SIZE REDUCTION

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Content

- Size reduction
- Objectives of size reduction
- Mechanism of size reduction
- Laws governing of size reduction
- Hammer mill
- Ball mill
- Edge runner mill
- End runner mill
- Fluid energy mill

Pharmaceutical engineering

It is concerned with the study of industrial process in which raw material are changed into pharmaceutically useful products.

Size reduction

Size reduction is a process of reducing large solid unit masses - vegetables or chemical substances into small unit masses, coarse particles or fine particles. Size reduction is commonly employed in pharmaceutical industries. Size reduction process is also referred to as Comminution and Grinding. When the particle size of solids is reduced by mechanical means it is known as Milling. The size reduction operation can be divided into two major categories depending on whether the material is a solid or a liquid. If the material is solid, the process is called grinding and cutting, if it is liquid, emulsification or atomization.

Objectives of size reduction

- Size reduction leads to increase of surface area.
- Pharmaceutical capsules, insufflations (i.e. powders inhaled directly into the lungs), suppositories and ointments require particles size to be below 60 mm size.
- To increase the therapeutic effectiveness of certain drugs by reducing the particle size.
- Size reduction produces particles in narrow size range. Mixing of powders with narrow size range is easier and uniform .
- Pharmaceutical suspensions require finer particle size. It reduces rate of sedimentation.

Mechanism of size reduction

- **Impact** – this involve hammer or bar at high speed (hammer mill).
- **Compression**- particle crushed b/w rollers by the application of force (roller mill).
- **Cutting** – the material cut by a sharp blade (cutter mill)
- **Attrition** - arising from particles scraping against one another or rubbing action (fluid energy mill).

Laws governing size reduction

- **Griffith theory** -The amount of force to be applied depends on the crack length.
- **Kick's law**- Work required to reduce the size of a given quantity of material is constant for the same reduction ratio regardless of the original size.
- **Rittinger's law** -Worked use for particulate size reduction is directly proportional to the new surface produced.
- **Bond's law** -Worked used to reduce particle size is proportional to the square root of the diameter of the particle produced.

Factors affecting Size Reduction

Selection of mill - It is related to feed, milled product, safety and economics

Factors related to nature of raw materials affecting size reduction

- **Hardness -** It is easier to break soft material than hard materials. Ex: For iodine hammer mill is used.
- **Fibrous -** These are tough in nature. A soft, tough material has more difficulty than a hard, brittle substance. Ex: Raowulfia, Ginger. Here cutters can be used.

- **Elastic / Sticky** - Become soft during milling. Ex: synthetic gums, waxes, resins. Low melting substances should be chilled before milling. These are milled using hammer, colloid or fluid energy mill.
- **Melting point** - Waxy substances, fats and oils are softened during size reduction due to heat generated. This is avoided by cooling the mill and the substance.
- **Hygroscopic** - Certain substances absorb moisture content rapidly. This wet mass hampers the milling process. Ex: Potassium carbonate. Closed system such as porcelain ball mill is used.

Hammer Mill

- **Principle**

  It operates on the principle of impact between rapidly moving hammers mounted on rotor and the stationary powder material.

- **Parts**

  Consists of a metal casing, enclosing a central shaft, to which 4 or more swinging hammers are attached. Lower part of casing consists of a screen, through which material can pass and collected in a suitable receiver.

Construction & Working

- A hammer mill is essentially a steel drum containing a vertical or horizontal rotating shaft or drum on which hammers are mounted.
- The hammers swings on the ends or fixed to the central rotor.
- The rotor is rotates at a high speed inside the drum while material is fed into a feed hopper.
- The material is put into the hopper which is connected with the drum.
- The material is powdered to the desired size due to fast rotation of hammers and is collected under the screen
- This are mainly operated at 1000 to 2500 rpm for the reduction of the large sized particles. High speed rotor uses 10000 rpm speed.

