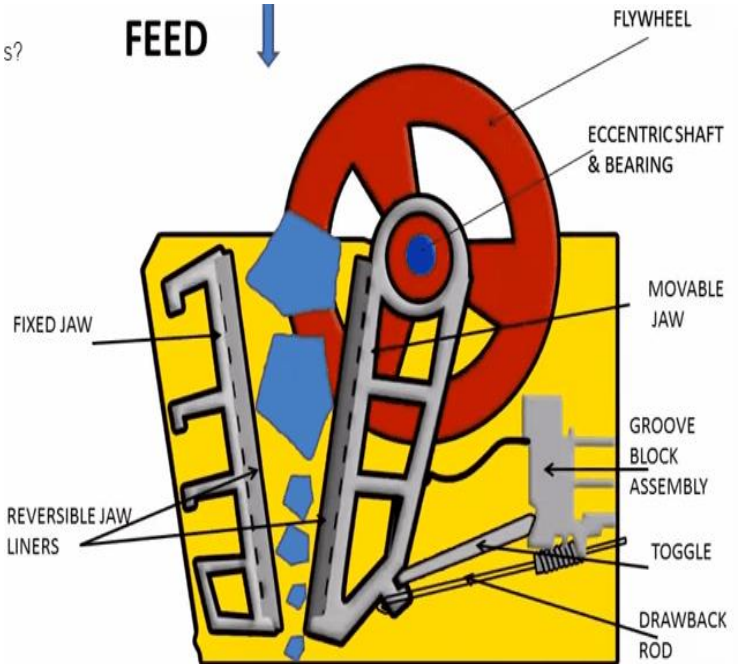

1. Jaw Plates. 2.Toggles. 3. Pitman. 4.Main Shaft. 5. Eccentric.
6. Flywheel. 7. Top Hinge. 8. Check Plates. 9. Bearings.

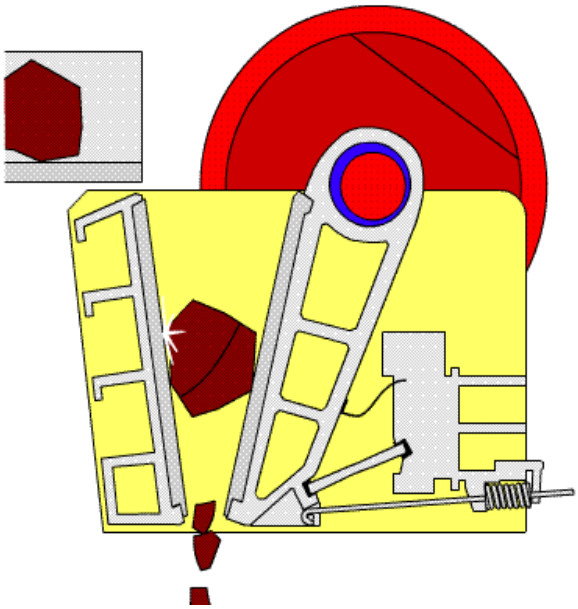
8. As the moving jaw is pivoted at the top, the amplitude movement is largest at the bottom. The maximum distance the moving jaw travels is called *throw* of the crusher.
9. *Gape* is defined as the distance between the jaw plates at the feed opening end.
10. The Blake crusher has a varying discharge opening. This distance between the jaws in the discharge side is termed as *set.*

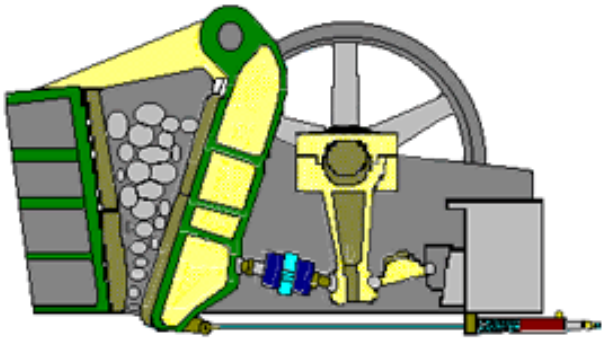


## Working Principle:

- Initially the large lump is caught at the top and is broken. The broken fragments drop to the narrower bottom space and is crushed again when the jaws close in next time.
- This action continues until the feed comes out at the bottom.
- The crushing force is least at the start of the cycle and highest at the end of the cycle. In this machine an eccentric drives the pitman.
- The circular motion of the main shaft is converted to up and down motion of the pitman via the eccentric and finally the up and down motion is converted to reciprocating(to and fro) motion with the help of two toggles.
- One of the toggles is fixed to the main frame and pitman while the other one is fixed to the moving jaw and pitman.
- From mechanical stand point, toggles are the weakest members of the jaw crusher. This is specifically made so to work as a safety device for the entire jaw crusher installation.
- There is every probability that an extremely hard material may enter into the jaw space along with the usual feed.





## Characteristics of Blake jaw crusher:

**1. Reduction Ratio:**

R.R. is defined as the ratio between average feed size to average product size. Mathematically:

$$\text{Reduction Ratio (R.R)} = \frac{\text{Avarage Feed Size}}{\text{Avarage Product Size}}$$

This is a very important parameter for determining the energy consumption in the crusher. Keeping all other variables fixed, higher the reduction ration (R.R.) higher is the energy consumed by the crusher.

**2. Capacity:**

The capacity of the jaw crusher mainly depends on the length and width of receiving opening and the width of discharge.

**As per Taggart, the empirical formula for capacity of jaw crusher is: T = 0.6LS**

where, T is the capacity expressed in tons per hour.

L is the length or width of the receiving opening in inches.

S is the set or width of discharge opening in inches.

**3. Energy Consumption and Efficiency:**

Energy consumption in a jaw crusher varies considerably. Largely it depends on following factors:

a. Size of feed

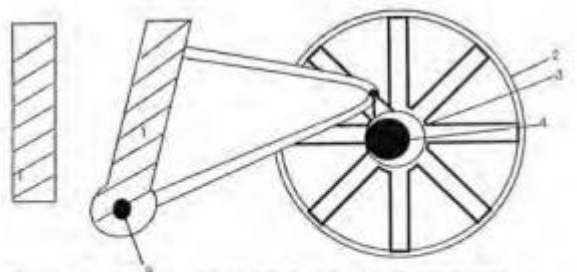
b. Size of Product

c. Capacity of the machine

d. Properties of rock such as hardness, specific gravity, etc

## Dodge jaw Crusher:

- Both Dodge and Blake crushers look similar to each other.
- In Dodge crusher the moving jaw is pivoted at the bottom in place of of the top as in case of Blake crusher.
- Hence the maximum swing of the moving jaw is obtained at the top. The gape is a variable while width of discharge opening (set) is fixed.
- Due to the fixed set, the product is more uniformly sized as compared to the product from the Blake.



