

A Review on the Technology of Size Reduction Equipment

A. Kumar^{1,3*} and R. Yedhu Krishnan^{2,3}

¹Department of Chemical Engineering,

²Department of Biomedical Engineering,

³Saveetha Engineering College, Thandalam, Chennai – 602105, India

Abstract : Size reduction or comminution is among the most comprehensively used unit operation of widespread application in chemical and other related industries. Subjugation of the materials to stress and consequent reduction in the size of larger solid units into smaller or finer unit masses is called as comminution. The transmission of stress is through the application of mechanical force to the larger solid unit. The most common methods utilized in industries include the use of crushers and mills. The concept of comminution is not novel as it has been utilized by man since time immemorial. Even though many different size reduction machines are available currently the key is the knowledge on the properties of the material to be processed. Size reduction offers advantages like increased surface area and separation of entrapped components.

Key words : Size reduction, reduction, crusher, mills.

Introduction:

Particle size is one of the most important factor affecting the process ability of powder including their mixing, flow and compaction properties. Particle size reduction is significant to enhance surface area and flow property. Larger sized particles face issues with solubility as they require more time for dissolving. In certain special cases particles are not soluble in any media. In those cases, particles are to be dissolved in a suspension of particle size same as that as that of the dissolving particles. The importance of particle size in absorption is that with the decrease in particle size, there is an increase in surface area of particle which leads to increased absorption itself. [1]

The process of reducing larger solid unit masses using various techniques like jaw crusher, gyratory crusher, roll crusher, hammer mill and ball mill into smaller or finer particles is called as size reduction [2-3]. The principle of attrition and impact is mainly used here.

The process of size reduction, also known as comminution or diminution or pulverization is chiefly achieved by two methods – precipitation and mechanical. Precipitation involves the use of dissolution in appropriate solvent and mechanical process involves subjugation to mechanical forces using grinding machines. The former is used mainly for the production of bulk drugs or inorganic raw materials and chemicals like magnesium carbonate or calcium carbonate [4].

Size reduction is influenced by various factors. These include various physical properties like moisture content, hardness, stickiness, toughness, slipperiness, abrasiveness etc. Other material properties like coarse and bulk density of the product, material structure, flow, shape and size also influences size reduction [5-7].

The main purpose of size reduction is to increase the surface area of the particles. Other advantages of size reduction includes enhanced and uniform mixing of powders due to the narrow size range of the particles, rapid rate of absorption, reduced sedimentation rate, improved physical appearance and increased stability in the case of emulsions. [8].

Mechanisms of Size Reduction

The mechanisms have demonstrated that stresses of varied nature are required to achieve size reduction. The common mode of size reduction are explained as follows [Table 1]. [4]

Table 1: Mechanism of size reduction

Methods	Examples	Approximate size of particle (μm)
Cutting	Scissors, Cutter mill and Shears	100-80,000
Compression	Roller mill and Pestle-Mortar	50-10,000
Impact	Hammer mill and Disintegrator	50-8000
Attrition	Colloidal mill and Roller mill	1-50
Impact and attrition	Ball mill and Fluid energy mill	1-2000

General Parts of Size Reduction Equipment

A size reduction equipment have three main components, namely Hopper, Milling chamber and Discharge chute (Figure 1)[8-10]

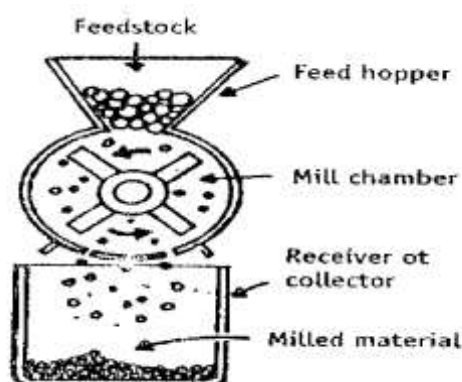


Figure 1: General Parts of Size Reduction Equipment (Three basic Components)

Advantages of size reduction

- Improved mixing and minimized segregation
- Improved chemical reactivity
- Improved surface area
- Rapid dissolution and increased absorption of drugs in the case of drugs
- Slower rate of settling and creaming in the case of suspensions and emulsions
- Less grittier cosmetic products

Types of Size Reduction

Methods

Size reduction is a unit operation process and the operations include grinding, compression and impact forces. The types of forces involved are compression, impact and attrition forces.

