UNIT-2

Size Reduction –

It refers to the operation wherein particles of solid are cut or broken into smaller pieces.

The size reduction machines more commonly reduced the size of solids by

(a) Compression
(b) Impact
(c) Attrition or rubbing
(d) Cutting

* Compression is used in case of coarse reduction of hard solids
* Impact yields coarse, medium or fine products.
* Attrition gives very fine product from soft, non-abrasive material.
* Cutting produces a product of a definite particle size and sometimes a definite shape.

It is not possible to estimate accurately the power requirement of crushing and grinding equipment to effect the size reduction of a given material, but a number of empirical laws ~~have~~ are:–

(1) Rittinger's Law
(2) Kick's Law
(3) Bond's Law

Rittinger's Law →

It state that work required for reduction of part size is directly prop to the new surface created.

Mathematically.

$$\frac{P}{\dot{m}} = K_r \left[\frac{1}{D_{sb}} - \frac{1}{D_{sa}} \right]$$

P = Power required by machine

$\dot{m}$ = feed rate to machine

K_r = Constant of Rittenger's law

D_{sa} and D_{sb} . Volume-surface mean diameter of feed and Product.

This Law has been shown to apply in case where the energy input per unit mass of solid is not too high.

Kick's Law →

It state's that, the work required for crushing a given material is prop to the logarithm of the ratio between the initial and final diameters.

$$\frac{\dot{P}}{\dot{m}} = K_k \ln \left[D/d \right]$$

K_k = Kick's Constant.

D and d are the initial and final sizes.

As the energy required is directly related to the reduction ratio (D/d), the energy required to crush a given quantity of material from a 50mm to 25mm is the same as that required to reduce the size from 12mm to 6mm.

Bond's Law and Work Index →

Bond has suggested a law intermediate between Rittinger's and Kick's law for estimating the power required for crushing and grinding operation.

Bond suggested that the work required to form a particle size Dp from a very large feed is prop. to the square root of the surface to volume ratio of the product.

$$\frac{\dot{P}}{\dot{m}} = \frac{K_b}{\sqrt{D_p}}$$

K_b → Bond's Constant

D_p → Particle size

$$\frac{S_p}{V_p} = \frac{6}{\phi_s D_p}$$

ϕ_s = Sphericity

The Bond's Law is somewhat more ~~rela~~ realistic in estimating power requirement of commercial size reduction machine.

Work Index → Wi -

A work index Wi is defined as the amount of gross energy in kilowatt-hours per ton of feed material required to reduce a very large feed to such size that 80% of the product passes through a 100-μm screen.

If D_p is in millimeter, P is in kW and $\dot{m}$ is in tons per hour.

$$K_b = \sqrt{100 \times 10^{-3}}\ w_i$$
$$= 0.3162\ w_i$$

$$\frac{P}{\dot{m}} = 0.3162\, w_i \left(\frac{1}{\sqrt{D_{pb}}} - \frac{1}{\sqrt{D_{pa}}} \right)$$

D_{pb} → Product particle size; D_{pa} → feed

<u>Crusing efficiency</u> →

It is the ratio of the surface energy created by crushing to the energy absorbed by the solid.

$$\eta_c = \frac{e_s\,(A_b - A_a)}{W/m}$$

η_c = crushing eff.

W/m = energy absorbed by the material. J/kg

e_s = Surface energy per unit area J/m²

A_b = Area of the product m²

A_a = Area of feed m²

Jaw Crusher :-

There are two types of jaw crushers :-

(i) Blake jaw crusher (Movable jaw pivoted at the top)

(ii) Dodge jaw crusher (Movable jaw pivoted at the bottom)

Blake jaw Crusher →

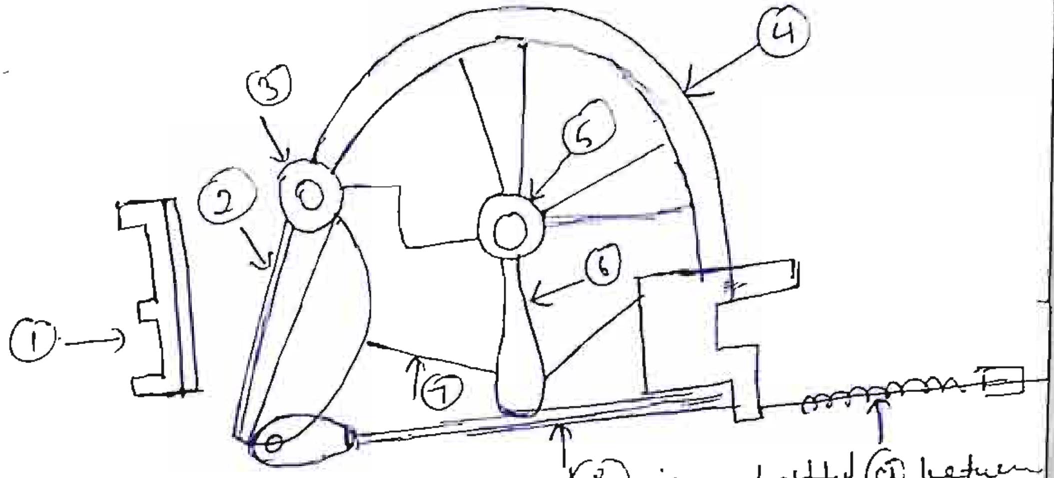
Principle →

It works on the principle of Compression.

Construction →

It has a fixed jaw and a movable jaw which is pivoted at the top. The jaws are set to form a V open at the top. The swinging jaw which reciprocates in a horizontal plane usually makes an angle of 20° to 30° with the fixed jaw.

Jaw crusher Consists of : (1) Fixed jaw (2) Movable jaw (3) Shaft (4) Fly wheel (5) Eccentric (6) Pitman (7) Toggle (8) Tie Road (9) Spring.



Working → The material to be crushed in admitted between the two jaws from top. The material caught between the upper part of the jaw crushed to smaller size during forward motion by Compression. The crushed material then drop

3

Types of Size Reduction Equipment →

Size reduction equipments are divided into four principal types

(1) Crushers (Coarse and fine)

(a) Jaw Crusher (b) Gyratory Crusher (c) Crushing roll

(2) Grinders (Intermediate and fine)

(a) Hammer mills

(b) Rolling - Compression mills

(i) Bowl mills

(ii) Rolling mills

(c) Attrition mills

(d) Revolving mills

(i) Rod mill

(ii) Ball Mill

(iii) Tube Mill

(3) Ultrafine grinders

(a) Hammer mill with internal classification

(b) Fluid-energy mills

(c) Agitated Mill

(4) Cutting Machines

knife cutters, dicers,

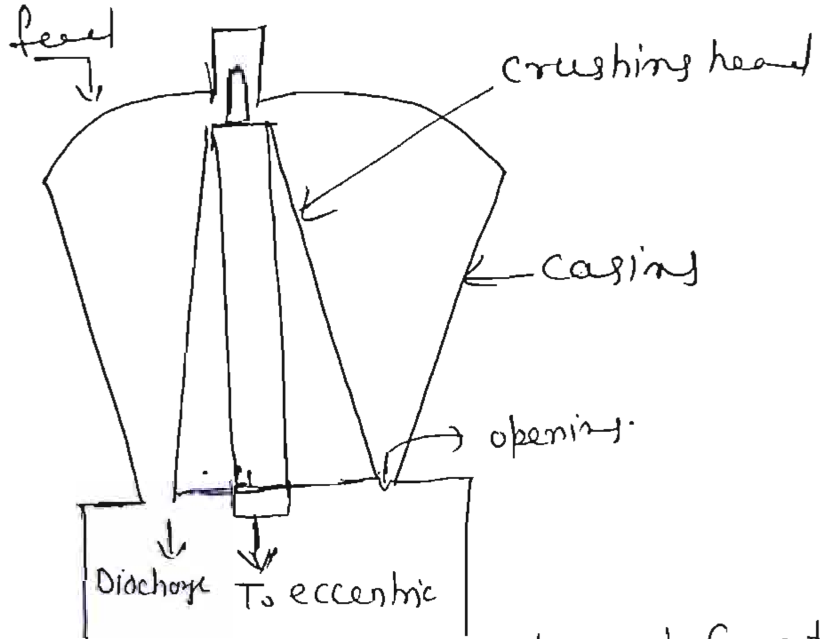
Crushers →

Crushers are slow-speed machines employed for coarse reduction of large quantities of solids. The

so

into the narrower space below during backward motion ~~by compression~~. and is recycled as the jaw closed next time: After sufficient reduction the material the jaws open and drops out the bottom of machine. The jaws close 250 to 400 times per minute.

