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An Overview on Size-Reduction

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Sahishna S.S*[1], Subash Chandran M.P[2], Prasobh G.R[3], Akhila J.B[1], Pooja Rejakumar[1], Renjini A.S[1]

[1]B Pharm student, Sree Krishna College of Pharmacy and Research Centre, Parassala, Thiruvananthapuram, Kerala, India. 695502

[2] Professor and Head, Department of Pharmaceutics, Sree Krishna College of Pharmacy and Research Centre, Parassala, Thiruvananthapuram, Kerala, India. 695502

[3]Principal, Sree Krishna College of Pharmacy and Research Centre, Parassala, Thiruvananthapuram, Kerala, India. 695502

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ABSTRACT

Size reduction is a process of reducing large solid unit mass into small coarse particles or fine particles, size reduction process is also termed as comminution or diminution or pulverization. There are many types of size reduction equipment, which are often developed empirically to handle specific materials and then are applied in other situations. Probably the most important characteristic governing size reduction is hardness because almost all size reduction techniques involve creating new surface area and this requires adding energy proportional to the bonds holding the feed particles together. In addition to the standard adjustments of the milling process. This systemic review highlights advantages and disadvantages, mechanisms, theories, techniques, advances, and pharmaceutical applications of size reduction technologies.

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INTRODUCTION

Size reduction is a process of reducing large solid unit mass or particles, chemical substances into small unit masses, coarse particle or fine particles. Size reduction is commonly employed in pharmaceutical industries. Size reduction is also referred to as comminution and grinding.[1]When the particle size of solids is reduced by mechanical means it is known as milling. Size reduction also plays an important role in the size separation plays a very important role in producing very fine particles. Figure 1 shows the general parts of size reduction in the pharmaceutical industry. There are many types of size reduction equipment, which are often developed empirically to handle specific materials and then are applied in other various situations.

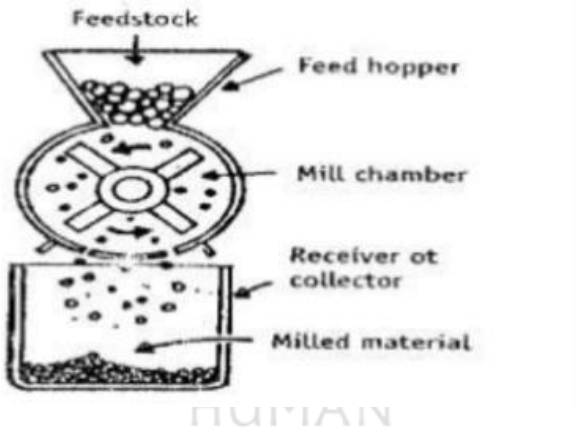

Fig. No. 1: General parts of Size Reduction

OBJECTIVES OF SIZE REDUCTION

In the materials processing industry, [2]size reduction or comminution is usually carried out in order to:

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

- To mix solid particle more intimately

ADVANTAGES

- Uniformflow[3]
- Effective drying
- Content uniformity
- Increase surface area or viscosity
- Improve rate of absorption, smaller the particle greater is absorption
- Improved is solution rate.

DISADVANTAGES

- Drug degradation
- Contamination
- Decrease in small particle size may leads to agglomeration of small particle as result of static charge that may decreases the dissolutionrate[4]
- Possible change of polymorphic form of the Active Pharmaceutical Ingredients

MECHANISM OF SIZE REDUCTION

IMPACT

Impact occurs when the material is kept stationary and is hit by an object moving at a high speed or when the material is kept moving at high speed against a stationary object.

Eg.: Hammermill.

ATTRITION

It involves collision between the two particles having high kinetic energy or a high velocity particle with a stationary phase.[4]

Eg.: Roller mill & fluid energy mill.

SHEAR

Produced when the particle is compressed between the edges of two hard surface moving tangentially.

Eg.: Scissors.

COMPRESSION

In this mechanism the size reduction is achieved by crushing the material by application of pressure.

Eg.; Sharp knife.

Here the various mechanisms which are used in the size reduction are figured out in figure 2.

