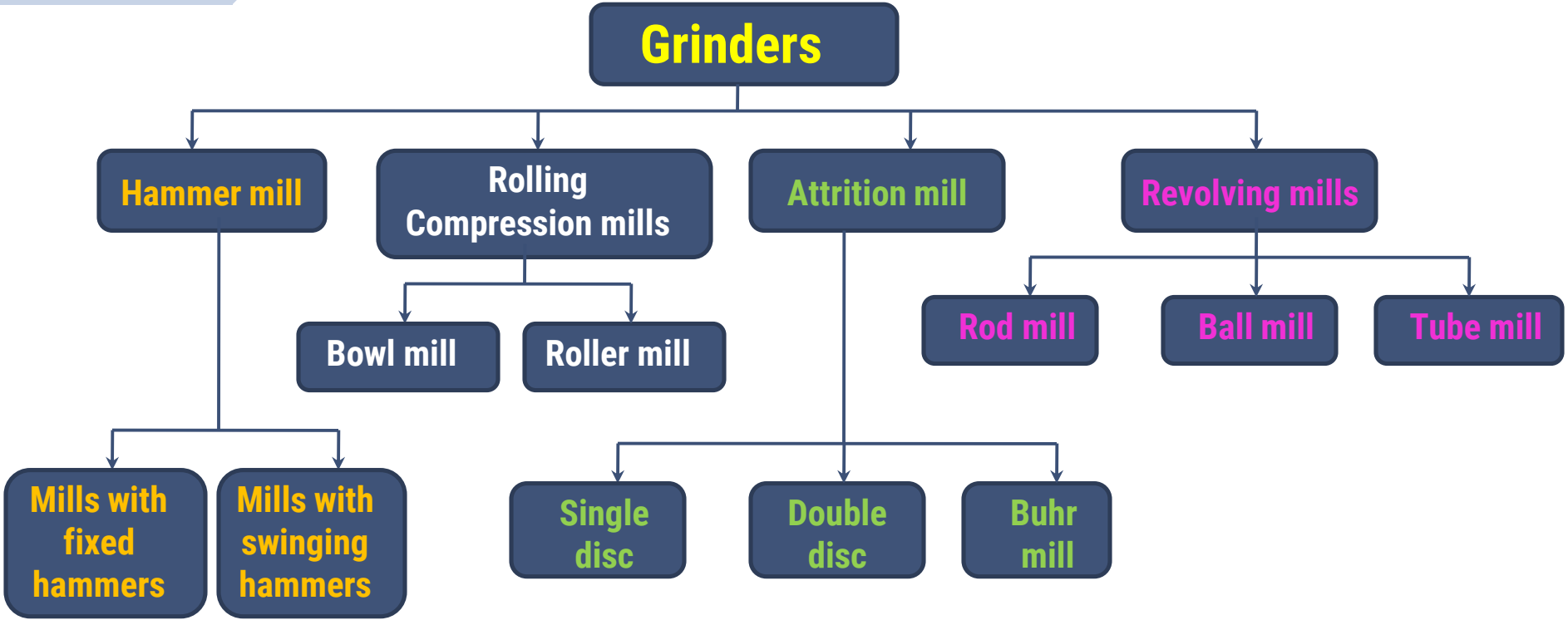
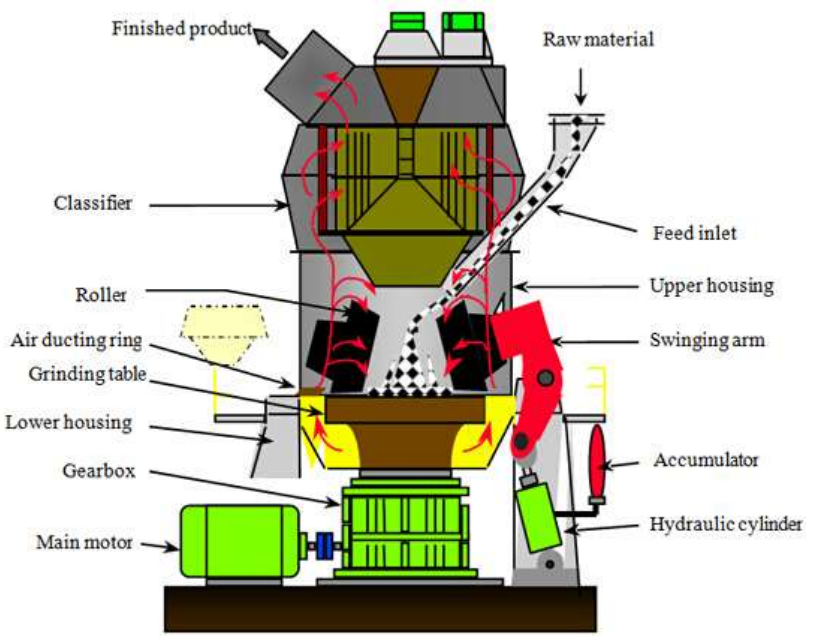
Points to be covered

- Grinders
  - Rolling compression mills
  - Attrition mill
  - Rod mill, Ball and Tube mills
  - Construction and working
- Ultra fine grinders
- Cutting machines

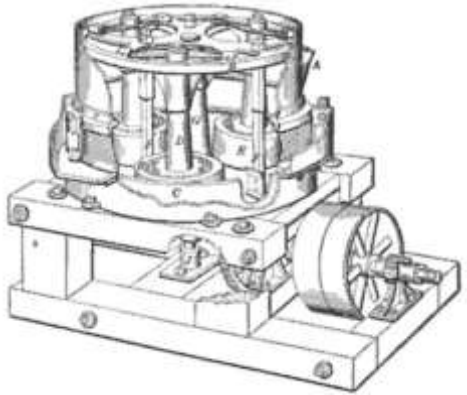

Grinders
Hammer mill
Rolling Compression mills
Attrition mill
Revolving mills
Bowl mill
Roller mill
Rod mill
Ball mill
Tube mill
Mills with fixed hammers
Mills with swinging hammers
Single disc
Double disc
Buhr mill

Rolling Compression mills

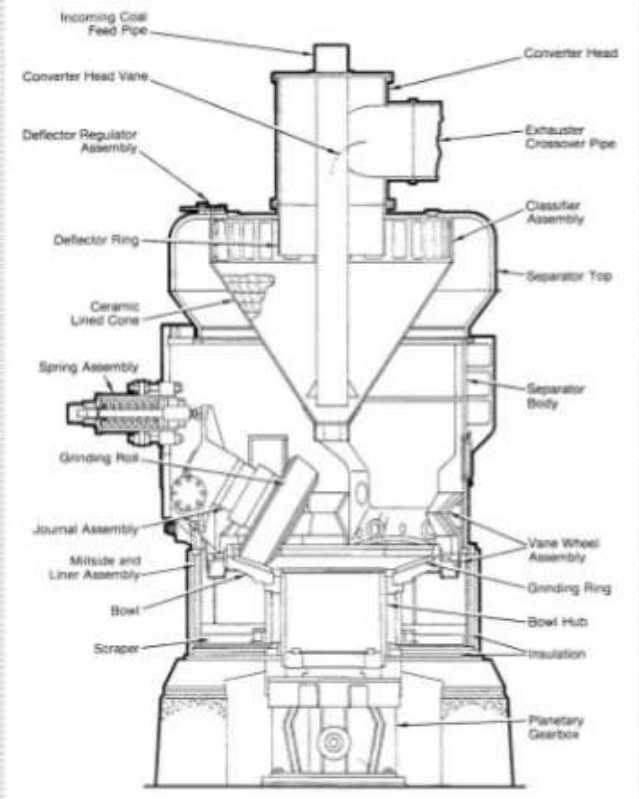


https://www.youtube.com/watch?v=ItjpblWKx80

- Feed material are caught and crushed between a roller member and the face of a grinding ring or casing.
- The most common types are ***rolling-ring pulverizers, bowl mill, and roller mills.***
- In the ***roller mill,*** cylindrical rollers are vertical which press outward with a huge force against a stationary anvil ring or bull ring.
- Driven at medium speeds in a circular motion.
- Feed materials fed between the ring and the rolls, where the size-reduction takes place.
- Product is taken out of the mill by a stream of air to a classifier separator, from which oversize materials are returned to the mill for further reduction



