crushing

crushing is that operation or group of operations in a Mineral Beneficiation plant whose object is to reduce large lumps to fragments, It is the first stage of size reduction, Crushing is generally a dry operation and is usually performed in two or three stages.

The extent of size reduction achieved by any crushing operation is described by the **reduction ratio**. It is defined in a number of ways. Broadly it is defined as the ratio of the maximum size of the particle in the feed to the maximum size of the particle in the product. Two definitions commonly used are termed as average reduction ratio and 80% passing reduction ratio which are defined as follows:

As the crushing is performed in stages, crushing may be divided into primary, secondary, tertiary and quaternary stages based on the particle size. Correspondingly, the crushers can be classified into five groups according to the size of the product they produce.
1- **Primary Crushers:** Jaw crusher, Gyratory crusher.
2-**Secondary Crushers:** Reduction gyratory, Cone crusher, Rolls crusher.
3- **Tertiary Crushers:** Short-head cone crusher.
4- **Fine Crushers:** Impact crushers.
5- **Special Crushers:** Bradford Breaker, Toothed Roll crusher.

Lumps of run-of-mine ore usually of 1 m size is reduced to 100–200 mm size in heavy duty primary crushers. The usual size of feed to secondary crushers is 600 mm and the product is usually 10–100 mm size.
In tertiary crushers, particles of 250 mm size are reduced to 3–25 mm size.
Fine crushers reduce the coarse particle to fine, even to 200 mesh in some cases.
Special crushers are designed for specific ores, for example, rotary breaker and toothed rolls crusher for coal and gravity stamps for gold ore milling.

JAW CRUSHERS

Jaw crushers consist of two jaw plates set at an acute angle, called **angle of nip**, to each other which forms a crushing chamber. One jaw is fixed and kept vertical, the other jaw is a movable or swing jaw and is moved to approach and recede alternately from the fixed jaw.

The reduction ratio of jaw crushers varies from 4 to 7.

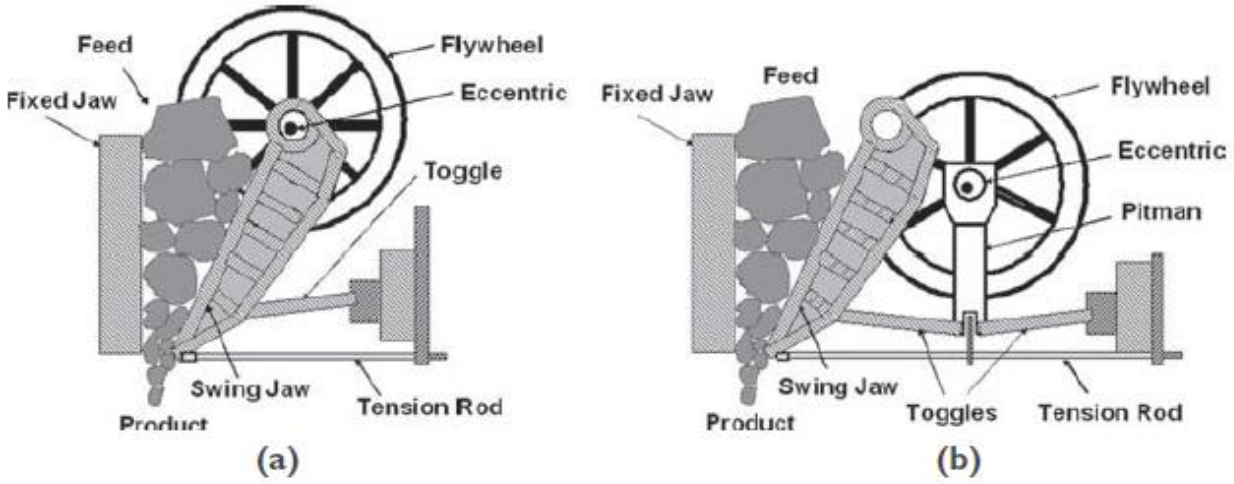


Figure 8.1 (a) Single toggle jaw crusher; (b) Double toggle jaw crusher.