During size reduction the material subjected is under due stress and the resulting internal strains leads to deformation or fracture of the material. The factor that affects the degree of deformation includes the hardness of material, structure of materials, the amount of heat generated in the material and its tendency to crack. Also harder materials require higher energy to fracture. The nature of materials determines the type of impact it required for size reduction. For example, softer materials require shearing forces and a combination of shearing forces and impact is necessary for fibrous materials.

Some of the common mechanical size reduction methods are listed as follows:

Equipment for cutting: Extensively used in food industry for cutting of vegetable or meat products. A bowl chopper is a common example.

Equipment for milling: These include both grinders and crushers. Grinders make use of impact and shear forces for size reduction. Examples include hammer mills, roller mills and hammer mills. Crushers can be commonly seen in usage in sugar cane industry where, sugar cane is subjected to compression forces.

Equipment for homogenization: In homogenization, two immiscible liquids are combined together into an emulsion thereby dispersing the particles. During this the liquid is forced through a narrow nozzle resulting in shear, impact, turbulence and compressive forces acting on the particles in the liquid.

Size reduction laws:

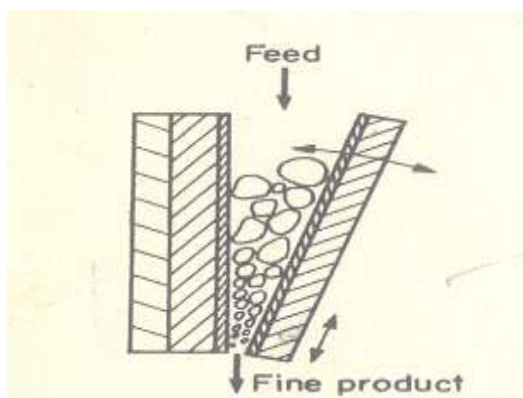
1. Kicks law states that the energy required to reduce the size of particles is directly proportional to the ratio of the initial size to the final size of the material.
2. Rittinger's law states that the energy required for size reduction is proportional to the change in surface area of the pieces.
3. Bond's law states that the work required to form particles of size D_p from very large feed is proportional to the square root of the surface to volume ratio of the product.

Equipment for size reduction:

1. Jaw crushers

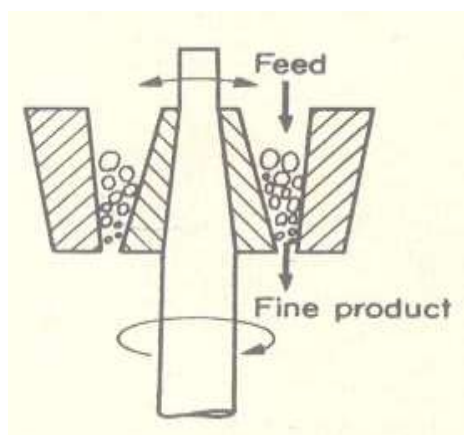
The jaw crusher is V shaped consisting of two jaws – one movable and the other fixed making an angle of 10-20 ° between them. The materials for size reduction are introduced between the two jaws at the top and compressive force is exerted by the movable jaw. The size reduction happens from top to bottom with larger lumps in the upper part of the jaw and successively broken and plunged in to the lower narrower portion below.

Further, the cracked pieces are reduced at the next stroke. Normally, the jaw crusher is operated at 300 times per minute.