Uses

- Brittle material is best fractured by impact from blunt hammers.
- Fibrous material is best reduced by cutting edges

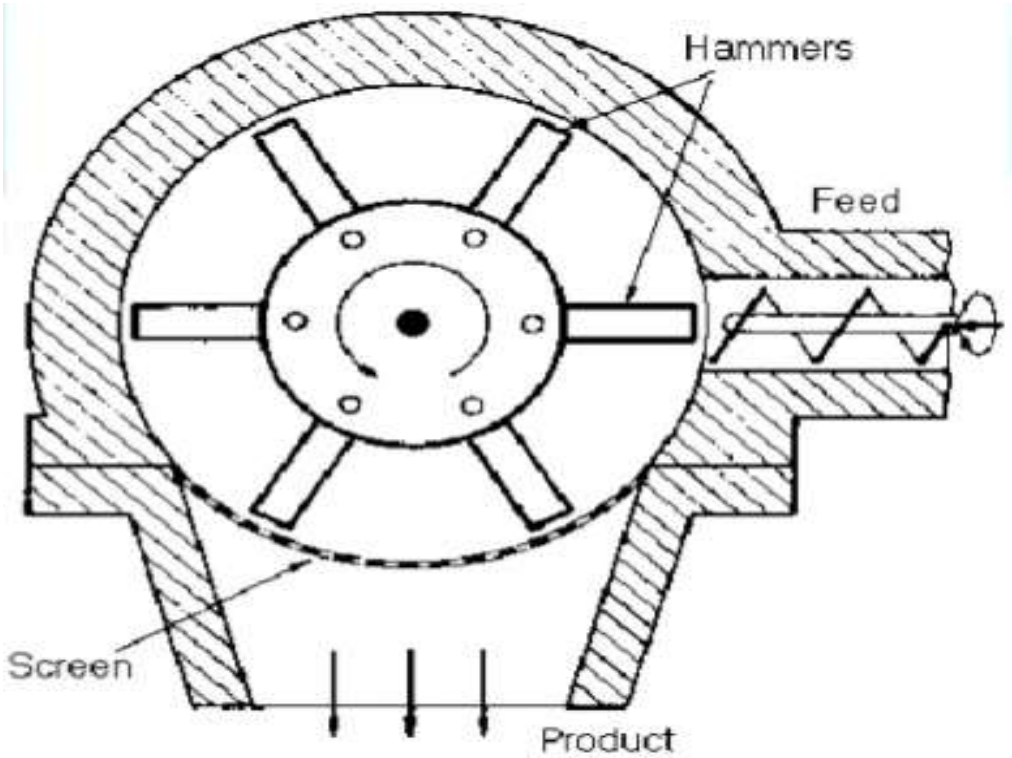


Fig. Hammer Mill

Advantages

- It is rapid in action, and is capable of grinding many different types of materials.
- They are easy to install and operate, the operation is continuous.
- There is little contamination of the product with metal abraded from the mill as surface move against each other.
- The particle size of the material to be reduced can be easily controlled by changing the speed of the rotor, hammer type, shape and size of the screen.

Disadvantages

- Heat build up during milling is more, therefore, product degradation is possible.
- Hammer mills cannot be employed to mill sticky, fibrous and hard materials.
- The screens may get clogged.

Ball Mill

- **Principle**

  It operates on the principle of impact and attrition between the rapidly moving balls and the powder material, both enclosed in a hollow cylinder.

- **Parts**

  Consists of a hollow cylinder mounted on a metallic frame such that it can be rotated along its longitudinal axis. Cylinder contains balls occupying 30–50 % of mill volume. Weight of ball is constant; Size depends on the feed quantity and diameter of mill.

Working:

- At low speeds, the ball roll over each other and attrition (rubbing action) will be the predominate mode of action.
- Thus, in the ball mill, impact or attrition or both are responsible for the size reduction.

Advantages:

- It can produce very fine powder.
- Ball mill is used for both wet and dry grinding processes.
- Toxic substances can be ground, as the cylinder is closed system.
- installation, operation and labour costs are low.

Disadvantages:

- The ball mill is a very noisy machine.
- Ball mill is a slow process.
- Soft, fibrous material cannot be milled by ball mill.