[Dodge Crusher]

- The crusher has got fewer mechanical parts as compared to Blake crusher.
- The moving jaw is activated by a lever It is activated by a lever-eccentric arrangement mounted onto the main shaft as compared to the toggle-pitman combination in case of Blake crusher.
- The inherent problem with this crusher is its tendency to choke frequently and that is why it is used less widely.
- This crusher is usually made in smaller size than the Blake crusher because of high fluctuating stresses working on the machine members.
- The major advantage of this machine is its power to effect larger size reduction because of larger-opening at the top with a fixed set.
- The advantage of uniform product size is the most significant where a single crusher is used as the only comminution machine.
- In industries where elaborate screening is available Blake crusher is preferred because of its higher capacity and more balanced mechanical design.
- The Dodge crushers are usually used in college and research laboratories

## Comparison between Blake & Dodge Crusher

| ***Blake Jaw Crusher*** | ***Dodge Jaw Crusher*** |
|---|---|
| It has got two toggles. | It has one toggle in the form of a lever |
| It has one pitman. | It has no pitman. |
| The movable jaw is pivoted at the top, so has a variable product discharge opening while feed receiving opening is fixed. | 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. |
| No choking takes place here as it has variable discharge. It operates on principle of forced feed. | Choking is a very common problem as the set is quite small compared to receiving opening. |
| This crusher is mechanically more balanced and has fewer breakdowns. Further it is built for much larger capacity. | 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. |
| Product size distribution is large & produces more fines. | Product size distribution is more uniform. |
| Blake is preferred at large industrial setups where elaborate screening facility is available along with other comminution machines. out. | A dodge is preferred where jaw crusher is to be used as the only comminution equipment. |
| This machine is of higher cost for same output. | This machine is cheaper for same output. |
| Because of forced feed lubrication it yields a coarser product.. | As choke feeding is possible, it can yield a much finer product. |

## Gyratory Crusher:

### Classification of Gyratory Crusher:

The best known gyratory crushers are:

1. Suspended spindle gyratory crusher.

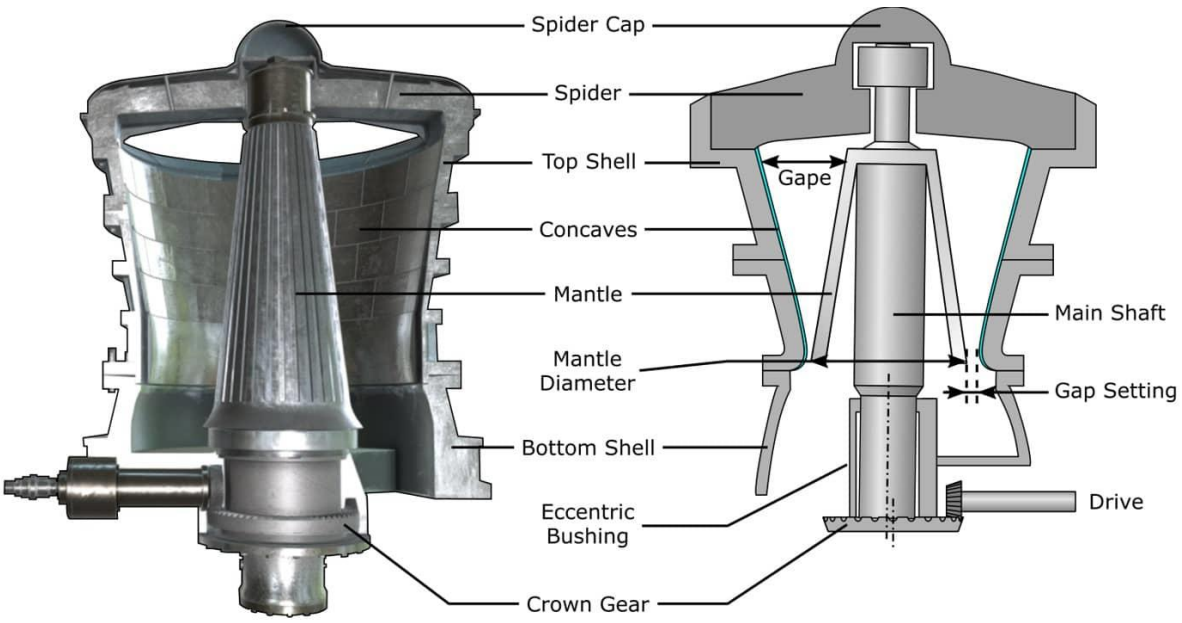
2. Parallel Pinch or Telsmith gyratory crushers

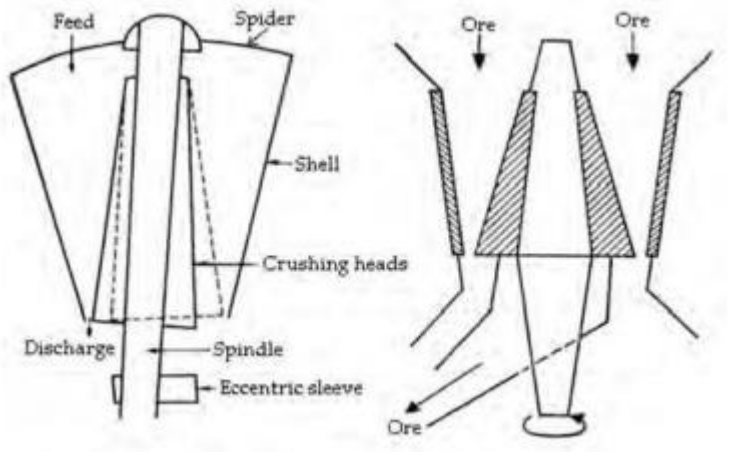
Gyratory crushers have been developed recently in order to supply a machine with a larger capacity than jaw crushers.

### 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 outershell 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 orthe 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.
- Since the jaw movement is largest at the bottom, the operational characteristics of the gyratory crusher are similar to Blake jaw crusher.
- The machine operates continuously throwing product all around the periphery at different instants.
- When one point on the periphery is involved in crushing the opposite point is set at maximum opening to accept feed into the Vshaped crushing head.
- This crusher mainly employs compressive force for size reduction. The materials for crushing head is had field manganese steel in cast form.
- 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 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.

