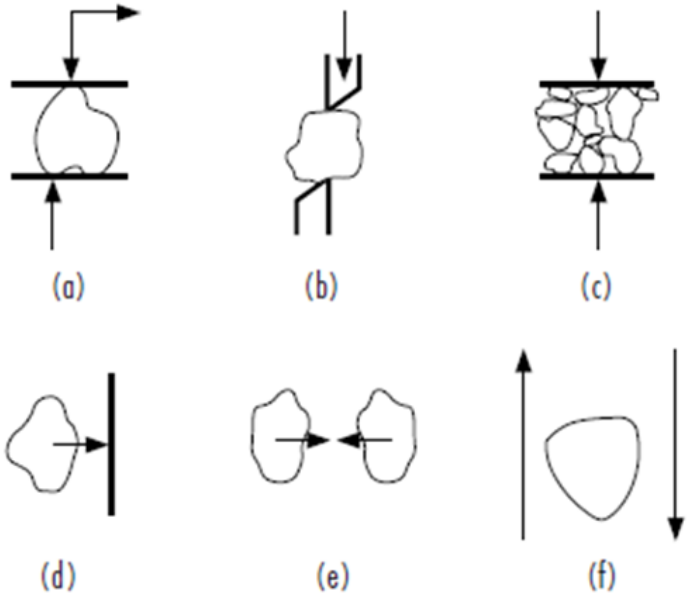
SIZE REDUCTION

APPLICATIONS

- To obtain workable size
- To obtain powders
- Obtain specific shape and size
- Increase reactivity
- Permit separation of unwanted ingredient
- Mineral, Metallurgical Industries, Pharmaceutical Industry, Food Industry, Nanotechnology,

MECHANISM OF SIZE REDUCTION

- COMPRESSION
- IMPACT
- ATTRITION
- SHEAR
- Non-mechanical introduction of energy (Thermal shock, explosive shattering, electrohydraulic)



- (a) Between two solid - crushing or attrition;
- (b)shearing;
- (c) Compression crushing in a particle bed
- (d)Impact at one solid surface
- (e) Impact between particles
- (f) Shear action of the surrounding medium

ENERGY & POWER REQUIREMENT IN SIZE REDUCTION

When stress is applied, material are distorted and strained.

- Work necessary to strain is stored as mechanical energy till the ultimate strength is reached
- Breaks up into pieces – increase in surface area
- Energy goes to increase in surface area, and excess energy is liberated as heat

$$Crushing\ Efficiency, \eta_c = \frac{surface\ energy\ created\ by\ crushing}{energy\ absorbed\ by\ the\ material}$$

$$\eta_c = \frac{e_s \left[A_{w_p} - A_{w_f}\right]}{W_s}$$

es= Surface energy per unit area, J/m2

Aw = specific surface area, Suffix p = product, f= feed., m2/kg

Ws = energy absorbed by unit mass of solid.J/kg

$$Mechanical\ Efficiency, \eta_m = \frac{energy\ absorbed\ by\ material}{energy\ input\ to\ the\ machine} = \frac{W_s}{W}$$

$$W = \frac{W_s}{\eta_m} = \frac{e_s \left[A_{w_p} - A_{w_f}\right]}{\eta_m \eta_c}$$

POWER REQUREMENT: $$P = W\dot{m} = \frac{e_s \left[A_{w_p} - A_{w_f}\right]\dot{m}}{\eta_m \eta_c}$$

POWER REQUIREMENT IN SIZE REDUCTION

$$P = W\dot{m} = \frac{e_s\left[A_{w_p} - A_{w_f}\right]\dot{m}}{\eta_m \eta_c}$$

$$\overline{D_s} = \frac{6}{\varphi_s \rho_p A_w} \text{ or} A_w = \frac{6}{\varphi_s \rho_p \overline{D_s}}$$

$$P = \frac{6e_s\dot{m}}{\eta_m \eta_c \rho_p}\left[\frac{1}{\varphi_{sp}\overline{D_{sp}}} - \frac{1}{\varphi_{sf}\overline{D_{sf}}}\right]$$

RITTINGERS LAW [1867]

- The work required for size reduction is proportional to the new surface area created:

$$W_R = \frac{P}{\dot{m}} \propto \left[A_{wp} - A_{wf}\right]$$

$$W_R = \frac{P}{\dot{m}} \propto \left[\frac{1}{\varphi_{sp}\rho_{pp}\overline{\overline{D_{sp}}}} - \frac{1}{\varphi_s\rho_{pf}\overline{\overline{D_{sf}}}}\right]$$

$$W_R = \frac{P}{\dot{m}} \propto \frac{1}{\varphi_s\rho_p}\left[\frac{1}{\overline{\overline{D_{sp}}}} - \frac{1}{\overline{\overline{D_{sf}}}}\right]$$

$$W_R = \frac{P}{\dot{m}} = K_R\left[\frac{1}{\overline{\overline{D_{sp}}}} - \frac{1}{\overline{\overline{D_{sf}}}}\right]$$

- Where KR is called the Rittinger's Constant.
- Application of the law
  - Where surface area created is significant – fine grinding
  - Particle size less than 0.05mm
  - Energy in put is not very high

Kicks Law (1885)

The work required for crushing a given mass of material is constant for a given reduction ratio irrespective of the initial size.

Reduction ratio is the ratio of the initial particle size to final particle size.

$$W_K = \frac{P}{\dot{m}} = constant\ x\ \ reduction\ ratio$$

$$W_K = \frac{P}{\dot{m}} = K_K ln\left[\frac{\overline{D_{sf}}}{\overline{D_{sp}}}\right]$$

- KK is called the Kick's Constant
- Kicks law is application
  - based on stress analysis if plastic deformation within the elastic limit.
  - More accurate than Rittingers law for course crushing.
  - Applicable for feed size greater than 50mm

Bond's Law (1952)

The work required to form particles of size Dp p from a very large particle size is proportional to the square root of the surface to volume ratio (s_p/v_p) of the product.

$$\varphi_s = \frac{6}{s_p \varphi D_p}, \qquad OR \qquad \frac{s_p}{v_p} = \frac{6}{\varphi D_p}$$

$$W_B = \frac{P}{\dot{m}} \propto \sqrt{\left(\frac{s_p}{v_p}\right)_p}$$

$$W_B = \frac{P}{\dot{m}} = K\sqrt{\frac{6}{\varphi D_{pp}}} = K_B \frac{1}{\sqrt{D_{pp}}}$$

- Where , K_B = Bonds constant

Energy required to reduce from Dpf to Dpp

$$W_B = \frac{P}{\dot{m}} = K_B \left(\frac{1}{\sqrt{D_{pp}}} - \frac{1}{\sqrt{D_{pf}}}\right)$$

- If feed is very large, $W_B = \frac{P}{\dot{m}} = K_B \frac{1}{\sqrt{D_{pp}}}$

WORK INDEX

- Work Index, Wi, is the gross energy requirement in kilowatt hour per ton of feed (kWh/ton of feed) to reduce a very large particle to such a size that 80% of the product will pass through a 10micrometer, or 0.1 mm screen.
- If Dp is in mm, $W_i = K_B \frac{1}{\sqrt{D_{pp}}}$

$$K_B = \sqrt{0.1} W_i = 0.3162 W_i$$

$$\frac{P}{\dot{m}} = 0.3162 W_i \left(\frac{1}{\sqrt{D_{pp}}} - \frac{1}{\sqrt{D_{pf}}} \right)$$

- Values of WI for wet Grinding:

Property	Soft	Medium	Hard	Very hard
Work Index, W_i, KWh/ton	7-9	9-14	14-20	>20

Work indexes for dry crushing† or wet grinding‡

Material	Specific gravity	Work index, W_i
Bauxite	2.20	8.78
Cement clinker	3.15	13.45
Cement raw material	2.67	10.51
Clay	2.51	6.30
Coal	1.4	13.00
Coke	1.31	15.13
Granite	2.66	15.13
Gravel	2.66	16.06
Gypsum rock	2.69	6.73
Iron ore (hematite)	3.53	12.84
Limestone	2.66	12.74
Phosphate rock	2.74	9.92
Quartz	2.65	13.57
Shale	2.63	15.87
Slate	2.57	14.30
Trap rock	2.87	19.32

† For dry grinding, multiply by $\frac{4}{3}$.

‡ From Allis-Chalmers, Solids Processing Equipment Div., Appleton, Wisconsin, by permission.

Assumption in the theories/empirical equations of size reduction

- Energy W, required to produce a change dDp in a particle of size Dp is a power function of size Dp

$$\frac{dW}{dD_p} = -\frac{C}{{D_p}^n}$$

- For Rittinger's law n=2
- Kick's Law n=1
- Bonds law n=1.5

- Particles of average feed size 50 x 10(-4) m are crushed to an average product size of 10 x 10 (-4) m at the rate of 20 tonnes per hour. At this rate, the crusher consumes 40 kW of power of which 5 kW are required for running the mill empty. Calculate the power consumption if 12 tonnes/h of this product is further crushed to 5 x 10 (-4) m size in the same mill? Assume that Rittinger's law is applicable.

- It is desired to crush 10 ton/hr of iron ore hematite. The size of the feed is such that 80% passes a 72.6 mm screen, and 80% of product a 3.175mm screen. Calculate the gross power requirement for wet grinding and dry grinding. Work index of Hematite is 12.68 [Ans 17.96kW]

Size Reduction Equipment

A. Crushers (Coarse and Fine)
   1. Jaw Crusher
   2. Gyratory Crusher
   3. Crushing Rolls

- A primary crusher operates on run of mine material accepting anything that comes from the mine face and breaking into 150-250 mm (6-10 in).
- A Secondary crusher reduces these lumps into 6 mm (1/4 in).

B. Grinders (Intermediate and Fine)
   1. Hammer Mills
   2. Rolling Compression Mills
      a. Bowl Mills
      b. Roller Mills
   3. Attrition Mills
   4. Tumbling Mills
      a. Rod Mills
      b. Ball Mill; Pebble Mill
      c. Tube Mills; Compartment Mills

- Grinders reduce crushed feed to powders
- The product from a intermediate grinder might pass a 40-mesh screen
- Most of the product from a fine grinder would pass a 200 mesh screen with 74 micron opening.

Size Reduction Equipment

C. Ultrafine Grinders
   1. Hammer Mills with internal classification
   2. Fluid Energy Mills
   3. Agitated Mills

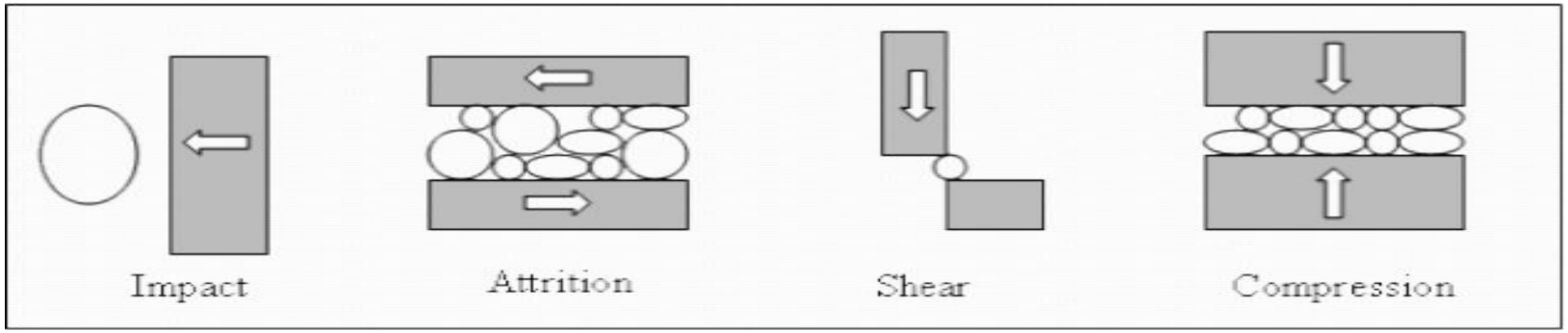
- Feed Size is less than 6mm.
- Product size is 1-50 microns

D. Cutting Machines
   1. Knife Cutters; dicers; millers.

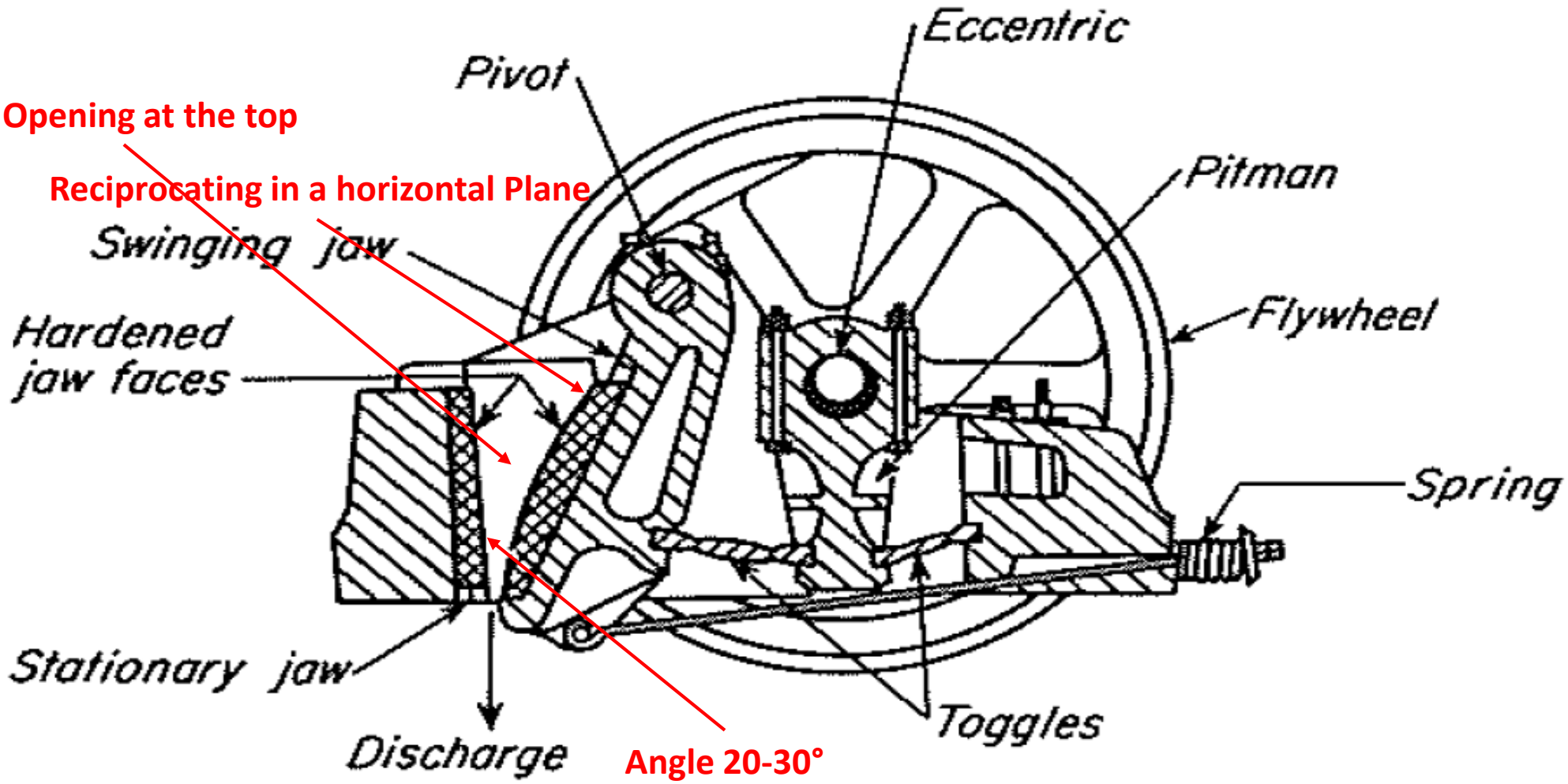
- Definite size and shape
- Product size will be 2-10 mm in length.

