UNIT-01

SCOPE AND BASIC CONCEPTS OF ORE DRESSING / MINERAL PROCESSING

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1.1. Define the term ore dressing / Mineral processing.

ore dressing/ Mineral processing is commonly regarded as the processing of raw minerals to yield marketable products and waste by means that donot destroy the physical and chemical identity of the minerals.

Hydrometallurgy, Pyrometallurgy, and oil refining may also deal with raw materials, but those processes change the character of some or all of the constituents of the raw material.

1.2 State the scope of mineral processing.

~~(The mill recieves its raw materials from the ore areas by mining)~~

~~(In a general way, the scope of mineral dressing is)~~

With the improvement in mineral processing techniques, it has become possible to carry out the mining of low grade and complex ores employing bulk mining. (mining of desired mineral along with unwanted gangue at much lower cost)

In general, the scope of mineral processing is a 3 fold. This means.

(a) Elimination of undesirable chemical species (or)
(b) Elimination of undesired size or structure
(c) Selective seperation of desired ~~mineral~~ materal.

The first two are commonly considered to be more important in mineral processing.

1.3 State the Important operation of ore dressing.

There are 4 principal types of operations which are involved in ore dressing

They are.

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1. comminution
2. Sizing
3. concentration
4. Dewatering. and other auxilary operations

Comminution :- comminution means reduction to smaller size. Depending upon size of the material being comminuted, the operation is regarded as crushing and grinding.

Sizing:- Sizing is the seperation of a material into products characterised by difference in size.

Concentration:- This can be accomplished by washers, sluice boxes, shaking tables, floatation cells, magnetic seperators, electrostatic seperators or other specific concentrating device

Dewatering :- This is generally carried only to the extent of producing a damp cake, in two steps

(1) First in thickers to remove most of the water, then

(2) In filters, which recieve the thickened pulp and yeild the damp mineral cake.

The other auxilary operations are naturally quite diverse, They involve storing in bins, conveying, sampling, weighing, reagent, feeding, pulp distributing etc.

1.4 List the properties of Mineral useful in concentration

The various physical properties of minerals are as follows.

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1. transparency
2. Lustre
3. colour
4. Specific gravity
5. Hardness
6. Cleavage
7. Fracture.
8. Magnetic properties
9. Electrical properties
10. Radio active properties
11. Optical properties
12. Luminescence.

Physio chemical properties

Chemical properties utilised in ore processing are necessarily limited due to the mechanical nature of ore processing operations. The properties utilised are those which effect the physical behaviour of minerals in an ore processing operation without giving a chemical change to the bulk of the minerals or are directly applicable in chemical benificiation.

1.5. State the necessity & Advantages of Mineral processing:

Necessity:-

The various economic factors including the choice of a process and efficiency operations are

(1) required reduction in bulk of the ore for transportation

(2) standardisation of product required for selling and

(3) A proper balance of processing cost with the market values of products / concentrates.

Advantages :

1) Cheaper physical/chemical method of rejecting the waste material is substituted for the more expensive chemical/ metallurgical methods, such as smelting, refining etc

2) Rejected waste material is not transported which saves freight (amount spend on transportation)

3) In the case of non-metalliferous ores, such as graphite, emery and precious stones, the mechanical methods can only work in seperation/ concentration.

4) Seperation of two valuable minerals associated in the ore, fetches more money than selling together in one ore

5) Mineral processing results in reduced losses at the smelter, due to reduction in amount of metal-bearing slag produced in smelting.

6) The total smelting cost is reduced due to reduction in tonnage of ore to be smelted.

2.1 Define communition

Comminution is the term used for reduction of ore to a smaller size. Communition of an ore canbe performed in dry or wet condition, depending upon the required size of material.

The operations involved in comminution are regarded as crushing or grinding. Crushing is almost always conducted on dry ore, where as grinding may be wet or dry. The extent of comminution depends on the mineralo-gical nature of the associated gangue minerals.

2.2 State the objectives of comminution.

The objectives of comminution are as follows

(a) Reduction of large lumps into smaller pieces

(b) Production of solids of desired size ranges or specific surfaces for direct metallurgical treatment.

Ex:- powdered coal for boilers & 3-8cm iron ore for blast furnace

(c) Breaking apart valuable minerals from intimately associated gangue material. i.e: liberation of valuables from gangue

(d) Convinience in handling and transportation

(e) Preparation of feed material for different ore processing methods. Ex: granular material for gravity methods and fine particles for forth flotation.

2.3 List the purpose of comminution:

(same as 2.2)

2.4 Classify the comminution process

The comminution process may be divided into 3 stages

(1) Coarse size reduction carried out by primary crushing

(2) Intermediate size reduction carried out by secondary crushers

(3) And fine size reduction carried out by grinders or fine crushers

Q.5 State the law of comminution process 6

(a) Rittinger's law:

* In 1867 Rittinger proposed that

* The energy required for reduction of particle size, should be directly proportional to the new surface formed (Increase in surface) ~~area~~. In other words, it may be said that the minimum energy required is the surface energy of new surfaces created

Rittinger's law can be written as

$$E_r = \frac{a}{d_0}$$

where

a = constant

d_0 = original size.

(b) Kick's law:

* In 1885, Kick suggested that

* The energy required for producing a specified reduction ratio is proportional to the log of reduction ratio.

Kick's law can be written as

$$E_r = b$$

where

Er = Energy required to obtain a specified reduction ratio

* The Kick's law is based on the assumption that geometrically similar particles would always break in geometrically similar manner, irrespective of their size. Thus if a hypothetical crystal of a mineral initially $1 cm^3$ in volume and 1 cm ~~is~~ in side, is broken in 8 cubes, each of 0.5 cm side, the energy required would be exactly the same as that required to reduce the cube of 1mm side down to 0.5 mm side or even from 1 micron to 0.5 micron. The energy required for unit volume, would thus be proportional to the number of reduction stages (n). In the above case, the reduction ratio would be $(1/2)^n$. 7

(c) Dobie's Equation.

* The two approches ~~by~~ given by Rittinger & kick are quite different.

* Rittinger considered the energy in the product of particular size distribution. where as

* Kick has considered the energy required to break the original particle, irrespective of number of pieces produced

* In Rittingers theory, the net free energy of the change of stage is measured, where as, in Kick's theory, the activation energy of the process is measured. Rittinger's energy is an irreducible minimum, while kick's energy may modified by changing the mechanism of breaking.

* Dobie has reconciled the hypothesis of Rittinger and kick. The equation can be written as

$$E_r = b + a/d_p$$

where

d_p = product size

(d) Bond theory:

* It has been confirmed that the fracture usually occurs by the extension of cracks, already present in the surface of the particle, and such cracks lower the activa-tion energy of fracture to a great extent.

* Therefore, the energy required shouldnot be proportional to the volume of the particle, rather to the length of the crack produced with energy. Following this line of argument a new approach was given by F C Bond. the theory is based on following 3 considerations, which were not considered by Rittinger and Kick.

i. The work previously done on feed, can't be neglected

ii. In milling, regularly shaped particles are handled, rather than cubes

iii. The energy released as heat, cannot be neglected

(e) Holme's Equation:

* Holmes proposed a modified form of kick's law, suited to ores in following Equation

$$B = K D^{1/r}$$

* where B = Theoritical elastic energy absorbed in deformation

* to produce unit area of fracture in a cube of side "D"

r and k = constants

* For a reduction ratio "R" and product side "P". This equ can be written as

$$W = W_i\left[1-\left(\frac{1}{R}\right)^r\right]\left[\frac{100}{P}\right]^r$$

where W_I = Work Index

r = Kick's law deviation exponent, expressing the degree of variation of particle strength with variation is size

specific material, mode of stress application.

2.7 state the principles of crushing (same 2.5)

2.8 Classify the crushing operation (same 2.4)

2.9 List the types of crushers.

(1) Primary (or) coarse crushing Machines

i, Jaw crusher

(a) — Blake Jaw crusher

(b) — Telsmith Jaw crusher (universal crusher)

(c) — Dodge Jaw crusher

ii, Gyratory crushers.

(a) suspended spindle type Gyratory crusher

(b) Telsmith parallel pinch crusher

(2) Secondary or Intermediate crushing Machines

i, Cone crusher (symon cone crusher)

ii, Telsmith Gyrasphere

iii, Roll crushers.

iv, Toother or slugger Roll

(v) disk crusher

(3) Fine crushing machines

i, Gyra Disc crusher

ii, Hammer Mills

(4) Special crushers

i, squirrel cage disintegrator

ii, Disk crusher.

Q.10 State Jaw crusher and Gyratory crusher.

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Jaw Crushers:-

Jaw crushers consist of two crushing faces or jaws one of them which is stationary, being mounted rigidly in the crusher frame and the other moving alternately towards the stationary face and away from it by a small throw.

Jaw crushers can be classified according to the point of minimum amplitude of motion on the moving face and according to the way in which the motion of the movable face is transmitted.

① Blake type crusher
② Dodge crusher
③ Telsmith crusher.

Blake type: In this crushers, the movable jaw is hinged at the top so that the greatest amplitude of motion is at the bottom of the crushing face

Dodge crusher:- The reverse is true, the bottom jaw is the fulcrum, and the top moves by the greatest amplitude.

GYRATORY CRUSHERS:-

A. Gyratory crusher mainly consists of two vertical conical or domed shaped crushing member. The inner member (apex of which is pointing up) gyrates around the vertical axis inside the stationary outer crushing member (apex of which pointing downward).

