CHAPTER – 3
Size Reduction and Size Separation

Syllabus:
Definition, objectives of size reduction and size separation, factors affecting size reduction, laws governing energy and power requirements of mills including ball mill, hammer mill, fluid energy mill etc., sieve analysis, standards of sieves, size separation equipment shaking and vibrating screens, gyratory screens, cyclone separator, air separator, bag filters, cottrell precipitator, scrubbers, size separators basing on sedimentation theory.

Definition

Size reduction (or Comminution)
Size reduction or *comminution* is the process of reducing substances to smaller particles.

Size separation (or Classification)
Size separation (or classification) is a process in which particles of desired size are separated from other fractions.

Objectives

Objectives of size reduction

1. Size reduction leads to increase of surface area.
   Example-I: The rate of dissolution of solid drug particles increases many folds after size reduction. Griseofulvin, an antifungal drug, when administered in its micronized form shows around five times better absorption.
   Example-II: The absorptive power of charcoal and kaolin increases after size reduction due to increase in surface area.
2. Size reduction produces particles in narrow size range. Mixing of powders with narrow size range is easier.
3. Pharmaceutical suspensions require finer particle size. It reduces rate of sedimentation.
4. Pharmaceutical capsules, insufflations (i.e. powders inhaled directly into the lungs), suppositories and ointments require particles size to be below 60μm size.

Objectives of size separation

1. Any solid materials, after size reduction, never gives particles of the same size but contains particles of varying sizes. The size-reduced particles are then passed through sieves to get fractions of narrow size range.
2. During tablet granulation the granules should be within narrow size range, otherwise, weight variation will take place during tablet punching.

Factors affecting size-reduction

The pharmaceutical industry uses a great variety of materials, including chemical substances, animal tissues and vegetable drugs.

A. Factors related to the nature of raw materials

Hard materials: Hard materials like pumice and iodine are most difficult to comminute. During size reduction these types of materials will produce abrasive wear of milling surfaces, which will then contaminate the material.

Fibrous materials: Crude drugs obtained from plants like glycyrrhiza, rauwolfia, ginger etc. are fibrous in nature and cannot be crushed by pressure. So they may be size-reduced by cutter mill.

Friable materials: Sucrose and dried filter cakes are friable (i.e. brittle) hence they are easy to comminute by hammer mill or fluid energy mill.

Plastic materials: Synthetic gums, waxes and resins become soft and plastic during milling. These low melting substances should be chilled (made cold) before milling. These types of materials are milled by using hammer mill and fluid energy mill.

Hygroscopic materials: Hygroscopic materials absorbs moisture rapidly hence they must be comminuted inside a closed equipment like ball-mill.

Thermolabile materials: Thermolabile materials like vitamins and antibiotics are milled inside chilled equipment.

Inflammable materials: Fine dust, such as dextrin, starch and sulphur, is a potential explosive mixture under certain conditions. All electrical switches should be explosive proof and the mill should be earthed properly.

Particle size of the feed: For a mill to operate satisfactorily, the feed should be of proper size.

Moisture content: Presence of more than 5% moisture hinders the milling process and produces a sticky mass.

B. Factors related to the nature of the finished product

Particle size: Moderately coarse powders may be obtained from various impact mill. If very fine particles like micronized particles of griseofulvin may be obtained from fluid energy mill.

Ease of sterilization: When preparations are intended for parenteral (injection) purpose and ophthalmic uses, size reduction must be conducted in a sterile environment. Mills should be sterilized by steam before use.

Contamination of milled materials: In case of potent drugs and low dose products, contamination of the products should be avoided. Equipment free from wearing (e.g. fluid energy mill) may be used in this case.

Laws governing energy and power requirements of mills

During size reduction energy is supplied to the equipment (mill). Very small amount of energy (less than 2%) actually produce size reduction. Rest of the energy is dissipated (wasted) in:

- (i) Elastic deformation of particles
- (ii) Transport of material within the milling chamber
- (iii) Friction between the particles
- (iv) Friction between the particles and mill
- (v) Generation of heat
- (vi) Vibration and noise.
- (vii) Inefficiency of transmission and motor.

Theories of milling

A number of theories have been proposed to establish a relationship between energy input and the degree of size reduction produced.

Rittinger's theory

Rittinger's theory suggests that energy required in a size reduction process is proportional to the new surface area produced.

$$E = K_R (S_n - S_i)$$

where, E = energy required for size reduction

K_R = Rittinger's constant

S_i = initial specific surface area

S_n = final specific surface area

Application: It is most applicable in size reducing brittle materials undergoing fine milling.

Bond's theory

Bond's theory states that the energy used in crack propagation is proportional to the new crack length produced

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

where, E = energy required for size reduction

K_B = Bond's work index

d_i = initial diameter of particles

d_n = final diameter of particles

Application: This law is useful in rough mill sizing. The work index is useful in comparing the efficiency of milling operations.

Kick's theory

Kick's theory states that the energy used in deforming (or fracturing) a set of particles of equivalent shape is proportional to the ratio of change of size, or:

$$E = K_K \log\frac{d_i}{d_n}$$

where, E = energy required for size reduction

K_K = Kick's constant

d_i = initial diameter of particles

d_n = final diameter of particles

Application: For crushing of large particles Kick's theory most useful.

Walker's theory

Walker proposed a generalized differential form of the energy-size relationship:

$$dE = -K \frac{dD}{D^n}$$

where E = amount of energy (work done) required to produce a change

D = size of unit mass

K = Constant

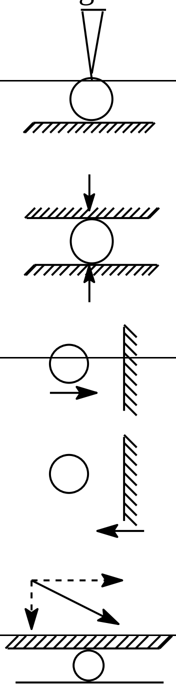
n = constant

For n =1.0 Walker equation becomes Kick's theory used for coarse particles > 1 μm.

For n =1.5 Walker equation becomes Bond's theory. This theory is used when neither Kick's nor Rittinger's law is applicable.

For n =2.0 Walker equation becomes Rittinger's theory used for fine particles < 1 μm size.

