MINERAL DRESSING (MD)

Mineral -

A mineral is a homogeneous and naturally occuring substance, having definite physical properties and a composition that may be expressed by a chemical formula.

Rock -

Rock may be composed of one mineral only; but is usually a mechanical mixture or aggregate of 2 or more minerals.

Ex :- Granite (Rock) ⟶ Quartz (M) + Feldspar (M) + Mica (M)

Ore -

Ore is a rock which contains minerals and which can be used for economic extraction of metal after processing separate mineral from gangue.

→ Ores are concentration of minerals in rock that are high enough to be economically extracted for use.

Grade of ore

The grade of ore refers to the concentration of the desired material it contains.

Gangue

In mining gangue is the commercially worthless material that surrounds or is closely mixed with a wanted material in an ore deposite.

Mineral dressing (MD)

(Mineral Benefication M.B)
(Mineral Processing)
(Ore Dressing)

MD may be defined as the upgradation of ore values by extracting the unwanted particle (gangue) from the valuable mineral in an economical and environmental friendly way without changing its physical & chemical identity.

Necessity of MD

1/- Day by day the grade of ore decreasing gradually.

2/- Due to mechanised mining generation of fines is more.

3/- To increase the age of ore reserves.

(5 mark)

→ The working of a plant extracting metals is conveniently represented by means of a flow diagram.

→ The flow diagram is a combination of operation and processes which are followed in the plant to extract a metal economically from its ore.

→ While analysing the flow diagram we come across few chemical and mechanical activity which are term as unit process & unit operations respectively.

Unit Process

The unit process is characterized by chemical reaction such as roasting, leaching etc.

Unit operation

→ Unit operation is a physical activity carried out discreetly on the ore.

→ The physical activity usually represented by crushing, grinding or similar such process.

(DATE - 29/03/2022)

5-Mark

Economy Justification of Mineral Dressing

1/- To purify and upgrade the ore.

2/- Making smelting practice easier.

3/- Saving on freight (transporting).

4/- Reduction in metal loss at the smelter.

5/- Reduction in the total smelting cost.

6/- Enhancing the efficiency of unit processes.

Scope of Ore benefication

In general the scope of ore benefication are as follows -

(i) It helps to eleminate particles of improper size and physical structure which may subsequently affect the working of roaster/smelters adversely.

(ii) It helps in eleminating unwanted chemical species from the ore.

Objective of mineral dressing

The objective of mineral dressing can be summerized as follows -

A. To prepare the ore with proper physical condition :-
preparation of ore with proper physical properties involves -
(i) Particle size of reduction
(ii) separation of physically dissimilar particles from the bulk .

B. To eleminate unwanted chemical species :-
Preparation of ore from chemical stand point primorily involves the following activities :-
(i) Liberation of dissimilar particles appearing in the bulk ore .
(ii) Separation of chemically dissimilar particles .

- The first stape in ore benefication is the size reduction and it causes liberation automatically .
- subsequently it is followed by separation among the liberated particles .
- These two steps are made to alternate few time to accomplish the desire end production most economically .

Historical development of mineral dressing

The dressing operation started developing chronologically in the following manner .

(i) Hand Sorting :

→ Undoubtedly it is the oldest method of ore benefication .

→ This is a method of choosing valuable ore lumpts from worthless lumps baseing on the appearance, fracture, cleavage and gross weight .

→ This method is used where cheap labour force is available.

(ii) Washing:

→ Washing in all probability is the next process that evolve.

→ Water exerts a cleaning action and remove slimes.

→ Now this method is used for washing cleaning of coal & Iron ores.

(iii) Crushing:

(iv) Tabling and Gravity concentration

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General Operation of Mineral Dressing

1/- Comminution

Comminution of size reduction is the most general operation in ore dressing which is accomplished both in dry & wet condition.

2/- Sizing

This is the separation of product material into various fraction on the basis of their sizes on employing screens or sieves.

3/- Concentrating

→ Concentration of valuable portion of the ore is carried out by various means involving physical characteristics of the ore particles.

→ Sizing, Jigging, Tabling, Classification, Magnetic & Electrostatic separation are few such examples.

→ We may opted for froth flotation method for concentring the ore particle depending upon their physio chemical properties.

4/- Dewatering

When aqueous medium is involve, water is to be removed before smelting takes place.

This involves :-

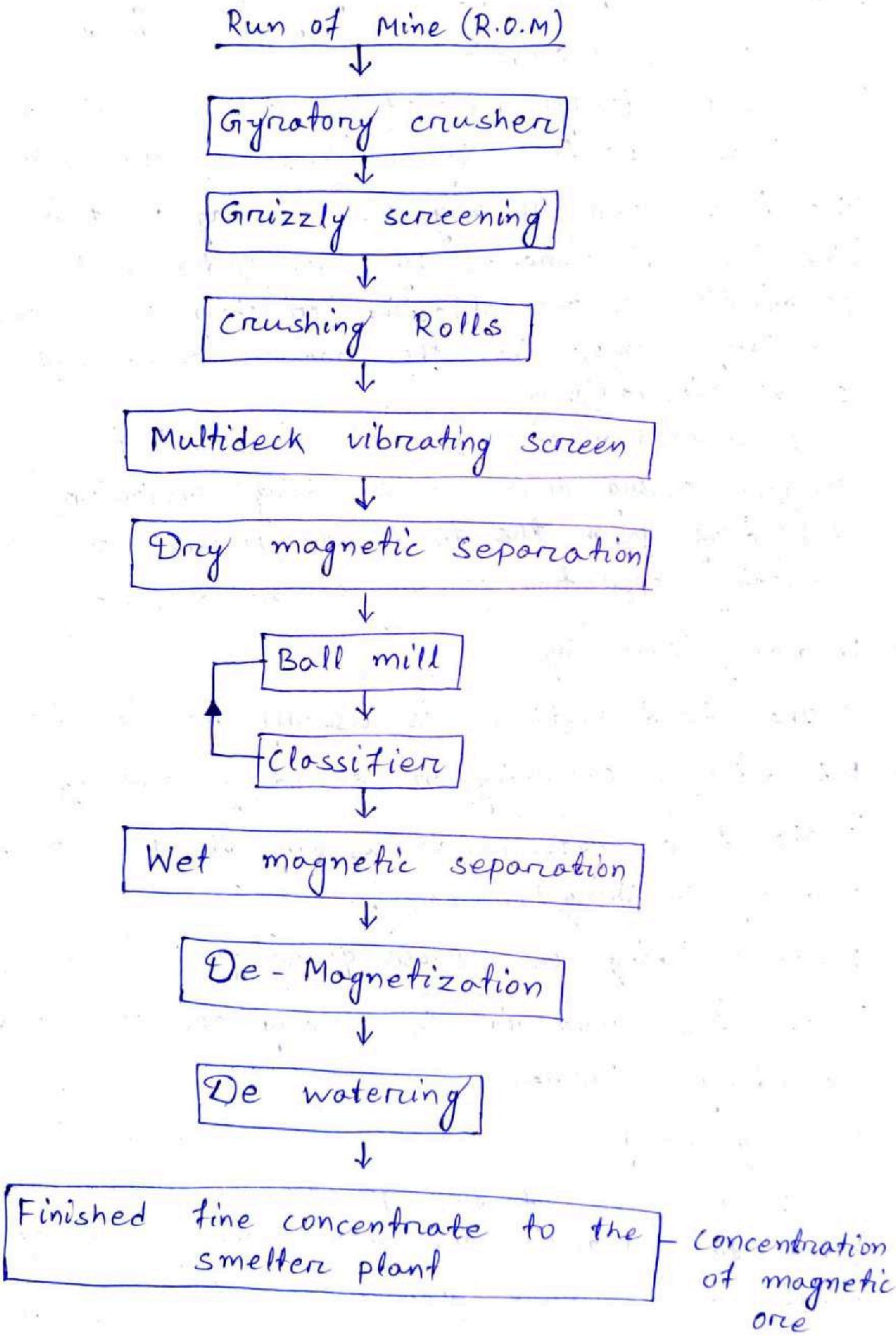
a) Removal of most of the water by the use of the thickner.

b) Use of filter presses to prepare damp cakes of the upgraded ore.

c) Then drying the cake in a furnace.

General flow sheet of a mineral benefication plant

The below figure show the flow diagram of a ore dressing plant for upgrading magnetite ore using general operation of ore dressing.



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Size Reduction Method

- Liberation

(i) The phenomenon of making the mineral grain free from each other perticularly from gongue is termed as liberation.

(ii) This is practically achieved by size reduction & comminution perform by various crusher & mill.

(iii) The first step in any ore dressing plant in liberation of mineral by size reduction & comminution so the objective crushing is to reduce the large lumps into the smaller sizes and cause liberation.

(iv) size reduction of ore is carried out in several stages using different crushing equipment depending upon the field and product size the crushing operation can be classified as -

(a) Primary crushing

The feed material is usually the Run of mine.

(b) Intermidiate crushing or secondary crushing

The feed material is usually the product of primary crushing / crusher.

(c) Fine crushing or coarse grinding

The feed material is usually the product of secondary crusher.

(d) Fine grinding

The objective of fine grinding is to produce ultra fine material less than 1 micron utilising the product from coarse grinder as feed.

Process	Feed size	Product size
coarse crushing —	ROM (150 - 4 cm)	(5.0 - 0.5 cm)
Intermideate crushing -	(5.0 - 0.5 cm)	(0.5 - 0.01 cm)
course grinding —	(0.5 - 0.2 cm)	(Less 75 Micron)
Fine grinding (special type) —	0.02 cm	0.01 Micron

Basic requirement for crushing equipment

An ideal comminution equipment like jaw or gyratory crusher should have the following characteristic

(i) They should have a large capacity.

(ii) They should consume less energy per unit weight of production.

(iii) Should yield a product of uniform size or as required.

Classification of size reduction equipment

A classification of the size reduction equipment is suggested on the basis of average feed and product sizes as follows.

(A) **Primary crushers**

(i) Jaw crusher

(ii) Gyratory crusher.

(B) **Intermediate crusher**

(i) crushing Roll

(ii) cone crusher

(iii) Disc crusher.

(C) **Fine crushers or coarse grinders**

(i) Ball mill

(ii) Symonds Mill

(D) Fine Grinders

(i) Rod mill
(ii) Pebble mill
(iii) Tube mill
(iv) Hammer mill with internal classifier

Primary crusher

→ Crusher's are slow speed machine for coarse size reduction with large tunnage output capacity.

→ The major types of crushers are - Jaw, Gyratory, crushing roll, Toothed Roll crushers.

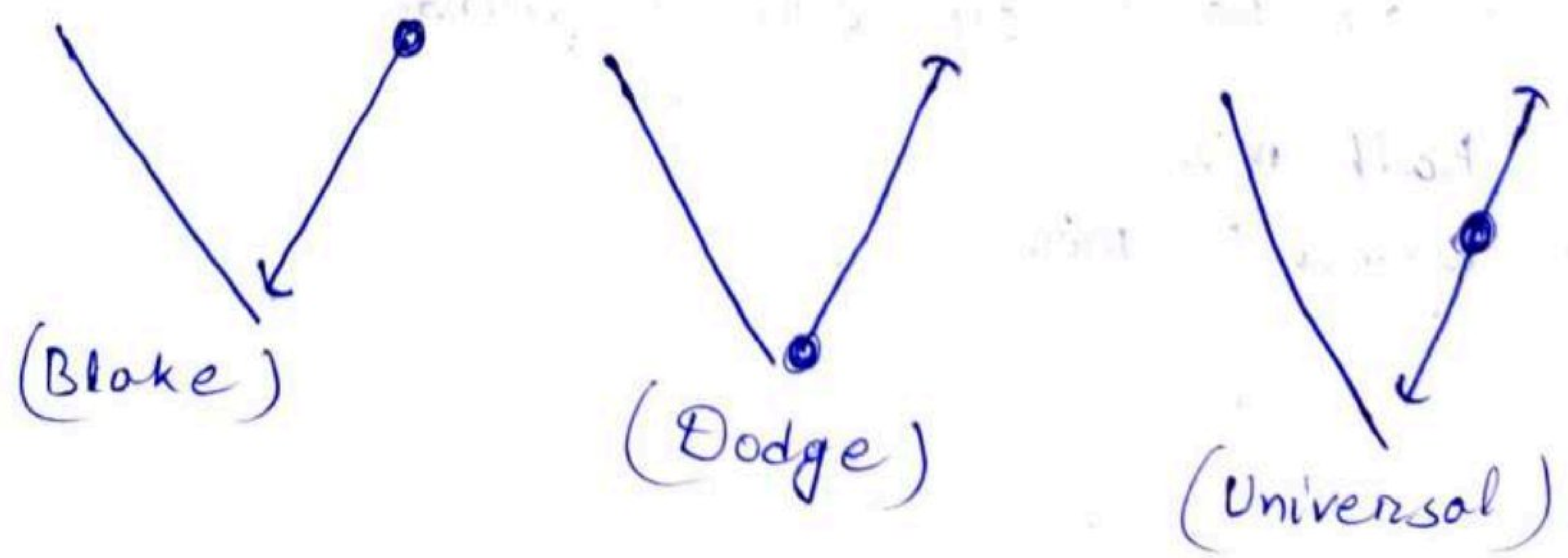
→ The first three crusher operate on pure compressive force and can crush very hard and brittle rocks.

