

Construction, Working and Maintenance of Crushers for Crushing Bulk Materials

By

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The information contained in this booklet represents a significant collection of technical information about construction, working and maintenance of crushers for crushing bulk materials. This information will help to achieve increased reliability at a decreased cost. Assemblage of this information will provide a single point of reference that might otherwise be time consuming to obtain. Most of the information given in this booklet is mainly derived from the literature on the subject from sources as per the reference list given at the end of this booklet. For more information, please refer them. All information contained in this booklet has been assembled with great care. However, the information is given for guidance purposes only. The ultimate responsibility for its use and any subsequent liability rests with the end user. Please view the disclaimer uploaded on <http://www.practicalmaintenance.net>.

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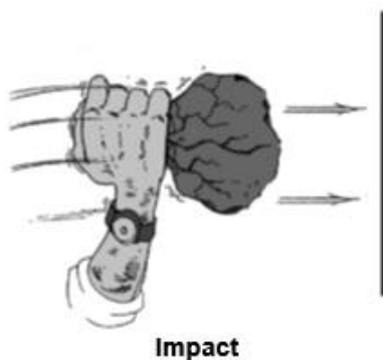
Crushers for Bulk Materials

Crushers and breakers are used to reduce size of mined and quarried material for further processing or to size suitable for the intended end use. The goal of a crusher is to crush the given material into the material with certain size and shape. Information about crushing technology, construction, working and maintenance of crushers for bulk materials is given in this article.

Crushing Technology

There are four basic ways to reduce size of a material: by impact, by compression, by shear or by attrition. Most crushers employ a combination of all these crushing methods.

Impact



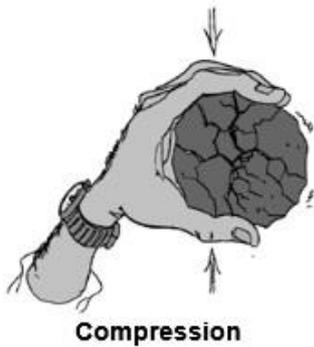
Impact refers to the sharp, instantaneous collision of one moving object against another. During the collision, both the objects may be moving, such as a cricket bat hitting a fast moving ball, or only one object may be moving, such as a rock being struck by hammer blows.

There are two types of impact: gravity impact and dynamic impact. Coal dropped onto a hard surface such as a steel plate is an example of gravity impact. Gravity impact is most often used to separate two materials which are having relatively different friability. For example, in a rotary breaker, separation of the more friable material can be done by screening the material after the more friable material is broken due to the impact while the less friable material has remained unbroken. Material crushed in an impact crusher is an example of dynamic impact. When the material is crushed in an impact crusher, the freely falling material first breaks due to dynamic impact by a moving hammer and then the force of impact accelerates movement of the reduced particles toward breaker blocks and/or other hammers for further size reduction.

Dynamic impact has specific advantages for the reduction of many materials and it is specified under the following conditions.

- When a cubical particle is needed.
- When finished product must be well graded and must meet intermediate sizing specifications, as well as top and bottom specifications.
- When ores must be broken along natural cleavage lines in order to free and separate undesirable inclusions (such as mica in feldspars).
- When materials are too hard and abrasive for hammer mills, but where jaw crushers cannot be used because of particle shape requirements, high moisture content or capacity.

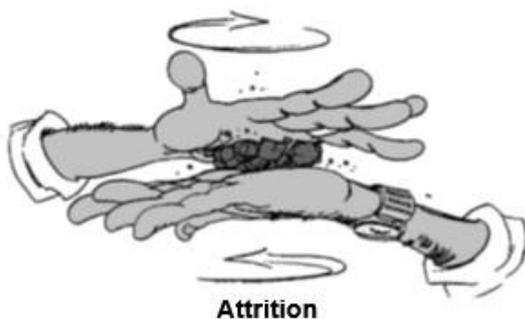
Compression



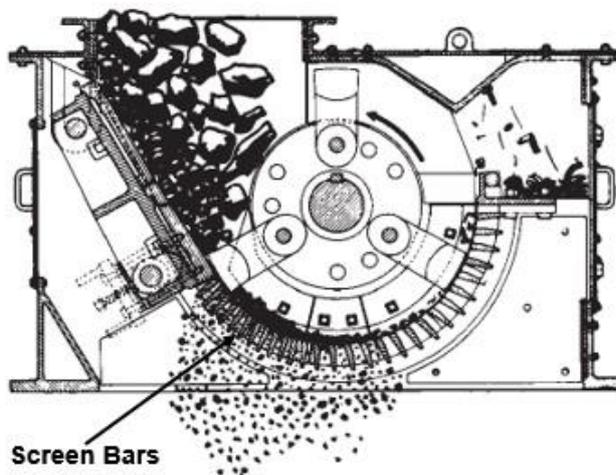
Crushing by compression is done between two surfaces, with the work being done by one or both surfaces. For example, jaw crushers using this method of compression are suitable for reducing extremely hard and abrasive rock. As a mechanical reduction method, compression should be used for the following.

- If the material is hard and tough.
- If the material is abrasive.
- If the material is not sticky.
- Where the finished product is to be relatively coarse, i.e., top size to be 38 mm (1 1/2") or larger.

Attrition



Attrition is the reduction of materials by scrubbing it between two hard surfaces. However, attrition consumes more power and exacts heavier wear.



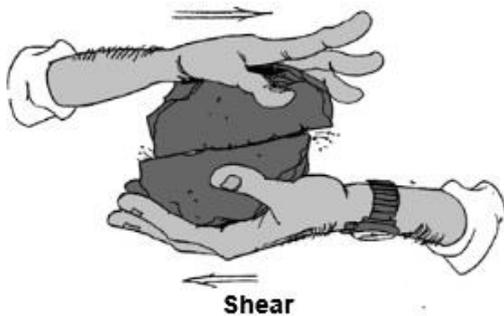
Non-Reversible Hammer Mill

In a non-reversible hammer mill with screen bars, shown in above figure, material is broken first by impact between hammers and breaker plates and then by a scrubbing action (shear and attrition) of material against screen bars.

Attrition crushing is most useful in the following two circumstances.

- When material is friable or not too abrasive.
- When a closed circuit system (detailed in next section) is not desirable to control top size.

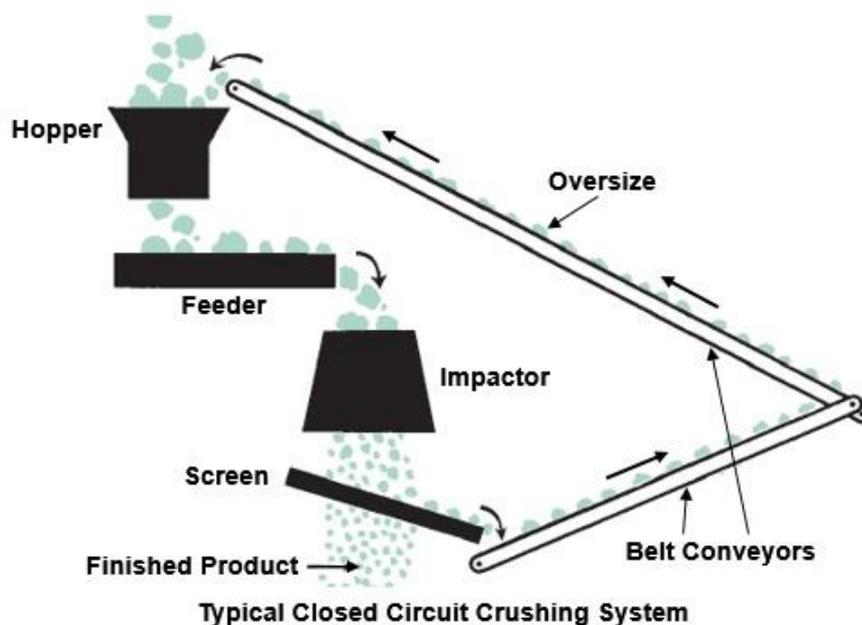
Shear



Shear consists of a trimming or cleaving action. Shear is usually combined with other methods. For example, a single-roll crusher, employ shear together with impact and compression. Shear crushing is normally used under following conditions.

- When material is somewhat friable and has relatively low silica content.
- For primary crushing with a reduction ratio of 6 to 1.
- When a relatively coarse product is desired, top size usually larger than 38 mm (1 1/2")

Closed Circuit Crushing System



To control top size from a single crusher operating in an open circuit, material must remain in the crushing chamber until the material is reduced to top size. This results in over grinding a percentage of the product, with a corresponding increase in fines and a loss of efficiency. As

shown in above figure, a closed circuit crushing system is a means of controlling product top size by screening the product and then returning oversize material to the feed end of the crusher for another pass through the machine.

Efficiency of a multiple stage crushing plant can be maximized by operating a primary crusher at a setting which produces a satisfactory feed size for the secondary crusher and operating the secondary crusher (or the last stage crusher) in a closed circuit.

Glossary of Terms

Breaker Block (Breaker Plate)

The steel surface of a crusher against which material is crushed by impact or pressure.

Bridging

Blocking of a crusher opening by large pieces of material.

Burbank Abrasion Test

A standard testing method for comparing the relative abrasiveness of rocks, minerals and ores.

Cage

A screening device, made of precisely spaced bars or slotted plate, where final sizing is accomplished within the crusher.

Choke Feed

Operating the crusher with a completely filled crushing chamber.

Choking

Stoppage of the flow of material through the crusher, which is usually due to the wet and sticky material clogging exit points.

Circulating Load

The amount of oversize material returned back to the crusher from a screen in a closed circuit crushing system.

Finished Product (also called Product or Output)

The material produced after it has been processed.

Friable Material

Material that breaks easily.

Hammers

Freely swinging or fixed metal impact surfaces attached to the rotor assembly of an impactor or hammer mill crusher. Sometimes they are also called "beaters".

Oversize

Material which is too large to pass through a specific size of a screen or grizzly opening.

Primary Crusher

The first crusher in a crushing system into which material is fed. Succeeding crushers in the system are referred to as secondary (second), tertiary (third) or quaternary (fourth) crushers.

Reduction Ratio

The ratio of the top size of input material to the top size of crusher discharge material.

Run of Mine (ROM)

Material from a mine that has not been crushed or screened.

Run of Quarry (ROQ)

Material from a quarry that has not been crushed or screened.

Scalping

Removing all sizes smaller than output top size from the crusher input material.

Side Liners / Cheek Plates

Wear plates used to protect the crusher frame side plates. They are made from abrasion resistant (AR) plate (400 to 450 Brinell hardness), also called Boron steel.

Top Size

The largest particle size in an input or output size.

Tramp Iron

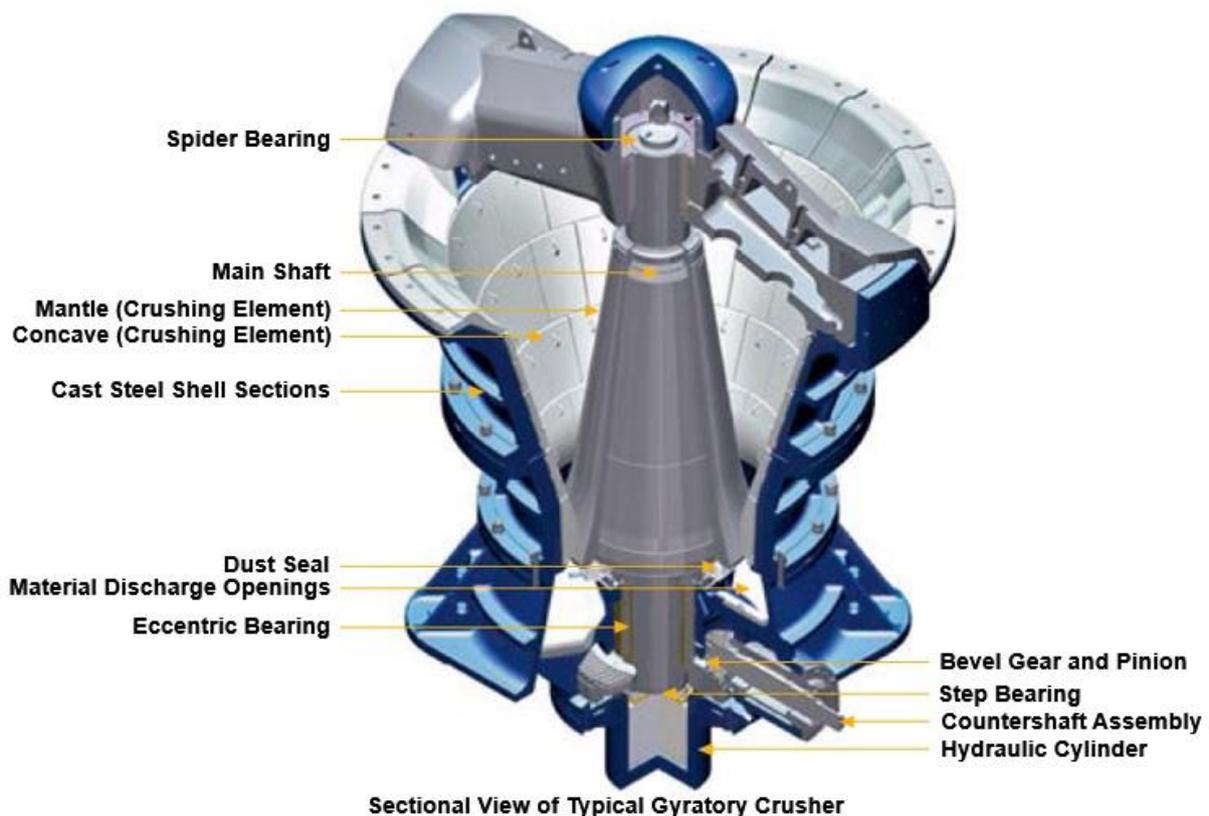
Bolts, shovel teeth, picks and other uncrushable metal that is often present in crusher input.

As the term "primary" implies, primary crushers are used in the first stage of any size reduction cycle. Generally gyratory crushers, jaw crushers, high speed double roll crushers, low speed sizers, impactors and hammer mills are used as primary crushers. In the secondary and subsequent stages, the material is further reduced and refined for proper size and shape, mostly based on specifications. Most secondary crushers are cone crushers and horizontal shaft impacts. For coal, many times, rotary breakers are used as primary crushers and ring granulators are used as secondary crushers. Information on construction and working of various crushers is given in the following chapters.

Gyratory Crushers

Gyratory crusher is generally used as a primary crusher. The crusher is popular due to its high throughput capacity and the large sized opening. The crusher is well suited for handling direct feed from haul/dump trucks. The gyratory crusher is mainly used in rock that is abrasive and/or has high compressive strength. The crusher is the workhorse of the hard rock crushing industry.

A gyratory crusher uses a mantle that gyrates (rotates) within a cone shaped inner surface lined with wear resisting plates often called concaves. As the mantle gyrates within the crushing chamber, progressively approaching, and receding from, each element of the cone shaped inner surface, it creates compressive force, which fractures the material.



Above figure shows sectional view of a typical gyratory crusher. Essentially, a gyratory crusher consists of a heavy cast-iron, or steel, shell/frame which includes in its lower part an actuating mechanism (eccentric and driving gears), and in its upper part a cone shaped crushing chamber, lined with wear resisting plates (concaves). Construction detail and working of the crusher is as under.

The main shaft of the crusher is journaled in the spider bearing and in the eccentric bearing assembly. The spider bearing fixes the position of the upper end of the main shaft. Eccentric bearing assembly with inner bushing can be replaced, or in some models turned, to adjust the stroke. The step bearing located on the piston of the hydraulic cylinder provides axial support for the main shaft.

The rotational movement of the drive motor is transferred to the eccentric bushing in the eccentric bearing via the countershaft assembly. This rotating eccentric bushing imparts an eccentric motion to the main shaft, a characteristic of the gyratory crusher.

In this way the crushing gap located between the fixed concaves in the crusher shell and the eccentrically gyrating mantle continuously changes.