**Comparison between Jaw & Gyratory Crusher:**

| *Jaw Crusher* | *Gyratory Crusher* |
|---|---|
| The loading on machine components is intermittent and the power draft irregular. | Uniform loading on the machine components with regular power draft |
| Crushing action is intermittent. | Crushing action is almost continuous. |
| For a particular gape size the capacity is less compared to gyratory crusher | For the same gape size the capacity is much larger. |
| Its feed acceptance size is much larger compared to gyratory crusher. | Its feed acceptance size is much less compared to jaw crusher for the some capacity. |
| Product particle size distribution varies widely &it has a reduction ratio less than that of the gyratory crusher. | More uniform sized product is obtained with a larger r.r. |
| Power consumption is higher for jaw crusher for a particular r.r. & capacity. | With the same r.r. & capacity, the gyratory crusher requires less power. |
| The crusher is less efficient compared to gyratory crusher It has an efficiency of 10 -20%. | It has an efficiency of 30 - 50%. |
| 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. | 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 to reduce the gap. So the heads can serve for a longer time |
| Not much variation can be obtained with regards to product particle size. | Wide variation in product size can be obtained by varying the setting of the central shaft. The set can be varied as per requirement |
| It has a low cost of installation. | It has a high cost of installation. |
| It is better for lower production rates. | . It is better for higher production rates. |

## Intermediate Crushers:

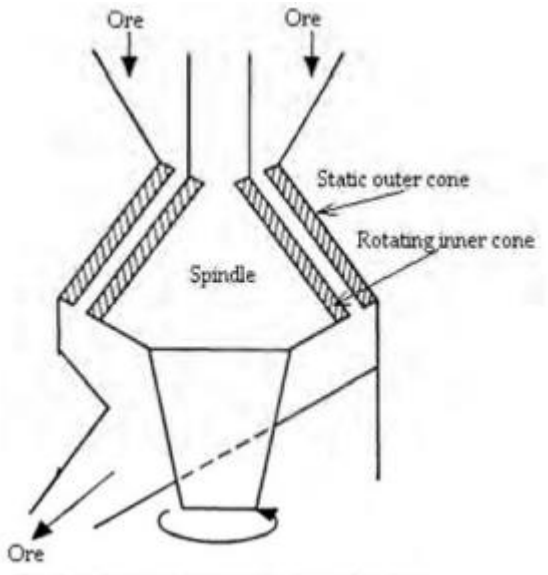
Generally products from the jaw crusher or gyratory crusher are not fine enough for the complete liberation of mineral grains and needs further size reduction. The product is charged into either cone crusher or crushing rolls for further size reduction. Cone crushers and crushing rolls are the equipments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

- 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. Here both the rotating inner cone & stationary outer cone apex point upwards.

- The outer stationary cone is fixed on to the main frame while the inner crushing head is mounted on a heavy central shaft rotating eccentrically. T
- The material used as crushing heads is hadfield manganese cast steel containing at least12%Mn. The sectional view of a cone crusher is shown in the figure .




- The central shaft is fixed with an adjustable bearing and is mounted on an eccentric drive. Due to the adjustable bearing on the central shaft, the position of the internal cone can be altered so as to provide a variable discharge opening (set) as per the requirement.
- This arrangement also takes care of the wear on the crushing faces which may enlarge the set. The eccentric performs the same work as does in the case of gyratory crusher.
- Due to this the inner cone (crushing head) alternately approaches and recedes from a particular point on the periphery of the outer cone resulting in continuous crushing action.
- This results in regular power draft and much finer product at a better efficiency. The efficiency of the Cone crusher is comparable to that of the gyratory crusher.
- The crushing forces here are compressive and frictional in nature. Compared to crushing rolls they have better capacity with comparable product fineness.
- To operate the cone crushers most efficiently, a dry feed, free from fines are to be used.
- If wet ore is used the cone crushers may clog. The problem of clogging in cone crushers makes it necessary to use efficient screens in closed circuit with them.

LIMITATIONS:

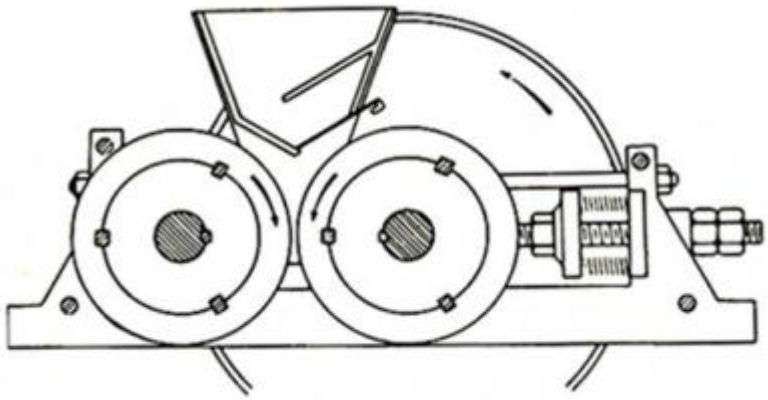
1. It operates only on closely sized brittle material.
2. It has a low reduction ratio.
3. It needs extensive lubrication of all its moving part regularly.
4. It operates best in closed circuit grinding.

### *Crushing Rolls:*

This is an important class of intermediate comminution machine in the intermediate range of size reduction. Crushing rolls consists of pair of heavy cylindrical rolls revolving towards each other so as to nip a falling ribbon of rock and discharge it crushed below rolls. They were invented around 1850A.D

### *Mechanical Design:*

- The two rolls are heavy and rigid ones.
- The material is cast steel and wear resisting.
- Both the rolls are positively driven towards each other by motors.
- The heavy rolls turn on parallel horizontal plane having the roll centres at the same height separated by a distance, S.



- The feed caught between the rolls are broken by compressive force and drop down below. The rolls turn towards each other at the same speed.
- They have narrow faces but have large diameter so that they call nip moderately large lumps. Figure shows the crushing rolls schematically.

- Typical rolls are 600 mm long with 300 mm diameter. Roll speed ranges from 50 - 300 rpm. The feed size varies from 12-75mm & the product size varies from 12 to 20 mm .
- The product size mainly depends on the roll separation distance d. The operation is quite continuous. At a lower reduction ratio the crushing rolls produces less fines as compared to other crushers.
- However, the crushing rolls have large capacity at lower reduction ratio. The roll clearance d is adjustable and depends on feed size and product size requirement.
- The machine is protected against damage from very hard material, by the spring loader mounted onto the rolls.
- When a hard material, having breaking strength is higher than the strength of the spring loader, is nipped the rolls simply widen allowing the hard rock to drop down without being crushed.
- The most important characteristic of a roll crusher, which controls the crushing activity, is the angle of nip or angle of bite of the rolls. This can be deduced mathematical.

### *Angle of Nip:*

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. Angle of nip is also termed as angle of bite. Crushing is performed only when the ore particles are nipped properly by the rolls.

