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FUNDAMENTALS OF THE OPERATION AND MAINTENANCE OF CONE CRUSHERS IN THE MINING INDUSTRY

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Abstract: The operation and maintenance of cone crushers in the mining industry represent key aspects of the mineral processing cycle. Cone crushers are used for secondary and tertiary crushing of materials, achieving the optimal particle size required for further processing. Their efficiency depends on the proper selection of operating parameters, the quality of the crushed material, and the technical condition of the machine itself. The maintenance of cone crushers includes regular inspections, lubrication, replacement of wear parts (such as liners and bushings), and timely repair of malfunctions, all of which contribute to extending the machine's service life and reducing downtime. Special attention should be given to cooling and lubrication systems, as their malfunction can cause serious damage to the drive components. In modern mining facilities, automated monitoring and diagnostic systems are increasingly applied, allowing real-time tracking of crusher performance and process optimization. Proper operation and systematic maintenance of cone crushers directly influence productivity, operational safety, and cost reduction, making them an essential element of an efficient mining system.

Keywords: cone crusher, preventive maintenance, mining industry

INTRODUCTION

Primary crushing is the first step in the process of reducing ore to finer sizes. The primary crusher is designed to break the ore into pieces suitable for further processing, whether in a mill or a secondary crusher. The crushed ore is discharged from the hopper located beneath the crusher through a feeder onto a conveyor belt, which transports the ore to the stockpile area.

A number of variables affect the performance of a crusher. Some of the most important factors include:

- Oversized ore pieces – These can lead to reduced throughput and capacity due to material retention inside the crusher.
- Harder ore – Also results in lower throughput because of slower crushing and retention of material.
- Excessive fine content – Fine material should be below 10%; otherwise, it may cause "packing" of the crusher (adhesion of material to the crusher walls), leading to system overload.
- Moisture content in the ore – Excessive moisture may cause ore clumping, reducing material flow and causing potential overloading.
- Abrasiveness of the material – While it does not directly affect throughput, highly abrasive material increases wear on the concave liners and the main shaft mantle.

To achieve a uniform product size, it is necessary to ensure a consistent feed into the crusher. Sudden surges or decreases in feed flow tend to cause crushing issues and result in irregular product size at the crusher outlet. Improper feeding leads to uneven load distribution and reduced efficiency. Overfeeding the crusher decreases crushing effectiveness and increases load, while underfeeding causes greater liner wear due to reduced crushing action.

THEORETICAL BASIS OF CONE CRUSHER OPERATION

The operation of a cone crusher is based on the principle of compressive crushing, where the material is reduced in size between a rotating mantle and a concave liner. It is important to understand the fundamental physical and energy parameters that define the crusher's capacity, required power, and the overall efficiency of the crushing process.

The amount of energy required to break down the material can be estimated using Bond's equation, which relates particle size reduction to energy consumption.

Bond's law of comminution (size reduction) states that the energy required to reduce particle size is proportional to the square root of the ratio between the surface area and the volume of the processed material.

$$E = 10 \cdot W_i \left(\frac{1}{\sqrt{d_2}} - \frac{1}{\sqrt{d_1}} \right)$$

where:

- E = Specific energy required for crushing [kWh/t]
- Wi = Bond Work Index [kWh/t]
- d_1, d_2 = Initial particle diameter [mm]

START-UP OF THE CRUSHER

The crusher must not be started until all downstream equipment is ready to receive the discharged material. All service and auxiliary equipment of the crusher must be in operation before starting the process equipment. The general start-up sequence is as follows:

1. Crusher lubrication systems.
2. Crusher hydraulic system.
3. Air supply for dust seals.
4. Conveyors and belts ready to receive material.
5. Crusher drive motor.
6. The spider bearing lubrication system must be ready to operate once the main shaft begins to rotate.

Starting the crusher from *standby mode* is essentially the same as starting it after a full shutdown, except that in most cases, the auxiliary systems are already in operation. Regardless of the type of start-up, the operator must ensure that the crusher is ready and that no personnel are too close to the equipment. The operator in the central control room usually performs the motor start-up. Their duty is to be in a position to observe all major components of the operating equipment and to report any stoppages or irregularities.

The start-up procedure after shutdown is carried out as follows:

1. Inspection.
2. Selection and activation of the lubrication pump.
3. Verification that the compressed air system is working and that air is available for the crusher's dust seal and spider lubrication system.
4. Checking the height of the main shaft and ensuring it is within the operating limits (the main shaft height should be at least 50 mm above its lowest position to allow for vertical cylinder movement).
5. Start the discharge conveyor.
6. Start the crusher.