The feed material that is fed into the crushing chamber from above is progressively crushed between the crushing elements (mantle and concaves), finally exiting the crushing chamber at the bottom under the influence of gravity. The crushing elements, mantle and concaves are made of high wear resistant material.

The crushing gap is adjusted by hydraulically lifting or lowering the main shaft by the hydraulic cylinder. The hydraulic shaft adjustment is used mainly when crushing abrasive material and when the gap frequently needs to be corrected. It is also used to compensate for liner wear. It also serves as overload protection when uncrushable tramp material enters the crushing chamber. It may be noted that overload can occur if the feed material is sticky or contains high amount of moisture.

Moreover, the main shaft hydraulics make it easier to restart the crusher in an emergency when the crushing chamber is full by adjusting the height of the shaft (to clean the chamber).

Gyratory crushers are designated by two numbers. These are the size of the feed opening (in inches) and the diameter of the mantle at its base (in inches). The feed material should be at least 15 to 20% smaller than the width of the feed opening.



Open Side Setting of Gyratory Crusher

Gyratory crusher's discharge setting is referred to as the Open Side Setting (OSS). Open side setting is a single pre-determined setting at which the crusher and its crushing chamber are designed to operate. The setting can be changed to produce different product sizes by modifying shape and thickness of the bottom tier of the concave. Crusher's capacities (throughput) are listed for open side settings of the crusher in tons per hour. Close Side Setting (CSS) = Open Side Setting (OSS) – Eccentric Throw.

As compared to the jaw crusher, where it only crushes when the swing jaw moves towards the fixed jaw, with its rotational action, the gyratory crusher is always crushing. Hence the gyratory crusher can process a much greater throughput than a jaw crusher.

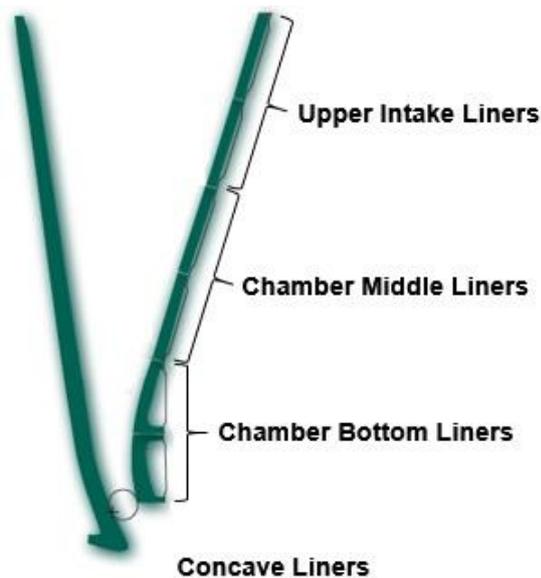
Wearing Parts

Wearing parts in a gyratory crusher may be either manganese steels, low alloy steels or high chromium irons (white cast irons) depending on the character of the material to be crushed.

Manganese steels are available with manganese content from 11% to 24% with different alloying to suit each customer's application. The following table shows various manganese steel grades (XT series) used by Metso.

Mn Grade	Alloying
XT510	Low grade Hadfield manganese steel
XT520	Low grade manganese steel with molybdenum alloying
XT610	Low grade manganese steel with chromium alloying
XT710	High grade manganese steel with chromium alloying
XT720	High grade manganese steel with chromium alloying
XT750	High grade special manganese steel
XT770	High grade special manganese steel with molybdenum alloying
XT810	High grade manganese steel with chromium alloying and special treatment

Material of Concave Segments



As the upper concave tiers must withstand high impact forces (falling of large and heavy pieces of material) and the lower tiers require maximum abrasion resistance, depending on the feed characteristics, material of concave segments should be as given below.

Upper Intake Liners

- Manganese alloys
- Low alloy steel, impact resistant

Chamber Middle Liners

- High manganese alloys
- Low alloy steel, abrasion and impact resistant

Chamber Bottom Liners

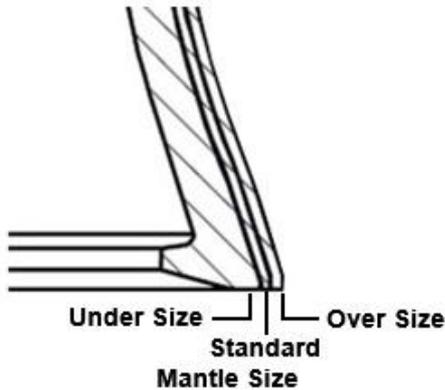
- Low alloy steel, high abrasion and impact resistant
- High-chrome special material, maximum abrasion resistance

Mantle Options and Material

Choosing the correct mantle is always an application-specific process. The following mantle designs are available.

- 1, 2 and 3 piece
- Under size, standard, over size
- Smooth, partially corrugated, fully corrugated

During operation the primary gyratory crusher's wear parts are subject to shock and impact loads in the upper chamber, abrasive wear in the bottom of the chamber and a combination of these in the middle part of the chamber. By using a 2 or 3 piece mantle, best performance can be obtained by selecting optimal material characteristics for each piece of mantle according to the target application.



For each primary gyratory crusher model, generally there are several basic mantle sizes: standard, under size and over size. Over size mantles can be used, for example, to maintain the primary gyratory crusher's setting during concave wear. Under size mantles are needed if extra thick concaves are used.

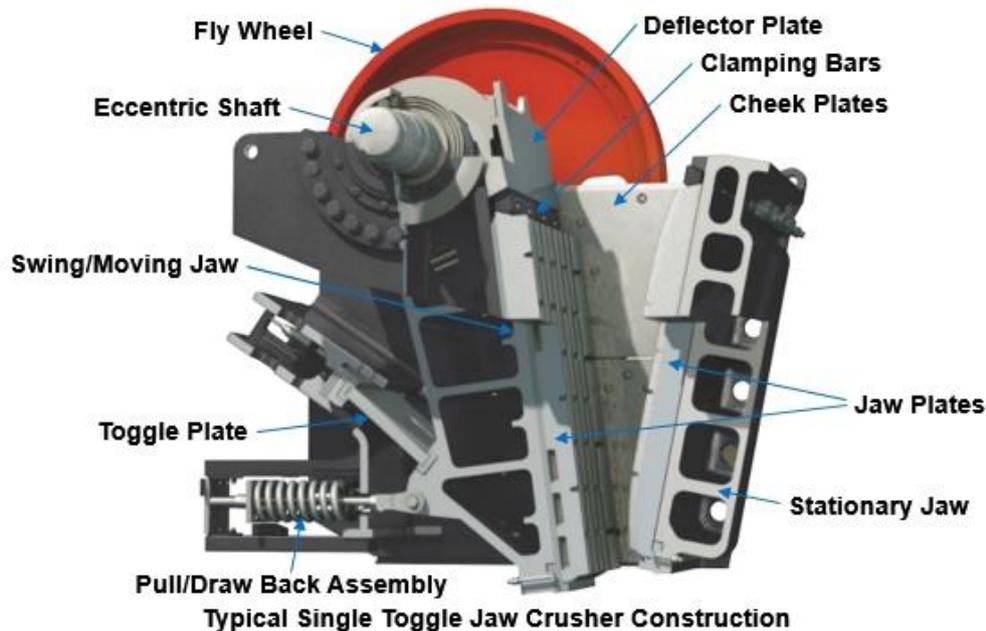


Mantles are designed either as smooth or corrugated. Two corrugated profiles are available: partially and fully corrugated.

The smooth mantle design is an ideal choice for high abrasive applications. Depending on the application properties, the corrugated profile may provide better performance. A corrugated surface effectively removes fines from the mantle surface and provides better grip on the feed material. The fully corrugated design is for special applications.

The first choice of material for standard mantles is low grade Hadfield manganese steel. To further maximize performance and wear life, high alloy materials should be used.

Jaw Crushers



Jaw crushers are used in mines and quarries as primary crushers. A jaw crusher uses compressive force (mechanical pressure) for breaking of particles. Above figure shows construction of a typical single toggle Blake type jaw crusher. As shown in above figure, a jaw crusher consists of a set of vertical jaws. The volume or cavity between the two jaws is called the crushing chamber. The gap between the jaws becomes narrower farther down into the crushing chamber. One of the jaw is kept stationary and is called a fixed/stationary jaw (front frame/wall) while the other jaw called a swing/moving jaw, moves back and forth relative to the fixed jaw. The inertia required to crush the material is provided by a weighted flywheel that moves the eccentric shaft.

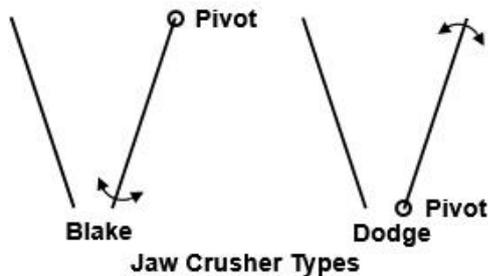


Cross-section of Eccentric Shaft and Drive-side Main Bearings

Above figure shows cross-section of eccentric shaft and drive-side main bearings.

When the swing jaw moves forward, the pressure required to crush the material is generated because the crushing chamber narrows and the material gets crushed. When the swing jaw moves back again, the material crushed to the size of the pre-selected jaw opening exits the crushing chamber at the bottom due to gravity while new material flows in from the top.

In most of the jaw crushers, the toggle plate also serves as a safety mechanism. Should a piece of non-crushable material, generally called tramp iron, enter the jaw crusher and be larger than the bottom opening, it can't be crushed nor pass through the bottom opening. In this case, the toggle plate will crush and prevent further damage. In some designs, the toggle plate is made up of two steel plates which are bolted together with shear bolts.



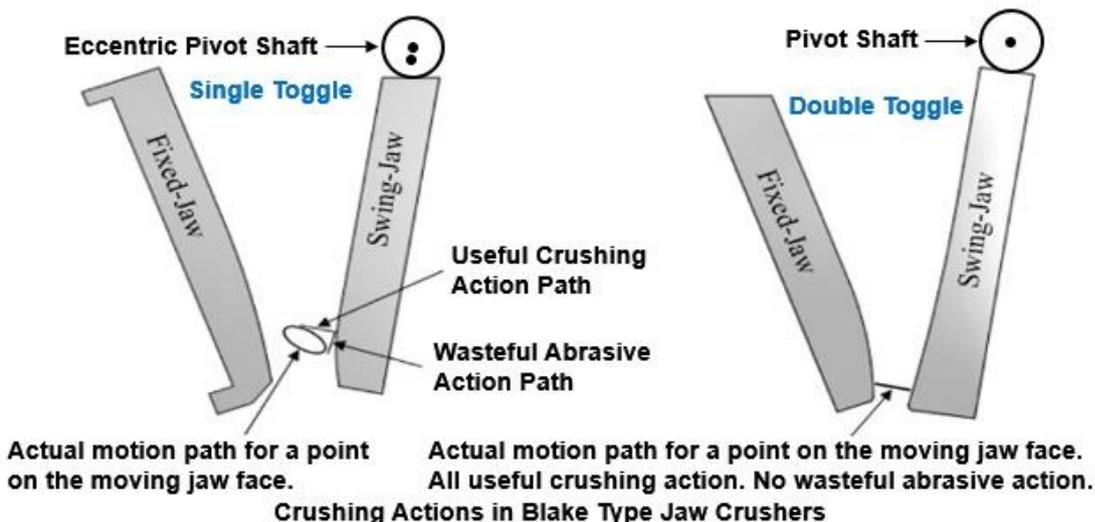
As shown in above figure, jaw crushers are generally classified by the method of pivoting the swing jaw.

- In a Blake type jaw crusher, the swing jaw is pivoted at the top (upper position).
- In a Dodge type jaw crusher, the swing jaw is pivoted at the bottom (lower position).

The Dodge type jaw crusher has a variable feed area and a fixed discharge area which leads to choking of the crusher and hence it is used only for laboratory purposes and not for heavy duty application.

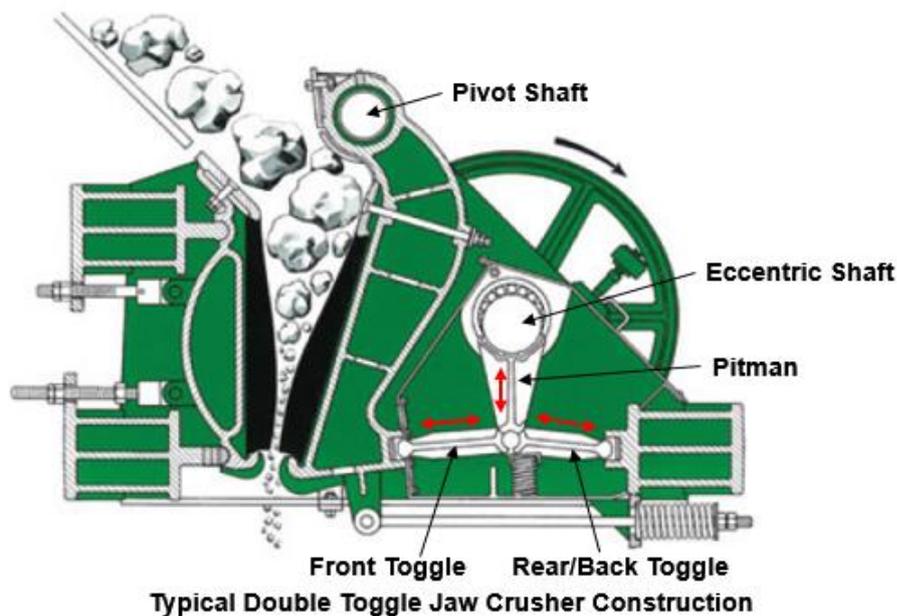
The Blake type jaw crusher has a fixed feed area and a variable discharge area. As the maximum amount of motion is at the bottom, discharge area, tendency for choking is less.

Blake jaw crushers are of two types: single toggle and double toggle jaw crushers.



In the single toggle jaw crushers, the swing jaw is pivoted/suspended on the eccentric drive shaft which leads to a much more compact design than that of the double toggle jaw crusher. As shown in above figure, the swing jaw, pivoted on the eccentric shaft, undergoes two types of motions: swing motion towards the fixed jaw due to the action of toggle plate and vertical movement due the rotation of the eccentric shaft. These two motions, when combined, lead to an elliptical motion of the swing jaw (at the feed opening it is elliptical and at the discharge opening it is a thin crescent, whose chord is inclined upwardly toward the fixed/stationary jaw). This motion is useful as it assists in pushing the particles through the

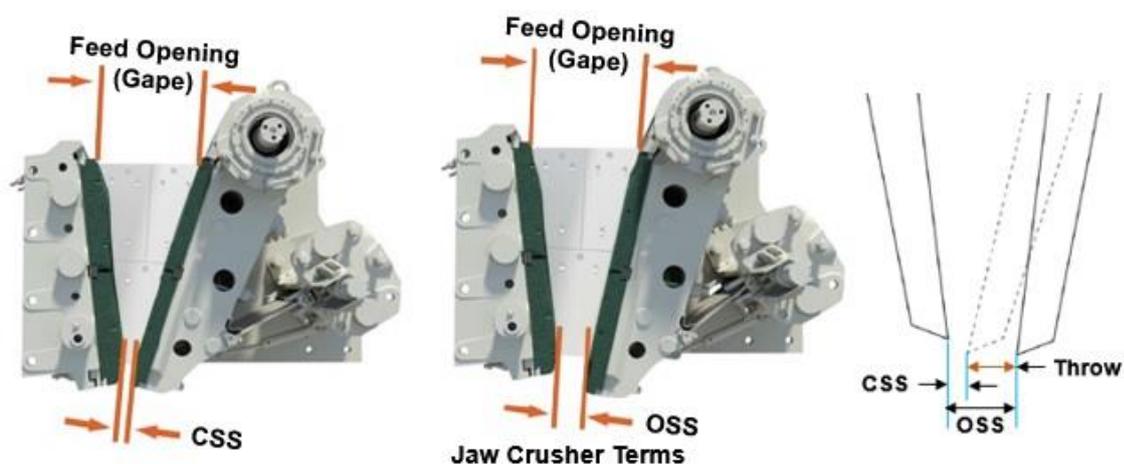
crushing chamber. This phenomenon leads to higher capacity of the single toggle jaw crushers but it also results in higher wear of the crushing jaws. Hence, these type of jaw crushers are preferred for the crushing of softer materials.