Gyratory Crusher →



Difference between Jaw Crusher and Gyratory Crusher →

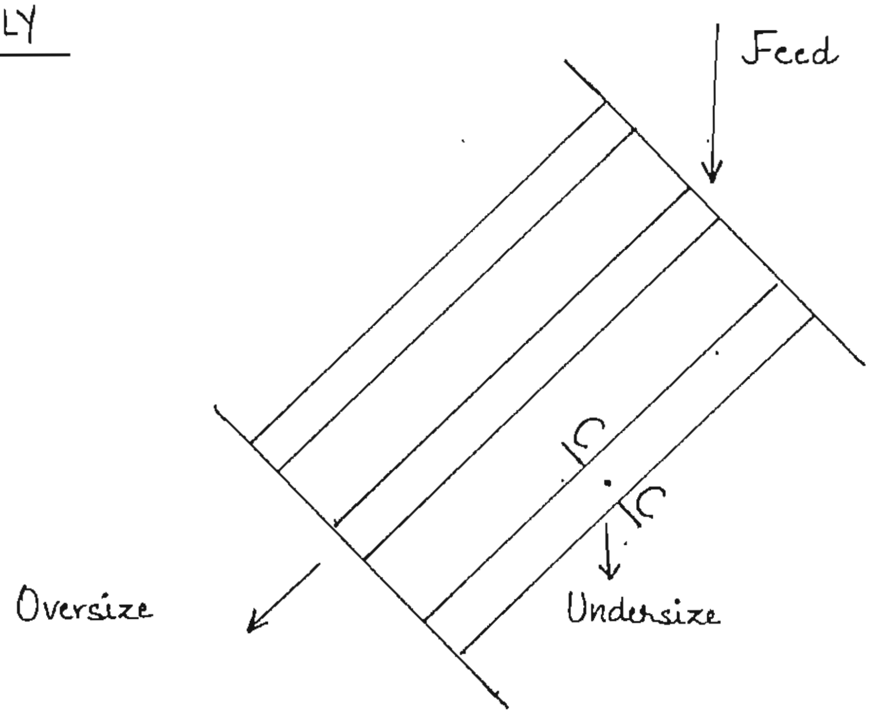
Jaw Crusher	Gyratory Crusher
(1) It is a reciprocating machine.	(1) It is a gyratory machine.
(2) Intermittent in action i.e. discharge is discontinous	(2) Continuous in action i.e. discharge is continous.
(3) It is primary crusher. It take feed of large size	(3) It is a secondary crusher. It take feed of smaller size.
(4) The load on motor is not uniform.	(4) The load on motor is nearly uniform.
(5) More maintenance are requir	(5) Low maintenance are requir
(6) Power consumption high	(6) less
(7) Capital cost low	(7) Capital cost high.
(8) It has smaller capacity when used to produce small size reduction	(8) It has large capacity when used to produce a small size reduction.

...PES OF SCREENING EQUIPMENTS

...he screening equipments can be classified based largely on size of the material as the screens may be called upon to pass grains ranging from several mm in diameter to 200-mesh.

... Grizzlies (fixed inclined screens)
... Trommels (revolving screens)
3. Shaking and vibrating screens
4. Oscillating screens.

GRIZZLY



Construction :-

It is a grid of parallel metal bars set in an inclined station--ary frame, with a slope to 30° to 45° which is parallel to the bars length. The length of the bar may be upto 3m and spacing b/w the bar is 50 to 200mm. It is generally made of manganese to reduce wear. Usually, the bar is shaped such tha[t] its top is wider than bottom and hence, made fairly deep for strength without being choked by the lumps passing part way through.

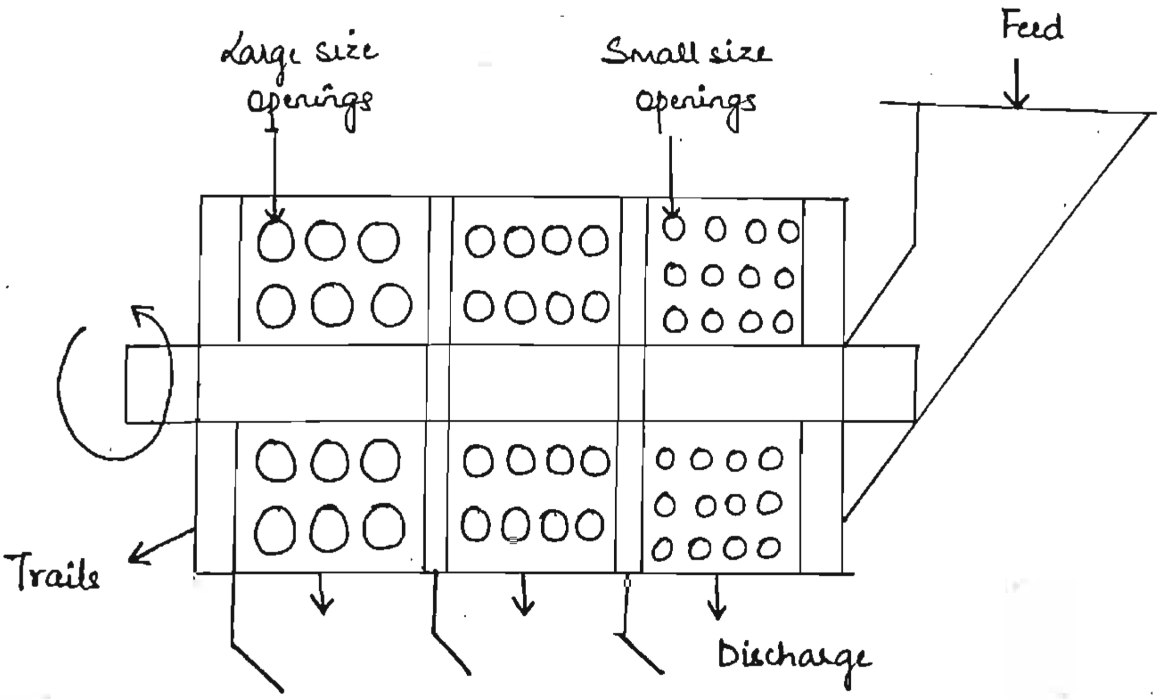
Working :-

Very coarse feed as from primary crusher is fed at the upper end of the grizzly. Large chunk rolls and slide down to its lower end while small lumps having size less than the opening in the bars fall through the grid into separate collector.

If the angle of inclination to horizontal is greater, greater is the output but the lower is the screen efficiency. Stationary inclined woven-metal screens operate in a same way and separate particles 12 to 100mm in size, usually adopted for dry material.

The grizzly find its greatest application in the separation of undersize from a feed to the primary crusher. It requires no power and is least expensive to install and maintain. As the openings have tendency to get blocked, the labour requirement is high. Also, it is difficult to change the openings in the bars.

TROMMELS



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[illegible]truction :-

[illegible]rommels are revolving screens consist of a cylindrical frame & surrounded by wire cloth or perforated plate (acts as screening surface). It is open at one or both ends, and inclined at a slight angle to horizontal so material is advanced by the rotation of the cylinder. The perforations in the screening surface may be of same size throughout or may be different in which case small size section is near the feed end and is driven through feed gear mechanism. Feed point at upper end, the undersize product discharge below the screening surface and oversize discharge at opposite end. (lower end).

Working :-

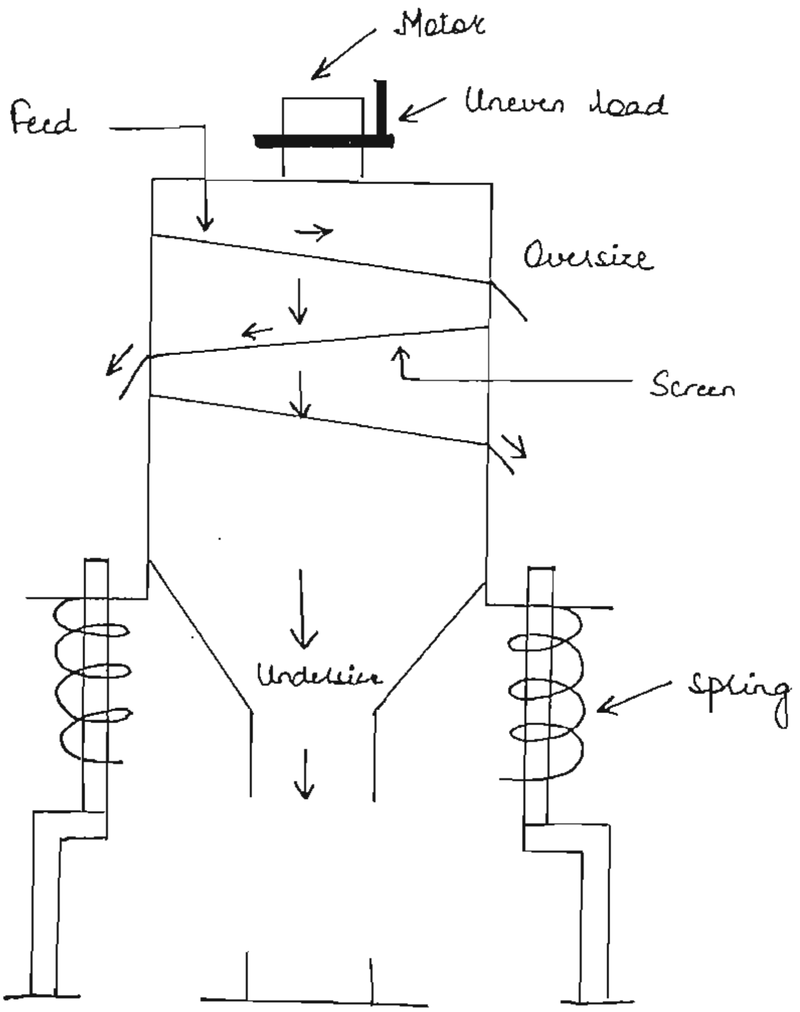
The material to be screened is fed at the upper end and gradually moves down the screening surface towards the lower end. In doing so, the material passes over appertures of gradually increasing size. If the cylinder is provided c̄ the 3 diff. size perforated screen then we get four fractions. The finest material is collected as underflow in the compartment near feed end and oversize material is withdrawn from the discharge end. Such type of arrangement is usually adopted for smaller capacities.