- In a ***bowl mill*** and some roller mills the bowl or ring is driven;
- The rollers rotate on stationary axes, which may be vertical or horizontal.
- Used for the reduction of limestone, cement clinker, and coal.
- They pulverize up to 50 ton/h.
- When classifying separator / screen are used, the product may be as fine as 99 percent through a 200-mesh screen.



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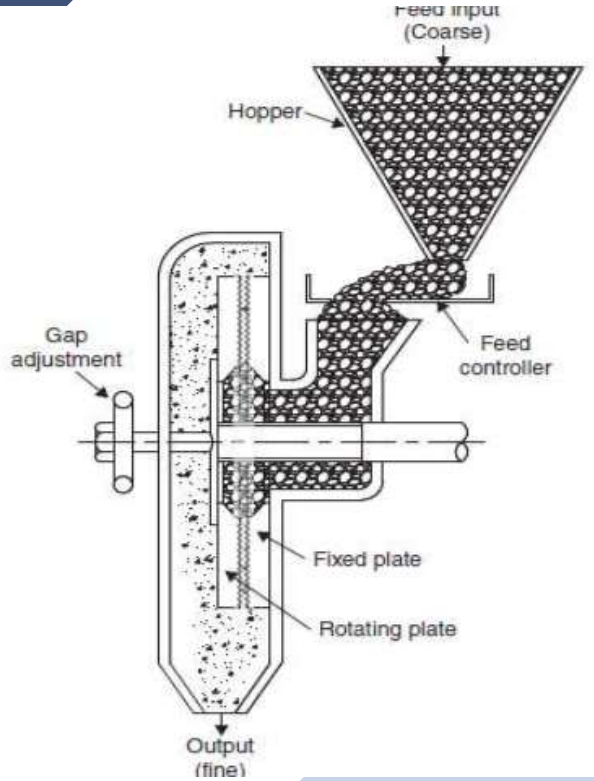
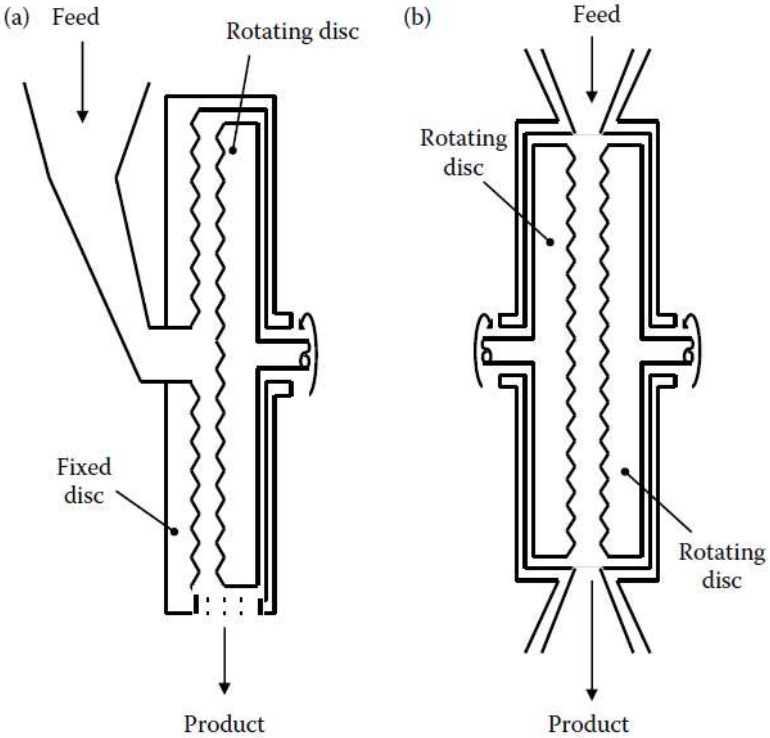
Attrition mill

- Attrition mills are also known as plate mills or disc pulverizes and are widely used for small-scale milling
- These mills use the working principle of the shearing and cutting actions.
- Grains are fed in between two circular plates with the flute or roughened surface
- One of the plates is fixed with body while the other one has a rotation facility

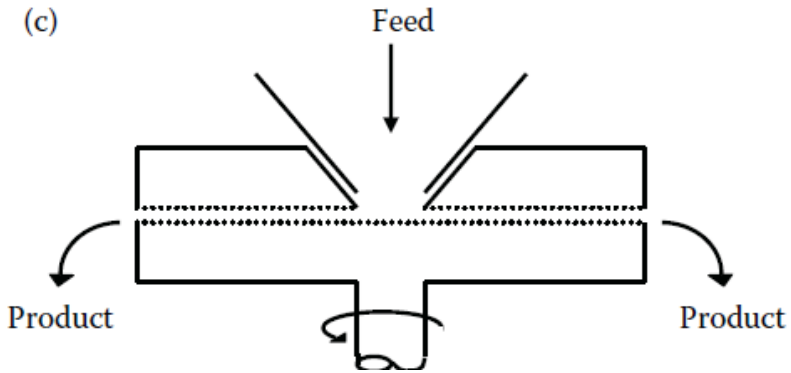


- Axis of the roughened disks may be horizontal (Buhr mill) or vertical
- Material is fed between the plates and is reduced by crushing and shear