Methods of size reduction

	Method	Diagram	Common Examples
Approximate increase in fineness of product	Cutting		Scissors Cutter mill
	Compression		Roller mill Crusher mill

	Impact		Hammer mill
	Attirtion (Pressure and friction)		File Fluid energy mill

Table: Uses of size reduction methods

Degree of size reduction	*Typical methods*	*Examples*
Large pieces	Cutter or compression mills	Rhubarb
Coarse powders	Impact mills	Liquorice, cascara
Fine powders	Combined impact and attrition mills	Rhubarb , belladonna
Very fine powders	Fluid energy mills	Vitamins and antibiotics

CUTTER MILL

Method of size reduction: Cutting

Construction and working principle:

The equipment has two parts – one is rotor and another part is the casing. Stationary knives are fitted on the casing and rotating knives are fitted on the rotor. Feed enters through the top hopper. The rotor rotates and both stationary and rotating knives cut the material into pieces. The lower part consists of a screen, so that material is retained in the mill until sufficient degree of size reduction has been effected.

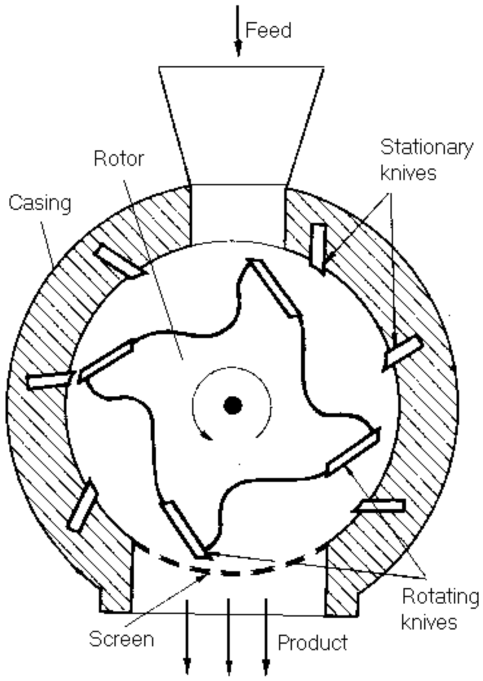


Fig. Cutter Mill

Applications:

This method is used to obtain coarse degree of size reduction of soft materials. Applied in size reduction of roots, peels or woods, prior to extraction.

ROLLER MILL

Method of size reduction: Compression

Construction and working principle:

The roller mill has two cylindrical rolls of stone or metal, mounted horizontally, which are capable of rotating on their longitudinal axes. One roll is rotated directly and the other rotates freely. When material is placed above the rolls it is drawn in through the nip and the second roll is rotated b y friction.

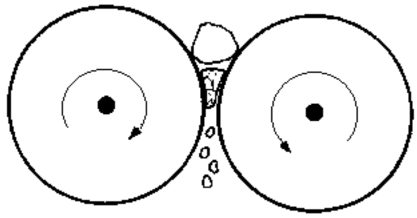


Fig. Roller mill

Diameter of the rolls: Few centimeter up to several meters

The gap between the roll may be adjusted to control the degree of size reduction.

Applications:

Used for crushing or cracking seeds prior to extraction of fixed oils or bruising soft tissues (often after cutting) to aid solvent penetration.

HAMMER MILL

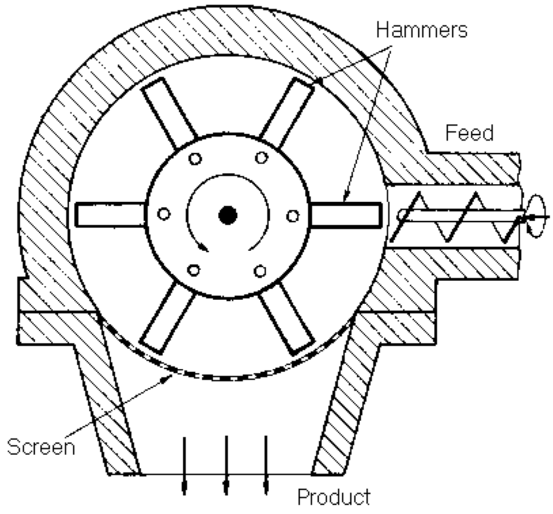


Fig. Hammer Mill

Method of size reduction: Impact

Construction and working principle:

Hammer mill consists of a stout metal casing, enclosing a central shaft to which four or more *hammers* are attached. These are mounted with *swivel* joints, so that the hammers swing out to a radial position when the shaft is rotated. The lower part of the casing consists of screen through which materials can escape, when sufficiently size reduced. The material is collected in a container placed below the screen.

- The screen can be changed according to the particle size required.
- According to the purpose of operation the hammers may be square-faced, tapered to a cutting form or have a stepped-form.
- The interior of the casing may be undulating in shape, instead of smooth circular form for better impact.
- The rotor operates at a speed of 80cycles per second.

Advantages:

(a) It is rapid in action, and is capable of grinding many different types of materials.
(b) The product can be controlled by variation of rotor speed, hammer type and size and shape of mesh.
(c) Operation is continuous.
(d) No surface moves against each other so very little problem of contamination of mill materials.

Disadvantages:

(a) High speed of operation generates heat that may affect thermolabile materials or drugs containing gum, fat or resin.

(b) The rate of feed should be controlled otherwise the mill may be choked.

(c) Because of high speed of operation, the hammer mill may be damaged if some foreign materials like stone, metal pieces etc. are present in the feed.

Applications: Powdering of crystals and filter cakes.

BALL MILL

Construction

The ball mill consists of a hollow cylinder rotated on its horizontal axis. Inside the cylinder balls or pebbles are placed.

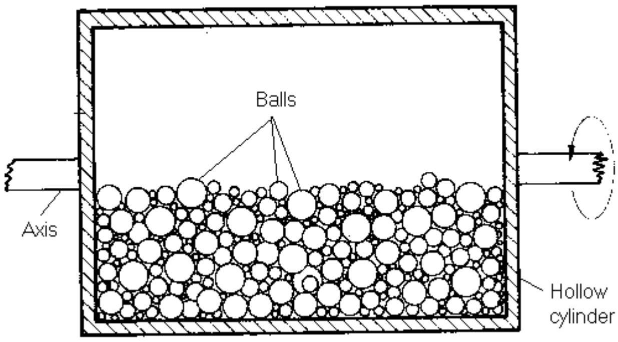


Fig. Ball mill

Cylinder:

- Cylinder may be made up of metal, porcelain or rubber.
- Rubber reduces the abrasion. Diameter of the cylinder ranges from 1 to 3m in pharmaceutical practice.

