SIZE REDUCTION

PRESENTED BY,
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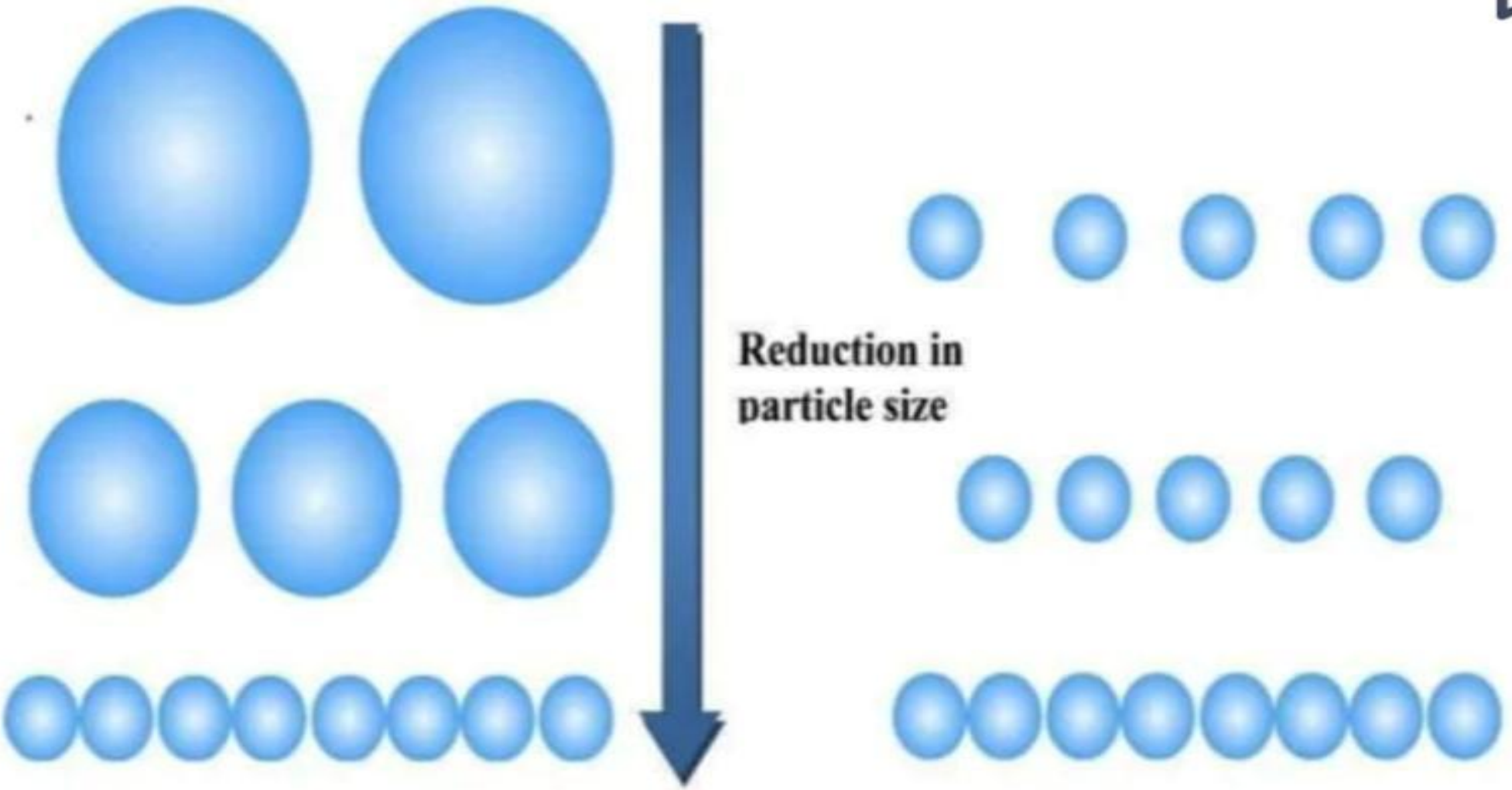
DEFINITION:

- Size reduction is the operation carried out for reducing the size of bigger particles into smaller one of desired size and shape with the help of external forces.
- **COMMINUTION** is another term used for size reduction.


Reduction in
particle size

OBJECTIVES OF SIZE REDUCTION:

- Increase the surface area because, in most reactions involving solid particles, the rate of reactions is directly proportional to the area of contact with a second phase.
- Break a material into very small particles in order to separate the valuable amongst the two constituents.
- Achieve intimate mixing.
- To dispose solid wastes easily .
- To improve the handling characteristics.
- To mix solid particle more intimately.

ADVANTAGES:

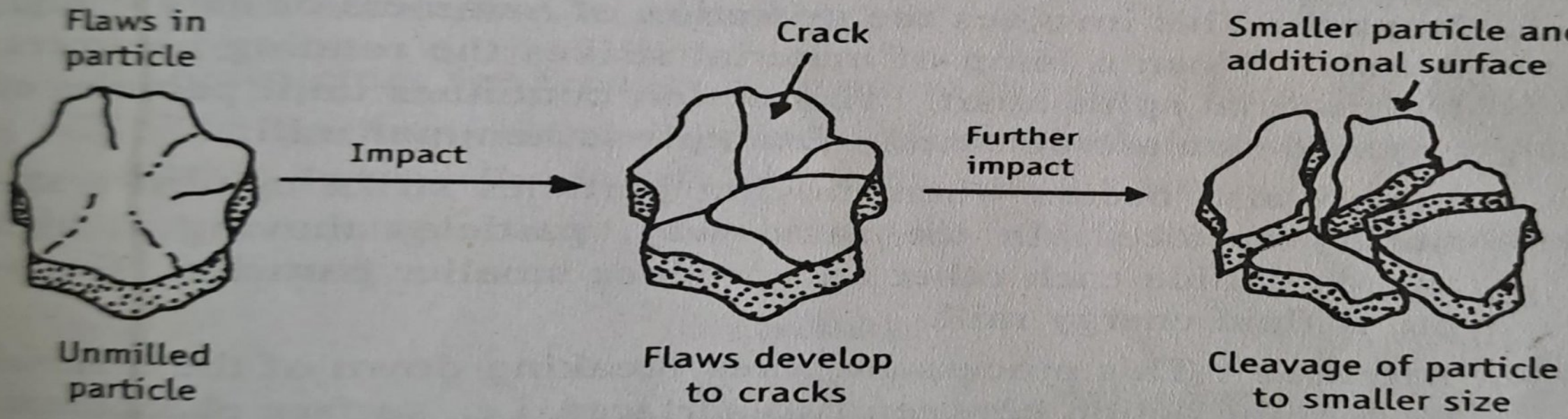
- Content uniformity
- Uniform flow
- Effective drying
- Increases surface area or viscosity
- Uniform mixing and drying
- Improve rate of absorption. Smaller the particles greater is absorption.
- Improve dissolution rate.