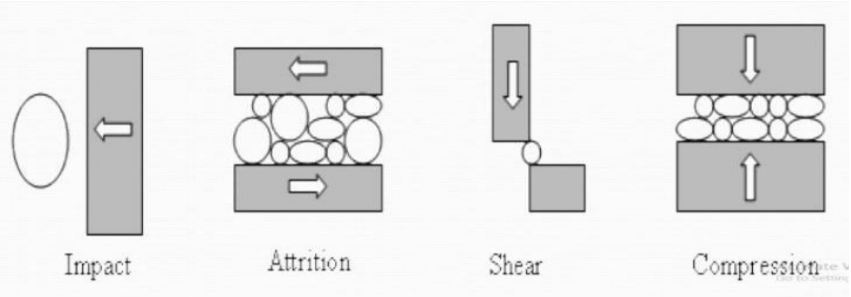

Fig. No. 2: Various mechanisms of size reduction

APPLICATIONS

- Size reduction helps in rapid solution formation in the case of a chemical substance by increasing the surface area of drugs.[5]

- Extraction from animal glands (liver and pancreas) and crude vegetable drugs is facilitated because the solvent can easily penetrate the tissue due to an increase in surface area and resulting quick extraction of their active constituents.

- Therapeutic effectiveness of some drugs is increased by reducing the particle size, e.g. dose of griseofulvin is reduced to half that of originally required.

- Size reduction is very important in the case of suspension; if the size of the particle is too

small they can form a cake which may not redisperse easily, so suitable particle size is important.

LAWS GOVERNING SIZE REDUCTION:

Kick's Law:

States that the energy required to reduce the size of the particle is directly proportional to the ratio of the initial size to the final size of the material.

$$E=K_k \ln[\frac{d1}{d2}]$$

Where,

E = the energy required per mass of feed

K_k = Kick's constant

d1 = the average of initial size of pieces(m)

d2 = the average size of ground particles(m)

Rittinger's Law:

States that the energy required for size reduction is proportional to the change in surface area of the piece.[6]

$$E = R_R(Sn - Si)$$

Where,

E = the energy required per mass of feed

Kg = Rittinger's constant.

d1 = the average of initial size of pieces(m)

d2 = the average size of ground (m)

S = surface area.

Bond Law:

States that the work required to form particles of size from the very large feed is proportional to the square root of the surface to volume ratio of the product. More realistic method for predicting energy requirement in size reduction. Energy requirement for size reduction of a set of particles is proportional to change in particles dimension,[7] which can be mathematically written as

$$E/M = K_B[1/\sqrt{dp} - 1/\sqrt{df}]$$

Where,

Dp = diameter of product particle.(m)

Df = diameter of feed particles. (m)

K_B = constant

EQUIPMENT IN SIZE REDUCTION

Many types of size reduction equipment are:

- Crushers
- Grinders
- Ultra-fine grinders
- Cutting machine

CRUSHERS

Crushing is the first step of mineral processing and they are slow-speed machines employed for the coarse reduction of large quantities of solid. They operate by compression and can break large lumps of hard materials. Particle size range from 150mm to 250mm. It is employed mainly for breaking large pieces of solid particles into small lumps. Crushers are classified according to the stage of crushing,[8] they are

- Primary
- Secondary

TYPES OF CRUSHERS

- Jaw crusher
- Gyratory crusher
- Roll crusher

JAW CRUSHER

The jaw crusher compresses the feed between a stationary jaw and a movable jaw, that's operated by allowing stone to flow into the space between two jars, one of which is stationary while the other is movable. The distance between the jaws diminishes as the stone travels downward under the effect of gravity and the motion of the movable jaw until the stone ultimately passes through the lower opening, compression is the principle behind works on it. The jaw crusher is usually made of manganese steel or some other material that will withstand abrasion. The faces of the crushing jaws are usually corrupted for concentrating the pressure on relatively small area springs and frames. In this machine, an eccentric causes the pitman to oscillate in a vertical direction; in this vertical movement is communicated horizontally to the movable jaw by toggles. The speed of operation should not be high or otherwise, a large quantity of fines is produced as the material cannot escape quickly and gets repeatedly crushed, since the crushing action is intermitted, the loading on the machine is uneven and due to this the crusher in co-operates a heavy flywheel. The material to be crushed is admitted between two jars, the material then drops/falls into a narrow space below during the backward motion and is crushed at the jaws.[9] The jaw usually opens and closes 250 to 400 times per minute. The diagrammatic representation of the Jaw crusher is shown in figure 3.