Breaking Pattern

- There are different mechanisms by which size reduction may be achieved.
- Impact: Particle breaks by a single rigid force
- Compression: Particle disintegration by two rigid forces
- Shear: Produced when the particle is compressed between 2 edges of the hard surfaces
- Attrition: Arising form particles scrapping between 2 surfaces.

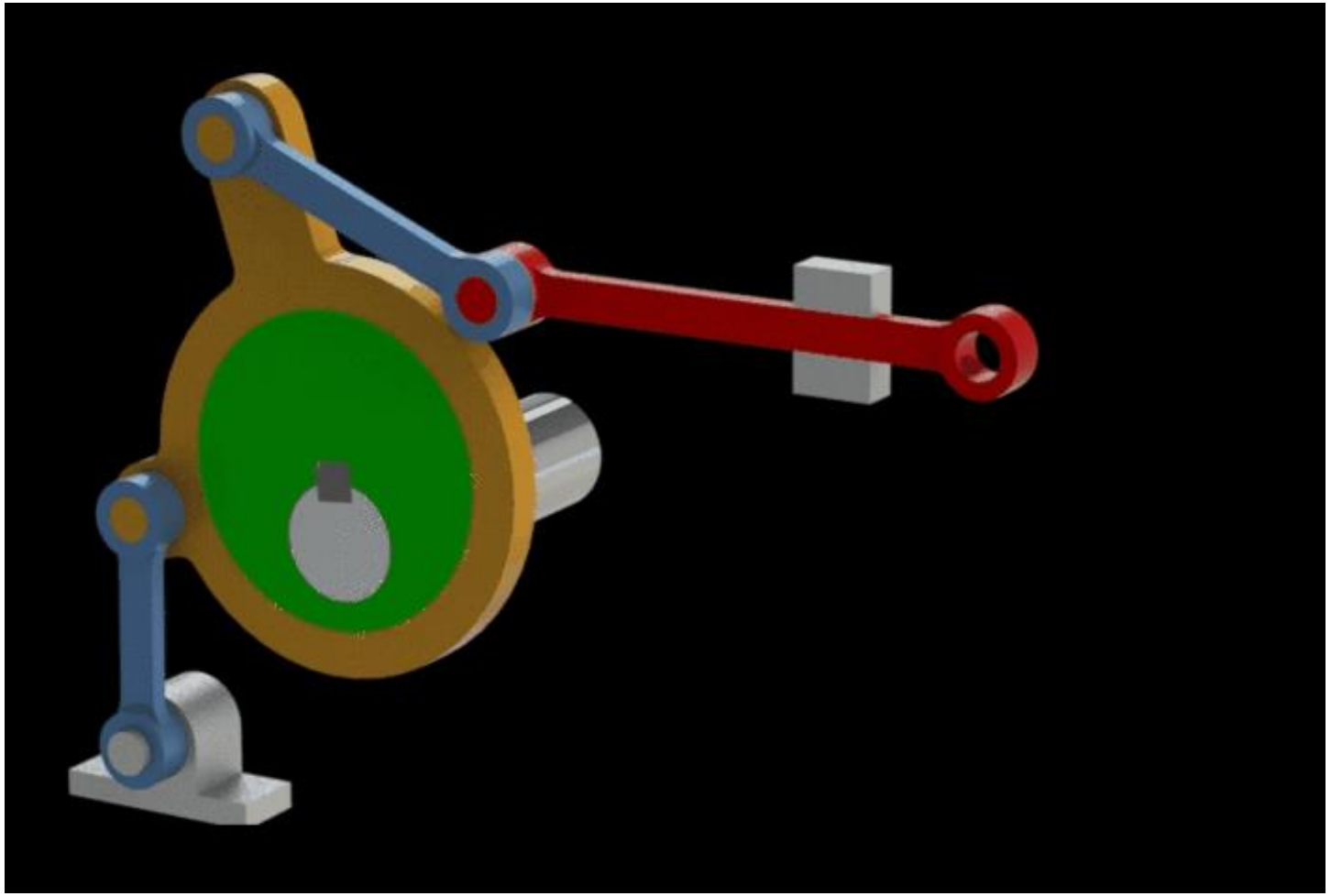


Crushers: Blake Jaw Crusher

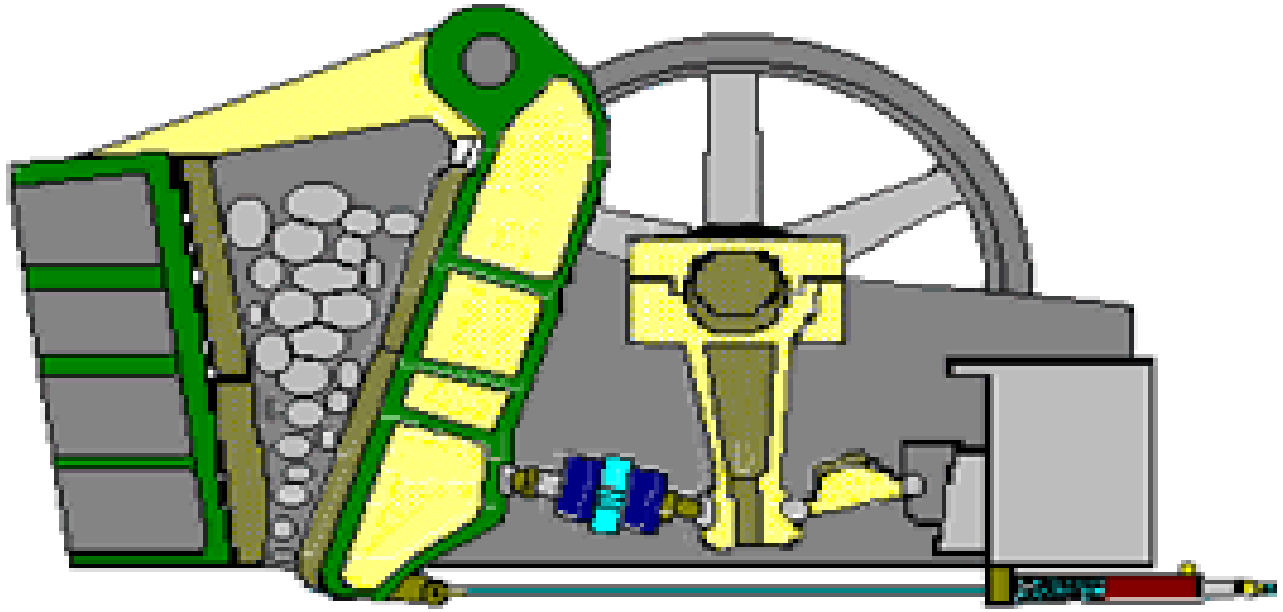


Crushers: Jaw Crusher

- **Eccentric Motion**



Crushers: Jaw Crusher



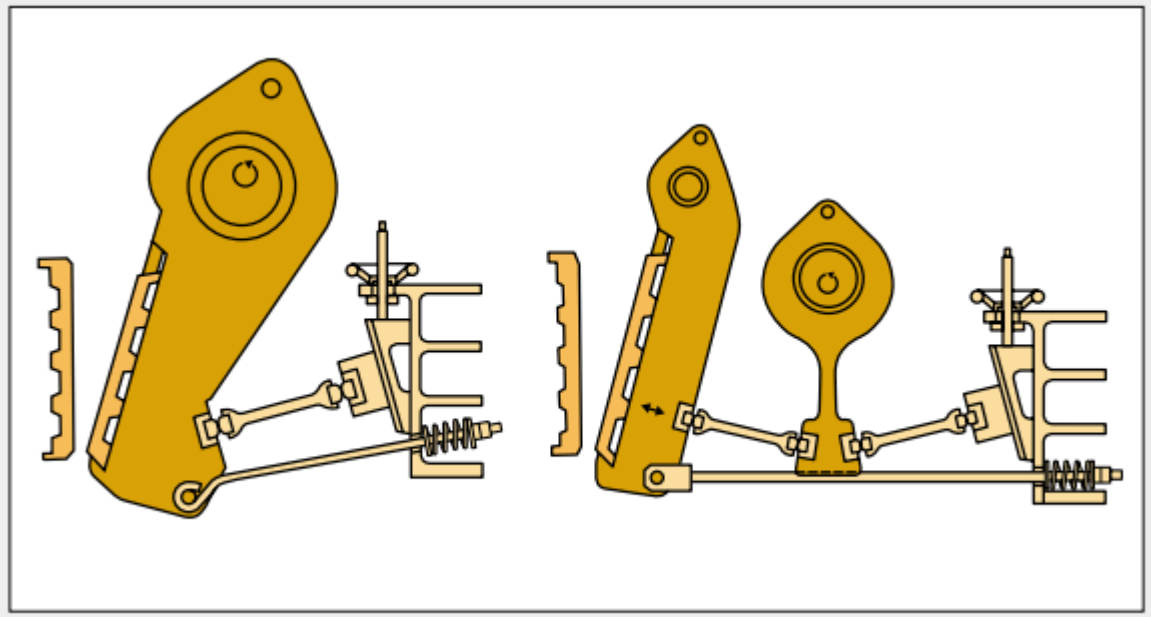
- The jaw open and close 250-400 times per minute.
- Mechanism: Compression
- Eccentric drives a pitman which is connected to two toggles among which one is connected to frame another to moving jaw.
- The greatest motion is at the bottom of ‘V’ which means there is little tendency to choke.
- Feed size 1.8m (6ft) in diameter.
- Product Size: 250 mm (10in)
- Capacity: 1200 ton/hr

Crushers : Types of Jaw Crusher

Single Toggle – An eccentric shaft positioned at the top of the crusher.

Double toggle – Two shafts – first pivoted at the top of the crusher where as other is an eccentric shaft which drives the both the toggles.

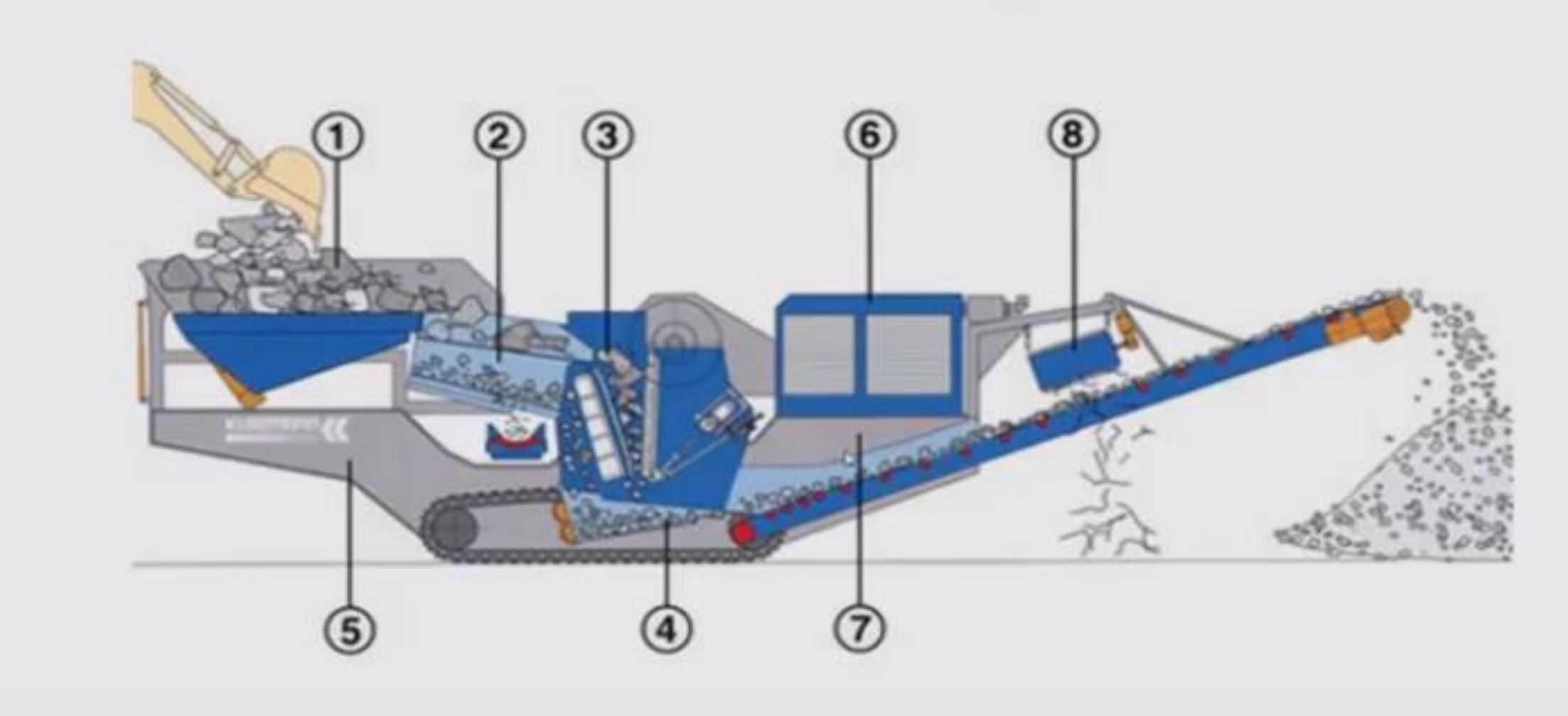
- Eccentric positioned behind the swinging jaw. It has two effects.
  1. It keeps the eccentric out of harm.
  2. The other effect is limited motion for swinging jaw, which reduces the productivity of the jaw.