The inner conical member may gyrate equally at the top & also at the bottom or only gyrate at the bottom & crush the ore or mineral

out of many varieties available, the short shaft suspended spindle and fixed-spindle type gyratory crusher are worth to mention.

The best known gyratory crushers are the supported-spindle gyratories, the ~~sp~~ suspended-spindle gyratories, and the "parallel-pinch" crushers.

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Q.11 State the working principle & operation of Blake and Dodge crusher

Blake-Jaw crusher: Blake crushers are made in the largest size and have the distinction of being oldest type of coarse crushing machinery in current use.

- In a typical Blake crusher. as shown in fig
- The crushing frame is made of cast steel (1).
- The jaws are made of cast steel lined with replacable jaw plates (8). of alloy steel, generally manganese steel, and the sides of the crushing opening are made of manganese steel check plates (9)
- Motion is transmitted from the main crusher shaft (4) by means of pitman (3) working on an eccentric on that shaft, and of toggles (5). The pitman is nearly vertical and the toggles nearly horizontal.
- One of the toggles is set in steel bearings at one end of the frame and at the other on the pitman;

The other toggle is set in steel bearings on the back of the movable jaw at one end and in the pitman at the other (6)

As a result of this design, the rotation of the drive shaft causes an up-and-down translation of the pitman & consequently an increase and decrease of the ~~pitman and~~ distance b/w the back of the movable jaw and the frame.

The movable jaw is kept pressed against the toggles by a tension rod and spring.

Provision is made for wear on the movable jaw by shims or by making it possible to move the setting block of the rear toggle (10).

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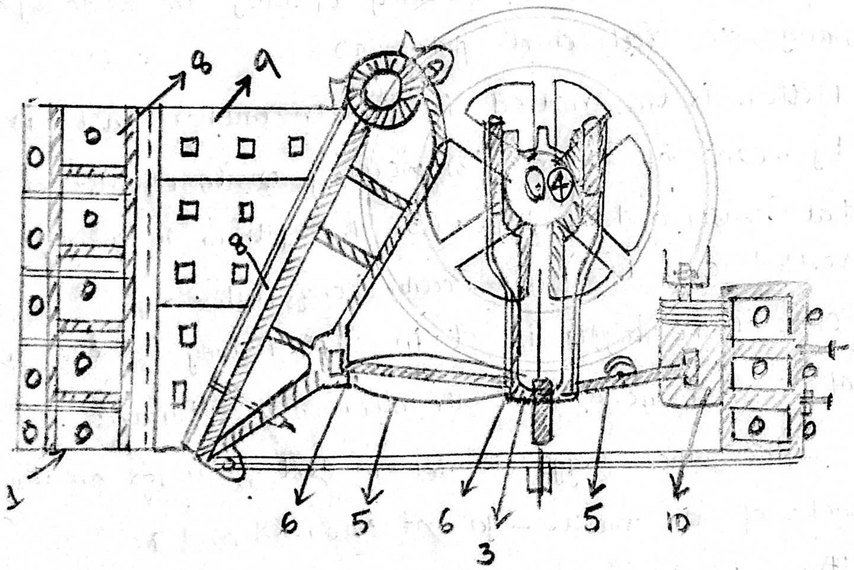
Forced feed lubrication is the rule.

Because of the intermittent load on a jaw crusher, it is necessary to equalise this load by means of fly wheels.

One of the two flywheels are generally mounted on the mainshaft of the crusher, and the drive is by flat belt or V-belts.



Dodge Crusher :-

1) The Dodge crusher is made only in small sizes

2) It differs from the Blake crusher in that the fulcrum of the motion of the movable plate is at the bottom of the plate, so that the width of the discharge opening remain practically constant

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3) This results in the production of a more closely sized product.

4) Also, the crusher has fewer parts : one toggle instead of two and no pitman.

5) The advantage of constant discharge opening and of more uniform size of product may be significant if the crusher is the only communicating device used, but if the crusher is followed by other comminuting machinery, This minor advantage is a little practical value.

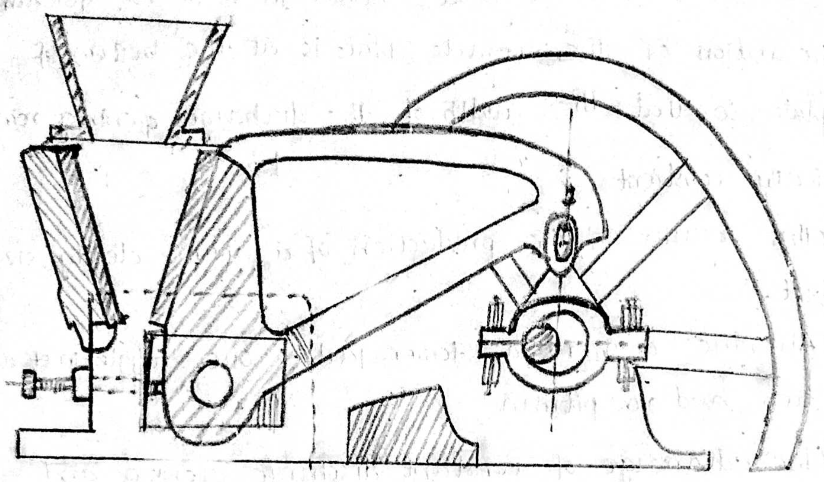
6) The Dodge crusher, also represents a less satisfactory design from a mechanical stand point in that the displacement of movable jaw is atleast where the crusher is required to disintegrate the finer lumps and greatest where the crushers has to deal with coarser ~~than~~ lumps.

7) The stresses are therefore uneven

8). This make the machine weaker and it is the reason why it is not build in large sizes.

9) In large installations where elaboration of flow sheet by the introduction of screens is not a serious objection, Blake crusher is preferred

Fig: Dodge Type Jaw crusher.



Q.12: State Working principle & operation of Roll crusher.

1) Crushing rolls (or) Roll crusher consists of cylinders revolving towards each other so as to nip a falling ribbon of rock and discharge it, crushed, below.

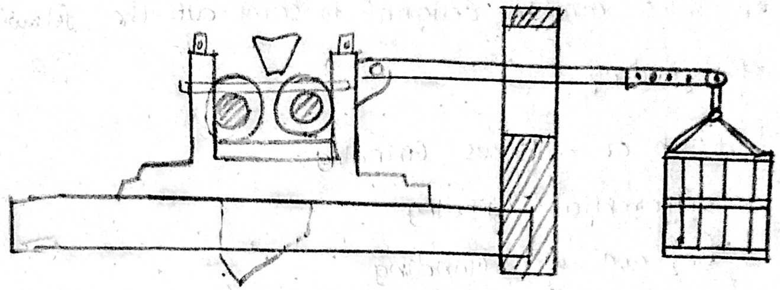
2) Rolls were crushed (invented) more than 100 years ago, record of their use in cornwall going back to 1806.

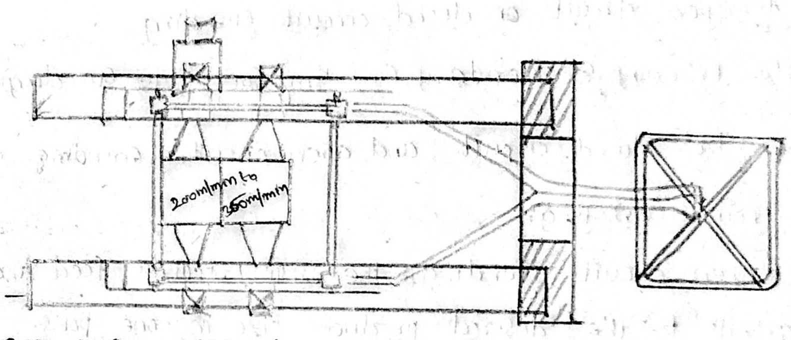
3) In early machines the rolls mounted on heavy shafts revolving in open bearings contained within cast-iron side frames.

4) one of the rolls was driven positively and the other by friction

5) To assure rotation of Idler and to prevent breakage, the Idler was pressed sideways against the live roll by a heavy weight hang from a yoke.

6) In modern designs both rolls and positively driven at much higher speeds, and brakage is prevented by mounting the bearing of one roll shaft against coil springs (input 4-5m and output 2.5mm)





Q.13 Define the term Grinding.

Grinding may be referred to breaking down the relatively coarse material (produced by crushing) to ultimate fineness.

A part from the grinding of ore, for their subsequent beneficiation, the grinding is also done for preparing the materials for industrial applications, such as grinding of quartz and feldspar to fine mesh below 70 microns, grinding of talc to prepare body powder, grinding of Iron ore for preperation of pellets and many others.

2.14 List the types of Grinding Machines

The types of grinding employed depends on the type of ore, quantity of ore to be ground, the use of the ground product etc. The mills can be designed to carry out the following types of grinding

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1. Batch or continous Grinding
2. Differential Grinding
3. Dry and wet Grinding
4. Open circuit or closed-circuit Grinding
5. Primary & secondary Grinding (or stage Grinding)

2.15. Describe closed circuit and open circuit Grinding.

Open circuit Grinding:-

1. In open circuit Grinding, the mill receives feed and grinds to the desired product size in one pass.

2. Depending upon sizes of feed and product, open circuit Grinding requires more power than closed circuit grinding

3. Open circuit Grinding is usually employed in following cases

i) For coarse Grinding
ii) To grind the wet cement - raw mix
iii) Where sizing costs make a closed circuit grinding uneconomical
iv) When tramp oversize and extreme fines can be tolerated

4. In continous open circuit operation the discharge from one mill goes to the next operation.

Closed circuit Grinding:-

1. In closed circuit Grinding the mill discharge is fed to a sizing device to seperate out the oversized material which is recycled to the grinding mill.