The Particle that can be nipped by the crushing rolls depends largely on the following factors:

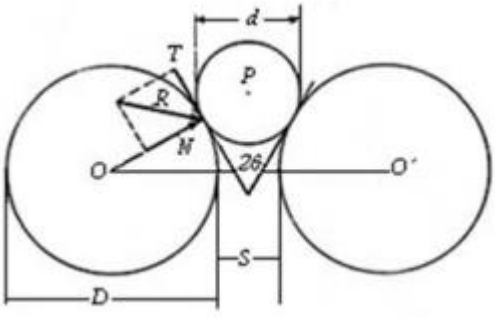
1. Roll diameter (D).

2. Particle diameter (d).

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

4. Friction factor between the roll & the mineral ($\mu$).

These parameters are shown schematically in the figure. The angle of nip is represented as $2\theta$ in the figure.



# CHAPTER-3

# GRINDING

## GRINDING:

- The usual meaning of grinding is the comminution of an ore particle that has already been reduced to a size less than 6mm size by crushing. Hence any comminution process aiming at a product size less than 6mm size is known as grinding.
- Grinding is a slower process usually carried out in a ball or tumbling mill or any other equipment like tube, rod & pebble mill. These mills perform size reduction in closed chambers containing hard balls, rods or quartz pebbles as grinding media.

***Critical Speed of the Ball Mill:*** The minimum rotational speed at which centrifuging occurs in a ball mill is defined as its critical speed. It has already been noticed that no grinding takes place in the ball mill when it centrifuges

### *Dry & Wet Grinding*

It is to be noted that ball mills can he operated dry or wet. Mills are usually employed to grind ore in wet condition. But for some specific purpose essentially in chemical industries dry grinding is employed.

During dry grinding the mills are connected with pneumatic classifiers in closed circuit to produce extremely fine powder. Pulverized coal is obtained in this manner.

### *Advantages of Wet Grinding Over Dry Grinding:*

Though wet grinding is generally applicable in low speed mills there are number of advantages of wet grinding over dry grinding:

1.Wet grinding facilitates better removal of the product, eliminates dust problem, lessen the noise and heat produced though the wear may actually increase by 20 %.

2. Power consumption is lowered by10-30% over dry grinding per ton of product.

3. The capacity increases per unit volume of the mill.

4. This grinding makes wet screening possible for producing materials in narrow size range.

5. Dust problem is eliminated.

6. Wet grinding makes handling & transportation of product easier.

7. Sticky solids are more easily handled.

***Mechanical construction of a Cylindrical Ball mill:***

Ball mill has few important components as follows:

1. Cylindrical shell.

2. Inner surface or liners.

3. Balls or grinding media.

4. Drive.

**1. Cylindrical Shell:**

- It is the rotating hollow cylinder partially filled with the balls.
- The ore to be crushed is fed through the hollow turnnion at one end & the product is discharged through a similar turnnion at the other end.
- The material of construction for this hollow shell is usually high strength steel.
- The shell axis is either horizontal or at a small angle to the base.
- Large ball mills have a length of 4 - 4.25 mts, diameter of 3mts. They use hardened steel balls of size varying between 25-125 mm.

2. Inner Surface or Liners:

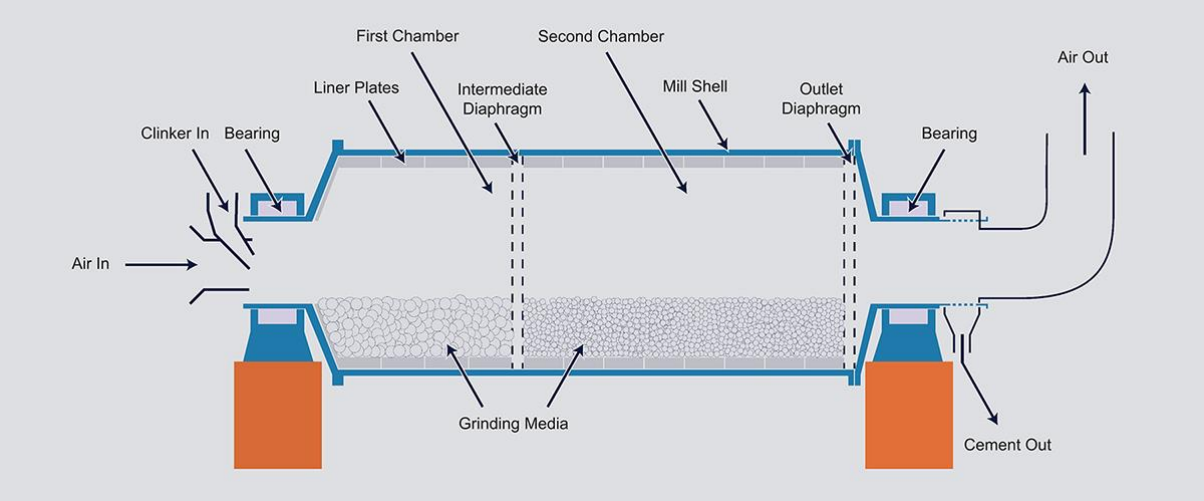
- As the grinding process involves impact and attrition the interior of the ball mills is lined with replaceable wear resisting liners.
- The liners are usually high manganese alloy steels, stones or rubber. Least wear takes place on rubber lined interior.
- As the coefficient of friction between balls and steel liner is specifically large, the balls are carried up taken to a higher height along the inner wall of the shell and dropped down onto the ore with a larger impact force resulting in a better grinding.

3. Balls (Grinding Media):

- The balls are usually cast steel unless otherwise stated. In some cases flint balls may be used.
- The diameter of the grinding media varies from 1-5inches.
- he optimum size of the ball is proportional to the square root of the feed size. The ball and liner wear are usually in the range of 450 – 1250 and 0.50 – 250 grams per ton of ore ground.

4. Drive:

- The mill is rotated by electric motors connected through reduction gear box - ring gear arrangement




***Advantages of the Ball Mill:***

1. The mill can be used both for wet and dry grinding.

2. The cost of installation of a ball mill is low.

3. The ball mill can use an inert atmosphere to grind explosive materials.

4. Media used for grinding is relatively cheap.

5. The mill is suitable for grinding materials with any degree of hardness.

6. It can be operated in batches or continuously.

7. It is used for both open and closed circuit grinding effectively.

**Explain the procedure for size analysis & use of standard screen as also screening techniques employed.**

- 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 play during 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 Shape:**

- The primary function of precise particle analysis is to obtain quantitative data about size and size distribution of the particles in the product material.

- The shape of the particle plays an important role in the size determination. 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 ($\vec{d}$).

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.