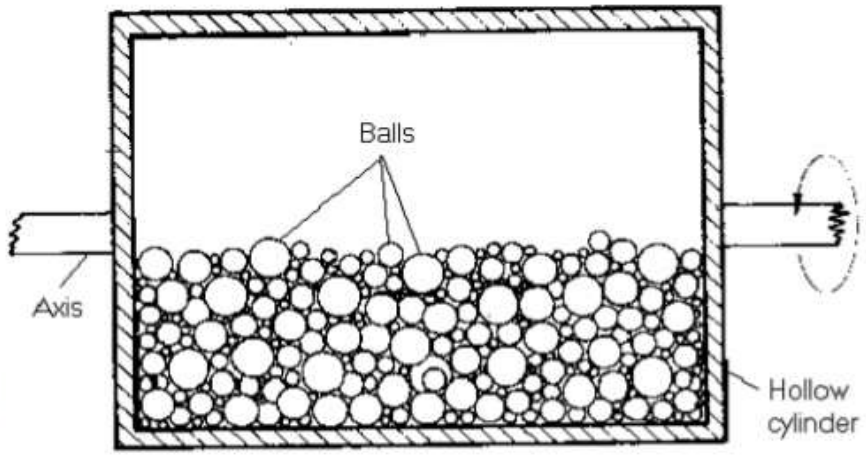


Fig. Ball mill

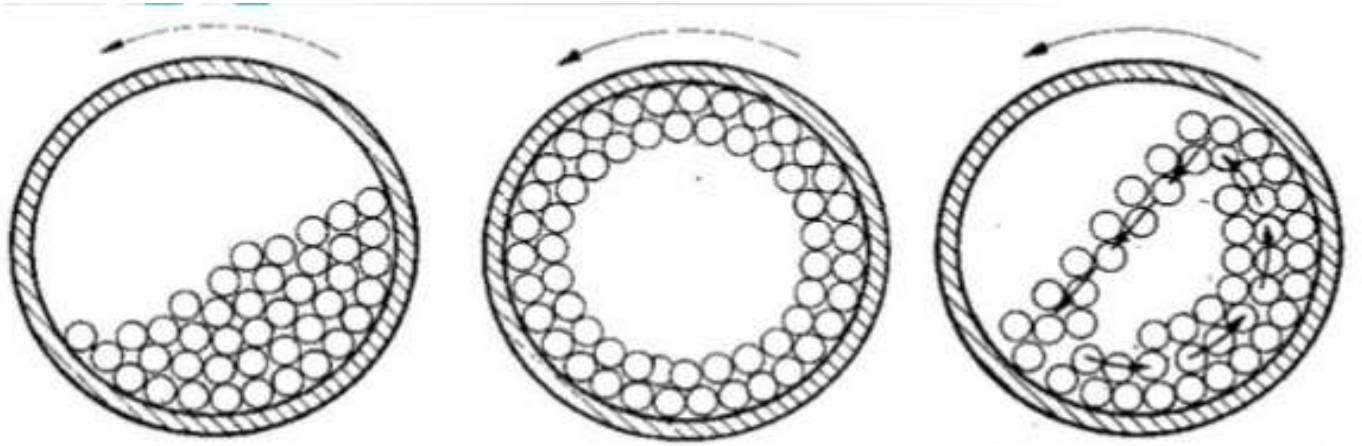


Fig. Ball mill operation

USES –

- Stainless steel are preferred in the production of ophthalmic & parentral products.
- ball mill at low speed is used for milling dyes , pigments & insecticides.

EDGE RUNNER MILL

Principle

The size reduction is done by crushing due to heavy weight of stone.

Construction

- It consist of two heavy rollers and may weigh several tons.
- The roller move on a bed which is made up of granite or stone.
- Each roller has a central shaft and revolve on its axis.
- The rollers are mounted on horizontal shaft and move around the bed

Working:

- The material to be ground is placed on the bed with the help of the scrapper in such a way that it comes in the path of the stone wheel.
- These stones revolve on its own axis and at the same time travel around the shallow stone bed.
- The material is ground for definite period.
- The powder is collected and passed through a sieve to get powder of required size.

Advantages

- Does not require attention during operation.