Above figure shows construction of a typical double toggle Blake type jaw crusher. In the double (two) toggle jaw crushers, the oscillating (back and forth) motion of the swing jaw is caused by the vertical up and down motion of the pitman under the influence of an eccentric shaft, causing the toggle plates to alternately flex and stretch. The swing jaw moves like a swinging door that is hinged at the top and is being pushed and pulled at the bottom to open and close it. The term "pitman" generally means "connecting rod". In a double toggle jaw crusher, it connects eccentric shaft to the toggle plates. In case of a single toggle jaw crusher, eccentric shaft and swing/moving jaw functions as pitman.

As shown in the figure titled crushing actions in Blake type jaw crushers, due to absence of wasteful abrasive action path (absence of elliptical motion of the jaw due to absence of vertical motion), in a double toggle jaw crusher, abrasion or gouging of the jaw plates is reduced to a minimum. Hence, double toggle jaw crusher is commonly used to crush abrasive materials.

Jaw Crusher Terms



Feed Opening

It is the distance between the jaws at the feed opening. The feed opening (gape or depth of the cavity) is measured from the top of the tooth of the fixed jaw to the bottom of the tooth of the movable jaw in a straight line perpendicular to the center line of the crushing cavity.

Feed opening defines the maximum feed size of the crusher. The maximum feed size is approximately 80% of the feed opening.

Open Side Setting (OSS)

The open side setting is measured when the crusher is at rest. The setting is measured either top to top (for closed profile jaw plate, i.e. use of heavy duty jaw plate), or bottom to top (for open profile jaw plates, i. e. jaw plates with tooth), depending on the tooth profile of the jaw plates. It is the maximum discharge opening/gap.

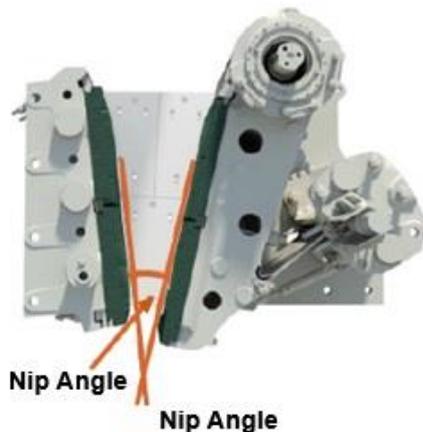
Throw/Stroke

The throw is stroke of the swing jaw. It is the difference between OSS and CSS.

Closed Side Setting (CSS)

The closed side setting can be calculated by deducting the throw/stroke from the OSS. CSS is the most important crusher parameter since it defines the maximum product size and has significant bearing on capacity, product gradation, power draw and wear. It is the minimum discharge opening/gap. Check the instruction manual for the permitted minimum CSS.

Nip Angle



The nip angle is the angle between the fixed and movable jaw plates. Too large a nip angle reduces the capacity (due to material squirt out like a large ball which might squirt out from under a car tire) and increases the wear as the feed material grinds and gouges the jaw plates in an upwards direction during the compressive stroke.

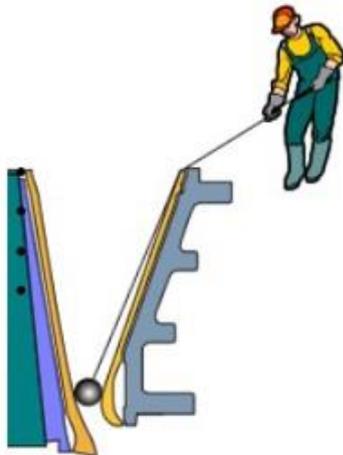
Jaw Plates

Replaceable liner plates protecting the jaws from wear.

Cheek Plates

Wear plates used to protect the sides of crusher frame.

Leading



Leading a Jaw Crusher

Leading is a technique for measuring the gap between fixed and moveable jaws. The procedure is performed while the crusher is running empty. As shown in above figure, to measure the gap between the fixed and moveable jaws, a lead wool or aluminum foil ball/plug is lowered in to the jaw crusher up to the discharge opening. After the crusher has compressed it, it is removed and measured to find out how much thickness remains after its compression. This measurement gives the closed side setting. The open side setting is equal to this measurement plus the throw of the mantle.

Size

Jaw crushers size is specified in terms of the feed opening (gape) and jaw width, typically listed as feed opening x jaw width.

Construction Details

A jaw crusher is designed with sacrificial parts to protect the main components of the crusher such as frame and jaws.

Crusher Frame and Jaws

Crusher frame and jaws are made of high-grade steel or special cast steel that has been subjected to a stress relieving heat treatment in order to prevent residual stresses from the welding or casting process.

Eccentric Shaft

Eccentric shaft is forged from hardened and tempered alloy steel.

Cheek Plates

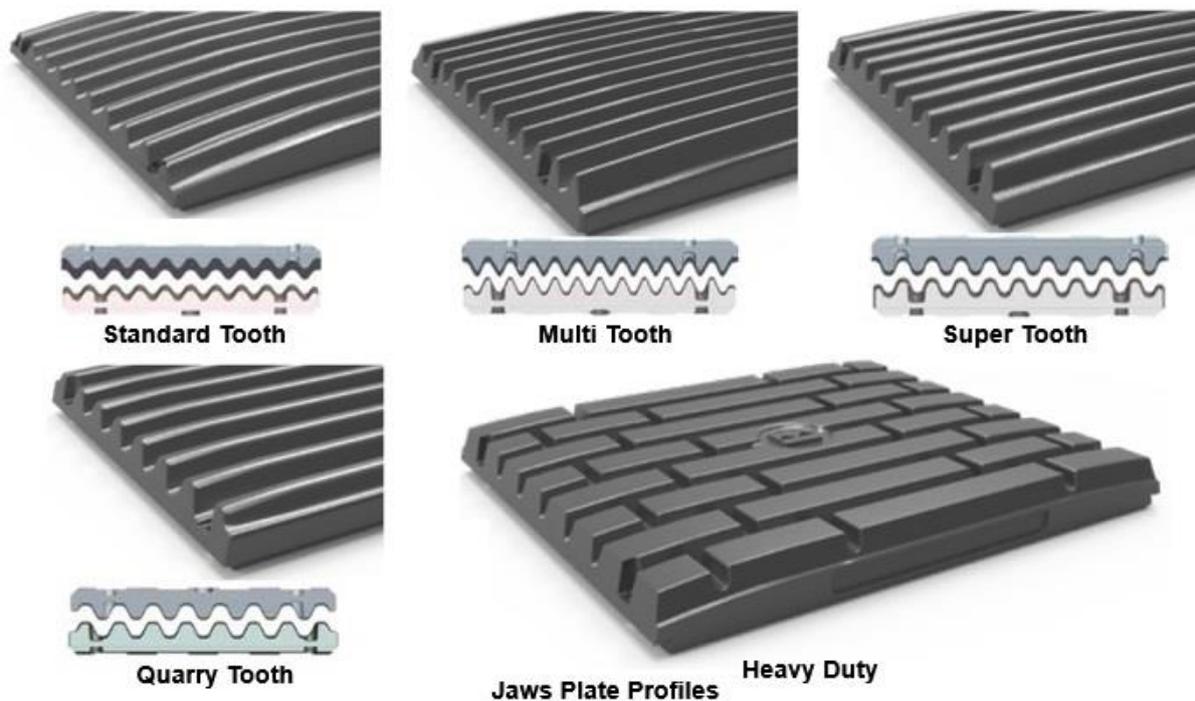
Cheek plates are made of high strength special steel (400 to 450 Brinell hardness).

Jaw Plates

Jaw plates are made of high grade austenitic manganese steel.

As the earth's natural resources are becoming scarce, recycling is becoming important. Recycling of material is generally carried out in the building industry. **Recycling** means reuse of demolition concrete, reclaimed asphalt pavement, etc.

Due to the wide range of applications and feed material, jaws plates of many profiles are available.



Jaws Plate Profiles	Applications
Standard Tooth (Sharp Teeth)	Recycling and soft rock applications.
Multi Tooth (Sharp Teeth)	Recycling applications. Good grip on smooth flat surfaces.
Super Tooth (Corrugated Teeth)	Medium to hard rock applications. Grips material to allow better crushing.
Quarry Tooth (Corrugated Teeth)	Hard rock and high abrasive applications. Deeper tooth profile allows for extra wear.
Heavy Duty (Flat)	To improve the wear life jaw plate on fixed/stationary jaw.

Note: **Profile names are indicative only.** They vary from manufacturer to manufacturer.

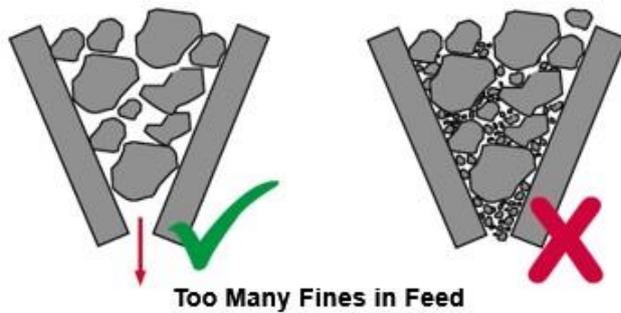
Above figure and table shows basic jaw plates profiles and recommendations for their applications.

Different type of jaw plate profiles can be broadly classified in to three categories/groups: sharp teeth (e.g. standard tooth), corrugated teeth (e.g. super tooth) and flat (e.g. heavy duty). The applicability of these three categories depends on the material being crushed. Sharp teeth are used for softer materials (hardness below 5 on the Mohs' hardness scale), corrugated teeth are used for medium hard materials (hardness between 5 and 7 on the Mohs' hardness scale) and flat profiles are used for very hard rocks (hardness greater than 7 on the Mohs' hardness scale).

Operation and Maintenance of Jaw Crushers

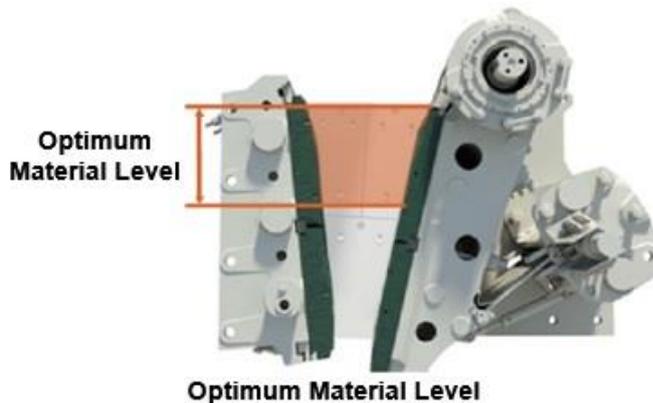
In order to get optimum capacity and maximum lifetime of wear parts, follow the recommendations given in the operation and maintenance manual.

Operation



Fines (material smaller than CSS) should be removed from the feed material. This can be done by installing a grizzly feeder. This reduces wear on the jaw liners and can improve overall plant performance.

Check the feed size. Oversize feed material decreases capacity and can cause unnecessary stresses to the crusher components.



In order to reach optimum capacity and maximize on the life of the wear parts, the crusher cavity/chamber should be full. Above figure shows the optimum material level. The feed must be distributed evenly across the crushing chamber.

The crusher must not be operated at a smaller CSS than what is stated in the operation and maintenance manual. A tight CSS will lead to higher wear on jaw plates.

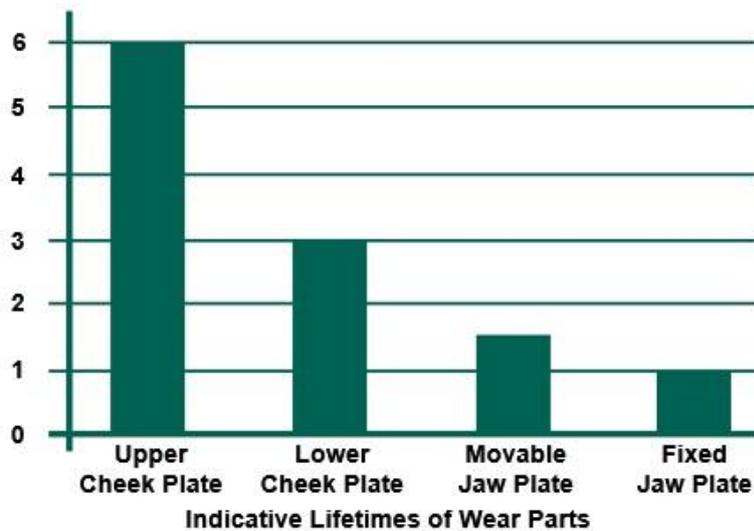
Check the wear profile of the jaw plates. An uneven wear profile will decrease capacity, increase wear, and increase crushing forces.

Maintenance

Check plates and jaw plates should be changed before they are fully worn out in order to avoid damage to the crusher components (worn jaw plates imposes unnecessary excessive loads on the crusher).



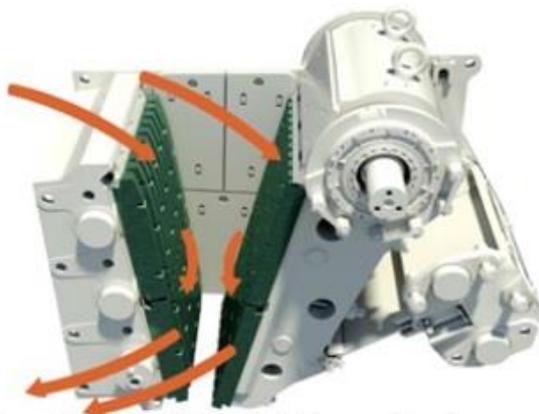
As shown in above figure, it is recommended that a jaw crusher should not run any longer once the tooth profile of jaw plate has reduced to below 90% of its profile height.



Above figure shows indicative lifetimes of wear parts. It may be noted that usually the fixed jaw plate wears the fastest (compared to the movable jaw plate, the sliding distance between the crushed particle and the fixed jaw plate is more).

As the wear in the inlet part of the crushing chamber is small as compared to the middle and exit sections, it is recommended to rotation and replacement jaw plates as under:

After a new one-piece jaw plate installation, rotate it when 30% of the tooth profile is worn. Rotate it a second time when the tooth profile at the bottom of the jaw plate is completely worn. Replace the jaw plate after it is completely worn.



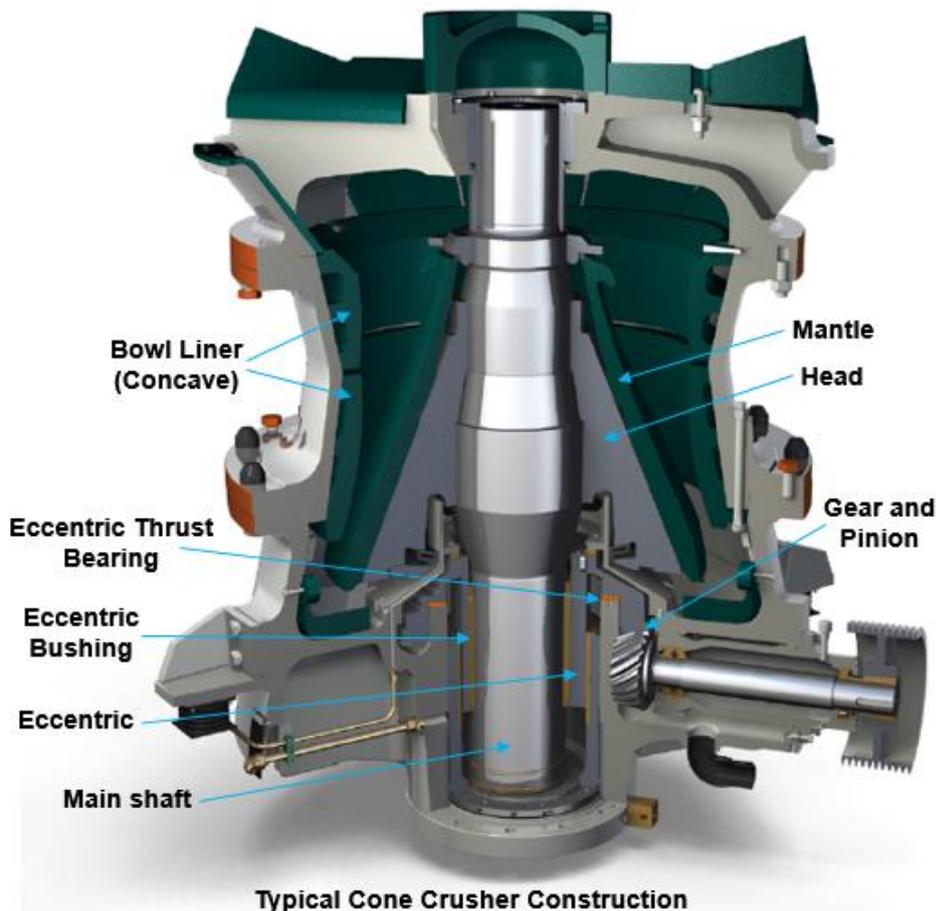
Two-piece Jaw Plate Rotation and Replacement

As shown in above figure, in case of two-piece jaw plates, worn out jaw plates are removed from the bottom of the crushing chamber and work hardened upper jaw dies are installed at the bottom of the crushing chamber. New jaw plates are installed at the top of the crushing chamber.