10. Spherical: Globular particles

**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 of Particle size Determination:**

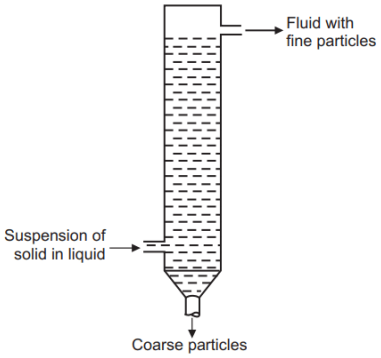
| Methods | Approximate size range (microns) (1 $\mu m = 10^{-6} m$ ) |
|---|---|
| Sieve analysis | 100000 -10 |
| Elutriation | 40 – 5.0 |
| Optical microscopy | 50 – 0.25 |
| Sedimentation(gravity) | 40 – 1.0 |
| Sedimentation(centrifugal) | 5 – 0.05 |
| Electron microscopy | 1 – 0.005 |

***1. 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.

***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.
- Elutriation is a process for separating particles based on their size, shape and density, using a stream of gas or liquid flowing in a direction usually opposite to the direction of sedimentation.

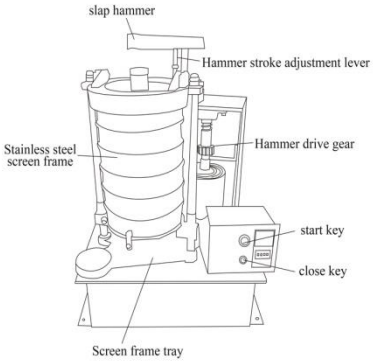



- This method is mainly used for particles smaller than 1 µm.
- The smaller or lighter particles rise to the top (overflow) because their terminal sedimentation velocities are lower than the velocity of the rising fluid.

***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 or sieves used worldwide for the purpose.

***Ro-Tap Sieve Shaker:***



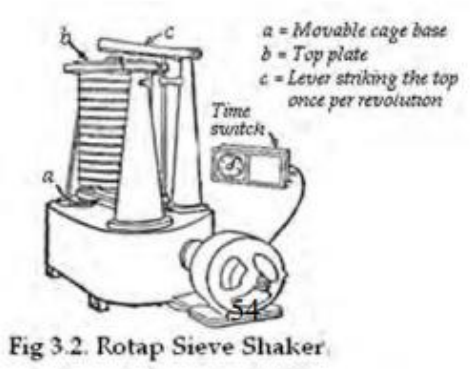




Fig 3.2. Rotap Sieve Shaker

- Figure 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.
- 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.

***Average Size Determination by Sieve Analysis:***

- Product sample of certain weight is taken along with standard sieves.
- The screens are arranged in the order of increasing mesh nos. from top to bottom with a pan at the bottom.
- The feed is kept in the top sieve, After closing the top screen, the entire set is kept in the sieve shaker machine and.

**Representation of Sieve Analysis Data:**

| Mesh No. | Mesh opening $D_i$ (in mm) | Weight % retained $w_i$ in gms. | Cummulative weight % retained $C_i$ . |
|---|---|---|---|
| 8 | 1.651 | - | - |
| 10 | 2.350 | $w_1$ | $\frac{w_1}{W} \times 100$ |
| 14 | 1.651 | $w_2$ | $\frac{w_1 + w_2}{W} \times 100$ |
| 20 | 1.168 | $w_3$ | $\frac{w_1 + w_2 + w_3}{W} \times 100$ |
| 28 | 0.833 | - | ---------- |
| 35 | 0.417 | - | ---------- |
| 48 | 0.295 | - | ---------- |
| Pan | 0.000 | $W = \sum w_i$ | $\frac{\sum w_i}{W} \times 100$ |

- The product is allowed to be shaken for 15 minutes and then removed. Basic method of representing analysis data and typical analysis data are presented in the table .

# CHAPTER-5

# INDUSTRIAL SCREENING

**5.1 Explain the principle of industrial screening, type of screening ( without calculation)**

***Industrial screening:***

- The screening of the crushed product is quite important in a large scale.
- Screening segregates the bulk of the crushed product into few fractions.
- This segregation is beneficial in many ways as follows:

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.

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.

***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.

***Types of Screens:***

The screens are classified as:

1. Stationary.

2. Moving.

Moving grizzlies.

Trommels or Revolving screens.

Shaking screens.

Vibrating screens.

1. ***<u>Stationary screens:</u>***

- 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.
- A typical stationary grizzly is shown in the figure.
- The major disadvantage of this type of screen is clogging.
- Rails are used under severe service conditions with openings greater than five (5) inches

***2. Moving.***

***i. Moving Grizzlies:***

- The grizzly is made up of rods and bars but have movements as compared to stationary grizzly.
- 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 :**

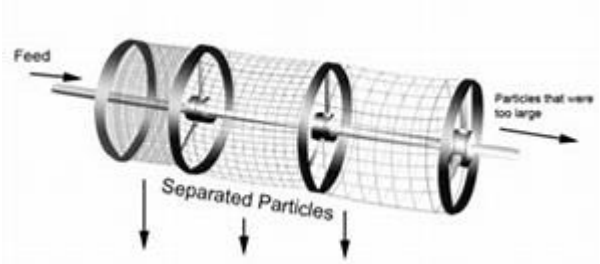
a. Low floor space is required for installation.

b. They act as feeders to intermediate crushers.

c. Result in better screening than stationary screens

***ii. Revolving screens or Trommels***

- Revolving screens or Trommels have been used more widely than any other type of movable screens but recently they have been replaced by vibrating screens.
- Trommel consists of rotating cylindrical, prismatic, conical or pyramidal sells of punched plates or thick woven wires.
- A trommel has one or more shells which are arranged in a concentric manner.
- When the trommel has only one shell, it is known as simple trommel.
- With more than one shell it is known as compound trommel.
- In case of compound trommels screen opening aperture) gradually decrease from the innermost screen to outermost screen.
- The trammel is commonly 3 - 4ft in diameter and 5-10ft. in length.




- The Shells lire driven by a central shaft attached to them by 4 or 6 armed spiders.
- The material to be screened is charged into the inner most shell and is made to flow out peripherally.
- When the trommel is rotated by the central shaft the material inside starts revolving and gets screened.
- The under sized material comes out of the trommel all along the periphery & oversized material comes out at the other end.
- Central shaft of the trommel is made to inclined on the horizontal to facilitate automatic flow of the material from one end (feed end) to the other end (discharge end) due to force of gravity.
- Cylindrical trommels outnumber all other types of trommels.