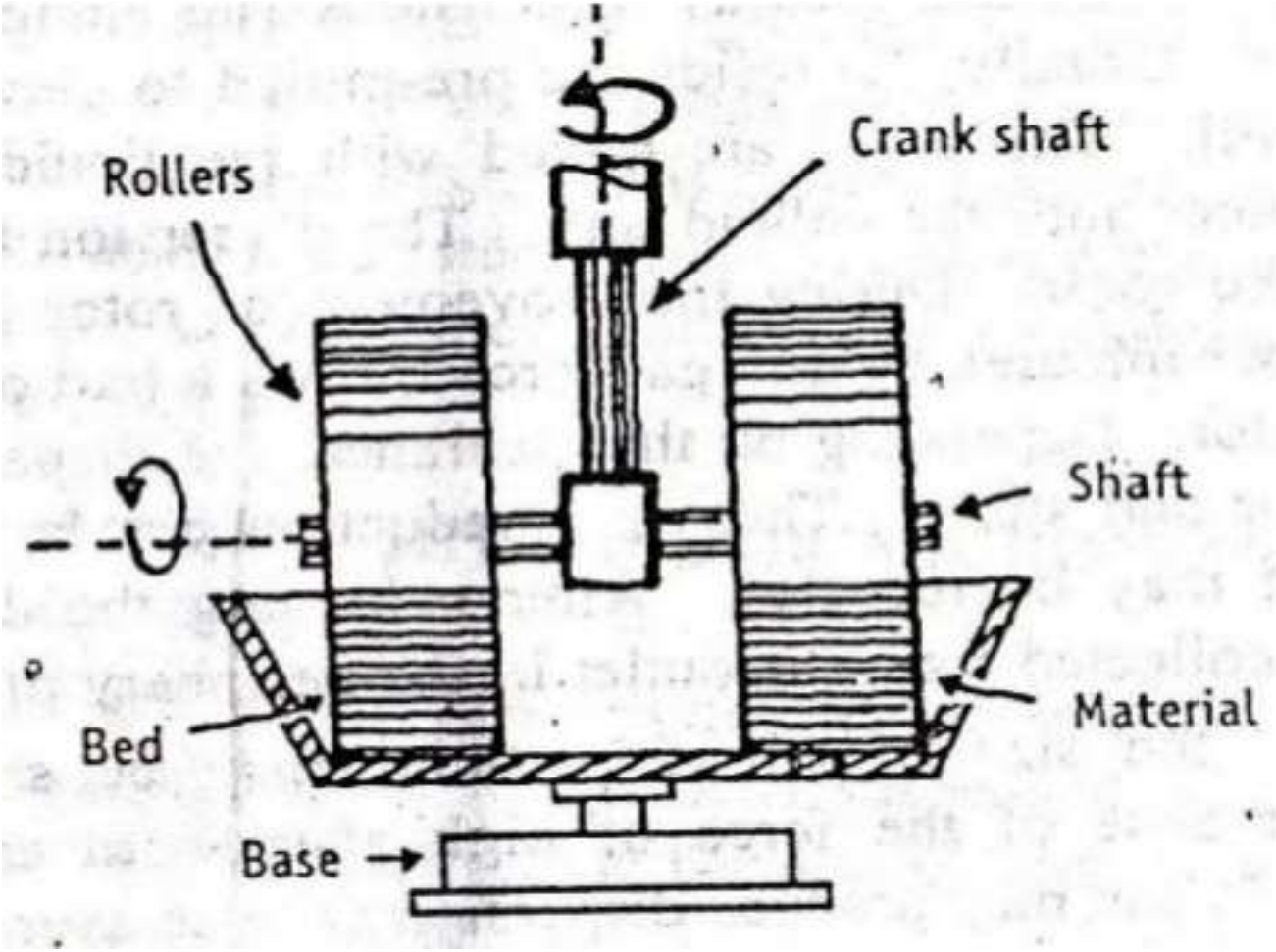
Disadvantages

- More space than other mill, Contamination, Time consuming, Not use for sticky materials.

Uses

- Grinding tough material to fine powder.

fig. of edge runner mill-



EDGE-RUNNER MILL

END-RUNNER MILL

PHOTO CREDIT: PLEDGE INTERNATIONAL

END RUNNER MILL

Principle

Size reduction is done by crushing due to heavy weight of steel pestle. Shearing stress is also involved during movement of mortar and pestle.

Construction

- It is considered as mechanical mortar pestle.
- It consist of a steel mortar which is fixed to a plate.
- The construction of mortar is connected to horizontal shaft bearing a pulley so the plate with mortar can be rotated at high speed.
- The pestle is dumb-bell shaped and bottom of pestle is flat.
- Construction of pestle is done in such a way that it can be raised from mortar for cleaning and emptying

Working

- The material to be ground is placed in the mortar. The mortar revolves at a high speed. The revolving mortar causes the pestle to revolve during this process, size reduction is achieved.