Balls:

- Balls occupy about 30 to 50% of the volume of the cylinder.
- Diameter of the balls depends on the feed size and diameter of the cylinder. The diameter of balls ranges from 2cm to 15cm.
- Balls may be of metal, porcelain or pebbles.

Working Principle:

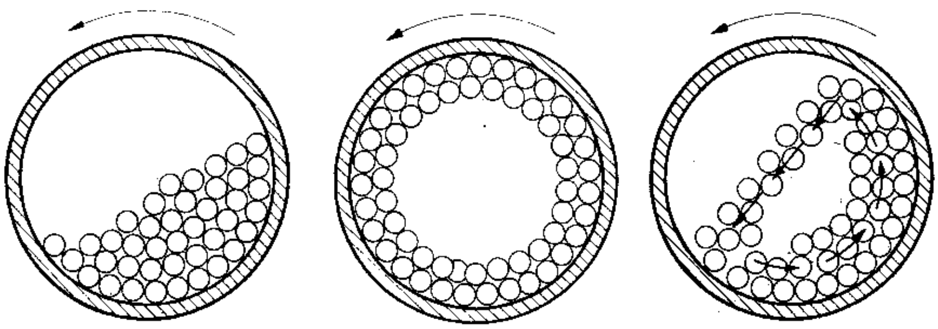
Larger particles are fed through an opening of the cylinder. The opening is closed. The cylinder is rotated at the critical speed of ball mill. The optimum size reduction in a ball mill depends o the following factors:

Feed quantity:

Too much feed will produce cushioning effect and too little feed will produce loss of efficiency of the mill.

Speed of rotation of the cylinder:

- At low speed the mass of balls will



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

Fig. Ball mill operation

slide or roll over each other and only a negligible amount of size reduction will take place.

- At high speeds, balls will be thrown out to the wall of the cylinder due to centrifugal force and no grinding will occur.
- At 2/3rd speed at which centrifugation just occurs is called the critical speed of the ball mill. At this speed the balls are carried almost to the top of the mill and then fall in a cascade across the diameter of the mill. By this means the maximum size reduction is obtained by impact of the particles between the balls and by attrition between the balls. Generally it is 0.5 cycles per seconds (cps).

Advantages

1. It is capable of grinding a wide variety of materials of differing hardness.
2. It can be used in completely enclosed form, which makes it suitable for use with toxic materials.
3. It can produce very fine powders.
4. It is suitable both for dry and wet milling. Wet milling is required for preparation of pharmaceutical suspensions.

Disadvantages

1. Wear occurs from the balls and the inside surface of the cylinder hence there is possibility of contamination of product with mill material. Abrasive materials increase wear.
2. Soft or sticky materials may cause problems by caking on the sides of the mill or by holding the balls in aggregates.
3. The ball mill is a very noisy machine, particularly if the cylinder is made of metal.

Applications:

Large ball mills are used to grinding ores prior to manufacture of pharmaceutical chemicals. Smaller ball mills are used for grinding of drugs or excipients or for grinding suspensions.

Various types of ball mills:

Hardinge mill: In this type of ball mills the cylinder has a conical end towards a discharge point. In this mill the larger balls remain within the cylinder and the smaller balls are collected in the conical portion. As a result, coarser grinding takes place in the cylinder portion and finer grinding takes place in the apex of the conical portion. The product is more finer and uniform than general cylindrical ball mill.

Tube mill: They consist of long cylinder and can grind to a finer product than the conventional ball mill.

Rod mill: Instead of balls they contains rods, which extends the length of the mill. This rods are useful with sticky materials since rods do not form aggregates like balls.

Vibration mill: In this type of mills vibratory movements are given instead of rotation. The cylinder is mounted on springs which sets up vibration. The cylinder moves through a circular path with an amplitude of vibration up to abut 20mm and a rotational frequency of 15 to 50 per second.

FLUID ENERGY MILL

Construction:

It consists of a loop of pipe, which has a diameter of 2 to 20cm. The height of the loop may be up to 2m. Several nozzles are fitted at the bottom of the pipe. A classifier is fitted at the product collection point.

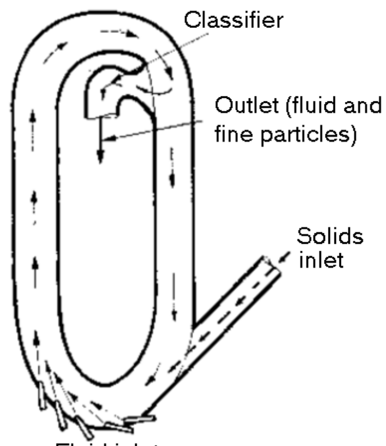


Fig. Fluid energy mill

Working principle

A fluid usually air, is injected at very high pressure through nozzles at the bottom of the loop. This gives rise to a high velocity of circulation that produce turbulence. Solids are introduced into the stream through the feed inlet. As a result of high degree of turbulence, impacts and attrition occur between the particles. A *classifier* is fitted in the system so that only finer size particles are collected as products and the larger size particles are again sent to the stream of air for further size reduction.

The feed to the mill is previously size reduced and passed through a 100mesh screen.

The size of the product may be 5μm or below.

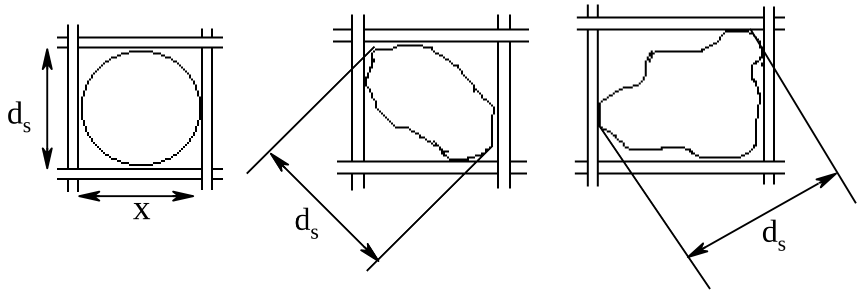
Advantages:

1. The particle size of the product is smaller than that produced by any other method of size reduction.
2. Expansion of gases at the nozzles lead to cooling, counteracting the usual frictional heat that can affect heat-sensitive (thermolabile) materials.
3. Since the size reduction is by inter-particulate attrition there is little or no abrasion of the mill and no contamination of the product.
4. For oxygen or moisture sensitive materials inert gases like nitrogen can be used instead of normal air.
5. This method is used where fine powders are required like micronization of griseofulvin (an antifungal drug), antibiotics etc.