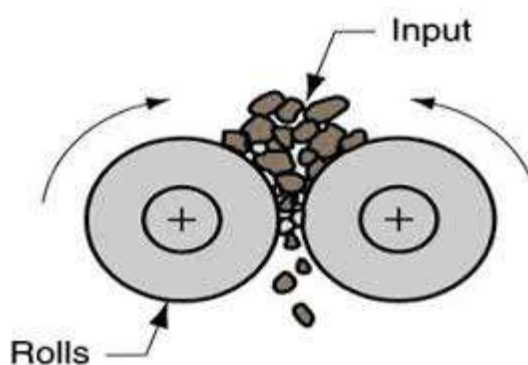
2. Gyratory crusher

The solid materials are fed between circular jaws. The solid materials are introduced into a V-shaped notch between the metal casing and the head. Size reduction happens in this V-section where the materials are caught up and the comminuted particles pass out from the bottom. The speed of operation varies from 100 to 450 gyrations per minute. The gyratory crusher has added advantages like lower energy consumption and reduced maintenance compared to jaw crusher.



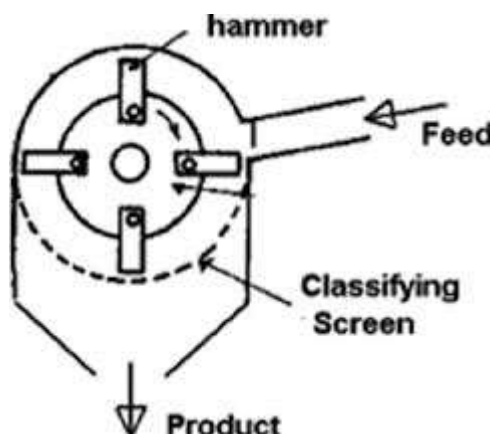
3. Roll crushers

Roller crusher consist of two equal sized and smoothened rolls, one rotating in clockwise and the other in anti-clockwise direction with the same speed. The two rollers are sufficiently heavy, rotating on the same parallel horizontal axes. The rolls can also be jagged depending on the intended need. The coefficient of friction between the material to be size reduced and the surface of roller is the primary factor influencing the extent of size reduction. Larger particles can also be accommodated in a roll crusher as the size reduction is influenced by impact, shear and compression – all acting together.



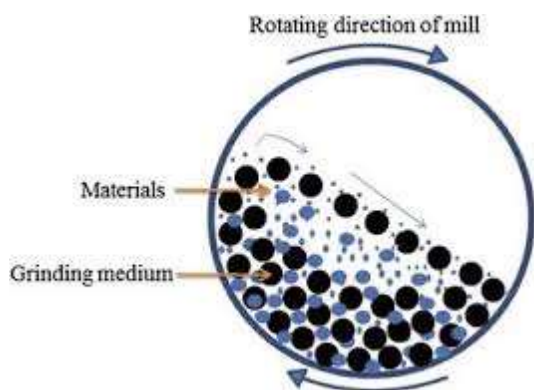
4. Hammer mill

Hammer mill consist of a rapidly moving hammer connected to a high speed rotor in a cylindrical casing. Hammers upto 4 numbers are mounted on a horizontal shaft. It works on the principle of impact between the hammer and the particles to be size reduced. In hammer mill, the materials are introduced through the top of metal casing and are directly exposed to the hammer in operation thereby leading to size reduction. Later, the particles pass through a screen at the bottom and are collected at the receiver. The critical factors affecting size reduction includes – feed rate, size of the screen and rotor speed. A hammer mill is typically operated between 2500-5000 rpm.



5. Ball mill

The ball mill consists of hollow cylindrical rotating shell made of steel lined with porcelain or high carbon steel plate. Upto 50 % of its volume, the shell is filled with balls made of steel or pebbles. The balls are of constant weight and varying size which depend on the amount of feed. The size reduction happens due to the grinding of the balls against the material to be comminuted. The particle size and shape of the material to be comminuted depends on the size of the ball, speed of rotation of the shell and feed rate. When the shell is rotated, centrifugal forces inside the shell carry the ball along the mill wall and get dropped when reaching a height due to gravitational force. This ensures the grinding of the material. Some of the added advantages of ball mill include the fine grinding of a large spectrum of materials and grinding of toxic substances due to the closed environment in a ball mill.



Advances in Size Reduction Technologies [11-13]

Micron technology

In micronization, high pressure gas or air are exposed to particles thereby causing particle collision. Micronizing is the process of reducing the particles to less than 20 μm . This process is particularly effective in the pharmaceutical industry leading to enhanced bioavailability, solubility and optimized formulation with right mix of the excipients.