With this type of Trommel, there is a tendency of blockage and the screen c̄ the finest opening being the weakest is subjected to heaviest wear. The operating speed is 30 to 50% of the critical speed.

For the separation of a given material into several size fraction several Trommels are operated in series. The first one have the coarsest perforations so that it produces coarest finished product which is delivered to next Trommel and so on. If the eqpment is used for more finer separation then the cylinder may be covered c̄ fine wire instead of perforated plate called a reel.

VIBRATING SCREENS

These are the screens which are rapidly vibrated c̄ small amplitude, keep the material moving and prevent binding as far as possible. They are commonly used in industry where large capacity and high efficiency are desired. Their capacity of producing finer size particle is so high that it can replace all the other equipment if efficiency is of prime importance.
The vibrating screens can be further classified as —
Mechanically vibrated screens
Electrically vibrated screens
Mechanical vibrations are usually transmitted from high speed eccentrics to the casing and from there to the screen so that whole assembly is vibrated.



ctrically vibrated screens usually transmitted from the heavy duty solenoids directly on the screen so that only screen is vibrated.

Vibrating screens are mounted in multideck fashion c̄ coarest screen at the top, either horizontally or inclined upto 45°. They have accuracy of sizing, increased capacity and low maintainance cost.

Principle & Operation of vibrating screens :-

The vibrations are given to the screen to effect the separation of solid particles. Proper selected frequency and amplitude keeps the capacity constant.

The material to be separated is fed from the top and simultaneously, the screens are vibrated. at a frequency of 1000 to 3500 per minute. Due to vibrations the particles on the screen kept moving and due to inclination, oversize material travels along the screen and is collected separately. The undersize material passes through the screens and are collected. Four fractions are obtained c̄ 3 deck screen.

• • •

UNIT - 2
SIZE REDUCTION
Mechanical Operation (NCH-302)
Faculty :- Divya Agarwal
CH (III Sem)

the Crushers. (Coarse & fyn) (compression)

(i) Jaw Crusher <
- Blake (top)
- Dodge (bottom)

(ii) Gyratory Crusher.

(iii) Crushing Rolls. <
- Smooth Roll Crusher
- Toothed crusher.

(B) Grinders. (intermediate & fyn). {Impact) & Attrition)

(i) Hammer Mills

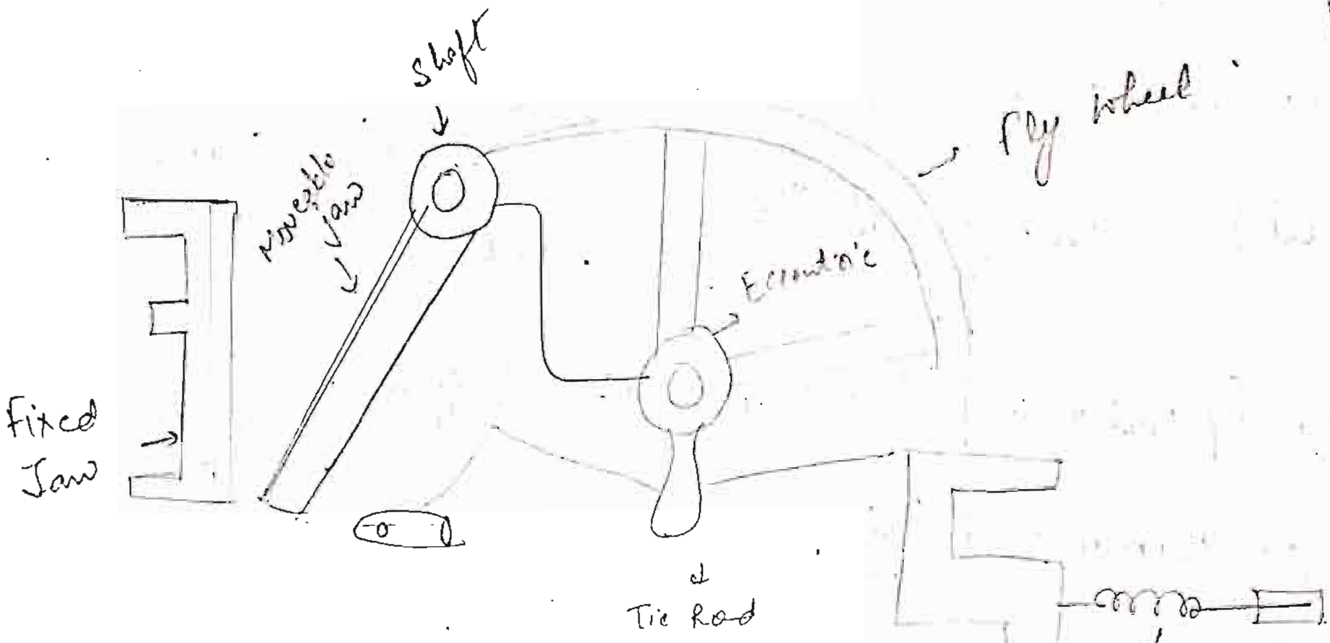
(ii) Rolling compression Mills.
 (a) Bowl mill
 (b) Roller Mill.

(iii) Attrition Mill.

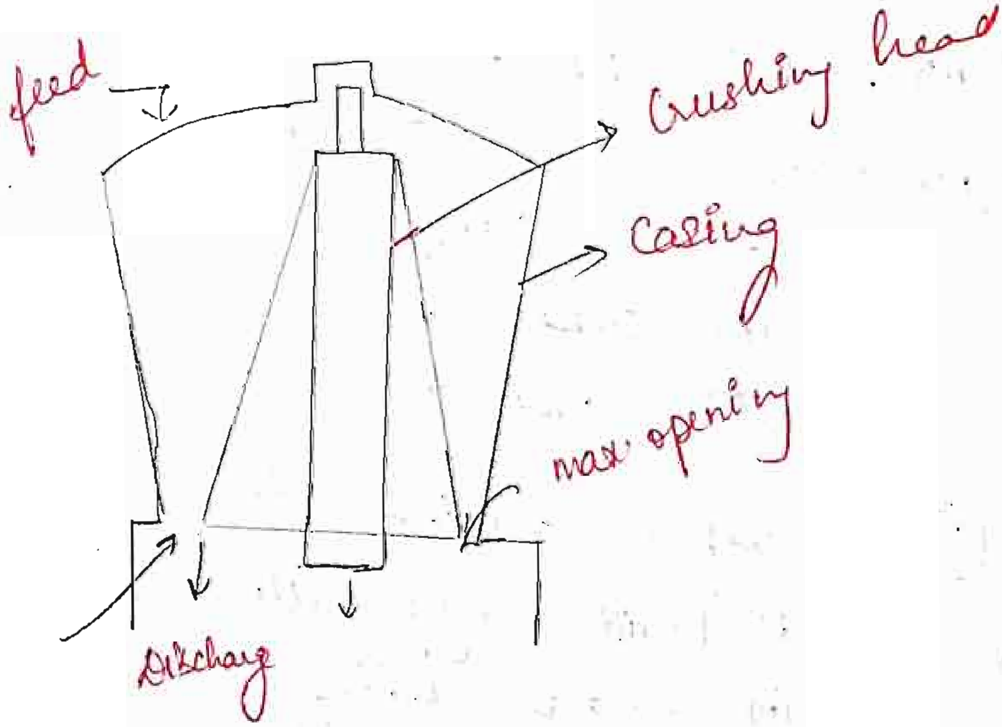
(iv) Tumbling Mill (Revolving Mills)
 (a) Ball Mill
 (b) Tube "
 (c) Rod "

(C) Ultrafine grinders (Attrition)
 (i) Fluid energy Mills
 (ii) Agitated Mills.
 (iii) Colloidal Mills

(D) Cutting Machines.
- → knifes
- → Cutters
- → Dicers



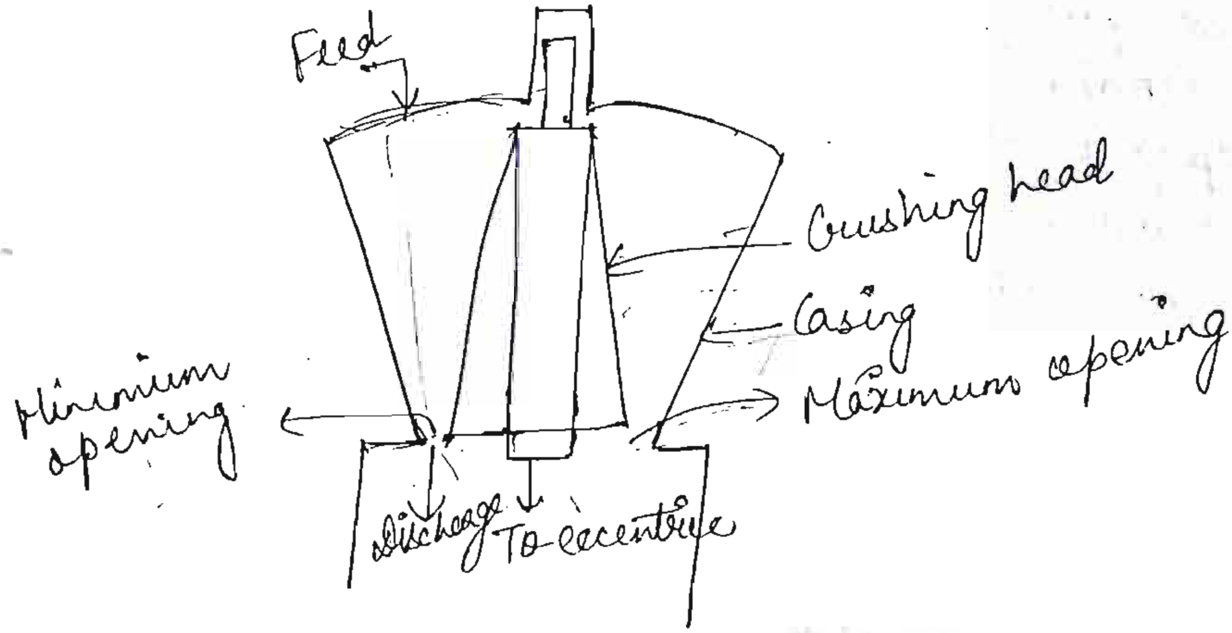
Blake Jaw Crusher



Gyratory Crusher

he jaws close next time. After sufficient reduction materials drops out the bottom of the machine. The jaws open and close 250 - 400 per minute.