***Advantages of Trommels:***

1. It requires smaller floor space

2. It has a larger capacity per unit screening area.

3. It is cheap to operate. 4. Several fractions are obtained in one go.

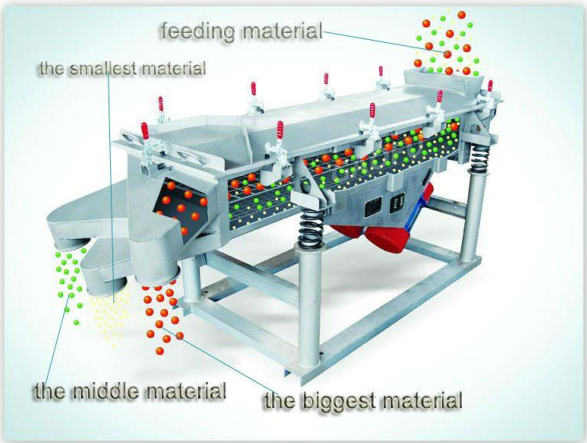
5. Screening operation is quite efficient, can utilize both wet and dry screening.

***iii. Shaking Screens:***

- It essentially consists of a shallow rectangular box where the length is at last 2- 4 times the width.
- It is open at one end and is fitted a screen bottom.
- It is shaken by means of a suitable mechanism. Speed, slope and length of the stroke should be adjusted to produce rapid stratification of the feed with a forward motion so that minimum blinding of the screen surface is resulted.
- It is widely used in case of screening of coal. It looks very similar to the vibrating screen.

***iii. 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.

**2.2 Explain the operation of classifier & their application.**

**Explain the operation of classifier & their application.**

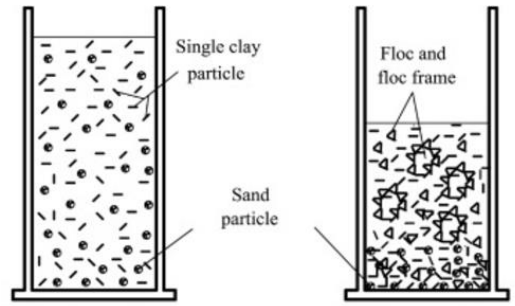
***Classification:***

- Classification is a process by which particles of various sizes, shapes and specific gravities are separated into separate groups by allowing them to settle in a fluid medium.
- The coarse and heavier grains settle faster than the finer and lighter grains. Usually, air or water is used as the fluid medium. Classification may be regarded as a mineral beneficiation process based primarily on Stokes‟ law of sedimentation.

**Free settling**

• When a particle is at sufficient distance from the wall of the container and from other particle, so that its fall is not affected by them, the process is called free settling.

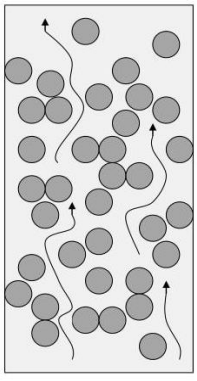
• Terminal velocity is also known as free settling velocity.




**Hindered settling**

• When the particles are crowded, they settle at a lower rate and the process is called hindered settling.

• The particles will interfere with the motion of individual particles



• The velocity gradient of each particle are affected by the close presence of other particles.

***Factors affecting classification:***

***1. Specific gravity:*** For particles of same size but different specific gravities, the particle having the highest specific gravity will settle fastest than any other particle.

***2. Size:*** For particles of same specific gravity but different sizes, the largest one will settle fastest than any other particle.

***3. Shape:*** Spherical particles settle faster than the narrower, longer and flatter particles.

***4. Specific gravity of the fluid:*** In fluids of different specific gravities, the particle will settle fastest in the lightest fluid.

***5. Air bubbles:*** Adherence of air bubbles to the solid particles would decrease the settling speed.

***Classifiers:***

Basing on the above discussed ideas, classifiers are broadly classified into three categories:

1. Sorting classifier: It uses a relatively dense aqueous suspension as the fluid medium for classification.

2. Sizing classifier: It uses a relatively dilute aqueous suspension as the fluid medium for classification.

3. Sizing classifiers: It uses air as the fluid medium for classification.

1.**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.

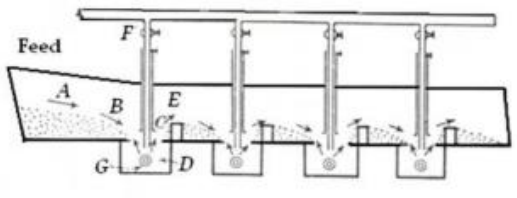
b. Richard's hinder settling classifier.

c. Richard's pulsator classifier.

d. Hydrotator classifier.

***a. A simple launder classifier or Evans' classifier.***

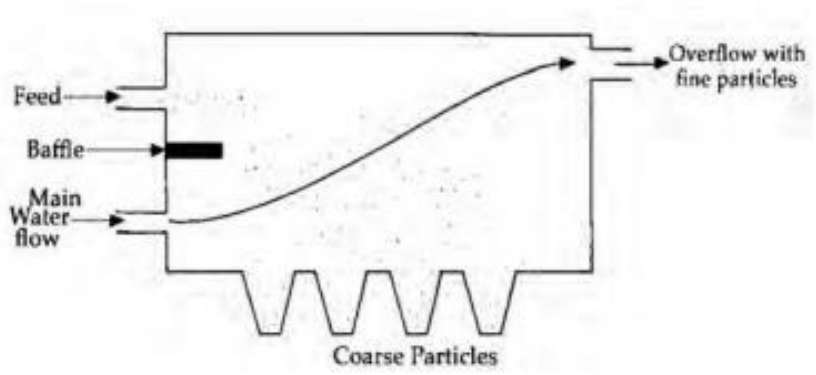
- Evans' classifier consists of a sloping launder, A. Opening to this launder several rectangular boxes BC are attached.
- To the rectangular boxes spigots, O are fitted which are capable of discharging out. Pipes are suspended from a main water pipeline into the rectangular boxes.




- Water is introduced into the boxes through these pipes and the flow is controlled by valve, F
- 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.




***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:

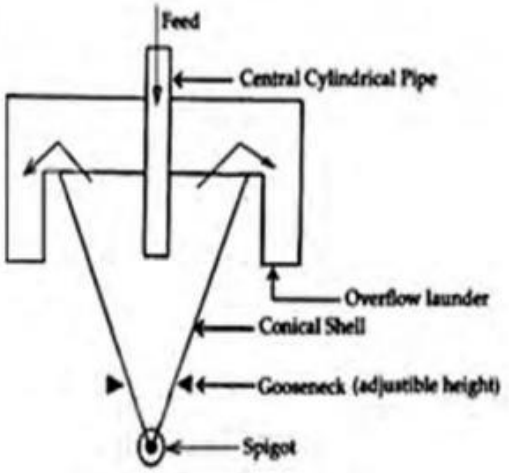
a. Settling cones having no moving parts and

b. 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.