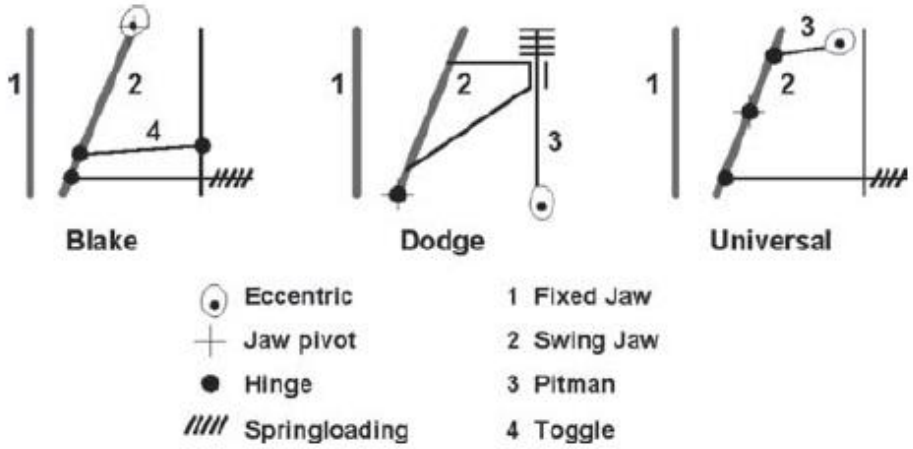


Figure 8.2 Types of jaw crushers.

GYRATORY AND CONE CRUSHERS

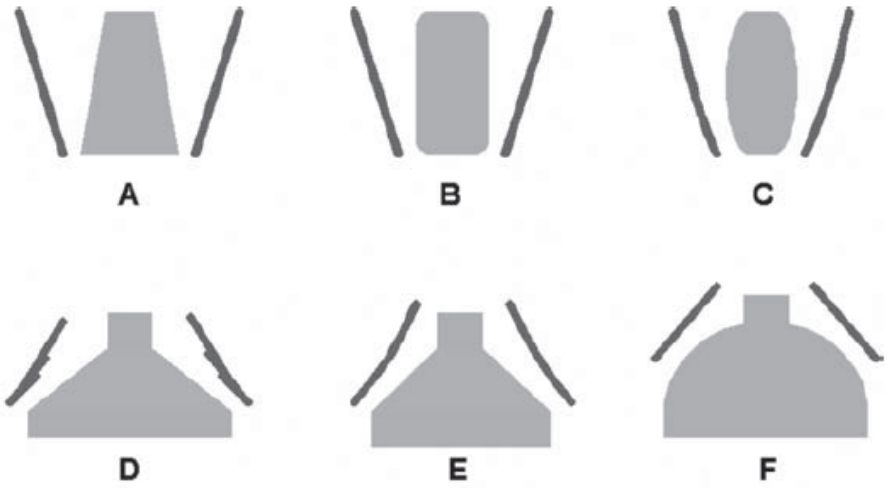
Gyratory and Cone crushers are of similar in construction and working. They consist of two vertical truncated conical shells of which the outer hallow conical shell is stationary and the inner solid conical shell is made to gyrate.

In a gyratory crusher the inner conical shell is pointing up and outer conical shell is pointing down. The reduction ratio varies from 3 to 10. Figure 8.3 shows the cut section of a gyratory crusher.

Reduction gyratory crusher is the modification of gyratory which has straight or curved heads and concaves and used for secondary crushing. The fine reduction gyratory crusher can also be used for tertiary crushing.

The **cone crusher** is a modified gyratory. Both the outer and inner conical shells are pointing up. **Simons cone crusher** is the most widely used type of cone crusher. It has two forms: **Standard cone crusher** and **Short-head cone crusher**
. The outside surface of the standard cone crusher has stepped liners to allow a coarser feed. It yields the product at reduction ratio of 6 to 8. The Short-head cone crusher has a steeper head angle to prevent choking of finer material. The reduction ratio is about 4 to 6.

Figure 8.3 Cut section of Fuller-Traylor gyratory grusher.
(Courtesy FLSmidth Minerals).



(A) Gyratory; (B) Straight head and concave reduction gyratory; (C) Curved head and concave reduction gyratory; (D) Standard cone; (E) Short-head cone; (F) Gyrasphere

Figure 8.4 Types of crushing chambers.