GYRATORY CRUSHER



PRINCIPLE :- Works on Compression.

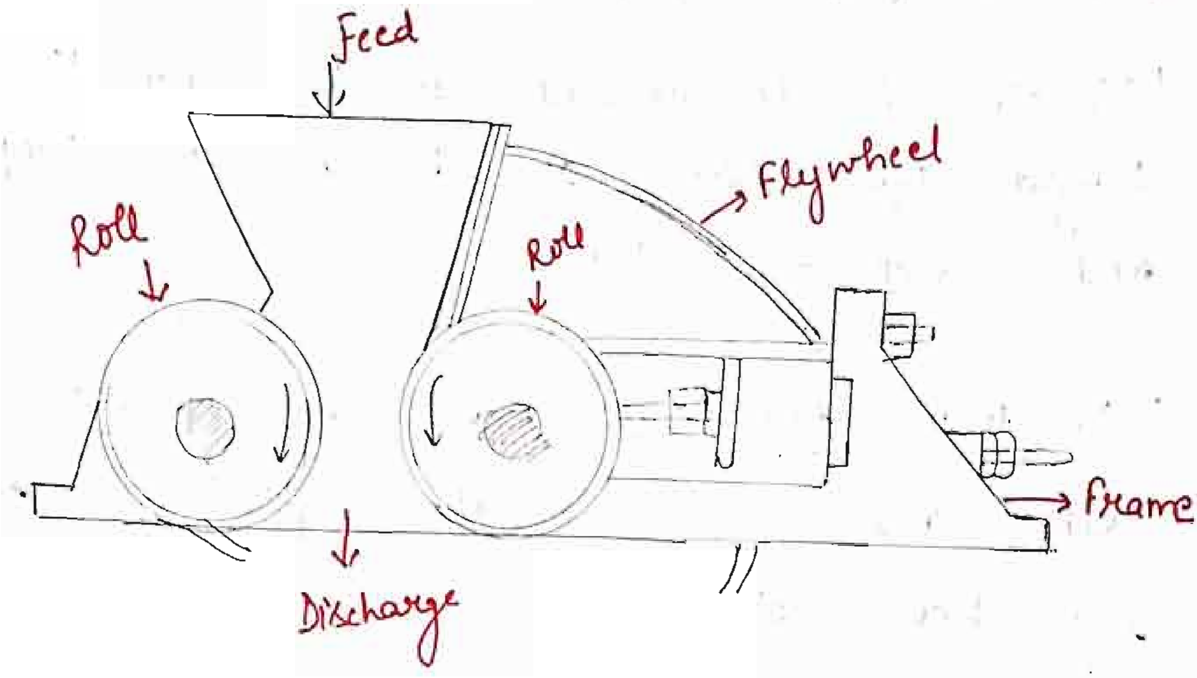
CONSTRUCTION :- It consists of a funnel shaped casing open at the top. A conical crushing head in the form of a truncated cone, gyrates inside a casing. The crushing head is mounted on a heavy shaft pivoted at the top of the machine. The upper end of the shaft is held in a flexible bearing and the lower end of the shaft is driven by an eccentric so as to describe a circle. At any point, on the periphery of the casing, therefore, the bottom end of the crushing head moves towards and then away from the stationary wall.

WORKING :- The material to be crushed is charged at the top. The conical head gyrates inside the casing. At any point on the periphery of the casing, the bar of the crushing head moves towards, and then away from the stationary wall. The solids caught in the V-shaped space between the head and the casing are broken and rebroken until they are discharged from the bottom. The speed of the crushing head is usually 125-425 gyrations per minute. As the same part of the crushing head is working at all times, the discharge from this crusher is continuous instead of intermittent in a Blake Crusher.

FEATURES :-

1) Power consumption per ton of material is lower.
2) Give finer and Uniform product.
3) It has large capacity
4) Power load is uniform throughout the equipment.

* Crusher / Crushing Rolls :-



Principle: size reduction is achieved by compression (i.e. it employs compressive force for size reduction).

* Smooth roll-crusher consists of two heavy metal rolls of the same diameter placed side by side each other in the horizontal position.

* Rolls are rotated towards each other at same speed.

* They are sec. crusher accepting feed 12 to 75 mm in size and yielding products 12 mm to 20 mesh.

* Speed of rolls varies from 50-300 rev/min.

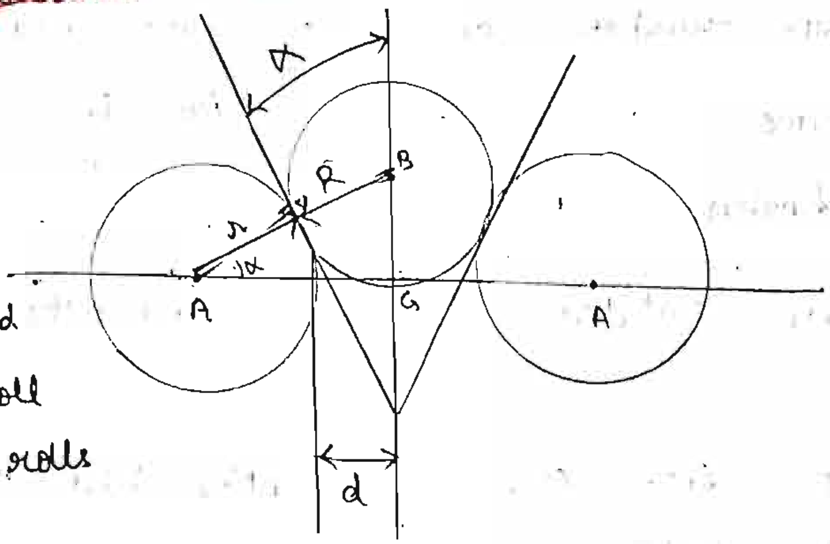
* These m/c are characterized by production of few fines and by a smaller 10 reducn ratio of order 4 to 1.

Working:- 2 heavy smooth faced metal rolls turning on ∥ horizontal axis are the working elements of smooth roll crusher.

* Material to be crushed is fed from the top, caught b/w rolls are broken in compression and drop out below

* In toothed hed crusher the roll phases carrying teeth and they handle softer feed like coal and bone etc.

Angle of nip (2α) is the angle formed by the tangents to the rolls faces at a point of contact with a particle to be crushed.



R = radius of feed
r = " " roll
2d = dist. b/w rolls

$$\cos\alpha = \frac{AG}{AB} = \frac{r+d}{r+R}$$

$\alpha = \frac{1}{2}$ angle of nip.

$\mu = \tan\alpha$ (μ = coeff. of friction).

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Grinders :- The term grinder describes a variety of size reduction machines for the intermediate duty. The product from ~~grindo~~ a crusher is often fed to a grinder, in which it is reduced do powder form. Commercial grinders are hammer mills and revolving mills.

(A) Revolving / Tumbling Mills :- A cy. shell slowly rotating on a horizontal axis and charged with a grinding medium to about half its volume forms a revolving mill / tumbling mill

* The shell is usually made of steel and lined with abrasion resistant materials such as Mn steel, ceramic or rubber. ~~The shell is usually made of steel and lined with abrasion resistant materials~~

Ball, pebble, tube and rod mills are the various types of revolving mills.

Ball Mills → length = diameter.
Grinding medium → steel balls.

Tube Mill → length ? diameter
(balls). $l = 2d$ or more..

Pebble Mill: ceramic pebble as a grinding medium

Rod Mill :- Metal rods (steel rods)
Most uniform product than any other mill..

Ball Mill }
Pebble.. } → Impact.