→ The toothed roll crusher tears the feed apart and crushes them. It works based on soften materials like coal, bone and soft slate.

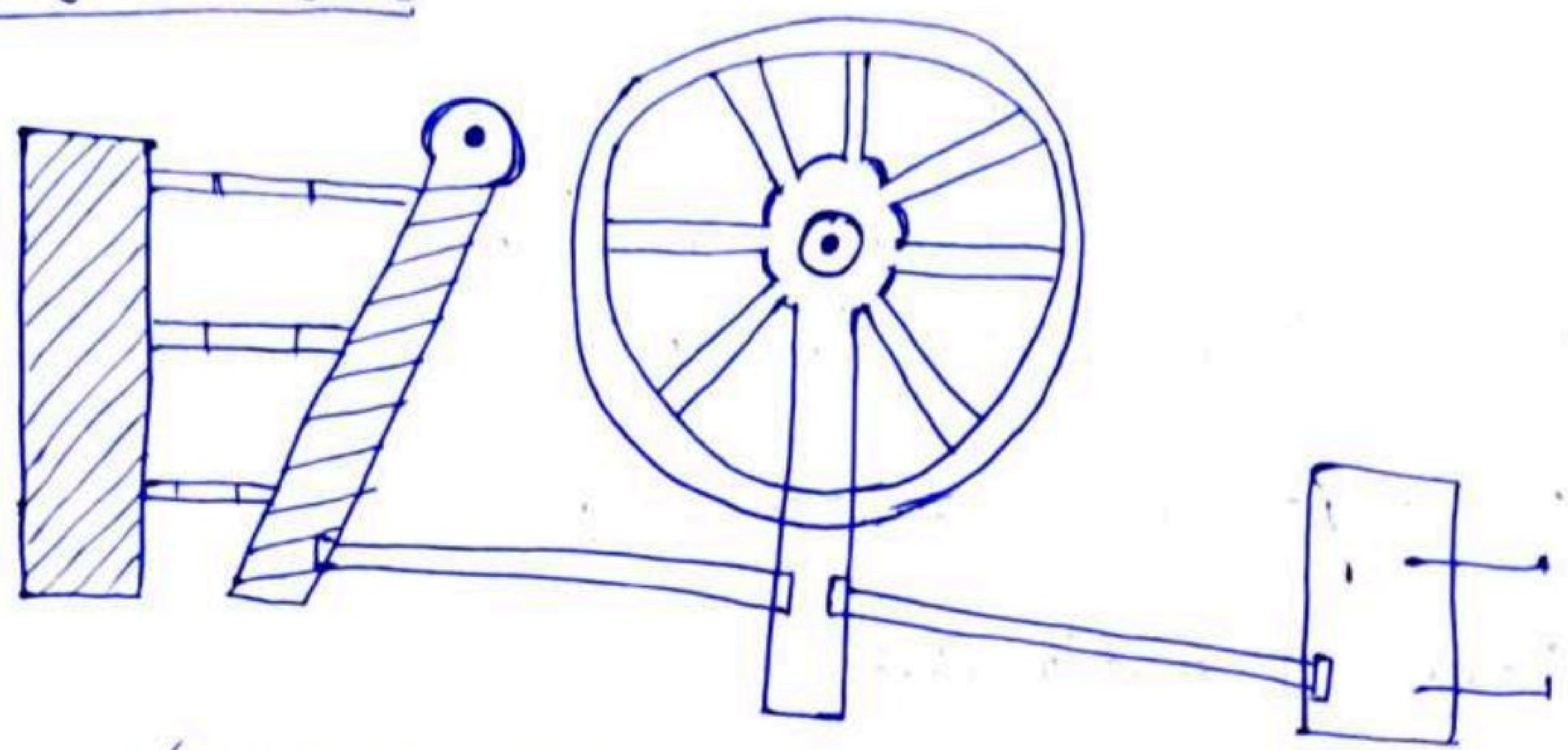
Primary crushers which operate on the run of mine are of two types -
- Jaw crusher
- Gyratory crusher

Classification of jaw crusher

From working mechanism point of view jaw crushers are 3 types -
(i) Blake jaw crusher
(ii) Dodge jaw crusher
(iii) Universal jaw crusher.



Blake jaw crusher



(schematic Blake jaw crusher)

It is the most popular & widely used crusher. It has a moving jaw pivoted by hinged at the top. Through the working principle of blake & dodge crusher are different constructionally both look a like accepting two notable differences between them. The blake crusher may be classified as single toggle or double toggle.

Constructional features

1/- As the name suggest a jaw crusher has 2 jaws said to form a D shape at the top through which feed is admitted into the jaw space.

2/- Among the two jaws, one is fixed and another one is moveable.

3/- The swinging jaw is driven by an ~~ess~~ eccentric that reciprocates in a horizontal plane making an angle of 20 to 30° with the fixed jaw.

4/- The angle between 2 jaws is refered to the "angle of bite" or "angle of nip".

5/- When the jaws approched each other a huge compressive force is develops on the one lumps caught between them and ultimately the lumps get crushed.

6/- Replaceable crushing faces are fitted on to the jaws by nut and bolt. The crushing faces are made of hadfield manganese steels for ~~swallow~~ enhanced service life.

7/- The crushing face is never flat, it is usually wavy or may have shallow grooves.

The jaw width varry from 2-48 inches. The jaw speed is between 100 - 400 cycles per minutes.

Characteristics of Blake jaw crusher

Reduction ratio (R.R)

- As the moving jaw is pivoted at the top, it makes maximum swing at the bottom. The maximum swing distance travelled by the moving jaw defined as the throw of the crusher.
- BJC have fixed 'gape' and that determines feed size.
- The width or length of the feed receiving opening is some what is greater than the
- The set of crusher determines the average size of the product.
- For a crusher the R.R is defined as the ratio between the average feed to average product size.

Mathematically

$$R.R. = \frac{\text{Average feed size}}{\text{Average product size}}$$

- The value of reduction ratio generally varries from 4 to 7. This is an important parameter for determine the energy consumption during crushing.
- Higher the R.R., higher the energy consumption during crushing.

Capacity

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

(ii) The capacity of a jaw crusher is calculated as

$$\boxed{T = 0.6\,L\,S}$$

where T = Capacity expressed in tonnes per hours.

L = Length or width for the receiving opening in inches.

s = shape or width of the discharge opening in inches.

(iii) The capacity may be high 4.725 tonnes / hour for a jaw crusher of 2260 x 1680 mm jaw size.

Energy consumption

Energy consumption in jaw crusher varries and largely depends on the following factor.

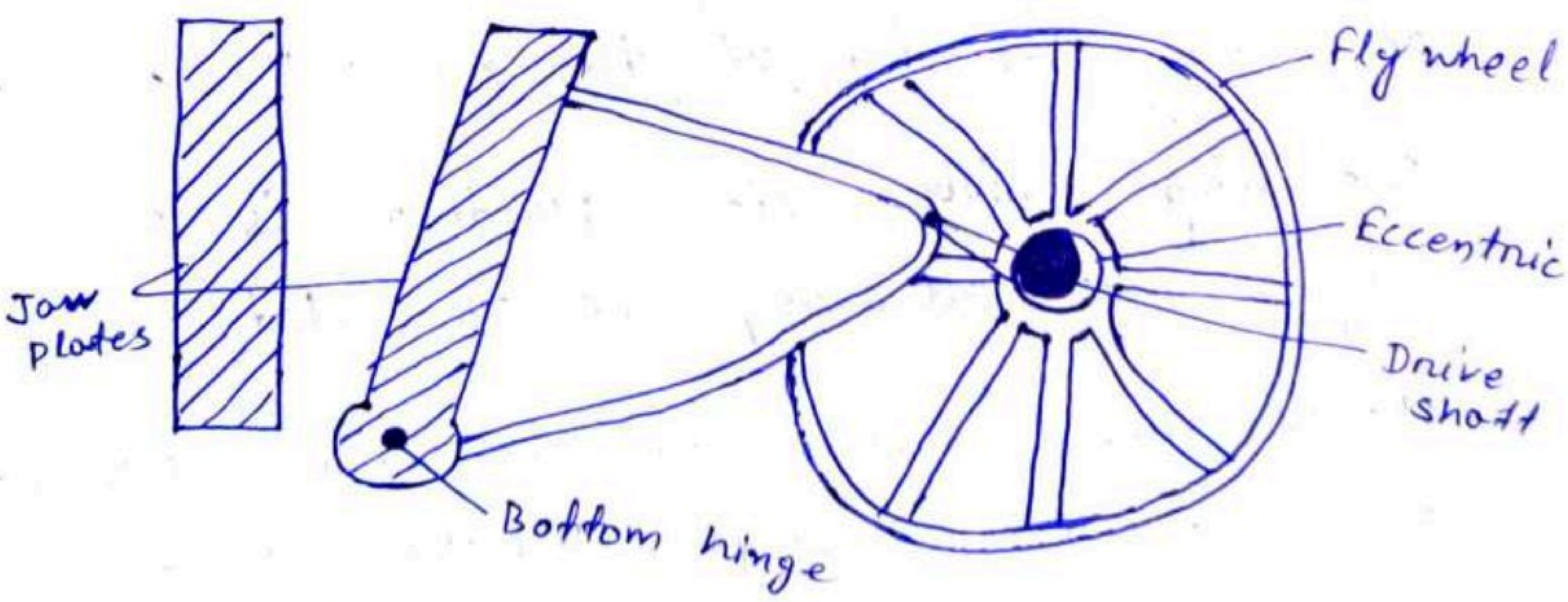
1. Average size of feed material.
2. Average size of product material.
3. Capacity of the machine
4. Physical properties of the feed rock.
5. Hardness and specific gravity.

→ Proper lubrication and reduction in frictional losses increase the efficiency of crusher.

→ Further the physical properties of ore also affect the efficiency of crusher the parameter are -

1. Specific gravity of the ore.
2. Hardness of ore
3. Moisture content of ore.
4. Planes of structural weakness present in the ore.

Dodge crusher



Dodge crusher

→ In dodge crusher the moving jaw is pivoted at the bottom in place of 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 the width of the discharge opening set is fixed.

→ Due to the fixed set, the product is more uniform size as compare to the product of blake jaw crusher.

→ This crusher ~~is~~ has fewer mechanical parts as compare to blake crusher. The moving jaw is activated by a lever accentric arrangement mounted on the main shaft.

→ The main problem with this crusher is its tendency to choke frequently which restricts its use.

→ This crusher is usually made to smaller size than the blake crusher because of high fluctuating stresses working on the machine member.

→ The major advantage of this machine is its ability to effect larger size reduction because of larger opening at the top with a fix shape.

→ Obtaining uniform size product is the most significant advantage of the dodge crusher.