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2. The particles may pass several times through the mill before being ground to a final size.

3. The recycled material is termed as circulating load and is referred in terms of percent of new feed.

4. In general, the closed-circuit system requires minimum power except for rod mill applications.

5. The product size is controlled by the sizing device, and this system lends to instrumentation and automation.

6. Closed-ciruit grinding requireds less skilled operators to give a constant product size analysis.

7. Closed-circuit grinding is used in most mineral processing industries.

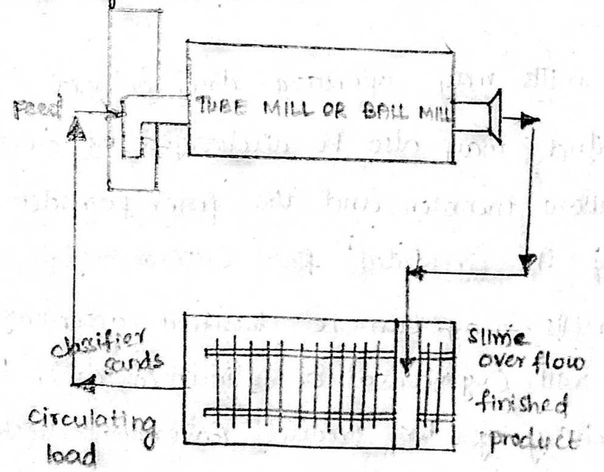


Fig: Schematic diagram showing closed circuit grinding.

2.16 State the principles of working of Ball Mills or Rod mills

Ball Mills

1) The ball mills date back to 1876 and are characterised by the use of balls (made of Iron, steel or tungsten carbide) as grinding medium.

2) These mills are horizontal, rotating cylindrical or cylindroconical steel shells, usually working as continous machines.

3) The size reduction is accomplished by the impact of these balls as they fall back after being lifted to certain height by the rotating shell.

4) The length of the cylinder is normally equal to the diameter

5) The feed enters at one end and the product is discharged either through the opposite end or through the pheriphery

6) The ball mills may operated dry or wet.

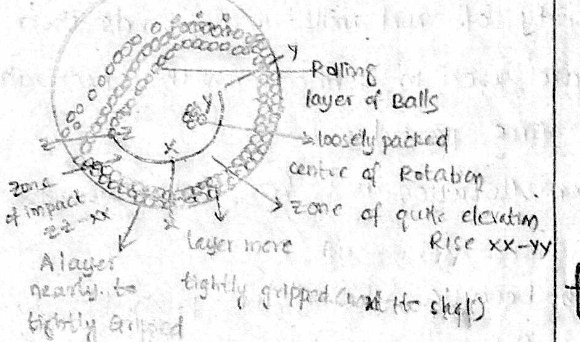
7) The product may also be discharged by overflow through a hallow trunnion and the finer particles are carried away by the circulated fluid (air or water).

8) The ball mills ~~may~~ can be classified according to the shape of mill (cylindrical or cylindroconical), the method of discharging the product (overflow discharge, or grate / diaphragm discharge mill), discharge rate (high discharge mill, low discharge mill), and whether operated dry or wet.

9) In dry grinding, the load is kept lower (below 40%) than in wet grinding to avoid over-carry at cataracting speeds

10) Theory of ball mills :

In action the balls are lifted up the rising portion of the shell & rolled down or thrown over into the pool, nipping ore particles, against other balls, the lining, or other pieces of ores.



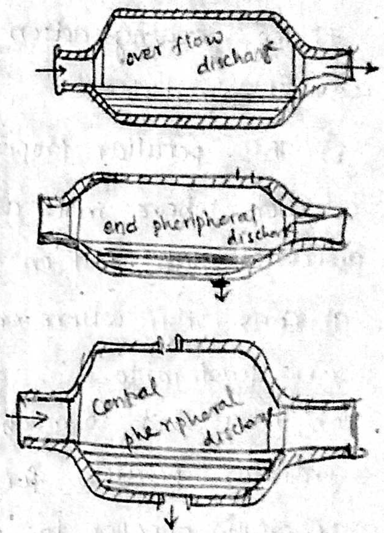


Fig: Rod Mills

ROD MILLS

1) Rod mills are similar to ball mills in appearance and general principle

2) They may be defined as rotating cylindrial shells loaded with rods that grind the ore by tumbling with in the shell.

3) Rod mills are made of a length greater than their diameter in order to avoid jamming of the rods in the mill.

4) Ball mills, on the other hand, generally have a diameter commensurate with their length, since that type.

of construction yields the greatest capacity for a given weight of machine.

5) cylindro conical mills can be filled with rods instead of balls, provided the cylindrical section is relatively long and the diameter small

6) Rod mills differ from ball mills in their grinding action in that the rods are kept apart by the coarsest particles

7) The grinding action is exerted preferentially on the coarsest particles.

8) This peculiar property of rod mills recommends their selection where mills are used in connection with concentrating processes that fail on fine particles

9) Conversely, wherever flotation is to be used, ball mills are preferable.

10) This is not so much because "slimes" are preferable to granular particles for flotation as because ball mills are generally cheaper to operate than rod mills.

~~11) An objection to rod mills are generally cheaper to operate than~~

11) An objection to rod mills is that as rods wear down they become thin and occasionally warp, causing an entangling of the rod load, unless removed at intervals.

12) To avoid this difficulty, periodic opening and inspection of rod mills are in order.

13) It is also possible to minimise this difficulty by using rods of high-carbon steel, which is brittle rather than malleable.

14) The worn rods are then discharged as small bits of steel.

2.11 Comparision b/w Grinding and crushing

crushing	Grinding.
1) crushing is normally carried out on "run of mine".	1) one, while grinding (normally carried out after crushing) may be conducted on dry (or) slurried material.
2) Compression and impact forces are extensively used in crushing operation	2) Attrition is the Dominant force in Grinding
3) Crushing is done in crushers like: Jaw, Gyratory, Cone Roll crushers.	3) Grinding is done in Mills like: Ball, Rod mills
4) Crushing is done in closed (or) open circuit operation depending on crushing strength of mineral.	4) closed circuited with a classifier unit, are generally employed for grinding
5) crushing is a dry process	5) grinding is generally performed wet and hence is more energy intensive
6) Crushing mainly reduce the particle/ metal size	6) Grinding is mainly after reduction of size, then powder formation obtained
7) Lumps to chips formation for using crushing operation (i.e: reduction of size)	7) The chips then become a powder formation
8) Reduction ratio is less while comparing to grinding operation	8) Reduction ratio is high while comparing to crushing operation.

9. crushing is cheaper	9. Grinding is very expensive
10. It's performed in multi-stages like: i, Primary crushing. ii, Secondary Crushing iii, Tertiary crushing	10. It is in tumpling performed mills like: i, Ball mills ii, Rod mills iii, Pebble Mills iv, Autogenious, semi Autogenious mills based on the media used for grinding operation

3.4 Define Mesh number and Mesh size

Mesh Number:-

- A 4 mesh screen means there are 4 little squares openings across one inch of the screen.
- A 100 mesh screen has 100 openings per inch, and so on. Note: As the number indicating the mesh size increases, the size of the opening and thus the size particles captured decreases

Mesh size:

- Mesh size is the relationship to the size of the opening in mesh and thus the size of particle that can pass through these openings.

INDUSTRIAL SIZING

3.1. Understand the Importance of sizing.

Importance of sizing:-

1. The shape and size of mineral particles (ratio of surface to volume) influence mineral processing to a great extent
2. Higher the surface-Volume ratio, faster will be the rate of reaction.
3. A sphere possesses the minimum surface area for its volume, whereas a thin flat plate posseses a minimum volume for its surface
4. The most important functions of laboratory sizing control are to find the correct liberation size, and the size of grind for optimum unlocking of the desired mineral from the gangue
5. Another purpose of sizing, may be the grading of the product
6. However, commnution control is generally concerned with economic liberation of values from the ore.

3.2 Know the Methods of sizing

1. Hand screening
2. Mechanical shaker
3. Sub sieve sizing
   - i, Elutriation Method of sizing
   - ii, Sedimentation
   - iii, Infrasizing
   - iv, Permeability Method.

(v) Measurement with Microscope.

3.3. Define screening and classifiers :

Screening is defined as "A process of dividing a mixture of particles of different sizes into no. of fractions based on their size"

In screening operation the material retained on the screen is called over size (or) plus fraction, where as the material which passes through, is called undersize (or) minus fraction.