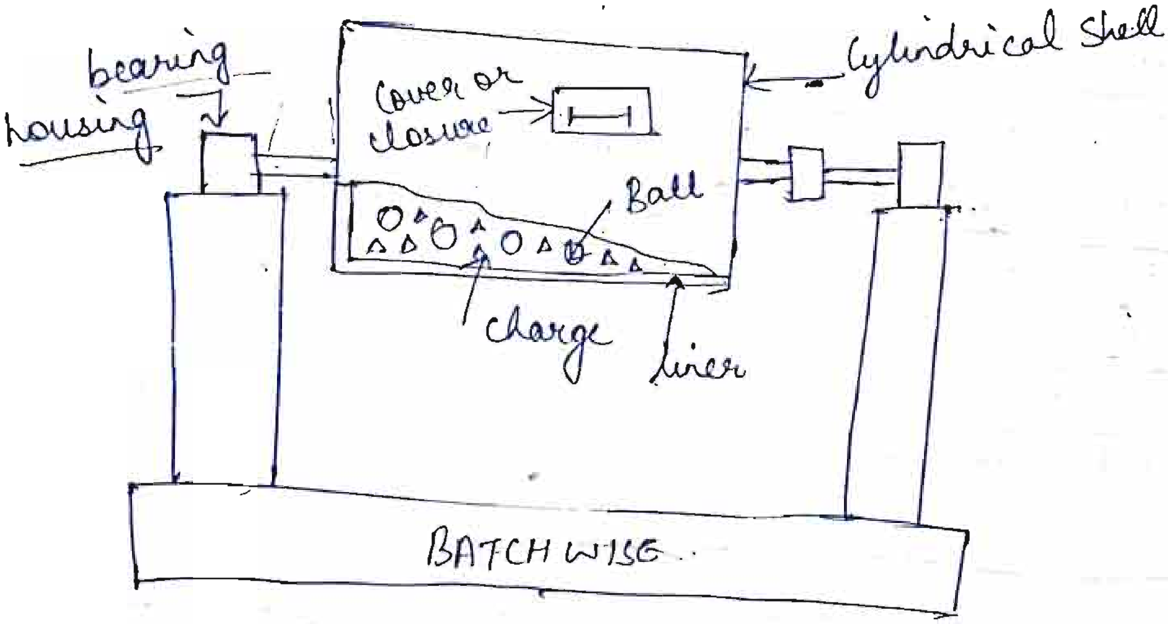
Rod Mill → rolling, compression & attrition.

* Revolving Mills may be operated batchwise or continuously

and $\cos\alpha = \frac{R+d}{R+r}$

Angle of nip (2α) is the angle between the roll faces at the level where they will just take hold of a particle and draw it into the crushing zone or it is the angle formed by the two tangents.

BALL MILL (GRINDER)



The Ball mill and Tube mill are very important class of fine grinding machines. The difference between the two types is largely one of the ratio of length (L) to Diameter (D),

Ball mill, $L = D$

Tube mill, $L = 2D$.

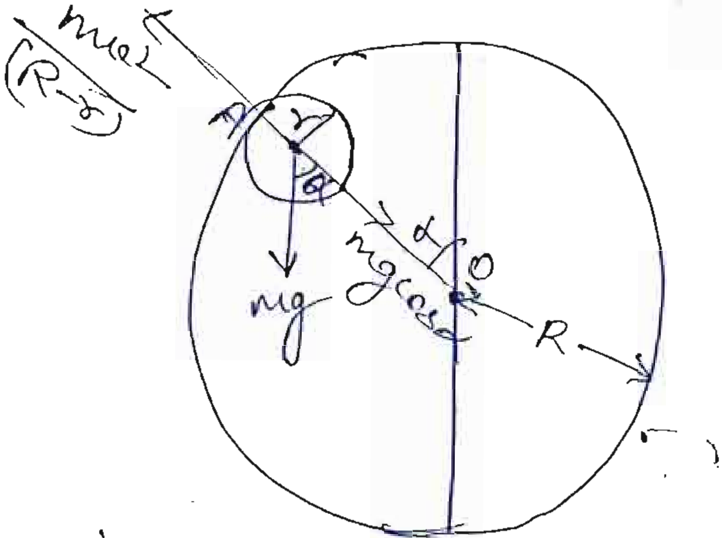
Both mills consist essentially of a horizontal cylinder, containing balls of steel, rubber or wood and rotated slowly about its axis the feed is introduced at one end and impact of balls on the material causes fine pulverising.

WORKING :-

The load of balls in a ball/tube mill is such that when the mill is stopped, the balls occupy more than half volume of the mill. In operation the balls are picked up by the wall of the mill and carried nearly to the top where they break contact with the wall and they fall to the bottom of the mill to be picked up again. Centrifugal force keeps the ball in contact with the wall and with each other during the upward movement. While in contact with the wall, the balls do some grinding by slipping and rolling over each other but most of the grinding occurs at the impact zone where the free falling balls strike the bottom of the mill. The faster the mill is rotated, the farther the balls are carried up inside the mill and greater the power consumption.

If the speed is too high, the balls are carried over and the mill is said to be centrifuging. The speed at which centrifuging occurs is called critical speed. Little or no grinding is

ie when the mill is centrifuging and operating speed must be less than the critical speed. 6
The speed at which the outermost balls loose contact with the wall of the mill depends on the balance between gravitational and centrifugal forces.



Consider a ball at point A on the periphery of the mill. If the radii of the mill and of the ball are R and r respectively, then the centre of the ball is (R-r) distance away from the axis of the mill. Let the radius OA form an angle α with the vertical. Two forces act on the ball:
The force of gravity mg, where m is mass of ball,
the centrifugal force, $\frac{mv^2}{R-r}$, where v is the peripheral speed of the centre of ball.
Centripetal component of force of gravity is $mg\cos\alpha$ and this force opposes the centrifugal force. As long as the centrifugal

cylinder.

force exceeds the centripetal force, the ball w... not break contact with wall. As angle α ... decreases, the centripetal force increases and ... unless the speed exceeds the critical speed, a point is reached where the opposing forces are equal and the ball is ready to fall away. The angle at which this occurs is found by equating the two forces

$$mg\cos\alpha = \frac{mv^2}{R-r}$$

$$\cos\alpha = \frac{v^2}{g(R-r)}$$

$$v = (R-r)\omega = (R-r)2\pi N$$

N = revolutions per sec

at $\alpha = 0$, $\cos\alpha = 1$ and $N = N_c$

$$1 = \frac{(R-r)^2 4\pi^2 N_c^2}{(R-r)g}$$

$$N_c = \frac{1}{2\pi}\sqrt{\frac{g}{R-r}}$$ **

co

i.e. balls occupy 30-50% of the volume of mill. diameter of ball used lies between 12mm and 125mm. The optimum diameter is approx. proportional to the square root of the size of the feed. The shell is rotated at low speed through a drive gear (60-100 rpm) and in a large ball mills, the shell might be 3m in diameter and 4.25m in diameter.

The ball mill may be operated in a batch or continuous fashion, wet or dry.

WORKING :- In case of continuously operated ball mill, the material to be ground is fed from the left through a 60° cone and the product is discharged through a 30° cone to the right. As the shell rotates, the balls are lifted up on the rising side of the shell and then they cascade down from near the top of the shell, the solid particles in between the balls are ground and reduced in size by impact.

The mill contain balls of various sizes. As the shell rotates, the large balls seggregate near the feed end and small balls seggregate near the product. ~~The initial~~

During grinding, ball themselves wear and are constantly replaced by new ones so that mill contains balls of various ages and thus of various sizes. Ball mills produce 1 to 50 t/hr of powder of which near about 70 - 90% would pass a 2 screen and the energy requirement of a ball mill is about 16 KWh/t

APPLICATIONS :- It is used for grinding materials such as coal, pigments and felspar for pottery.

ADVANTAGES OF BALL MILL :-

1. Cost of Installation is low.
2. Cost of power required is low.
3. Suitable for materials of all degrees of hardness.
4. Suitable for batch as well as continuous operation.
5. Grinding medium is cheap.

CRITICAL SPEED OF BALL MILL :-

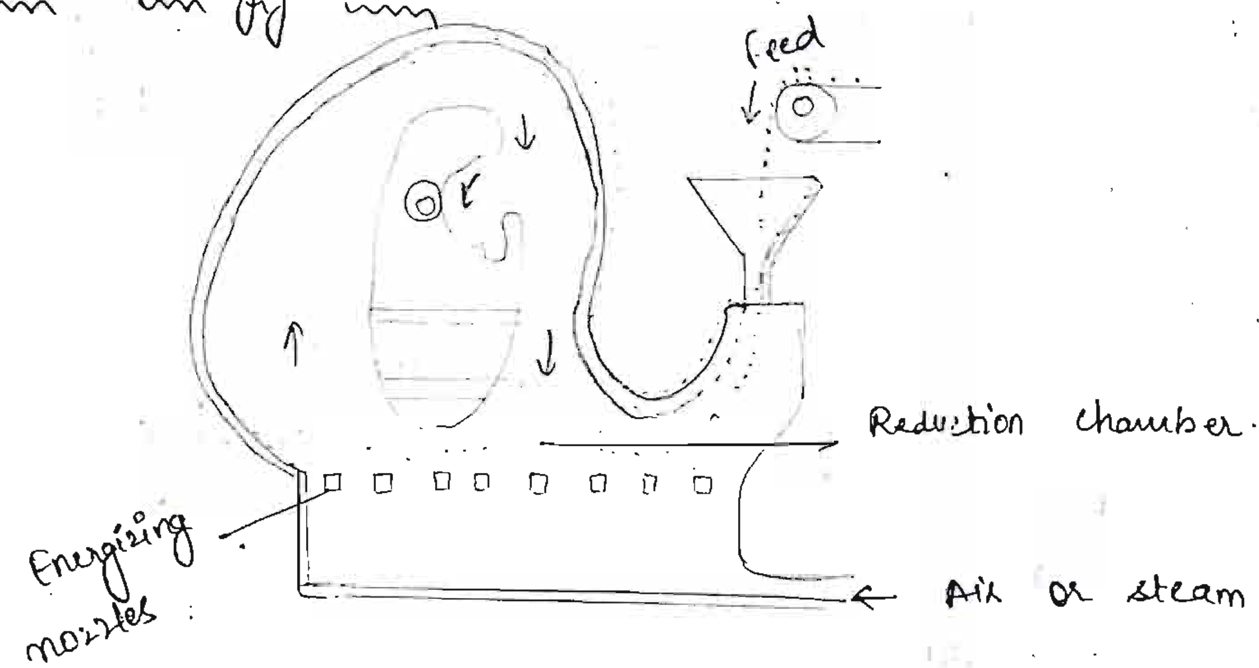
If the mill is operated at very high speeds, the balls are carried right round in contact with the sides of mill and the mill is said to be centrifuging. The minimum speed at which centrifuging occurs is called critical speed.