→ Hence this crusher finds extensive use at the faces where a single crusher is used as the only comminution machine.

Gyratory crusher

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Gyratory crusher are developed to recent years in order to have a machine with much larger capacity than the jaw crusher.

It is of two types -

(1) Parallel pinch or Telsmith gyratory crushers (Theoritically the parallel pinch is not a gyratory crusher as the crushing head rotates eccentrically instead of gyrating)

(2) Suspended spindle gyratory

Suspended spindle gyratory

→ The suspended spindle gyratory crusher consist of two substanciallly turncated vertical conical shells.

→ The outer shell's apex points down and is fixed rigidly to the main frame.

→ The apex of the inner cone points up and is mounted on a heavy central staff known as spindle.

→ The upper end of the staff is held in a flexible bearing while the lower end is driven by accentric so as to describe a circle inside the outer shell.

→ Because of accentric rotation of the inner cone, it ulternately opproches on receeds from all the points on the inner peripheri on the outer shell.

→ The solids cut in the V-shope space between the crushing heods ore broken repeatedly untill they get dischorge at the bottom.

→ The operational charocteristic of the gyratory crusher ore similar to that of blake crusher as the lateral movement of the inner crushing cone is maximum at the bottom.

→ The machine operates continously throwing product all around the periphery at the regular interval.

→ This crusher mainly employes compressive force for size reduction.

→ The crushing heads are mode up of had field manganese steel in cast form. The speed of gyration that is varries from 125-425 rpm.

Characteristics of gyratory crusher

→ The capacity of gyratory crusher is much larger than that of a jaw crusher having equivalent gape size.

→ It has more regular power shaft due to continous crushing action.

→ With respect to the reduction ratio at fixed power consumption and equivalent capacity both jaw and gyratory crusher are at path.

→ The rule of installing a gyratory crusher/jaw crusher is governed by Taggart's rule as describe below -

"If the hourly tonnage to be crushed divided by squore of gape expressed in inches yields a quotient less than 0.115 then use a jaw crusher or else use a gyratory crusher".

Mathematically,

If $T/gape^2 > 0.115$ select gyratory crusher and
If $T/gape^2 < 0.115$ select Jaw crusher.

where, T is expressed in Tonne / Hour and
Gape is expressed in inch.

Advantages

- It is very simple machine
- Higher capacity.
- Larger reduction ratio is possible by it.
- Reduction of higher speed is not necessary.
- Handling of ore of O/B rock through out it's peripheri is possible.
- It is more economic.

Intermediate crushers

→ Generally product from either jaw or gyratory crushers are not fine enough for the complete liberation of mineral bench and needs further size reduction.

→ The product of a primary crusher is fed into either cone or roll crushers for further size reduction to result in better liberation.

→ The cone and roll crushers are known as intermediate crusher.

Cone crusher

→ Cone crusher is an example of intermediate crusher.

→ Basically it is of two types (i) simon's cone crusher
(ii) Telsmith Gyro sphere

→ Cone crusher is a modified Gyratory crusher, mechanism of crushing is similar to gyratory crusher, designs are similar but in this case the spindle is supported at the bottom of the gyrating cone instead of being suspended as in gyratory crusher.

→ However it has much smaller feed and product size as compare to gyratory crusher.

→ The crushing heads are made up of hadfield manganese steel in a cast form.

→ This crusher has a continous crushing action. This results regular power draft and yields much finer product.

→ The crushing force employed here are compressive and frictional in nature.

→ Compare to the crushing roll, it has better capacity with comparable product fineness.

→ To operate the cone crusher in a efficient manner, a dry feed free from fines should be used.

→ Use of wet feed make clog the crusher.

Limitations of cone crusher

→ It operates only on closely sized brittle material.

→ It has a low reduction ratio.

→ It needs extensive lubrication of all its moving parts regularly.

→ It operates based in close circuit grinding.

Crushing roll / Roll crusher

→ Crushing roll is an important class of comminution machine in the intermediate range of size reduction

→ It consist of a pair of heavy cylindrical rolls revolving towards each other. So as to nip a falling rock and discharge it crushed below the rolls

→ The rolls are made up of hadfield manganese steel.

→ Both the rolls are driven parallel to each other on a horizontal plane having the roll centre ~~same~~ at the same height. Separate by a distance known as set.

→ The feed cut between the rolls is broken by compressive force developed on the ore piece as it passes through the roll gape.

→ The rolls turn towards each other at the same speed so as to avoid slip. They have narrow spaces with large diameter so as to nip moderately large lumps.

→ Typical rolls are 300 MM in diameter and 600 MM long Rolls speed ranges between 50 - 300 R.PM.

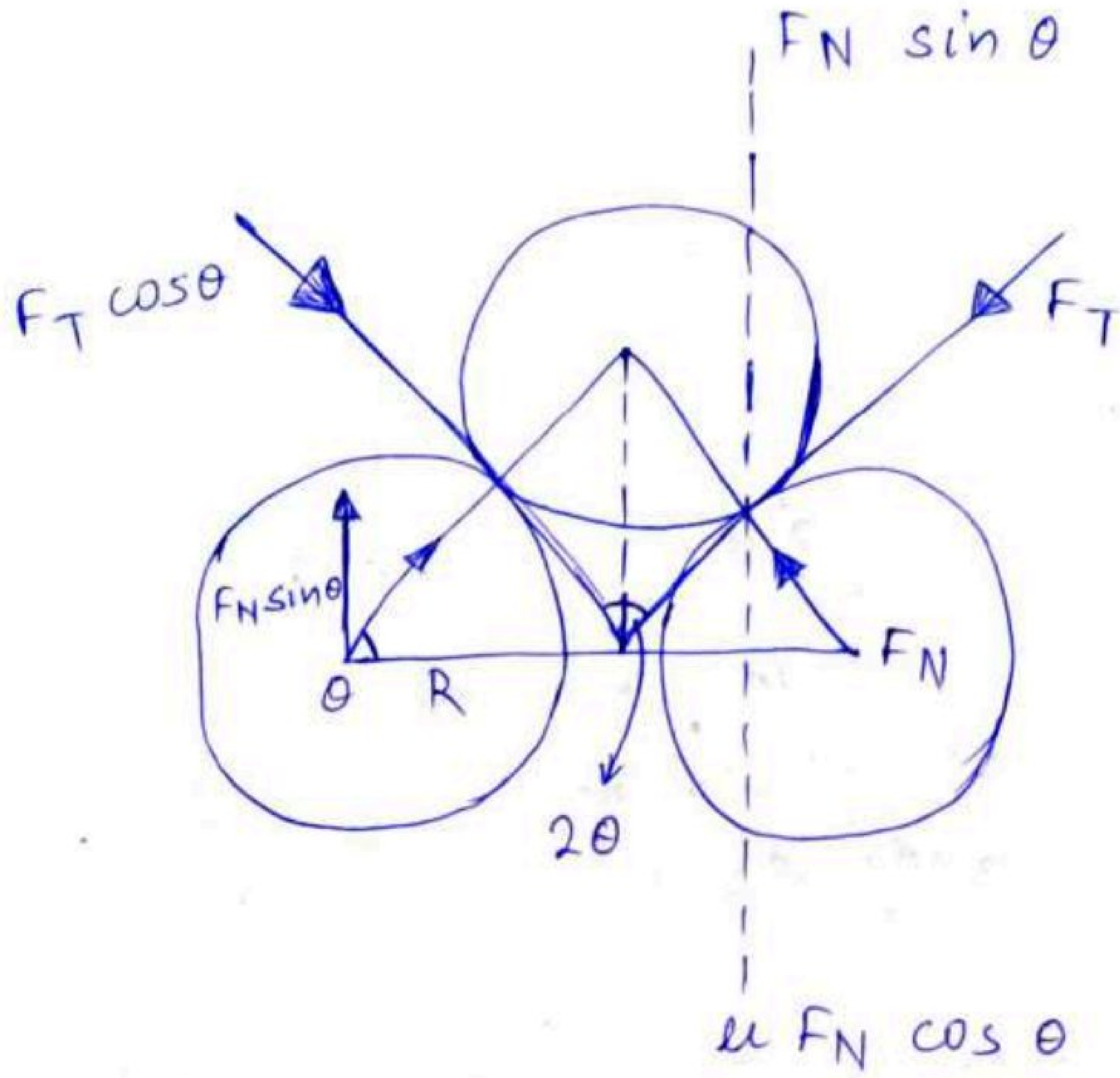
→ The feed size varies between 12 to 75 MM and the product size ranges between 12 - 20 MM. The product size depends primarily on the set.

→ The operation is contineous.

→ At a lower RR the crushing roll produce less fines as compare to other crusher and has larger capacity

→ The set is adjustable and depends on the average feed ~~size~~ and product size.

Angle of nip (2/5 mark)



→ Angle of nip is defined as the angle subtended between the two tangents drawn at the point of contact between the rolls and the particle to be crushed.

→ Crushing is performed only when the ore particles nipped properly by the rolls.

→ The particle that can be nipped properly by the crushing rolls depend largely on the following factors

(i) Roll diameter, D

(ii) Particle diameter, d

Assuming the particle is spherical

(iii) Inter roll distance or set 's'

(iv) Friction factor between the roll & mineral (μ)

Here 2θ = Angle of Nip

θ = Half angle of nip.

From the figure we have $\cos\theta = \frac{D+s}{D+d}$

→ Angle of nip should never exceed 30° or else the particles will fly up.

Characteristic of crushing roll

- It has a smaller reduction ratio of around 3-4
- It produce a product of almost uniform size.
- Crushing rolls products contain lesser fines.
- capacity of the roll crusher depends on the following factor :

  a) Speed of revolution 'N'

  b) Width of faces 'W'

  c) Diameter of the rolls 'D'

  (d) The inner roll distance or set 's'

  (e) Specific gravity "ƒ" of the rock.

  The theoritical capacity (Tons/hour) is given by the expression

  $$C = 0.0034\ NDWs\rho$$

  Where,
  W, D & S are expressed in inches

  How above the actual capacity is consider is less in only around 30 % of the theoritical capacity.

  If the set 's' is zero the capacity of roll is also zero (0).
- Roll can be operated either wet or dry.
  Dry crushing has a lower out put but causes lesser wear of the rolls.
- It is best operated on choke feeding for maximum output. Under free feeding the output is less.

Feeding methods in comminution equipment

There are two distinct methods of feeding material to a crusher (i) free feeding

(ii) Choke feeding.

Free Feeding (2 Mark)

1/- This involves feeding of material to the crusher comparatively at a low rate. So that the product readily escaped out of the machine.

2/- As the residence time of the feed in the crusher is very less, it produces less quantity of under sized or fines.

3/- This reduces the probability of clogging of the crusher.

Choke Feeding :-

(i) During choke feeding the crusher is always kept full with material & the discharge is impeded so as to increase the retaintion time of the feed ore in the crusher.

(ii) This results in a higher degree of crushing at a reduce capacity.

(iii) Energy consumption is also high than the free feeding.

(iv) The feeding practice is adopted mainly in dodge crusher.

(v) The important problem of this feeding system is clogging which causes higher wear on the crushing faces or even failure

- Therefore this method is used only when comparatively smaller amount of material is to be crushed with an objective total size reduction is one go.

Classification of grinding circuits

- Open circuit grinding
- Close circuit grinding.

Open circuit grinding

Run of mine

↓

Jaw crusher

↓

Crushing Rolls

↓

Ball mill

↓

Marketable product

1/- The usual meaning of grinding here is comminution and has is nothing to do with the product size.

2/- In many mills the feed is broken into particles of satisfactory size by charging it once through the mill.