DISADVANTAGES:

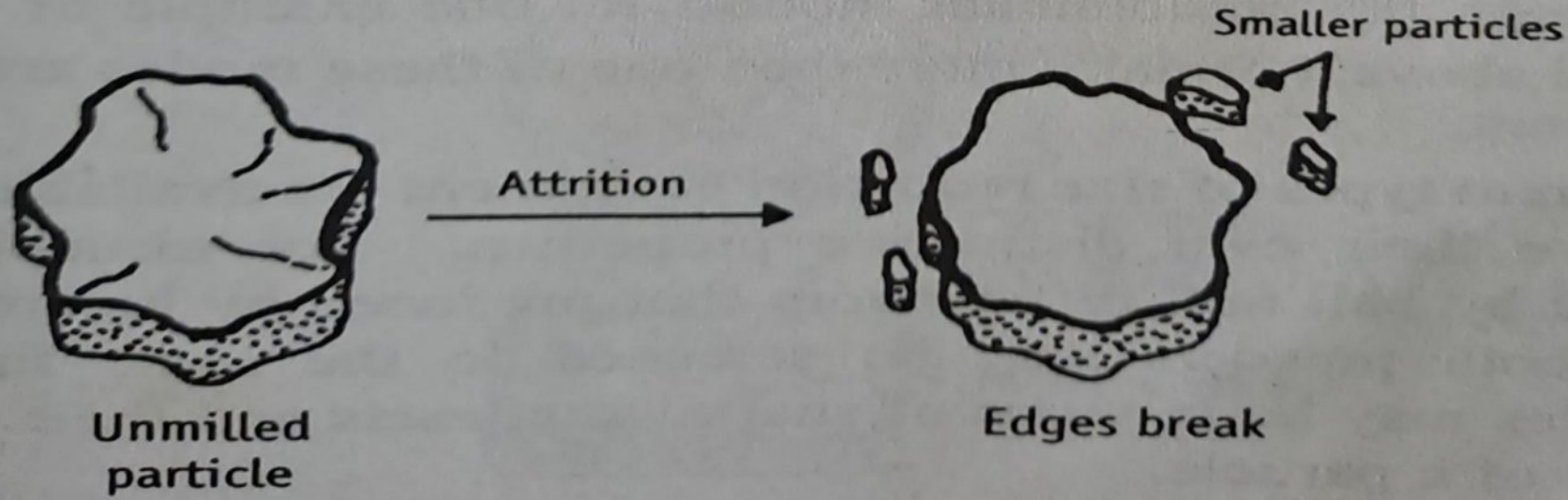
- Drug degradation
- Contamination

MECHANISM OF SIZE REDUCTION:

- Impact- particle size reduced by a single rigid force (hammer).
- Compression- in this mode material is crushed between rollers by the application of pressure.
- Attrition- arising from particles scraping against one another or against a rigid surface by rubbing action.
- Cutting- the material is cut by means of sharp blades.

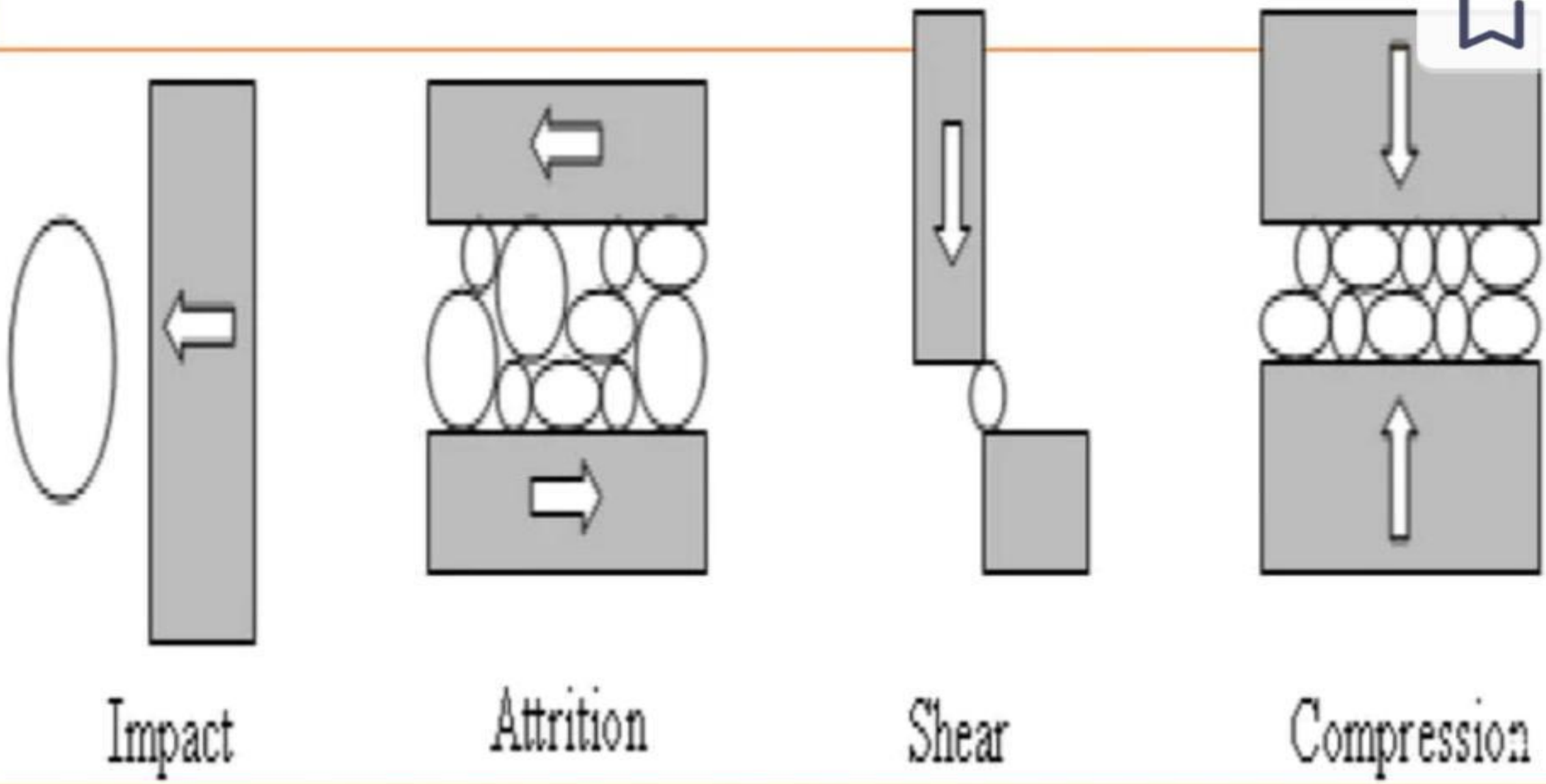


(a) Mechanism of size reduction when impact type of stress is applied.