9

(ii) Ultra Fine Grinders:- Many commercial outer crust contains particles avg 170-20 μm in size. Mills which reduce solids to such fine particles are called as ultrafine grinders.

Principle: grinding takes place by impact and attrition.

(a) Fluid Energy Mills:-



In these mills particles are suspended in high part stream in some designs. The gas flows in circular or elliptical path.

Some reduction occurs when the particles strike or rub against the wall of confined chamber but most of the reduction is believed to be caused by interparticle attrition. Internal classification keeps the larger particle in the mill untill they reduced to desire size. Suspending gas is usually compressed air or super heated steam admitted at a pressure of 7 atm through energizing nozzle.

In mill grinding chamber is an oval loop of pipe 25×200 mm in dia and 1.22-2.4 high. fluid energy mills can accept feed particle as large as 12 mm (1.2 cm) and reduces upto half-10 μm, using 6-9 kg of air per kg of product.

(b) Agitated Mills; - for small ultra fine grinding operation small batch non-rotatory mills containing a solid grinding medium are available. The medium consist of ~~hard~~ hard solid elements such as ball packets or sand grains. These mills are vertical vessel 4 to 1200 lt. in which the grinding medium is suspended in some design.

In some design the charge is agitated with multi arc compellers in others used specially for grinding hard materials. These mills are specially useful in producing particles 1 μm in size or finer.

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Colloids Mills :- In a colloid mill intense fluid shear a high vel. stream is used to disperse particles or liq. droplets to form a stable suspension. Final size of particles or droplets is usually less than 5 μm. Often there is a little actual size reduc^n in the mill. The principal action is disruption of lightly bonded clusters.

In most colloid mills the feed liquid spun b/w close surfaces. One of which is moving relative to another i.e. speed of 50 m/sec. or more.

Cutting Machines :- In some cases the feed must be reduced to particles of fixed dimensions These requirements are met by machine known as granulators which yield more or less irregular pieces and cubes and cutters which produce cubes. These devices find application in many manufacturing processes, but are specially ~~adapt~~ adopted to size reduc^n problems.

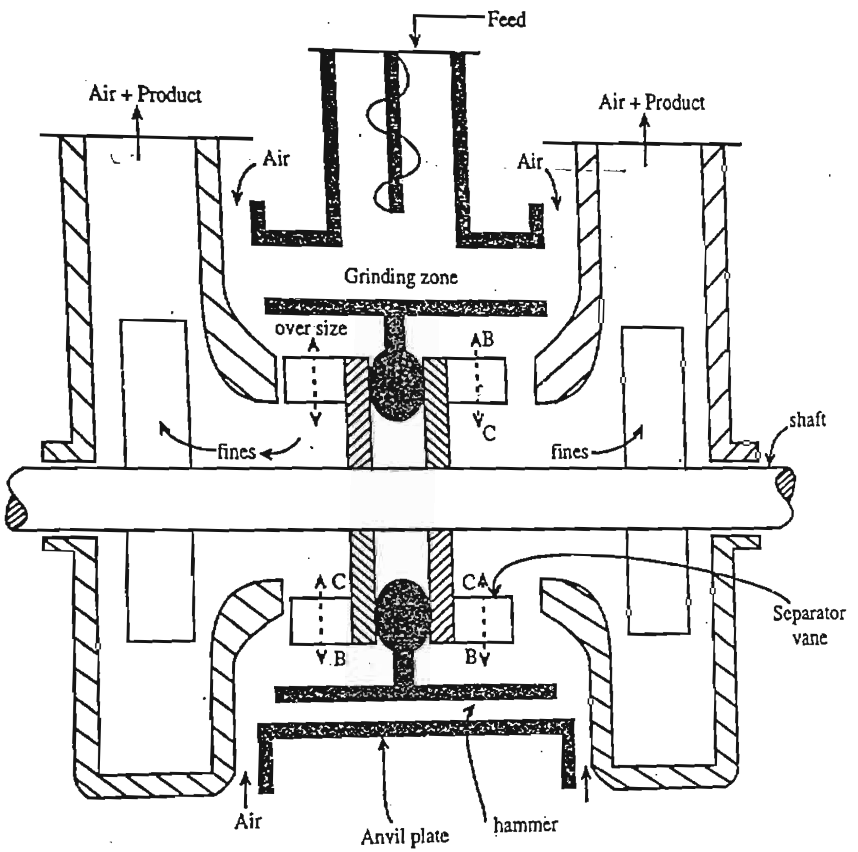

Fig. 2.10 : Classifying Hammer Mill (Miko-Atomiser)

Working :

In the grinding chamber, the solid particles are given a high rotation velocity. Coarse particles are concentrated (get collected) along the wall of the chamber due to centrifugal force acting on them. The airstream carries finer particles inward from the grinding zone toward the shaft in the direction BC. The separator vanes tend to throw particles outward in the direction CB. The chance of a particle passing between the separator vane (classifier wheel) [illegible] out to the discharge depends upon the force that dominates - the drag exerted by the air or the centrifugal force exerted by the vanes. Fine particles (acceptable) are carried through the [illegible] and particles that are too large are thrown back in the grinding chamber for further [illegible] product size can be varied by changing the speed of the rotor or the size and

... Ans.

Such type of mills reduce 1 to 2 t/h to an average particle size of 1 to 20 μm and need energy of about 40 kWh per tonne.

	Size Reduction Equipment	Feed Size	Product size
1.	Blake jaw crusher	1500 – 40 mm	50 – 5 mm
2.	Gyratory crusher	1500 – 40 mm	50 – 5 mm
3.	Crushing rolls	50 – 5 mm	5 – 0.1 mm (200 - mesh)
4.	Hammer mill	50 – 5 mm	5 – 0.1mm
5.	Ball mill	5 – 2 mm	0.1 mm (about 200 - mesh)

Open-Circuit and Closed-Circuit Grinding :

In many machines, the feed material is reduced to satisfactory size by passing it once through the machine. If the material is passed only once through the machine (crushing or grinding), and no attempt is made to return the oversize material to it for further reduction, the process is known as *open-circuit grinding.* If the partially ground material from the machine is sent to a size separation unit, from where the undersize is withdrawn as the product and the oversize material is returned to the machine for reground, the process is known as *closed-circuit grinding.* In case of coarse particles, the size separation unit is a screen or grizzly while it is some form of classifier in case of fine powders. Closed-circuit grinding though useful for any crusher, it is commonly employed to machines yielding a fine product. The size separation unit is sometimes incorporated inside a machine (ultrafine grinder) but it is the common practice to have such unit outside the size reduction equipment. A flow sheet for typical closed-circuit grinding consisting of a set of size reduction machines and separators, is shown in Fig. 2.11.

The product from a crusher is screened into three fractions : oversize, intermediate and fines. The oversize is returned back to the crusher. The intermediate particles are fed to a rod mill where they are reduced in size and are then fed to a ball mill alongwith the fines from a size separation unit.

The ball mill shown in Fig. 2.11 runs wet, i.e., the stream of water is introduced in the mill with the feed material to carry the product to a Dorr classifier, that furnishes a simple method for separating oversize and undersize. The oversize obtained as a sludge from the classifier is repulped with more water and returned back to the ball mill. Closed-circuit grinding requires less energy as compared to open-circuit grinding and is of most value in reduction to fine and ultrafine sizes.

r = radius of the ball

Numericals of Power Laws, Crushers (Roll crushers) Grinder (Ball Mill)

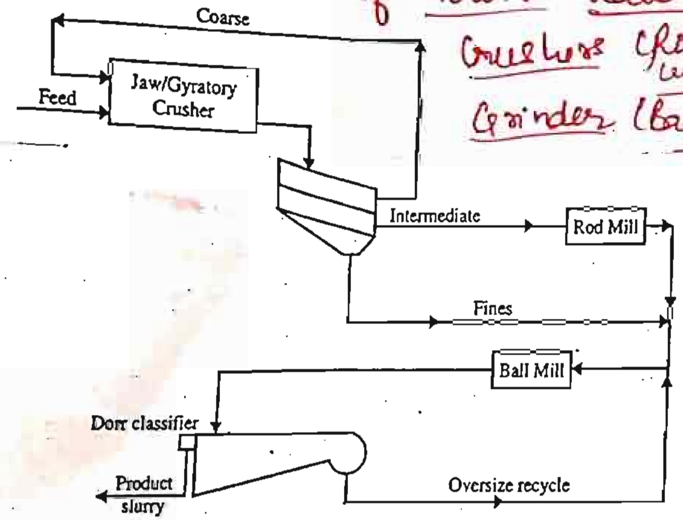

Fig. 2.11 : Flow sheet for closed-circuit grinding system

The equipments which are used in industry are :

1. Jaw crusher in Cement Industry.
2. Ball mill in Paint Industry.
3. Ultrafine grinders in Cosmetic and Pharmaceutical Industries.
4. Cutters in Leather Tanning Industry.
5. Hammer mill in Food Industry.