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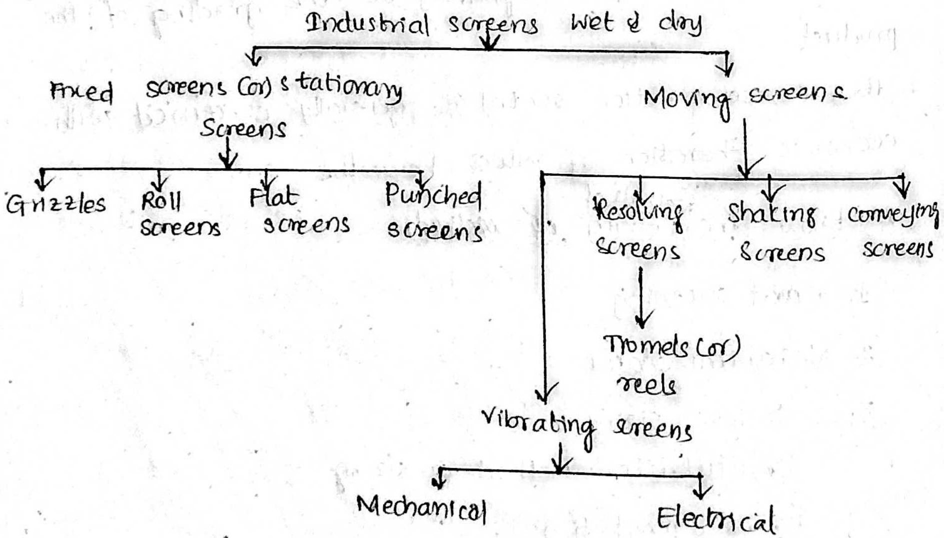
Classifiers:-

Classifiers can also be reffered as a screen since, they are used for the same purpose, but the choice of selecting a screen (or) classifier is based on a simple rule as for sizing particles coarser than 20 mesh, screens are preferred whereas classifiers are for sizers finer than 35 mesh.

3.6 List the types of industrial screens



* Industrial screening is performed on screen ranging from 300 mm down to 45 μm (325 mesh). Screening is performed both on dry and wet basis

3.7 State the working principle & operation of Mechanical classifiers

* Mechanical classifiers mainly consists of a rectangular or bowl shaped tank.

→ The pulp is feed under such conditions which allow the fall of heavier and coarser solids downward quite freely and flowing away of the lightest particles to wet discharge

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1. The mechanical part of the classifier generally consists of a drag belt, a set of rakes, or spiral screw which stir the pool of pulp and remove settling solids.

2. The pulp from the grinding mill with more addition of water (pulp density adjusted to about 30% solids). flows to the classified through a short launder under gravity (some times aided by a centrifugal pump)

3. If the feed contains equal size particles, a clean seperation of feed into heavy (sinking) mineral & light (overflowing) mineral can be obtained.

4. In practice, the feed contains a wide range of sizes with various stages of liberation.

5. As a result some particles drop swiftly, some flow away, while others accumulate in the sorting zone, which ~~exist~~ varies in its density from the uppermost watery layer to the densest part of the pool just above the raking zone.

6. These strata of varying densities ~~of~~ are stirred

by the rakes and bottom of tank.

7 Each layer of the pool continously recieves new particles from above which would be either

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i, allowed to fall through the layer

ii, Rejected back to the layer above it, or

iii, Retained by the layer.

As long as the layer sorts the entering particals according to i, or ii, the layer will maintain its integral composition & will carry out the work consistently.

8. However in practice, capture of more practicles is inevitable and there by its density increases.

9. The continous rise of pool density is partly offset by the stirring action of the rakes or spirals.

Dorr Rake classifiers

A section through the rake classifier is shown in fig below.

It consists of an inclined rectangular settling tank (inclination of the bottom may be about 12 cm/m) provided with rakes moving through an elliptical orbit with the help of an eccentric motion.

Mechanically operated rakes start their climb at the lowest settling portion of the tank and gather settled sand which is lifted sharply at the rising end of the stroke.

The rakes then return and drop the sand. The cycle is repeated.

The rake classifiers may be simplex when the trough has one compartment, duplex (two compartments), triplex (3 compartments), or multiple rake unit (many compartments), where compartments are seperately raked.

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The rakes can also be raised

The feed is introduced at either end of a transverse trough near the over flow, which is provided with splitter vanes to ensure even distribution of feed across the entire width of the tank.

The tanks are usually made of steel, but some-times can be constructed of wood or concrete.

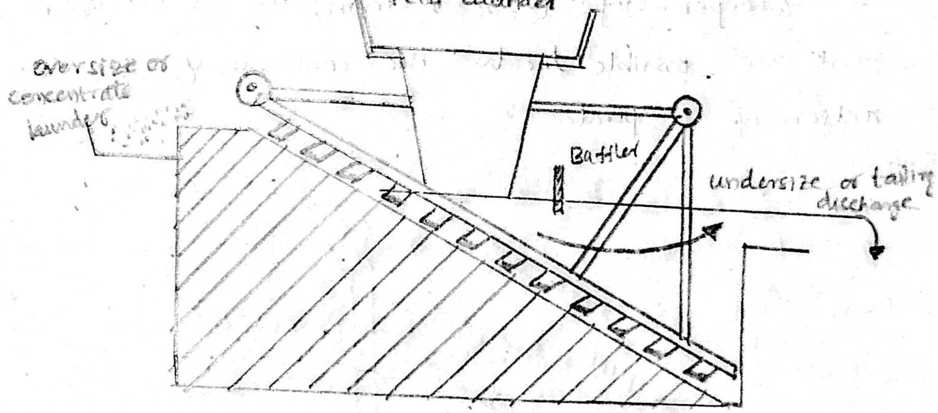


Fig: rake classifier

Spiral classifier:

The spiral classifier consists of a usual sloping trough (as in rake classifier) in which the pulp is maintained in stirring condition with the help of one or more helix (spiral ribbons) mounted on the shaft.

This helix does the same work as the rakes in rake-classifier i.e: to remove the material from the bottom of the tank.

The helix also works as an elevator for the bottom sand.

In the classifier, the settled material is turned over and over again, before its final discharge.

It offers better opportunity for complete desliming of sand.

The helix is run at a speed varying from its mixing diameter. The speed of the shaft is usually 3-20 rpm (lower RPM for a large spiral & higher for a small) depending on the size of the spiral.

Steeper slopes (25-35 cm/m) in the classifier tank are possible due to the continous & gentle action of a spiral.

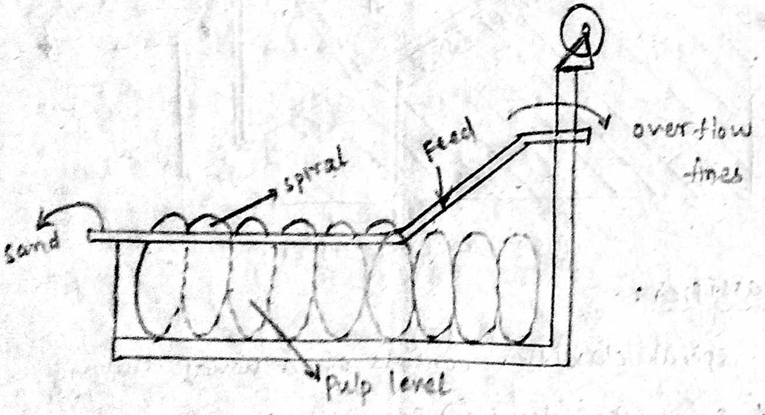


Fig:- Spiral classifier.

3.8. State the working principle and operation of hydrocyclones.

1. The hydrocyclone is made of conical shape having a cylindrical top.

The feed is introduced tangentially near the top.

A spinning motion is imparted to the suspension in the cylindrical portion and a vortex is generated about the longitudinal axis.

This accompanying centrifugal acceleration increases the settling rate of the particles, and tends to throw them radially.

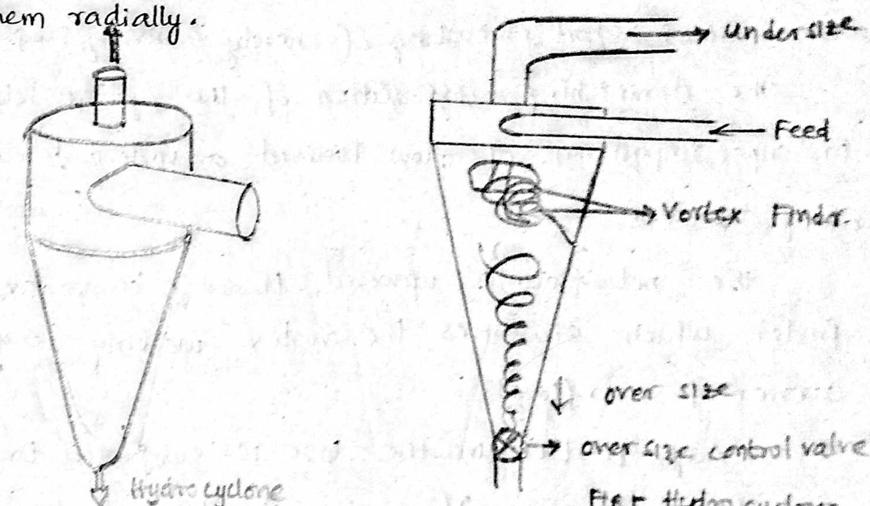


Fig:- Hydro cyclone.

The coarser particles spiral down to the cone's wall (where a zone of reduced pressure exists) and flow downward to the apex through which they are discharged.

The amount of feed joining the coarse product depends on the size of the inlet and vortex finder (provided the underflow donot exceed about 30% of the feed).

At the centre of the cyclone, a zone of low pressure and low centrifugal force exists, which surrounds an air filled vortex.

Therefore, a part of the feed carrying finer particles tends to move inward towards the vortex.

As a result, some newly entrained feed may be picked up by the vortex finder (a central pipe provided for removal of over flow) and removed along with the overflow.