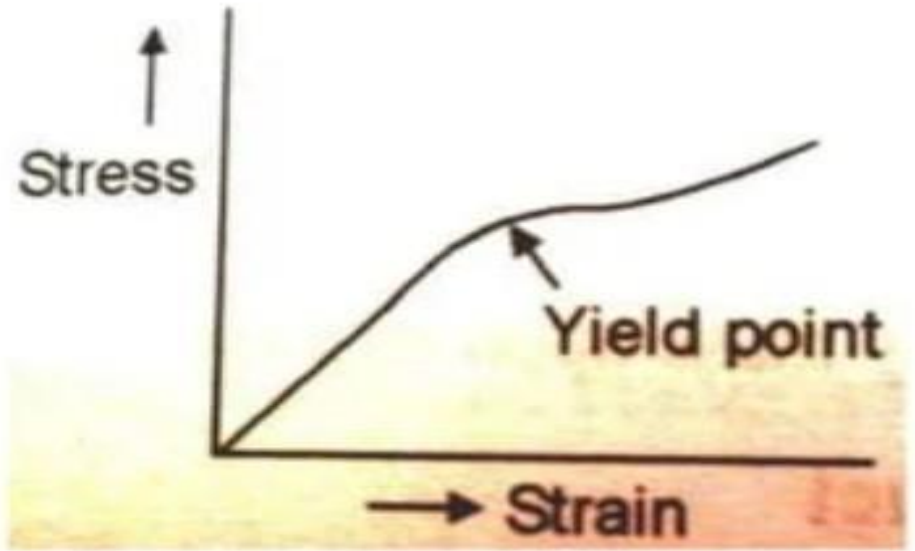


(b) Mechanism of size reduction when attrition type of stress is applied.

Figure 6-1. Mechanisms of size reduction.


Impact
Attrition
Shear
Compression

Theory and laws governing size reduction



Relationship between Stress and Strain

- Griffith theory
- Rittinger's theory
- Kicks theory
- Bonds theory

Griffith theory

- According to Griffith theory, all solids have some structural weakness or flaws in them.
- A flaw developes into crack under strain
- Amount of force to be applied depends on crack length & focus of stress at the atomic bond of crack apex.

$$T = \sqrt{\frac{Y\epsilon}{C}}$$

T – Tensile strength MPa

Y = Young's modulus MPa

ϵ = Surface energy of crack wall expressed as J / μ^2

C = Critical crack path required for fracture

MECHANISMS AND LAWS

- The energy requirement for particle size reduction is a function of input and output of particle size, hardness, strength and other properties of solids.
- Various theories for energy requirement are:-
  - **Rittinger's theory**
  - **Kick's theory**
  - **Bond's theory**

The energy required to reduce the size of par ticles is inversely proportional to the size raised to the some power.

$$\frac{dE}{dD} = -c/D^{n} \quad \ldots\ (1).$$

Where,

E=amount of energy required to produce a change

D=size of unit mass

C, n=constants.

- Integrating equation (1),

$$E = C \ln(d_i/d_n) \ldots . (2)$$

(d_i/d_n) = reduction ratio.

If n=1.0 equation **(2)** becomes Kick's theory.
If n=1.5 equation **(2)** becomes Bond's theory.
If n=2.0 equation **(2)** becomes Rittinger's theory.

RITTINGER'S THEORY

- According to this theory energy E required for size reduction of unit mass is directly proportional to the new surface area produced.

$$E=K_R\ (Sn - Si) \ldots . \textbf{(3)}$$

Where

- S_i = initial surface area
- S_n = new specific surface area
- K_R = Rittinger's constant.
- E= amount of energy

BOND'S THEORY

- According to bond theory the energy used in crack propagation is proportional to the new crack length produced.
- It states that energy required for deforming a set of particle of equivalent shape is proportional to the change in particle dimensions.

$$E = 2K_B \left(\frac{1}{\sqrt{d_n}} - \frac{1}{\sqrt{d_i}}\right) \qquad (5)$$

where K_B = Bond's work index, energy per unit mass, $kW \cdot h \cdot \sqrt{\mu m}$
d_i = initial diameter of particles, μm
d_n = new diameter of particles, μm

1. Bond's work index is the work required to reduce unit weight from a theoretical infinite size to 80% passing 100μm.
2. This theory is useful for rough mill sizing.
3. The work index is useful for comparing efficiency of milling operations

KICK'S THEORY:

- It states that energy required for deforming a set of particle of equivalent shape is proportional to the ratio of the change in particle size.

$$E = K_K \ln \frac{d_i}{d_n} \qquad (6)$$

where K_K = Kick's constant, energy per unit mass, kW·h
d_i = diameter of the particle in the initial stage, μm
d_n = diameter of the new particle, μm

Rittinger's theory:(n=2.0)

- Energy α new surface area formed.

Bond's theory:(n=1.5)

- Energy used in crack propagation α Crack length produced.
- Energy α Ratio of change in particle dimensions.

Kick's theory:(n=1.0)

- Energy α Ratio of change in size.

FACTORS AFFECTING SIZE REDUCTION

a. Hardness

- Harder the materials; more difficult to reduce the size.

b. Toughness

- Toughness is the ability of a material to absorb energy and resist impact.
- Soft but tough material is more difficult to reduce size than hard but brittle.
- **Increase toughness, decrease in reduction of sizes**
- For example it is difficult to break rubber than a stick of blackboard chalk

c. Abrasiveness

- Abrasiveness is a property of hard materials (particularly those of mineral origin) and may limit the type of machinery that can be used.
- Increase abrasiveness, Increase particle size reduction rate but increase contamination (worn out).

d. Softening temperature

- During size reduction process sometimes heat is generated which may cause some substances to soften, and the temperature at which this occurs can be important.
- Waxy substances, such as stearic acid, or drugs containing oils or fats are examples that may be affected and choke or block the machine.

e. Stickiness & Slipperiness

- pharmaceutical substances that are gummy or resinous may be troublesome to the size reduction process If the method used for size reduction produces heat.

f.Moisture content

- Moisture content of a material can affect its hardness, toughness or stickiness. Generally materials should be dry and contain less than 5% moisture

g. Physiological effect

- Some substances are very potent and small amounts of dust have an effect on the operators.
- To avoid this dust, enclose mills must be used, systems that can extract air are also desirable, and wet grinding also, if possible, as it eliminates the problem entirely.

h. Purity required

- Certain types of size reduction apparatus cause the grinding surfaces to wear, and such methods must be avoided if a high degree of purity of product is needed.
- Similarly, some machines will be unsuitable if cleaning between batches of different materials is difficult.

j. Ratio of feed size to product size

- Machines that produce a fine product require a small feed size.