Size reduction operation is carried out in coal washeries, ore processing, cement industry, paint industry, chemical industry, and food processing industry.

SOLVED EXAMPLES

Ex. 2.1 : A certain crusher accepts a feed material having a volume-surface mean diameter of 19 mm and gives a product of volume-surface mean diameter of 5 mm. The power required to crush 15 tonnes per hour is 7.5 kW. What will be the power consumption if the capacity is reduced to 12 tonnes per hour ?

Solution :

We have,

$$\frac{P}{\dot{m}} = K_r\left[\frac{1}{\bar{D}_{sb}} - \frac{1}{\bar{D}_{sa}}\right]$$

where P is the power consumption in kW, $\dot{m}$ is the feed rate in t/h and $\bar{D}_{sb}$, $\bar{D}_{sa}$ is the surface-volume mean diameters of product and feed respectively.

Case I :

$P = 7.5$ kW, $\dot{m} = 15$ t/h

$\bar{D}_{sb} = 5$ mm $= 0.005$ m

$\bar{D}_{sa} = 19$ mm $= 0.019$ m

$$\frac{7.5}{15} = K_r\left[\frac{1}{0.005} - \frac{1}{0.019}\right]$$

$$K_r = 3.4 \times 10^{-3}$$

Case II :

$\dot{m} = 12$ t/h, $P = ?$, $K_r = 3.4 \times 10^{-3}$

$$\frac{P}{12} = 3.4 \times 10^{-3}\left[\frac{1}{0.005} - \frac{1}{0.019}\right]$$

$$P = 6 \text{ kW}$$ **... Ans.**

Ex. 2.2 : What will be the power required to crush 150 tonnes per hour of limestone if 80 percent of the feed passes 50 mm screen and 80 percent of the product a 3.125 mm screen ?

Work index of lime stone = 12.74.

Solution :

We have,

$$\frac{P}{\dot{m}} = 0.3162\, W_i\left[\frac{1}{\sqrt{D_{pb}}} - \frac{1}{\sqrt{D_{pd}}}\right]$$

In this equation, P is in kW and D_p is in mm.

$\dot{m} = 150$ t/h, $W_i = 12.74$

D_{pb} = product size = 3.125 mm

D_{pa} = feed size = 50 mm

$$\frac{P}{150} = 0.3162 \times 12.74\left[\frac{1}{\sqrt{3.125}} - \frac{1}{\sqrt{50}}\right]$$

$$P = 256.4 \text{ kW}$$ **... Ans.**

Ex. 2.3 : Find out the critical speed of the ball mill by using following data :

Diameter of ball mill = 450 mm

Diameter of ball = 25 mm

Solution :

Data : Diameter of ball mill = 450 mm

Diameter of ball = 25 mm

Critical speed of ball mill (in r.p.s.) = N = $\frac{1}{2\pi}\sqrt{\frac{g}{\ldots}}$

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$$D = \text{diameter of ball mill in m}$$
$$D = 450\text{ mm} = 0.45\text{ m}$$
$$\therefore R = 0.225\text{ m}$$
$$\text{Diameter of ball} = 25\text{ mm} = 0.025\text{ m}$$
$$\therefore r = 0.0125\text{ m}$$
$$g = 9.81\text{ m/s}^2$$
$$N_c = \frac{1}{2\pi}\sqrt{\frac{9.81}{0.225 - 0.0125}} = 1.08\text{ r.p.s.} \cong 64.8\text{ r.p.m.}$$
$$\text{Critical speed} = 65\text{ r.p.m.}$$ ... Ans.

Ex. 2.4 : A pair of rolls is to take a feed equivalent to sphere 38 mm in diameter and crush them to sphere having a diameter of 12.7 mm. If the co-efficient of friction is 0.29, what should be the diameter of the rolls ?

Solution : μ = co-efficient of friction = 0.29.

For particles to be drawn between the rolls and crushed $\mu \geq \tan\alpha$, where α is half the angle of nip. Hence α should be less than $\tan^{-1}(0.29)$ or 16° 17'. So for margin of safety, take angle of nip to be 16°.

We have :

$$\cos\alpha = \frac{r + d}{r + R}$$

where
r = radius of roll
d = radius of largest possible particle in the product
$d = \frac{12.7}{2}\text{ mm} = 6.35\text{ mm}$
R = radius of feed particle $= 38/2 = 19\text{ mm}$

Putting the values of R, d and α in above equation

$$\cos(16) = \frac{r + 6.35}{r + 19}$$
$$0.96126\,(r + 19) = r + 6.35$$
$$r = 307.5\text{ mm}$$
$$\text{[Dia]meter of rolls} = 2r = 2 \times 307.5 = 615\text{ mm}$$

[...] not made, so the diameter of rolls is 600 mm. ... Ans.

Ex. 2.5 : Calculate the operating speed of the ball mill from the following data :

(i) Diameter of ball mill = 500 mm

(ii) Diameter of ball = 40 mm

(iii) Operating speed is 50% of the critical speed of the mill.

Solution :

The critical speed of the ball mill in revolutions per second is given by,

$$N_c = \frac{1}{2\pi}\sqrt{\frac{g}{R - r}}$$

where
$g = 9.81\text{ m/s}^2$
Diameter of ball mill $= 500\text{ mm} = 0.5\text{ m}$
$\therefore R$ = radius of ball mill = 0.25 m
Diameter of ball = 40 mm = 0.04 m
$\therefore r$ = radius of ball = 0.02 m

$$N_c = \frac{1}{2\pi}\sqrt{\frac{9.81}{0.25 - 0.02}} = 1.04\text{ r.p.s.} = 62.4\text{ r.p.m.} \cong 62\text{ rpm}$$

The operating speed of ball mill $= 0.5\,N_c = 0.5 \times 62 = 31\text{ r.p.m.}$ ... Ans.

Ex. 2.6 : What rotational speed, in revolutions per minute, would you recommend for a ball mill 1200 mm in diameter charged with 75 mm balls ?

Solution :

The critical speed of ball mill is given by

$$N_c = \frac{1}{2\pi}\sqrt{\frac{g}{R - r}}$$

where
$g = 9.81\text{ m/s}^2$
R = radius of the ball mill
Diameter of ball mill = 1200 mm
$\therefore R = 1200/2 = 600\text{ mm} = 0.60\text{ m}$
r = radius of the ball

∴ $r = 75/2 = 37.5 \text{ mm} = 0.0375 \text{ m}$

$$N_c = \frac{1}{2\pi}\sqrt{\frac{9.81}{0.60 - 0.0375}}$$

$= 0.66$ r.p.s.

$= 39.6$ r.p.m. ≈ 40 r.p.m.

Operating speed of the ball mill is 50 to 75% of the critical speed.

Operating speed = 50 to 75% of 40 r.p.m.

= 20 to 30 r.p.m.

The rotational speed that can be recommended is between 20 to 30 r.p.m. ... Ans.

Ex. 2.7 : A certain set of crushing rolls has rolls of 1000 mm diameter and 375 mm width face. They are set so that the crushing faces are 12.5 mm apart. The manufacturer recommends their speed to be 50 to 100 r.p.m. They are employed to crush a rock having specific gravity 2.35 and the angle of nip is 31° 30'. What is the maximum permissible size of the feed and maximum actual capacity of rolls in tonnes per hour if the actual capacity is 12% of the theoretical ?

Theoretical capacity in t/h, $Q = 4.352 \times 10^{-7}$ N.D.w.d.s

where N in r.p.m., D (roll diameter) in mm, w (width) in mm, d (half the gap/width between roll surface) in mm and s (specific gravity).

Solution :

We have :

$$\cos\alpha = \frac{r + d}{r + R}$$

where r = radius of roll = 1000/2 = 500 mm

d = (gap between the rolls)/2 = 12.5/2 = 6.25 mm

R = radius of feed particle in mm

For margin of safety, take $2\alpha = 31°$.

∴ $\alpha = 15°$

$\cos\alpha = 0.9659$

$$0.9659 = \frac{500 + 6.25}{500 + R}$$

$R = 24.12$ mm

∴ Diameter of the feed particle = 48.24 mm ≈ 48 mm. ... Ans.

Theoretical capacity of the rolls is given by

for N = 50 r.p.m.

$Q = 4.352 \times 10^{-7} \times N \times D \times w \times d \times s$

where D = 1000 mm,

w = 375 mm,

d = 6.25 mm,

s = 2.35

$Q = 4.352 \times 10^{-7} \times 50 \times 1000 \times 375 \times 6.25 \times 2.35$

= 119.85 t/h

Actual capacity at 50 r.p.m. = 12% of theoretical

= 0.12 (119.85)

= 14.38 t/h

For N = 100 r.p.m.

Q theoretical = 2 × 119.85 = 239.7 t/h

Actual capacity at 100 r.p.m. = 0.12 (239.7)

= 28.76 t/h

Maximum capacity (at speed of 100 r.p.m.) = 28.76 t/h. ... Ans.

Ex. 2.8 : Calculate the operating speed of the ball mill from the data given below :

Diameter of ball mill = 800 mm, diameter of ball = 60 mm

If (I) operating speed is 55% less than the critical speed.

(II) critical speed is 40% more than the operating speed.

Solution :

The critical speed of a ball mill is given by

$$N_c = \frac{1}{2\pi}\sqrt{\frac{g}{R - r}}$$

where R is radius of a ball mill and r is the radius of ball.