Advantages

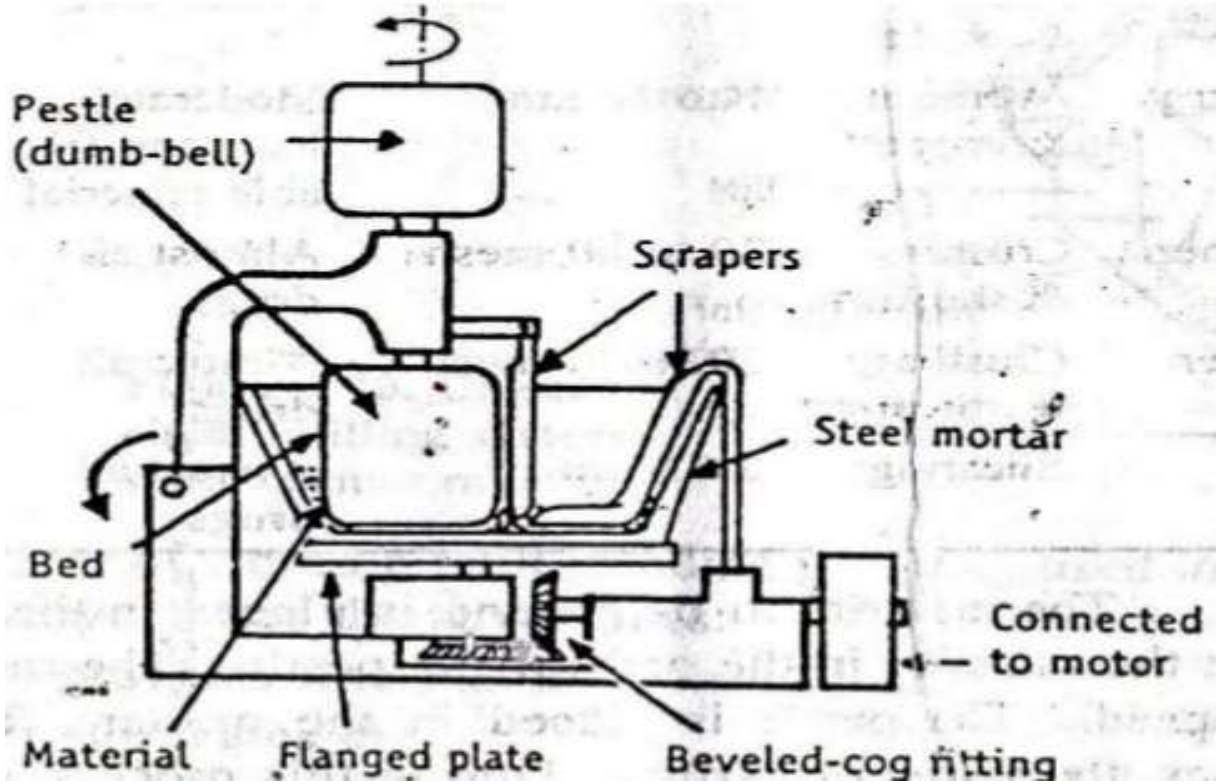
- End runner mill provides moderately fine powder and operates successfully with fibrous materials, bark, woods fruits, leaves, etc. Wet grinding with very viscous material such as ointments and paste is also possible

Disadvantages

- Not suitable for unbroken or slightly broken condition of drug.

Uses:

- Use for fine grinding.



Fluid Energy Mill

Principle

It operates on the principle of impact and attrition.

Parts

- Consists of a loop of pipe with diameter 20-200 mm. The overall height of the pipe is 2 m.
- Inlet for feed and a series of nozzles for air, inert gas. Outlet with classifier which prevents the particles to pass until they become sufficiently fine.

Construction

- It consists of a loop of pipe, which has a diameter of 20 to 200 mm , depending on the overall height of the loop ,which may be upto about 2 m .
- There is an inlet for the feed and a series of nozzles for the inlet of air or an inert gas.
- It also has an outlet with a classifier which allow the air to escape but prevents the particles to pass until they become sufficiently fine.

Working

- The air or inert gas is introduced with a very high pressure through the nozzles .Solids are introduced into air steam through inlet .due to high degree of turbulence, impact and attritional forces occurs between the particles.The fine particles are collected through a classifier .Fluid energy mill reduces the particles to 1 to 20 micron. To get a very fine powder ,even upto five micron, the material is pretreated to reduce the particle size to the order of 100 mesh and then passed through fluid energy mill.