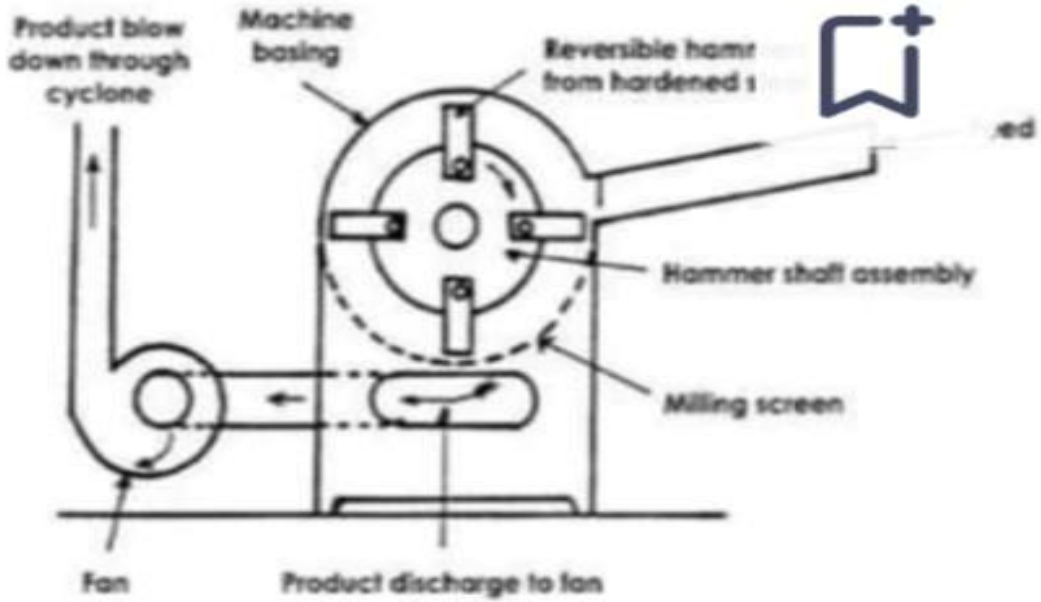
k. Bulk density

- The capacity of most batch mills depend on volume, whereas processes usually demand solid materials by weight.
- Hence, all other factors being equal, the output of the machine is related to the bulk density of the substance.

CLASSIFICATION OF SIZE REDUCTION EQUIPMENT'S

Sr. No.	Types Size reduction equipments	Examples
1.	**Crushers**	Edge runner mill, End runner mill
2.	**Grinders**	
	(a) Impact mill	Hammer mill
	(b) Rolling-compression	Roller mill
	(c) Attrition mill	Attrition mill
	(d) Tumbling mill	Ball mill
3.	**Ultra fine grinder**	Fluid energy mill
4.	**Cutting machine**	Cutter mill

Hammer mill:



Principal: Material is impact b/w rapidly moving hammers on a rotor & the powder material

Uses: it is used to mill dry materials, wet filter press cakes, ointments, slurries etc. Brittle material is best fractured by impact from blunt hammers; fibrous material is best reduced in size by cutting edges.

Variants: Stocks tornado mill, Fitzpatrick comminuting machine (Fitz mill), Micropulvelizer, hammer crusher etc.

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.

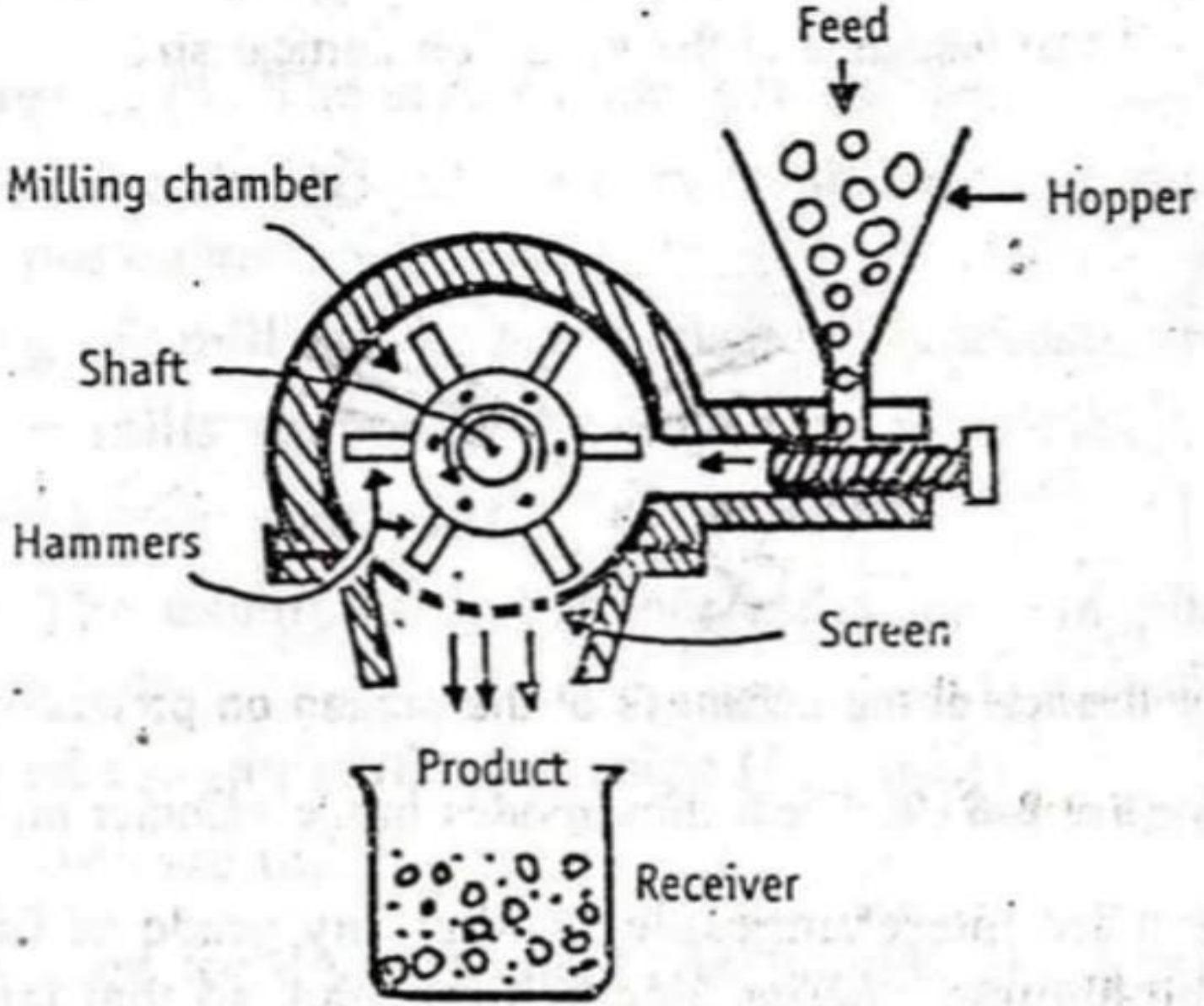
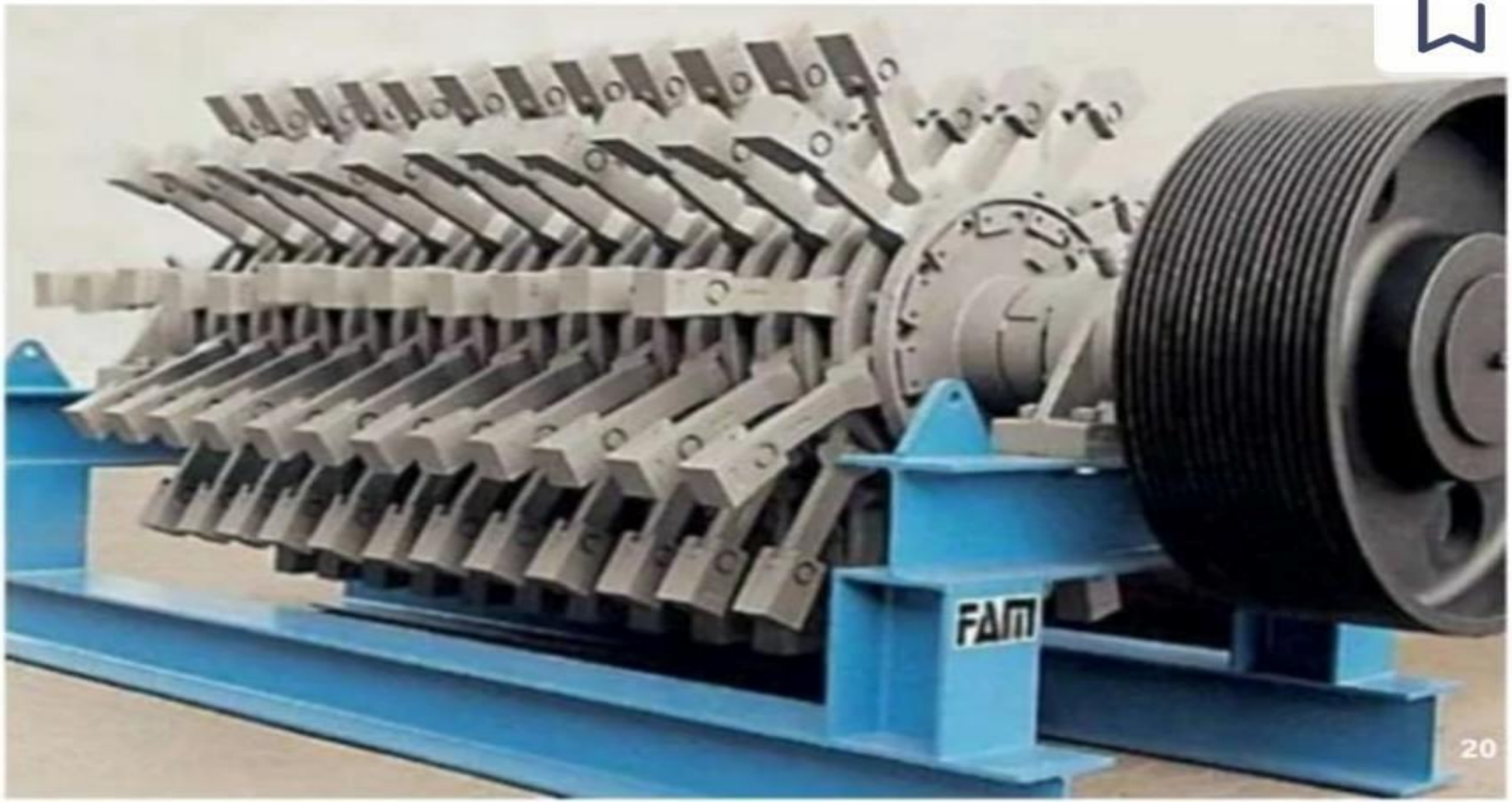