30

Therefore, the vortex finder is so adjusted as to project into the conical section of the cyclone and thus to minimise short circuiting of newly arriving pulp.

The diminishing cross section of the cyclone helps in super imposition of flow toward a vortex developed along the axis.

The net flow is upward through a vortex finder which stabilises the vortex working as a carrier of overflow.

Any particle in the size is subjected to a centrifugal force mv^2/R, characteristic of its tangential velocity 'v' and radius 'R' of its path (almost equal to radius of cyclone), and a drag force caused by the local inward flow of the fluid which depends on the relative radial velocity, the viscosity of the fluid, size of particles and specific gravity of particles

2.6 Define the terms

Sorting:

It is the process of seperating an ore into constituent parts

Ores are typically sorted to increase the efficiency of other refining process, by reducing the amount of material to be processed while simultaneous increasing its purity.

Liberation:

With in an ore body, valuable minerals are surrounded by gangue and it is the primary function of mineral processing to liberate and concentrate those valuable minerals. Generally mineral processing begins when ore is delivered from a mine to processing facility.

UNIT - 04

CONCENTRATION

4.6 Explain the Gravity method of Seperation:

* Gravity concentration in streaming currents:

1. Gravity concentration in streaming currents is also known as "flowing film concentration".
2. The transporting force is proportional to the cross section exposed to flow, which can be employed to the size the homogeneous sand, to wash out particles of light mineral from heavier particles and to seperate particles of similar density but different shape and size.

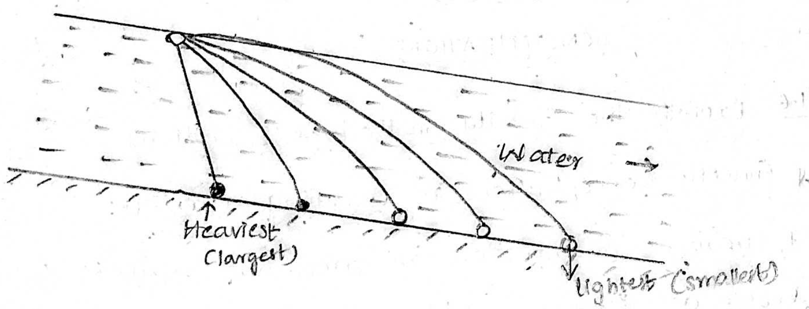
* Theory of Film concentration

1. Behaviour of a no. of spheres ~~expos~~ composed of 2 kinds of minerals (heavy and light) and of different sizes introduced into thick layer of H_2O running gently down a smooth plane can be represented as shown in fig (a)

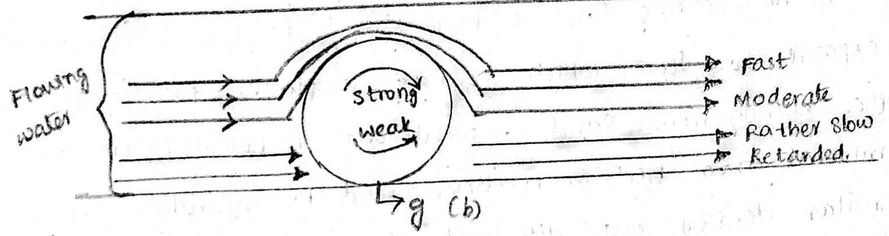
2) The relative displacement and thereby their seperation is based on the mass effect, according to which largest heavy spheres will fall faster and will be least affected by the water current and therefore, these spheres will collect nearest of downstream to the feed entry point. (2)

3) On the other hand, smallest light particles will be drifted farthest downstream. The other spheres will overlap to some extent.

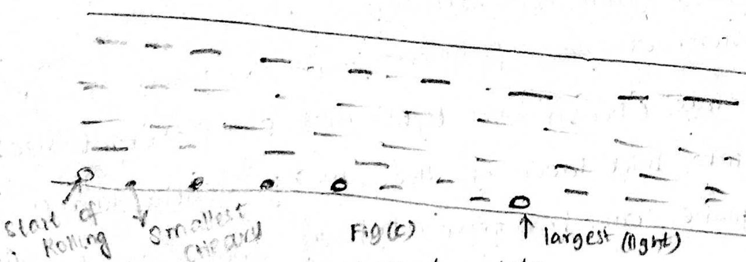
4) Therefore, this process will result in clean coarse, concrete upstream, a clean light gangue downstream, and overlapped mixture in between, which can be seperated by screening.



a) Behaviour of spherical particles (a) of 2 kinds of minerals and of different sizes



(b) Effect of various forces



(c) classifying effect on streamed particles

5) In particles, the mineral particles are never spheres and their shape is an important determining factor to the push of the stream and the ease of rolling.

6) The flattened flakes would be first to stop, the cubes would come next and rounded particles would roll farthest. (3)

7) Further, in pratice it is not possible to provide the large surface area required to develop the seperating conditions fully and thus for efficient seperation, a bed of material having many particles along the depth is necessary, which is provided by the use of riffles across the flow of water.

8) The riffles introduce turbulance and vortexing in the waterflow. The lighter particles will climb over the obstacles and would be carried along by the water stream, while the heavier particles find their way in the pockets.

9) Therefore, an increased dynamic pressure along a seperating surface (sluice) may be obtained by increasing

(a) flow rate of water

(b) slope of the surface and

(c) roughness of surface.

The main factors controlling the seperation are

(a) Slope of the seperating surface

(b) Thickness of water film and rate of flow

(c) Relation b/w maximum and minimum settling rate of feed particles in water

(d) % of solids in pulp (solid-liquid ratio)

(e) Relative density of concentrate and tailing particles

(f) Shape and size of particles

g) Tightness of particles interlock along the bed

h) viscosity of the fluid, if water is not used

4.7 Describe the tabling method (Wilfley's Shaking table)

1. Various shaking tables mainly differ in the design of riffles and the way in which the motion is imparted

2. most widely known shaking table is wilfley table. original wilfley table was made by Arthur R. Wilfley in May 1896 at colorodo

3. The most important features of wilfley table are.

(a) the introduction of riffles which increased the capacity and permitted the treatment of coarser material and

(b) use of effective and rugged head motion

The wilfley table consists of a 4 sided nearly rectangular deck with the adjustable slope towards one of the long sides. This deck is actuated by a pitman and toggles type adjustable head motion as shown in fig.

Construction of shaking tables:

1) The shaking table consists of a large flat surface (deck) made of canvas, wood, which is inclined slightly (about 5°) both front to back and from left to right. Its surface may be roughened or provided with grooves or cleats to form riffles

2) The cleats are usually made of wood, and are 5 to 15m wide and 5 to 10 mm high, spaced at 15 to 50 mm apart

3) The cleats cover most of the deck as shown in figure. The riffles form a large no. of parallel channels usually 2cm wide x 1 cm deep at the starting point and tapering down to (zero) 0 depth at the lowest end

4) Pulp is fed at the top high corner and flows through the channels. A flow of water is maintained, across the table

5) The table is given a reciprocating horizontal motion at the rate of about 300 cycles per minute

6) Each cycle consists of a relatively slow forward motion and a very rapid return which causes the particles to creep forward along the channels.

7) Riffles are responsible for the increased capacity of concentrating tables over smooth ones due to the possibility of treating a suspension of material many particles deep.

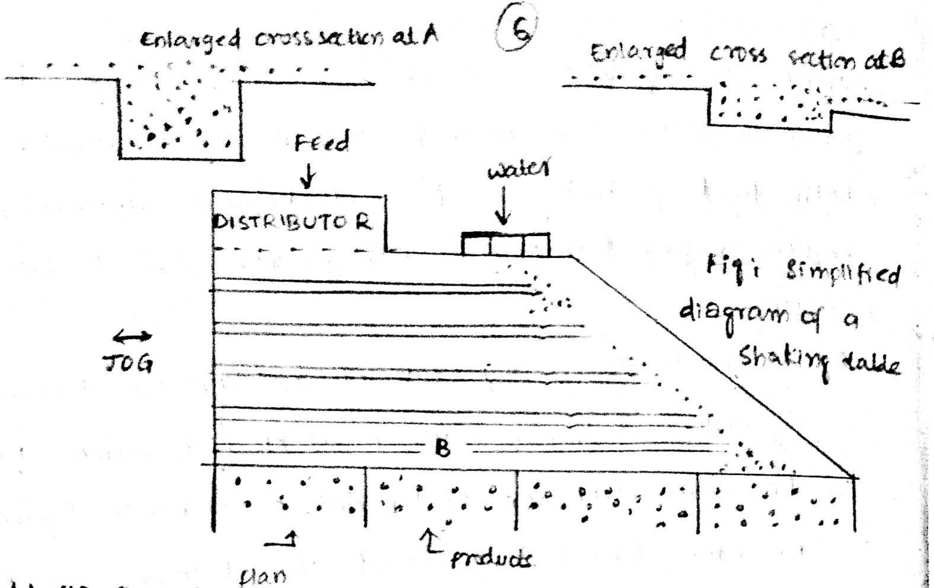


Fig: Simplified diagram of a Shaking table

Working principle & operation of Shaking tables

1) In shaking tables a no of spheres may be considered as rolling down a slightly tilted plane under the combined influence of a flowing stream of water & gravitational pull.

2) Under such conditions, the movement of various spheres can be represented as shown in fig.