ROLL CRUSHERS

Roll Crusher (Figure 8.5) consists of two smooth heavy horizontal cylinders revolving towards each other and the feed material is nipped between the rolls and pulled downward through the rolls by friction. The distinguished feature of a roll crusher is that the material is crushed one time only whilst it is passing through the crushing chamber.

Due to this fact, the reduction ratio of a roll crusher varies from 2 to 4, the lowest among all the crushers. Production of fines is minimum. They can handle friable, dry, wet, sticky, frozen, and less abrasive feeds well. Smooth-surfaced roll crushers are generally used for fine crushing whereas corrugated or toothed roll crushers are used for coarse crushing of soft materials.

Single toothed roll crusher and **Double toothed roll crusher** are the two types of toothed roll crushers used for crushing coal.

8.4 IMPACT CRUSHERS

Impact crushers reduce the particles by impact forces applied through sharp blows of fixed or free swinging hammers revolving about central rotor at high speed to the free falling particles against stationary surfaces. They are used for relatively soft, friable, and sticky ores such as phosphates, limestone, clay, graphite and coal. Hammer mill

(Figure 8.7) is one type of impact crusher.

8.5 BRADFORD BREAKER

Bradford breaker is a typical machine resembling cylindrical trommel screen in operation.

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It consists of a slightly inclined cylindrical chamber with a perforated wall (Figure 8.8) and rotates about its axis at a low rpm. It is extensively used for primary crushing of run-of-mine coal.

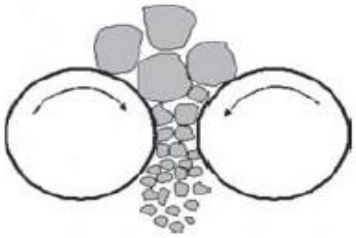

Figure 8.5 Roll crusher.

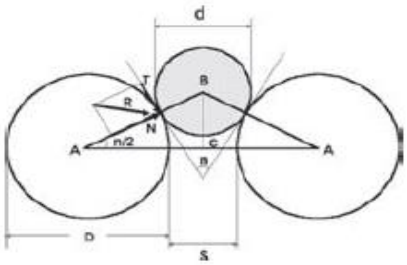

Figure 8.6 Angle of nip of roll crusher.

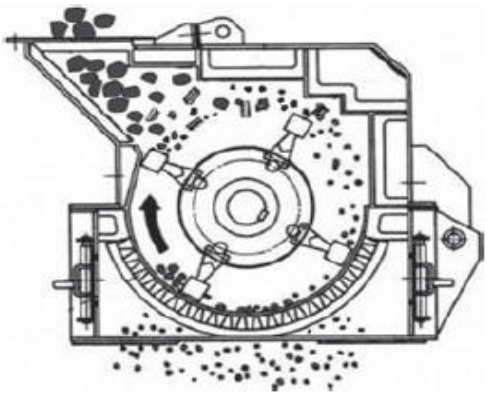

Figure 8.7 Hammer mill.

8.6 HIGH PRESSURE GRINDING ROLLS (HPGR)

In a roll crusher, the force of compression and friction makes the particles to crush. In High Pressure Grinding Rolls (Figure 8.9), rolls are subjected to high pressure so that comminution takes place by compressive forces as well as by inter-particle breakage. The force applied to the crushing zone is controlled by a hydro-pneumatic springs. As the product size from HPGR is fine, it can replace the conventional secondary and tertiary crushers.

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8.7 CRUSHING OPERATION

Crushers are usually operated dry. When the material fed to the crusher is at a slow rate, the individual particles are crushed freely. The crushed product is quickly removed from the crushing zone. This type of crushing, known as free crushing, avoids the production of excessive fines by limiting the number of contacts.

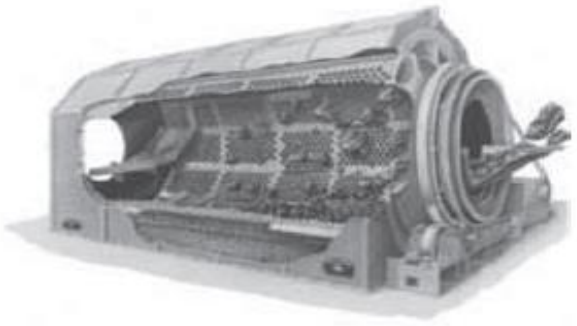

Figure 8.8 Bradford breaker.
(Courtesy Pennsylvania Crusher Corporation).