Figure 6-5. The construction of Hammer mill.

This are m operated 2500 rpm or 1000 to 2500 rpm for the reduction of the large sized particles. High speed rotor uses 10000 rpm speed.


FAM

ADVANTAGES:

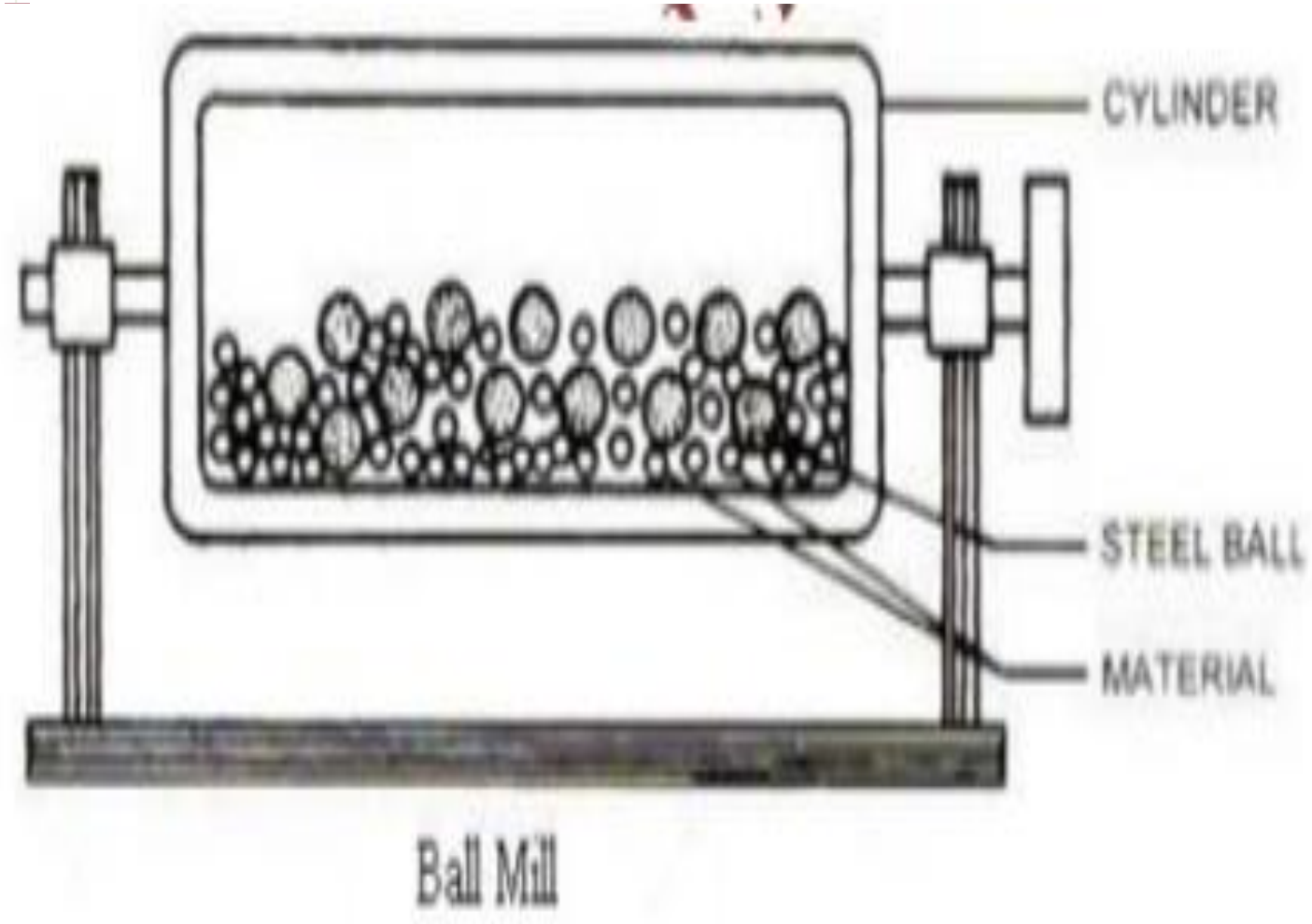
- It is rapid in action, and is capable of grinding many different types of materials.
- They are easy to install and operate, the operation is continuous.
- There is little contamination of the product with metal abraded from the mill as no surface move against each other.
- The particle size of the 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 buildup 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:

- These are also knows as tumbling mills or pebble mills.
- **Principle:** The ball mill works on the principle of impact between the rapidly moving balls and the powder material, both enclosed in a hollow cylinder.
- At low speed the balls roll over each other attrition will be mode of action thus in the ball mill attrition and impact both mechanisms takes place.



