Ball mill

- The ball mill consists of a horizontally rotating hollow vessel of cylindrical shape with the length slightly greater than its diameter. The mill is partially filled with balls of steel or pebbles are used, it is known as rod or bars are used, it is known as a rod mill.
- The rod mill is particularly useful with sticky material that would hold the balls together ,because the greater weight of the rods causes them to pull apart.
- Ball milling is combination of impact & attrition.

The tube mill is a modified ball mill in which the length if about four times that of the diameter and in which the balls are somewhat smaller than in a ball mill. Because the material remains in the longer tube mill for a greater length of time, the tube mill grinds more finely than the ball mill. The ball mill may be modified to a conical shape and tapered at the discharge end. If balls of different size are used in a conical ball mill, they segregate according to size and provide progressively finer grinding as the material flows axially through the mill. Recently, small-scale vibration ball mills, which produce particles of a few microns, have been introduced.[60]

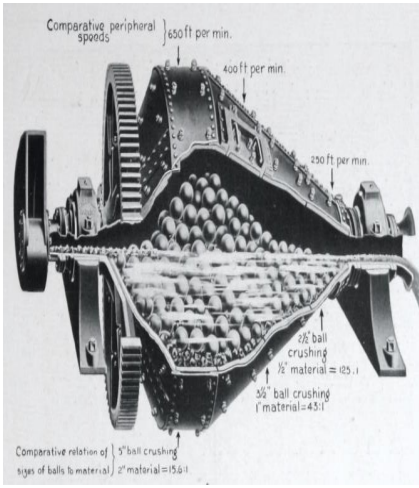
Most ball mills utilized in pharmacy are batch-operated; however, there are available continuous ball mills, which are fed through a hollow trunnion at one end, with the product discharged through a similar trunnion at the opposite end. The outlet is covered with a coarse screen to prevent the loss of the balls.

In a ball mill rotating at a slow speed, the balls roll and cascade over one another, providing an attrition action. As the speed is increased, the balls are carried up the sides of the mill and fall freely onto the material with an impact action, which is responsible for most size reduction. Ball milling is a combination of impact and attrition. If the speed is increased sufficiently, the balls are held against the mill casing by centrifugal force and revolve with the mill. The critical speed of a ball mill is the speed at which the balls just begin to centrifuge with the mill.

The charge of balls can be expressed in terms of percentage of volume of the mill (a bulk volume of balls filling one half of a mill is a 50% ball charge). To operate effectively, a ball charge from 30 to 50% of the volume of the mill is required.

The amount of material to be milled in a ball mill may be expressed as a material-to-void ratio (ratio of the volume of material to that of the void in the ball charge). The efficiency of a ball mill is increased as the amount of material is increased until the void space in the bulk volume of ball charge is filled; then, the efficiency of milling is decreased by further addition of material.

Increasing the total weight of balls of a given size increases the fineness of the powder. The weight of the ball charge can be increased by increasing the number of balls or by using a ball composed of a material with a higher density. Since optimum milling conditions are usually obtained when the bulk volume of the balls is equal to 50% of the volume of the mill, variation in weight of the balls is normally effected by the use of materials of different densities. Thus, steel balls grind faster than porcelain balls, as they are three times more dense. Stainless steel balls are also preferred in the production of ophthalmic and parenteral products, as there is less attrition and less subsequent contamination with particulate matter.



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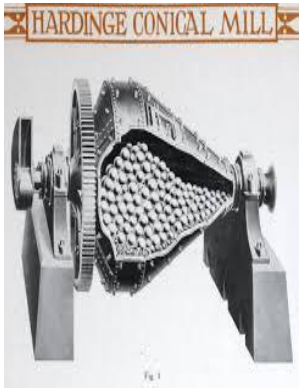
In dry milling, the moisture should be less than 2%. With batch processing, dry ball milling produces a very fine particle size. With wet milling, a ball mill produces 200-mesh particles from slurries containing 30 to 60% solids. From the viewpoint of power consumption, wet grinding is more efficient than dry grinding. A slower speed is used in wet milling than in dry milling to prevent the mass from being carried around with the mill. A high viscosity restricts the motion of the grinding medium, and the impact is reduced. With 1.27-cm steel balls, a viscosity from 1000 to 2400 centipoises (cp) is satisfactory for wet milling.