3) The largest particle (sphere) will travel fastest and the smallest one slowest in case of spheres having the same density

4) On the otherhand, if two spheres have same diameter but different densities, the lighter spheres will tavel faster

5) If the plane is moved sideways during downward travel of these spheres, the horizontal displacement of spheres will vary according to the time taken in rolling down (varying inversely as the square of ϕ of particles)

6) Under the combined effects of all the forces, the particles will travel along a diagonal line begining at the feed box

7) fig. shows the largest light sphere has undergone atleast horizontal displacement due to its maximum velocity while the smallest heavy one has been carried farthest to one side

8) Therefore, the feed can be spread into suitable bands according to the size and density particles by applying a displacing movement to the seperating plane.

9) The feed thus gets seperated into 3 products as follows which can be collected seperately as they leave the deck.

ⓐ Fast moving: These consist of coarse lightest grains [gangue]

ⓑ Medium moving: These consist of fine light and coarse heavy particles (middlings)

ⓒ Slowest moving: These consist of fine heavy particles (usually concentrate)

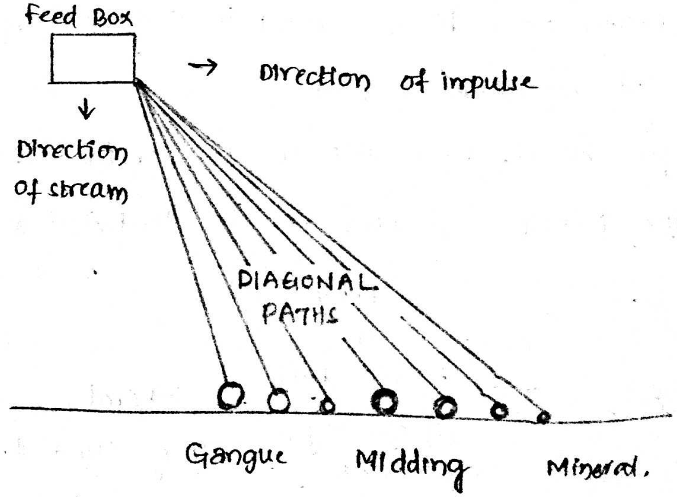


Fig: Representation of movement of various spheres under shaking conditions.

Q.9 Describe the working principle of Dense Media Seperation (DMS)

1). When an ore or material having particles of different densities are immersed in a liquid having sp.gravity in b/w the sp.gravity of associated particles, lighter particles would float and the heavier would sink.

2) The floats and sinks can be withdrawn seperately. This process is based on purely on density of ~~Materials~~ minerals and doesn't depend on rate of fall or size of an ore or ~~mineral~~ material

3) This process is known in the industries by various names such as sink and float, dense media seperation, heavy media seperation and heavy liquid seperation.

4) However the process is usually reffered as ~~dense~~ dense media Seperation (HMS) or Heavy media seperation (HMS)

5) The seperation can be carried out in a quite single bath or controlled agitation of bath.

6) Centrifugal action may also be incorporated in some cases. The principle of DMS can be illustrated as follows

Feed
↓
Media bath
Sp.gravity
1.5

Mineral
Sp.gravity – 1.5
(floats)
← Media bath →

Mineral
sp.gravity + 1.5
(sinks)

7) The most common example illustrating the above process is the seperation of wood chips, from sand and gravel using water as the medium

8) However, water can't be employed in seperation of minerals since all minerals are heavier than H_2O. Therefore, some heavy liquids. such as organic liquids (sp.gr. 1.5 to 3.5), aqueous solutions of soluble salts and heavy pseudo liquids made by suspending solids in water, should be employed, depending upon the specific gravity for a given ore system

9) Though the use of heavy media seperation known for laboratory seperation, since 100 years back, the first commerical success was achieved in 1917 by the chance process using hydraulically dilated sand

10) The DMS process is applicable in seperating the minerals having adequate difference in specific gravities & liberated at coarser size (+0.3mm) eg: seperation of tungsten, uranium, and vanadium minerals from calcite and quartz

11) The characteristics of DMS process and the densities of pseudo liquids, commonly obtainable, make the process most attractive for cleaning / washing of coals where a graded and end product is clean coal having low ash content.

4.11. Describe the working principle of Jigging

1) Jigging may be considered as hindered settling consisting of satisfaction of the particles into layers of different densities caused by repeated ~~thick~~ ~~suspensn~~ upward & downward ~~and~~ current of fluid to a very or fall for short periods of time

2) The pulsator forces the water up through the screen with a dequate velocity to bring all the particles momentarily into suspention resulting into fluided condition

3) This upward movement is called "pulsion" and the minerals of two or more specific gravities arrange themselves according to the law of hindered settling.

4) The water is then allowed to drain back through the screen and this downward movement is called "Suction".

5) During this action, small grains move downward through the interstices b/w the large grains.

6) The cycle of pulsion and suction is repeated continously.

7) Finally the stratified layers are discharged into concentrate, tailing and middlings

8) Details of cycle are important and vary from case to case

9) The cycle normally includes a very sudden upthrust, a period of free fall (in which hindered settling and differential acceleration bring the dense particles below the light one) and finally draining or suction period, during which small particles (particularly small and dense) are drawn low in the bed and even some may pass through the grid.

10) Further, after the large particles come to rest on a grid, the small ones will continue to fall and may trickle through the interstices between the big one.

11) This consolidation ~~tea~~ trickling can be exaggerated by allowing the water to drain through the arrested solid bed ~~for~~ for a short duration.

12) Jigging operation yeilds 3 product i.e.

a) Gangue tailing skimmed over a weir

b) Concentrate drawn via a gate which excludes the tailing, and

c) a hutch product (usually dense fines) drawn from a spigot at the bottom of the cell

13) However, the seperation is not clean enough and thus jigs are operated in series or in batteries to produce a concentrate tailing.

14) The middling produced may be re-ground and returned for further sorting.

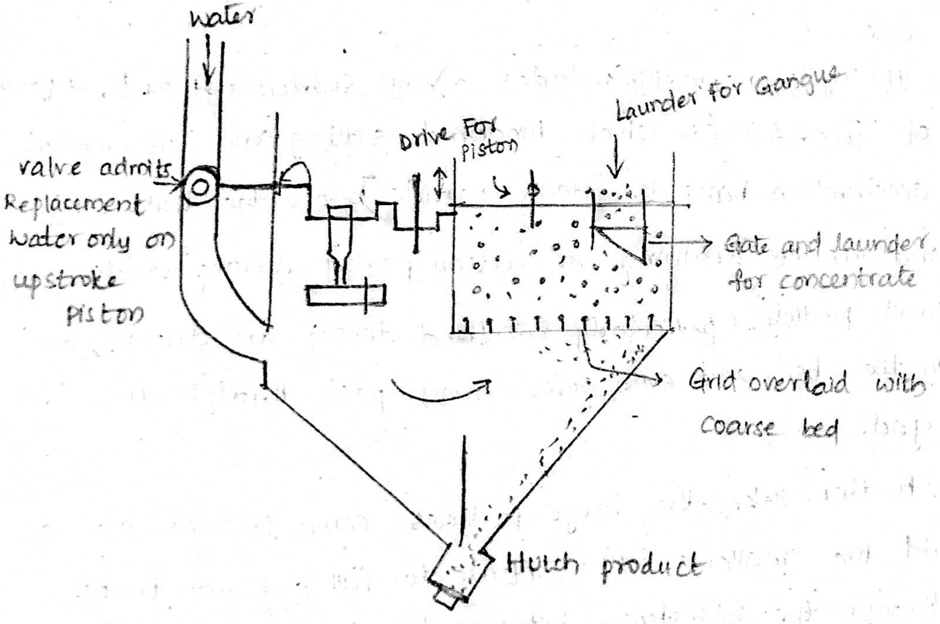


Fig: Schematic illustration of Jig.

4.18. Describe the working principle of froth floation:

FROTH FLOATATION:-

1) The flotation process relies primarily on the fact that hydrophylic particles are wetted by water, where as hydrophobic particles are wetted by oils and air bubbles.

2) Therefore, if air bubbles are introduced into an acqueous slurry, the bubbles adhere to the hydrophobic solid particles

3) As a result, air solid aggregates are carried to the surface, forming a forth layer; this explains the name forth flotation.

4) The froth layer can be removed manually or mechanically: the result is the seperation of hydrophobic from hydrophilic particles.

5) This is the most commonly employed technique in concentration of mineral/ores.

6) The process is based on making use of difference in the physio-chemical surface properties of various minerals.

7) The difference can also be enhanced by the treatment of minerals with specific reagents

8) In the froth floatation, valuable part of mineral usually pases into the forth product (sometimes gangue is also floated) and becomes the float fraction, where as the other part remains in the pulp as an unfloated fraction (Chamber product). Both the fractions can be remored sperately from floatation machine by suitable mechanisms.

9) When the desired minerals are seperated as froth product, the process is referred as direct floatation where as, if the gangue is drawn into the froth product, the process is known as "reverse flotation".

(14)

10) In froth floatation, air is blown through the pulp containing flotation reagents.

11) The particles having water repellent surfaces (not wetted easily) attach the air bubbles to them and rise to the surface through the pulp in the form of mineralised froth.

12) On the other hand, particles having water avid surfaces (wetted readily) do not attach the air bubbles to them and thus remain in suspension of the pulp.

Other Types of flotation process:

1) Film flotation
2) Oil flotation
3) combined Floatation - Gravitational method.
4) Ion flotation.