Ball Mill

- Construction:

- It consists of a hollow cylinder which is mounted on a metallic frame in such a way that it can be rotated on its longitudinal axis.
- The length of the cylinder is slightly higher than its diameter.
- The cylinder contains balls that occupy 30 to 50% of the mill volume.
- The ball size depends on the size of the feed and the diameter of the mill. Balls are made up of steel, iron or stoneware and act as grinding medium.

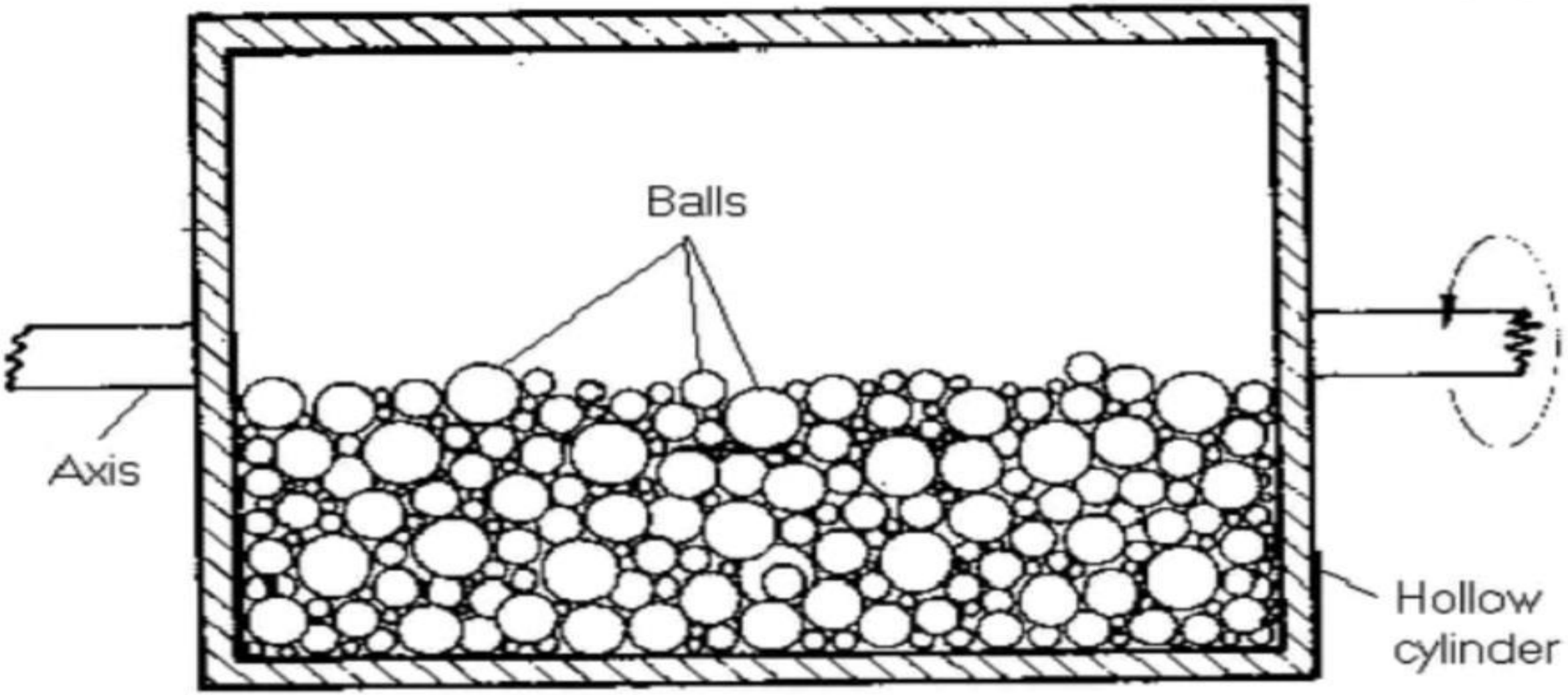
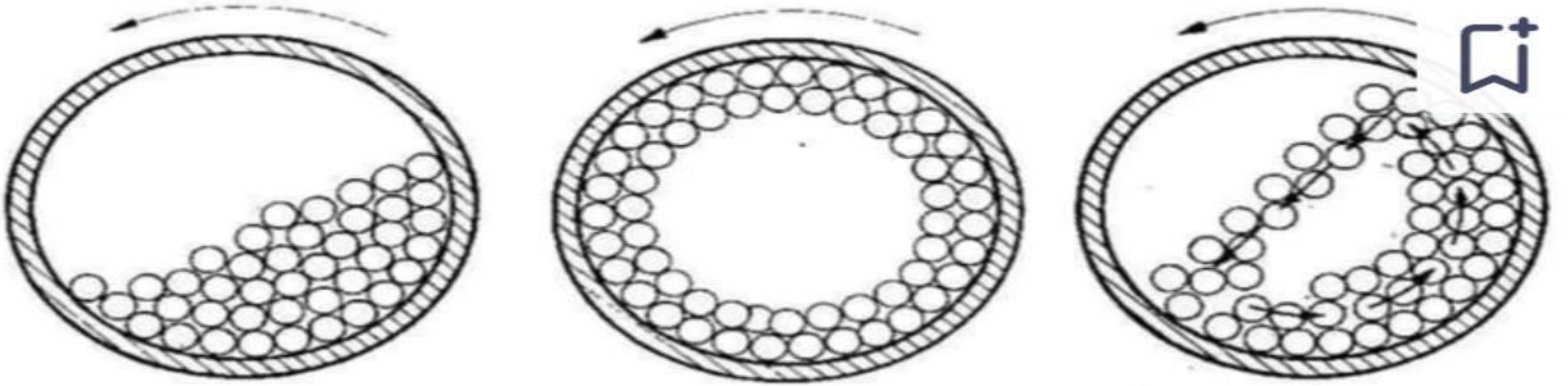


Fig. Ball mill

- Working:

- ✓ The drug to be ground is put into the cylinder of the mill in such a quantity that it is filled to about 60% of the volume.
- ✓ A fixed number of balls are introduced and the cylinder is closed. The mill is allowed to rotate on its longitudinal axis.
- ✓ The speed of rotation is very important



(a) Low speed with sliding (b) High speed with centrifuging (c) Correct speed with cascading

Fig. Ball mill operation

Uses:

- ✓For fine grinding with a particle size of 100 to 5 mm or less.
- ✓For production of ophthalmic and parenteral products.
- ✓For milling dyes, pigments and insecticides at low speed.

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.
- Rod or bars can also be used as grinding media.
- Sticky material are size reduced in ball mill,
- Installation, operation and labor costs are low.
- Since the mill is closed system used for sterile products and oxygen sensitive products.

DISADVANTAGES:

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

FLUID ENERGY MILL/ JET MILL/ MICRONIZERS/ ULTRAFINE GRINDERS

- Principle:
  - ✓ Fluid energy mill operates on the principle of impact and attrition. Milling takes place because of high velocity collisions between the suspended particles.
- Construction:
  - ✓ It consist of an elliptical pipe which has a height of about 2 meters and diameter may be ranging from 20 to 200 mm.