Wetting agents may increase the efficiency of milling and the physical stability of the product by nullifying electrostatic forces produced during comminution. For those products containing wetting agents, the addition of the wetting agent at the milling stage may aid size reduction and reduce aggregation.



In addition to being used for either wet or dry milling, the ball mill has the advantage of being used for batch or continuous operation. In a batch operation, unstable or explosive materials may be sealed with an inert atmosphere and satisfactorily ground. Ball mills may be sterilized and sealed for sterile milling in the production of ophthalmic and parenteral products. The installation, operation, and labor costs involved in ball milling are low. Finally, the ball mill is unsurpassed for fine grinding of hard, abrasive materials.

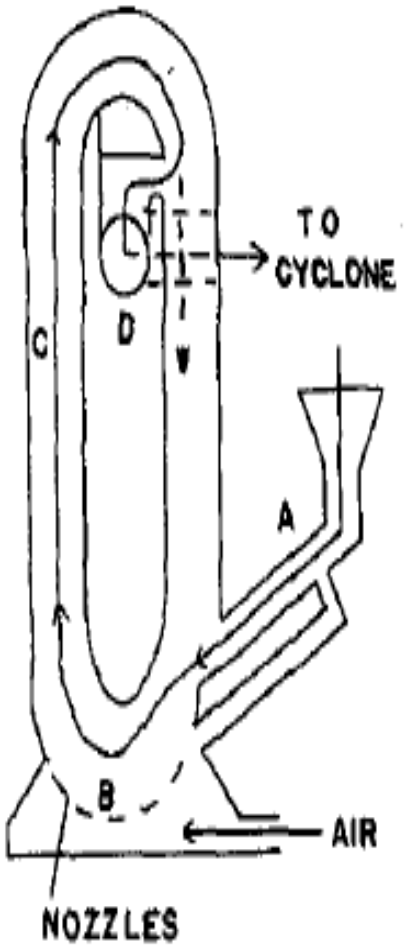
Fluid energy mill

in the fluid energy mill or (micronizer) the material is suspended & conveyed at high velocity by air steam

The violent turbulence air& steam reduces the particle size by interparticular attrition

Air is usually used because most pharmaceuticals have a low melting point or are thermoliable.

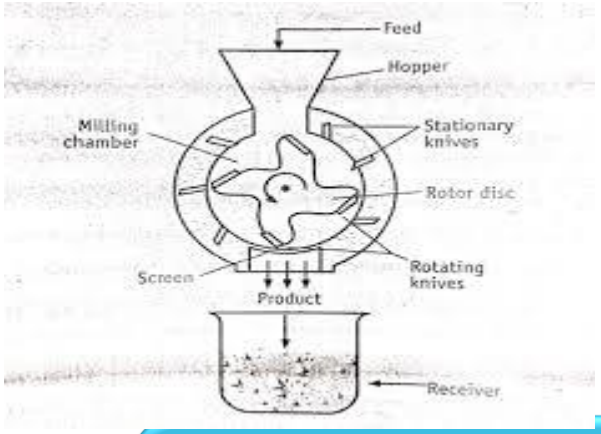
As the compressed air expands at the orifice ,the cooling effect counteracts the heat generated by milling.