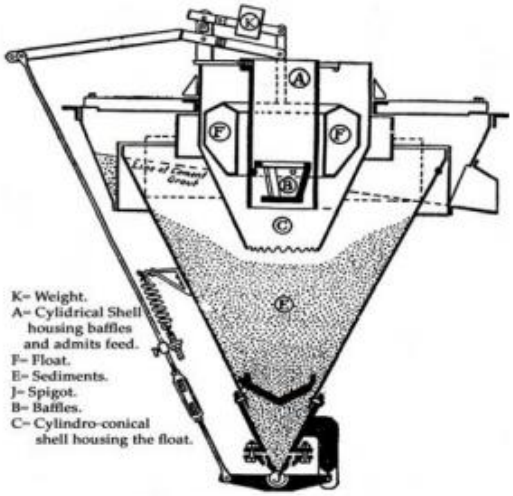
***Settling Cones:***

- 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 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.




***Allen Cone Classifier and its Construction:***

- This is mechanical classifier as it involves moving parts.
- The main difference between Settling & Allen cone is the automatic discharge of the classified material in case of the later one.
- The shape of Allen cone classifier is quite similar to that of settling cone.
- A float, F is situated within the cylindro-conical shell, C which surrounds the feed shell, A.
- The baffle, B is working against a spring to keep the spigot, J closed. When the level of sediment, E rises sufficiently in the cone, it prevents the passage of pulp from the feed shell, C to the body of the classifier.
- Then the float is raised and it opens the spigot allowing discharge to take place automatically.
- Discharge will continue until the float is brought back to its redetermined initial position.
- The effect will be same when density is raised.



Allen Cone Classifier.

- The discharge will continue until the density is brought back to the initial level.
- The density is regulated by a mechanical weight, K adjustment.

Chapter-6

# Gravity concentration

***Explain the general principles of wilfly table & its operation.***

## ***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.

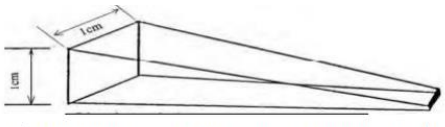
• Table is shaken asymmetrically .

• 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.

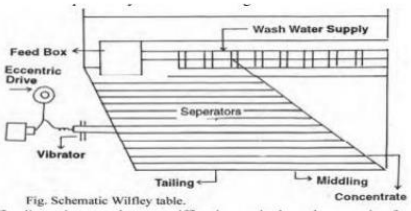



Fig. Schematic Wilfley table.

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.

***Develop elementary idea regarding the operation jigs.***

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:

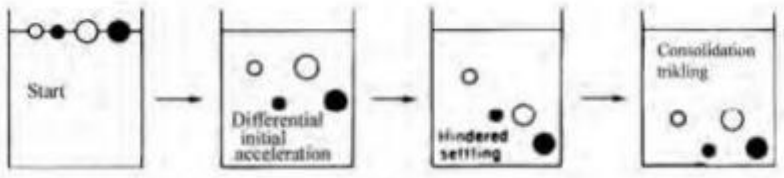
a. Hindered settling classification.

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.




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.

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,

**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.

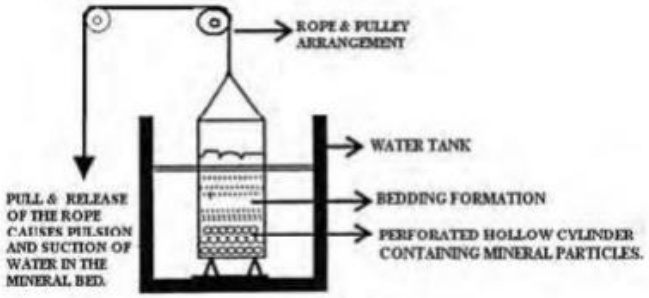


Fig. Laboratory Hand Jig.

**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. Typical Mechanical Jig:

There are different mechanical jigs such as:

1. Fixed sieve plunger jig.

2. Fixed sieve Pulsator jig.

3. Pneumatic or Baum jig.

1. Fixed Sieve Plunger Jig (Harz Jig):

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).

2.Plunger Jig:

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. 3. Pulsator jigs: 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.

**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. 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.

**5. Pneumatic or Baum Jigs:** 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.

**Advantages of Jigs:**

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-7

# Heavy media separation

## ***● Explain the fundamental principle of heavy media separation – Chance process.***

**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 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.

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 CaCl2 solution. The wash liquor is returned to the concentration tank for recalculation CaCl2 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 CaCl2 71 solution of specific gravity 1.4. Subsequently the solution is recirculated to the separating tank for further cleaning of coal. 6.7.1.1.

**Process Characteristics:** 1. The loss of calcium chloride solution during washing of coal is in the order of 2-3 liters per ton of raw coal cleaned. 2. The process produces extremely clean coal. 3.

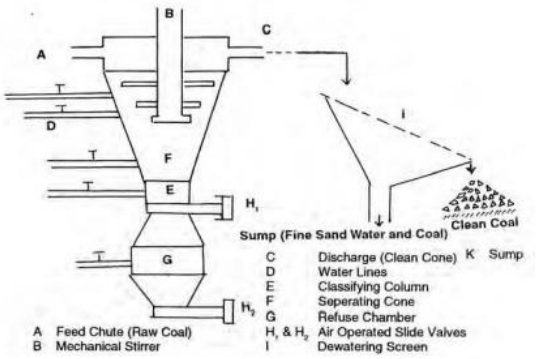
Because the process constitutes a costly thermal concentration process, widespread adoption of this process has been restricted.

***Bertrand Process:*** Bertrand process also uses calcium chloride solution as separating medium and is applicable only to deslimed coal. The process is mainly utilized for washing of coal of 1-5mm size. This process is different to Lessing process with respect to feeding method. Here the feed material is charged into the system in a counter current fashion starting from water to separating solution. Purified coal & waste are being withdrawn in a similar counter current fashion. There are five (5) circulating liquors such as hot water, weak solution, medium solution, strong solution & separating solution as shown schematically in the figure .

**Characteristics of the process:** 1. This process avoids costly thermal concentration of dilute solution. 2.This process introduces relatively complex hydro-metallurgical flow sheet compared to Lessing process. 3.The results obtained by the above two process are excellent and coal of extremely high grade coal is obtained.

***Chance Process:***

Chance Process is in use for last 100 years for cleaning coal. The parting fluid is a suspension of quartz or sand particles in water. The sand used here is in the size range of -40 to +80 #. The Chance Cleaner consists of a separating tank or a Cone Separator in which sand suspension moves up gently. An agitator is used for stirring the suspension to prevent packing. The overflow of clean coal and sand passes over to the cleaning screens which desand and dewater the coal. Spray water is used for desanding. The specific gravity of the fluid is adjusted by varying the proportions of sand and water. For cleaning anthracite coal a heavier fluid is used than compared to the fluid used for cleaning bituminous coal. Figure shows the Chance process schematically.