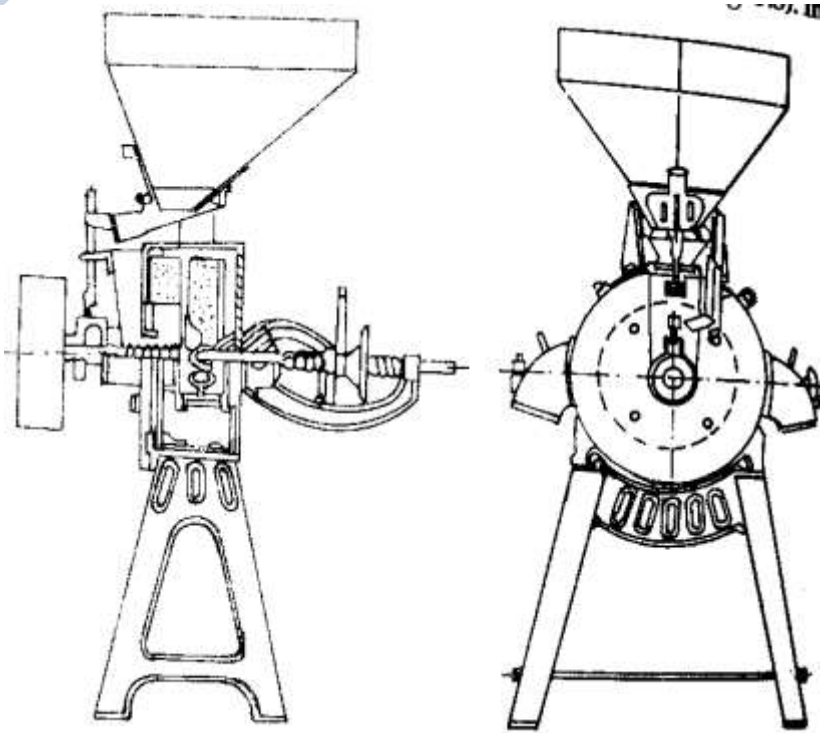
Single disc mill

Double disc mill

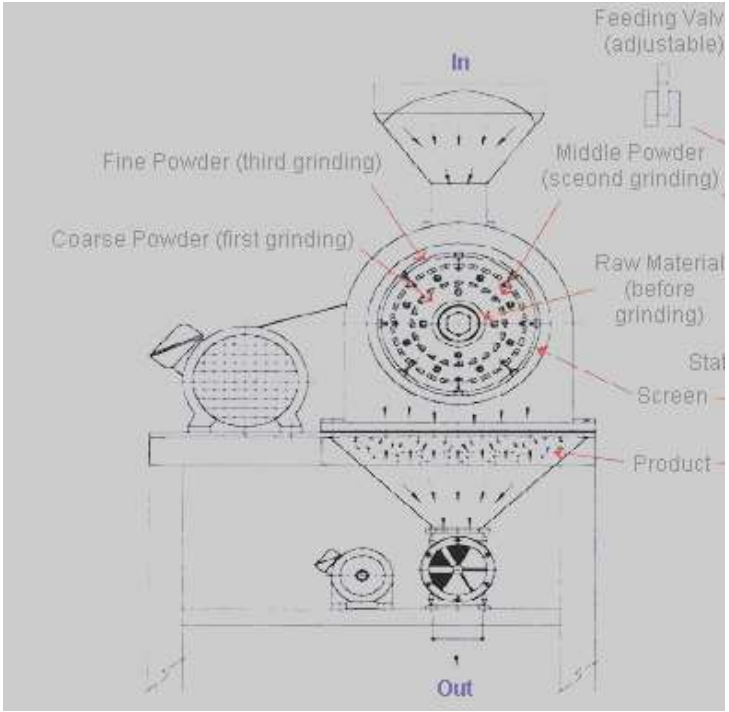


Buhr mill

Attrition mills



Single disc mill



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Pin mill

Cont.,

- Used for making whole grain and dehusked grain flour
- Use in spice grinding is limited
- Double runner disks type attrition mills are also available
- Used for grinding of soft materials
- Both disks are driven at high speed in opposite direction
- These mills produce a narrow range of particle sizes.
- Operated between 1200 to 7000 rpm
- The low clearance and higher speed facilitate the production of finer size particles
- Capacity is large
- These mills are extremely used like shred, curl, granulate, grind, shear, twist, blend, rub.

Salient features

- Fineness of grinding is controlled by the type of plates and the gap between them
- Spacing between the plates is adjustable
- Arrangement is spring loaded
- to avoid damage to plates in case of overloading
- to overcome the damage to plates by foreign material coming along with the feed
- Lower initial cost
- Lower power requirements

Comparison of attrition mills

Parameter	Single disk runner	Double disk runner
Disk Diameter	250-1400 mm	250-1400 mm
Speed	350-700 rpm	1200-7000 rpm
Capacity	0.5- 8 ton/hr	0.5-8 ton/hr
Product size	Passed through 200 mesh i.e 0.074mm	Passed through 200 mesh i.e 0.074mm
Power consumption	8-80 kWh per ton of product	8-80 kWh per ton of product

Tumbling mills

The main types in this category are:

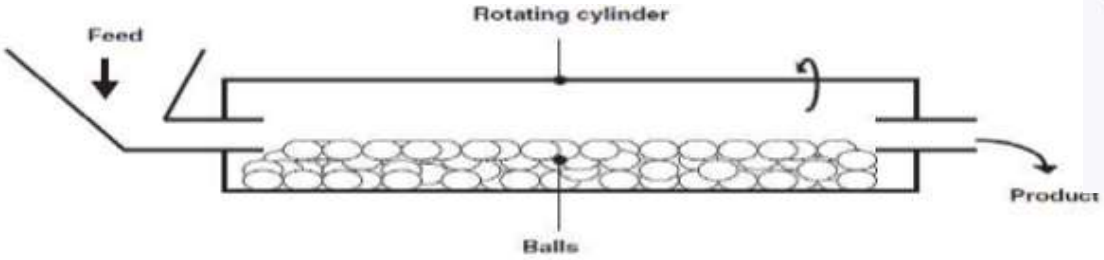
a. ***The ball mill*** of length almost equal to its diameter

b. ***The tube mill*** of length greater than the diameter usually used when a finer product is desired.

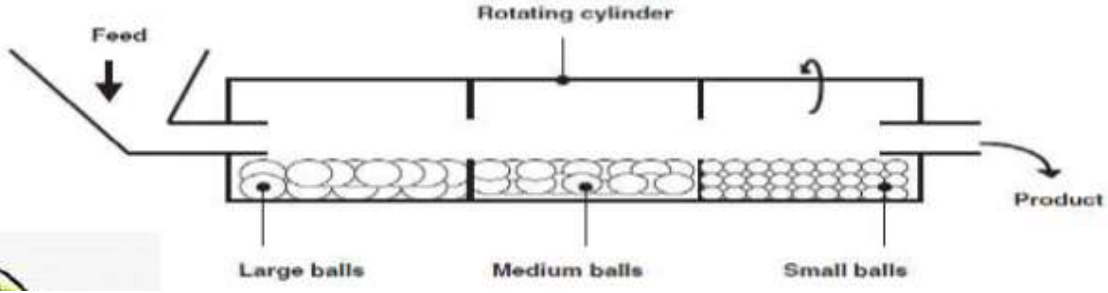
c. ***The compartment mill*** which is a combination of the above types consisting of a cylinder divided into compartments separated by screens such that preliminary and final grinding take place in the first and in the last compartment respectively.

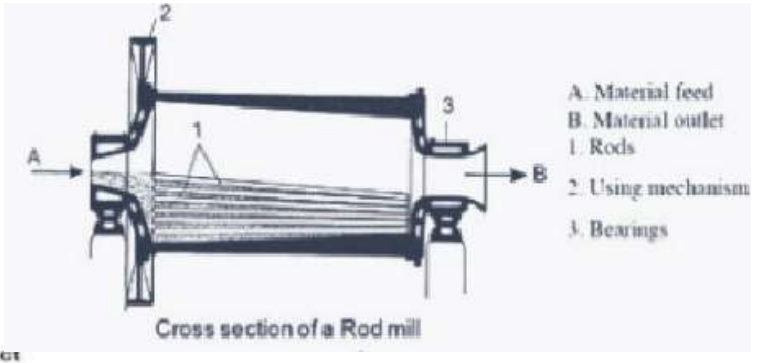
d. ***The rod mill*** in which the grinding medium consists of rods rather than balls and is known to deliver a more uniform size distribution.