SIEVE ANALYSIS

Equivalent diameter

Sieve diameter, d_s , is the particle dimension that passes through a square aperture (length = x).



Sieve diameter, d_s for various particle shapes

Range of analysis

The International Standards Organization (ISO) sets lowest sieve diameter of 45μm. Powders are usually defined as particles having a maximum diameter of 1000μm, so this is the upper limit. In practice sieve analysis can be done over a range of 5 to 125000μm.

ISO Range : 45 to 1000 μm

Range available in practice: 5 to 125000 μm

Sample preparation

- Powders in dry state is usually used.
- Powders in liquid suspension can also be analyzed by sieve.

Principle of measurement with sieve

Sieve analysis utilizes a set of sieves. Each sieve is a woven, punched or electroformed mesh, often in brass or stainless steel, with known aperture diameter which form a physical barrier to particles. In sieve analysis a set of sieves (known as 'stack' or 'nest' of sieves) are arranged in such a way that the smallest aperture will be at the bottom and the largest aperture will be at the top.

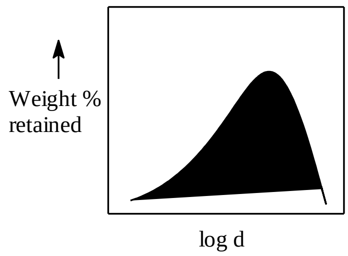
1. A sieve-nest usually comprises 6 to 8 sieves with an aperture progression based on $\sqrt{2}$ or $2\sqrt{2}$ change in diameter between adjacent sieves.
2. Initial weight (W_0) of powder sample was taken on the first sieve (i.e. topmost sieve). The sieve-set was closed and shaking was started. After shaking for a stipulated time, the sieve-set was taken out. All the sieves were disassembled.
3. The powder retained on each sieve was collected on a paper (bearing the mesh number) and weighed.

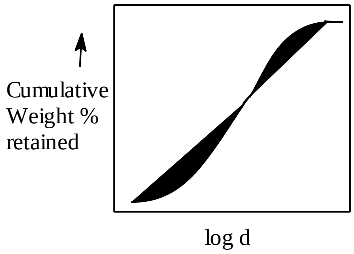
TABLE - 1

Sieve number (Passed/ Retained)	Size of opening (Passed / Retained)	Arithmetic mean Size of openings d (μm)	Weight Retained on smaller sieve (gm)	% Retained on smaller sieve	Cumulative % oversize
M1/M2	d1/d2	½(d1 + d2)	W1	p1=100w1/ W	p1
M2/M3	d2/d3	½(d2 + d3)	W2	p2=100w2/ W	p1+p2
M3/M4	d3/d4	½(d3 + d4)	W3	p3=100w3/ W	p1+p2+p3
--	--	--	--	--	--
--	--	--	--	--	--
--	--	--	--	--	--
			Total = W	Total = 100	

TABLE – 2: Plot

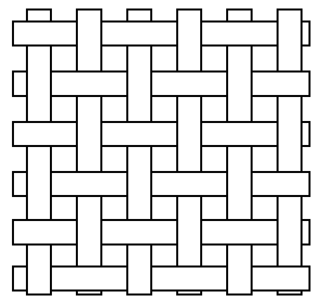
log d	Weight % retained	Cumulativ e % oversize





STANDARDS OF SIEVES

It is required that wire-mesh sieves will be made from wire of uniform, circular cross-section and for each sieve the following particulars are stated:



Number of sieve

This is the number of meshes in a length of 25.4mm (i.e. 1 inch), in each direction.

Nominal size aperture

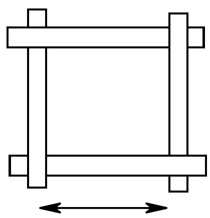
This is the distance between the wires, so that it represents the length of the side of the square aperture.

N.B. While it is the diameter of the largest sphere that would pass the mesh, it is not necessarily the maximum dimension of the particle, plate like particles will pass through diagonally and long fibrous particles require only suitable orientation.

Nominal diameter of the wire

The wire diameter is selected to give a suitable aperture size. It is also required to give the necessary strength to avoid distortion.

The diameter of the wire is represented by Standard Wire Gauge.



Approximate screen area

This standard expresses the area of the meshes as a percentage of the total area of the sieve.

It is governed by the diameter of the wire. It is generally kept within 35 to 45% of the total area of the sieve.

This represents the useful area of a sieve. Greater screen area is preferred.

$$\text{Approximate Screen Area} = \frac{\text{Total sieve area - Area occupied by the wire}}{\text{Total area of the screen}} \text{x} 100\%$$

Aperture tolerance average

Some variation in the aperture size is unavoidable and this variation is expressed as a percentage, known as aperture tolerance average. It is the maximum limit within which the dimension of meshes can be allowed to vary and still be acceptable for sieving.

Finer wires are likely to be subject to a greater proportional variation in diameter than coarse mesh. Hence, the aperture tolerance average is smaller for sieves of 5 to 10 mesh than in case of 300mesh.

Tyler Standard Screen Scale

Mesh	Clear Opening, mm	Wire Diameter, mm
3	6.680	1.778
4	4.699	1.651
6	3.327	0.914
8	2.362	0.813
10	1.651	0.889
14	1.168	0.635
20	0.833	0.437
28	0.589	0.318
35	0.417	0.310
48	0.295	0.234
65	0.208	0.183
100	0.147	0.107
150	0.104	0.066
200	0.074	0.053

SIZE SEPARATION EQUIPMENTS

SHAKING SCREEN

Principle:

Particles of different sizes are separated by passing them through a sieve, which oscillates to-and-fro continuously.