Single toggle jaw crusher Double toggle jaw crusher

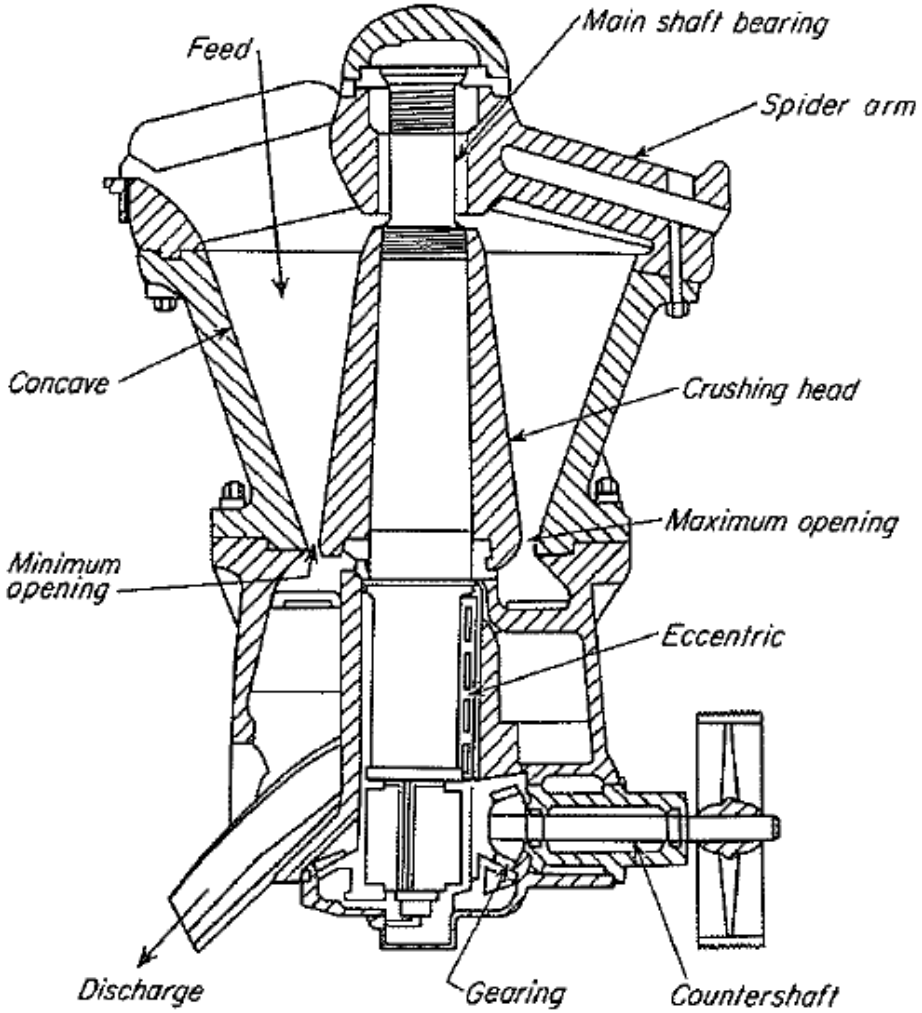
- In contrast, the single toggle jaw crusher has fewer shafts. It has two motions simultaneously: swinging motion that double toggle has and up and down motion from the eccentric.
- Single toggle crusher has better capacity compared to a double toggle crusher.

Crushers : Portable Jaw Crusher



Crushers : Gyratory Crusher

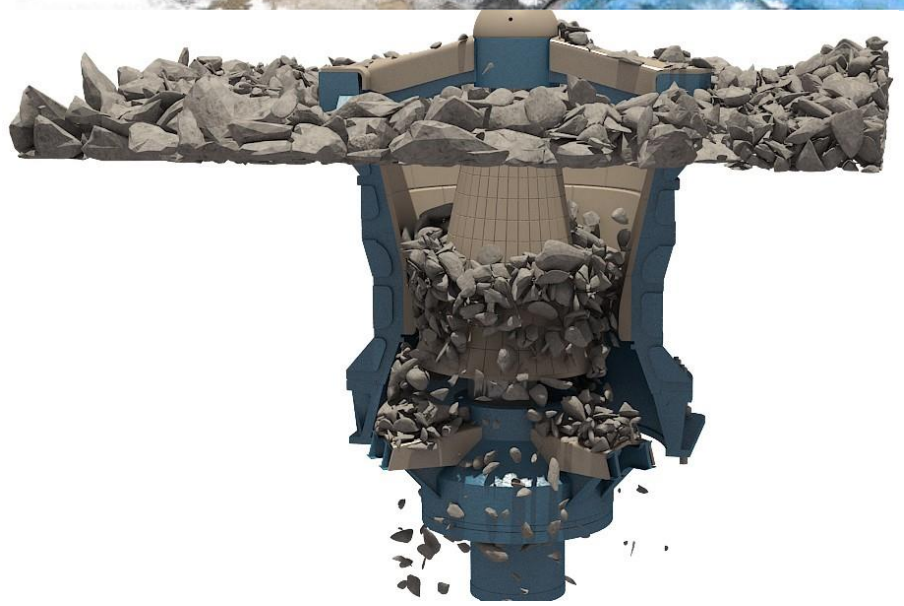
- Mechanism : Compression
- A gyratory crusher may be looked up on as a jaw crusher with circular jaws, between which material is being crushed at some point all the time.
- A conical crushing head gyrates inside a funnel shaped casing open at the top.
- A crushing head is pivoted at the top.
- An eccentric drives the bottom end of the shaft.
- The bottom of the crushing head move towards and away from the wall.
- Solid caught in the V-shaped space between the head and casing are broken and re-broken until they pass out the bottom.



Crushers : Gyratory Crusher

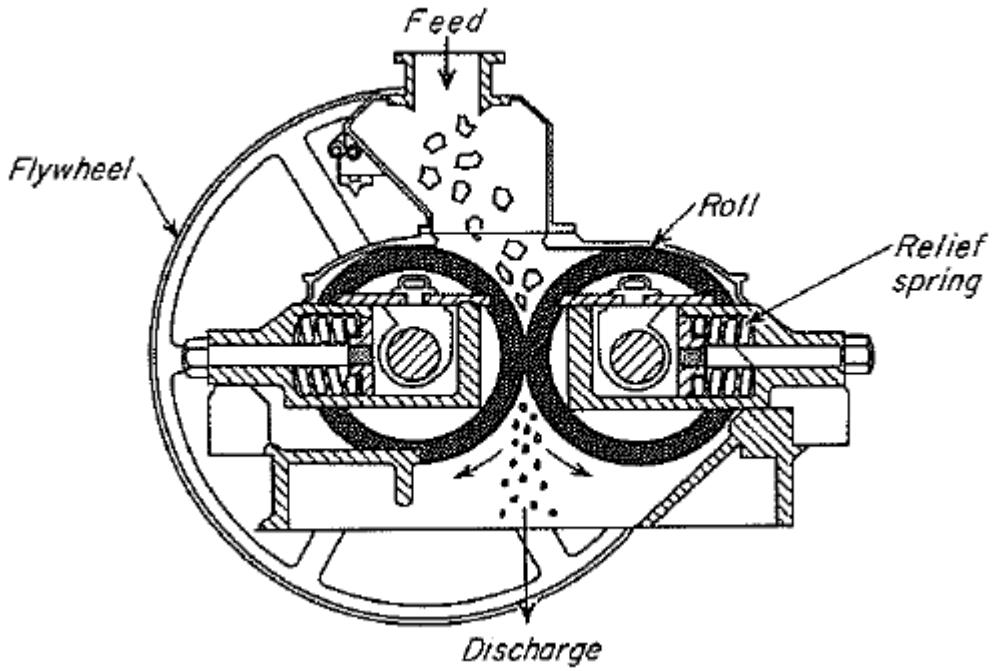
- Speed of gyratory is 125-425 gyratory per minute.
- Because some part of the working head is working all the time the discharge from the gyratory is continuous instead of intermittent as jaw crusher.
- Less maintenance and power requirement is small compared with jaw crusher.
- And the capacity is more than jaw crusher 4500 ton/hr.
- The capacity varies with
  1. Jaw setting
  2. The impact strength of the feed.
  3. Speed of the gyratory machine.

Crushers : Gyratory Crusher



Crushers : Smooth Roll Crushers

- Heavy smooth faced metal rolls turning on parallel horizontal are working elements of smooth roll crusher.
- Particles of feed caught between the rolls are broken in compression and drop out below.
- The rolls turn towards each other at the same speed.
- They have relatively narrow faces (300-917mm) and large diameter (600-1200mm) so that they can ‘nip’ the large lumps.
- Rolls speed 50-300 rpm.
- These are consider as secondary crushers with feeds 12-75 mm in size and the product is 12-1 mm.



- The product size can be estimated as

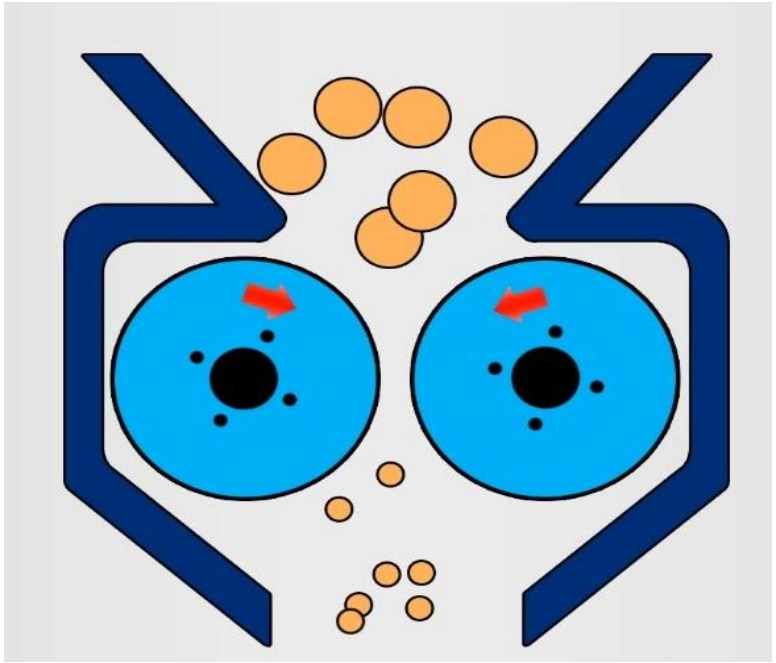
$$D_p = 0.04R+d$$

Where R = Radius of the roll

d = half the width of the gap between the rolls.

Crushers : Smooth Roll Crushers

- The maximum size of the product is 2d.
- These operates most effectively when set to give a reduction ratio of 3 or 4 or 1.
- That is the max diameter of the particle is 1/3rd or 1/4th of that feed.
- The forces exerted by these rolls are very great from 8700 – 70000 N/cm.
- To allow unbreakable material to pass through without damaging the machine, at least one roll must be spring mounted.