Gran-U-Lizer™ technology

Low friction shearing is the basic concept behind Gran-U_Lizer technology. Designed by the Modern Process Equipment Corporation, USA, The method involves shearing of the particles between two rolls. This technology can reduce particle size between 4760 to 50 μm . It is widely used in various food milling applications like – coffee, pepper, salt, sugar, rice etc. Gran-U-Lizer technology is also utilized in the minimization of various minerals.

Jet-O-Mizer particle size reducer

Designed and manufactured by the Fluid Energy Processing and Equipment Company, USA. The Jet-O-Mizer is versatile machinery as along with size reduction it also blends the ingredients, free entrapped solvents and coats the products with waxes/oils thereby saving time and energy. The Jet-O-Mizer is capable of producing particle size in the range of 0.5 to 45 μm .

Jet-Stream Homogenization (Microfluidization)

Developed by Microfluidics International, USA, this method is based on the jet-stream principle. The particle size reduction is brought about by the particle collision and cavitation due to the introduction of jet stream at high pressure through the interaction chamber. Along with particle size reduction, they averts agglomeration of the particles resulting in the production of products with longer shelf life.

Conclusion

Different types of size reduction equipment are discussed here. The process of size reduction is crucial to various industries like chemical, pharmaceutical, food, etc. A plethora of size reduction equipment of varying

sizes and capacity are available currently. They have the ability to handle a wide variety of feeds. The nature of feed to be processed is also as critical as the choice of size reduction equipment. Overall, size reduction helps in achieving uniform mixing, homogeneity and ideal flow of the materials.

References

1. Jameel Ahmed S Mulla, Shraddha C Hajare, Rajendra C Doijad. Particle Size and it's Importance in Industrial Pharmacy: A Review. Indian Journal of Novel Drug Delivery 2016; 8(4):191-198.
2. Abouzeid AZ. Processing of fine particles in mineral beneficiation. Part1. Powder Handling and Processing 1994;6:35-48.
3. Dana L. Bishop. A sedimentation method for the determination of the particle size of finely divided material. Part of Bureau of Standards Journal of Research; 1934; 12: 173-183.
4. Rakesh P Patel, Ashok H Baria, Nikunjana A Patel. An overview of size reduction technologies in the field of pharmaceutical manufacturing. Asian Journal of Pharmaceutics 2008; (October – December): 216-220.
5. Price M. Size reduction. In: Othmer K, editor. Encyclopedia of chemical technology. New York: John Wiley and Sons; 1999:836-8.
6. Rudd DF, Powers GJ, Sirola JJ. Process synthesis. Englewood Cliffs, N.J.: Prentice-Hall; 1973:205-208,
7. Subramanyam CV. 'Size reduction'. In: Pharmaceutical Engineering. 1st ed. Vallabh Prakashan; 2004: 144- 176.
8. Sushant S and Archana K. Methods of Size Reduction And Factors Affecting Size Reduction In Pharmaceutics. Inter Res J of pharmacy, 2013; 4(8); 57-64.
9. Snow RH, Kaye BH, Capes CE, Srety GC. Size reduction and size enlargement. In: Perry RH, Green D, editors. Chemical Engineers Handbook. McGraw Hill International; 1963. p. 1-72. PMID:14068170
10. Connor RE, Schwartz JB, Powder. In: Gennaro AR, editor. Remington: The science and practice of pharmacy. USA: Lippincott Williams and Wilkins; 2001. p. 681-99.
11. Micronization, Micron Technologies, Kent United Kingdom. Available from: <http://www.microntech.com/micron/index.html>
12. Gran U Lizer™ Technology, Modern Process Equipment Corporation, Chicago, Illinois 60623 U.S.A. Available from: <http://www.mpechicago.com/pharm>
13. Jet O Mizer™ Technology, Fluid Energy Processing and Equipment Company, Telford, PA 18969. Available from: <http://www.fluidenergype.com/lit.htm>