Construction:

Shaking screen consists of metal frame to which a screen is fixed at the bottom. The screen cloth may be riveted directly or fitted by using a removable bolted frame. The metal frame is suspended by hanger rods, so that it can move freely. The metal frame may be suspended either horizontally or in inclined position. One side of the frame is attached with an ordinary eccentric on a rotating shaft. The entire frame experiences a reciprocating (to-and-fro) motion.

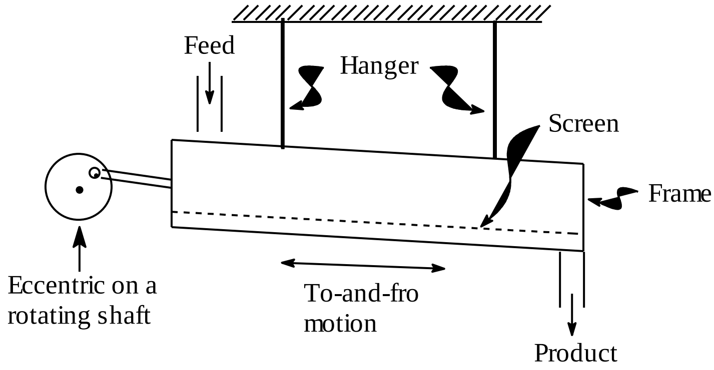


Fig. Shaking screen

Working:

The screen is allowed to shake in a reciprocating motion. The feed (material to be screened) is introduced on to the screen from a side. . Fine particles are screened off initially. The remaining materials moves forward and the over-sized particles are collected at the other end.

Advantages:

It requires low-head room and low power requirement.

Disadvantages:

High cost of maintenance of screens and supporting structures.

Its capacity is low.

SHAKING AND VIBRATING SCREENS (ROTEX SCREEN)

Principle: Rotex screen works on oscillating agitation (to-and-fro motion) by means of an eccentric mechanism. Further vibrations are caused by rubber balls.

Construction:

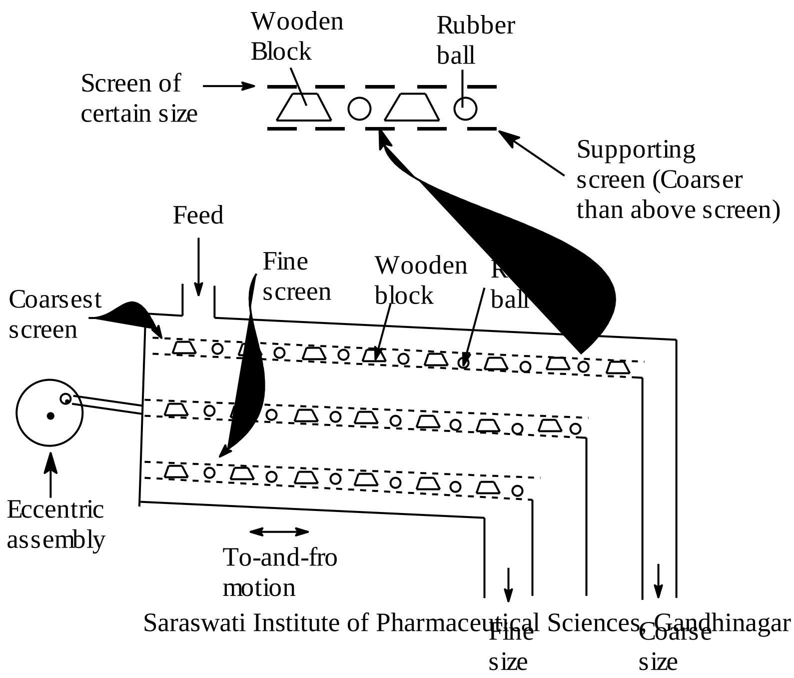


Fig. Rotex Screen

This equipment consists of a set of screens, which are slightly inclined at 5 degrees with horizontal axis. Each screen set is double layered. The upper screen is of a fixed size and the lower one is coarser screen, which is a supporting sieve. Between these two screens, wooden blocks are placed at different intervals. Between the wooden blocks rubber balls are placed. This two-sieve system represents one unit. Several such units are arranged in the descending order, i.e. sieve or larger size opening remains at the top and finer size opening remains at the bottom. The overall assembly of screens is supported on sliding contacts at the lower end. The upper end of the screen system is connected to an eccentric pin on a flywheel.

Working:

The screen system is allowed to agitate with the help of eccentric. The shaking motion of the screen causes the balls to fly between the screens. As they strikes the inclined surface of the wooden blocks, the balls deflect upward and strike the screen cloth and thus prevents blocking of the mesh. The feed is introduced at the higher end of the screen. The material passes through the upper screen and reaches the next screen. This process continues until all the materials are separated into fractions. The fractions are collected separately at the outlet point.

Uses: Rotec screen is used for handling a variety of dry powders, granules and dry foods.

GYRATORY SCREENS (FINEX)

Principle:

The Finex shifting machine consists of a horizontal screen to which a gyratory movement of great intensity and small amplitude is imparted by eccentric mechanism. Every particle is given a rotary movement on one axis and a second rotary movement on an axis at right angles to the first.

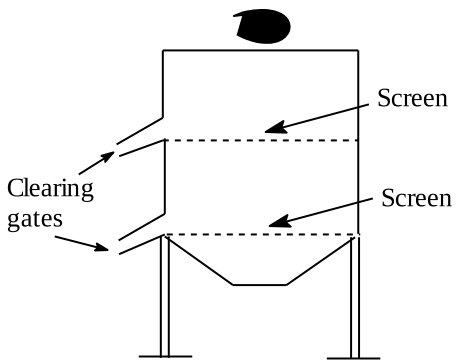


Fig. Gyratory Screens

Construction:

Screens are fitted horizontally. The topmost has the largest opening and the bottom one will have finer opening. The overall assembly is given a gyratory motion by eccentric mechanism. Clearing gates are fitted at one side of the periphery.

Working:

The feed is introduced at the center of the screen and the gyratory motion drives the larger sizes to the periphery of the screen where it is discharged through a clearing gate set in upright side of the sieve. In some devices a spiral strip of metal is welded to the screen. The larger size passes progressively from the center to the periphery.