Crushers : Smooth Roll Crushers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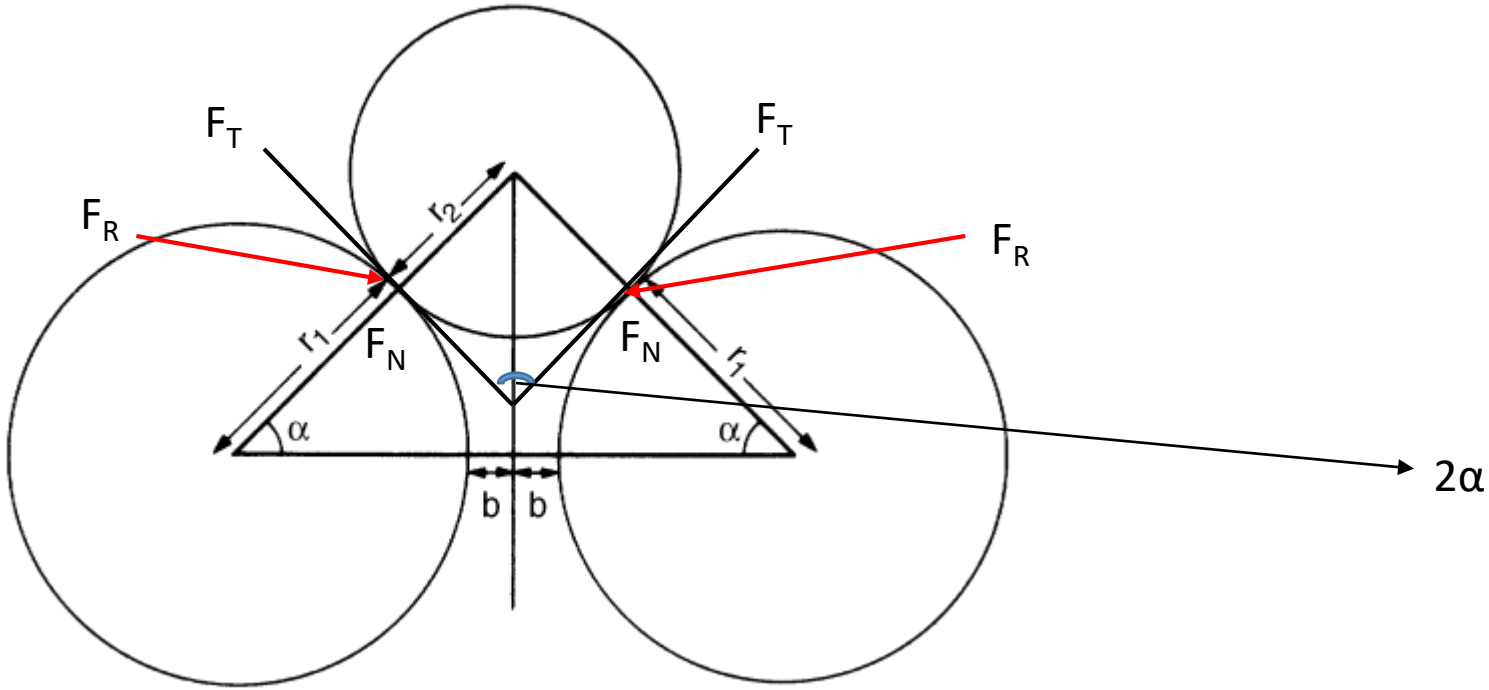
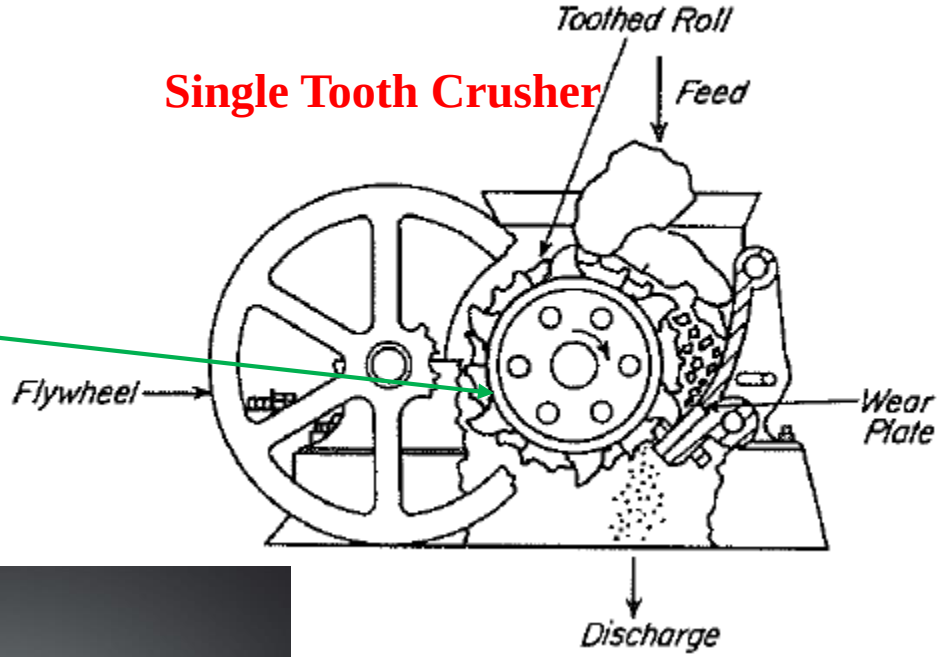
Crushers : Smooth Roll Crushers



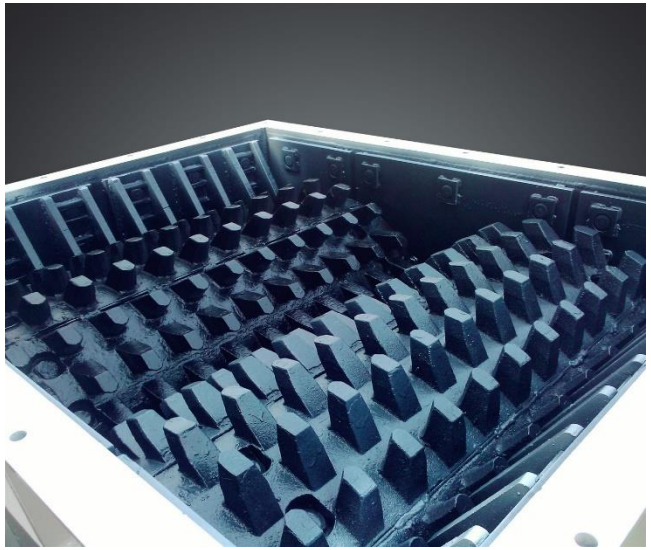
Crushers : Toothed Roll Crushers

- Roll faces carry corrugations, breaker bars, or teeth.
- Contains 2 rolls as in smooth roll crusher or one roll acting against stationary curved breaker plate.
- Machine shown in a figure is single roll toothed crusher.
- Machines known as disintegrators contain two corrugated rolls turning at two different speeds which tear the feed apart.

Single Tooth Crusher



Double Tooth Crusher



Pyramid Tooth

Crushers : Toothed Roll Crushers

- Toothed roll crushers are much more versatile then smooth roll crusher, within the limitation that they cannot handle very hard solids.
- Operated by compression, impact and shear.
- The particle size feed to these machines may be given as great as 500 mm and the capacity is 500tons/hr.

Crushers : Toothed Roll Crushers

Breaking Pattern of the Crushers

Crusher	Compression	Impact	Attrition	Shear
Jaw Crusher	Y			
Gyratory Crusher	Y			
Smooth Roll Crusher	Y			
Tooth Roll Crusher	Y	Y		Y

Comparison

Crusher	Feed Size	Product Size	Capacity (ton/hr)	Power Requirement
Jaw Crusher	1.8 m	250 mm	1200	High
Gyratory Crusher	Same	Same	4500	High
Smooth Roll Crusher	12-75 mm	12-1 mm	350	Low
Tooth Roll Crusher	500 mm	Same	500	Low

Grinders

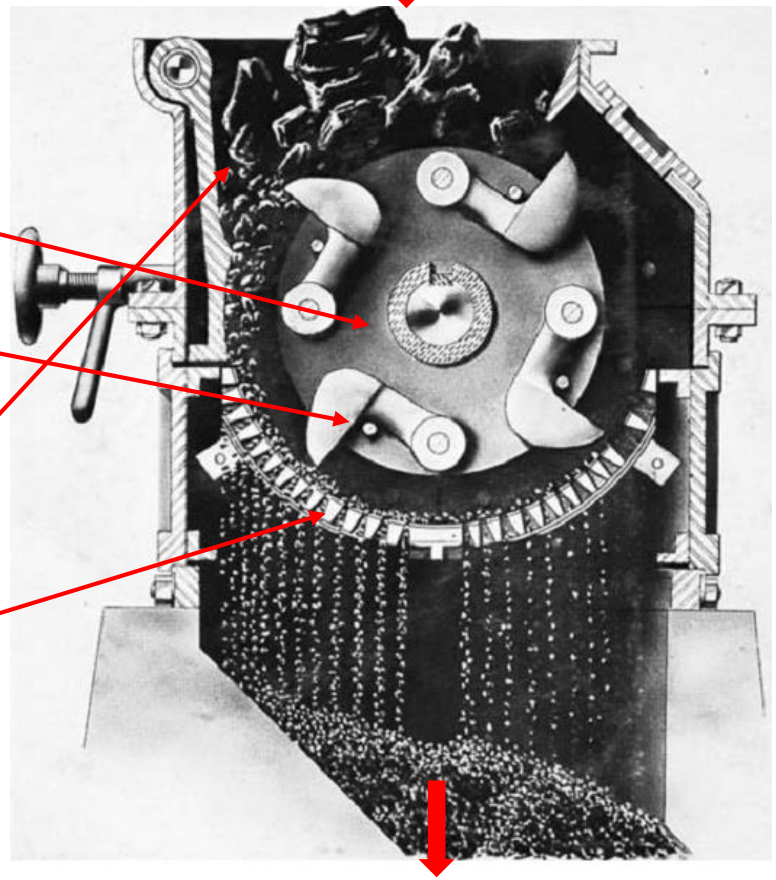
- The product from a crusher is often fed to grinder in which it is reduced to powder.

Grinders (Intermediate and Fine)

1. Hammer Mills
2. Rolling Compression Mills
   a. Bowl Mills
   b. Roller Mills
3. Attrition Mills
4. Tumbling Mills
   a. Rod Mills
   b. Ball Mill; Pebble Mill
   c. Tube Mills; Compartment Mills

Grinders: Hammer Mill

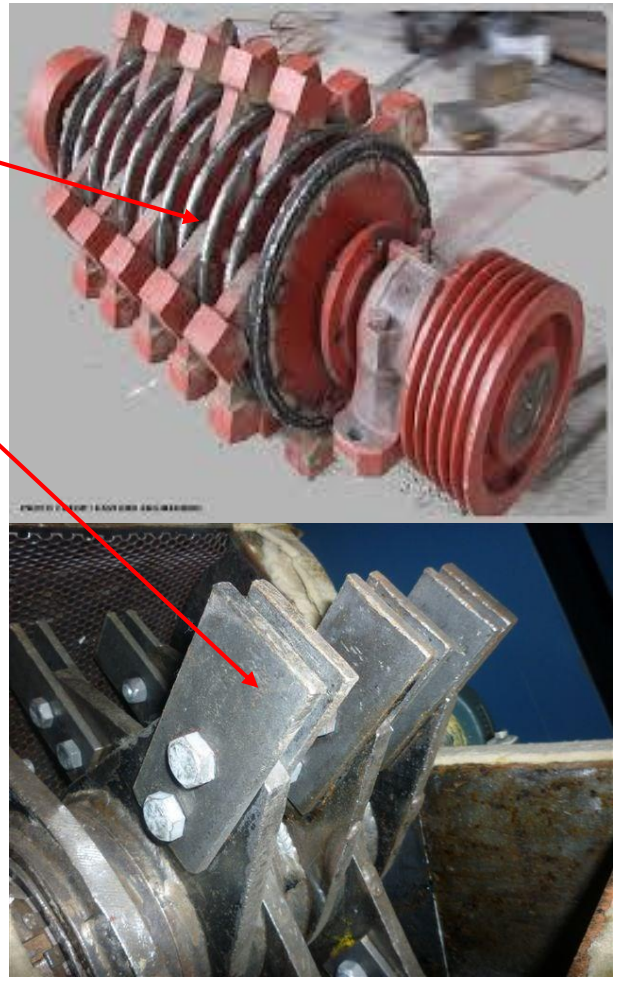
- Contains high speed rotor.
- Feed dropped into the top of casing is broken and fall out through the bottom opening.
- Particles are broken by sets of swing hammer pinned to a rotor disk.
- Particle enter into the casing can not escape being struck by the hammers.
- It shatters into pieces, which fly against stationary anvil plate and break into small pieces.
- These in turn rubbed into powder by hammers and pushed through the grate or screen that covers the discharge opening.



Swing claw hammer mill

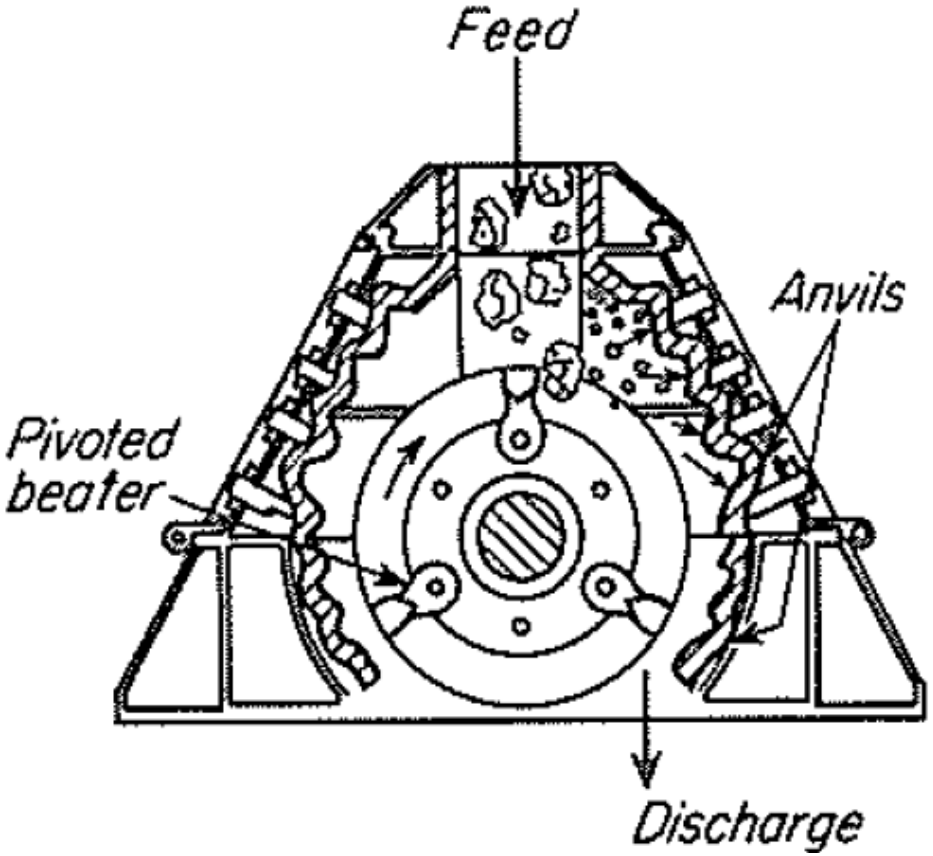
Grinders: Hammer Mill

- Several rotary disks 150-450 mm in diameter contains and each having 4 to 8 hammers mounted on the same shaft.
- The hammers may be straight bars of metals with plain or enlarged ends or with ends sharpened to a cutting edge.
- Product size will be from 25 mm to 20 mesh (0.833 mm) in particle size.
- Operating speed is 110 m/s.
- Type of material crushed
  - ✓ Tough fibrous solids
  - ✓ Steel
  - ✓ Soft wet pastes
  - ✓ Sticky clay
  - ✓ Hard rock
- Capacity is depends on the type of material to be crushed.
- 1 KWh of energy is consumed for every 60-240 kg of