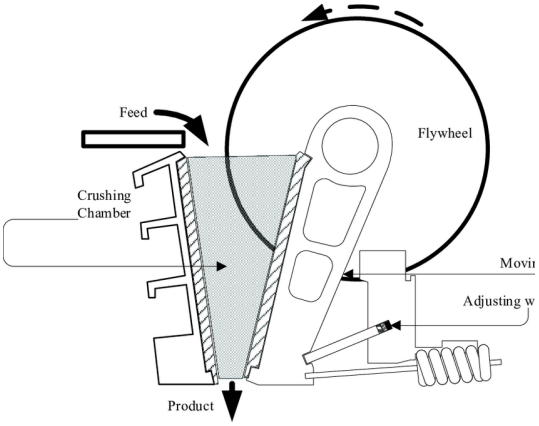

Fig. No. 3: Jaw Crusher

The advantages of jaw crusher are simple structure, low cost, maintenance is convenient, reliable work, small machine body easy device, the high viscosity also is not easy to join and disadvantage includes lower productivity, lower power consumption, bigger vibrations, small crushing ratio, uneven particle size, and mainly used in a wide variety of applications, including construction and recycling demolition, quarrying and mining, etc.[10]

GYRATORY CRUSHER

Gyratory crushers provide continuous crushing action and are used for both primary and secondary crushing of hard tough abrasive rock. Gyratory standard cone crushers are used as secondary crushers gyratory crushers are capable of producing large quantities of uniformly fine crushed unbounded water and it works on the principle of compression. It consists of a funnel-shaped casing, open at the top, the crushing head is mounted on a heavy shaft in the form of a truncated cone, gyrates inside a casing. The upper end of the shaft is held in a flexible bearing and the lower end of the shaft is driven by an eccentric so as to trace a circle. The crushing action takes place around the whole of the cone. The working of the material to be crushed is charged from the top, the bottom of the crushing head usually moves towards and then away from the stationary wall. The speed of the crushing head is usually between 125 to 425 gyrations per minute.[11] The pictorial representation of the gyratory crusher is shown in figure 4.

Fig. No. 4: Gyratory Crusher

It has a relatively stable working state, less vibration, and less weight of the equipment foundation. The basis weight of the gyratory crusher machine is usually 2-3 times the weight of the main part, and the basis weight of the jaw crusher machine is 5-10 times the weight of the machine itself; Sheet products generated by gyratory crusher are much less than jaw crusher. However, it also has disadvantages that the body of the gyratory crusher is higher, and the crusher is generally 2-3 times higher than the jaw crusher, so its cost is larger, its weight is greater, and its mine mouth size is 7-2 times larger than jaw crusher, so the equipment investment cost is higher; It is not suitable for the crushing of wet and sticky ore.[11]

ROLL CRUSHER

Roll crushers are used for producing additional reductions in the size of stones. A roll crusher consists of a heavy cast from frame equipped with either one or more hard steel rolls, each mounted on a separate horizontal shaft. For any given setting for jaw or roll crusher approximately 15% of the total amount passing through the crusher will be larger than the setting, the theoretical maximum reduction ratio of 4:1. The particle drawn into the gap between the rolls by their rotating motion and friction angle formed between the rolls and the particle called the nip angle.[12] The two rolls force the particle between their rotating surface into the ever smaller gap area, and the fractures from the comprehensive forces presented by the rotating rolls. Roll crusher's diagrammatic representation is shown in figure 5.

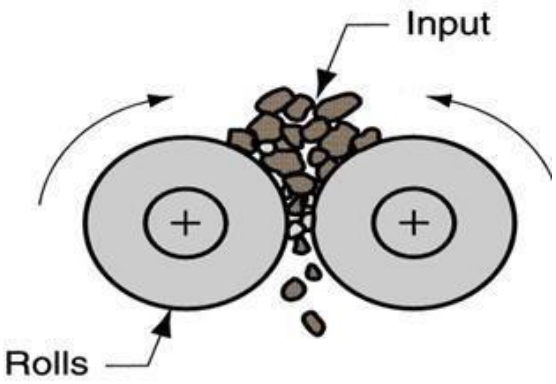

Fig. No. 5: Diagrammatic representation of roll crusher

The major advantages of roll crushers are they give a very fine product size distribution and they produce very little dust or lines. Roll crushers are effectively used in minerals crushing where the ores are not too abrasive and they are also used in smaller scale production mining of more abrasive metal ores, such as gold. It is probably the largest user of roll crushers, currently, coal plants will use roll crushers, either single roll or double roll, as primary crushers reducing the ROM coal. Due to the simple structure, the production capacity of a reliable toothed roll crusher is low, which requires continuous and uniform feeding, the easy abrasion of the roller surface increases the gap between the two rollers, which results in uneven product size, which requires frequent repairs. The actual crushing effect of roller crusher for sand making in flat material is not ideal. This is because there are many gaps between the two rollers of the double roll crusher, and the raw material "leaks", thus reducing the actual crushing effect.[13]

GRINDERS

The grinder is any of various power tools or machine tools that are used for grinding particle size is74µm-350µm. Grinding is a powdering or pulverization process using the rock mechanical forces of impaction, compression, shearing, and attrition.