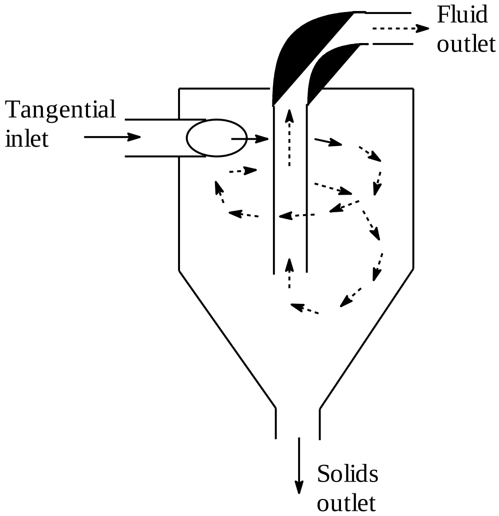


Fig. Cyclone separator

CYCLONE SEPARATOR

Principle

In cyclone separator centrifugal force is used to separate solid from fluids. The separation process depends on particle size and particle density. It is also possible to allow fine particles to be carried with the fluid.

Construction

It consists of a short vertical, cylindrical vessel with a conical base. The upper part of the vessel is fitted with a tangential inlet. The solid outlet is at the base. Fluid outlet is provided at the center of the top portion, which extends inwardly into the separator. Such an arrangement prevents the air short-circuiting directly from the inlet to the outlet of the fluid.

Working

The solids to be separated are suspended in a stream of fluid (usually air or water). Such feed is introduced tangentially at a very high velocity, so that rotary movement takes place within the vessel. The centrifugal force throws the particles to the wall of the vessel. As the speed of the fluid (air) diminishes, the particles fall to the base and collected at the solid outlet. The fluid (air) can escape from the central outlet at the top.

Uses

1. Cyclone separators are used to separate solid particles from gases.
2. It is also used for size separation of solids in liquids.
3. It is used to separate the heavy and coarse fraction from fine dust.

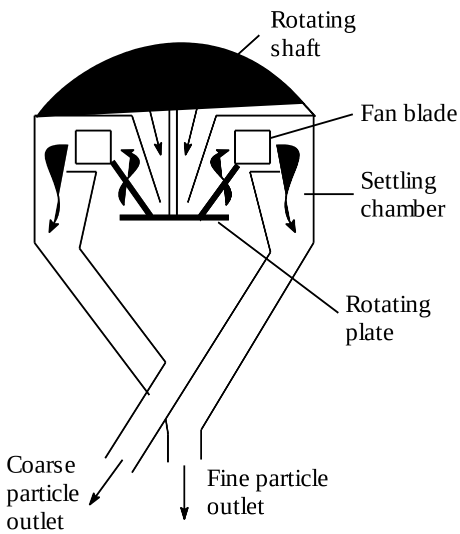


Fig. Air separator

AIR SEPARATOR

Principle

The cyclone separator alone cannot carry out size separation on fine materials. For such separations a current of air combined with centrifugal force is used. The finer particles are carried away by air and the coarser particles are thrown by centrifugal force, which fall at the bottom.

Construction

It consists of a cylindrical vessel with a conical base. A rotating plate is fitted on a shaft placed at the center of the vessel. A set of fan blades are also fitted with the same shaft. At the base of the vessel two outlets are provided: one for the finer particles and the other for coarse particles.

Working

The disc and the fan are rotated by means of a motor. The feed (powder) enters at the center of the vessel and falls of the rotating plate. The rotating fan blades produce a draft (flow) of air in the direction as shown in the diagram. The fine particles are picked up by the draft of air and carried into space of settling chamber, where the air velocity is sufficiently reduced so that the fine particles are dropped and removed through the fine particle outlet.

Particles too heavy to be picked up by the air stream are removed at the coarse particle outlet.

Uses

Air separators are often attached to the ball mill or hammer mill to separate and return over sized particles for further size reduction.

BAG FILTER

Principle

In a bag filter, size separation of fines (or dust) from the milled powder is achieved in two steps. In the first step, the milled powder is passed through a bag (made from cloth) by applying suction on the opposite side of the feed entry. This facilitates the separation. In the next step, pressure is applied in order to shake the bags so that powder adhering to the bag falls off, which is collected from the conical base.

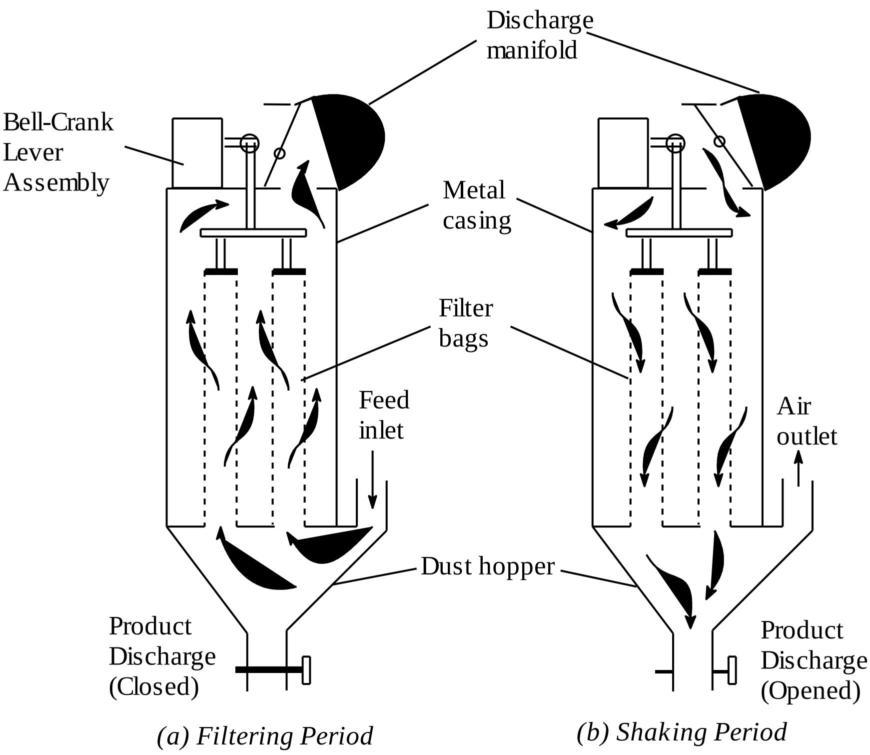


Fig. Bag filter

Construction

It consists of a number of bags made of cotton or wool fabric. These are suspended in a metal container. A hopper is arranged at the bottom of the filter to receive the feed. At the top of the metal container, a provision is made for vacuum fan and exhaust through discharge manifold. At the top of the vessel a bell-crank lever arrangement is made to change the action from filtering to shaking.