Above procedure will allow for good work hardening of the manganese jaw plates and maintain the best nip angle for maximum through put.

Carry out lubrication as per manufacturer's recommendation.

Cone Crushers



Above figure shows construction of a typical cone crusher. Cone crushers are used in secondary, tertiary and quaternary stages. They are compression crushers. A cone crusher is similar in operation to a gyratory crusher, with less steepness in the crushing chamber and more of a parallel crushing zone. A cone crusher breaks material by squeezing it between an eccentrically gyrating main shaft, which is covered by a wear resistant mantle and the concave hopper, covered by bowl liner (concave). As material enters the top of the cone crusher, it becomes wedged and squeezed between the mantle and the bowl liner. Large pieces of the material are broken and then they fall to a lower position (because they are now smaller) where they are broken again. This process continues until the pieces are small enough to fall through the narrow opening at the bottom of the crusher.

The spring or hydraulic release system (not shown in above figure) of a cone crusher acts as an overload protection that allows tramp iron to pass through the crushing chamber without damaging the crusher. For automation, many manufacturers provide modern features such as hydraulic mechanism for setting adjustment. These automation systems constantly adjust the CSS (Closed Side Setting) with no need to shut the machine down. They compensate for variations in feed material and wear in wear parts. They are also used for cavity clearing (if the machine stops during operation under load due to electric failure, etc.).

Wear parts, mantle and bowl liner are made of manganese steel. The performance of wear parts depends on the feed arrangement, speed, stroke and closed side setting (CSS) of the crusher. Trickle feed results in irregular liner wear. As shown in the following figure, choke feeding is the correct method for uniform liner wear.



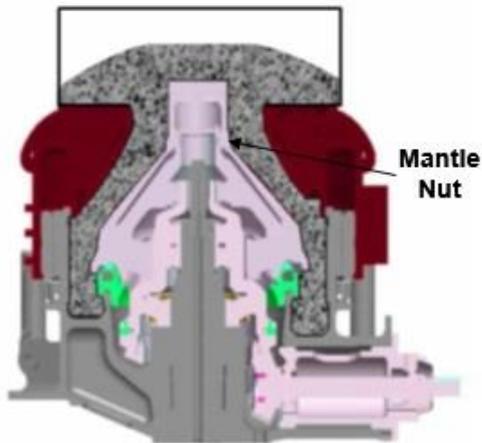
Choke Fed (Correct Method)



Trickle Fed (Incorrect Method)

Cone Crusher Feeding

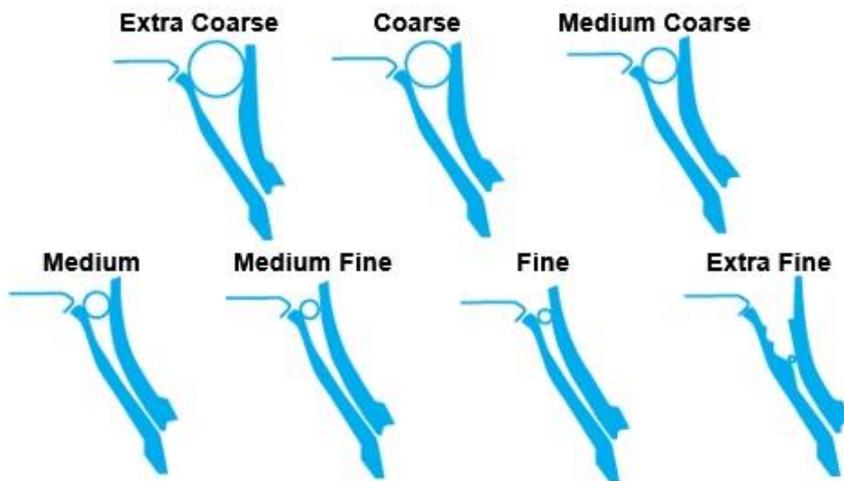
The condition in which the feed rate exceeds the product rate is known as choke feeding.



Choke Fed Cone Crusher

As shown in above figure, in a choke fed cone crusher, feed material is always filled above the mantle nut.

Crushing Chamber Designs



Crushing Chamber Designs

As shown in above figure, for different materials and outputs demand, different designs of crushing chambers are available. For best performance, select the right chamber design.

Designed for Ease of Maintenance

Time spent on changing parts during service/maintenance, and the number of people it takes, also affect profitability. Premium machines are often designed for easy fitting and maintenance (for example: mechanical rotation of the bowl for its removal), saving time and costs.

Use of a mantle lifting device can save time and increase safety.

Crusher Performance

The following factors will detract from crusher capacity and performance.

- Sticky material in crusher feed.
- Excessive moisture in the feed.
- Fines in crusher feed (smaller than crusher setting) exceeding 10% of crusher capacity.
- A lot of single size product in the feed.
- Feed segregation in crusher cavity.
- Improper feed distribution around circumference of crusher cavity.
- Operation of crusher at less than recommended full load countershaft (pinion shaft) speed.

Cone Crusher Terms

Mantle

Covers the cone head of the crusher to protect it from wear. It is the inner sacrificial wear liner that sits on the cone head.

Concave (Bowl Liner)

Sits in the upper frame of the crusher to protect it from wear. It is the outer sacrificial wear liner that sits inside the upper frame.

Backing Compound

A resin that is poured behind the manganese liners to fill the void and secure the manganese liners.

Open Side Setting (OSS)

The maximum distance between concave and mantle at a given close side setting.

Close Side Setting (CSS)

The minimum distance between concave and mantle to give the required output and grading for a crusher.

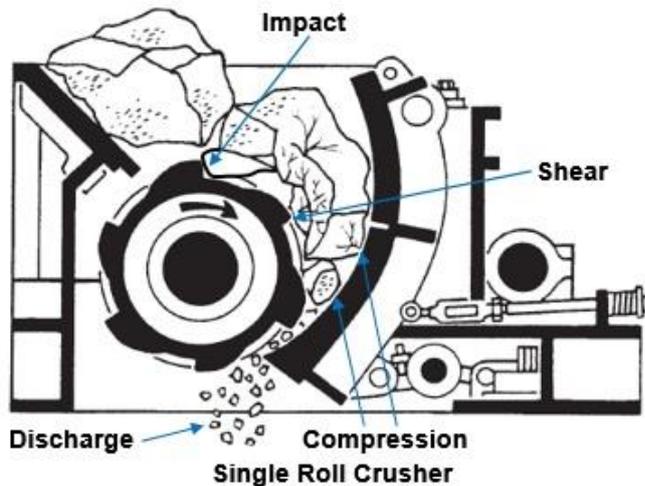
Mantle Nut

Used on the top of the mantle to secure the mantle in place on the cone head.

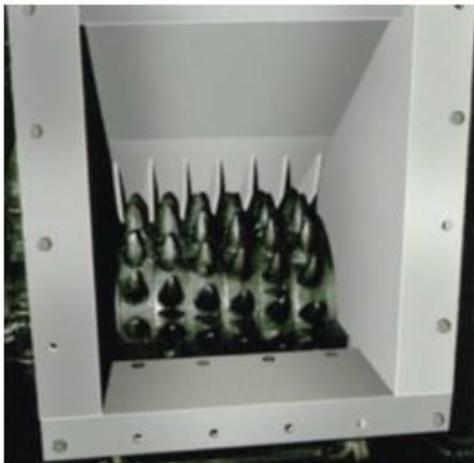
Roll Crushers

Roll crushers are used for primary as well as secondary and tertiary stages. They are used for crushing lignite, coke, coal, soft to medium-hard rock, ore, iron ore and similar products. Roll crushers are of two types: single roll crusher and double roll crusher. Single roll crushers are typically used as primary crushers. Double roll crusher are typically used in situations in which fines are to be minimized.

Single Roll Crushers



As shown in above figure, a single roll crusher consists of a roll assembly and a breaker plate. In these crushers, reduction occur due to impact, shear and compression. As shown in the following figure, sometimes, comb teeth-like projections are provided at bottom of the breaker plate, which are duly hard-faced by special electrodes of wear-resistant quality.



Breaker Plate with Comb Teeth-Like Projections

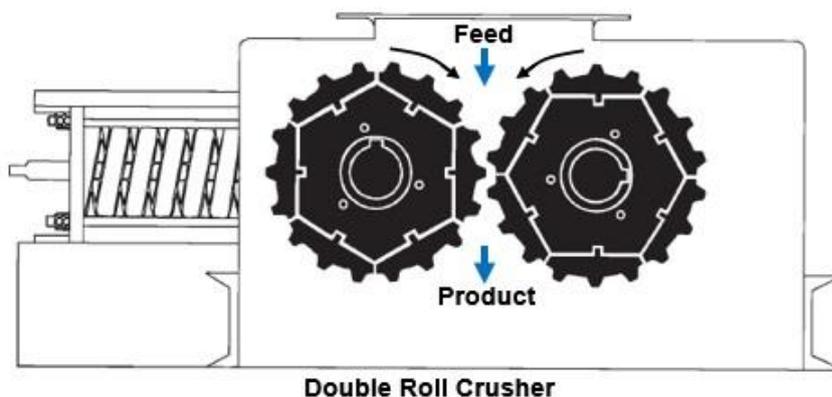
As material enters the crusher through the feeder hopper, it is struck by the teeth of the revolving roll and initial breakage occurs from the impact. The rotation of the roll then guides the material further into the crushing chamber, the space between the breaker plate and the roll itself. The roll then pinches the material against the stationary breaker plate, and simultaneously, the material is crushed by the shearing action of the roll teeth and by compression, providing final sizing. The crushed material exits through the bottom discharge portion of the crusher.

The gap between the bottom lip of the breaker plate and the rotating roll determines output size of the product. The output size of the product is adjusted by changing the size of the gap.

This gap is adjustable from outside the machine by a shim (or spindle) arrangement. Adding or removing shims (or rotating the spindle) causes the breaker plate to pivot about its top hinge, moving it into or away from the roll.

For protection against uncrushable debris (tramp iron), the breaker plate assembly is secured with an automatic release device. As pressure from the uncrushable is exerted against the plate, the device allows the entire breaker plate assembly to move away from the roll instantly. The uncrushable drops clear of the machine by gravity, and the breaker plate assembly immediately returns to its normal crushing position. Many times crushers are also provided with shear pin and zero speed switch as additional safety device.

Double Roll Crushers



As shown in above figure, a double roll crusher consists of two parallel rotating rolls turning together (in opposite directions and turning in the direction of the downward material flow through the centre), with feed being directed through the moving gap between them. The rolls are individually powered or coupled by gears.

The crushing material is fed into the crusher such that it is spread over the whole width of the rollers. As the two rolls rotate toward each other, the material is pulled down into the crushing zone where it is grabbed and compressed by the rolls. Since both rolls rotate at the same speed, there is no relative motion between the two roll surfaces, and crushing is primarily accomplished by compression. Fines are reduced because already sized material passes freely through the crusher with no further reduction.

Product size is determined by the size of the gap between the rolls, and this gap can be changed to vary product size or to compensate for wear. To change the gap, one of the two crushing rolls is designed as a loose roll. The gap adjustment is done mechanically, hydraulically or electro-mechanically.

Protection from uncrushable debris (tramp iron), is provided by the loose/retractable roll assembly. It retracts instantly when an uncrushable is encountered, then reverts to its original position once the uncrushable has cleared the crushing chamber with no stoppage of the crusher.

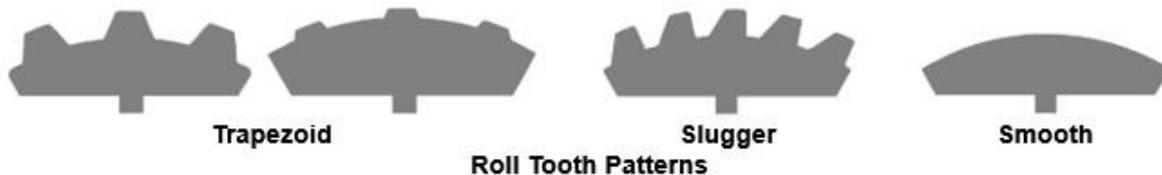
Double roll crushers are well suited for extremely hard and abrasive materials.

Construction Details

Housing/Frame

Housing/Frame is generally fabricated from structural steel plates and heavy section duly stiffened by ribs. Replaceable wear resistant steel liner plates are fitted at the crushing zones.

Rotor Assembly (Rolls)

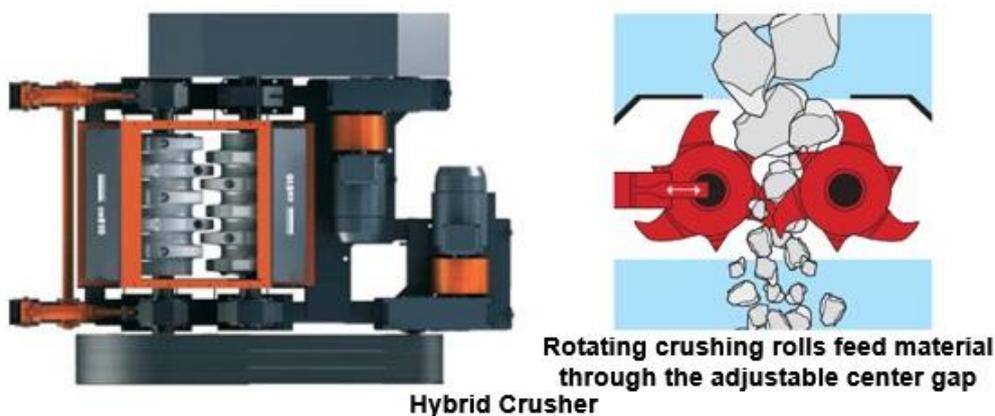


The rotor assembly is fitted with smooth or toothed circular crushing rings or segments to suit individual application. Above figure shows some common roll tooth patterns.

In double roll crushers, smooth rolls are used for crushing medium hard to hard materials whereas toothed rolls are used to crush soft to moderately hard materials.

The wear parts, toothed circular crushing rings or segments and breaker plate are made of manganese steel or wear resistant steel.