$g = 9.81$ m/s²

$R = 800/2 = 400$ mm = 0.40 m

$r = 60/2 = 30$ mm = 0.03 m

$$N_c = \frac{1}{2\pi}\sqrt{\frac{9.81}{0.40 - 0.03}}$$

= 0.82 r.p.s.

(I) Operating speed is 55% less than the critical speed.

55% of the critical speed = 0.55 × 0.82 = 0.45 r.p.m.

∴ Operating speed = 0.82 – 0.45 = 0.37 rps (22 r.p.m.)

(II) Critical speed is 40% more than the operating speed.

∴ Critical speed = 1.40 (operating speed)

∴ Operating speed = 0.82/1.40

Ex. 2.9 : A certain set of crushing rolls has rolls of 1000 mm diameter by 375 mm width of face. They are set so that the crushing surfaces are 12 mm apart at the narrowest point. The angle of nip is 30°. What is the maximum permissible size of feed ?

Solution :

r = radius of roll = 1000/2 = 500 mm

R = radius of feed particle = ?

d = gap between the rolls / 2 = 12/2 = 6 mm

α = angle of nip/2 = 30/2 = 15°

$$\cos\alpha = \frac{r+d}{r+R}$$

$$\cos(15) = \frac{500+6}{500+R}$$

$$0.9659 = \frac{500+6}{500+R}$$

∴ R = 23.86 mm

Size of feed particle = $2R = 2\times 23.86 = 47.72$ mm ≃ 48 mm ... **Ans.**

Ex. 2.10 : What should be the diameter of a set of rolls to take feed of size equivalent to 38 mm spheres and crush to 12.7 mm ?

The co-efficient of friction is 0.35.

Solution :

$\mu = \tan\alpha$

∴ $\tan\alpha = 0.35$

∴ $\alpha = \tan^{-1} 0.35 = 19.29°$

$\cos\alpha = 0.944$

$$\cos\alpha = \frac{r+d}{r+R}$$

where r = radius of roll ?

R = radius of feed particle = $\frac{38}{2}$ = 19 mm

d = gap between rolls / 2 = $\frac{12.7}{2}$ = 6.35 mm.

$$0.944 = \frac{r+6.35}{r+19}$$

r = 206.9 mm

Diameter of the rolls = $2r = 2(206.9) = 413$ mm

Diameter of the rolls = 413 mm.

...dd sizes are not available, so 400 mm rolls should be used. ... **Ans.**

...ameter of rolls = 400 mm

EXERCISES

1. Give the classification of size-reduction machines.
2. Name the four common ways of breaking solids in size-reduction machines.
3. Write a brief note on Blake jaw crusher.
4. Write in brief the construction and operation of a ball mill.
5. What do you mean by closed-circuit grinding and open-circuit grinding ?
6. State why centrifuging is not desirable in a ball mill ?
7. Define critical speed and give the formula for calculating the critical speed.
8. Define angle of nip and give relationship between angle of nip, feed size, gap between rolls and diameter of rolls.
9. Draw a neat sketch of Blake jaw crusher and name its parts.
10. State Rittinger's and Kick's law.
11. What should be the diameter of set of rolls which accepts feed equivalent to spheres of 50 mm in diameter and crush them to spheres having a diameter of 15 mm ? The co-efficient of friction is 0.30. **(Ans. 750 mm)**
12. Differentiate between crushing and grinding operation.
13. Differentiate between jaw crusher and gyratory crusher.
14. Draw a neat sketch of conical ball mill and name its parts.
15. State the difference between Blake jaw crusher and Dodge jaw crusher.

Sol^n

$\mu = 0.30$

$\alpha = 16.69$

$\cos\alpha = \frac{R+d}{R+[illegible]}$

$0.95 = \frac{R+7.5}{R+25}$

$23.94 + 0.95R = R+7.5$

$R = 32[illegible]$

- Low maintance cost
- High screening efficiency

Ques ⇒ What is the power required to crush 100 ton/h ~~required to crush to~~ of limestone if 80% of feed passes the 2 inch screen and 80% of the product through a 1/8 inch screen

$D_{pa} = 2\text{inch} = 50.8\ mm$ (1inch = 25.4mm)

$D_{pb} = 1/8 = 0.125\text{inch} = 3.175\ mm$ $w_i = 12.74$

$\dot{m} = 100\text{ton/h}$

$$\frac{P}{\dot{m}} = .3162\, w_i \left[\frac{1}{\sqrt{D_{pb}}} - \frac{1}{\sqrt{D_{pa}}}\right]$$

$$\frac{P}{100} = .3162 \times 12.74 \left[\frac{1}{\sqrt{3.175}} - \frac{1}{\sqrt{50.8}}\right]$$

$P = 169.55\ kW$

Ques ⇒ A material is crushed an average size of particles is reduced from 10cm to 2.6cm with the consumption of energy at rate of 74 Wh/m ton. What will be the consumption of energy ~~at a~~ necessary to crush the same material of average size of 16cm to an average size of 6cm. Energy remains unchange do the calculation using Rittinger's law or kick's Law

Ri

K

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$D_{pa} = 10\,cm = .1\,m$ $D_{pb} = 2.6\,cm = 0.026\,m$

$\frac{P}{\dot{m}} = 74$ wh/mton

Rittinger's law

$$\frac{P}{\dot{m}} = K_r \left[\frac{1}{D_{pb}} - \frac{1}{D_{pa}} \right]$$

$$74 = K_r \left[\frac{1}{0.026} - \frac{1}{0.1} \right]$$

$$74 = 28.46 K_r$$

$$K_r = \frac{74}{28.46} = 2.6$$

$$\frac{P}{\dot{m}} = 2.6 \left[\frac{1}{0.06} - \frac{1}{0.16} \right]$$

$D_{pa} = 0.16$
$D_{pb} = 0.06$

$$\frac{P}{\dot{m}} = 27.08 \text{ wh/m ton}$$

Kick's law

$$\frac{P}{\dot{m}} = K_K \ln \frac{D}{d}$$

$$74 = K_K \ln \frac{0.1}{0.026}$$

$$K_K = \frac{74}{0.585}$$

$$K_K = 126.49$$

$$\frac{P}{\dot{m}} = 126.49 \ln \frac{0.16}{0.06}$$

$$\frac{P}{\dot{m}} = 53.83 \text{ Wh/ m ton}$$

Ques:) A certain set of crushing rolls of dia 1000 mm by 375 mm width of face They are set so that the crushing surface are 12mm apart at a narrowest point. Angle of nip is 30°. What is the max. permissible size of the feed.

$d = 1000 \text{ mm} \Rightarrow r = 500 \text{ mm}$

$2d = 12 \Rightarrow d = 6$ $\quad\quad 2\alpha = 30 \Rightarrow \alpha = 15$

$$\cos\alpha = \frac{r+d}{r+R}$$

$$\cos 15 = \frac{500+6}{500+R}$$

$$482.9 + 0.966R = 506$$

$$0.966R = 23.1$$

$$R = 23.91 \text{ mm}$$

$$R = 24 \text{ mm}$$

Ques:) In crushing a certain material the feed is such that 80% is less than 50.8mm in size and product size is such that 80% is less than 6.35mm. Power required is 89.5 kW

What will be the power required. Using the same feed so that the product size is such that 80% is less than 3.18 mm

$D_{pa} = 50.8$ mm $\quad D_{pb} = 6.35$ mm $\quad P = 89.5$ kW

Case I

$$\frac{P}{\dot{m}} = .3162\, w_i \left[\frac{1}{\sqrt{D_{pb}}} - \frac{1}{\sqrt{D_{pa}}}\right]$$

$$\frac{89.5}{\dot{m}} = .3162 \times w_i \left[\frac{1}{\sqrt{6.35}} - \frac{1}{\sqrt{50.8}}\right]$$

$$\frac{89.5}{\dot{m}} = .3162\, w_i \times 0.2563 \quad \text{——— (I)}$$

Case II

$D_{pb} = 3.18$ mm $\quad D_{pa} = 50.8$ mm

$$\frac{P}{\dot{m}} = .3162\, w_i \cdot \left[\frac{1}{\sqrt{3.18}} - \frac{1}{\sqrt{50.8}}\right]$$

$$\frac{P}{\dot{m}} = .3162\, w_i \times 0.4205 \quad \text{——— (II)}$$

divide (II) by (I)

$$\frac{\frac{P}{\dot{m}}}{\frac{89.5}{\dot{m}}} = \frac{.3162\, w_i \times 0.4205}{.3162\, w_i \times .2563}$$

$$\frac{P}{89.5} = \frac{0.4205}{.2563}$$

$$\boxed{P = 146.8\ \text{kW}}$$

Ques 2) Calculate the operating speed of ball mill from the following dia of ball mill = 1000 mm

Dia. of ball = 80 mm. Operating speed is 35% less than the critical speed.

$R = 500\,mm = 0.5\,m \qquad r = 80\,mm = 40\,m = 0.04\,m$

$$N_c = \frac{1}{2\pi}\sqrt{\frac{g}{R-r}}$$

$$N_c = \frac{1}{2 \times 3.14}\sqrt{\frac{9.81}{0.5-0.04}}$$

$N_c = 0.735\ rps$

$N_c = 44.12\ rpm$

$\boxed{N_c = 44\ rpm}$

$$O.S = 44.12 - \frac{35}{100} \times 44.12$$

$O.S = 28.67\ rpm$

$\boxed{O.S = 29\ rpm}$