Starting the crusher from *standby mode* is performed in the same way as after shutdown; however, the previously described inspection of auxiliary systems is not required. During start-up from standby, auxiliary equipment (lubrication and hydraulic systems) are already operational. Before starting, it is necessary to assess the time elapsed since the last start. Excessive start-ups within a short period can damage the crusher motor. If sufficient time has passed since the previous start, the primary crusher may be started.

In the event of an *unplanned shutdown*, the crusher retains all ore contained in the feed hopper and within the crushing chamber, remaining under load. The hydraulic and lubrication systems continue to operate unless they were the cause of the shutdown. If equipment failure caused the stoppage, a thorough inspection must be performed to ensure the cause has been eliminated. When ore remains inside the crusher, it is often necessary to clean out residual material before restarting the system. The main shaft should be lowered to reduce the motor load during subsequent start-up; failure to do so may result in motor damage.

There are two main objectives in the shutdown procedures:

1. To secure the equipment and prevent potential damage.
2. To ensure efficient and timely restart of the crusher.

FEEDING THE CRUSHER WITH ORE

For the crusher to operate at maximum efficiency, the operators must maintain the following conditions:

1. The ore fed into the crusher should occupy no more than 80% of its capacity.
2. Oversized rocks should be avoided.
3. A rock breaker should be used for oversized rocks.

In the case of excessively large material, a hydraulic hammer should be used to reduce the ore size in order to prevent overloading or shutdowns. In such cases, the crusher maintenance personnel are required to inspect the liners, spider arm shields, and spider cap more frequently to ensure no damage has occurred.

If the feed contains a higher percentage of fine particles, the crushing effect in the lower parts of the chamber and mantle will also increase. Increased bulk density will impose a greater load on the eccentric bushing. Maintenance personnel must therefore carefully monitor the temperature of the eccentric bushing and check for any increase in crusher clearance, especially if the power consumption (in kilowatts) becomes excessive.

Such conditions can lead to accelerated wear of the concave plates and the mantle.

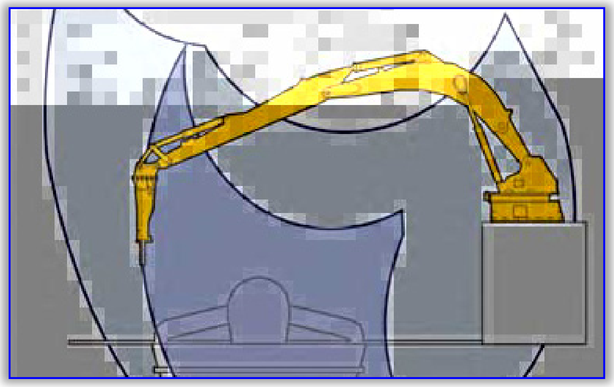

Figure 1. Hydraulic Hammer

FEEDING ANGLES AND THEIR IMPACT ON CRUSHER OPERATION

The angles at which material is fed into the crusher also affect its operation and must be carefully managed. Large ore pieces can become lodged around the spider assembly, potentially requiring breaking with a hydraulic hammer and possibly damaging the bushing seal.

For optimal feeding, material should roll into the crushing chamber rather than being dropped directly onto the top of the spider, as direct impact can cause damage. Using a loader can also lead to damage due to the additional throwing of material, unlike feeding from hoppers, which allows for a more controlled flow.

Material should be fed parallel to the spider arms. If direct feeding of rock into the crusher adversely affects the spider's operation, the spider arms and spider head should be inspected for potential damage

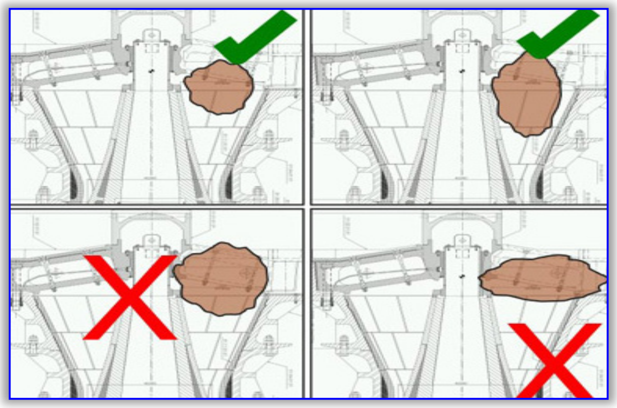

Figure 2. Ore Size at the Crusher Feed Opening

EFFECTS OF UNEVEN CRUSHER FEEDING

Uneven feeding of the crusher can cause several operational issues. The concave liners inside the crushing chamber will wear at different rates because certain parts of the crusher are subjected to higher crushing stresses due to uneven feeding. Crushers fed from single-sided discharge points often exhibit this type of zonal wear. Even if only a few concave liners wear prematurely, it is necessary to replace the entire set and reline the whole crushing chamber.