Hybrid Crushers



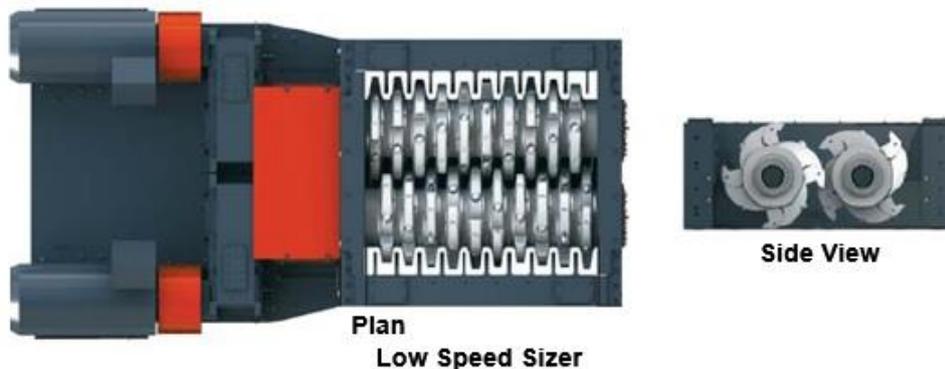
As shown in above figure, a hybrid crusher (CR800 series by Sandvik) results in a compact design as a result of aggressive tooth geometry. Hybrids are used for primary and secondary crushing of soft and medium hard materials that also have the tendency to be wet and sticky. They are equipped with an advanced hydraulic gap adjustment system with integrated overload protection to realize different product sizes and to protect the machine against foreign bodies within the feed material. Furthermore, the hybrid is able to compensate peaks with "energy storage" in the flywheels.

Crusher Feeding

Once the crusher reaches operating speed, it may be choke-fed from hoppers or fed at continuous, controlled rates from vibratory screens, apron feeders or belts.

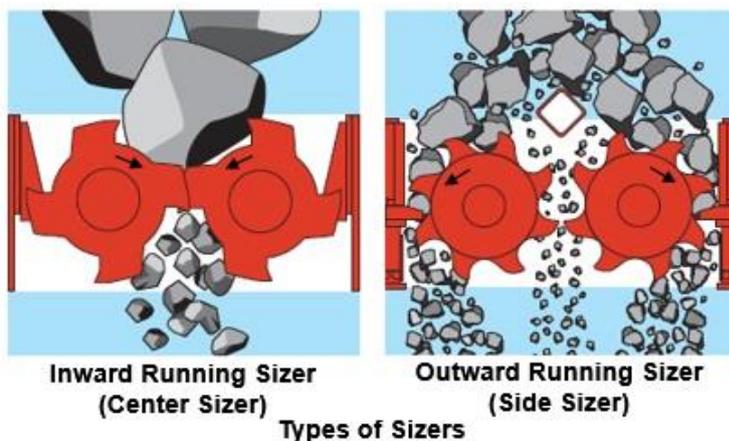
Low Speed Sizers

A low speed sizer is designed to accept feed material (either ROM, i.e. for primary crushing or pre crushed, i.e. secondary crushing applications) through the top of the crushing chamber, drawing it through the rotating shafts laced with teeth (rolls) and crushing or sizing it to a specified product size. Low speed sizers are insensitive to clay and sticky materials. Dust and noise generation are also low due to low roll speed. As low speed sizers allow high throughput capacities to be achieved with a compact machine design, plant dimensions can be significantly reduced, ensuring low investment costs.

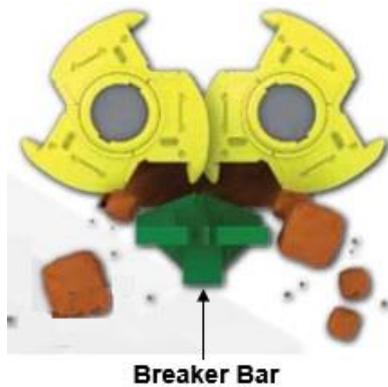


Above figure shows typical construction of a low speed sizer. As shown in the figure, in a low speed sizer, two toothed rolls revolve in a chamber at low speeds and high torque. The shear and tensile forces required for crushing or sizing are generated by the high rotor torques at low circumferential speeds. The low speed of the crushing rolls results in low fines content in the final product. Furthermore, low roll speeds maximize wear life of consumable elements due to positive bite and minimal feed slip.

As per one of the leading manufacturer, the actual rotating tip speed of the tooth or sizing element in a sizer can be as low as 0.8 m per second (primary applications) and up to 1.8 m per second (tertiary & quaternary applications).



As shown in above figure, there are two types of sizers: inward running sizer or center sizer (rolls rotating in the inward direction) and outward running sizer or side sizer (rolls rotating in the outward direction). Inward running is the normal method of operation for most tooth configurations and must be used on wet sticky materials. For secondary and tertiary applications, outward running sizer can be used on certain materials to produce a smaller product than is possible with inward running sizer. In the outward running sizers, the material gets crushed between the roll and the side/lateral crushing comb.



Breaker Bar

As shown in above figure, many times a breaker bar is provided in the inward running sizers or center sizers. The breaker bar is used to break any lumps of material that still remains oversized after the feed material has passed the rolls. Lumps are broken as the rotors chop through the fixed teeth of the breaker bar.

As there is no impact that will cause the material to pack in the crushing chamber, the low speed sizers are the only primary crushers that can handle the sticky materials effortlessly.

In most cases, pre-screening (pre-scalping) of undersize material is not necessary, as the fines contained in the feed material can pass smoothly through the crushing rolls.

Low speed sizers are protected against overload or from foreign particles contained in the feed material (tramp iron) by providing under speed sensors (proximity probe) for auto-reverse operation or discharge to by-pass chutes (provided with hydraulically operated doors) so that they will not suffer catastrophic damage. In case of drives with fluid couplings, thermal overload switch if provided or fusible plug on the fluid coupling also provides protection against overload or from tramp iron.

Construction Details

Generally, the main frame (housing) is fully fabricated and machined from carbon steel plates. Wear plates (usually 500 BHN) are used to completely cover the sizing/crushing chamber (the inside of the housing).



Primary Teeth



**Secondary Teeth
Crushing Teeth**



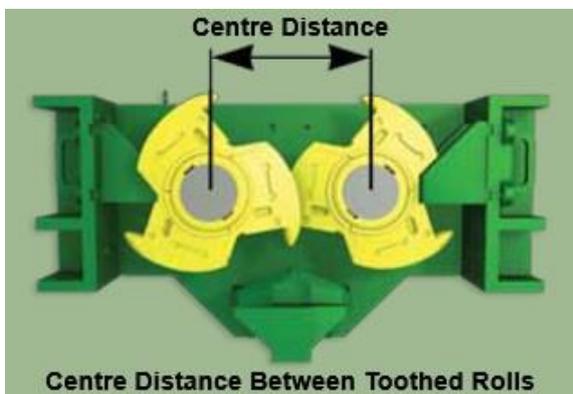
Tertiary Teeth

The rolls consist of the bearings and shafts, which are fitted with easily replaceable crushing segments/picks (teeth) made of wear resistant material. The shafts and drive gears are fully machined from a solid high carbon steel (grade 4340) forging. Shaft bearings are spherical roller with C3 clearance.



Deep Scroll Tooth Pattern

If provided, a deep scroll tooth pattern/configuration helps in spreading the feed material evenly over the whole width of the crushing rolls. This is important in order to achieve high throughput capacities. Furthermore, uniform wear attained in the feeding area results in a longer lifetime of the wear parts.



Centre Distance Between Toothed Rolls

The centre distance between toothed rolls combined with the tooth configuration controls the maximum size of infeed material that the unit can process efficiently. The length of the inlet has a major effect on the volume of material that the unit can process.

To handle sticky materials, the low speed sizers can be provided with scraper bars that are located between the rows of sizing teeth to keep the toothed shafts clean at all times.

Maintenance

Routine maintenance requirements are minimal. Periodically check tightness of frame, tooth and liner bolts. Check wear and adjust breaker plates or replace breaking elements (teeth and breaker plates) as per requirement. Carry out lubrication as per manufacturers recommendations.

Manufacturers

FLSmidth ABON Pty Ltd, MMD Mineral Sizing Ltd, Sandvik and thyssenkrupp are leading manufacturers of low speed sizers.

Horizontal Shaft Impactors

The horizontal shaft impactor (HSI) has a shaft that runs horizontally through the crushing chamber with a rotor that turns hammers or blow bars. It uses the high speed impacting force of the turning blow bars projections to break the material. With impact crushing, the material breaks along its natural cleavage lines, resulting in a more cubical product at high reduction ratios. Horizontal shaft impactor can be used as primary or secondary crushers. In the primary stage, horizontal shaft impactors are better suited for softer and less abrasive material. In the secondary stage, the horizontal shaft impactors can process more abrasive and harder material.

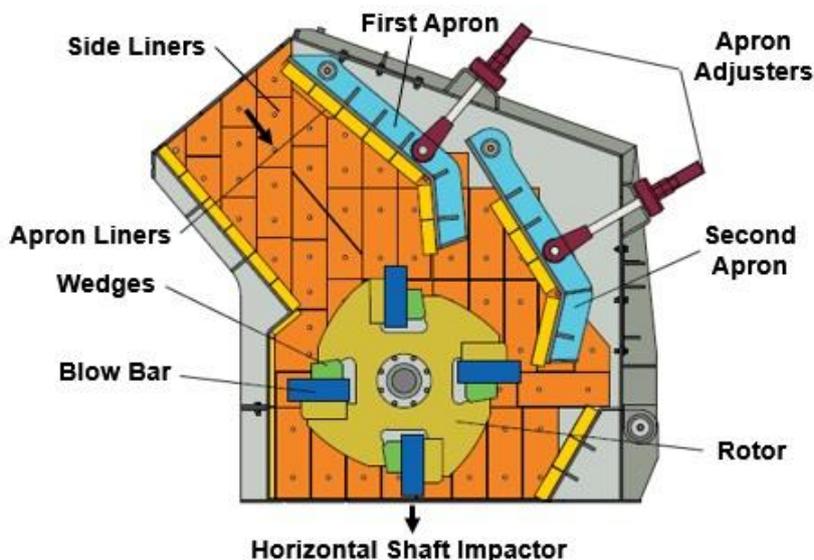
In compression crushing (primary gyratory, jaw crusher and cone crusher) the material is squeezed between 2 surfaces which get closer to each other. The crushing movement speed is between 0.5 m/s up to 1.5 m/s. In impact crushing (Horizontal Shaft Impactor - HSI and Vertical Shaft Impactor - VSI) the material is subject to shocks given by rotating parts (rotor equipped with blow bars, etc.) and thrown against metal surfaces. The movement speed is from 30 up to 80 m/s.

Horizontal shaft impactors are suitable for crushing hard rocks such as limestone, dolomite, granite and other similar materials under toughest operating conditions.

A reversible impactor generally uses hammers instead of blow bars and the material hits the breaker blocks/plates instead of aprons liners.

However, the horizontal shaft impactors and hammer mills cannot be used for clay bearing or sticky materials as the crushing chamber will build up with the clay (sticky material) and prevent impact crushing from taking place. The crushing chamber will also quickly pack.

Construction and Working of Horizontal Shaft Impactor



Above figure shows construction of a typical horizontal shaft impactor. The rotor has wedge-shape grooves extending parallel to the shaft for holding blow bars. The rotor shaft assembly is dynamically balanced to assure vibration free operation. The rotor is equipped with two, four or six blow bars. The blow bars extend over the full width of the rotor. The bars are so designed that they can be used by turning them after one face wears out. Two or three aprons (breaker plates) are positioned to form an arc of the circle centered to the point of

impact. The first apron is normally fixed in initial crushing zone. Liners (replaceable wear plates) are fitted to the aprons to ensure that the apron settings can be maintained. Sometimes reversible and interchangeable mono-block type aprons are also provided. The housing/frame is fabricated from heavy steel plates and is stress relieved. Inside surface of the housing is shielded/protected by the side/frame liners. Many times the housing is hydraulically hinged for its quick opening to reduce time required for maintenance.

After entering the crushing radius of the rotor, the feeding material is broken by primary impact of the blow bars and the material propels towards the first apron (liners) where it is broken by secondary impact. The material is then shot back from the apron to the blow bars. The material is also broken in the crushing chamber by material hitting material. Feed material is reduced approximately 60 % by initial impact with blow bars and 30 % by impact with aprons. The process repeats until the material is crushed to the required size and discharged through the discharge opening at the bottom of the machine.

The aprons can be adjustable by apron adjusters to compensation for wear of the blow bars and the aprons (liners). In order to prevent possible damage caused by any foreign bodies (tramp iron) entering the machine, the aprons are mounted on springs or hydraulic cylinders so that they can avoid any temporary overloads. The size and shape of the end products also can be changed by changing the gap between the blow bars and the aprons by adjusting the apron adjusters. It may be noted that in small mobile machines, generally only one apron is provided.

Design Considerations

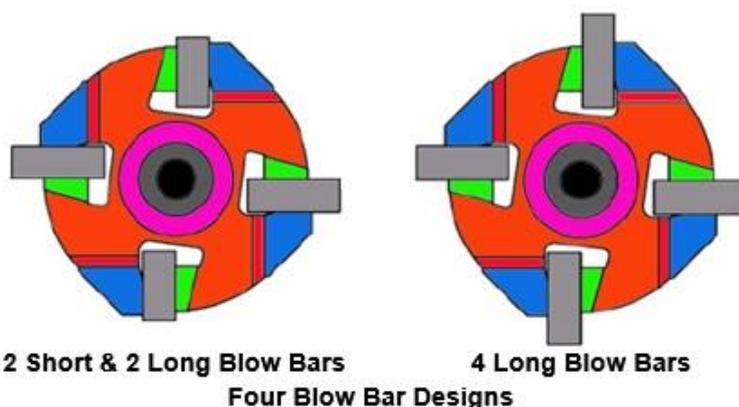
In design of a horizontal shaft impactor, peripheral speed of the rotor, number of impact bars and metallurgy of the wear parts play an important role.

Rotor Speed

Increasing the rotor speed results in a tendency for a higher fine-particle proportion and in some cases, to greater output. However, results in more wear of the blow bars. The wear doesn't increase proportionally with the speed; it is a function of the square of the speed.

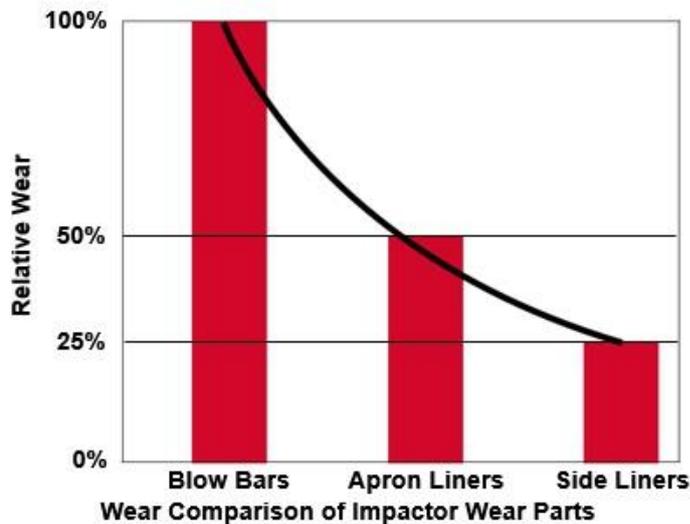
Number of Impact Bars

Generally, rotors with two or three blow bars are used for smaller crushing chamber geometries (inlet width of under 1100 mm with rotor diameter under 1100 mm). Larger crushing chamber geometries (inlet width over 1200 mm with rotor diameter over 1200 mm) are equipped with rotors having four or more blow bars.



As shown in above figure, for a rotor with four blow bars, there are two designs in use: 2 short & 2 long blow bars and 4 long blow bars. In design with 2 short & 2 long blow bars, time between blow bars is doubled improving penetration on material. It results in a higher tonnage for a given speed. It also produces less fines. This design is suitable for most applications. However, design with 4 long blow bars is good for secondary applications where shape and size outweigh throughput. But this design produces more fines.

Material of Wear Parts



The impact elements; blow bars, apron liners and side/frame liners are made from wear resistant materials for long wear life. Above figure shows wear comparison of an impactor's wear parts. The wear is maximum on the blow bars because the most reduction work takes place when the particles are struck by the blow bars. They account for about 60% of the total wear costs.

Material of blow bars, apron liners and side/frame liners is chosen according to the material type, abrasion, foreign elements and size at the feeding and the required product.