Tumbling mill - Ball mill

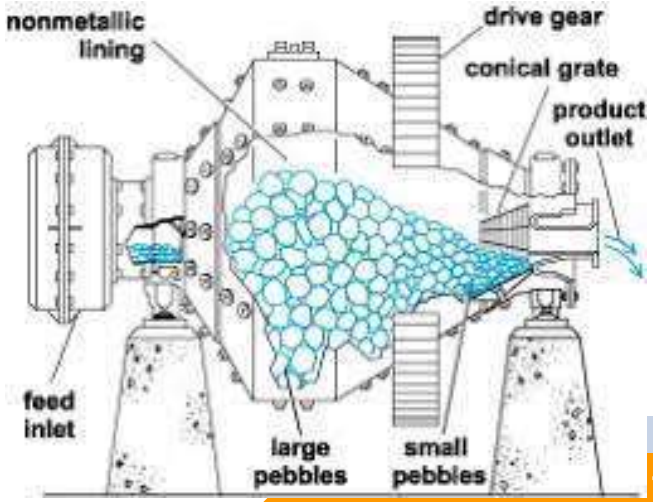


(a)



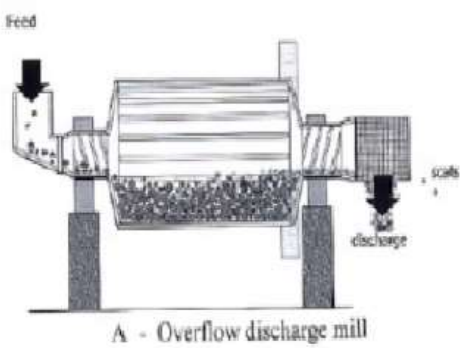


Cross section of a Rod mill

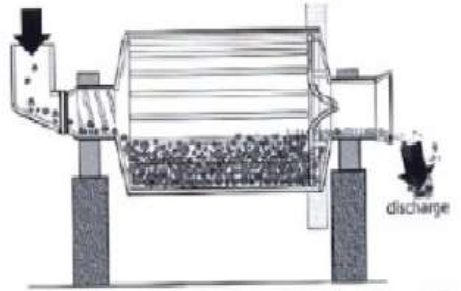


Tumbling mill - Ball mill

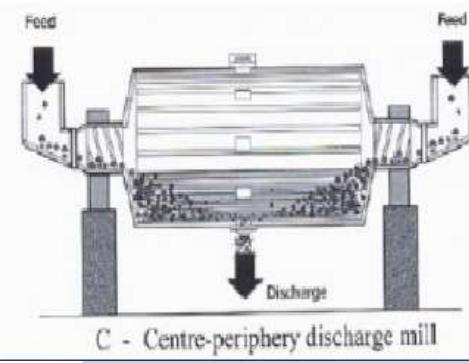
- Cylindrical or conical shell slowly rotating about a horizontal axis.
- Half of its volume is filled with solid grinding balls
- Shell is made of steel lined with high carbon steel plate, porcelain or silica rock.
- Size reduction is achieved by impact of the balls when they drop from near the top of the shell
- Energy consumed in lifting the balls is utilized for grinding job



A - Overflow discharge mill

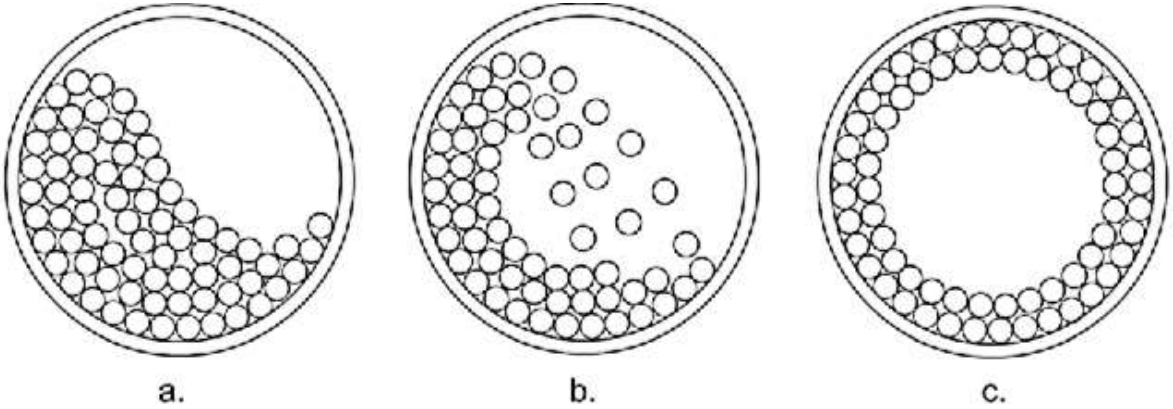


B - Diaphram or Grate discharge mill



C - Centre-periphery discharge mill

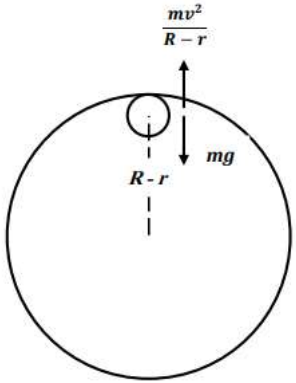
- When the ball mill is rotated , the balls are carried by the mill wall nearly to the top
- Balls are released by the gravitational pull and drop to the bottom and picked up again
- Centrifugal force keeps the ball in contact with the mill wall.
- Due to centrifugal force, if the speed of rotation of mill is faster, the balls are carried to more distance.
- **Centrifuging**: In case of too high speed, balls stick to mill wall and are not released



Scheme of a ball motion pattern in a single pot of a planetary ball mill – (a) cascading, (b) cataracting, (c) rolling.

Critical speed: Rotational speed at which centrifuging occurs

- ❖At this speed, no impact occurs hence little or no grinding results
- ❖Operating speed must be kept less than the critical speed
- ❖Speed at which the outermost ball released from the mill wall depends on the interaction of gravitational and centrifugal forces
- ❖As long as the centrifugal force exceeds the gravitational force, the particle will not loss contact with the wall.
- ❖If the speed does not exceed the critical value, a point is reached where the opposing forces are equal and the particle is nearly to fall.
- ❖The angle at which this occurs is found by equating the centrifugal and gravitational forces, that is,



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

Or $v^2 = g.(R-r)$

Since $v = \omega.(R-r)$, we get:

$\omega^2.(R-r)^2 = g.(R-r)$

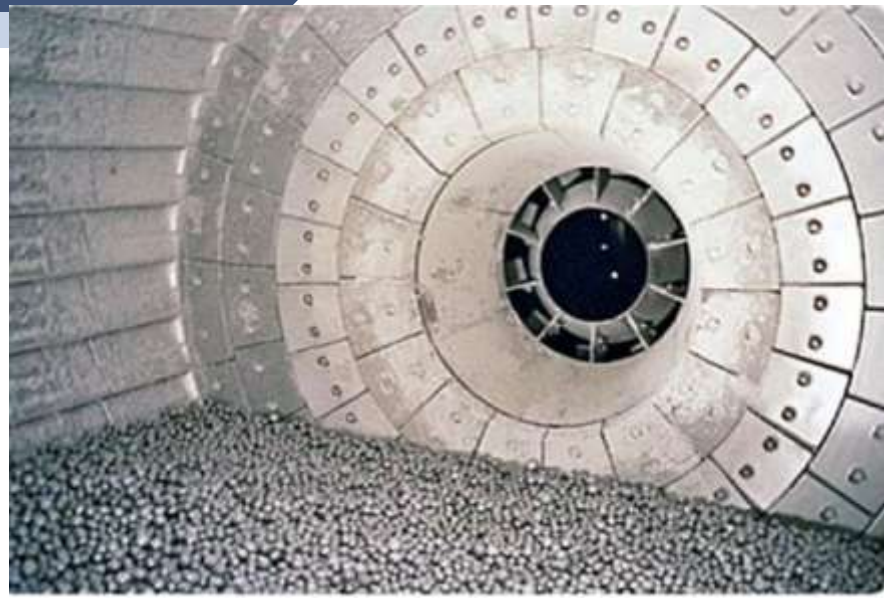
$\omega = \sqrt{\frac{g}{R-r}}$

Since $\omega = \frac{2\pi N}{60} = \sqrt{\frac{g}{R-r}}$

Substituting for $D = 2R$ and $d = 2r$, we get:

$N = \frac{42}{\sqrt{D-d}}$

Critical Speed, N_c



Critical speed can be determined by

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

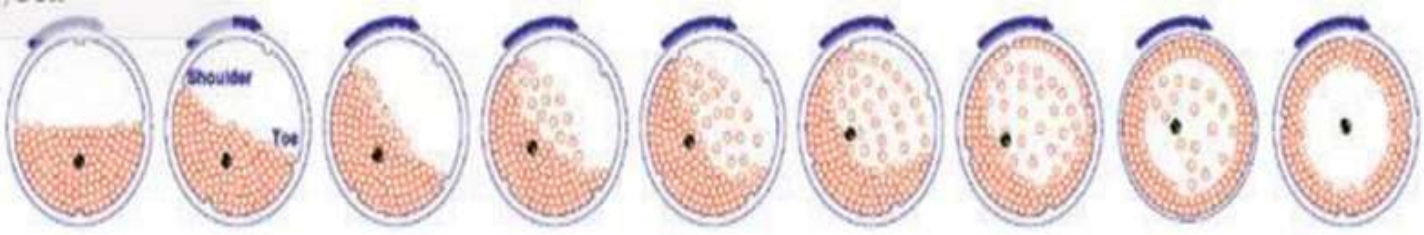
$$N_c = \frac{42}{\sqrt{D-d}}$$

Where,

N_c = critical speed, revolution/sec
g = acceleration due to gravity, 9.8 m/s^2
R = radius of the mill, m
r = radius of the ball, m

The rotational speed of mill is kept as 65 – 80 % of critical speed

Lower value is used for wet grinding

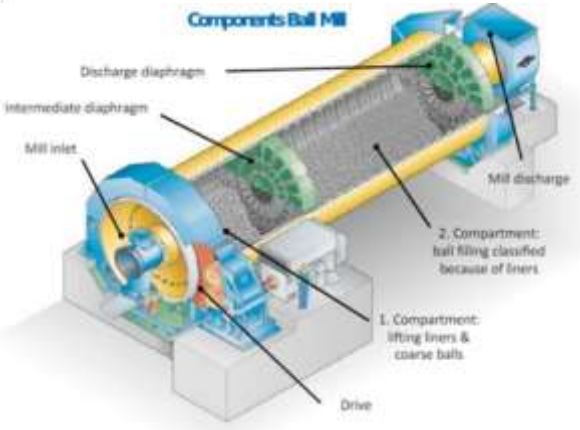


0% Critical Speed → milling 50%-70% C.S. → flaking 70%-80% C.S. → 100 % Critical Speed

milling is cataracting (impacting)

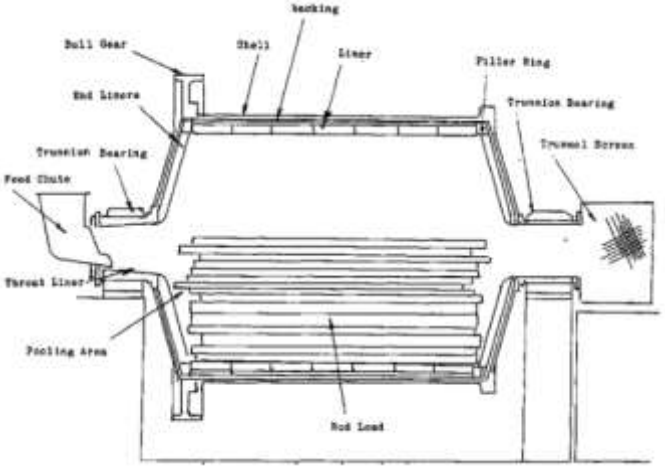
media centrifuging - no milling

Industrial ball mills



Rod Mills

- ✓ Used as the primary comminution unit in a grinding circuit.
- ✓ Rods are placed parallel along the length of the rod mill.
- ✓ Rods are 150mm shorter than the mill length.
- ✓ Breakage occurs more from cascading than cateracting.
- ✓ The product size distribution is narrower than a ball mill but significantly coarser.
- ✓ Most are overflow discharge type.
- ✓ Length-to-diameter= 1.4 to 2.3.
- ✓ Mill length = 7 meters.



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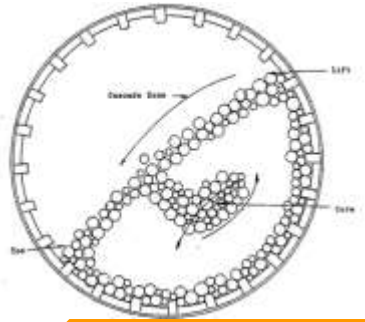
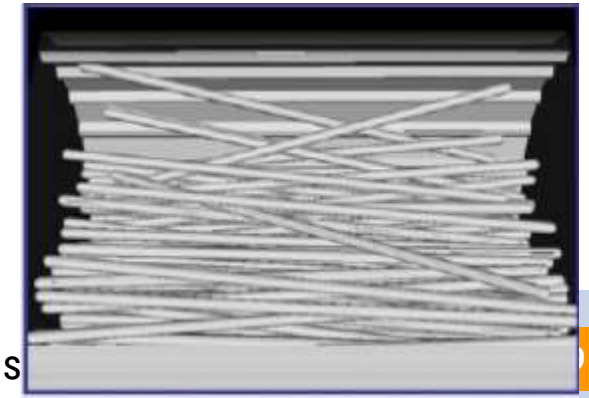


Rod Mill Operations

https://www.youtube.com/watch?v=1xe04RAE_HI

- ✓ Designed to accept feed from a secondary crusher.
- ✓ Feed particle size = 6 – 25 mm.
- ✓ Peripheral speed = 85 - 146 m/min
- ✓ Reduction ratio = 2 – 20 depending on material. Typically R = 8.