The crusher operates best with a constant supply and uniform material flow. This process largely depends on the availability of the hoppers and the distance of the transport system. Variable feed rates can reduce efficiency and cause excessive load on the machine.

- Too low feed rate leads to increased wear on the parts.
- Excessive feed rate causes higher stress on components and can lead to overloading.

Situations where ore is fed too slowly or too aggressively should be monitored by tracking the wear rate of the liners and mantle and carefully analyzing lubricating oil. Oil analysis can indicate overheating or the presence of excessive metallic particles, signaling potential operational problems.

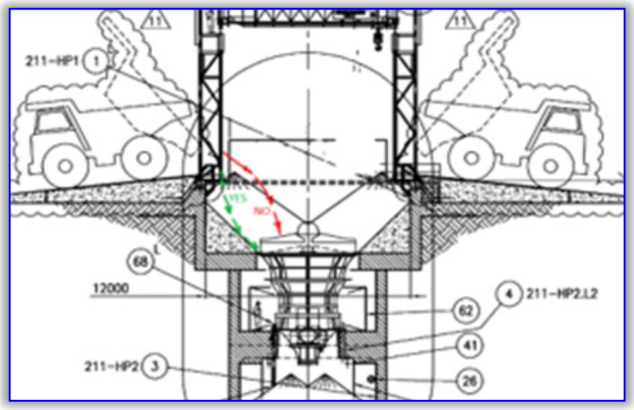

Figure 3. Proper Crusher Feeding

CRUSHER CONTROL MODES

There are three modes of crusher control:

1. Automatic Control
2. Manual Control
3. Local Control via Panels

Automatic control means that the crusher is operated from a control console located in the central control room. The control console is used to start and stop the equipment and to monitor the process. All functional groups are activated with a single action. All safety, operational, and start interlocks must be satisfied for the crusher to start.

Manual control allows individual crusher components, such as motors, valves, etc., to be started and operated independently, provided all safety and start interlocks are satisfied.

Local control allows certain components to be started or stopped from local stations. For example, the primary lubrication system of the crusher and spider, as well as the hydraulic adjustment system, can be operated from local control panels for maintenance purposes.

Interlocks are implemented to ensure specific conditions are met and not exceeded, protecting equipment and ensuring operator safety. There are three types of interlocks:

1. Critical interlocks – Prevent equipment damage. For example, the crusher cannot start without operational auxiliary systems such as lubrication, hydraulic, and air systems.
2. Start interlocks – Required only for machine start-up and do not affect operation once the machine is running.
3. Operational interlocks – Applied only to the process and not the crusher itself; these function only in automatic mode.

Critical and start interlocks apply to all three control modes (automatic, manual, and local). Interlocks are activated if system conditions exceed preset limits. These setpoints may be related to pressure, weight, temperature, rotational speed, flow, or time. During start-up, the crusher cannot be started until all required conditions are met and all setpoints are satisfied.

PREVENTIVE MAINTENANCE OF THE CONE CRUSHER

Planned maintenance is implemented to reduce unplanned shutdowns and ensure that the equipment operates at maximum efficiency at all times. As part of planned maintenance, there are several tasks that must be performed regularly, including:

1. Monitoring wear – tracking the condition of liners, mantles, and other wear-prone components.
2. Lubricant analysis and other condition monitoring activities – checking oil quality, temperature, and contamination levels.
3. Time-based inspections by frequency – daily, weekly, monthly, and yearly checks.
4. Time-based inspections by type – mechanical or electrical inspections.

In addition to inspections, it is important to follow an appropriate preventive maintenance schedule. Preventive maintenance checklists are provided to assist crusher operators and maintenance personnel in operating and maintaining the crusher and its systems. These checklists specify recommended mechanical, lubrication, electrical, and instrumentation inspections.