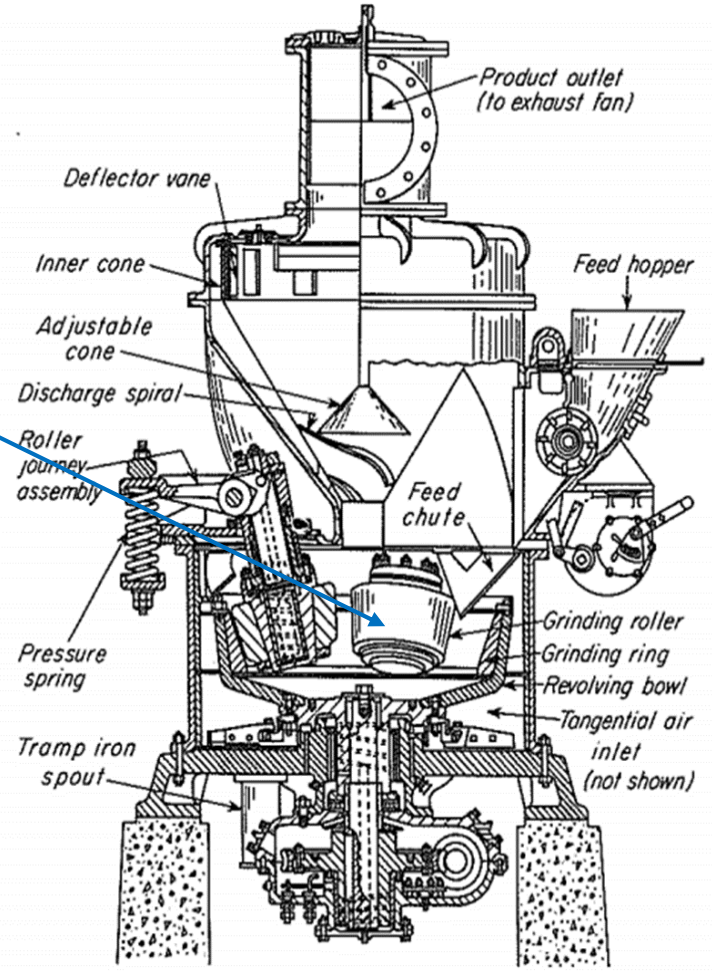
Grinders: Impactor

- An impact or illustrated in figure resembles the duty of heavy hammer mill except that it contains no grate or screen.
- Rotor will be same as in hammer mill.
- Particles are broken by impact alone without rubbing action as in hammer mills.
- Consider as a primary crusher for rock and ore, processing up to 600 ton/hr.
- Give equidimensional particles (mostly cubical) than slab shaped particles which are given by from jaw or gyratory crusher



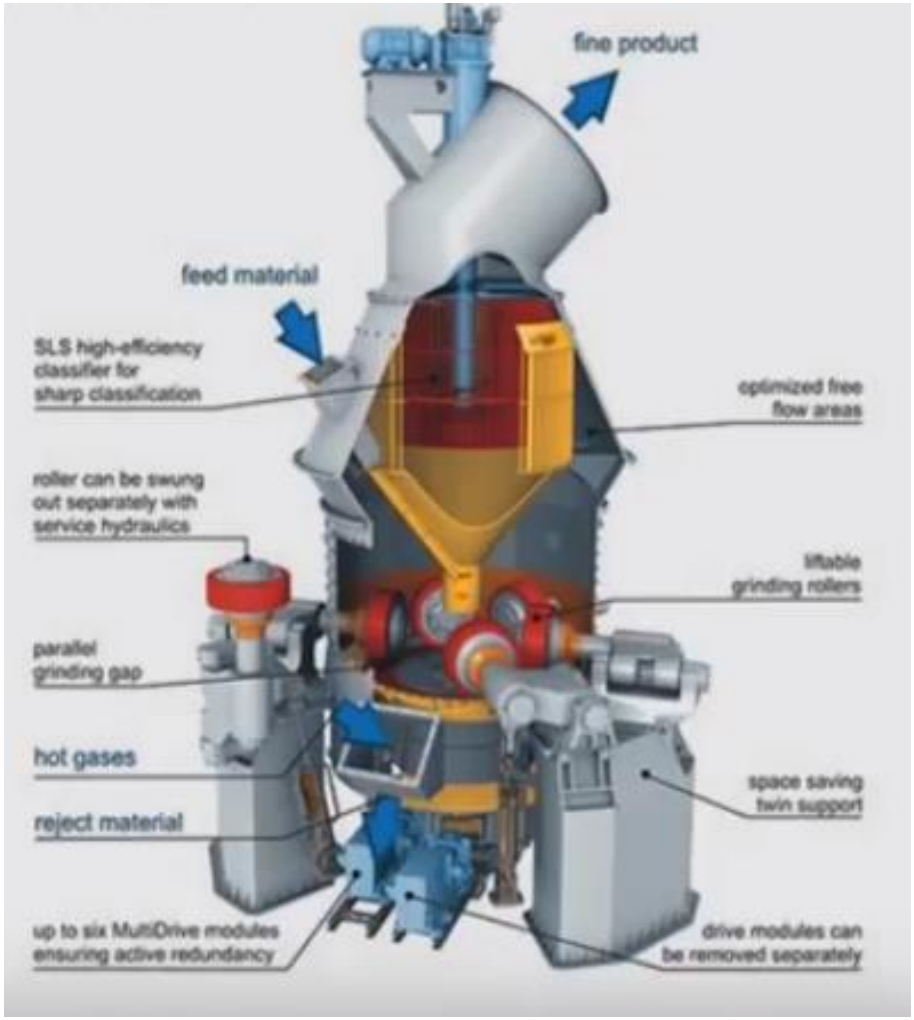
Grinders: Rolling-Compression Machines

- In this kind of mill the solid particles are caught and crushed between a rolling member and face of the ring or casing.
- The most common types are
  - Rolling ring pulverisers
  - Bowl mills
  - And the roller mills.
- One of the roller miller is showing in the figure.
- Vertical cylindrical rollers press outward with great force against a stationary anvil ring or bull ring.
- Plows lift the solid lumps from the floor and direct them between roll and ring.



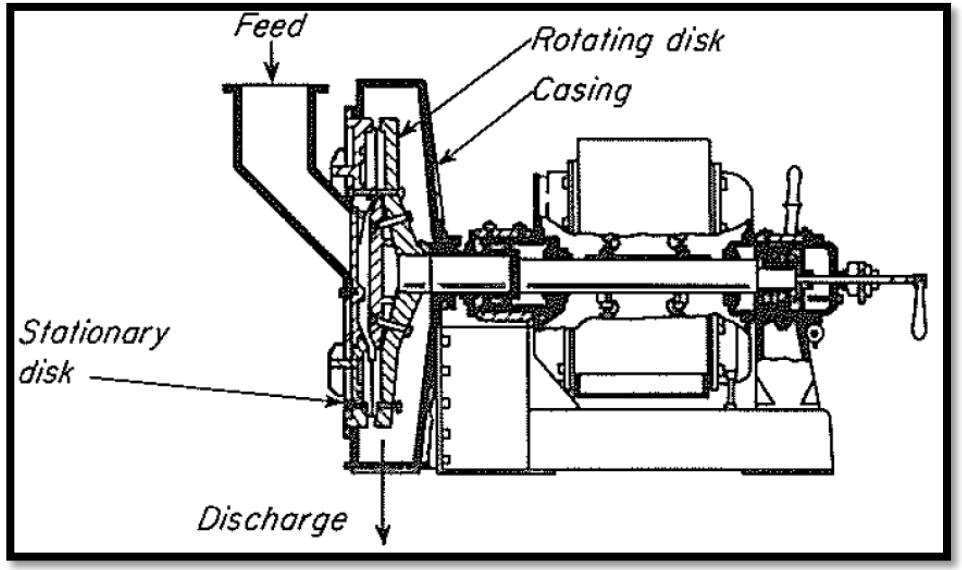
Grinders: Rolling-Compression Machines

- Product is swept out of the mille by stream of air to a classifier separator from which over size particles return to the mill for further reduction.
- The rollers rotate on the stationary axes which may be vertical or horizontal.
- These are used to grind the
  - Lime stone
  - Cement clinker
  - Coal
- Capacity is 500 ton/hr
- Product size may be as fine as 99% pass through a 200 mesh screen (i.e 74 micron).



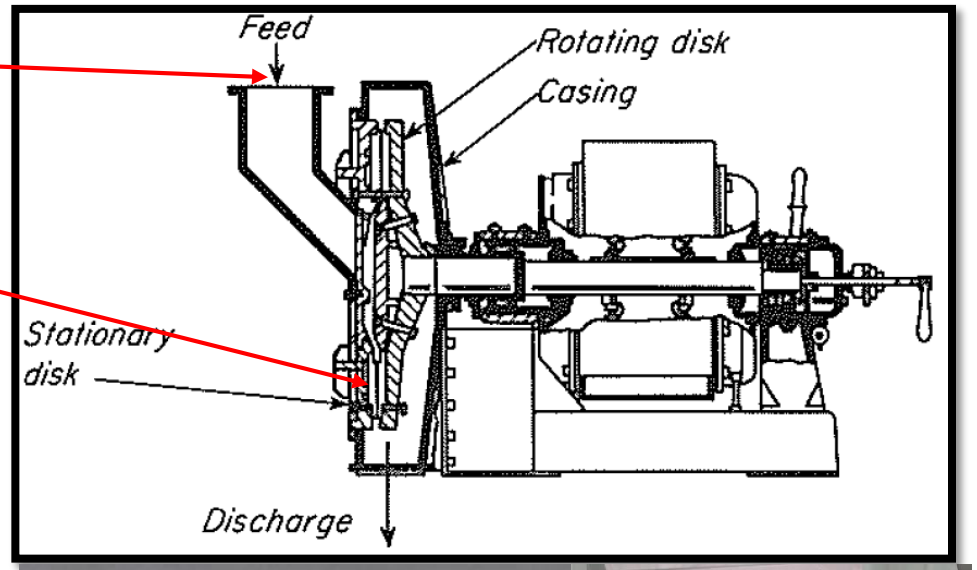
Grinders: Attrition Mills

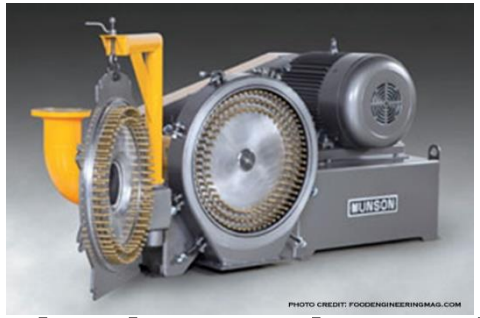
- Particles of soft solids are rubbed between the grooved flat faces of rotating circular disks.
- The axis of the disk usually horizontal, some times vertical.



Grinders: Attrition Mills

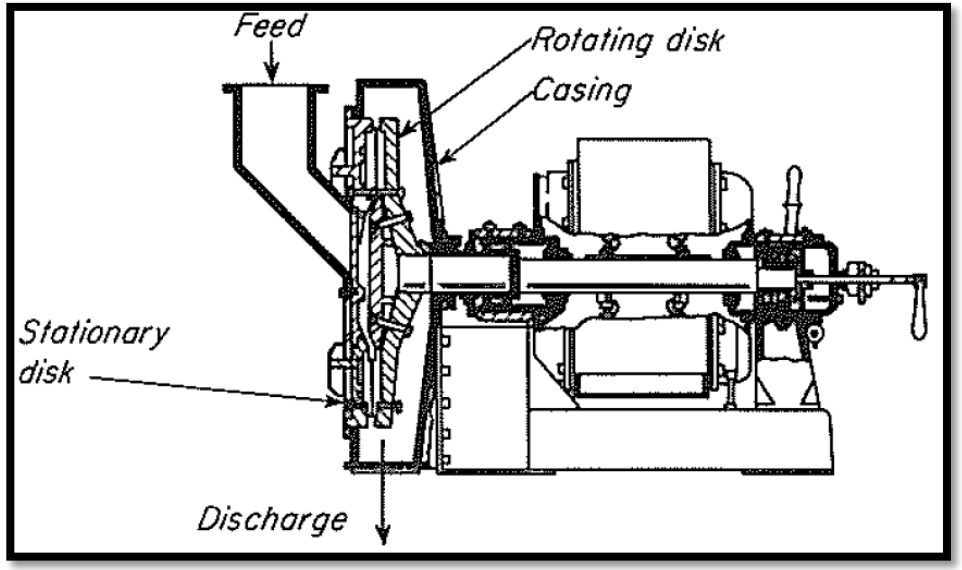
- Feed enters through an opening in the hub of one of the disk and passes outward through a narrow gap between the disks.
- The width of the gap within limits can be adjustable.
- At least one of the disk is spring mounted to allow unbreakable material.
- Disks with different patterns such as grooves, corrugations and teeth on the disk perform variety of operations.
  - Grinding
  - Cracking
  - Granulating
  - Shredding
  - And some operations not related to grinding such as blending and feather curling





Grinders: Attrition Mills

- A single runner attrition mill contains disks of rock emery for reducing solids like clay and talc.
- And metal disks for crushing wood, starch, insecticide powders and wax.
- Metal disks are usually made up of white iron, and in some cases stainless steel for corrosive materials.
- Double runner mills give fine products but process soft solids only.
- Air is drawn through the disk to remove the product and prevent choking.