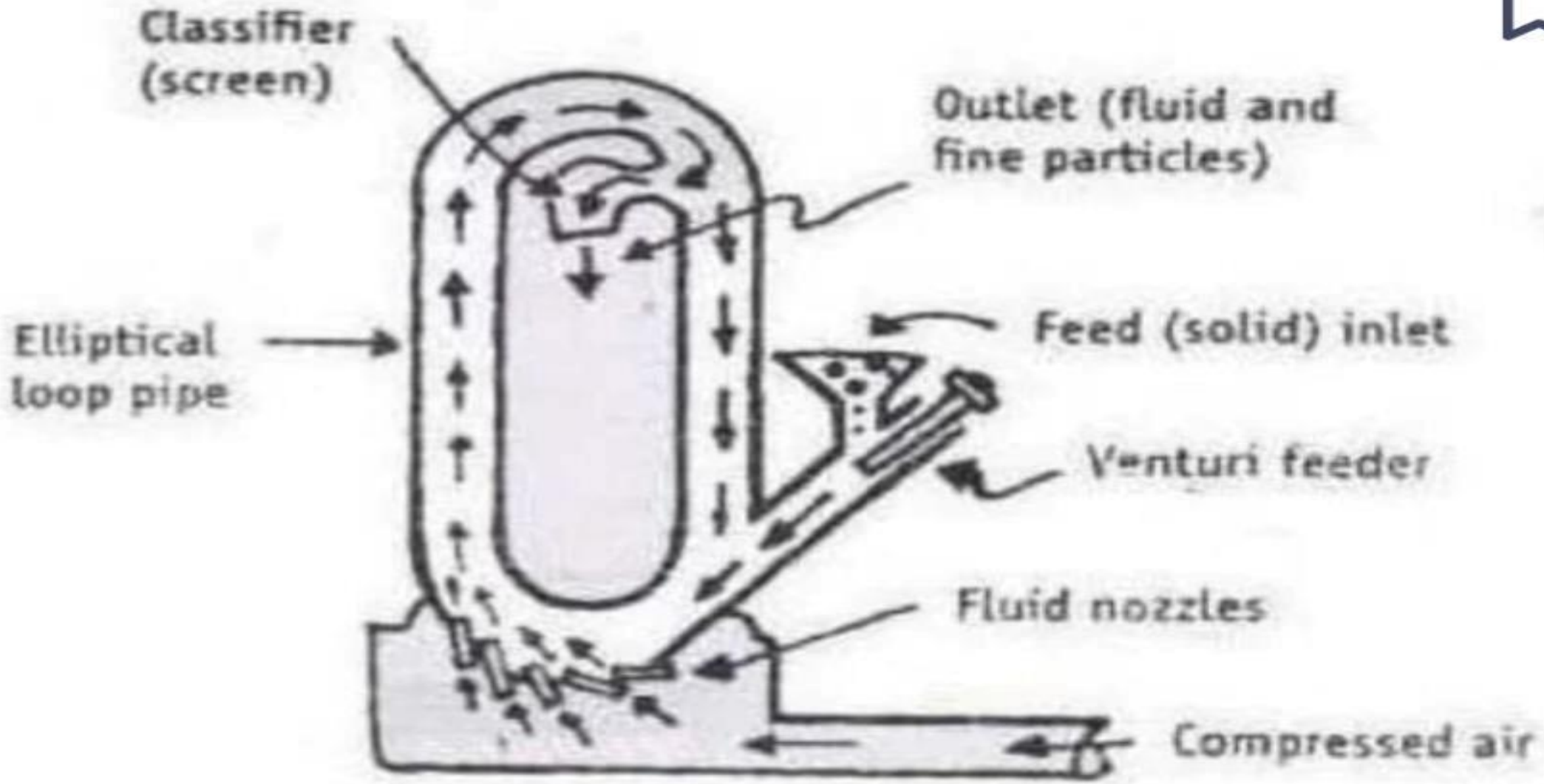


Figure 6-9. The construction of fluid energy mill.

- The mill surface may be made up of either stainless steel or tough ceramics.
- Grinding nozzles are placed tangential and opposed to the initial flow path of a powder.
- Compressed air is used at 600 kilopascals to 1 megapascals.
- Venturi feeder is provided in the path of the airflow. An outlet with a classifier is fitted to allow the escape of air.

Working : Powder is introduced through the inlet of venturi. The air entering through the grinding nozzles transport the powder in the elliptical or circular track of the mill. In the turbulent stream of air, the suspended particles collide with each other and break. Thus, impact and attrition forces operate in size reduction. The resultant small particles (by entrapment of air) are carried to outlet and removed by cyclone or filters.

The coarser particles undergo re-circulation in the chamber on account of its own weight. These re-circulated particles collide again with new in-coming feed stock particles. The powder remains in the mill, until its size is reduced sufficiently. Later it leaves via the sieve. Hence, fluid energy mill produces particles with narrow size distribution.

- Uses:
- ✓ To reduce the particle size of most of drugs such as antibiotics and vitamins.
- Advantages:
- ✓ It has no moving parts heat is not produced during milling.
- ✓ It is rapid and efficient method for reducing powder to 30 mm or less.
- ✓ No contamination is possible.
- Disadvantages:
- ✓ Not suitable for milling of soft, tacky and fibrous material.
- ✓ Equipment is expensive.

EDGE RUNNER MILL:

- Principle:
- ✓ The size reduction is done by crushing due to heavy weight of stones.
- 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.

