



Article

Introduction to Crushing

The process of reducing **mined ore** for processing is known as '**comminution**', which is defined as 'the action of reducing a material, especially a mineral ore, to **minute particles** or **fragments**'; this is normally achieved at **mining operations** through one or more stages of **crushing** and **milling**.

Early mining activities were labour intensive. Ore breakdown occurred via a **miner's pick, sledgehammer, or drill bit**. Until the mid-nineteenth century, most initial ore crushing and sizing continued to be done locally by hand. Later operations were assisted with **water powered trip hammers** (early-to-middle industrial revolution). The earliest known **crushers** were hand-held stones, where the weight of the stone increased the force a miner could apply when hammering against a stone anvil. The small volumes of **rock** and **aggregate** produced were then typically loaded into sacks for transport by road.



The Original Mining Tools

Explosives (gunpowder etc.) were introduced to commercial mining during the industrial revolution; using explosives to mine is referred to as **blasting**. Blasting came into widespread use for **bulk mining** in the mid-nineteenth century, followed later by **steam shovels**. For the first time, new mining techniques and machines began producing ever larger chunks of liberated materials.

Rapid growth in demand over the past century has required considerable upscaling of production tonnages, regardless of the types of ore being mined. To cater for this increase in demand, various **crushing** and **breaking** technologies were developed to allow for efficient transport of **bulk materials** (via **conveyors** etc.) from the **mine** to the **processing plant**.

Today, most **mining** and **quarry** operations utilise **crushers** as part of the front end of the ore **beneficiation** processes after the ore bed has been liberated by blasting or other techniques. Exceptions include mining of very loose materials such as mineral sands, where this crushing stage is often not needed. Similarly, many **coal** and **lignite** beneficiation/washing plants use other technologies such as **Bradford Breakers** and **Mineral Sizers**. But for **hard rock mining**, the use of **gyratory crushers**, **cone crushers**, and/or **jaw crushers**, is the starting point for **ore processing**.



Gyratory Crusher

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Purpose of Crushers

A **crusher** is a machine designed to reduce the size of **Run of Mine (ROM)** large rocks to **smaller rocks, gravel, sand, or rock dust**; this is essential for efficient transport of the ore via conveyors etc. Crushing is the first of many stages that lead to separation of the **ore** from the **waste (gangue)** material. Waste material can be discarded or recycled allowing the ore rich stream to be further processed at the main plant.

Various types of **crusher** and **mineral separator** may be employed depending upon the **throughput, hardness, and properties** of the ore being processed. In all cases, the crushing stage is essentially achieved by transferring a mechanically amplified force (via **mechanical advantage**) to a material, to breakdown the bonds which hold the material together.

Crushing is achieved by passing ore between two solid surfaces, then by applying sufficient force to bring the surfaces together so that the molecules of the material being treated are **separated** from (**fracture**), or, **change alignment** in relation to (**deform**), each other.

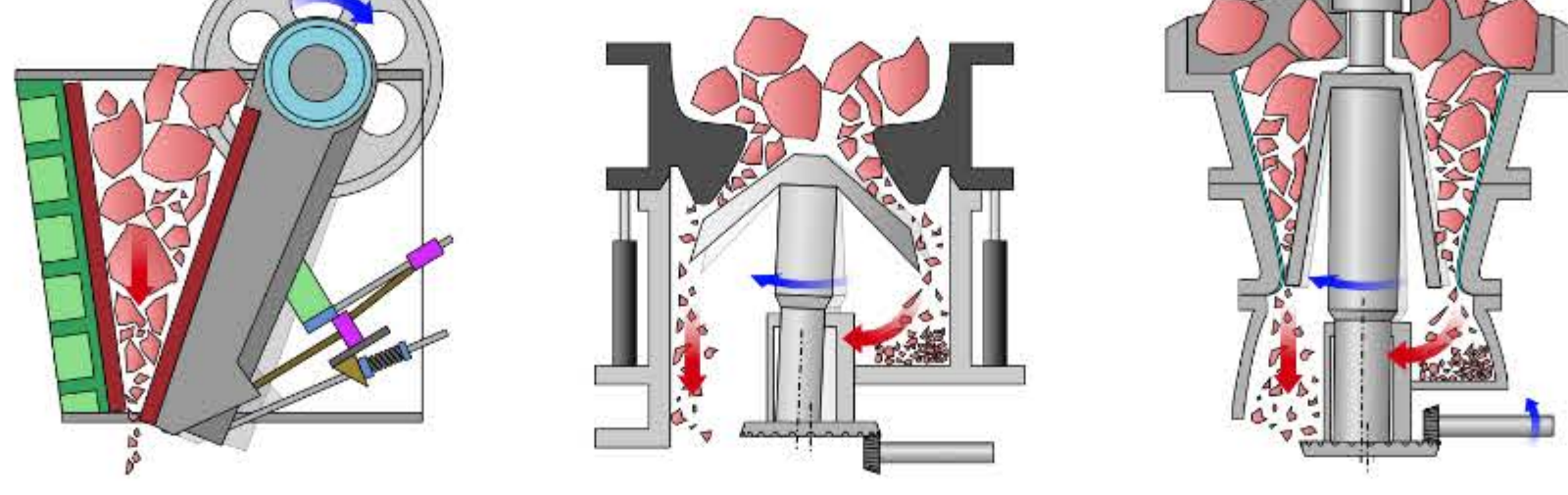
Crushers are commonly classified by the degree to which they fragment the starting material, with **primary** and **secondary** crushers handling **coarse materials**, and **tertiary** and **quaternary crushers** reducing ore particles to **finer** gradations. Each crusher is designed to work with a certain maximum size of raw material, and often delivers its output to a **screening machine (screener)**, which sorts and directs the product for further processing. In many cases, initial crushing stages are followed by further milling stages using e.g. **ball mills** etc.