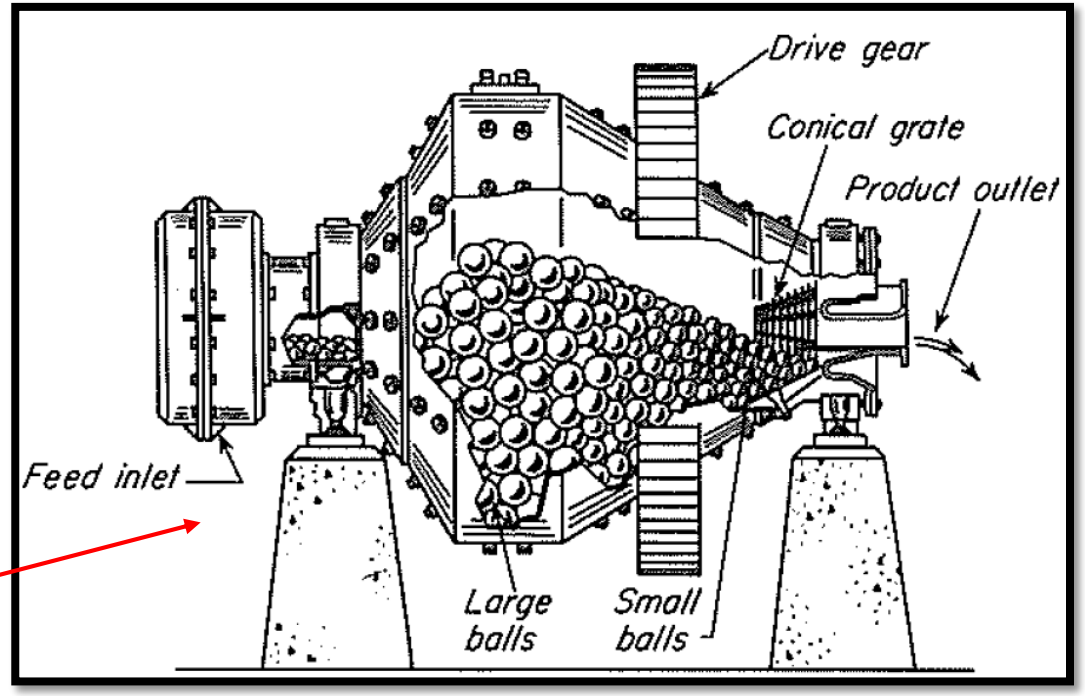
- More heat is generated which can be removed by spraying water or refrigerator brine.
- Removal of heat is essential in case of sensitive materials like rubber.

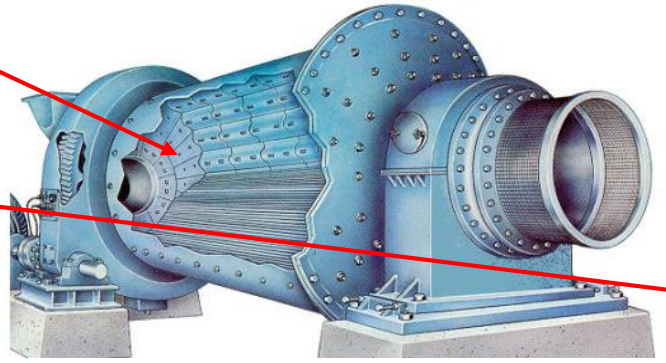
Grinders: Attrition Mills

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

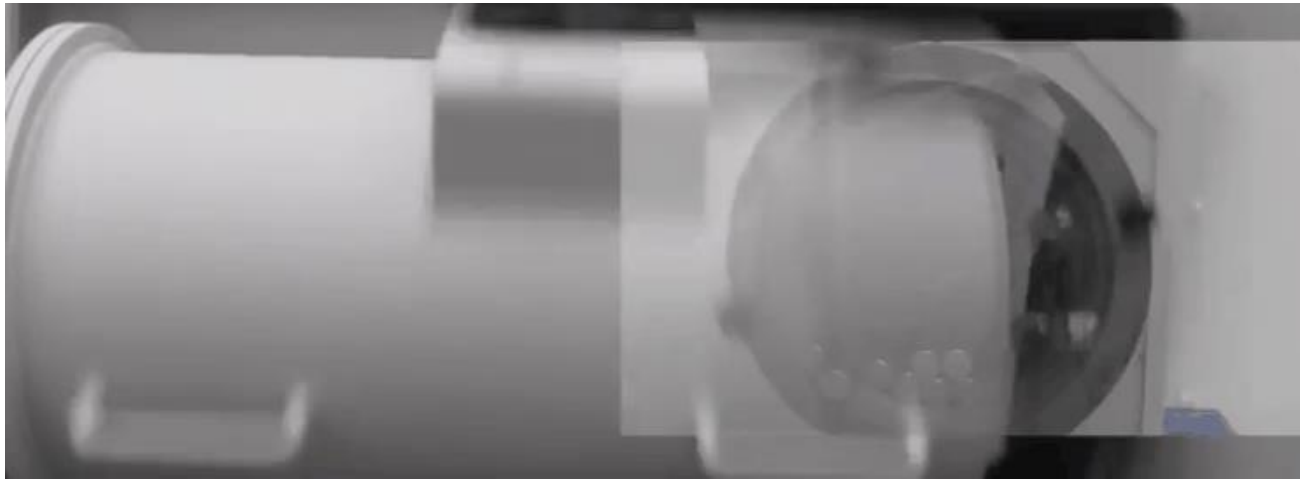
Grinders: Tumbling Mill

- A typical tumbling mill is shown in figure
- A cylindrical shell slowly turning about its horizontal axis and filled about half of its volume with grinding medium.
- The shell is usually steel line with carbon steel plate, porcelain, silica rock or rubber.
- The grinding medium
  - Is metal rods in rod mill.
  - Lengths of chain or balls of metal, rubber or wood in ball mill.
  - Flint pebbles or porcelain or zircon spheres in a pebble mill.



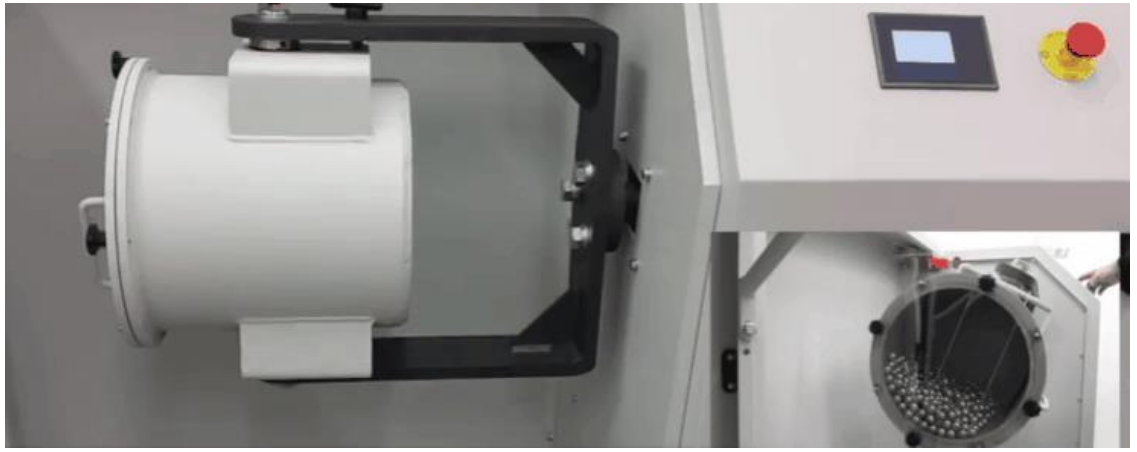


Grinders: Tumbling Mill



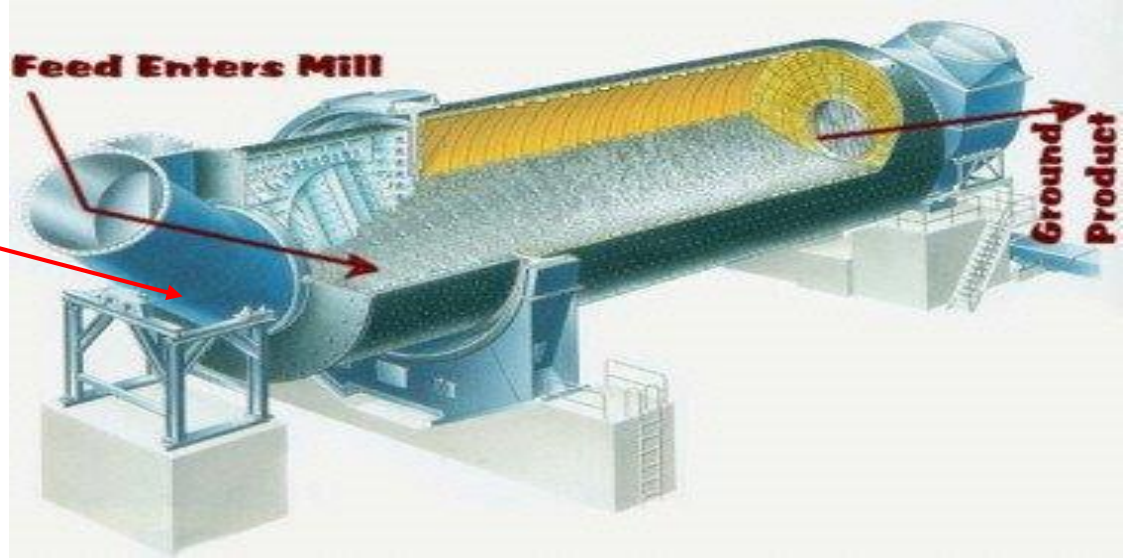
Motion in rod mill

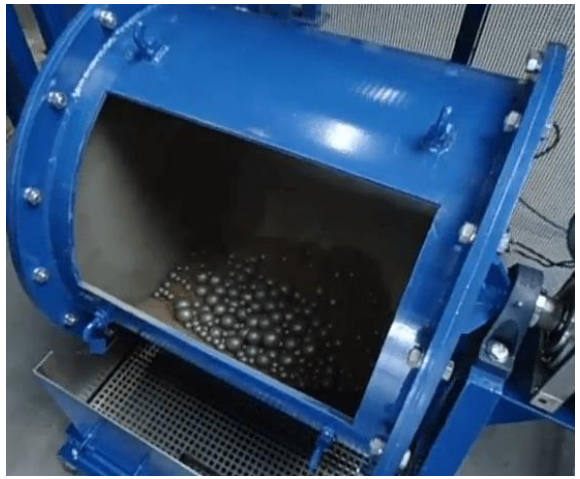
Motion in ball mill



Grinders: Tumbling Mill

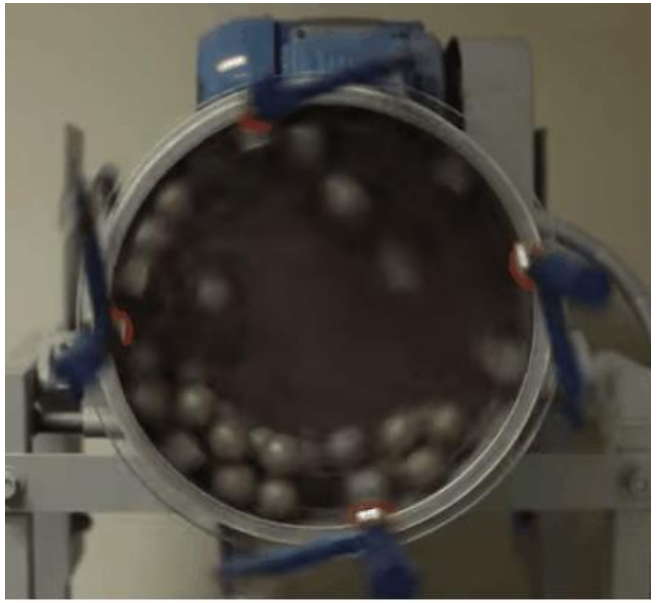
Continuous and
Batch tumbling mills





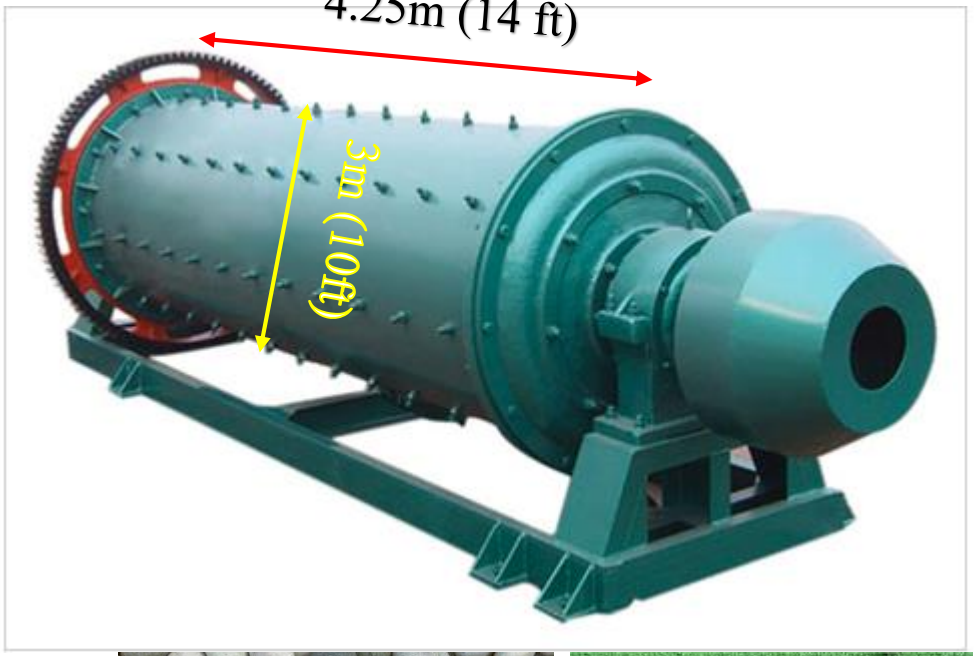
Grinders: Tumbling Mill

- In all tumbling mills the grinding elements carried up the side of the shell from there they fall on the particles underneath.
- The energy expanded in lifting the grinding elements is utilised in reducing particle size.
- Therefore the breaking pattern in ball mill is impact alone.
- Where as in other tumbling mills such as rod mill particles are reduced from the rolling compressing and attrition.
- The grinding rods are usually steel, 25-125 mm in size and extended the full length of the shell.
- Rod mills are intermediate grinders reducing 20 mm feed size to 0.833 mm (i.e 10 mesh screen).