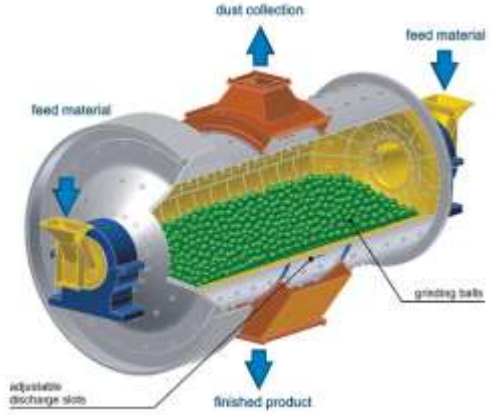
Rod Mill Charge:

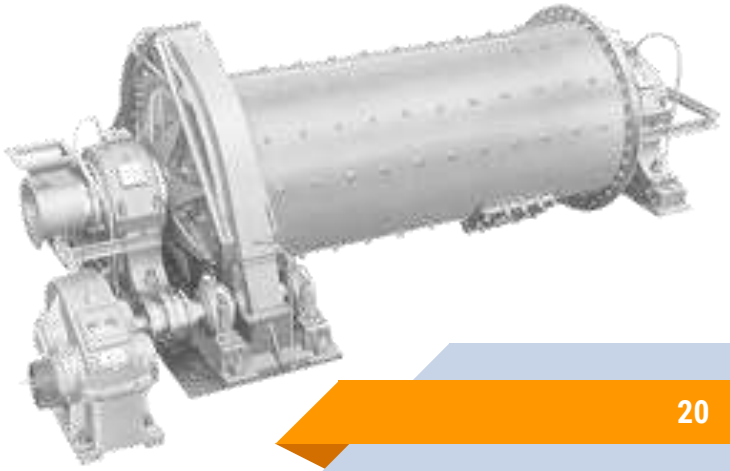


- ✓ Typically 45% of internal volume; 35% – 65% range
- ✓ Bed porosity typically 40%.
- ✓ Height of bed measured in the same way as ball mills.
- ✓ Bulk density of rods = 6.25 tons/m^3
- ✓ In wet grinding, the solids concentration 1s typically 60% – 75% by mas

Tube mills

- ✓ The difference b/n ball and tube mill are
- ✓ Length (4 -8 m) and diameter (1 -1.8 m) of tube mill is 2 to 5 time greater than ball mill
- ✓ Has only one inlet and outlet
- ✓ Cylinder interior is smooth
- ✓ Ball sizes also large (5 – 10 cm dia)
- ✓ No. of balls used also much larger
- ✓ Size reduction is the effect of grinding rather than impact
- ✓ Provision for return of uncrushed material is absent
- ✓ Speed of mill = 32 / √D
- ✓ D – inner dia of mill in m
- ✓ Normally 26 rpm





Problem

Calculate the critical speed in revolution/minute, of a ball mill with an internal diameter of 1200 mm loaded with balls of 70 mm diameter.

SOLUTION

Expressed in meters, the radius of the mill and the balls will be 0.6 and 0.035 m, respectively. Therefore, a direct substitution in the Equation 4.13 will lead to

$$N_c = \frac{1}{2\pi}\sqrt{\frac{9.81}{(0.6 - 0.035)}} = 0.6625 \text{ 1/s} = 39.75 \text{ rev/min.}$$

Solve the problems

1. **Problem : What would be the operating speed of rotation in revolutions per minute of a ball mill of 2,000 mm diameter charged with 100 mm balls? The ball mill is grinding solid matter.**

2. **Problem : What would be the critical speed and operating speed of rotation for wet grinding in viscous suspension by a ball mill of 1600 mm diameter charged with 75 mm balls?**

3. **A ball mill of 1500 mm diameter is charged with 75 mm balls to grind solid material. Determine its speed of operation in revolution per minute.**

Comparison of Tumbling Mill Characteristics

PARAMETER	BALL MILL	ROD MILL
Length: Diameter Ratio	1.4 to 1.8	0.5 to 3.5
Feed Size	2.5 cm maximum	-1.9 cm -1.25 to 0.9cm
Reduction Ratio	15:1 to 20:1	20:1 to 200:1

Ultra Fine Grinders

- Commercial powders contain particles size ranging 1 to 20 μm
- All particles passing a standard screen of 325-mesh that has 44 μm wide opening
- Mills used to reduce to such size particles are called ultrafine grinders
- Ultrafine grinding can be done based on dry and wet basis

Dry Basis

- High speed hammer mills with internal and external classification
- Fluid energy or jet mills

Wet basis

- Agitated mills and / colloidal mills

Ultra Fine Grinders

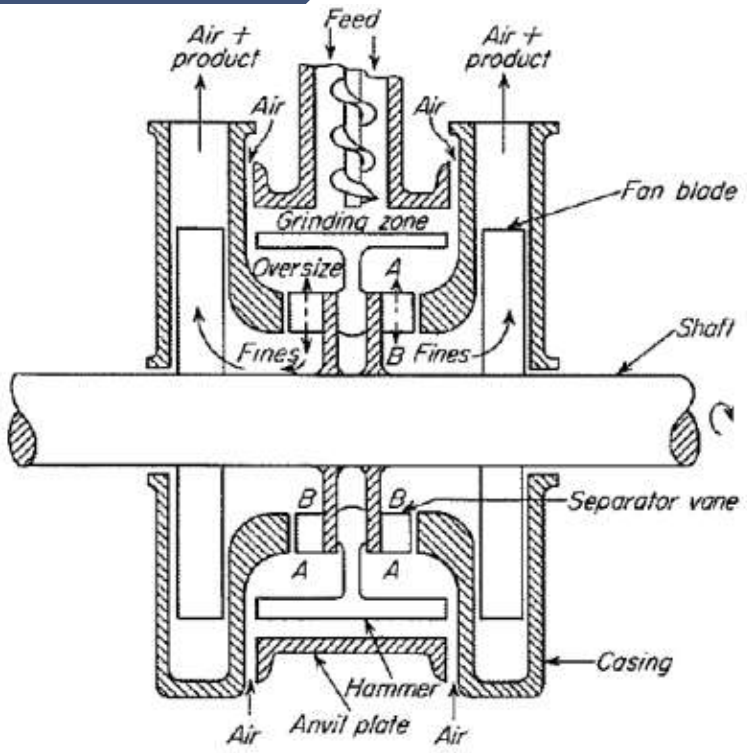
1. Hammer mills with internal classification
2. Fluid-energy mills
3. Agitated mills
4. Colloidal mills

Classifying Hammer Mills

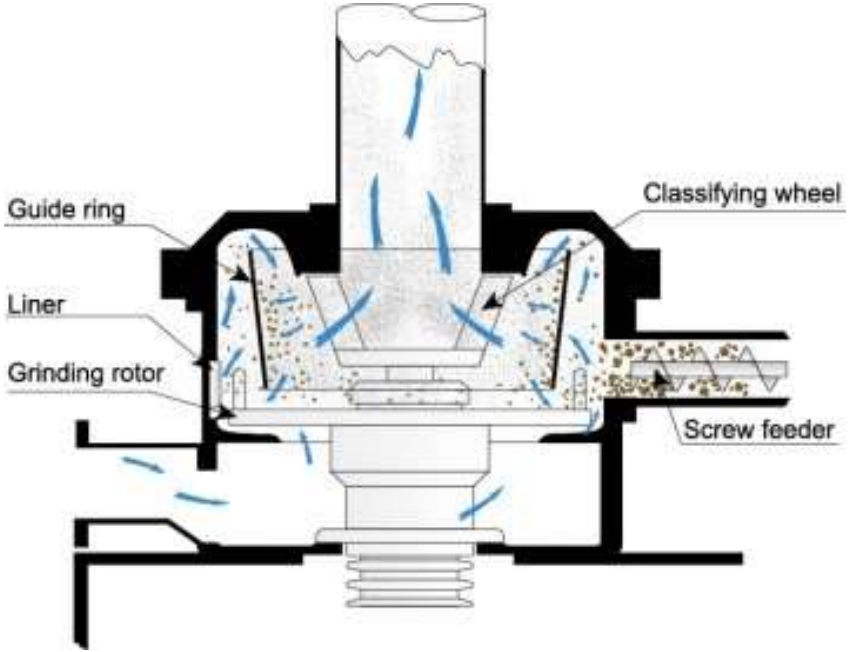
- ✓ Hammer mill with internal classification is the Mikro Automizer illustrated in figure.
- ✓ A set of hammers held between rotor and wall such as in conventional hammer mill.
- ✓ In addition to the hammers the rotor shaft carries 2 fans which draw air through the mill.
- ✓ On the rotor disk a short radial vanes are placed to separate the oversized particles from the acceptable size.