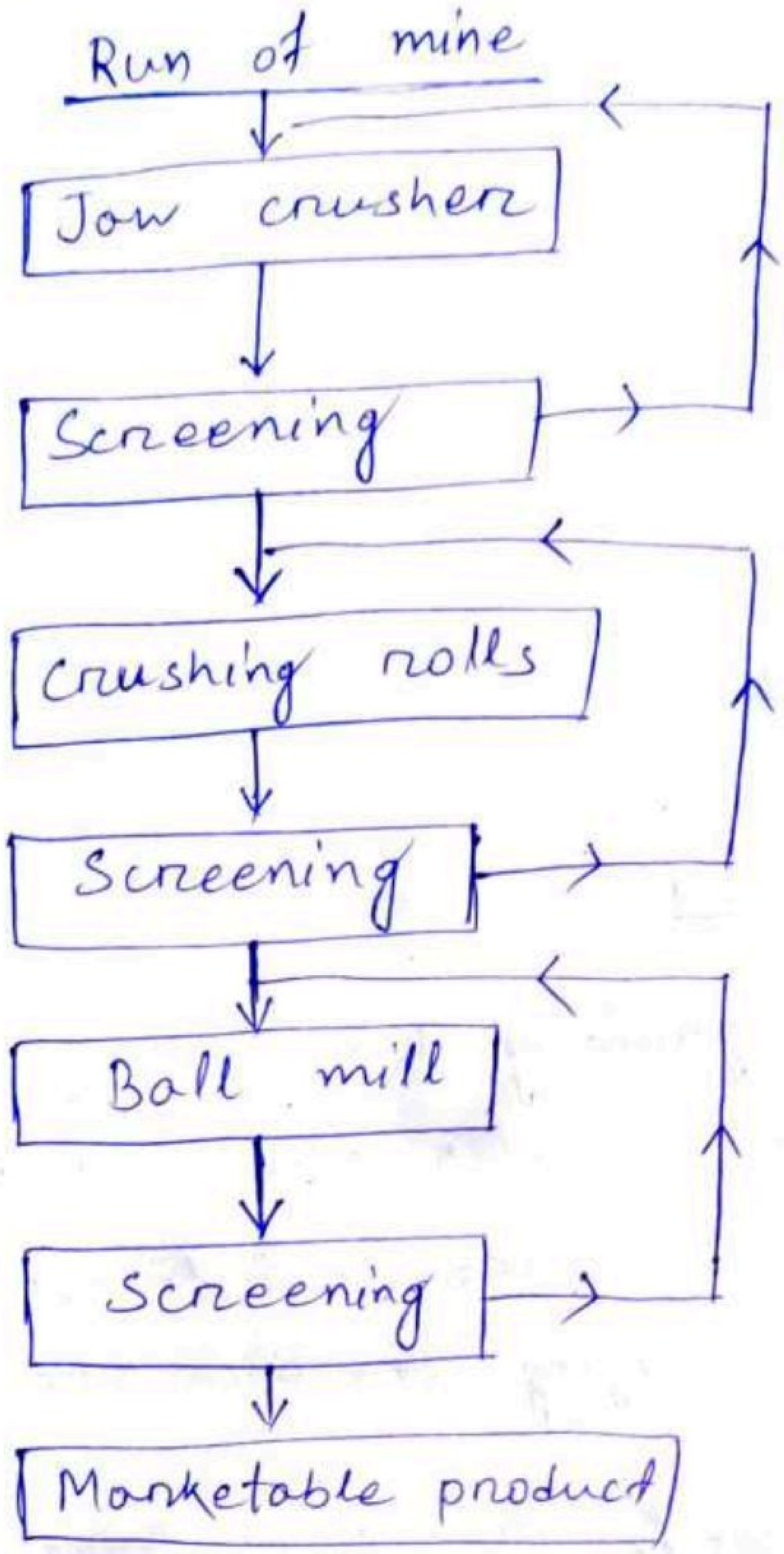
3/- When no attempt is made to classify the product and return the over size particles in the product once again to the same crusher for further size reduction rather the entire product is charged as feed to the next crusher and this kind of activity is continue till the desired product size is obtain is termed as Open circuit grinding.

Example

Example of open circuit grinding is a dodge crusher operating on choke feeding.

4/- This grinding may consume excessive amount of power where a large portion of energy is wasted in re grinding the product particle which are already fine enough.

Close circuit grinding



1/- In this method the partially crushed material is screened and the over size material is return back to the same crusher for further crushing while the under size product is given as the feed to the next crusher for further size reduction.

2/- If such a method is followed at all successive crusher till the desired product is obtained it is term as close circuit grinding.

3/- This method of grinding operation is generally adopted widely because of the process has been found to be in economical.

4/- It makes full capacity utilisation of all crushing equipment efficiently.

5/- This process avoids unnecessary re grinding.

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Fine crushing or grinding:-

→ Any comminution process aiming at a product size less than 6MM is known as grinding.
The usual meaning of grinding is the comminution of an ore particle that has already been reduce to a size less than 6 MM size by crushing.

→ Grinding is a slower process usually carried out in a ball, tumbling, tube, rod and pebble mills

→ These mills perform size reduction in close chambers containing hard bulb, rods or quarz levels as grinding media.

→ Among the above mention mills ball mill is extensively use.

Classification of Ball mill

Ball mills are classified according to the -

(i) Shape of the mill.

(ii) Method of discharging the ground ore.

(iii) Medium of grinding. wheather dry or wet.

Shape of the Ball mill

- Cylindro-conical Mill or Harding Mill
- (Cylindrical Mill) which represents the usual Ball Mill.

Method of Discharge

Cylindrical Mills are again classified according to the mode of product discharge taking place from the mill.

(i) Peripheral discharge mill

Discharge product through meshed cylindrical shell.

(ii) Grate Mill

Discharge product through a screen extending as a diaphragm across the full section of the mill at the discharge end.

(iii) Over flow mill

Discharge free over flow product through the axis of the mill.

Construction of the cylindrical ball mill

Ball mill has few important components as follow:

(i) cylindrical shell
(ii) Inner surface or liners
(iii) Ball or grinding media
(iv) Drive (Power transmission line)

Cylindrical shell

→ It is the rotating hollow cylinder partially filled with the balls.

→ The ore to be crushed is fed through the hollow ~~turnnion~~ turnnion of one end and the product is discharged through a similar turnnion at the other end.

→ The shell is usually made up of high strength steel. The axis of the shell may be horizontal & slightly incline to the base.

→ They use hardened steel balls as grinding media of size 25 - 125 MM.

Inner surface or liners

→ As the grinding process involves heavy impact and wear, the interior of the ball mill is lined with replaceable wear resisting liners.

→ The liners are usually high manganese alloy steel, stones or rubber.

Balls (Grinding media)

→ The balls are usually made of cast steels. The diameter of the grinding media varies between 25 - 125 MM.

→ The optimum size of the ball is proportional to the square root of the feed size. $\boxed{\text{Ball size} \propto \sqrt{\text{Feed}}}$

→ The balls wear at a much faster rate as compare to the liners.

Drive

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

Theory of Ball mill operation

1/- Ball mills may be continous or batch type in which grinding media and the ore to be ground are rotated around the axis of the mill.

2/- Due to friction between the liner balls and liner ore lumps and both the ore lumps & balls are carried up along the inner wall of the shell nearly to the top of the shell from where the media fall down to the toe of the ~~media~~ mill delivery a heavy impact on the ore particles ~~avaible~~ available there.

3/- The action is repeated till the ore particles are reduce to almost powder.

4/- The energy expanded in lifting up the grinding media is thus utilized. In reducing the size of the ore lumps.

5/- The entire grinding process is attributed to three (3) different stages of of ball mill working.

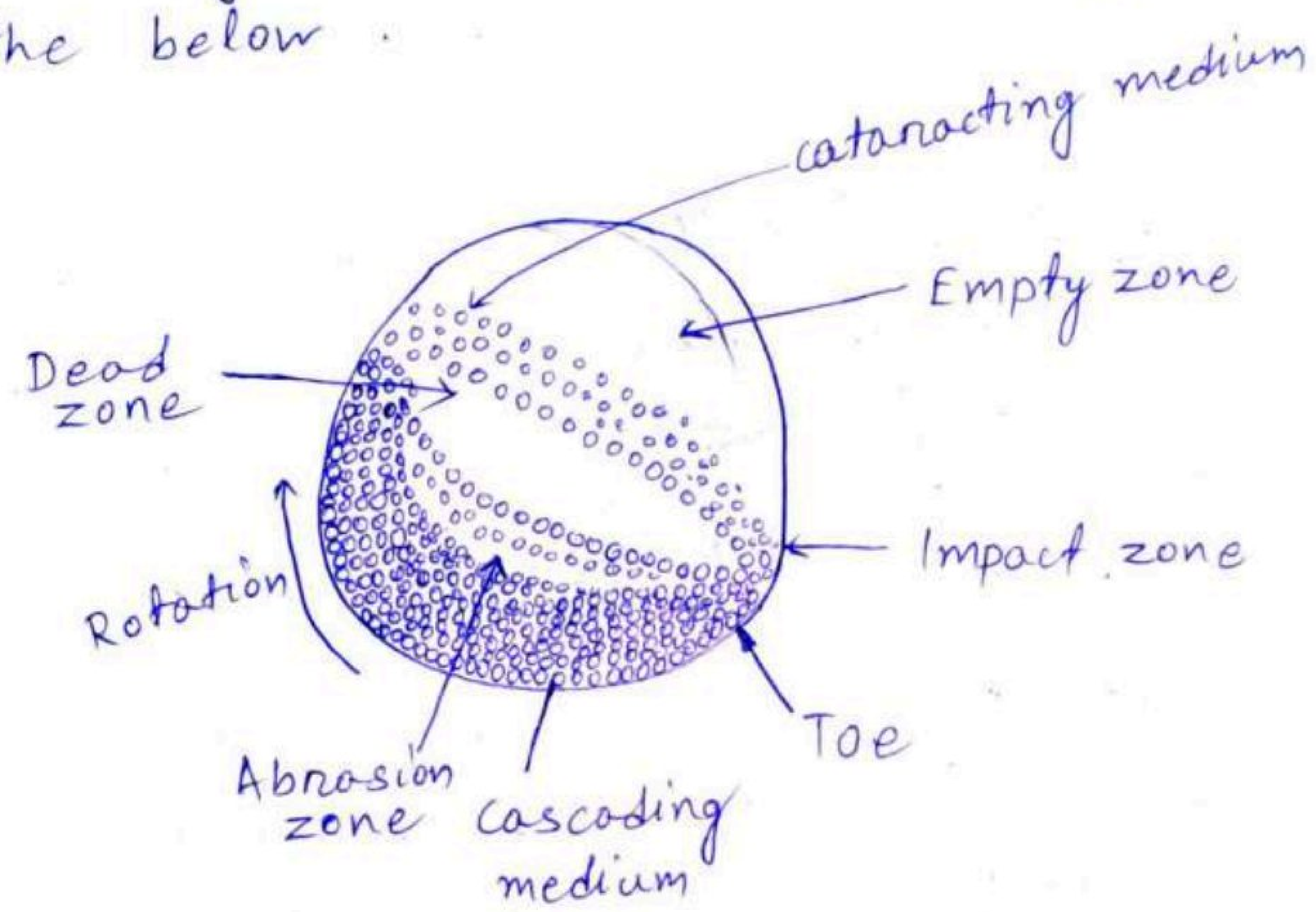
The stages are -

1/- Cascoding :- Attrition between the balls & particles.

2/- Cataracting :- Impact of the ball on the particles

3/- Centrifuging :- Revolving of media and charge as a single layer sticking to the inner peripheri of the mill.

These stages of ball mill working are shown in the below.



Effective grinding depends on the rotational speed of the mill. If the mill operates at a lower speed balls will not be carried up along the inner walls to a greater height to generate sufficiently large impact force on their fall which can grind the ore. Rather they roll over each other on slip. This type of operational condition is known as cascoding of the mill.

However little grinding occurs due to attrition during this stage of operation.

If the speed is raised the balls start moving up further along the inner wall and fall down from greater height imparting sufficiently large impact force at the toe of the mill.

This impact force is largely responsible for most of the grinding in the ball mill. This operational condition is known as cataracting.

If the speed of rotation becomes too high, the balls are carried over and over again along the inner liners as if they are sticking to the inner wall of the shell. This operational condition is known as <u>centrifuging</u> which hardly cause any grinding.

As cascading & centrifuging results in very little grinding for effective grinding the mill should be operated under cataracting condition only.