CHAPTER-8

# Floatation

***Comprehend elementary principle of froth floatation, practical utility of frother, collection, modifiers & depressants.***

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 such a case the adhesion is affected between a free water surface and the mineral particles.

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. Surface Energy or Surface Tension and Contact Angle: At any interface there exists certain amount of energy called surface energy

**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 figure .

***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.

***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

***Flotation Machines:***

Two important flotation machines are: 1. Pneumatic cell. 2. Mechanically agitated or Sub-aeration cell. In the pneumatic flotation cells compressed air is directly blown into the pulp while in the sub-aeration cell a rotating impeller serves as a pump which draws in air through the hollow shaft of the impeller and distributes the same into the pulp to produce the froth. In the laboratory, usually a rotating, hollow impeller type sub-aeration cell is used which is shown schematically in the figure

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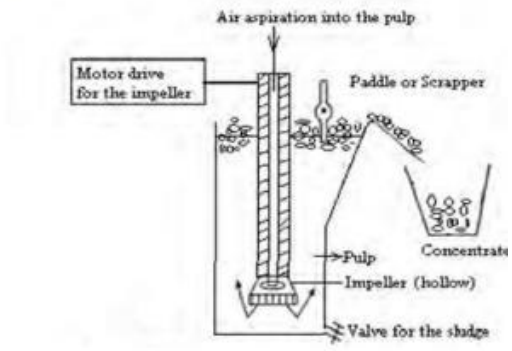
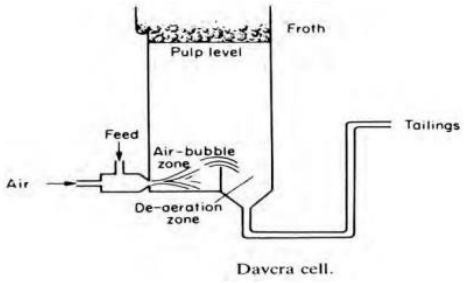



Laboratory model Sub-aeration Cell.

***Industrial Model:*** In industries hardly a single cell is used for practical floatation work. Rather a series of 10-15 cells connected in series are used-simultaneously. They are connected in such a fashion that one cell receives the defrothed pulp from the preceding cell as its feed. The recovery of such process is usually more than 90%. An industrial pneumatic cell is shown schematically in the figure




Davcra cell.

Industrial Flotation Cell.

# CHAPTER-9

## Magnetic & Electrostatic Separators

***Explain the principle of operation of magnetic & electrostatic separators.***

Introduction:

It is a fact that various metallic minerals exhibit magnetic properties. They are attracted by the magnet exhibiting specific attractability. Basing on the degree of attractability minerals can be classified as:

a. Ferromagnetic b. Paramagnetic c. Diamagnetic

1. Ferromagnetic Minerals: Few minerals such as magnetite and pyrrhotite are strongly attracted by magnets and behave as temporary magnets under the influence of magnetic fields. They are known as ferromagnetic minerals. 2.Paramagnetic Minerals:_ These are the minerals which are weakly attracted by the magnets. Minerals in this group are illmenite, hematite, garnets etc. 2. Diamagnetic Minerals: Minerals such as quartz, calcite and many others are practically non magnetic or may even be diamagnetic minerals. These minerals are repelled by a magnetic field along the lines of forces to a point where the magnetic field intensity is much smaller.

**Types of Magnetic Separation:**

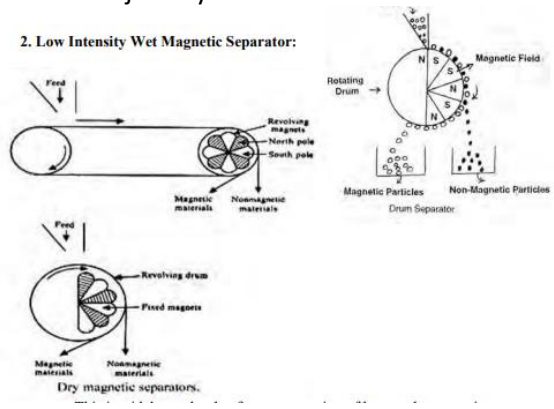
Depending on the magnitude of magnetic flux density, magnetic separation can be classified as follows: a. Low intensity magnetic separation. b. High intensity magnetic separation. A further subdivision within the group is possible depending on the medium in which separation is carried out. Depending on the medium of separation it classified as:

i. Dry magnetic separation.

ii. Wet magnetic separation.

**Different Types of Magnetic Separators:**

a. Low intensity dry magnetic separator: This is type of separation is commonly applied to separate highly magnetic particles like magnetite, tramp iron from the non-metallic utilizing a low intensity magnetic flux. When ore is travel on an endless conveyor belt passing over a magnetic pulley, the nonmagnetic particles follow a normal trajectory and are thrown clear but the magnetic particles are held firmly to the belt until it is carried out of the field and fall down when the belt just leaves the pulley. This phenomenon is shown schematically in the figure




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

**Electrostatic Separation:**

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: 1 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:

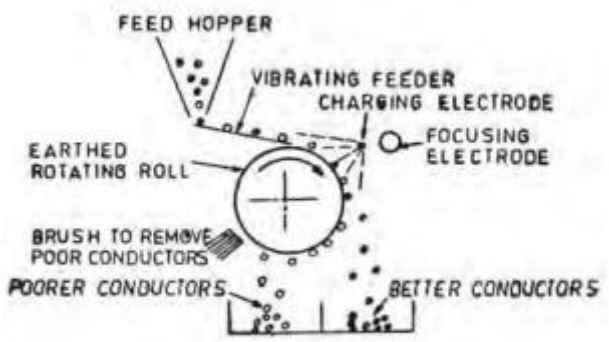
a. Conductor: When electrons are highly mobile in them (Metals).

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.

***High Tension Electrostatic Separation:***

Similar to high tension magnetic separation, there is also a high tension electrostatic separation. During this separation the material grains are chargedup electrically due to ion bombardment on them along with the induction from the electrified drum. Ions are produced in the air gap between the electrically charged wire and the grounded electrified roll due to very high potential difference of few thousand volts maintained between them. The air around the wire becomes ionized and is attracted toward the grounded roll to discharge its ions. Usually a potential difference of 30kV and above is applied to the wire electrode to make a corona discharge. The wire electrode is also known as corona electrode. If the voltage difference is sufficiently high the ionized corona is visible as a luminous discharge. On entering into the electric field the conducting mineral particles are bombarded with gaseous ions and get charged negatively and thus get deflected away from the ground roll. The non conducting particles are not deflected and have a free fall as it happens in case of usual electrostatic separator. The working principle of high tension separator is shown schematically in the figure.




High Tension Electrostatic Separator.

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.

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