Principle:

- ✓ In the grinding zone solid particles are given a high rotational velocity.
- ✓ Coarser particles are contracted along the wall due to the centrifugal force acting on them.
- ✓ The air stream carries the fine particles from the grinding zone in the direction of AB.
- ✓ The over sized particles thrown outward by the vanes in the direction of BA



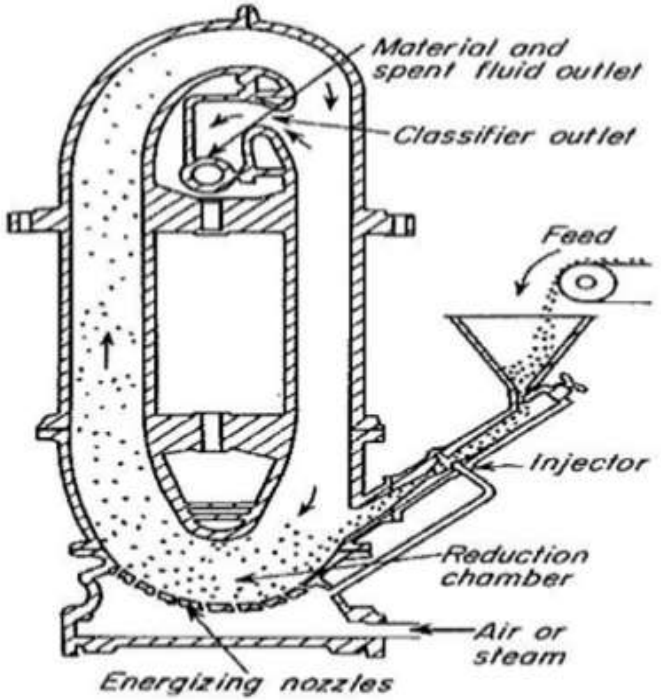
- ✓ The passage of particles through the vanes is depends on the two predominant forces.
    1. Centrifugal Force by vanes.
    2. Drag force by air stream.
- ✓ Coarse particle are thrown back into the grinding zone by the vanes.
- ✓ Fine particles are carried by the air stream.
- ✓ Capacity – 1 to 2 ton/h
- ✓ Average product size will be from 1- 20 microns.
- ✓ Power requirement 40 kWh/metric ton.



Working of Air Classifier Hammer Mill

https://www.youtube.com/watch?v=2IrQnIf9-rI&feature=emb_logo

Fluid Energy Mills



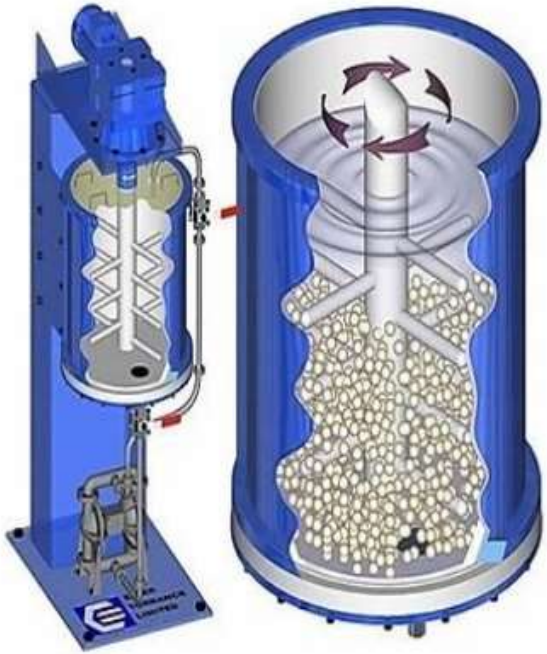
- Particles are suspended in a high-velocity gas stream which flows in a circular or elliptical path
- In some design there are jets that oppose one another or vigorously agitate a fluidized bed
- When the particles strike or rub against the walls of the confining chamber, size-reduction occurs
- Reduction is carried out by inter-particle attrition
- Due to internal classification, the larger particles are reduced to the desired size
- The suspending gas which may be compressed air or superheated steam, admitted through nozzles at a pressure of 7 atm

- ✓ In the mill the grinding chamber is an oval loop of pipe 25 to 200 mm in diameter and 1.2 to 2.4 m high
- ✓ Fluid-energy mills can accept feed particles as large as 12 mm but are more effective when the feed particles are no larger than 15 μm
- ✓ They reduce up to 1 ton/h of nonstick solid to particles averaging 0.5 to 10 μm in diameter, using 1 to 4 kg of steam or 6 to 9 kg of air per kilogram of product
- ✓ Loop mills can process up to 6000 kg/h

Agitated Mills

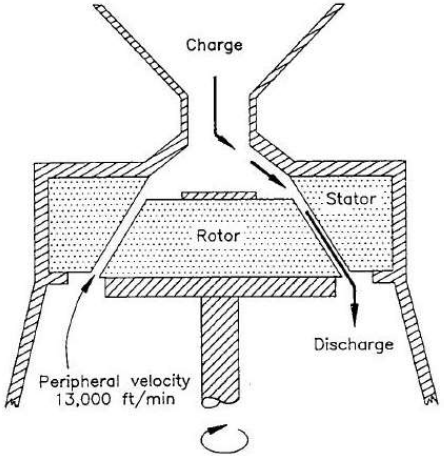
For some ultra fine grinders small batch non-rotary mills containing solid grinding medium are available.

- The grinding medium consists of hard solid such as
  - Balls
  - Pellets
  - Or sand grains
- These mills are vertical vessels 4 to 1200 L in capacity, filled with liquid in which the grinding medium is suspended.
- Fluid and grinding medium mixed with multiarmed impellers.
- A concentrated slurry is admitted at the top and product can be discharged from the bottom.
- These mills are useful to produce 1μ or less size of particle.