The speed at which the mill starts centrifuging is called the Critical Speed of the Ball Mill. and can be deduced mathematically.

<u>Critical speed of the ball mill</u> (5/2 Mark)

- The minimum rotational speed at which centrifuging occurs in a ball mill is defined as its critical speed.
- As we know that no grinding takes place in the ball mill when it centrifuges hence the operating speed of the mill should always be less than its critical speed so that the mill can cataract.
- The critical speed of the ball mill is practically very importance with regards to its efficient working.

<u>Determination of critical speed of the ball mill.</u>

Characteristics of the Ball mill

1/- **Speed of the Mill :**

Speed of the mill should be as high as possible without centrifuging .

2/- **Ball load :**

-> It is defined as the volume that occupied by the grinding media of the total volume of the ball mill without any ore or water in it .

-> The ball load should be such that it is slightly more than 30 % of the total volume of the ball mill .

-> During general operation media occupie between 30 - 50 % of the volume of the mill .

3/- **Reduction ratio :**

- The reduction ratio of the ball mill is quite large compare to primary & secondary crusher it may range from 50 - 100 .
- For a larger RR with higher output it is economical to use number of mills in series .

4/- **Capacity**

The capacity of the ball mill depends on its size, hardness of the rock and the reduction ratio attempted .

Ball mill can yield 1-50 Tonne/hour of ore fines, 90 % passing through 200 # screen (meshed size)

5/- **Energy consumption**

Energy consumption in the ball mills is around 16 KWh/Tonne of ore ground on an average .

Factors affecting the product size in a ball mill

1/- **Rate of feed**

Higher feed rate results in lower RR and higher average product size as the residence time of the ore in the mill is reduced .

2/- Properties of the feed ore

- Under a given operating condition, larger the average feed size, larger will be average product size.
- A lower RR is obtained with a hard and brittle materials.

3/- Weight of the Ball

Heavier balls produce finer product.

4/- Size of the Ball

→ Smaller balls facilitate production of finer material but they are not effective in grinding larger size particles in the feed.

→ The limiting size RR obtained with a given size of media is known as free grinding.

→ As far as possible smaller size balls are to be used to obtained finer product.

5/- Slope of the mill

Higher the slope of the mill, higher the capacity of the mill as the retaintion time of the feed ore in the mill is reduced and a coarser product is obtained due to higher slope.

6/- Discharge freedom

Increasing the discharge freedom of the product has the same effect as that of increasing the slope of the mill, means capacity of the mill decrease.

7/- Speed of rotation

- The mill should always be operate at a speed less than the critical speed.
- Usually the operational speed of the ball mill is around 65 - 75% of the critical speed.

8/- Level of material in the mill

- The total level of the material in the mill should be maximum of 50 % out of which 30% should be ball load and 20% is ore load.
- If the level increased beyond 50% of cushioning action is increased and energy is wastage producting excessive fine.

Advantages of ball mill

→ The ball mill performs both wet & dry grinding effectively.

→ Installation cost of the ball mill is low.

→ Media used for grinding is relatively cheap.

→ Mill can be operated either in batches or ~~continous~~ continuously.

→ Mill is effective both in open and closed circuit grinding operation.

Dry & wet grinding

→ Ball mills can be operated either dry or wet. However these are usually employed to grind ore in wet condition.

→ But for some specific purpose like 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.

Advantage of wet grinding over dry grinding

(Wet grinding is generally applicable to low speed mill)

→ Wet grinding facilitates better removal of product.

→ Power consumption is lower than the dry grinding. (10 - 30 % per tonne of product)

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

- As wet screening possible, fine powder can be produced.
- Dust problem is eleminated during grinding.
- Less noise and heat is produced during wet grinding.

Disadvantages of wet grinding

- It causes higher liner wear.
- During wet grinding water may react chemically with the ore.
- Dewatering of wet ground ore is costly operation.
- Sludge disposal may cost environment pollution.

Laws of comminution

- The most important consideration in any size reduction is the energy it consumes in performing the activity ~~on~~ as energy is costly.
- The empirical relations between the energy consumption and size reduction are termed as law of crushing or comminution.

Rittinger law

- This law state that energy consumed during comminution is proportional to the new surface area created due to particle fragmentation.

Mathematically the statement is represent by

$$E = K_R (S_2 - S_1)$$

where K_R = Rittinger constant or work index

S_1 & S_2 = The initial & final specific surface area respectively.

- Specific surface area is defined as the surface area per unit weight of the material.

In terms of particle size is can be stated as

$$E = K_R (1/d_2 - 1/d_1)$$

where d_1 & d_2 are initial & final diameter of ore particle respectively.

This law applies in the grinding range of 10 - 1000 um and evaluates the energy consumed during fine crushing most accurately.

Kick law

→ This law state that "the energy consume during size reduction is directly proportional to the logarithm of reduction ratio"

→ If d_1 & d_2 are the initial & final diameters of the particles during size reduction, the RR is estimated to be (d_1 / d_2)

→ Accordingly the energy spend for size reduction is proportional to $\log (d_1/d_2)$

Mathematically $$E = K_K \log (d_1/d_2)$$

Where K_K = kick's law constant

d_1/d_2 = Reduction ratio

Kicks law is successful in predicting the energy consumption during coarse crushing that is in the range of 1 cm and above.

Bond Law

→ This law state that "the total amount of work input represented by a given weight of crushed or ground product is inversely proportional to the square root of the product particle diameter".

→ As per law $W_b \propto 1/\sqrt{D_P}$

Where D_P = average size of the product.

W = Bond's work input during crushing.

→ Mathematically $$W = 10\, W_i \left[\frac{1}{\sqrt{D_P}} - \frac{1}{\sqrt{D_F}}\right]$$

Where, D_P & D_F are the average size of the product and feed expressed in microns respectively.

W_i = Bonds work index which is an intrinsic property of the material being crushed.

→ Work index is comminution parameter that expresses the resistance of the material through crushing & grinding.

Numerically is = work input in KWh/Te that is required to reduce a material from an infinitely large size to a produce of which 80% passes through the screen of 100 um aperature size.

Ore grindability

It refers to ease with which the material can be crushe or ground.

Particles size determination

Particle shape

(1) The primary function of the size analysis is to obtain quantitative data about size and size distribution of the particle of the product material.

(2) The shape of the particle plays an important rule in the size determination.

(3) The size of the spherical particle can be defined in quickly by its diameter but there is no unit dimension by which the size of an irregular particle can be described.

(4) The term most often used to describe the size of an irregular particle is its equivalent diameter ($\bar{d}$).

Size

Common method of particle size analysis

* For irregular particle the size is usually defined as the smallest regular aperture through which mineral particle passed through.

-> This defination is applicable to polyhedrons and is not valid for rod shaped narrow particles.

-> In the laboratory size can be determined by various sizing method as mention below.

Methods of particle size determination

Method	Approximate size range in micron
(1) Sieve analysis	100000 - 10
(2) Elutriation	40 - 5.0
(3) Optical microscopic	50 - 0.25
(4) Sedimentation (Gravity)	40 - 1.0
(5) Sedimentation (Centrifugal)	5 - 0.05
(6) Electron microscopic	1 - 0.005

[1 Micron = 10^{-6} MTR]

Sieve analysis

→ This is the most important method of determining the average size of the product particles.

→ This is used widely to determining effiency of size reduction operation also works as a yardstick for assending the finess of a ground product.

→ Different standard screens or sieves are used for this purpose.

→ Among them the most important one is British standard sieves.

British Standard sieve

(1) In the british system the screen is designated with a number called mesh number.

(2) Mesh number is defined as the number of square opening available per linear Inch length on the screen surface.

FPS (Foot Pound Second)

(3) If the screen have 4 opening per linear Inch length of the screen surface then the mesh screen number is 4.

(4) Like wise we have screens of different mesh number such as 20, 40, 200, 27; & 400

(5) When the mesh number of the screens increases the screens opening of aperature decreases & vise versa.

Industrial screening

(1) Screening of the crushed product on a large scale is termed as industrial screening.

(2) Screening segregates the bulk of the crushed product into few fractions and is benificial in many ways as follows.

(a) Properly sized of the required size material can be change to the next comminution equipment for further size reduction.

(b) Proper feed size reduces the overlooding of on the machines & increases the overall effiencieny of the comminution.

(3) Properly sized material can be charged to the process reactors such as smelters, roasters, or calcinators making the unit process more efficiency.

Purpose of screening

→ The basic purpose of screening as follows.

1) To prevent the entry of under sized material to a perticular crushing machine so as to increase its capacity & eleminate over grinding.

(2) To prevent the over sized material from passing over to the next stage of crushing in closed circuit grinding to increase efficiency.

(3) To prepair closely sized and product for subsequent unit process

Mechanism of screening

(1) When the crushed product is feed to the screen a portion of the product posses through and rest is retained on the screen.

(2) The fraction of the material passing through the screen is known as under flow.

→ When the portion of material retained on the screen is known as overflow.

(3) So the basic fact attached to screening is the passage of the under sized material through the screen. The factors which affect screening are listed below.

(i) The absolute size of the screen opening or operature.

(ii) The relative sized of the particle with that of screen operature.

Classification of screen

The screen are classified as (i) stationary
(ii) Moving.

Stationary screen

1/- These screens are of limited use.
2/- These screens are grizzlies.
3/- They consist of parallel rods, bars or woven wire mesh, set at an angle to the ground.
4/- Under sivear condition wear & strength with openings greater than 5 inches, steel rails are used to make the screen surface.
5/- The screen surface are of high strength.
6/- The bars are held together at right angle to their length, spaced at the desired distance using sleeves and bolts.
7/- They are employed to classified to the product for primary crusher.
8/- The screens are in sloppy nature, so that the feed material automatically rolls down due to force of gravity.
9/- The major disadvantages of this type of screen is clogging.

Moving screen

The important types of moving screens are.
1/- Moving Grizzlies
2/- Trommels or revolving screen.
3/- Shaking screens.
4/- Vibrating screens.

Moving grizzlies

- → This grizzly is made up of rods and bars and have movements.
- → In moving grizzlies alternate bars or rods raise and subsides.
- → The feed material move forward gently with sufficient turning over.
- → This machine is used for very coarse feed.

Advantages of grizzlies

- Lower floor space is required for installation.
- They act as feeder to intermediate crusher
- They result in better screening than stationary screens.

4. Imp Trommels or Revolving screen

- → Revolving screens or Trommels are used more widely than any other moving screen.
- → It consists of rotating cylindrical, prismatic or conical shells made up of punched plates or thick woven wires.
- → When the trommels has only one shells it is known as simple trommels and if it has more than one shells it is known as compound trommels.
- → In compound trommels the shells are arranged in concentric manner with screen aperature gradually decreasing from the inner most to the outer most screens.

-> Commonly the trommel has a diameter of 3 to 4 feet and length of 5 to 10 feet.

-> It is driven by a central shaft attached to to it by 4 or 6 armed spiders.

-> The material to the screen is feed on the Inner most shells & it is made to flow out peripherally when the trommel is rotated and get screen through different peripheral screen.

-> Central shaft of the trommels is kept little incline to the floor so that the feed material automatically flow from the feed end to the discharge end by using force of gravity.

-> cylinderical trommels are basically used.

Advantage

- It requires small floor space.
- Has a larger capacity per unit screening area.
- It is cheap to operate both on dry & wet feed.
- several fractions are obtain in one go.
- screening operation is quite efficient.

Operational characteristics of screen

1/- The operational characteristics of any ~~indivisual~~ Industrial screens are as follows.

(i) Capacity

(ii) Efficiency or performance

(iii) Operational cost.

(I) Capacity :-

The capacity of the screen depends upon -

1/- The area of screen surface

2/- The size of screen aperature

3/- Physical characteristics of ore i.e, specific gravity, moisture content, temperature, proportion of fines.

4/- Types of screening mechanism is used.

(II) Efficiency or performances of screen

1/- In screening the screen efficiency defined as a major of effectiveness of screening operation as compared to a perfect screening operation.