FLUID-ENERGY

As shown in Figure 2-11, the material is fed near the bottom of the mill through a venturi injector (A). As the compressed air passes through the nozzles (B), the material is thrown outward against the wall of the grinding chamber (C) and other particles. The air moves at high speed in an elliptical path carrying with it the fine particles that pass out of the discharge outlet (D) into a cyclone separator and a bag collector. The large particles are carried by centrifugal force to the periphery, where they are further exposed to the attrition action. The design of the fluid-energy mill provides internal classification, which permits the finer and lighter particles to be discharged and the heavier oversized particles, under the effect of centrifugal force, to be retained until reduced to a small size.

Fluid-energy mills reduce the particle to 1 to 20 microns. The feed should be premilled to approximately a 20- to 100-mesh size to facilitate milling. A 2-inch laboratory model using 20 to 25 cubic feet per minute of air at 100 psi mills 5 to 10 grams per minute. In selecting fluid-energy mills for production, the cost of a fluid-energy source and dust collection equipment must be considered in addition to the cost of the mill.



Cutting mill

Cutting mill is used for tough materials , fibrous materials & provide a successive cutting or shearing action rather than attrition or impact.

The rotary knife cutter has a horizontal rotor with 2 to 12 knives spaced uniformly on its periphery & a cylindric casing having several stationary knives.

the bottom of the case holds a screen.

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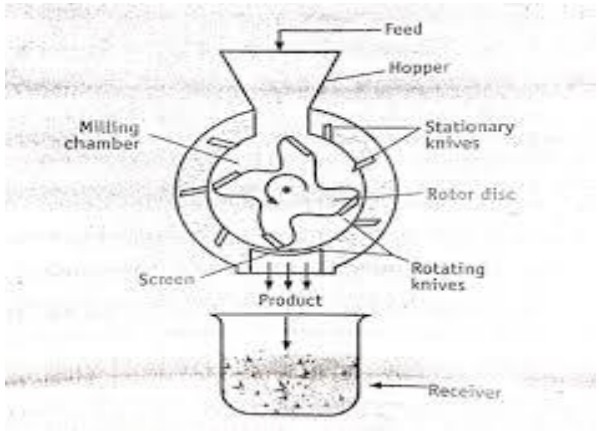

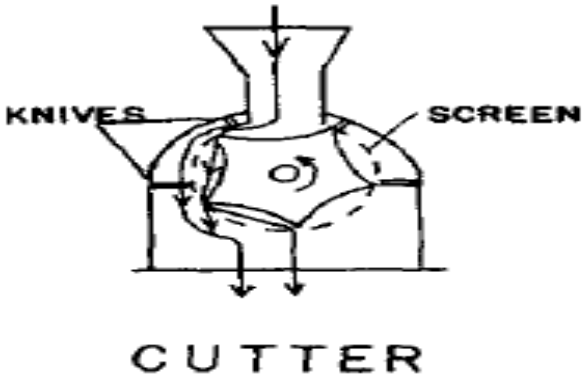

A disc mill consists of two vertical discs; each may rotate in opposite directions (double-runner disc mill), or only one may rotate (single-runner disc mill), with an adjustable clearance. The disc may be provided with cutting faces, teeth, or convolutions. The material is premilled to approximately 40-mesh size and is usually suspended in a stream of air or liquid when fed to the mill.

Roller mill

- **Roller mills consist of 2 to 5 smooth rollers operating at different rate.**

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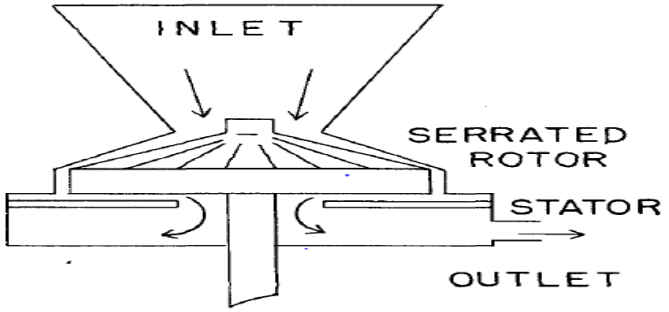
Colloid mill



Consists of a high speed rotor & stator with conical milling surfaces between which in is an adjustable clearance .