Working

(a) *Filtering period*: During this period the vacuum fan produce a pressure lower than the atmospheric pressure within the vessel. Gas to be filtered enters the hopper, passes through the bags, and out of the top of the apparatus. The particles are retained within the bags.

(b) *Shaking period*: During this period the bell-crank lever first close the discharge manifold and air enters through the top so the vacuum is broken. At the same time it gives a violent jerking action to the bags so that they are freed from the dust. The fine particles are collected at the conical base.

Uses

1. Bag filters are used along with other size separation equipment, e.g. a cyclone separator.
2. They are use on the top of fluidized bed dryer for drying to separate the dusts.
3. They are used to clean the air of a room.
4. Household vacuum cleaner is a simple version of bag filter.

COTTRELL PRECIPITATOR

Principle

If a gas is subjected to a strong unidirectional electrostatic field, the gas become ionized and drifts toward one electrode. If a finely divided solid particle (or liquid droplet) is suspended in the gas, the particle (or droplet) will become charged and will drift toward the same electrode as the ionized gas.

Construction

There will be two electrodes: (i) Discharge electrode and (ii) Collecting electrode.

- The discharge electrode is usually a wire, chain, wire screen or other arrangement with a large surface.
- The collecting (or smooth) electrode may be parallel plate or pipe.
- In case of parallel plate design the gas flows parallel to plates.

  Plate dimensions: Length = 10 to 18 ft Width = 3 to 6 ft.

- In case of pipe design the pipes are placed vertically and a wire (discharge electrode) is fitted at the center of the pipe. Gas flows from the bottom to the top of the pipe. At the bottom of the pipe a hopper is given to collect the particles. *Pipe dimensions*: Height 6 to 15 ft.

Working

AC current is first stepped up with a step up transformer to raise the potential difference to 50,000 to 60,000 volts. Then the voltage is made unidirectional by a motor-disc assembly where the motor is rotating at a speed similar to the frequency (i.e. cycles per second or Hz) of the AC current. This results in a pulsating but unidirectional electrostatic field.

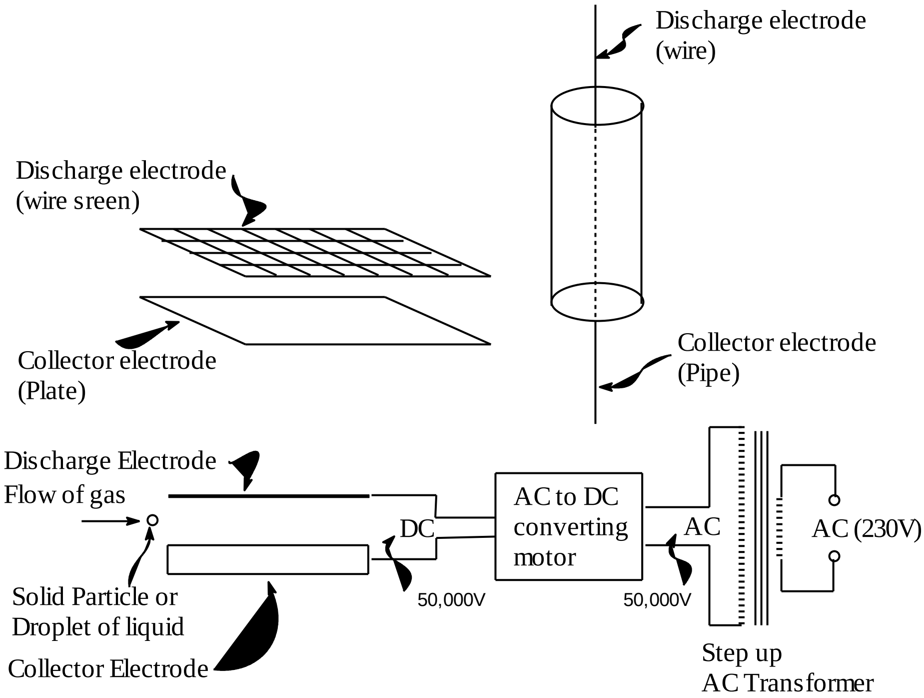


Fig. Cottrell Precipitator

The particles will be charged and precipitated on the smooth plate or pipe, which is then collected through the hopper.

Use

The Cottrell process is successfully used for the removal of fine dusts from all kind of waste gases.

SCRUBBERS

Principle

Solid and liquid particles suspended in gas can be removed (or scrubbed) by introducing water from the top of the equipment and gas through the bottom of the equipment, i.e. water and gas flow in counter-current flow.

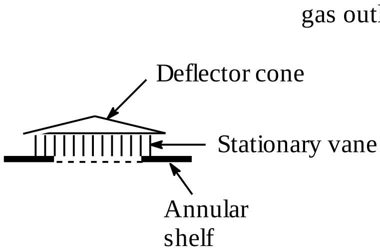


Fig. A contact

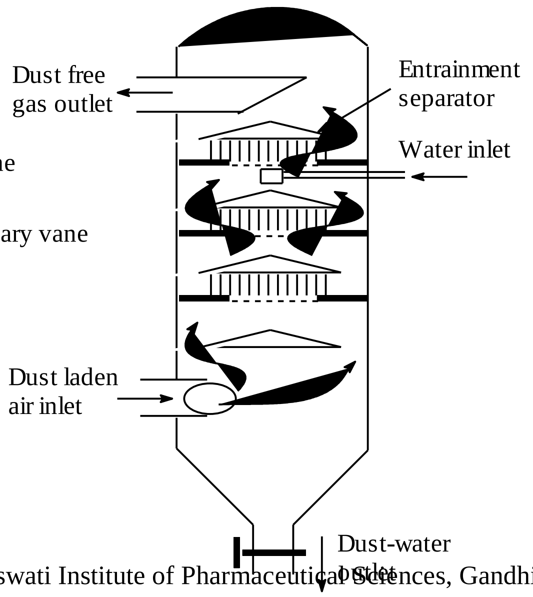


Fig. Scrubber

Construction

This equipment consists of a cylindrical *shell* with conical bottom. The gas containing the suspended particles enters through a tangential inlet at the bottom. *Deflector cones* are placed on *stationary vanes*. These vanes are placed on *annular shelves*. One deflector cone, vanes and the annular ring as a whole called a *contact*. There are several such contacts placed inside the shell. The *liquid inlet* is placed at the second top contact. The topmost contact is called *entrainment separator*. Dust collector outlet is placed at the bottom of the equipment. The gas is taken out through the gas outlet placed at the top of the separator.