Apron liners are made from either manganese steel castings or chromium iron. The side liners are made from AR plates, 400 HB or 520 HB. The various options for blow bars are: manganese steel, martensitic (alloy) steel, white cast iron (chromium) and metal matrix composites (MMC) - martensitic ceramic and chrome ceramic commonly called ceramics.

Blow Bar Material Selection



Above figure shows toughness versus abrasion resistance for various materials for blow bars. It can be seen that an increase in wear resistance (hardness) of a material such as chrome, is normally associated with a reduction in toughness (the impact resistance) of the material.

Austenitic Manganese Steel

The wear resistance of manganese steel with austenitic structure is attributable to the phenomenon of work hardening. The impact and pressure load results in a hardening of the austenitic structure on the surface. The initial hardness of manganese steel is approx. 200 HV (20 HRC, hardness test according to Rockwell).

After work hardening, the initial hardness can increase to an operational hardness of up to approximately 500 HV (50 HRC). The deeper, not yet hardened material layers provide for the great toughness of this steel.

In general, manganese steels will be used whenever very high shock resistance or some elongation is needed. This alloy is used for crushing less abrasive and very large feed material (e.g. limestone). The alloy is used in primary crushers or crushers that have tramp iron in the feed.

Martensitic (Alloy) Steels

Martensitic steel will be used whenever hardness and impact resistance are both needed, i.e. in all the applications where usage of white irons (chromium) can lead to breakage. Generally, martensitic steels have a higher lifetime than manganese steels in more abrasive applications when the feed size is below 900 mm. It can tolerate steel in the feed material. It is used in primary and recycling applications.

White Cast Iron (Chromium)

In chrome steel (e.g. ASTM A532), the carbon is chemically bonded in the form of chromium carbide. The wear resistance of chrome steel is based on these hard carbides. To prevent the material from becoming brittle, the blow bars are heat-treated. It is very important to assure that the temperature and annealing time parameters are exactly adhered to. Chromium is available as medium chrome and high chrome. Chrome steel typically has a hardness of 60 to 64 HRC and a very low impact strength.

White irons are used when the shock level is rather low and the castings rather thick. Feed to the crusher must be well prepared as far as top size and must be free of tramp iron. Because of the brittle nature of this alloy, tramp iron will cause catastrophic failure of the blow bars. This material is used in secondary, tertiary and asphalt recycle applications where there is no tramp iron.

Metal Matrix Composites (MMC) - Ceramics



Examples of Ceramic Inlays in Basic Materials

Metal matrix composites (MMC), consisting of metallic matrix (steel or cast iron) and ceramic alloy. The ceramic part consists of particles spread across the wear surface. Above figure shows examples of ceramic inlays in the basic materials. These composites have the effect of combining the very hard surface of ceramic with the useful mechanical properties of cast iron or steel. This combination makes the whole structure sufficiently tough to resist to breakage during service. Compared with standard alloys, metal matrix composites considerably increase the parts' life span and the tonnage crushed by each set of parts especially in more abrasive conditions.

The martensitic ceramic blow bars consist of hard ceramic particles on the wear surface in a martensitic steel matrix. This composite has the effect of combining the very hard surface of ceramic with the useful mechanical properties of steel. These (martensitic ceramic) blow bars can have two to four times the life of standard martensitic steel blow bars. Martensitic ceramic blow bars are used for recycling industries (primary), quarries (primary), concrete and asphalt. However, they are NOT suitable for slag recycling (too abrasive) or limestone (risk of metal stress due to too long lifetime).

Chromium ceramic blow bars consist of hard ceramic particles on the wear surface in a chromium iron matrix. This composite has the effect of combining the very hard surface of ceramic with the useful mechanical properties of chromium iron. These (chromium ceramic) blow bars can have two to four times the life of standard chromium blow bars. Chromium ceramic blow bars used for asphalt (when no risk of unbreakable parts) and secondary application in quarries & gravel pits. However, they are NOT suitable for primary crushers or extreme abrasive/hard materials because carbide based matrix accepts near to no shocks.

Crusher Feeding

Maximum feed size should be as per the manufacturers recommendations. In primary impact crushing process, the physical size of the crusher feed opening must not be considered as the true gauge to set the maximum crusher feed size and - as a result of that - assess that any lump passing through the crusher feed opening has the correct feed size. Significantly larger feed opening than recommended feed top size is recommended/provided to ease material flow and decreases bridging risks when several big lumps come at once.

The crusher should be started without load. Start feeding the material only after rotor attains the rated speed. Feeding of the crusher should be regulated one. Choke feeding must not be done as it would create high wear and damages to the equipment. Fines from the feed material should be removed before feeding the material to the crusher. Fines in the feed creates additional wear (if material is abrasive), rises risk of clogging if material is sticky and/or will generate additional dust emission. It may also require a larger crusher to achieve the same total production.

Impact crushers must always be fed on all width of the machine (80 to 90%) to ensure an even wear of the blow bars. Concentrated feed will generate localized wear of the blow bars. Typical case of a wrong feeding method is a direct material flow penetrating straight into the crushing chamber from a belt conveyor.

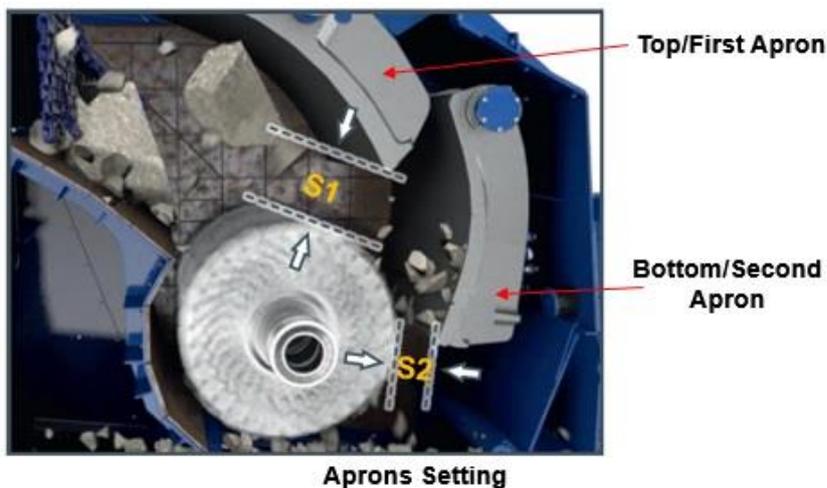
Note:

Crushed product has a high velocity when leaving the crushing chamber. Special care must be given to the design of the transfer point underneath the crusher, to prevent damages on collecting belt conveyor/vibrating feeder and to prevent excessive wear: stone box, thick chute liners wherever needed (20 to 30 mm thick AR steel, 400 HB), sufficient headroom underneath the crusher.

Aprons Setting (Crusher Gaps)

The space (gap) between the aprons (breaker plates) and the blow bars permits only sized material to exit from the crusher. Materials that are larger in dimension remain in the crushing cavity until the correct size is obtained. Then they are discharged. Normally the crushing cavity is limited by two adjustable aprons (breaker plates), which control crushed product size and capacity.

The closer the aprons are to the blow bars, the smaller is the product size and the lower the capacity through the crusher. The smaller the setting is, wearing is naturally faster. The further the aprons are from the blow bars, the higher is the throughput of the crusher, and the larger the product size.



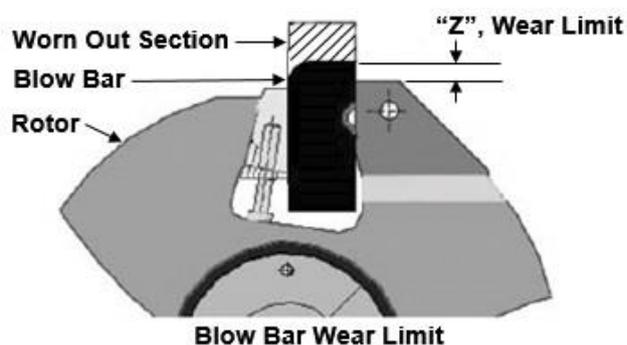
As shown in above figure, the bottom setting (S2) is the distance (gap) between the tip of the blow bar and the apron liner when the blow bar is facing the bottom/second apron liner.

The minimum operation/bottom setting (S2) depends on the size, the nature of the feed material and the capacity through the machine.

The bottom/second apron setting (S2) defines the size of the product discharged from the crusher (S2 = product size). In order to ensure the material flow and uniform filling of the crushing chamber, it recommended that the distance (gap) between the tip of the blow bar and the top/first apron liner (S1) should be approximately 30% of the maximum feed size.

For Nordberg NP series impact crushers, Metso recommends to calculate S1 using the formula: $S1 = (S2 + \text{Feed Material size}) / 4 + 20 \text{ mm}$

Blow Bar Wear



As shown in above figure, blow bar needs changed or rotated when the wear limit “Z” is reached otherwise considerable damage will occur to the rotor. For the wear limit “Z”, please see the operation and maintenance manual supplied by the crusher manufacturer.



Blow bars are reversible. When one face is used, the blow bar can be turned around to use the other face. Above figure shows when to turn or replace a blow bar.

It is recommended to change all 4 blow bars simultaneously. However, in some applications two worn blow bars and two new blow bars (diametrically opposed) may be used which works like a design with 2 short & 2 long blow bars.

To increase the life of blow bars the following guidelines should be adhered to:

- Select correct blow bars depending on application.
- Adjust machine parameters (rotor speed, gap, etc.) to match the application.
- Maintain and clean crushing chamber daily.
- Regularly inspect blow bars and take corrective action for premature wear or damage.



Ideal Wear Pattern

Above figure shows ideal wear pattern for blow bars. A gentle radius on the blow bar shows that the feed material is of the correct size. It also shows that the rotor penetration and rotor speed are correct.



Excessive Penetration

Above figure shows excessive/over penetration on the blow bar. Excessive penetration takes place if the rotor speed is too slow. It increases risk of blow bar breakage. It results in the underutilization of the blow bar before changing. It also leads to rotor wear.



It may be noted that as shown in above figure, when the blow bars are new and present a plane surface and a sharp edge, the impact is more violent, the energy explodes the material in many pieces. However, when the blow bars are worn and rounded, the material particles are only scuffed by the blow bar edges. As the energy of the impact is lower, there is less fragmentation.



Above figure shows poor penetration on the blow bar. Poor penetration on the blow bar means, the top of the blow bar is worn down flat. If the rotor speed is too high, it results in poor penetration on the blow bar. In case of high rotor speed, wear rate will be excessive. It also leads to reduced output and creates lot of fines.



As shown in above figure, a trickle feed, insufficient filling of the crushing chamber results in excessive wear at centre of the blow bar and reduces the life of the blow bar. To overcome the problem, increase feed to the crusher.

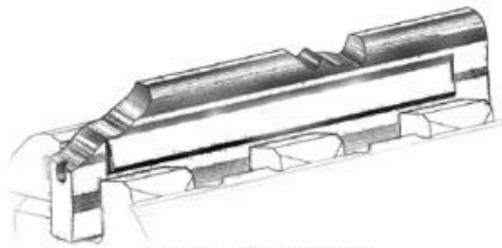


As shown in above figure, high percentage of fines in the feed or over feeding causing fines to be pushed to outside results in an excessive wear at both ends/sides.



Excessive Wear on One Side

As shown in above figure, blow bar wearing excessively to one side can be due to machine being on uneven ground (not positioned horizontally) or material is falling to one side.



Blow Bar Damage

As shown in above figure, blow bar can get damaged due to incorrect selection of the blow bar for the application (e.g. Chrome), if there is steel or rebar (unbreakable elements) in the feed material or the feed size is too large.

Blow Bar Replacement

A non-secured rotor can lead to severe injuries. Always observe safety instructions!

Completely extend the crusher gap before blow bar replacement in order to prevent a collision between the blow bars and the apron after new blow bars have been installed.

Make sure that all blow bars are in matched pairs pertaining to weight. The weight difference of paired blow bars should not exceed more than that recommended by the manufacturer (as per one reputed manufacturer, the difference should not exceed 0.5 kg) and the matched pairs should be installed on opposite sides of the rotor.

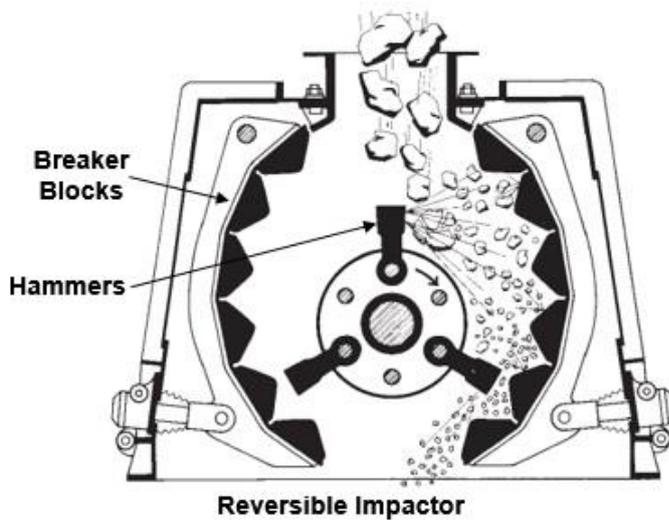
Before making the final settings, briefly operate the machine at the highest rotational speed and then check the wedge clamps. Tighten the screws if necessary.

Reversible Impactors

Reversible impactors are used for secondary and tertiary crushing, and occasionally for primary crushing. They are used for reduction of cement rock, gypsum, fertilizer, chemicals, limestone, lightweight aggregate, ceramics etc.

Reversible impactors are normally recommended for requirements like: high reduction ratio (35:1 or greater), high capacity, cubically shaped, well-graded product, and minimum fines.

These crushers can be easily adjusted to produce a wide variety of product sizes. For coarser output sizes, they are operated at lower speeds while for finer output sizes, they are operated at higher speeds. It is also possible to change product size by making adjustments to the breaker block assemblies.



As shown in above figure, a reversible impact has multiple rows of hammers. The hammers are of two types: single piece hammer and two part hammer. A two part hammer consists of a hammer arm and a hammer head. The following photograph shows construction of a typical two part hammer. These hammers are suspended in a pendulum fashion on pins between the rotor segments. Single piece hammers are made from alloy steel and then heat treated to required hardness or cast manganese steel. In case of two part hammers, the hammer arms are made of high quality steel and the hammer heads from alloy steel.



Feed material is feed to impactor through the centrally located feed chute. The feed material directly drops into the rotor, where it is struck by the rotating hammers. The material then impacts against the breaker blocks and rebounds into the path of the hammers. Since after first impact against the breaker blocks, the small, finished particles cease to react freely to additional hammer blows and are swept from the active reduction zone, the maximum crushing power is applied to large fragments while little energy is expended on finished particles. There are no cage bars or screens, therefore, impact and some shear are the methods of reduction. The bottom of the crusher is entirely open and the sized material passes out freely.

When the product must be held to a specific top size, the impactor should be operated in a closed circuit system. When operating in closed circuit, the impactor discharge is carried to external screens or classifiers for separation, with the oversized particles being returned to the impactor for further reduction.

As the reversible impactor is symmetrical in design, after the hammers have been worn out on one side, the rotor direction can be reversed presenting a fresh hammer face to the feed. The rotor direction can be reversed by the operator by simply pushing the reversing button of the motor to change its direction of rotation. Thus a reversible impactor eliminates manual turning of hammers.

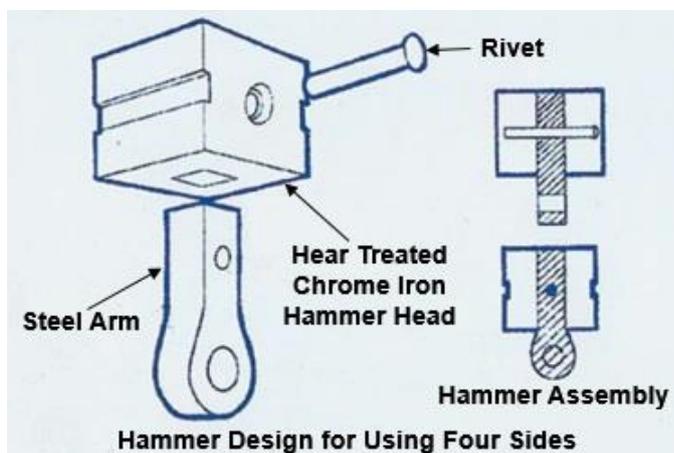
The final product size can be altered by adjusting the distance (gap) between the rotating hammer heads and the breaker blocks. At the same time the adjustment also serves for the compensation of hammer wear to a certain extent. However, the adjustment must be done very gradually and very carefully. In case the hammers strike with the breaker blocks, one of the two may break and damage the crusher. It is therefore desirable that the adjustment is stopped as soon as the desired product size of the material is achieved at the discharge end.