The material to be ground should be premilled as finally as possible to prevent damage to the colloid mill.

This mill is used to process suspension & emulsions, it is not use to process dry materials.

The premilled solids are mixed with the liquid vehicle before being introduced into the colloid mill.

In pharmacy, the colloid mill is used to process suspensions and emulsions; it is not used to process dry materials. The premilled solids are mixed with the liquid vehicle before being introduced into the colloid mill. Interfacial tension causes part of the material to adhere to, and to rotate with, the rotor. Centrifugal force throws part of the material across the rotor onto the stator. At a point between the rotor and stator, the motion imparted by the rotor ceases, and hydraulic shearing force exceeds the particle-particle attractive forces holding the individual particles in an aggregate. The particle size of milled particles may be smaller than the clearance, because the high shear is the dispersing force. In emulsification, a clearance of 75 microns may produce a dispersion with an average particle size of 3 microns. The milled liquid is discharged through an outlet in the periphery of the housing and may be recycled.

Rotor & stator may be smooth surfaced or rough surfaced

Smooth surfaced there is a thin uniform film of material between them & is subjected to the maximum amount of shear.

Rough *surfaced* mills add intense eddy currents turbulence & impaction of the particles to the shearing action & useful with fibrous material because fibers tend to interlock & clog smooth-faced mills.

A colloid mill tends to incorporate air into a suspension . Aeration may be minimized by use of a vertical rotor , which seals the point at which the rotor shaft enters the housing, & keep the rotor & stator in contact with the liquid.

The wasted energy of milling which appears as heat, may raise the temperature of a liquid by as much as $40^{o}C$. The passage of cooling water through the mill jacket may reduce the temperature by as much as $20^{o}C$. Sanitary design mills, which may be sterilized.

Techniques of milling
1-special atmosphere

Hygroscopic material can be milled in a close system supplied with dehumidified air.

Thermoliable , easily oxidizable. & combustable materials should be milled in a closed system with an inert atmosphere of carbon dioxide or nitrogen.

2- temperature control

As only a small % of the energy of milling is used to form new surface. The bulk of energy is converted to heat. This heat may raise the temp. of the material many degrees & unless the heat is removed, the solid will melt , decompose or explode. To avoid these things the milling chamber should be cooled by means of a cooling jacket or a heat exchanger.

Waxy & low melting materials are 1- chilled before milling or 2-fed to the mill simultaneously with dry ice.

Pretreatment. For a mill to operate satisfactorily, the feed should be of the proper size and enter at a fairly uniform rate. If granules or intermediate-sized particles are desired with a minimum of fines, presizing is vital. Pretreatment of fibrous materials with high-pressure rolls or cutters facilitates comminution.

Subsequent Treatment. If extreme control of size is required, it may be necessary to recycle the larger particles, either by simply screening the discharge and returning the oversize particles for a second milling, or by using air-separation equipment in a closed circuit to return the oversized particles automatically to the milling chamber. With materials to be reduced to micron size, an integrated air-separation, conveyor, and collection element usually are required.

Dual Process. The milling process may serve simultaneously as a mixing process if the feed materials are heterogeneous. If hot gas is circulated through a mill, the mill can be used to comminute and dry moist solids simultaneously. The fluid-energy mill has been suggested as a means of simultaneous size reduction and dispersion. It has been suggested that the particles in a fluid-energy mill can be coated with almost a monomolecular film by premixing with as little as 0.25% of the coating agent.

3- wet & dry milling

If the product undergoes physical & chemical change in water , dry milling is recommended .

The addition of a small amount of grinding aid may facilitate size reduction.

These dispersing agents are useful in the revolving mill if coating of the balls occurs.

The addition of less than 0.1% of surface active agent may increase the production rate from 20 to 40%.

Wet grinding

1-eliminates dust hazards & is usually 2- done in low speed mills,3- which consume less power .