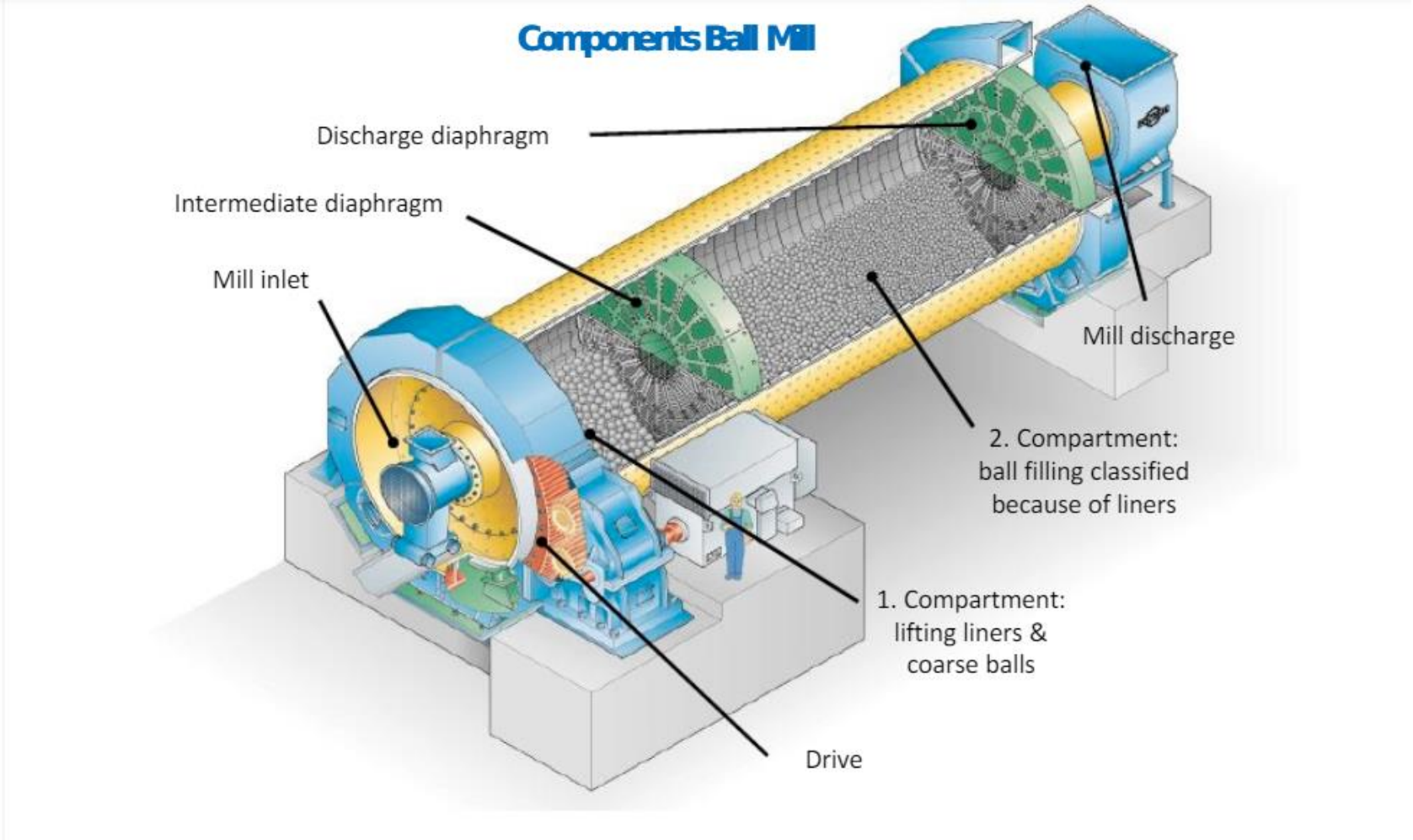


Grinders: Tumbling Mill – Ball Mill

Industrial ball mills

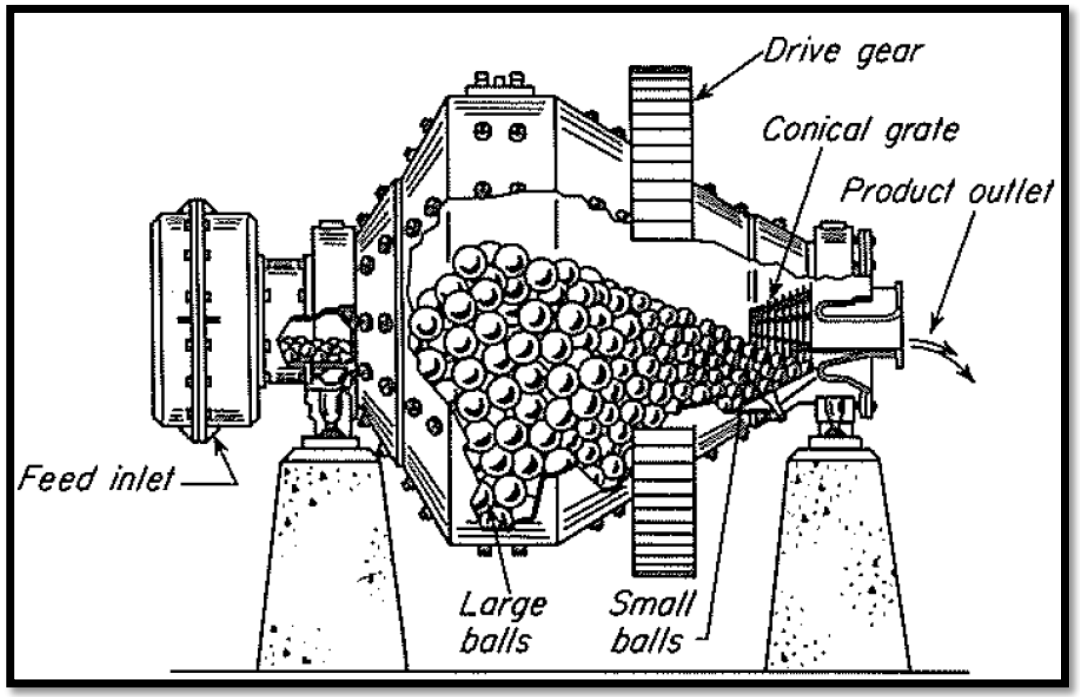


Grinders: Tumbling Mill – Compartment Ball Mill

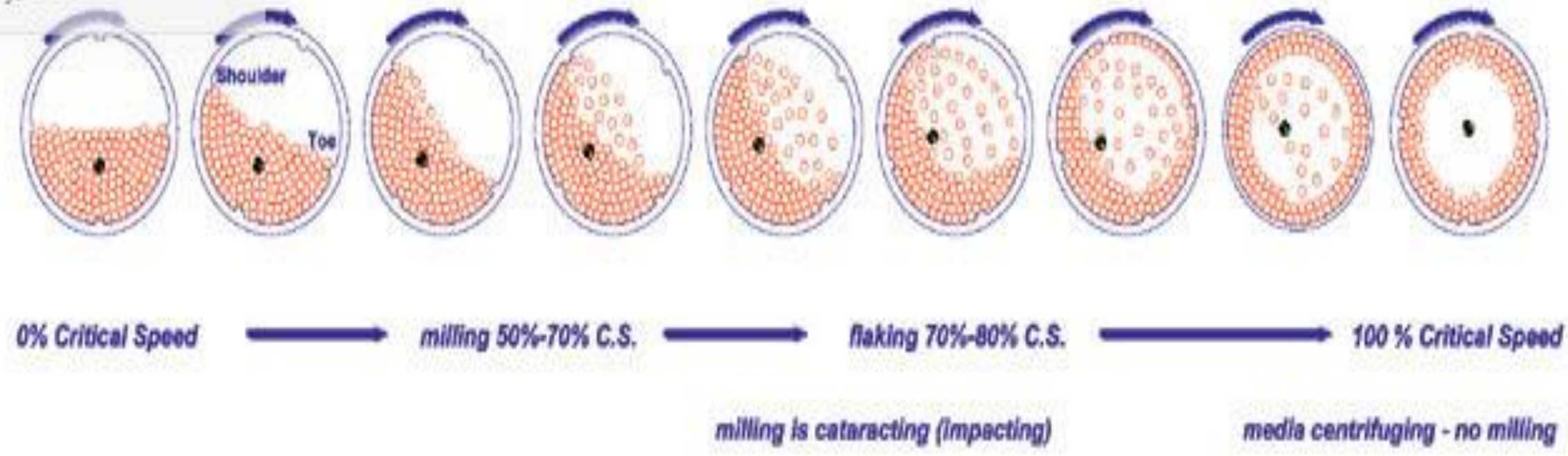


Grinders: Tumbling Mill – Compartment Ball Mill (Conical)

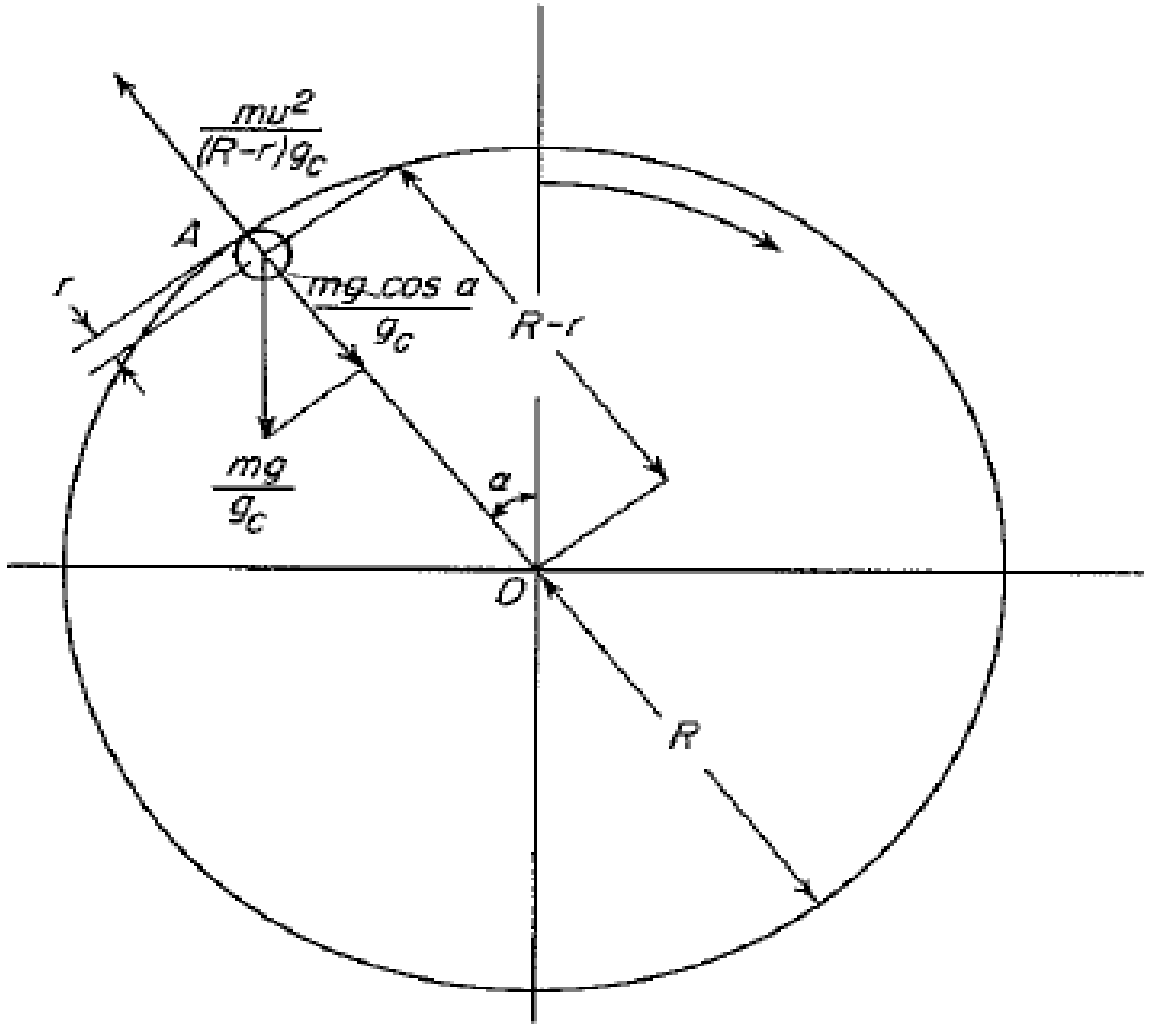
- Segregation of grinding units in a single chamber is a characteristic of conical ball mill shown in the figure.
- Feed enters from left through a 60° cone into the primary grinding zone where the diameter of the balls are large.
- And leaves through the 30° cone to the right where the dia of the balls are less.
- Large balls becomes small as mill is operated and migrates towards the discharge.
- New large balls are added periodically.
- Initial breaking of large particles occurs by large balls and small particle by small balls.
- This kind of mills increase the efficiency.



Grinders: Tumbling Mill-Action in Tumbling Mill



Grinders: Tumbling Mill-Action in Tumbling Mill



Grinders: Tumbling Mills – Capacity and Power Requirement

Type of Tumbling mill	Capacity	Power Requirement	Feed Size	Product Size
Rod Mill	5-200 ton/h	4kWh/metric ton	150-200 mm	Pass through 10 mesh
Ball Mill	1-50 ton/h	16kWh/metric ton	150-200 mm	Pass through 200 mesh screen
Tube mills and compartment mills	Less than above	More than above	150-200 mm	Fine powder than above

Ultrafine Grinders

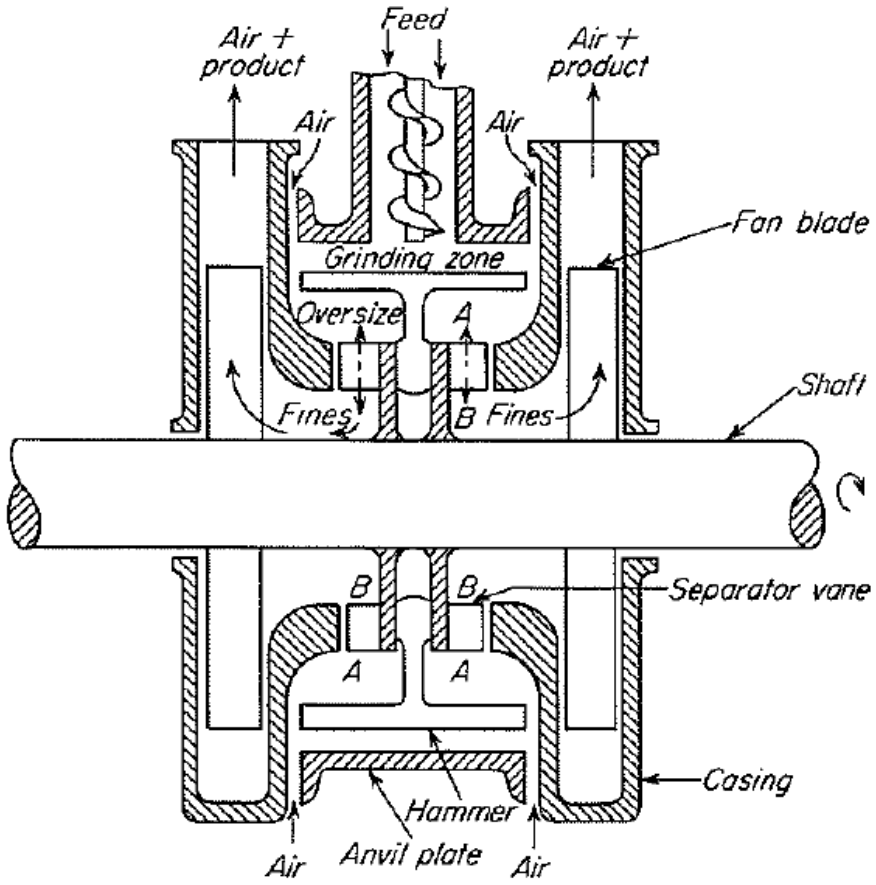
- Many commercial powders must contain particles averaging 1 to 20 microns in size.
- Mills that reduces solids to such fine powders are called ultrafine grinders.
- Ultrafine grinding can be done based on dry and wet basis
  - Dry Basis
    - High speed hammer mills with internal and external classification.
  - Wet basis
    - Fluid energy or jet mills.