Uses

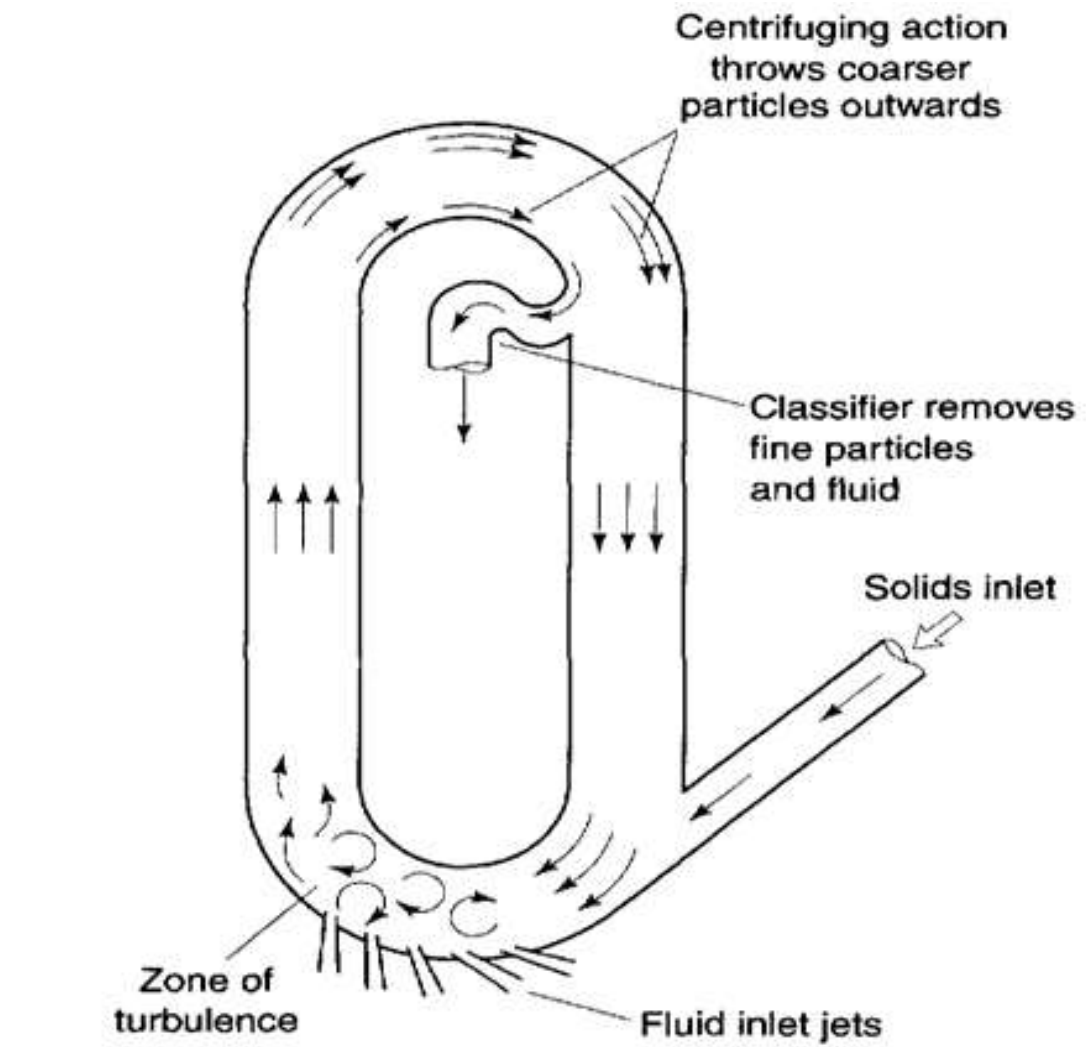
- The mill is used to grind heat sensitive material to fine powder.
- The mill is used to grind those drugs in which high degree of purity is required.

Advantages

- The mill is used to grind the material to fine powder.
- The particle size of powder can be controlled due to the use of a classifier.
- There is no wear of the mill and hence there is no contamination of the product.
- It is useful for grinding heat sensitive substances such as sulphonamides, vitamins and antibiotics.

Disadvantages

- Tendency of forming aggregates or agglomerates after milling.
- Generation of amorphous content due to high energy impact.
- Formation of ultra-fine particles
- High energy consumption.



FLUID ENERGY MILL

PHOTO CREDIT: AULTON'S PHARMACEUTICS: THE DESIGN AND MANUFACTURE OF MEDICINE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