2/- Factors affecting the efficiency of screening system are -

(i) Rate of feeding

(ii) Particle size

(iii) Moisture

(iv) Worn or damage screen.

(III) Operating cost

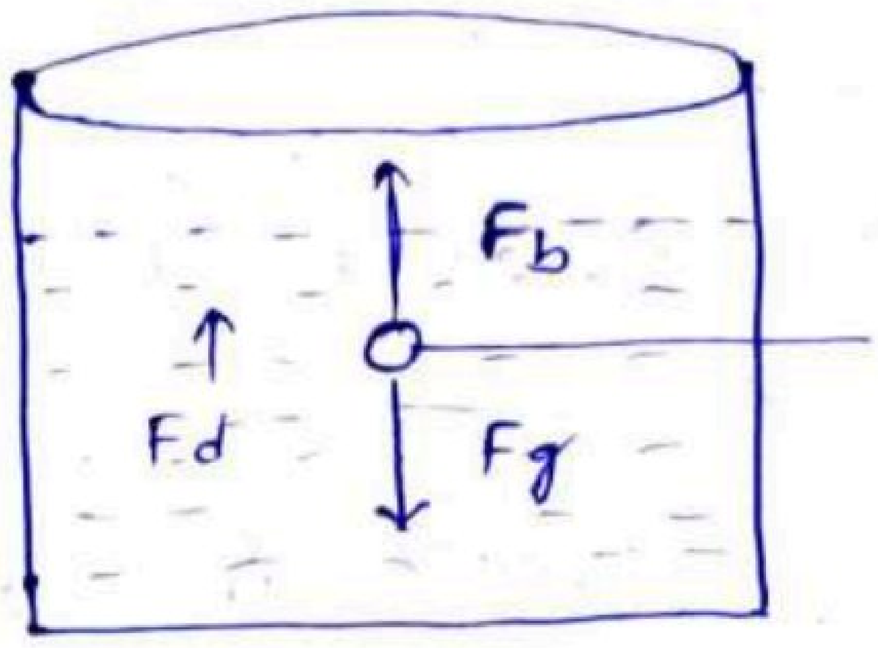
1/- The operating cost of screen is low.

2/- For stationary screen power cost is nill but there are other cost like attendant replacement and repair.

3/- The moving screen consume a little bit of power.

Movement of solids in fluid

Fluid resistance and terminal velocity of a falling particle



1/- With reference to the figure when a solid particle is immersed in a fluid at rest it is acted open by
(1) Gravity Force $F_g = m \times g$
(11) Buoyant force $F_b = m'g$
Where m' = mass of the fluid displaced by the solid particle.

2/- The gravity force act downward while the buoyant force act upward.
Such a condition is true as long as both particle and fluid are in a state of rest and there is no relative motion between them.

3/- As per the classical Archimedesis principle the net force acting on the body under the state of rest is

$$F_n = F_g - F_b \quad \text{—— (1)}$$

If $F_g < F_b \rightarrow$

The particle floats up on the surface of fluid

or If $F_g > F_b \rightarrow$

The particle settle down in the fluid

(i) Once the solid particle starts moving down to the relative to the fluid medium the situation with ~~respect~~ regards to the force action on the particles changes.

(ii) An additional force, R starts acting on the particle in addition to the existing force.

→ The new force, R is termed as the fluid resistance or viscous force which ~~occur~~ offers resistance to the particle movement in the fluid.

Numerically, $R = 6\pi\mu r v$

where μ = viscosity of the fluid

r = radius of the particle

v = velocity of the particle.

→ The fluid resistance force or drag force is always act in a direction opposite to the direction of settling or with same direction or of Buoyant force.

→ Under the condition of settling the net force working on the particle.

$$F_n = F_g - F_b - F_d$$

$$F_n = F_g - (F_b + F_d)$$

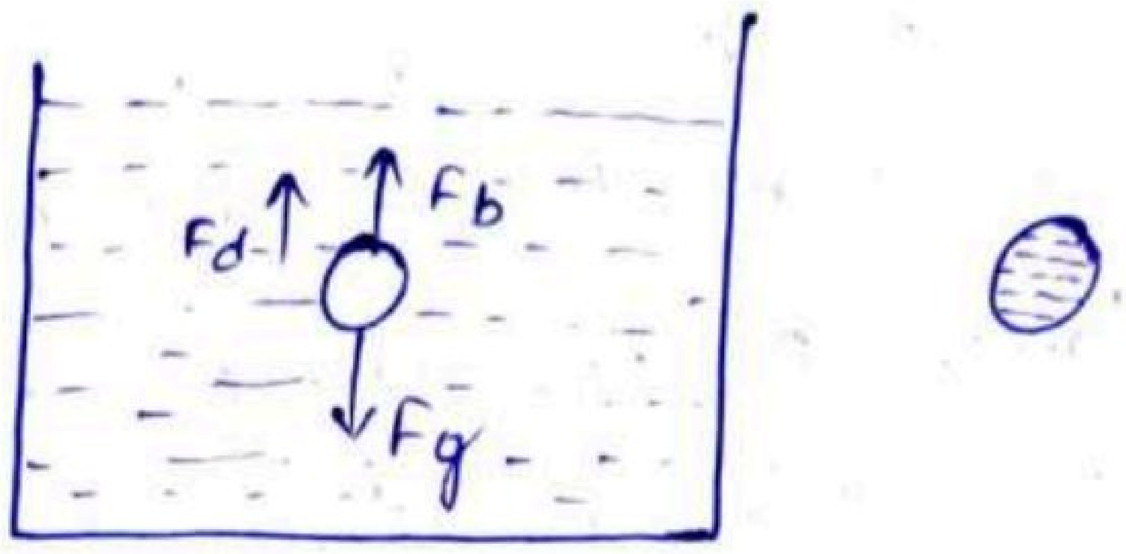
$$F_n = F_g - (F_b + 6\pi\mu r v)$$

Terminal velocity

→ The constant velocity at which the particle settle in a fluid after initial acceleration is termed as terminal velocity.

Determination of terminal velocity

→ It is the maximum velocity attained by a body while falling freely in a viscous medium.



In the above figure the two force Fb & Fg are constant

But we know $F_g = Mg$

$= V \rho g$

where V = volume of body

ρ = density of body

g = gravitational force

similarly $F_b = M'g$

$F_b = V \rho' g$

where V = volume of water which is equal to the volume of body because the body displace the water

ρ' = density of water

g = gravitational force.

When the body start moving their will be the another force acting on the body that is drag force (Fd)

So $F_d = 6 \pi \mu r v$ (according to stocks law)

→ When the velocity of particle increases the drag force will increases & Acceleration decreases.

→ But their is a point come where the net force is zero & the acceleration also zero.

At that time the body gain its maximum velocity then the velocity remain constant & the body settle at the constant velocity.

So that condition is

$$F_b + F_d = F_g$$

$$\rho' V g + 6\pi \mu r v = \rho V g$$

$$6\pi \mu r v = \rho V g - \rho' V g$$

$$6\pi \mu r V_t = \frac{4}{3}\pi r^{3}(\rho-\rho')g$$

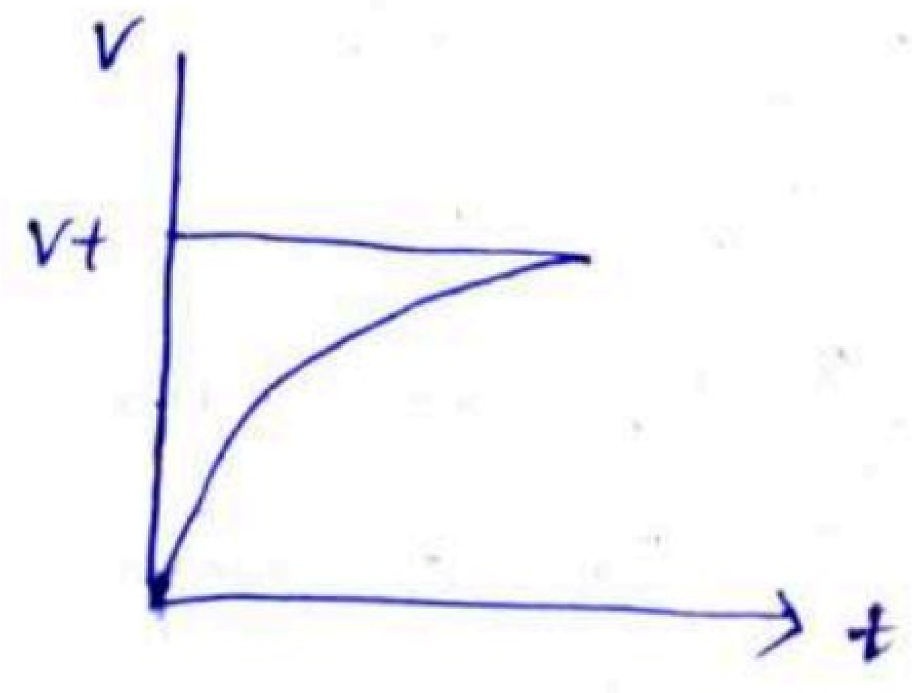
$[V = \frac{4}{3}\pi r^3$, sperical body$]$

$$6 \mu V_t = \frac{4}{3} r^2 (\rho-\rho')g$$

$$V_t = \frac{\frac{4}{3} r^2 (\rho-\rho')g}{6\mu}$$

$$\boxed{V_t = \frac{2}{9}\frac{r^2(\rho-\rho')g}{\mu}} \quad \text{(III)}$$

→ The terminal velocity is +ve if the ρ (density of body) is greater than ρ' (density of water) or vise versa.



→ The equation (III) determine the terminal velocity of a freely falling particle in the fluid & it also known as stokes law of settling

→ The settling of solid particle under stokes law is termed as free settling for any other condition the settling is known as Hindered settling.

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Free settling

1/- If a particle is at sufficient distance from the wall of the container or from other particle so that its fall is not affected by them the process is called free settling.

2/- Terminal velocity is also known as free settling velocity.

Hinder settling

1/- When the particles are crowded they settle at a lower rate and the process is called Hindered settling.

2/- The particles will interfear with the motion of indivisual particle.

3/- The velocity gradient of each particle are affected by a close presence of other particle.

Newtons law of Hindered settling

$$V_t = \sqrt{\frac{8g\,(\rho_p - \rho')\,r_p}{3Q\rho'}} \quad \text{——— (4)}$$

Where

Q = coefficient of fluid resistance

r_p = particle radius

ρ_p = specific gravity of particle

ρ' = specific gravity of fluid

Settling in a pulp or slurry -

1/- When tiny particles are added to the fluid in large quantity they get suspended in fluid and form a pseudo fluid.

2/- The Apparent sp. gravity of the pseudo fluid is higher than the sp. gravity of pure fluid such a fluid is known as slurry or pulp.

3/- The terminal velocity (v_t) of the particle settling in a slurry is given by Newtons law

$$v_t = \sqrt{\frac{8g(\rho p - \rho'')r_p}{3Q\rho''}} \quad \text{--- (5)}$$

where ρ'' = s.p. gravity of the slurry in place of the s.p gravity of pure fluid.

Equal settling particle - FSR and HSR

1/- The particles are said to be equal settling if they have identical terminal velocity in a fluid under the same field of force.

2/- The FSR (free settling ratio) is calculated by equating ~~there~~ their terminal velocity under stocks law as follows.

As per defination

$$V_{t_1} = V_{t_2}$$

We know

$$V_{t_1} = \frac{2r_1^2(\rho p_1 - \rho_f)g}{9\mu} = V_{t_2} = \frac{2r_2^2(\rho p_2 - \rho_f)g}{9\mu} \quad \text{--- (1)}$$

$$\Rightarrow \frac{2r_1^2(\rho p_1 - \rho_f)g}{9\mu} = \frac{2r_2^2(\rho p_2 - \rho_f)\times g}{9\mu}$$

$$\Rightarrow r_1^2(\rho p_1 - \rho_f) = r_2^2(\rho p_2 - \rho_f)$$

Now FSR, $R_f = \sqrt{\frac{(\rho p_1 - \rho_f)}{(\rho p_2 - \rho_f)}}$ --- (2)

Where ρp_1 & ρp_2 are specific gravity of the 2 particles respectively and ρ_f is sp. gravity of the fluid.