TYPES OF GRINDERS

- Hammer mills.
- rolling compression mills.
- Ball mills

HAMMER MILL

A Hammermill consists of a rapidly moving hammer connected to a high-speed rotor in a cylindrical casing. It works on the principle of impact between the hammer and the particle to be sized reduced. In a hammer mill, the materials are introduced leading to size reduction later the particles pass through a screen at the bottom and are collected at the receiver. The critical factor affecting the size reduction include feed rate size of the screen and rotor speed.[14] A hammer mill is rapidly operating between 2500 to 5000 rpm and the diagrammatic representation of the hammer mill is shown in figure 6.

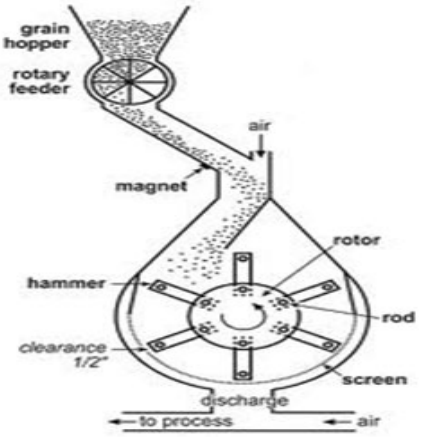

Fig. No. 6: Diagrammatic representation of hammer mill

It is mainly used in the pharmaceutical industries to process wet or dry granulation and disperse powder mixture and is also used in milling pharmaceutical materials, herbal medicine, and sugar. It produces a specified top size without the need for a closed-circuit crushing system. It produces relatively numerous size distributions with a minimum of fines due to self-classification. It has a high reduction ratio and high capacity whether used for primary, secondary, or tertiary grinding relatively reasonable energy requirements. The mill may be choked if the feed rate is not controlled leading to damage. The presence of foreign materials like stone or metals finds its way into the material due to inadequate garbling process. There is a possibility of clogging the screen.

ROLLING COMPRESSION MILL

Roller mill is a form of compression mill that uses a single, double, or triple cylindrical heavy wheel and rotated about their long axis either in opposing pairs or against flat plates, to crush or grind various materials, typical temperature, speed, inter-strand time (time between each

stand), and true strain and strain rate ranges at each stage. Since the cross-sectional area is reduced progressively at each set of rolls, the stock moves at different speeds at each stage of the rolling mill. Material is compressed by the application of stress and attrition.[16] Stress is applied by rotating heavy wheels and there are 2 cylindrical rollers of stone/metal – mounted horizontally, having a diameter ranging from a few millimeters to a meter. They rotate on a longitudinal axis; one roller is run by a motor and the other freely. The presence of friction between rollers and the strip is making it pull the strip into the rollers without applying any pulling and pushing. By the application of rolling, the length of the material increases and thickness reduces without any change in the width of the workpiece. Here the schematic diagram of the rolling compression mill is shown in figure 7.

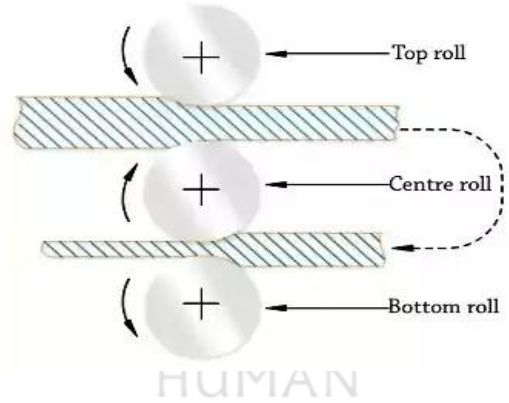

Fig. No. 7: Schematic diagram of Rolling Compression Mill

The advantages of rolling mill by rolling, uniform dimensions of the components can be obtained. It uses the same tool in the sense; the same rollers are responsible for the production of various components. Close tolerance is possible for the components in the rolling. High-speed production takes place in the rolling and the disadvantages include the cost of equipment is high. It is suitable for large-scale production only; thereby we need secondary operations like finishing etc. The main use of rolling mills in the pharmaceutical industry is making rods by rolling, and large-length cross sections are produced. It is also used in automotive industries for manufacturing various parts.[17]