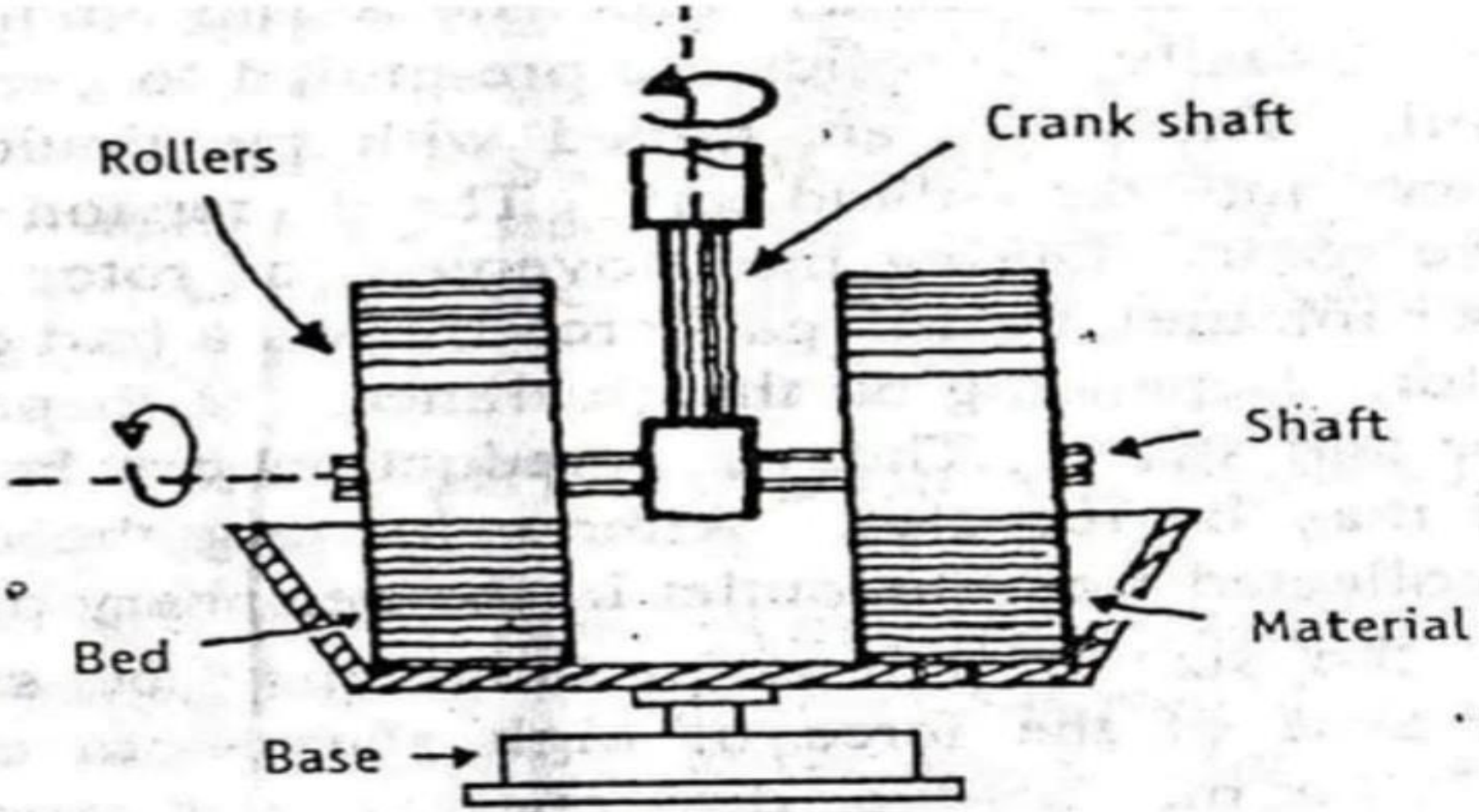


Figure 6-11. Construction of edge runner mill.

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.

Uses : Edge runner mill is used for grinding tough materials to fine powder. It is still used for plant-based products, while more sophisticated mills are used for chemicals and drugs.

Advantages : Edge runner mill does not require attention during operation.

Disadvantages : (1) Edge runner mill occupies more space than other commonly used mills.

(2) Contamination of the product with roller material is possible.

(3) The milling process is time consuming.

(4) It is not used for sticky materials.

(5) Energy consumption is quite high.

END RUNNER MILL:

- Principle:
  - ✓ Size reduction is done by crushing due to presence of heavy weight steel 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.

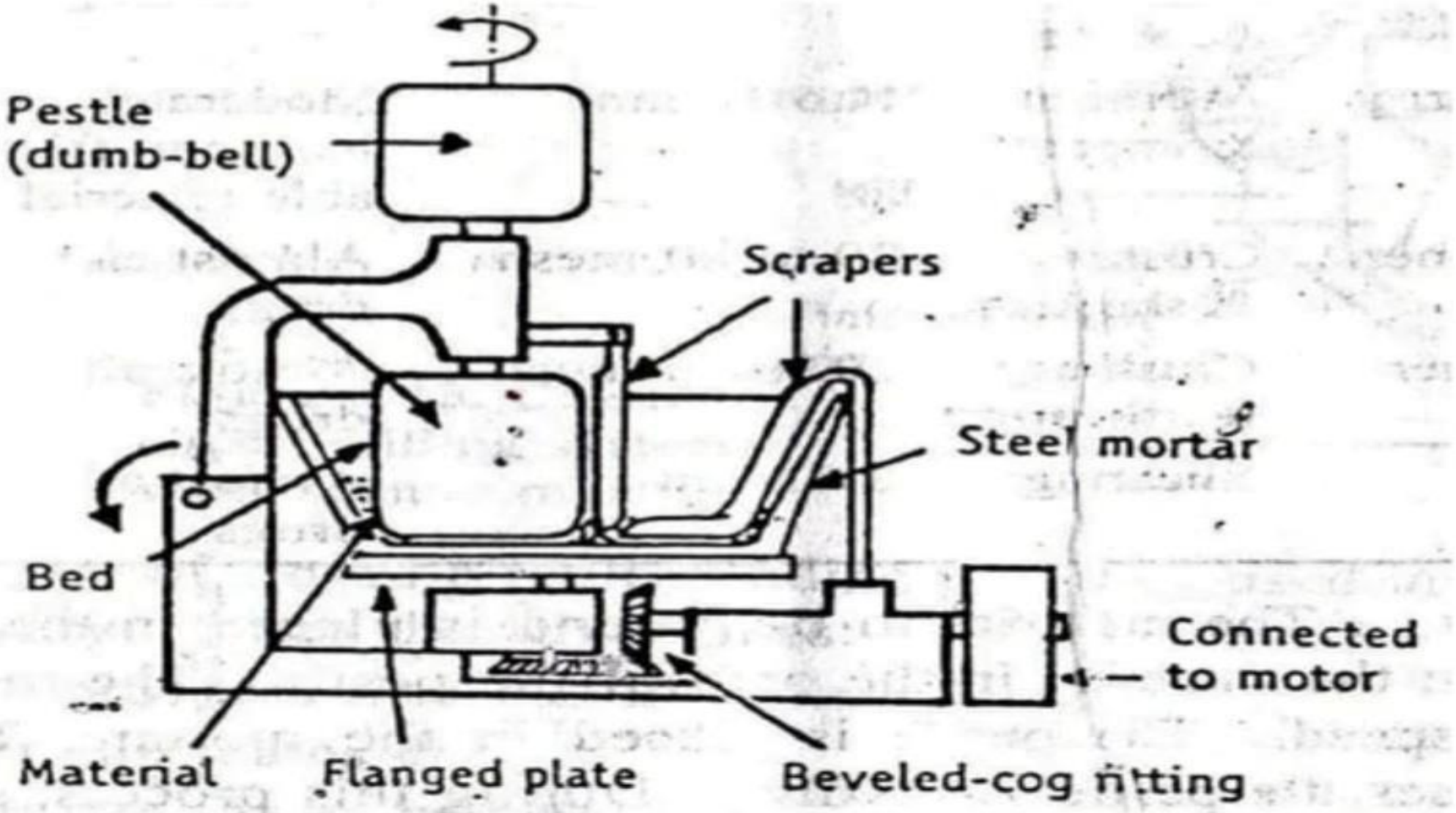


Figure 6-12. Construction of end runner mill.

- 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 scraper puts the material in the path of the pestle.
- The mortar revolves at high speed and the pestle is placed in the mortar.
- The revolving mortar causes pestle to revolve.
- The material is collected and passed through a sieve to get the powder of desired size.

Uses : End runner mill is suitable for fine grinding. Now a days, mill is replaced by more efficient and sophisticated milling equipment.

Disadvantage : End runner mill is not suitable for drugs, which are in unbroken or slightly broken conditions.


Thank
you!!