Crusher Types

There are **three** common crushers used at mining and processing plants:

- **Gyratory Crushers**
- **Jaw Crushers**
- **Cone Crushers**

Typically, the initial crushing stage is completed using either **gyratory crushers** or **jaw crushers**. It is often the case that there will be only one crusher installed, and this will be referred to as the '**Primary Crusher**'. **Cone crushers** are typically used for 2nd, 3rd & 4th stage crushing steps (although not always).



Jaw, Cone and Gyratory Crushers

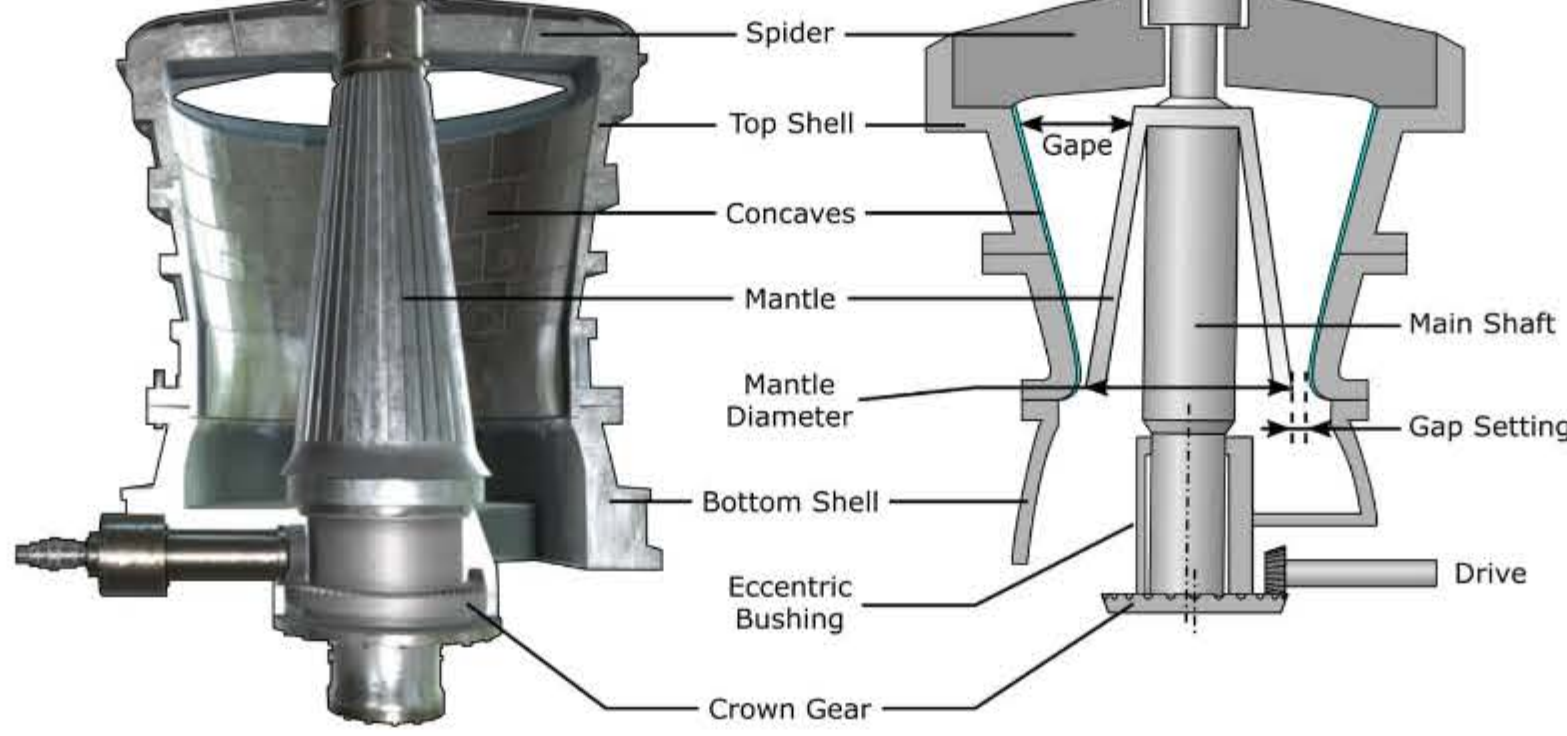
Gyratory Crusher Components

Gyratory crushers were invented by Charles Brown in 1877 and further developed by Gates in 1881 (they were commonly referred to as a 'Gate's crushers' in the early years).

A primary crusher is designed to receive run-of-mine (ROM) rocks directly from the mines. Gyratory crushers typically crush to reduce the size of **aggregate** to a maximum of about **one-tenth** of its original size. Gyratory crushers are always installed **vertically orientated**.

A gyratory crusher's size is classified by:

- Its **gape** and **mantle diameter**.
- The diameter of the **receiving opening**.



Gyratory Crusher Components

Key components of a gyratory crusher are:

- **Spider Assembly & Bushing**
- **Top & Bottom Shell Assemblies**
- **Main Shaft**
- **Mantle & Concaves**
- **Eccentric Drive & Bushing**
- **Pinion & Countershaft Assembly**
- **Hydroset Assembly (Hydraulic Support)**

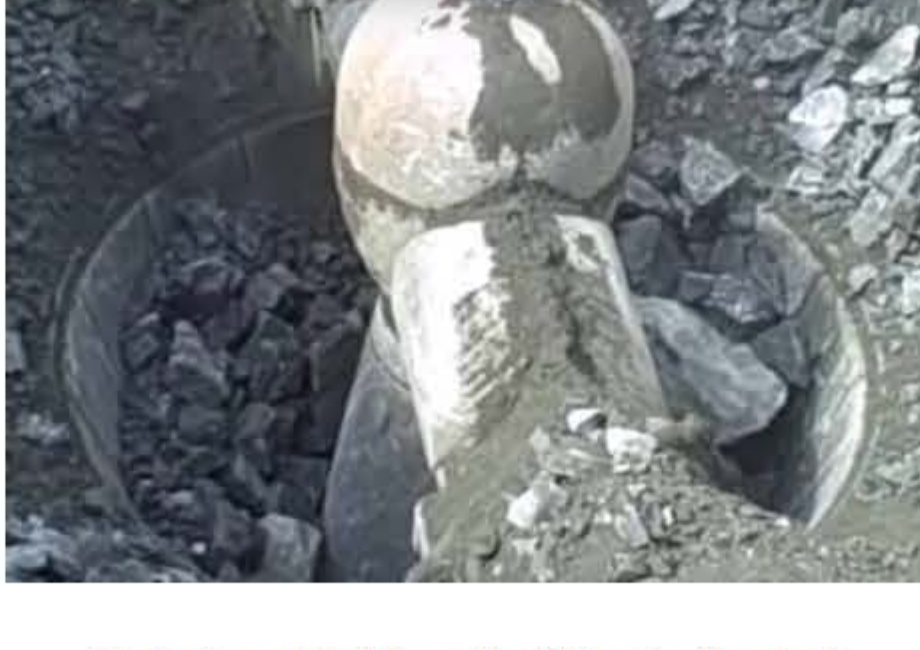
How Gyratory Crushers Work

ROM ore from the mine is typically transferred by **haul trucks** which discharge into a feed **hopper** at the upper level; crushed ore is then discharged from the bottom shell assembly. In some cases, a **grizzly feeder** may be used, and undersize ore can be **screened** to bypass the crusher (transferred directly to the output conveyor). There is typically also a **hydraulic rock breaker** to reduce large boulders received from the mine.



Haul Trucks Deliver ROM Ore to Crusher Hoppers

The ore enters the upper section of the crusher past the **spider assembly** which supports and houses the upper **main shaft bearing**.