Ultrafine Grinders: 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.

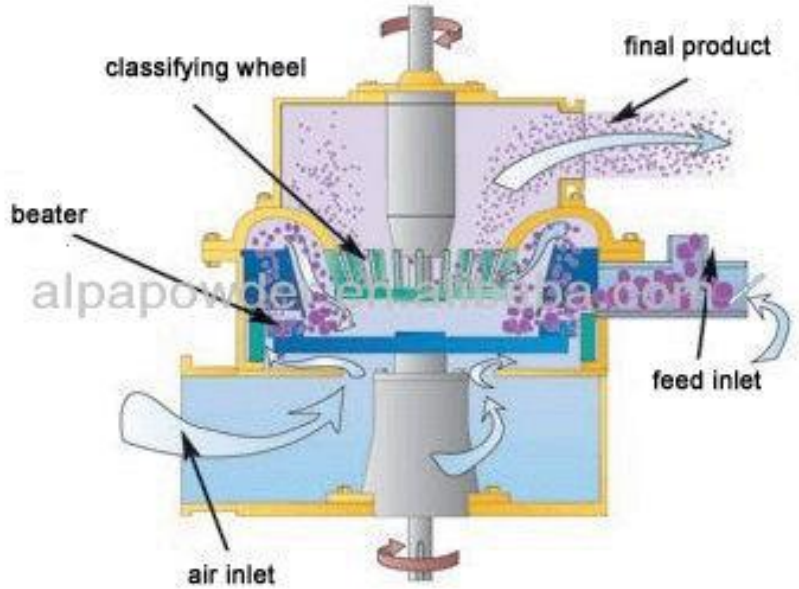
Principle:

- 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



Ultrafine Grinders: Classifying Hammer Mills

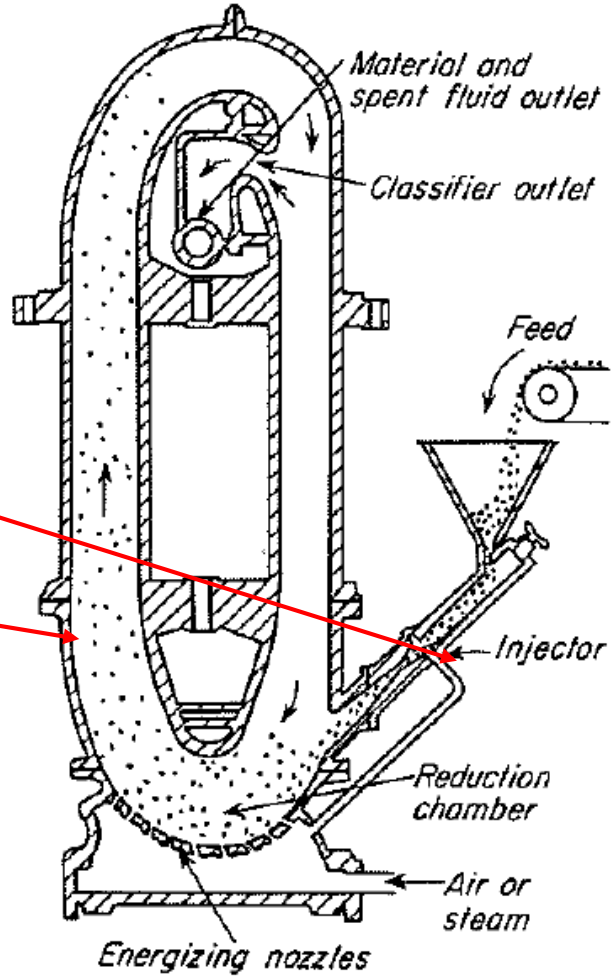
- The passage of particles through the vanes is depends on the two predominant forces.
  1. Centrifugal Force by vanes.
  2. Drag force by air stream.
- Coarse particle are thrown back into the grinding zone by the vanes.
- And fine particles are carried by the air stream.
- Capacity – 1 to 2 ton/h
-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



Ultrafine Grinders: Classifying Hammer Mills

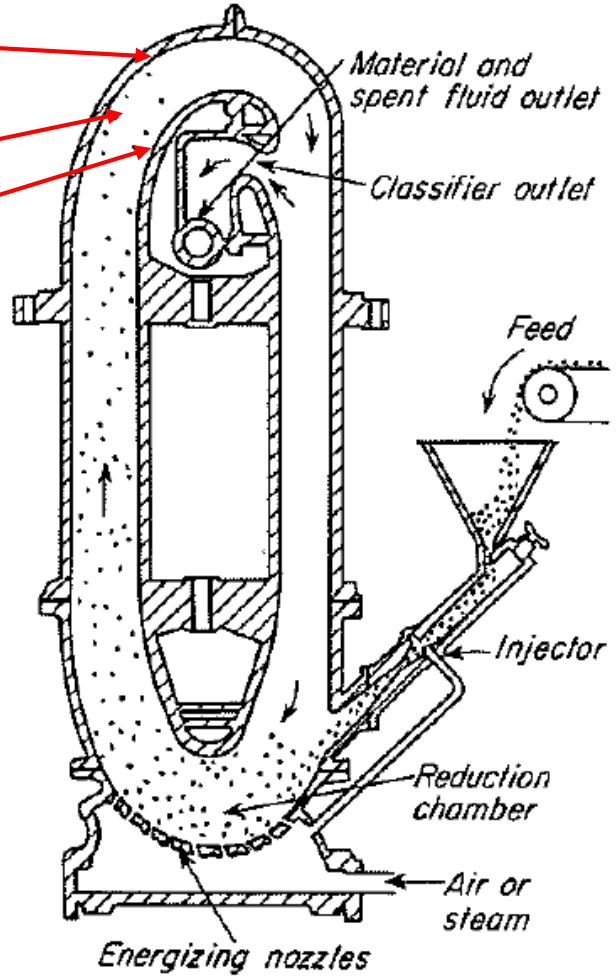
Ultrafine Grinders: Fluid Energy Mills

- In these mills the particles are suspended in a high velocity gas stream.
- The gas is injected along the particles into the confining chamber.
- Some reduction occurs when particles strike or rub against walls of the grinding chamber.
  - Grinding chamber is an over loop of pipe 25-200 mm in diameter and 1.2 to 2.4 m height.
- But most of the reduction is to be caused by the interparticle attrition.
- Internal classification keeps the larger particles in the chamber until they reduce into desired size.
- The suspending gas is usually the compressed air or superheated steam admitted at a pressure of 7 atm through the energizing nozzles.



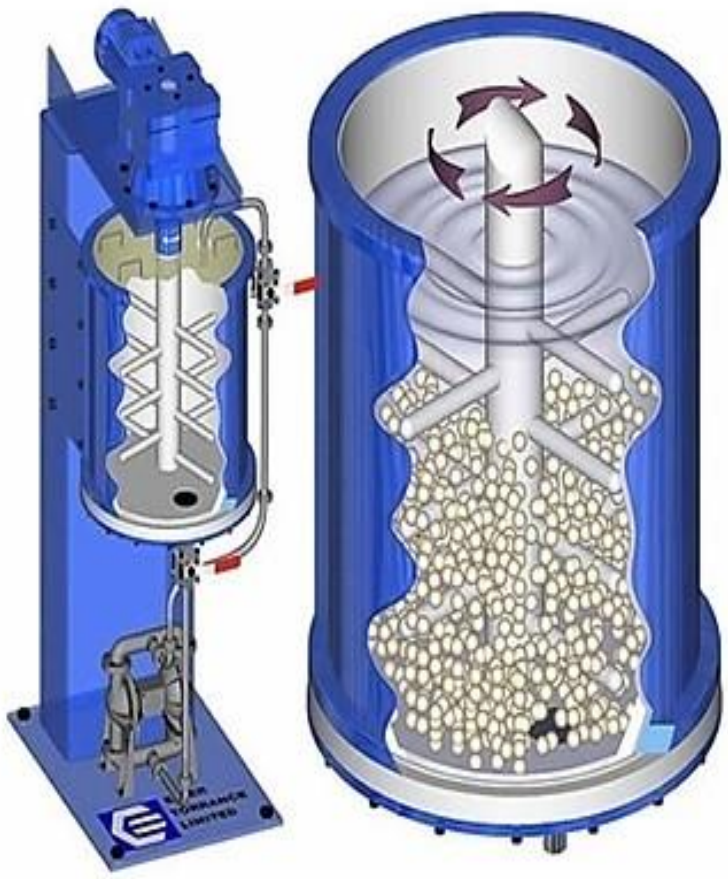
Ultrafine Grinders: Fluid Energy Mills

- Classification of ground particles takes place at the upper bend of the chamber.
- As the gas flows with high speed around this bend, the coarser particles thrown outward to outer wall of the chamber and the fine particles congregate inner wall of the chamber.
- A discharge opening at inner wall is connected to a cyclone separator or bag filters for the product.
- Feed size is 12 mm but it is more effective when the feed particles are less than 100 mesh screen.
- Product size is 500 nm to 10 microns
- And the amount of steam is used 1-4 kg/kg of product
- Compressed air is 6-9 kg of air /kg of product is used.
- Capacity is up to 6000 kg/h



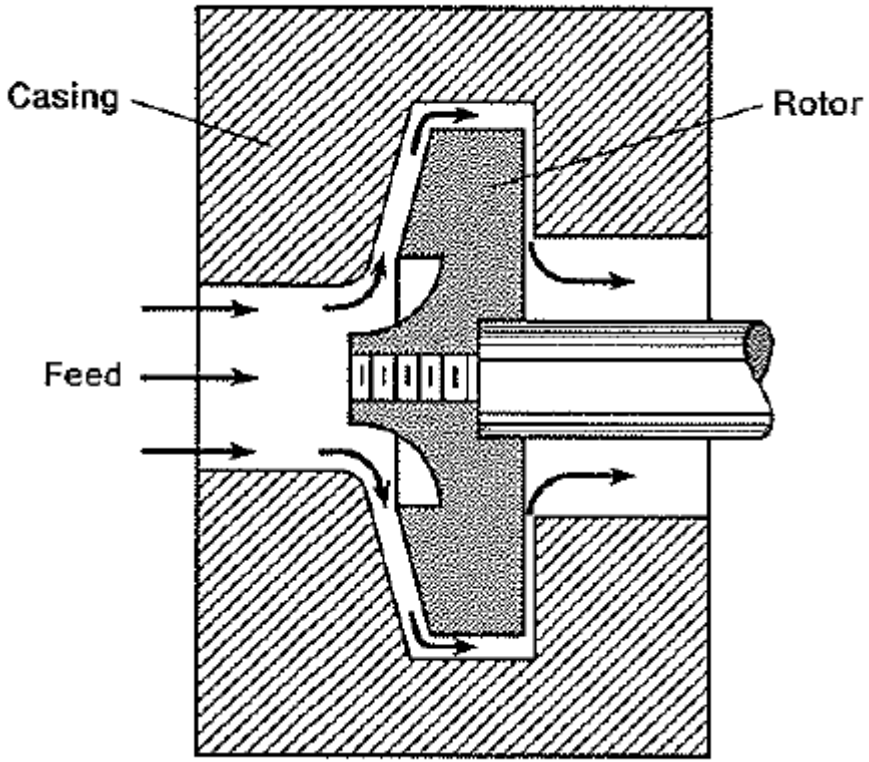
Ultrafine Grinders: Agitated Mills

- 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 1200L 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 1 micron or less size of particle.



Ultrafine Grinders: Colloid Mills

- The feed liquid with particles suspended in it is pumped to closely spaced surfaces.
- Among which one is stationary and other one is moving relative to other with a speed of 50 m/s or more.
- The principal action is disruption of lightly bonded clusters or agglomerates.
- The final size of the particle is less than 5 microns.
- And the space between the surfaces can be adjustable to 25 microns.
- Syrups, milk, ointments, paints etc. are processed in this way.
- The capacities of colloid mills are relatively low ranging from 2-3 L/min to 440 L/min



Cutting Machines:

- In some size reduction problems the feedstock is to tenacious or too resilient to broken by compression, impact, or attrition.
- In other problems feed must be reduced to particles of fixed dimensions.
- These requirements are met by the devices that cut, chop or tear the material into desired characteristics.
  - Rotary knife cutters and granulators are considered as the cutting machines.
- These are used in the manufacture of rubber, plastics and recycling of paper and pulp.

Cutting Machines: Rotary Knife Cutters

- A rotary knife cutter shown in figure contains horizontal rotor turning at 200 to 900 r/min inside a cylindrical chamber.
- On the rotary 2-12 flying knives with the edges of tampered steel or stellite pass with close clearance over 1-7 stationary bed knives.
- Feed particles entering the chamber from above are cut several times per minute.
- And emerged at the bottom through a screen with 5-8 mm opening.
- Rotary knife cutters and granulators are similar in design.
- A granulator yields more or less irregular pieces.
- But a cutter yield cube, thin squares and some times diamond shapes.