To achieve uniform hammer wear and maximum crushing efficiency, the feed material must be fed to the impactor uniformly and evenly spread across the entire width of the feed hopper opening.

For stopping the impactor, with impactor operating, stop all feed to it. After impactor is clear of all feed material, cut power. Impactor rotor will require several minutes to coast to a stop. When the rotor speed has been reduced to near stop, a loud clanking noise will be heard. This noise is caused by the hammers falling back on the suspension pins, and is no cause for concern.

Notes

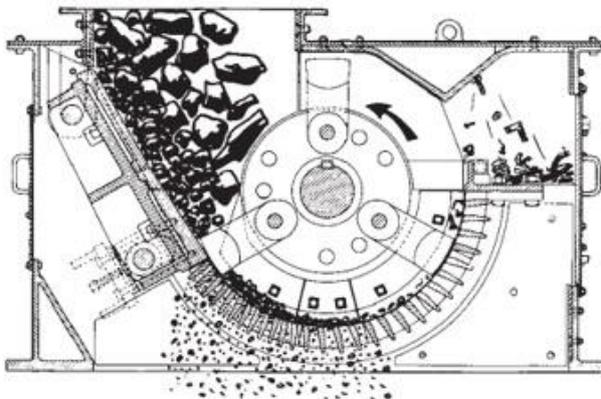
Hammer hardness is the most important factor in determining hammer life. In case of single piece hammers, while the hammer head must be extremely hard and resistant to wear, the arm (shank) must be ductile in order to absorb shock. For this, some manufacturers (e.g. Pennsylvania Crusher, brand owned by TerraSource Global) use special method of heat treating that creates a gradually varying hardness between the arm and the head (tip), without any abrupt changes. The heads of these special hammers are hardened to 500 BHN. However, in the vital arm/shank and eye areas, these hammers are normalized to a nominal 350 BHN, providing the ductility needed to resist shock.



As shown in above figure, some manufacturers (e.g. ABON Engineering) offer a hammer design for using all four sides of a hammer head. It may be noted that like hammers, the blow bars are also designed (e.g. by Telsmith) for 3 rotations allowing up to 4 wear surfaces.

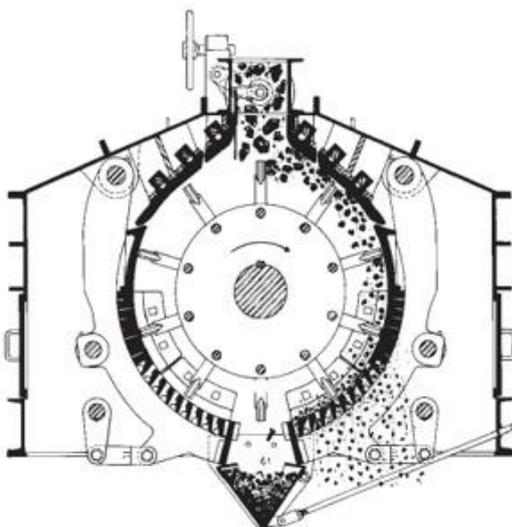
Hammer Mills

Hammer mills are similar to reversible impactors except they use breaker plates or breaker blocks and incorporate a grate circle (also called screen bars or cages) in the lower chamber of the crusher. The grate circle insures the product size. Hammer mills crush material in two stages. First, the material is reduced by dynamic impact, crushing then occurs by attrition and shear in the lower chamber, where small clearances exist between hammers and the grate. This second zone is the final sizing zone for the product. Hammer mills produces a cubical product, and is recommended when the material to be crushed is not unusually abrasive. Hammer mills have high reduction ratios and will produce high capacities whether used for primary, secondary or tertiary crushing. Both, non-reversible and reversible type hammer mills are available.



Non-reversible Type Hammer Mill

Above figure shows construction of a typical non-reversible type hammer mill. Non-reversible type hammer mills are used for primary or secondary reduction of dry, friable, low abrasive rocks, ores and chemicals, particularly when uniform product gradation is important. The hammer wear is compensated for by resetting the hammer suspension bars closer to the outside edges of the rotor discs, and by moving the breaker plates closer to the hammer circle. A tramp iron pocket is provided for non-crushable materials.



Reversible Hammer Mill

Like reversible impactors, reversible hammer mills are symmetrically designed crushers with a rotor that can be run clockwise or counter-clockwise. This ability to reverse the rotor eliminates the requirement of manual hammer reversal. A tramp iron pocket is provided for non-crushable materials.

Reversible hammer mills are used for coals, rock, limestone, minerals and chemicals. Above figure shows construction of a typical reversible hammer mill for coal. To produce the smaller product sizes required, reversible hammer mills for coal has more rows of hammers than are found in the reversible hammer mills used for stone or rock. However, the breaker blocks and the cage bars are more massive for crushing stone or rock than those used for crushing coal or other relatively friable materials. Though the internal configurations for the coal and rock models differ, the crushing actions are similar.

Bearings Temperature for High Speed Impactors

The following is (for a V-belt driven impactor: Capacity = 200 TPH, Motor = 200 KW, 1500 RPM and Rotor RPM = 927) as per one of the leading Indian crusher manufacturer.

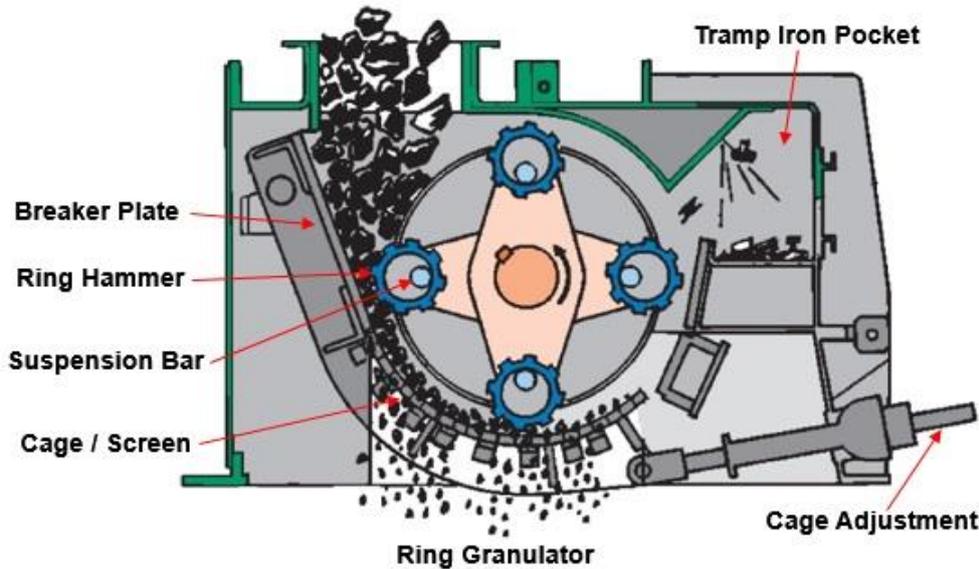
In case of a high speed machine, it is not unusual for some heating to occur when new antifriction roller bearings are first operated. This heating can go beyond 90 - 95°C when measured on the top of the bearing cap/housing with a magnetic thermometer depending upon ambient conditions. If heating does occur, stop the crusher and allow bearing to cool to 50°C. Then, restart the crusher and observe operating temperatures closely. Repeat process if bearings should heat again. Bearings can withstand temperature up to 200°C. After running for few days, temperature usually comes down to around 80°C.

Important Note

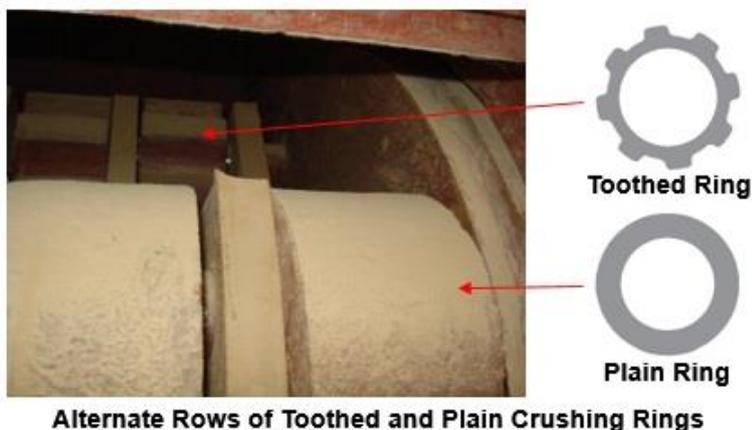
For reversible impactors and hammer mills, make sure that weight difference of opposite side hammers does not exceed more than that recommended by the manufacturer.

Ring Granulators

Ring Granulators (called granulators) are rugged, dependable units, specially designed for continuous high capacity crushing of ROM coal and other medium hard friable materials like gypsum, salt and chemicals. These are ideal machines for crushing coal to a size suitable for pulverization, in power stations.



Above figure show construction of a typical ring granulator. Ring granulators use rows of rings (ring hammers) which crush feed material with a slow, positive rolling action. This produces a granular product with minimum fines. The crushing action, combination of impact and rolling compression in a ring granulator results in higher output with lower power consumption. As shown in above figure, the crushing rings are mounted on suspension bars. When the rotor is set in the motion, centrifugal force brings the rings out against material to be crushed. As material is fed to the machine the rings are forced back towards the rotor center until suspension bar is encountered by the ring internal surface and a forward driving force is exerted. The material is broken and discharged through the cage bars or screen plates thus easing the load and allowing the ring to move out until it is held again by suspension bar before encountering the incoming feed once again. The rings are thus held in contact with the bed of material on the cage bars or screen plates and they revolve with planet like motion relative to the direction of rotor rotation. This positive rolling feature provides effective crushing action which in turn results in a granular product.



Alternate Rows of Toothed and Plain Crushing Rings

The rings are generally made of austenitic manganese steel (ASTM A128, Grade C or IS 276, Grade 3). Forged rings of alloy steel (e.g. ASTM A322, Grade 9260; 293 to 352 BHN) are also used. Depending upon application, they are toothed and/or plain. Toothed rings are used to impact the feed material sharply. Above figure shows a granulator with alternate rows of toothed and plain crushing rings.



Each Row with Alternate Toothed and Plain Crushing Rings

As shown in above figure, arrangement with alternate toothed and plain crushing rings in each row is also used.

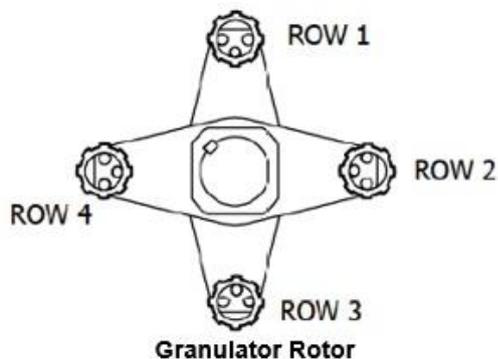
The size of product is determined by cage/screen openings, and is adjusted by changing the clearance between the cage and the path of the ring hammers. The adjustment of clearance between the cage and the path of the rings also provided to compensate for wear.

Granulators also have a tramp iron pocket for continuous removal of non-crushable material from the crushing zone.

Rotor assembly is statically/dynamically balanced to operate with minimum of vibration and noise. However, granulator will operate without vibration only if all the crushing rings/hammers are weighed and assembled in such a way that it results in a balanced rotating assembly.

Hammer Balancing Example

Hammer balancing example from Installation, Operation and Maintenance Instructions (Manual) of Pennsylvania Crusher, brand owned by TerraSource Global is reproduced here.



As shown in above figure, for this example, the granulator rotor is assumed to have 4 rows of hammers with 2 rows having 20 hammers per row and 2 rows having 18 hammers per row. There are a total of 76 hammers per set.

Hammers Weight

43-6	44-0	43-11	43-12	43-14
43-8	44-2	43-11	43-12	43-14
43-10	44-3	43-11	43-14	43-12
43-10	44-5	43-10	43-14	43-12
43-10	44-3	43-10	43-14	43-12
43-10	44-3	43-8	43-14	43-11
43-11	44-2	43-6	44-0	43-11
43-11	44-0	43-7	44-2	43-11
43-12	43-14	43-10	44-3	43-10
43-12	43-14	43-10	44-5	43-10
43-12	43-14	43-10	44-3	43-10
43-12	43-14	43-10	44-3	43-8
43-14	43-12	43-11	44-2	
43-14	43-12	43-11	44-0	
43-14	43-12	43-12	43-14	
43-14	43-11	43-12	43-14	

The hammers have been weighed and marked with their corresponding weights in pounds and ounces as per above figure.

Balancing requirement: the total weight variance between opposing rows does not exceed 6 ounces.

Arrangement 1

Row 1	Row 3	Oz. Out	Row 2	Row 4	Oz. Out
43-10	43-6	4	43-14	44-0	2
44-5	43-14	7	43-10	43-14	4
43-12	43-7	5	43-12	43-8	4
44-0	43-10	6	43-11	44-3	8
43-12	43-14	2	43-8	43-12	4
43-14	44-2	4	44-0	43-11	5
43-6	43-11	5	43-11	44-2	7
44-2	43-12	6	44-3	43-14	5
43-14	44-0	2	43-10	43-11	1
43-10	44-3	9	43-14	43-10	4
43-8	43-10	2	44-2	43-14	4
43-11	43-14	3	43-12	44-3	7
43-14	44-5	7	43-10	43-14	4
44-3	43-12	9	43-14	43-12	2
43-10	43-10	0	44-3	43-11	8
43-14	43-12	2	43-14	43-10	4
43-10	43-14	4	43-12	43-11	1
43-12	43-11	1	43-11	43-12	1
43-11	43-10	1			
43-12	43-12	0			
875-	875-		788-	788-12	
14	12		11		

Above arrangement, Arrangement 1, would satisfy the requirement that the total weight variance between opposing rows does not exceed 6 ounces.

It may be noted that Rows 1 and 3 are balanced within 2 ounces, and Rows 2 and 4 are balanced within 1 ounce. However, the opposing hammers at a suspension arm location are significantly different in weight.

In order to reduce the circular weight variance to a minimum, the hammers are then rearranged, Arrangement 2, for installation as shown in the following figure.

It can be seen that rearranging the hammers as per Arrangement 2 provides the rotor with the most efficient static balance possible for the set of hammers given in this example. Hence hammers should be installed in the granulator rotor as per Arrangement 2.

Arrangement 2

Row 1	Row 3	Oz. Out	Row 2	Row 4	Oz. Out
44-5	44-5	0	44-3	44-3	0
44-3	44-3	0	44-3	44-3	0
44-2	44-2	0	44-2	44-2	0
44-0	44-0	0	44-0	44-0	0
43-14	43-14	0	43-14	43-14	0
43-14	43-14	0	43-14	43-14	0
43-14	43-14	0	43-14	43-14	0
43-14	43-14	0	43-14	43-14	0
43-12	43-12	0	43-12	43-12	0
43-12	43-12	0	43-12	43-12	0
43-12	43-12	0	43-12	43-12	0
43-12	43-12	0	43-11	43-11	0
43-11	43-11	0	43-11	43-11	0
43-11	43-11	0	43-11	43-11	0
43-10	43-10	0	43-10	43-11	1
43-10	43-10	0	43-10	43-10	0
43-10	43-10	0	43-10	43-10	0
43-10	43-10	0	43-8	43-8	0
43-8	4-7	1			
43-6	43-6	0			
<hr/>	<hr/>		<hr/>	<hr/>	
875-14	875-13		788-11	788-12	

Notes on Common Problems

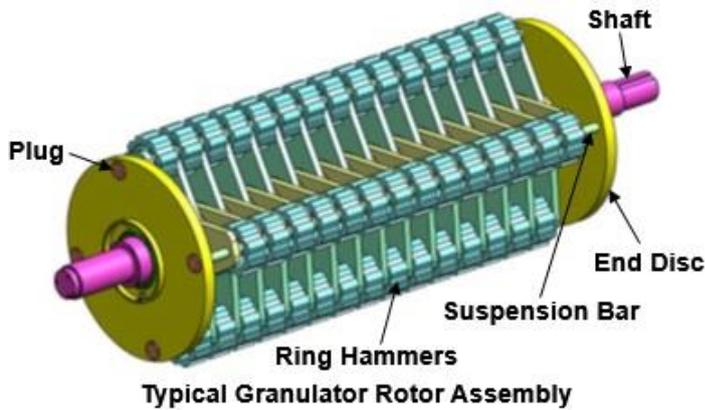
Information on problems (witnessed by me) with granulators is shared in this section.