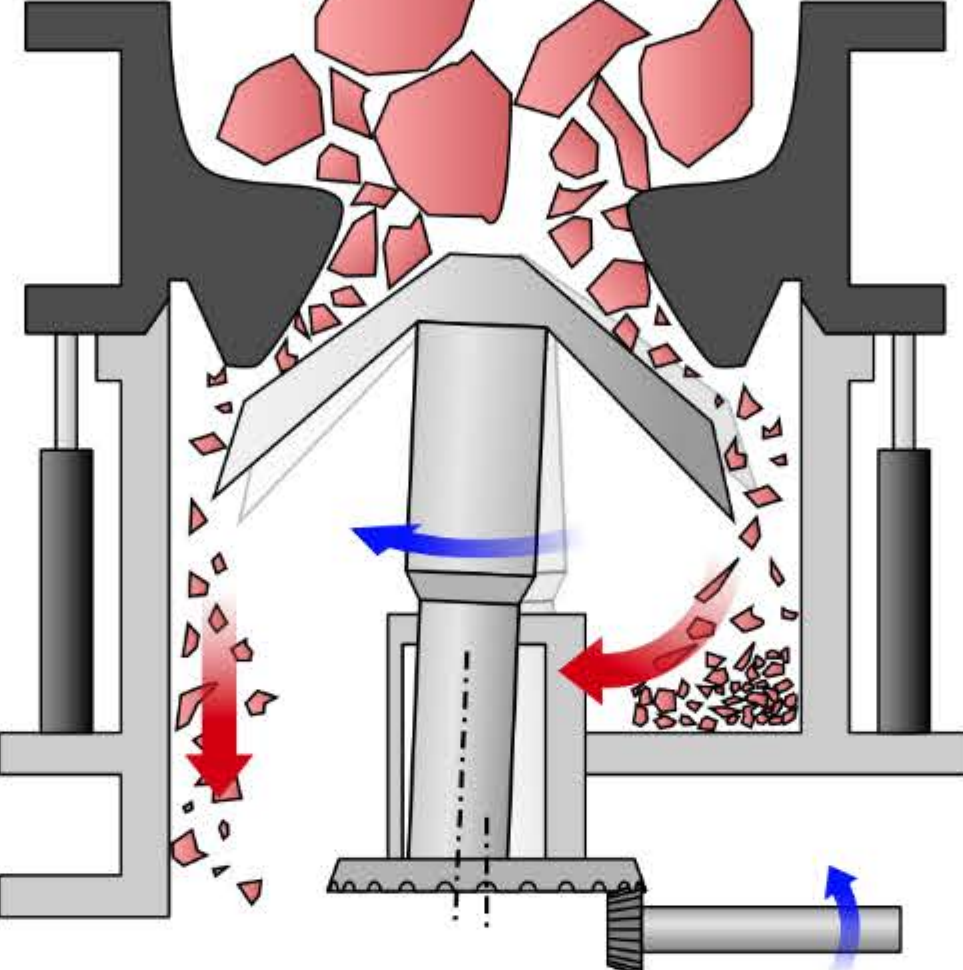
Spider Assembly (Upper Shaft Bearing Housing)

The gap between the **main shaft** and **concaves** reduces from the top to the bottom of the crusher assembly. The upper concave is lined with **hardened steel** concave **linings** and the main shaft is fitted with a **mantle liner (sheath)** of similarly hardened material.

Linings are the main wear components of a crusher. Linings wear over time and protect the main casing and shaft from damage. The maintenance strategy for a gyratory crusher will be largely influenced by the rate of wear of the linings, which can be monitored manually (thickness measurements) or by using suitable condition monitoring tools e.g. **laser scanning**. The **liners** and **mantle** are replaced at scheduled intervals or based on the wear rates recorded.

The **hydro set** system is a hydraulic mechanism which allows the vertical position of the main shaft (and mantle) to be raised and lowered. Changing the position of the mantle changes the **gap setting** at the outlet of the crusher, and consequently the size of the crushed output. The height of the mantle is often automatically adjusted based upon the **torque** produced, and has a **release mechanism** that allows the mantle to drop should the normal workload be exceeded; this is an **overload protection** feature.

The **upper shaft bearing** is enclosed within the central **spider bushing**. This arrangement allows slight **oscillation** of the upper shaft and limited vertical movement produced by the hydro set. The **spider bearing** is normally lubricated by **grease** (manual or automatic).