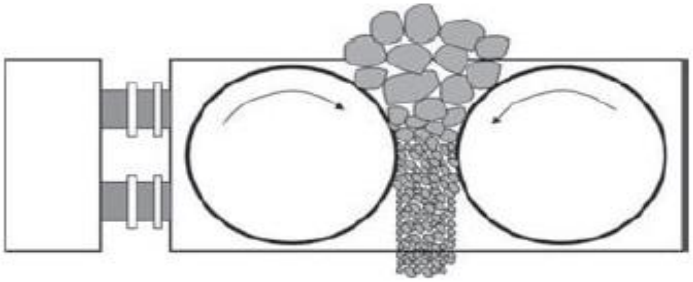

Figure 8.9 High pressure grinding rolls (HPGR).

OPEN CIRCUIT AND CLOSED CIRCUIT OPERATIONS

Usually each stage of size reduction is followed by a screen which forms a circuit.

Crushing may be conducted in open or closed circuit.

Figure 8.10 shows the typical open and closed circuit operations:

In an open circuit crushing operation, the feed material is reduced by one crusher.

The product of this crusher is screened and only oversize material is crushed by another crusher of small size as the **throughput** (the quantity of material crushed in a given time) is less.

The crushed product from the second crusher and undersize material from the screen together form the final product.

In a closed circuit crushing operation, the oversize material from the screen is fed back to the same crusher. The quantity of the oversize material fed back to the crusher is called as **circulating load**.

The undersize material from the screen is the required final product. Initially the quantity of final product produced is less than the quantity of the feed material. As the operation proceeds further the quantity of the final product gradually increases and will be equal to the quantity of the feed material after some time.

After attaining this equilibrium condition, the quantity of the final product is always equal to the quantity of the feed material and the circulating load is constant.

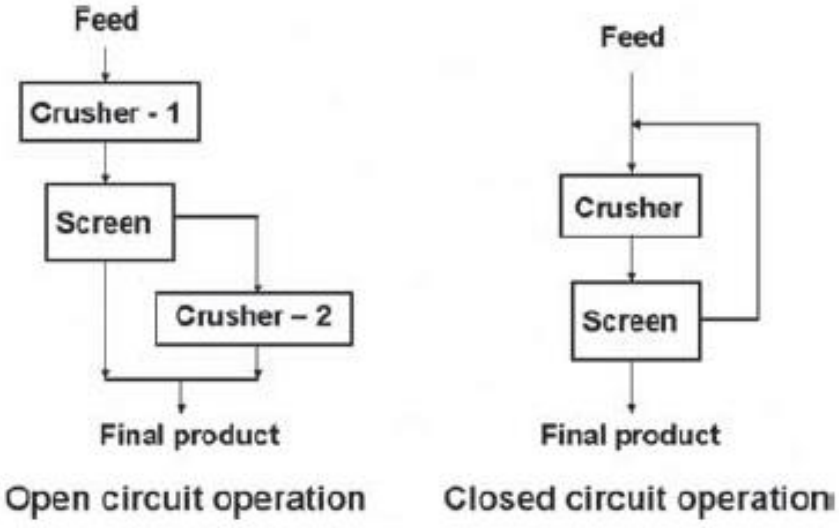

Figure 8.10 Crushing circuits.

Grinding

Grinding is the last stage of the comminution process. The particles are reduced from a maximum upper feed size of 3/8 inch, to some upper limiting product size ranging between 35 mesh and 200 mesh (420

microns and 74 microns). Grinding is performed in rotating steel vessels knows as **tumbling mills** or **grinding mills**.
A grinding mill consists of a horizontal rotating steel shell supported by end bearings on which hallow trunnions revolve. Loose crushing bodies, known as **grinding medium**, are placed inside the shell. Either steel balls/rods or pebbles are used as grinding medium. They are free to move inside the rotating shell making the particles break by repetitive blows and by rolling and sliding one over the other.