Checklists can also be used by operators for routine inspections and to report potential or current issues to maintenance personnel. Maintenance forecasts and failure mode effect analysis (FMEA) provide guidance for troubleshooting and maintaining the crusher and its systems. Proper use of these maintenance tools contributes to optimal efficiency and economic service life of the crusher.

Instructions for the replacement and repair of components are provided as a basic set of procedures for replacing and/or repairing critical wear components. The purpose of these procedures is to ensure consistency in replacement and repair efforts across work teams and to provide a foundation for continuous review and improvement.

WEAR MONITORING

Monitoring wear and consumption is a critical aspect of regular preventive maintenance. If properly recorded over time, wear data can be used to build a typical wear profile of the crusher, allowing for more accurate predictions of when the liners and mantle will need replacement. It also helps determine how changes in ore feed conditions affect wear-prone components.

During crushing, the surfaces of the crusher mantle and concave liners deform, reducing the clearance between the inner crusher liners and the mantle. The expansion of manganese steel, from which the liners and mantle are made, generates significant pressure at the joints between the mantle and inner liners, which can lead to cracks in the crusher body.

The wear rate may vary depending on changes in crusher operation and material characteristics. Proper wear monitoring provides valuable information about the crusher and helps increase efficiency while reducing operating costs.

Whenever possible, the mantle and liners should be measured to determine the degree of wear. Comparing measurements taken at installation with current measurements (after use) makes it possible to predict replacement dates based on historical wear patterns. It is also useful to take digital photographs to support visual inspections and record observations.

A wear sensor can provide measurements at specific points on the concave liners. To capture and predict the overall wear pattern of the concave liners, sensor measurements are typically correlated with wear intensity data across the concave surface.

$$Wx_{,,}z = Wi_{(x,y,z)}Ws_{O}/Wi_{O,}$$

where:

- Ws_0= Wear sensor measurements [mm]
- Wi_0 = Corresponding wear intensity results obtained from numerical modeling
- Wi(x,y,z) = Wear intensity at spatial positions where sensors are not installed.

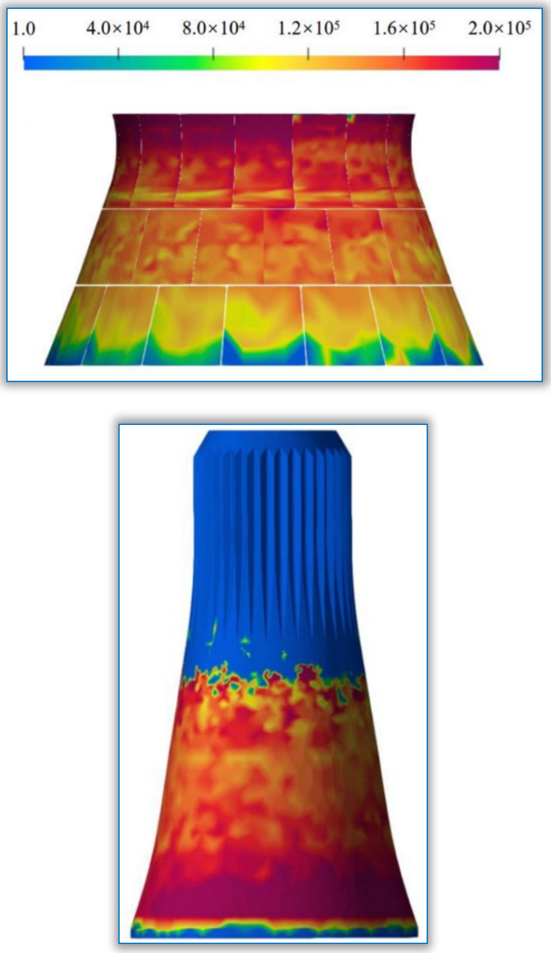

Figure 4. Wear intensity

OIL ANALYSIS

Over time, oil becomes contaminated with dirt particles that enter the system or with wear particles from inside the system. Contamination in the crusher's oil circulation system can originate from several sources and may be short-term or continuous long-term.

The information needed to increase crusher availability is obtained through an oil sampling and contamination monitoring program. Common contaminant particles include silicon dioxide, nickel, silver, aluminum, and sodium. High levels of these particles indicate that dirt has entered the system through damaged seals, leaking pipes or valves, faulty valves and seals on reservoirs, or poor maintenance practices.