BALL MILL

A ball mill is a type of grinder used to grind or blend materials, for use in mineral dressing processes, paints, pyrotechnics, ceramics, and selectivelasersintering.[18]It is a type of grinder used to grind and blend bulk material into QDs or Nanosize using different sized balls. The

cylinder contains balls occupying 30–50 % of the mill volume. Weight of ball is constant; Size depends on the feed quantity and diameter of the mill.[19]The working principle is simple, impact and attrition size reduction take place as the ball drops from near the top of rotating hollow cylindrical shell. The working of the ball mill's pictorial diagrammatic representation is shown in figure 8.

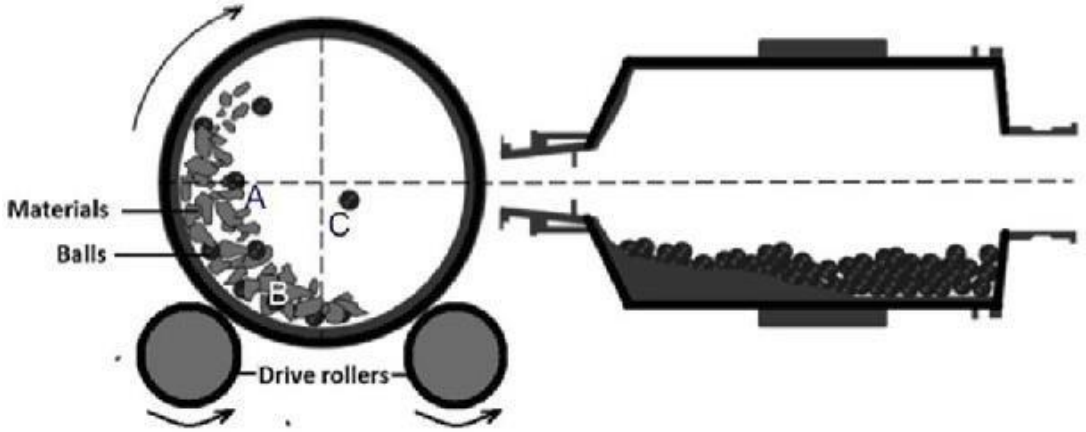

Fig. No. 8: Working of ball mill

The cost of installation, power requires, and grinding medium is low, it is suitable for both the batch and continuous operation, similarly, it is suitable for open as well asclosedcircuitgrindingandisapplicableformaterialofalldegreesofhardness.[20] Bulky size, running a strong vibration and noise, there must be a solid foundation, low efficiency, greater friction loss. Mainly the use of ball mill produces fine powder which can grind a large variety of materials.

ULTRAFINE GRINDING MILL

Ultra-fine grinding techniques are those techniques that are more energy-efficient than conventional milling techniques in the sub 100µm range, it is the new type of mining equipment for making micro powder, fine powder, etc.[21]The figure 9 shows a schematic diagram of ultra-fine grinding mill. Ultra-fine grinder used in the development of medical resources can produce micron-level powder, which can destroy the structure of the tissue cell wall and obtain the required material characteristics.

The medical ultra-micro grinder uses compressed air to be cooled, filtered and dried. The nozzle forms a supersonic airflow and is injected into the crushing cavity. The material is fluidized under the action of pressure difference.[22] The accelerated material is at the

intersection of multiple nozzles. Converge, produce fierce impact, collision, friction, and shear to achieve ultra-fine grinding of particles, which can be used to produce various micron-level powders. The medical ultra-fine grinder is used for ultra-fine pulverization and wall-breaking processing of various types of medicine; improvement of drug solubility; ingenious confusion and evacuation of compound drugs; manufacture of film ointment, etc.