Similarly the HSR can be calculated by

$$HSR,\ R_n = \left[\frac{(\rho p_1 - \rho'')}{(\rho p_2 - \rho'')}\right] \quad \text{---} \quad (3)$$

where,

ρ'' is the sp. gravity of the suspension rather than the pure fluid.

3/- General equation for settling ratio is expressed as

$$R_x = \left[\frac{\rho p_1 - \rho''}{\rho p_2 - \rho''}\right]^m \quad \text{---} \quad (4)$$

Where 'm' is the exponent which varies between $\frac{1}{2}$ and 1.

For stokes law $m = \frac{1}{2}$

For newtons law $m = 1$

The concept of FSR and HSR can be employed suitable in classifies to segrigate particle acconding to their size & specific gravity.

Classification

→ Classification is a method of separating mixture of minerals into two or more product on the basis of the velocity with which the particle fall through a fluid medium.

or

Classification is a process by which particles of various sizes, shaped and specific gravity are separated into different group by allowing them to settle in a fluid medium.

→ The carrying fluid can be liquid or gas.

→ In mineral processing these fluid is usually water and weight classification are generally applied to mineral particles that are consider too fine (less than < 200 μm) to be sorted efficiently by screening.

→ Classifier are nearly always used in close circuit grinding operation & so strongly influence the performance of these circuit.

Principle of operation

1/- The velocity of particle in a fluid medium is dependent not only on the size, but also on the specific gravity & shape of the particle.

2/- The principles of the classification are also Important in mineral separation utilising gravity concentration.

3/- The classification process involves the balancing of the accelerating (gravitational, centrifugal and opposing or drag etc) forces acting upon particle so that the resulting net force has a different direction for the fine and coarse particles.

4/- Coarser, heavier and spherical particles settle faster in a fluid medium than finer, lighter & angular particles.

5/- However emphasis of separation is based on size difference.

Factors affecting classification :-

1/- Specific gravity

Particle having the higher sp. gravity will settle faster than the other particles of same size and lower sp. gravity.

2/- Size :-

Among the particles of same specific gravity the longest particles will settle faster.

3/- Shape

Spherical particle settle faster than the narrower, longer and flatter particles.

4/- Specific gravity of the fluid

For fluid of different sp. gravity the particles will settle fastest in the lightest fluid.

5/- Air bubble

Adherence of air bubbles to the solid particle will ~~settle fastest~~ lower the settling speed.

Classifiers

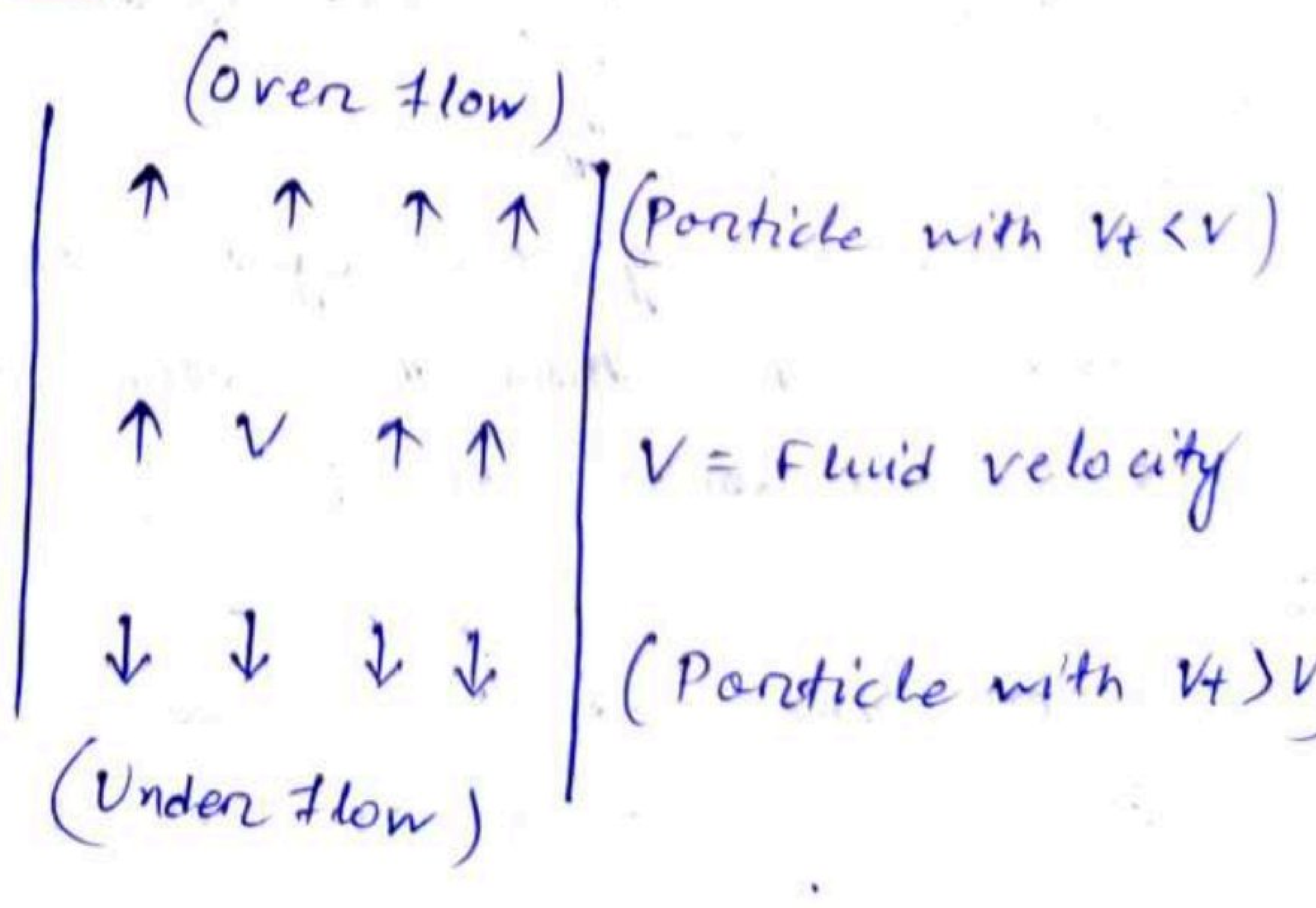
Defn

1/- The machines used for the classification is termed as classifier.

2/- Classifier consist of a sorting column in which a fluid raises at uniform rate.

3/- Particles introduced into the sorting columns sink & report as underflow. if their T.V. (terminal velocity) are greater than the velocity of water and in otherhand if there T.V is less than upward velocity of the fluid it raises & report as overflow.

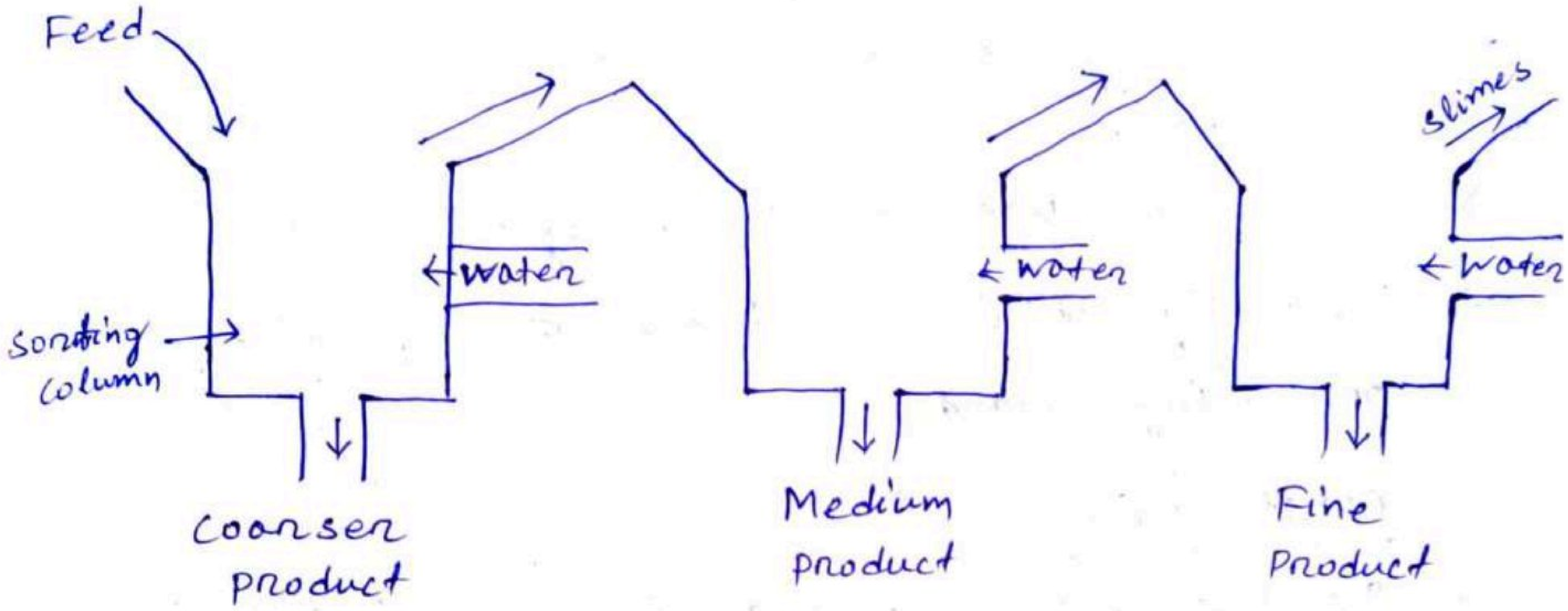
Sorting column



Classifier

- Hydraulic Classifier
  - Free settling classifier
  - Hinder settling Classifier
- Non-Hydraulic classifier
  - Mechanical classifier
  - Non-Mechanical classifier

Hydraulic classifier



1/- Hydraulic classifier unit is simple in design.

2/- It uses water additionally with the feed pulp introduce so that its direction of flow oppose that of the settling particles.

3/- They normally consist of a series of conical sorting columns through each of which a vertical current of water is raising and particles are settling out.

4/- The raising currents are greaded from a relatively high velocity in the first column to a relatively low velocity in the last.

5/- Due to this a series of spigot product can be obtained with the coarser, denser particles in the first spigot & the fine in the later spigot.

Working principle

→ Different is the settling rate of particles of feed pulp against the raising water column.

Imp Cyclone separator or Hydrocyclone (10/5 mark)

→ This is a continously operating classifying device that uses centrifugal force to accelerate the settling rate of particles.

→ It is extremely important and efficient classifier for fine material in mineral industries.

→ It is widely used in close circuit grinding operation.

→ It is also used to de-sliming and thickening

→ Basically it is the heart of any mineral processing plant.

Construction

1/- The hydrocyclone consist of a conical shaped vessel open at its apex to under flow of the coarser material.

2/- The conical vessel is joint to a cylindrical section ~~heading~~ having a tangential feed inlet.

3/- The top of the cylindrical section is closed with a plate having an axial mounted pipe for overflow.

4/- The pipe is extended into the body of the cyclone by a short and removable section known as the "vertex finder" which prevents the short circuiting of the feed directly into the overflow

Working of cyclone

1/- The feed is introduced to the cyclone under pressure through a tangential entry of port.

2/- This tangential entry imparts spinning motion to the feed pulp which generates the vertex in the cyclone with a low pressure zone along the central vertical axis.

3/- Particles introduced into the cyclones are subjected to opposing forces such as
(i) An outward centrifugal force.
(ii) An Inward drag force.

4/- These forces are acting symultaneously on the particles as shown in the figure.

5/- The centrifugal force accelerate the settling rate of the particles and separate them as per their sizes and sp. gravity.

6/- Heavier and larger particles moves towards the peripheral wall of the cyclone where they collide on the wall and lose there velocity. There after they migrate towards the apex opening.

7/- Due to the action of drag force the lighter and smaller particles moves towards the centre of cyclone a low pressure zone and carried of through the vortex finder to the over flow.