Working

The gas carrying the particles (or droplets) are introduced through the gas inlet at the bottom and passes upward through the vanes under deflector cones. Liquid (e.g. water) is introduced from the top. It falls on the conical deflector and flows over the vanes to produce a curtain of liquid. The gas passes through these curtains. Particles or droplets are retained in the liquid and gas passes to the next contact. After passing through several such contacts the gas passes through the entrainment separator where small droplets of water (known as entrainment) are separated and the gas leaves the separator through the gas outlet. The discharged gas goes to a cyclone separator where the entrained water (if any) are finally removed from the gas.

Use

To clean the dust of air before entering inside a room or before discharging a gas in the environment from an industry.

SIZE SEPARATORS BASING ON SEDIMENTATION THEORY

Size separation by sedimentation utilizes the differences in settling velocities of the particles with different diameter (d) and these can be related to Stoke's law.

Stoke's law

When a solid particle is suspended in a liquid the particle settles downward at a velocity, V. This velocity is called sedimentation rate. It is found that this rate of sedimentation depends on the diameter of the particle, density of the liquid and particle, viscosity of the liquid and the acceleration due to gravity. All this parameters can be combined in the form of Stoke's equation:

Where d = diameter of the particle
ρ_1 = density of the particle
ρ_2 = density of the liquid
g = acceleration due to gravity
η = viscosity of the liquid.

$$V = \frac{d^2(\rho_1 - \rho_2)g}{18\eta}$$

CONTINUOUS SEDIMENTATION TANK

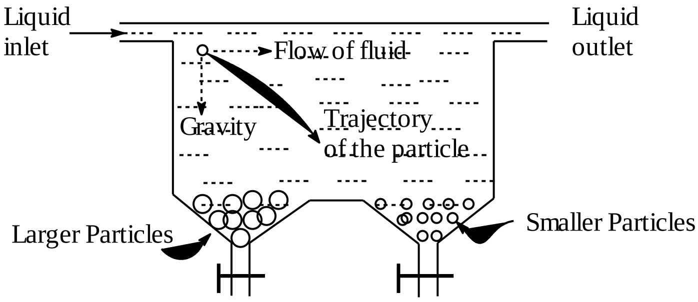


Fig. Sedimentation Tank

A shallow tank is arranged with inlet and outlet pipes as shown in the figure. Particles entering the tank will be acted upon by a force that can be divided into two components:

(i) a horizontal component due to the flow of liquid carrying the particles forward and

(ii) a vertical component due to gravity, which causes the particles to fall towards the bottom of the tank. This component is governed by Stoke's law so that the velocity of sedimentation is proportional to the square of the diameter of the particles.

Thus the particles will settle at the bottom of the tank in such a way that the coarsest (largest) particles will settle near to the inlet of liquid and the finest particles near to the outlet of the liquid. Partitions are arranged at the floor of the tank to enable collection of different size fraction particles.

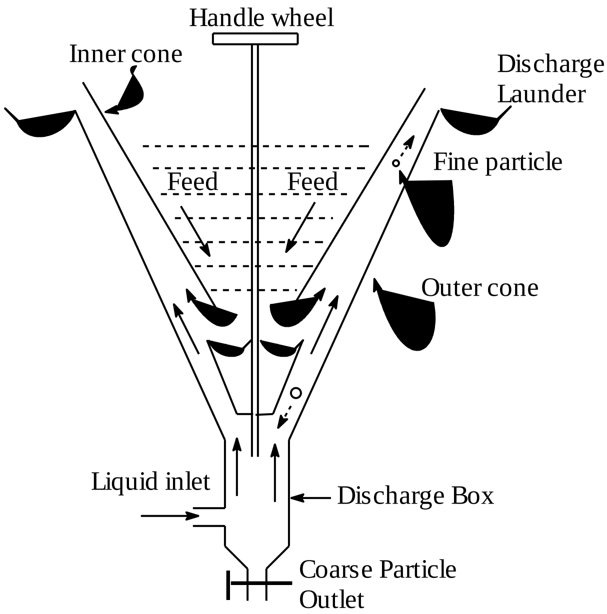


Fig. Double cone classifier

DOUBLE CONE CLASSIFIER

Principle

The separation takes place by elutriation principle.

N.B. In sedimentation method the fluid is stationary and the separation is taking place by the velocity of the particles. In elutriation method the liquid is flowing to the opposite direction of the sedimentation of the particle.

In elutriation method the fluid flows in opposite direction to the sedimentation movement. In this equipment the liquid moves upward. If the sedimentation velocity of a particle is less than the velocity of the liquid then the particle will move upward. If the sedimentation velocity of the particle is more than the velocity of the liquid then the particle will move downward. So if the velocity of the liquid is kept within the sedimentation velocities of the coarse and fine particles then the finer particles (has lesser sedimentation velocity) will move upward and the coarser particles (have greater sedimentation velocity) will move downward.

Construction

Two cones of different sizes are placed one in another. At the top of the outer cone a *discharge launder* is fitted at the outside surface of the outer cone. Water inlet is provided at the bottom of the equipment. The inner cone is shorter than the outer cone. The inner cone can be moved along its vertical axis with the help of a hand wheel. At the bottom a collecting box is provided to collect the coarse particles.

Working

The feed enters the inner cone and water is introduced through the water inlet at the bottom. The particles settle from the inner cone meet a rising stream of water at lower end of inner cone. The fine particles pass upward and are collected in the discharge launder. The coarse particles settle into the collecting box for coarse material and are drawn off at intervals.

The degree of separation is regulated by the velocity of water supply and the height of the inner cone regulated by the hand-wheel.