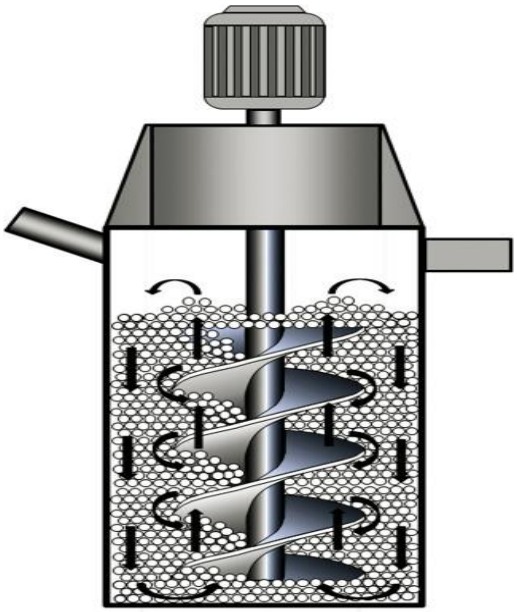

Fig. No. 9:Ultra-fine grinding mill

CUTTING MACHINE

Cutting machine may be accomplished by single point or multipoint tools and works on the principle of cutting[23]. Particle size ranges from 2mm to 10mm. In the cutter mill, size reduction involves successive cutting or shearing of the feed materials with the help of sharp knives. These are mills commonly used in the laboratory for the preliminary size reduction of soft, medium-hard, fibrous and tough, materials. Cutting mills should be used with care since they can contaminate finely- reduced samples with metals from the blades and screens. Such mills are suitable for reducing grains, dried bones, etc. A cutter mill consists of a series of knives attached to a horizontal rotor which act against a series of stationary knives attached to the mill casing.[24]The schematic representation of the cutter mill is shown in figure 10.

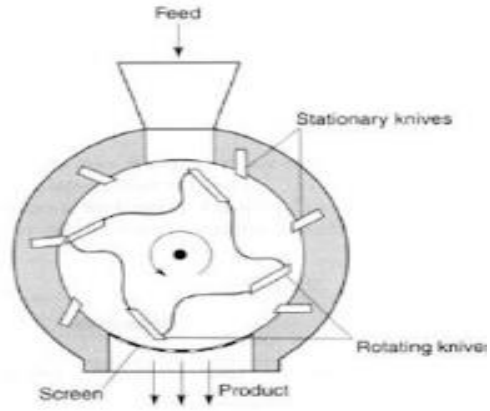

Fig. No. 10: Working of cutter mill

Advantages of cutter mill are the best option of size reduction when impaction, attrition, or compaction type milling is not effective, especially for tough, fibrous, or resilient materials. It is easy to install, operate and maintain.[25] The main disadvantage is that the machines can be very expensive, and the workers using the machine will need some sort of general training to operate the cutting mill in the pharmaceutical industry.

DISCUSSION

Size reduction is the major process in the manufacturing of solid dosage forms mainly used in the pharmaceutical industry, where the large solid particles are reduced into various sizes of particles of broken pieces, medium, fine particles, and very fine particles. It is also termed diminution or pulverization Various types of machines are used for the reduction of solid particles with a different mechanism based on the reduction of solid particles, which includes crushers, grinders, ultra-fine grinders, cutting mills, hammer mills, rolling mills, ball mills, etc. Different machines are worked on various mechanisms like impact, attrition, shear, and compression. Here jaw crushers work on the principle of compression based on that, it crushers the large raw particles are reduced into smaller particles, the hammer mill is the equipment works on the principle of impact in various industries also the rolling compression mill works on the principle of compression, etc. Various equipment in the pharmaceutical industry for size reduction uses various principles based on it gives different sized particles.

Size reduction is influenced by various factors and these include various physical properties like moisture content, stickiness, toughness, abrasiveness, etc. Other material properties like coarse and bulk density of the product, material structure, flow, shape, and size also influence

size reduction. The main purpose of size reduction is to increase the surface area of the particle, other advantages of size reduction include enhanced and uniform mixing of powders due to the narrow size of the particle, rapid rate of absorption, reduced sedimentation rate, improved physical appearance, and increased stability in case of emulsion.

CONCLUSION

Size reduction is a process of reducing large solid unit mass or particles, chemical substances into small unit masses, coarse particle or fine particles. Size reduction is commonly employed in pharmaceutical industries. Size reduction is influenced by various factors. These include various physical properties like moisture content, stickiness toughness, abrasiveness, etc. Other material properties like coarse and bulk density of the product, material structure, flow, shape, and size also influence size reduction. The main purpose of size reduction is to increase the surface area of the particle, other advantages of size reduction include enhanced and uniform mixing of powders due to the narrow size of the particle, rapid rate of absorption, reduced sedimentation rate, improved physical appearance, and increased stability in case of emulsion. The most commonly used equipment in the pharmaceutical industry is crushers because they produce various sized particles from medium-sized particles to finely powdered particles.

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