Gyratory Crusher Operation

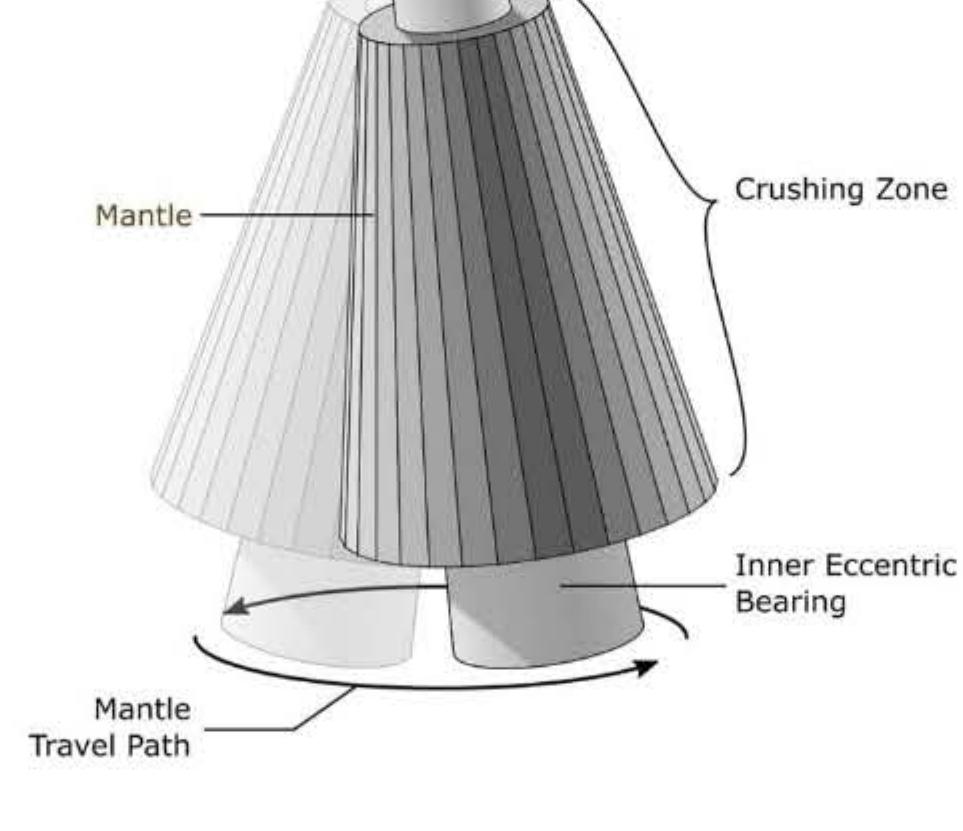
Crushing action is produced by the oscillation or **throw** (opening & closing) of the gap between the moving mantle liner, mounted on the **central vertical shaft (spindle)**, and the fixed concave liners mounted on the **mainframe (top shell)** of the crusher. The **mantle** and **concaves** from the working surfaces of the crusher, producing the force required to crush the ore.

Eccentric motion is achieved by the lower **eccentric bushing** and **drive arrangement** on the bottom of the **main shaft**. The input **pinion drive countershaft** is supported by **pinion bearings** and powered by an **electric motor**. An external **gearbox** or **belt drive** arrangement reduces the motor speed to approximately **100-200 RPM** at the crusher. In some cases, a **clutch system** may also be used to absorb shocks. The **pinion** on the **countershaft** meshes with and turns the **eccentric gear drive** or **crown gear**.



Crown Gear

The inner surface of the **eccentric bushing** is machined off-centre to the centreline of the crusher. As the eccentric bushing rotates, the lower shaft **oscillates** in an **elliptical** orbit around the centreline of the crusher. This action causes the gap between the mantle and concave liners to open and close upon each rotation of the shaft. At the upper end of the mantle this movement is very small, but as the ore falls lower, the throw increases and the crushing force also correspondingly increases.



Gyratory Crusher Mantle Travel Path

Crushed ore falls to the **bottom shell assembly** and is discharged into the crushed ore conveying system for further processing. The **lower casing** also houses a **forced lubrication** and **hydraulic** system, which is critical for the drive arrangement and hydro set mechanism.

Further processing can involve additional crushing stages (**secondary, tertiary, quaternary** etc.), **milling**, and other **beneficiation** steps to suit the ore being processed. It is worth noting that there will often be only a single primary crusher at many mining operations. As such, the primary crusher is a critical and major bottleneck machine for many mining sites, with little, or no bypass opportunities.

Additional Resources

- <https://www.911metallurgist.com/blog/gyratory-crusher>
- https://www.solidswiki.com/index.php?title=Gyratory_Crushers
- <https://www.sciencedirect.com/topics/engineering/gyratory-crusher>