4.19. Describe the principle of Magnetic seperation

- Magnetic seperation was employed to seperate ~~slightly~~ strongly magnetic iron ores (magnetic) from gangue or other less magnetic minerals.

(15)

- The method is based on the particle of magnetism i.e. for seperating magnetic impurities from non-magnetic particle of vice-versa

→ 1. Dry Belt Magnetic seperators:

1. One of the oldest and most successful magnetic seperator of belt type is wetheril magnetic seperators shown in figure.

2. This is a high powered machine, the material flows from the hopper to the feed roller, which discharges the feed in a uniform layer over the entire width of the belt conveyor, passing b/w the magnets (electromagnets).

3) The poles are arranged one above the other, the poles of of the upper magnets have the shape of a sharp, wedge, while the lower poles are flat.

4) This arrangement provides the jump of magnetic particles towards the upper poles (as soon as they are brought by conveyor belt into magnetic field due to concentration of magnetic force on the wedge-shaped edges

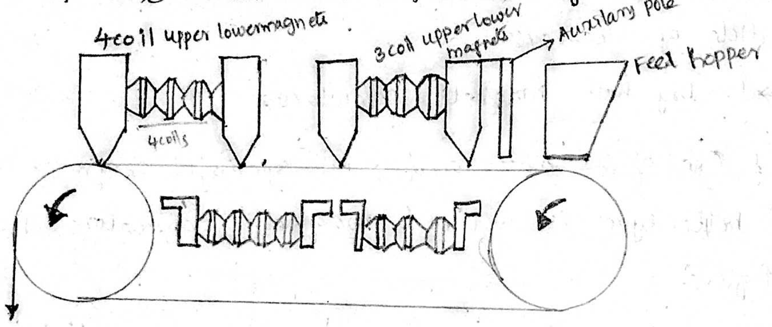
5) The cross belts move b/w feed belt and wedge pole and prevent the adhering of magnetic particles to the poles

6) The cross belts convey the magnetic particles out of the system. The same principle has been used in

many other belt magnetic seperators

7) This type of machine can be constructed with one, two or three pairs of magnets. Each pair of pole is provided with the control ~~of~~ for current strength

8) This machine has been widely used early in concentration of zinc - lead - iron sulphides, magnetic ores etc.



2) Dry-drum seperator:

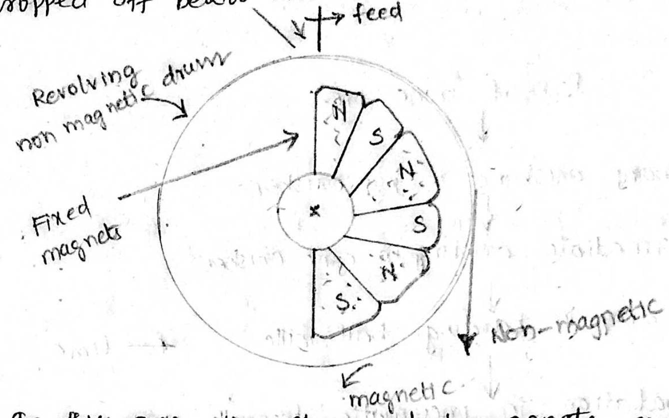
1> This is an early machine employing low intensity and is still used in various forms

2) It consists of a series of oppositely charged or same polarity magnets in a semi circular form as shown in fig

3) The magnet is held stationary and surrounded by a renewable non-magnetic rotating cylinder (eg: made of brass)

4) The feed is introduced at the top of the drum. ~~The~~ The non magnetic particles rebound off the drum or are carried around by the drum rotation untill they fall by gravity.

5) The ferromagnetics are gripped by magnets to the drum and roll with each change in polarity, till they are dropped off below into a suitable recievers.



6) In this case, the strong electromagnets can't be used and thus there are usually low intensity magnetic seperators (600 gauss field strength)

7) Though it has become obsolescent but can be successfully used for coarse feeds (+6mm)

8) With the development of strong magnetic alloys a large variety of drydrum seperators are developed to treat the wide range of materials.

4.20 Draw the simplified flow sheets for coal, Iron, Copper, lead and zinc. (18)

Copper ore

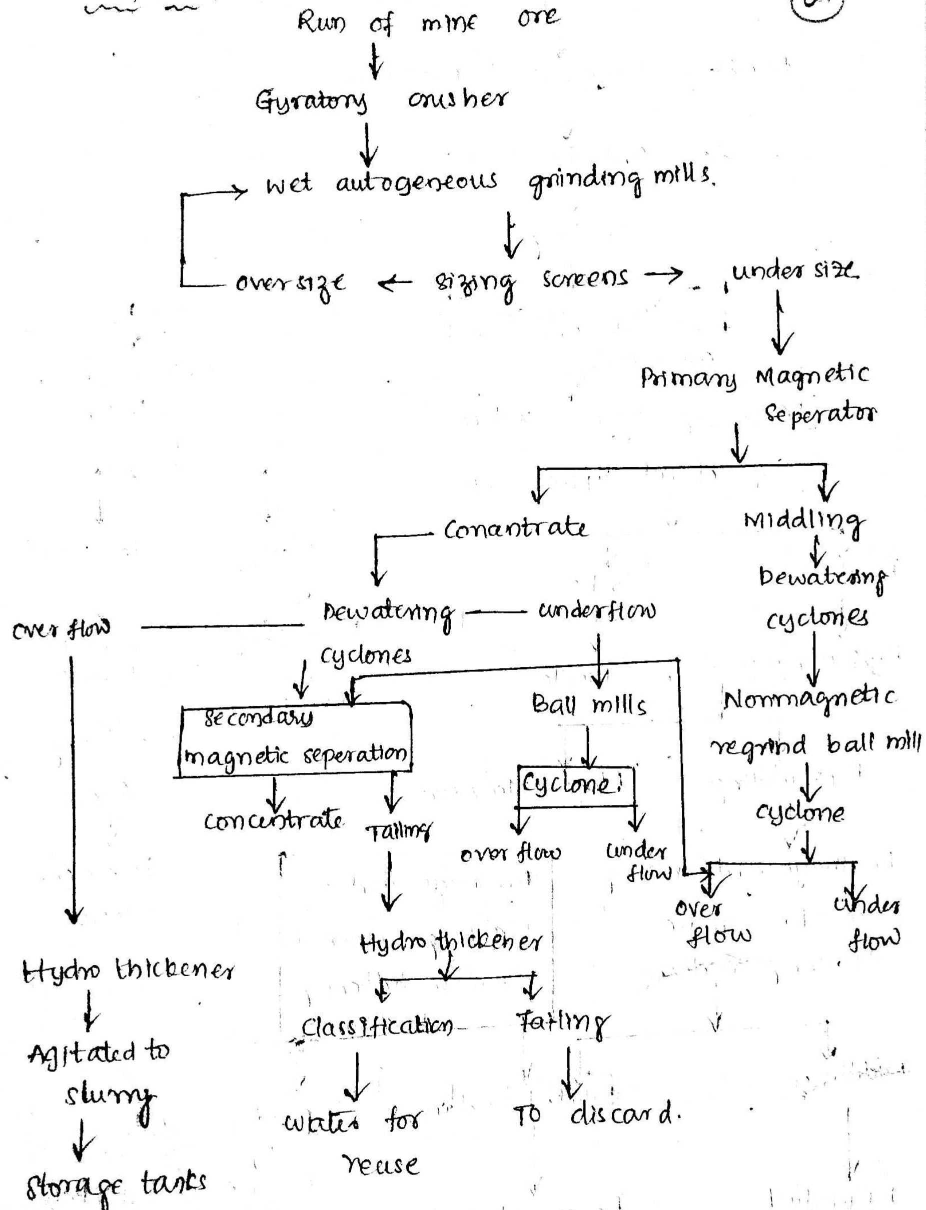
Run of mine ore.
↓
Primary crushing in jaw crusher
↓
Intermediate crushing in cone crusher
↓
Grinding in harding ball mills ← lime
↓
Floatation in pneumatic deep cells ← Poly Amyl / Ethyl xanthate pine oil
↓
- Tailings
  ↓
  Dump
- Copper concentrate
  ↓
  cone thickeners
  ↓
  Dorr thickeners
  ↓
  Drum filters
  ↓
  Driers
  ↓
  Dried copper concentrate to smelter.