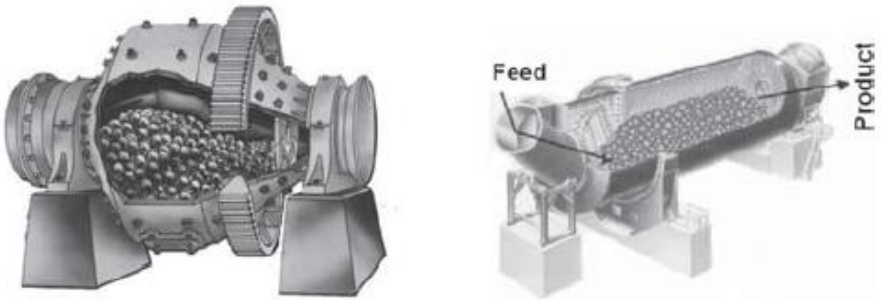

Figure 9.1 (a) Cylindroconical ball mill; (b) Cylindrical ball mill. (Courtesy Metso Minerals); (Courtesy www.mine-engineer.com).

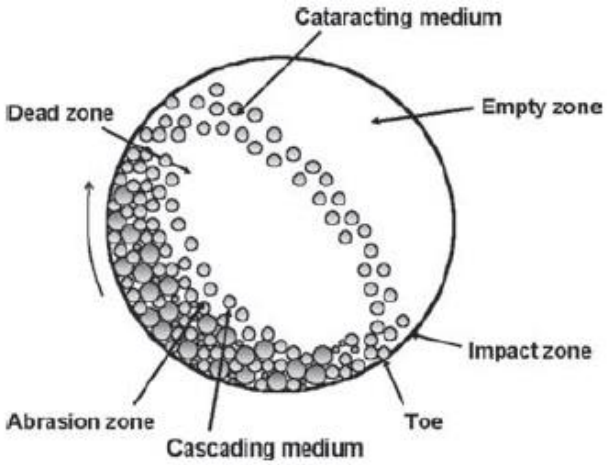

Figure 9.2 Motion of the charge in a ball mill.

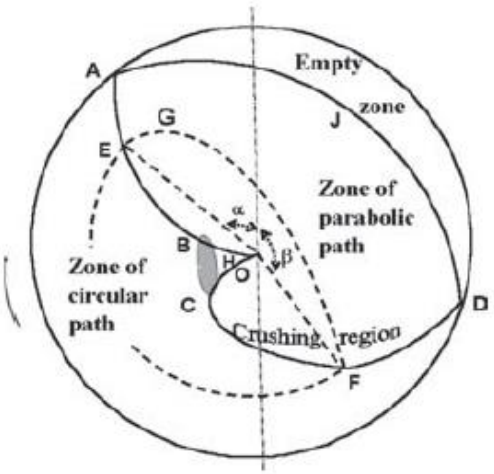

Figure 9.3 Zones in a ball mill.

Figure 9.4 Grinding action of rods.

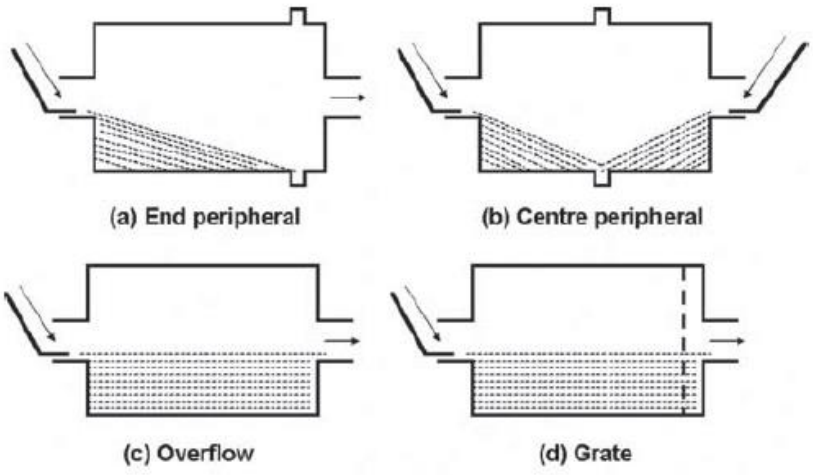

Figure 9.5 Types of rod mills according to method of discharge.