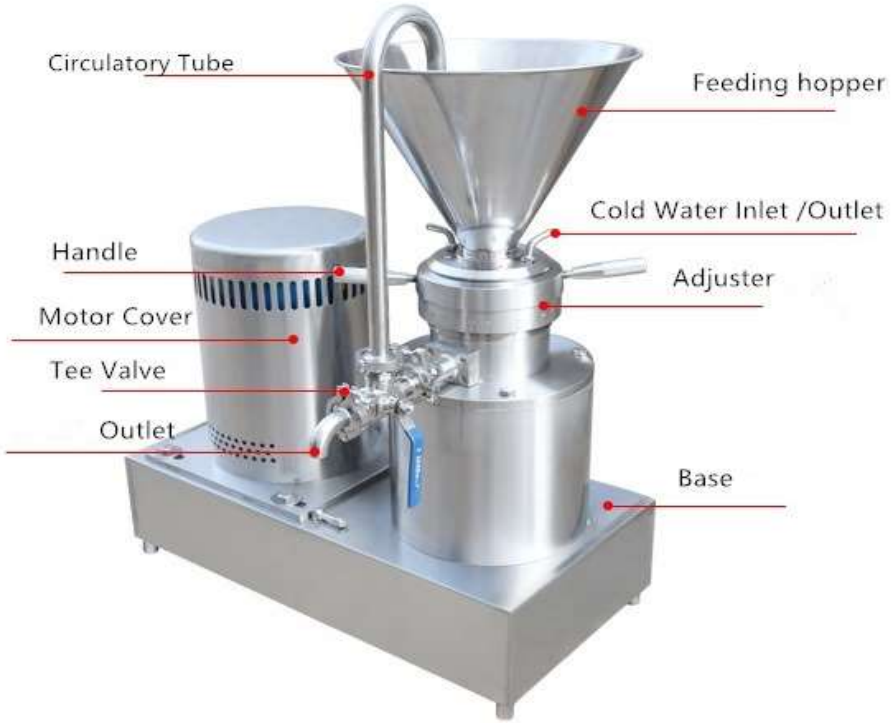


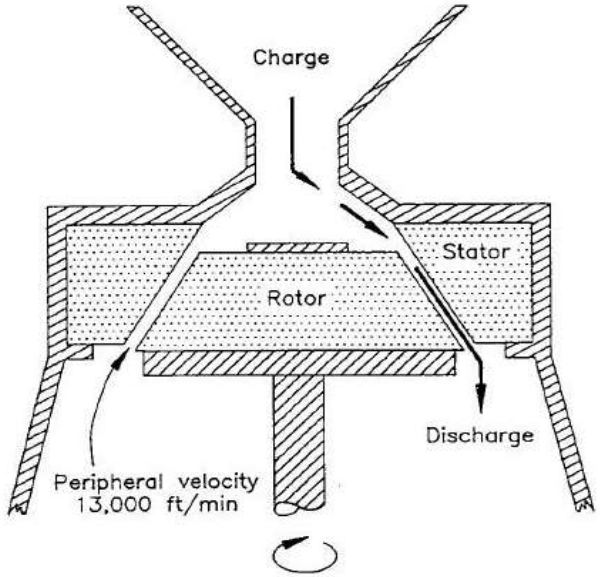
Colloid mills

- ✓ Colloid mill is a machine used in the disintegration of solid particles or droplet size of a liquid present in suspension or emulsion.
- ✓ The machine consists of an inlet and an outlet.
- ✓ Colloid mill works on the rotor-stator principle
- ✓ The equipment breaks down materials by forming dispersion of materials in a liquid
- ✓ Shearing takes place in a narrow gap between a static cone (the stator) and a rapidly rotating cone (the rotor)
- ✓ To reduce wear, the rotor and stator are constructed using toughened steel or corundum
- ✓ The rotor of a colloid mill can differ from one machine to another but the operating principle is the same for all.



Working Principle





Advantages and Disadvantages of Colloid Mills

Advantages

1. It has a wide range of use including comminution of slurry- fluid materials
2. No pressure is required for ionization.
3. The machine is simply constructed.
4. It can be easily adjusted.
5. Colloid mill is easy to clean after use
6. The machine is self-draining.
7. High capacity and minimal requirements.
8. Reduced wear as a result of the construction of the rotor-stator with toughened steel/corundum.
9. Low machine noise level.

Disadvantages

1. It has no wide application in solids
2. Wear of the rotating plates
3. No fine grinding

Cutting Machines

- Feed stocks are too tenacious or too resilient, they cannot be broken by compression, impact, or attrition, hence cutting machines are used
- In some cases of size-reduction the feed must be reduced to particles of fixed dimensions
- requirements are met by devices that cut, chop, or tear the feed into a product with the desired characteristics
- Cutting machines like rotary knife cutters and granulators used for the application of a variety of processes
- In agricultural industry, cutting machines are mainly used to cut fruits and vegetables

Cutting machines

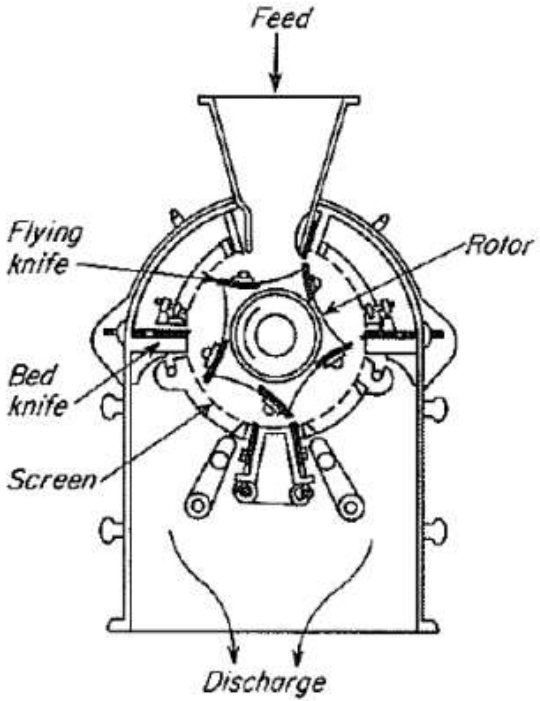
- Slicing and flaking equipment
- Dicing equipment
- Shredding equipment
- Pulping equipment

Table 2.4 Different cutting operations

Cutting operations	Description
Slicing	Blade slices by centrifugal force and each slice falls away freely
Dicing	Vegetables, fruits and meats are first sliced and then cut into strips by rotating blades. The strips are then fed to a second set of rotating knives that operate at right angles to the first set and cut the strips into cubes
Shredding	Commonly they are the modified form of a hammer mill in which knives are used instead of hammers to produce a cutting action. A second type of shredder, known as the squirrel cage disintegrator, has two concentric cylindrical cages inside a casing. They are fitted with knife blades along their length and the two cages rotate in opposite directions. Food is subjected to powerful shearing and cutting forces as it passes between them
Pulping	A combination of compression and shearing forces are used for juice/pulp extraction from fruits or vegetables and for producing pureed and pulped meats

Knife cutter

- A rotary knife cutter contains a horizontal rotor rotating at 200 to 900 rpm in a cylindrical chamber
- The rotor consist of 2 to 12 flying knives with edges of tempered steel or stellite passing with close clearance over 1 to 7 stationary bed knives
- Feed particles enter the chamber from top are cut several hundred times per minute and withdrawn at the bottom through a screen with 5 to 8 mm openings
- Sometimes the flying knives are parallel with the bed knives
- Sometimes, depending on the properties of the feed, they cut at an angle
- Rotary cutters and granulators are similar in design
- A granulator yields more or less irregular pieces
- A cutter may yield cubes, thin squares, or diamonds



Rotary Knife Cutter

Any questions?

THANK YOU

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