Coal : (19)

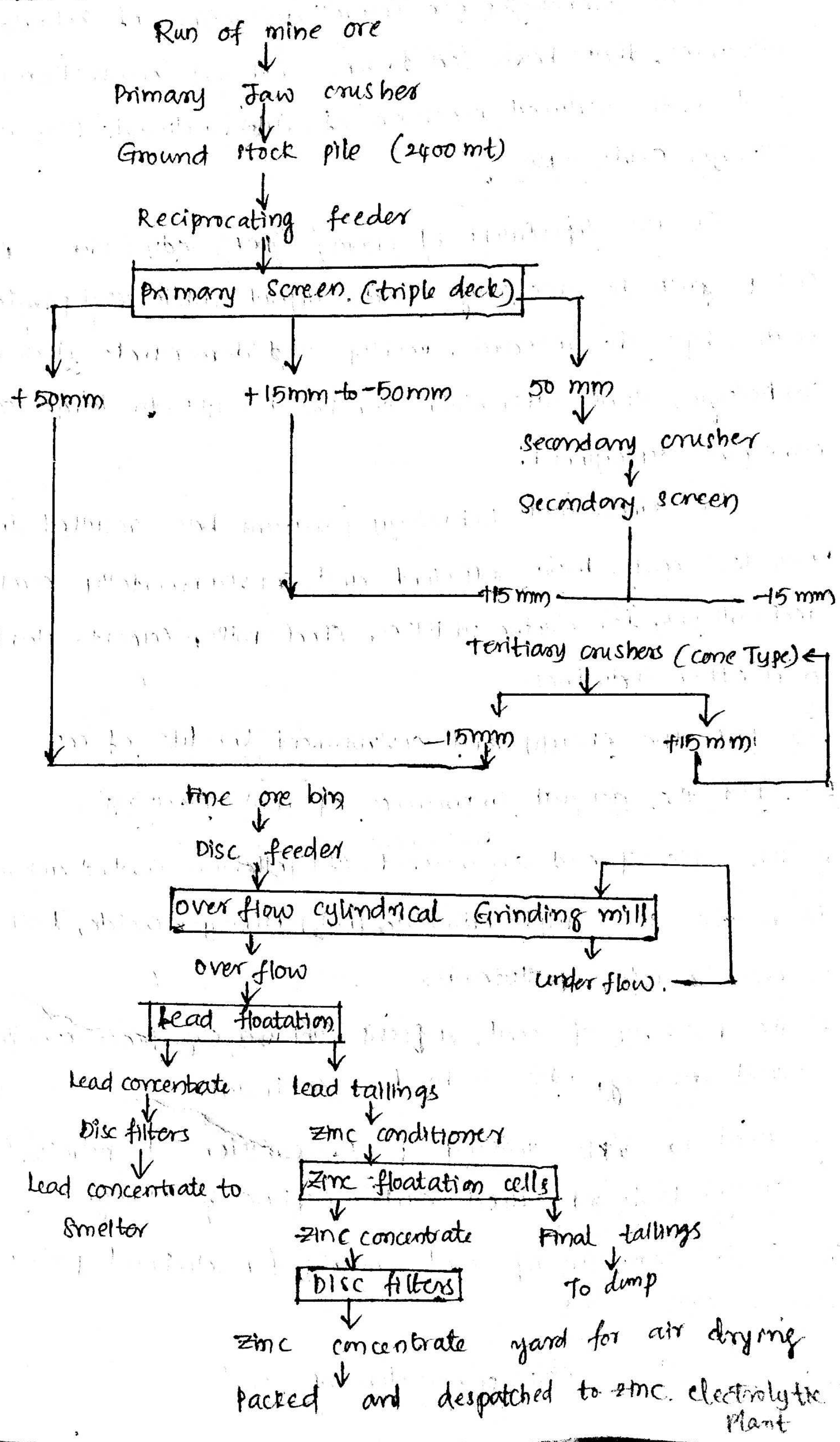
Coal from Mines
↓
Handling, storage and blending
↓
Blended feed to washery
↓
Crushing
↓
Shaking screens

- Coarse coal.
  ↓
  Baum jig (preconcentration)
  (Sp.gr of cut at +1.60 – 1.70)
  ↓
  - Floats
    ↓
    HMS using (Fe.Si)
    - Sink (middlings)
      ↓
      Drainage and washing screens to remove adhering medium
      ↓
      - Middlings
        ↓
        By product
      - Diluted medium
        ↓
        Recovered and Recirculated
    - Float (clean coal)
      ↓
      Drainage and washing screens to remove adhering medium
      ↓
      - Diluted medium
      - Float product (Coarse clean coal)
  - Sinks
    ↓
    waste
- cyclone or flotation
  ↓
  - Tailings
    ↓
    Dewatering
    ↓
    Dump
  - Clean coal
    ↓
    cone Dewaterers
    ↓
    Centrifugal filters
    ↓
    Fine clean coal

Iron ore:



Lead and zinc concentration



(23)

5.1. Define the term clean coal Technology.

" clean coal Technologies are several generations of Technological advances, that have led to more efficient combustion of coal with reduced emission of Sulphur dioxide (SO_2) and Nitrogen oxide (NO_x)."

The U.S department of energy (DOE) administers the CCT program to encourage and support public and private partnerships to research, Develop and demonstrate clean coal Technologies that ultimately can be brought to large scale comercial deployment.

The clean coal Technology program has resulted in 20 new, low cost, more efficient and environmentally compatible technologies, for electric utilities, steel mills, cement plants, and other industries.

5.2 List the energy and environment benifits of CCT

5.3. List the general importance of coal cleaning

1) The wide spread (deployment) development of pollution control awareness to reduce (SO_2) Sulphur dioxide, (NO_2) Nitrogen Oxide, Dust emi-ssions, & other pollutants.

2) The burning of coal, a fossil fuel is a significant contributor to Global warming, which is to be controlled.

3) Need to tackle raising of CO_2 emissions to adress climate changes leads introduced carbon capture & storage.

4) A rise from use of coal mainly, for electrical power generation

5.4. List the quality parameters of coal

(24)

1. Moisture
2. volatile matter
3. fixed carbon
4. Ash.
5. Useful heat value (UHV)

5.5 Explain the quality parameters of coal

* Moisture :

" Moisture is the water expelled in various forms when coal is heated under specified conditions."

1. Coal that has been exposed to contact with water in the seam in a washery, during storage in rainy season, in open wagons or trucks, may carry free or visible water adhere to the surface or the cleavages and cracks

2. Such moisture is known as "free moisture"

3. Some moisture is always present in the coal and formed part and parcel of it during its natural formation.

4. Such moisture is called "inherent moisture"

5. Total moisture in coal is the sum of free moisture and inherent moisture.

Volatile matter

Volatile matter which consists of various gases in the coal is equal to the total loss in wt minus the moisture when coal is heated under specified condition

$$V_m = \text{Total loss in wt when heated} - \text{Moisture content}$$

Fixed carbon

Fixed carbon is obtained by subtracting from 100 the sum of % of moisture, ash & vm

$$F_c = 100\% - (\%\ \text{Moisture} + \%\ \text{ash} + \%\ V_m)$$

Ash:-

Ash is the inorganic residue left when coal or coke incinerated in air to const. weight, under specified conditions.

Ash = inorganic residue left.

Useful Heat Value (UHV)

The existing Grates of coal were formulated by the government of India in july 1979 for non-coking, they are based on useful heat value (UHV) calculated from the results of proximate analysis.

The formula circulated by the Govt of India for calculation of useful heat value for non coking coals is only is

$$UHV = 8900 - 138\,(Ash\% + Moisture)$$

where, the useful heat value is kilocalories/kg

A = Ash in % a

M = Moisture %.

Non-coking coal (Except Andra, Assam, Arunachal, Meghalaya and Nagaland)

Grades	UHV Ranges.
A	Exceeds 6200 kcal/kg
B	From 5601 to 6200 kcal/kg
C	From 4941 to 5600 kcal/kg
D	From 4201 to 4940 kcal/kg
E	From 3361 to 4200 kcal/kg
F	From 2401 to 3300 kcal/kg
G	From 1301 to 2400 kcal/kg

5.6. Explain the proximate analysis of coal:

This method determines the fixed carbon, volatile matter, Moisture, & ash content present in the coal and is expressed in percentages.

(a) Moisture:

It is carried out by placing a coal sample in a powdered form (of size 200 μm) of known weight in an uncovered crucible (small pot) and is placed in the oven at a temperature of 120±5°c for one hour. Then the sample is cooled to a room temperature and weighted again. The loss in weight represent moisture and calculated as percentage.

$$\%\ of\ Moisture\ (M) = \frac{W_1 - W_2}{W_1} \times 100$$

W_1 = Initial wt of sample

W_2 = Final weight of sample

(b) Volatile matter:

1. Volatile matter refers to those combustible constituents of coal that vaporize when coal is heated. Vm's are the methane, Hydrocarbons, Hydrogen and (CO) carbon monoxide & incombustible gases like Co and Nitrogen found in coal
2. High volatile matter content indicates easy ignition of fuel
3. coal sample is weighed, placed in a covered crucible and heated in a furnace at 900°c ± 15°c
4. The sample is then cooled and weighed loss of weight represents moisture & V.M

$$(4)\ \%\ loss\ of\ weight = \frac{W_1 - W_2}{W_1} \times 100$$

% volatile matter (V.M) = L−M

(c) Fixed carbon:-

1. Fixed carbon refers to carbon in its free state not combined with other elements.

2. More the fixed carbon content, it indicates high quality and more presence of combustible matter in the coal

3. The amounts of fixed carbon and volatile combustible matter directly contribute to the heating value of coal

4. Fixed carbon acts as a main heat generator during burning.

5. The remaining sample after volatile matter test is placed in the crucible is heated over the Bunsen Burner until carbon is burned.

6. The Residue after burning carbon is weighed (W_3) which gives the incombustible ash content

$$\% \text{ Fixed carbon } (C) = \frac{(W_1 - W_2) - W_3}{W_1} \times 100$$

Where W_3 (ash) is weight of residue after burning carbon

(d) Ash:

Ash is the impurity present in coal. The residue from the combustion of carbon from the sample is weighed & calculated for ash content in terms of %.

$$\% \text{ Ash } (A) = \frac{W_3}{W_1} \times 100$$

Presence of ash content in the coal reduces handling and burning capacity, increases handling cost, affects adversely combustion efficiency and boiler

efficiency and causes clinkering & slagging.