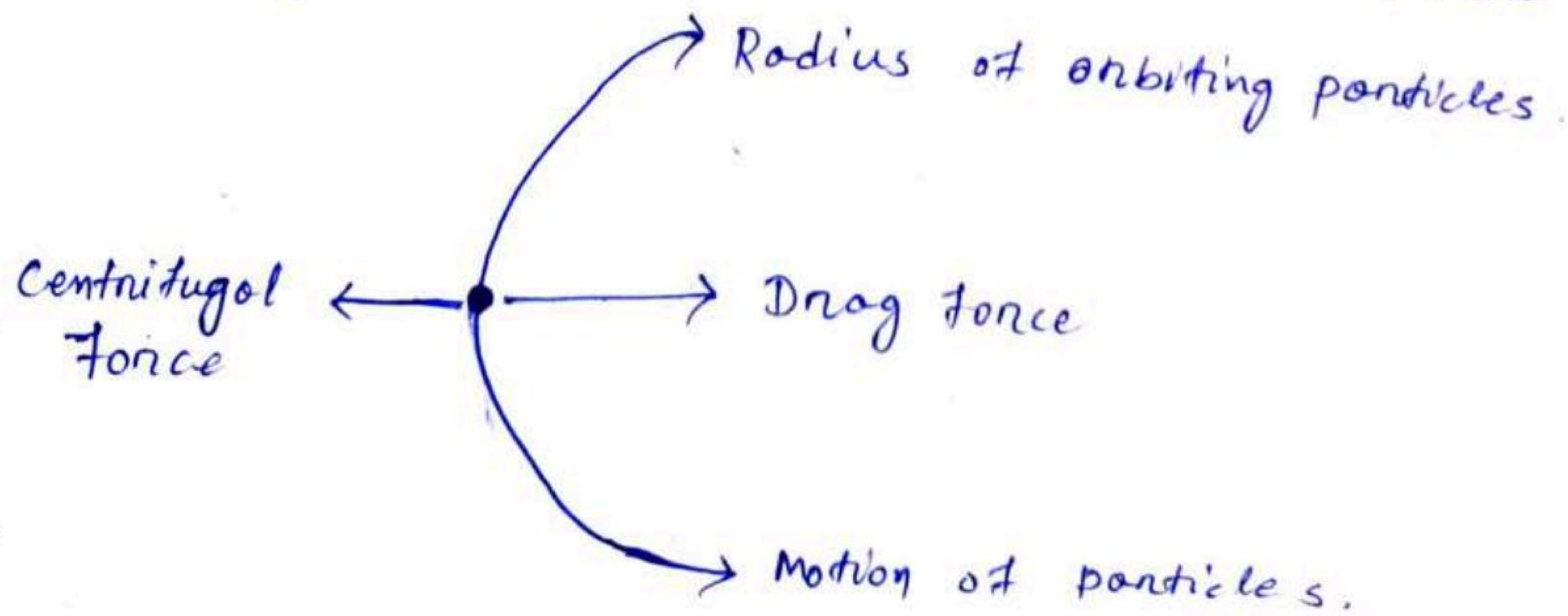


Fig: Force acting on an orbiting particles in the hydrocyclone

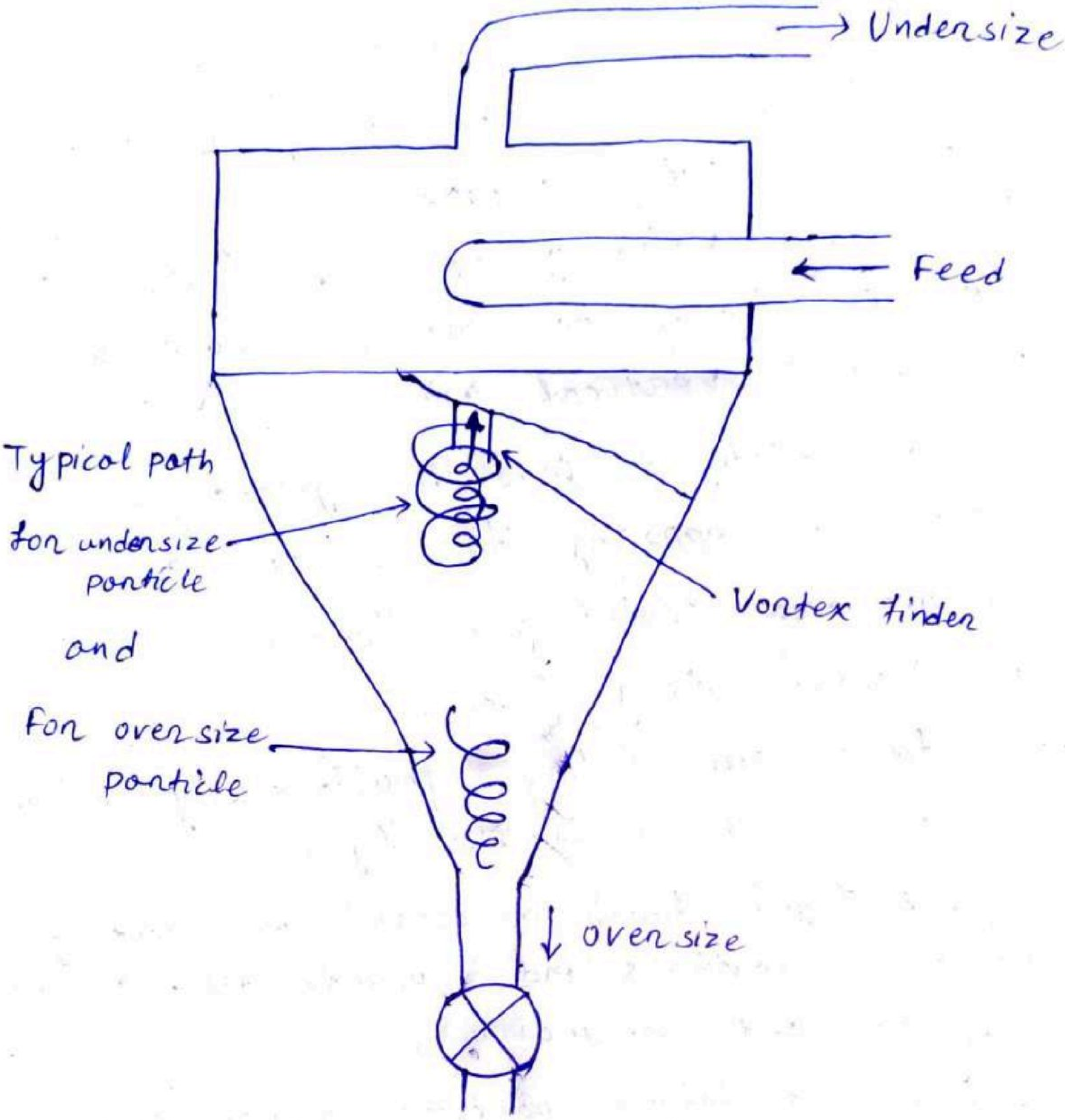


Fig: Schematic Hydrocyclone

Heavy media separation (HMS)

Principle of Heavy media separation

1/- Basic principle involves in the gravity concentration process is the float & sink.

2/- This is carried out by using a fluid whose sp. gravity lies between the sp. gravity of the two minerals particles in the ore.

3/- As all the minerals are heavier than water is not a suitable fluid medium to carried out HMS.

4/- For the process to be effective fluids heavier than water are required.

5/- The figure below explain the basic principle of H.M.S.

Feed
↓
Mineral of sp. gravity (- 2.8) (Float) ← Fluid medium sp. gravity (2.8) ← Mineral S.P. gravity (+2.8) (Sink)

Laboratory Grade heavy fluids

(i) Heavy fluids (S.P. gravity > 10) are not available naturally are to be synthesized or manufacturing.

(ii) Most useful heavy fluid → Acetylene tetrabromide (S.P gravity 2.96)

(iii) Extremly high cost of laboratory grade heavy fluid prevents their industrial application.

Industrial Grade Heavy fluids

1/- For industrial application pseudo fluids are prepoired by suspending fine solid particles in water.

2/- These fluids can be used almost like true fluids provided, the solid particles to be separated, the coarser compoired to the size of particles used to synthesized to pseudo fluid

3/- The fluid is conteneously agitated to prevent the settling of the suspended particles however the agitation does not affected settling the heavy one particles.

4/- Finely crushed quartz, Magnetite, galena or Ferrosilicon are used to make the suspension.

5/- Fluids with specific gravity in the range of 1.3 to 2 are of commercial interest.

6/- Such fluids are mainly used to remored clay from coal.

7/- Pseudo fluid are which much cheaper than organic liquids. Hence it is widely using in Industry.

Heavy media separation circuit

A simple heavy media separation circuit essentially consist a separating vessel with a provision to admit feed and withdraw product contineously.

→ Means to clean the seperated product recover the media and recirculate the same to the vessel for further utilisation.

Chance process

(Industrial HMS using pseudo fluid)

(i) Chance process is in use for last 150 year for cleaning ~~coke~~ coal

(ii) In this process the parting fluid is a suspension of quartz or sand particles in water in the size range of "-40 to + 80 #".

(iii) A schematic chance coal cleaner is shown in below figure.

(iv) It consist of a separating tank or a cone separator in which the sand moves of gently.

(v) An agitator is used to stir the suspension to prevent its packing.

(vi) The overflow the clean coal and sand passes over to the cleaning screens which desands & dewater the coal spray water is used to desanding.

(vii) The sp. gravity of fluid is adjusted by a varing the proportion of sand in suspension.

(viii) Anthrasite coal requires a heavier fluid compare to bitumeneous coal.

It is an example of industrial HMS pseudo fluid.

Gravity concentration

Gravity method of separation are used to treat a great variety of materials ranging from heavy metal sulphides such as Galena (sp.gr. 7.5) to coal (sp.gr. 1.3) at particle size in some cases below 50 micro meter (um)

Principle

→ The gravity concentration method separates mineral of different specific gravity by their relative movement in response to gravity and one or more other forces, the latter often being the resistance to motion occoured by a viscous fluid such as water or air.

Basic principle

Differential particle settling velocity

(i) The separation by gravity is based on the difference in settling rate in terminal velocity in particles of different density and size.

(ii) However with short distances by travel in some separation process particles may not have a chance to reach their terminal velocity.

(iii) How long it takes particles to reach their t.v. and what are the displacement distance between particle when they attend their t.v. could be determining factor in the concentration of particles by gravity separation.

Formula:-

$$\text{Concentration criteria} = \frac{\text{S.G. of heavy mineral} - \text{S.G. of fluid}}{\text{S.G of light mineral} - \text{S.G of fluid}}$$

$$= \frac{D_h - D_f}{D_L - D_f}$$

* The motion of a particle in a fluid is dependent not only on its S.G. but also on its size.

Gravity separation technique

Emphasis of separation is based on density difference although effects of particles size & shape can't be separated.

Important techniques of gravity separation

1/- Jigging / stratification
2/- Flowing film concentration
3/- Teetered bed separation
4/- Centrifugal separation
5/- Enhance gravity concentration.

Gravity separation devices

1/- Flowing film methods
- (i) sluices
- (ii) Reichenteones
- (iii) Tables.
- (iv) spirals.

2/- Sedimentation department
- (i) Jigs
- (ii) H.M.S or D.M.S

3/- Centrifugal concentration.
- (i) Dense media cyclone
- (ii) Enhance garavity concentrator.

Jig

Jig is a mechanical concentrator that uses for effective separations of heavy grains from lighter one by utilising difference in specific gravity of mineral particles.

Jigging

(i) It is a process of ore concentration carried out in any fluid whose effectiveness depends on difference in specific gravity of mineral particles.

(ii) It consist of separation of particles into layers of different specific gravity followed by the removal of the separated layers.

Principle of jigging

→ The three physical factors responsible for stratification of particle during jigging are

(i) Hindered settling classification.

(ii) Differencial acesseleration of the begining of the fall.

(iii) Consolidation trickling at the end of the fall.