Sudden Increase in Vibration Level

Many times, crushing rings break in operation resulting into rotor imbalance leading to high vibration. It is recommended to install new rings (or worn rings) such that the rotor assembly results in a balanced one.

Use of Correct Spare Parts

The following figure shows parts of a typical granulator rotor assembly.



As shown in above figure, sometimes plugs are used to keep suspension bar to locate them. The threaded plugs are made from soft material like brass/bronze so that they cannot damage threads in the end discs. When the plugs threads are worn out, many times they are replaced by cast iron / steel plugs. These plugs damage threads in the end discs.



Damaged End Disc

Above figure shows a rotor with damaged end discs. Once the threads are worn out, as it is difficult to repair them, technicians resort to welding MS plates instead of plugs to locate the suspension bars. The bad practice may lead to many problems. Hence, it is recommended to use correct (size and metallurgy of the material) spare parts.

Labyrinth Type Seals



Damage to Granulator Bearing and Shaft

To prevent bearings getting damaged due to dust/dirty, generally labyrinth type seals are provided to bearing housings. It is very important to check their condition during bearing replacement.

Due to repeated use or improper handling, labyrinth ring installed on the shaft may get loose. In such case, as shown in above figure for a granulator for crushing coal, coal particles may enter bearing housing from the gap between the shaft and the labyrinth ring. As shown in the photograph, it may damage bearing and the shaft.

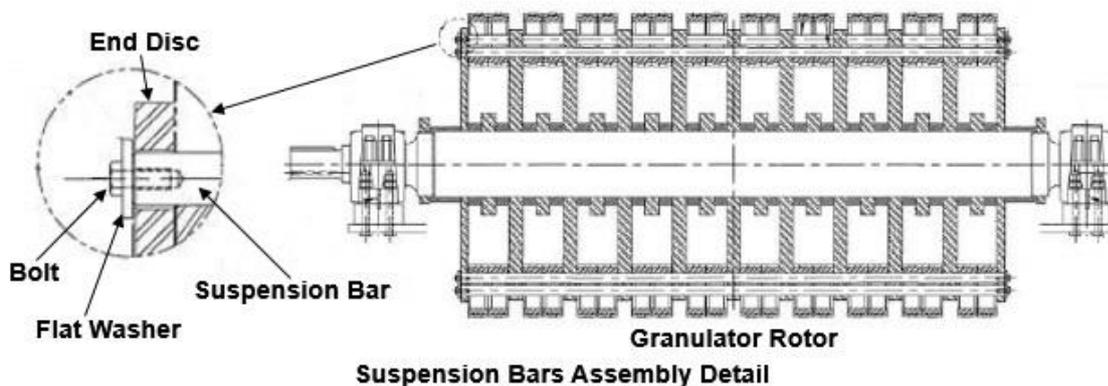


Repair of Granulator Shaft

As shown in above figure, because it was not possible to dismantle the rotor as it has got jammed, the rotor shaft was weld repaired and the rotor assembly was mounted on a lathe to machine the shaft to the required size.

Follow Maintenance Instructions

For trouble free operation, it is very important that maintenance instructions given in the drawings and maintenance manual are followed.



For example, above figure shows the suspension bars assembly detail in a manufacturer's drawing. It is instructed in the drawing that at the final assembly of the bolts, LOCTITE #242 should be used and bolts torque tightened. It is important that this instruction is followed to prevent bolts working loose during operation.

Rotary Breakers

Rotary breakers are used for crushing, sizing, and cleaning of run-of-mine coal and other friable materials. They are used to produce a product that is relatively coarse, with minimum fines, and that is 100% to size.



Rotary Breaker

As shown in above figure, a rotary breaker consists of a large rotating cylinder powered by an electric motor through a reducer drive and chain. The cylinder is fitted with perforated screen plates, lifting shelves and a refuse plow. The size of the screen plate perforations determines the maximum size of the product.

As the cylinder rotates, the lifting shelves lift the feed and, in turn, the feed slides off the lifting shelves and drops onto the screen plates below, where it shatters along natural cleavage lines. The sized product falls/pass through the perforations but oversized pieces will again be lifted and dropped by the lifting shelves until they too pass through the screen plates. Thus the material gets crushed by gravity impact only.

Tramp iron, lumber or other uncrushable debris that enters the breaker along with the feed is transported to the discharge end of the cylinder. There, these uncrushables are scooped out by a refuse plow which channels this debris out of the cylinder and into a disposal bin.

Cylinder of a rotary breaker rotates at slow speed, 10 to 18 RPM depending upon cylinder diameter. Compared with most other crushers, rotary breakers are extremely long lived. Screen plates, for example, frequently last ten years or more, crushing millions of tons of coal.

Generally, the screen plates in the breakers are designed to be interchangeable so that the screen plates from the feed end, where wear is greatest, can be switched with screen plates from other areas of the cylinder where there is less wear.

Manganese Steel

The strength of a liner / hammer is the ability to withstand crushing forces without failure, and is dependent on the metals microstructure. The original austenitic manganese steel, containing about 1.2% C and 12% Mn, was invented by Sir Robert Hadfield in 1882. Hadfield's steel was unique in that it combined high toughness and ductility with high work hardening capacity and, usually, good resistance to wear. As manganese steel has high hardness properties and is wear resistant, it is used as liner material (e.g. jaw plates of jaw crushers) and hammers (e.g. ring hammers in a ring granulators). In view of this information on manganese steel is given in this chapter.

When manganese content exceeds about 10%, the steel will be austenitic after slow cooling. One particular type of steel, known as Hadfield manganese steel, usually contains 12% manganese. Hadfield manganese steel and other manganese steels having more than 12% manganese has a property to work harden from an initial hardness of about 230 BHN to well over 500 BHN when they are placed in service and subjected to repeated compression or impact. The deformations of austenite microstructure due to repeated compression or impact results in conversion of some austenite microstructure to martensite microstructure. As this work hardening deformation process continues, hardness of the affected metal increases resulting in increasing abrasion/wear resistance. The hard layer thickness can be 5 to 10 mm, depending on the impact load. Thus, manganese steels perform most efficiently when external conditions cause extensive work hardening of the wear component's surface.

Hadfield manganese steels (14% manganese steels) are widely used in low abrasion applications such as ring hammers of a ring granulator.

ASTM designation ASTM A128 / A128M (Standard Specification for Steel Castings, Austenitic Manganese) and IS 276 (Austenitic Manganese Steel Castings - Specification) covers Hadfield austenitic manganese steel castings and alloy modifications.

Ring hammers of a ring granulator are generally made as per Grade 3 of IS 276 (Grade C as per ASTM A128). The material composition and hardness for grade 3 as per IS 276 are:

C = 1.05-1.35 %

Si = 1.00 %, Maximum

Mn = 11.50-14.00 %

P = 0.08 %, Maximum

S = 0.025 % Maximum and

Cr = 1.5-2.5 %.

Castings when supplied in the heat treated condition will have hardness of HB 229, Maximum.

However, for more demanding applications like liners for jaw crushers and cone crushers, steel containing higher manganese content, more than 14% manganese are used as under.

18% manganese steel is a standard material for all jaw & cone crushers. 22% manganese steel is an optional material for jaw & cone crushers.

The speed at which the part (hammer, liner, etc.) work hardens increases as the percentage manganese content increases; so 12-14% work hardens slowest & 20-24% fastest.

The work hardened face has a higher BHN value if the percentage manganese content is lower; so once work hardened the 12-14% will be more wear resistant than the 16-18% etc.

Lubrication

The main enemy of mechanical failures is friction. With proper lubrication, friction is reduced to a minimal impact in moving parts. Hence lubrication of moving parts/components of a crusher is very important for the trouble free operation and long life. Crusher components are either grease lubricated or oil lubricated. Information on their lubrication is given in this chapter.

It is recommended to use only approved lubricant and strictly follow the instruction regarding relubrication interval by the crusher manufacturer. Do not use contaminated oil/grease for lubrication.

Grease Lubrication

Motorized or hand-operated centralized greasing system is provided if asked for. However, for small machines, lubrication is carried out manually. For manual lubrication, lubricating points are equipped with grease nipples and must be greased with a grease gun.

Before hand operated grease guns are applied, clean the lubricating nipples and the nozzle of the grease gun.

It is generally recommended that the grease in the bearings should be replaced periodically (say after every two years of operation). Before replacing the grease, clean the bearings and bearing housing (pillow/plummer block) thoroughly. Bearing housings must not be filled fully with the grease. Too much of grease will cause the operating temperature to rise rapidly, particularly when running at high speeds due to grease churning. As a rule, only the bearing should be completely filled, while the free space in the housing should be partly (between 30 and 50 percent) filled with grease.

The bearings may discharge any excess grease through the labyrinths after a short period of operation. Do not replace this initial discharge of grease unless discharge continues and loss of grease is excessive. In this case, replace the grease. Excessive grease loss will cause sudden temperature rise.

Many times labyrinth covers (seal units) are filled with grease. In such case, grease the labyrinth covers until a fresh collar of grease has been formed (to ensure that lubricant is passing through). While greasing, it is necessary to rotate the shaft so that grease gets filled up all over the periphery of labyrinth alley. It is also recommended that periodically (say every six months), the labyrinths should be washed from old grease and filled with fresh grease. To do this, the covers should be opened and clean with Benzene or Kerosene.

Oil Lubrication

As grease is not suitable for lubrication under high load, oil is used for high load applications. Generally forced/pressure oil circulation method is used for lubrication of moving parts of a crusher. It also works as a conduit in which it transports contaminants to the filter for their removal. Follow manufacturers instruction regarding the oil quality.

Operating an oil lubricated crusher with contaminated lubricating oil (old, dirty oil) is a common mistake. When lubrication system maintenance is neglected, dust can infiltrate the lube unit and contaminate the oil.

As the dirty oil flows over the bearing surfaces within the crusher, it tends to act as a lapping compound, sanding down the bearing surfaces and resulting in severely worn components

and excessive bearing clearances. This leads to the unnecessary replacement of very expensive crusher components. Hence it is recommended that lube system maintenance checks, inspections or servicing must include the following.

Monitoring of Lube Oil Temperature

A crusher's normal drain line oil temperature and the normal temperature differential between the supply and drain should be monitored. An abnormal condition warrants an investigation.

Monitoring of Lube Oil Pressure

Some of the things that could cause a lower than normal lube oil pressure are: a low oil flow rate caused by a worn lube oil pump, a faulty main relief valve, or having excessive bearing clearances within the crusher caused by bushing wear. By monitoring lube oil pressure, corrective action can be scheduled and taken based on the abnormal condition.

Inspection of Lube Oil Tank Return Screen

The function of the return screen is to prevent large contaminants from entering the lube oil tank and possibly being drawn into the suction line of the lube pump. Any unusual-looking debris found on this screen warrants closer investigation.

Commitment to Oil Analysis Program

Oil analysis is an indispensable and valuable element of crusher predictive maintenance. An oil analysis program gives you the opportunity to watch the condition of the lubricating oil throughout its service life.

The five main tests completed in the analysis include viscosity, oxidation, water content, particle counts, and machine-wear. An oil analysis report that shows an abnormal condition gives the opportunity to investigate and correct the problem prior to failure.

Maintenance of Air Breathers

Air breathers are commonly neglected components of the lubrication system. The air breather allows atmospheric conditions in the crusher. They should be kept clean. If they are dirty/choked, oil will leak out. If they are removed or damaged, it will breath contaminants and make the lubricating oil dirty.

Recommended ISO Cleanliness Level

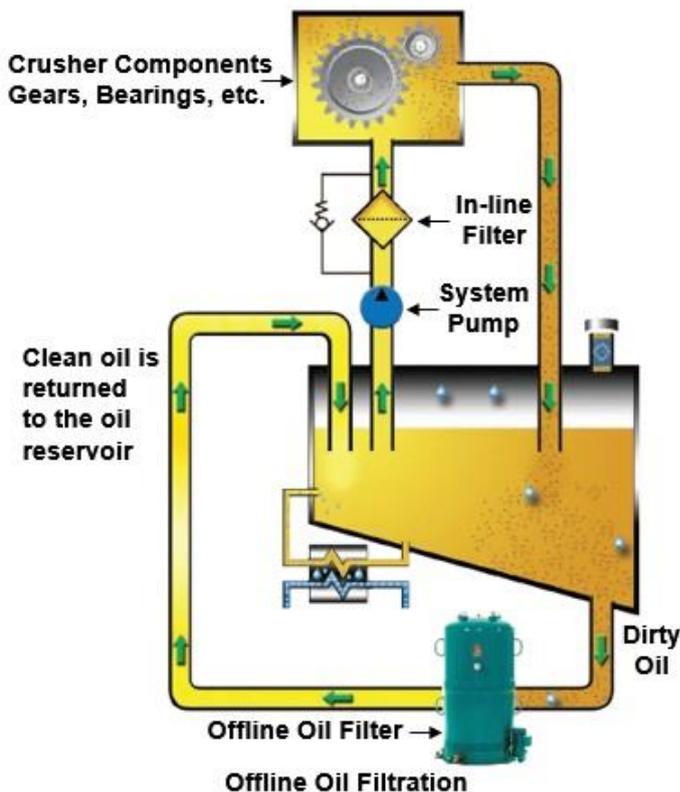
Recommended ISO Cleanliness Level		
ISO Code	Description	Suitable for
14/12/10	Very clean oil	All oil systems
16/14/11	Clean oil	Servo & high pressure hydraulics
17/15/12	Light contaminated oil	Standard hydraulic & lube oil systems
19/17/14	New oil	Medium to low pressure systems
22/20/17	Very contaminated oil	Not suitable for oil systems

Above table shows the recommended ISO cleanliness levels for various systems. For more information on ISO Cleanliness Level, please see "Particle Count and Size Distribution" on page number 57 of the booklet titled "Fundamentals, Selection, Installation and Maintenance of Gearboxes (Gear Drives) - Part 2" uploaded on www.practicalmaintenance.net.

It can be seen that new oil is not suitable for many crusher applications. Most people change oil not because the properties of the oil are lost, but because the oil is dirty! In such cases, by installing an offline oil filtration system and keeping the oil clean, the majority of all problems related to contamination can be prevented.

Offline Oil Filtration

Frequent component and oil changes due to contamination is very expensive, and it often takes several hours of downtime! However, with offline oil filtration, oil can be cleaned and kept clean during operation, significantly reducing wear on parts and oil consumption.



Above figure shows a typical offline oil filtration system. As shown in the figure, compared to a standard in-line filter, offline oil filters have the following advantages.

- 24/7 offline oil filtration
- Huge dirt holding capacity
- Non-system critical (e.g. machinery shutdown is not necessary when changing insert in offline filter system)
- Fine filtration capabilities with the removal of particles, water and oil degradation products in one operation.

For more information on offline oil filtration, please see *Crusher Maintenance - Introducing new standards for crusher uptime with offline oil filtration* by C.C.Jensen A/S (www.cjc.dk).

C.C.Jensen A/S and Metso (www.metso.com) are leading suppliers of offline oil filtration systems.

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