Typical wear particles include iron, copper, lead, tin, chromium, and nickel. Oil analysis is used to record and monitor these contaminants to gain insights into the internal condition of the equipment.

Water contamination in oil is also a concern, as it can cause lubrication problems. Oxidized oil loses its lubricating properties. The rate of oxidation doubles for every 7°C above 55°C.

Oxidation can be detected through fluid testing. Highly oxidized oil will appear dark, less slippery, and may emit a burnt smell. Oil tends to accumulate in areas where it is hottest and most turbulent within the system.

REPLACEMENT OF WEAR PARTS

Wear parts are components designed to gradually wear out over time and must be replaced periodically, even if no visible damage is present. Their replacement is planned based on the amount of processed material, operating hours, or wear measurement system data.

Wear parts in cone crushers are subject to constant abrasion due to contact with crushed material. Replacing wear parts is a preventive and planned maintenance activity, unlike repairs performed after a failure has occurred. The goal of replacing wear parts is to maintain operational efficiency, reduce downtime, and extend the service life of key machine components.

Typical wear parts include:
- Main shaft liners
- Concave liners
- Protective liners at the top of the crusher, as well as liners at the bottom
- Locks and wedges for securing the liners

These components are made of highly wear-resistant alloys, such as manganese steel, but exposure to extreme operating conditions still causes gradual material loss and the need for replacement.

Replacement procedure:
1. Stop the crusher and disconnect it from operation.
2. Remove the upper part of the crusher housing.
3. Carefully dismantle worn liners using cranes.
4. Inspect supports, threads, and contact surfaces to prevent damage to new parts.
5. Precisely position new liners; grease or paste may be applied at joints to facilitate later removal.
6. Adjust clearances between the moving and stationary liners according to manufacturer specifications.
7. Test the fully assembled crusher first without load, then with smaller loads, to verify stability and proper seating of the new components.

Replacing wear parts ensures optimal crushing profiles, reduces energy consumption, protects critical crusher components, and prevents unplanned downtime. Best practices include using original parts, maintaining service records, employing sensor-based diagnostics, and training personnel in proper maintenance procedures.

GEAR PAIR ADJUSTMENT

The gear pair is an integral part of the cone crusher's drive system, consisting of:
- Pinion gear – mounted on the eccentric assembly
- Drive gear – mounted on the intermediate shaft

Its function is to efficiently transfer torque from the drive assembly to the crusher's eccentric mechanism, enabling material crushing.

When adjusting the gear pair, it is important to consider:
1. Backlash (lateral clearance) – the space between the back of the drive tooth and the front of the pinion tooth when not under load. This clearance allows for lubrication and thermal expansion.
2. Contact pattern – the contact area between the teeth, which should be evenly distributed to ensure the load is spread over the widest possible surface.
3. Center distance – the spacing between the gear shafts, which must comply with the design specifications and tolerances.

Proper adjustment of the gear pair ensures smooth torque transmission, reduces tooth wear, and prevents excessive stress on the crusher drive system.

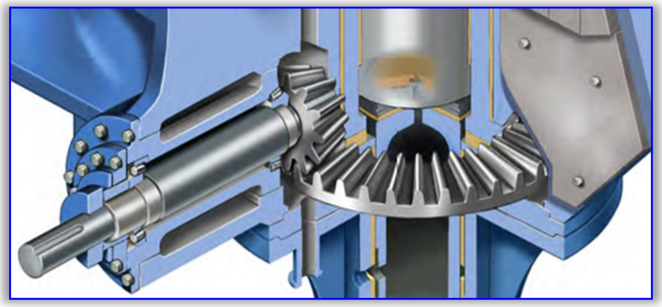

Figure 5. Gear Pair Adjustment

Cone crushers operate under extreme mechanical stress and abrasive conditions, which leads to the gradual degradation of their components. To maintain optimal performance, minimize downtime, and ensure safe operation, regular replacement of wearing parts is essential. These parts do not wear out as quickly as consumables, but their timely replacement is crucial to prevent serious failures and costly downtime.

Wearing parts are components that, over prolonged operation, lose material due to vibration, friction, impact, or corrosion.

The most commonly replaced wear parts include:

- Main shaft
- Bearings of the shaft and eccentric assembly
- Eccentric sleeve
- Slide rings
- Sealing rings
- Drive gears
- Bearing and gear housings
- Hydraulic components

Regular inspection and replacement of these components ensure reliable crusher operation, extended service life, and reduced risk of unexpected breakdowns.

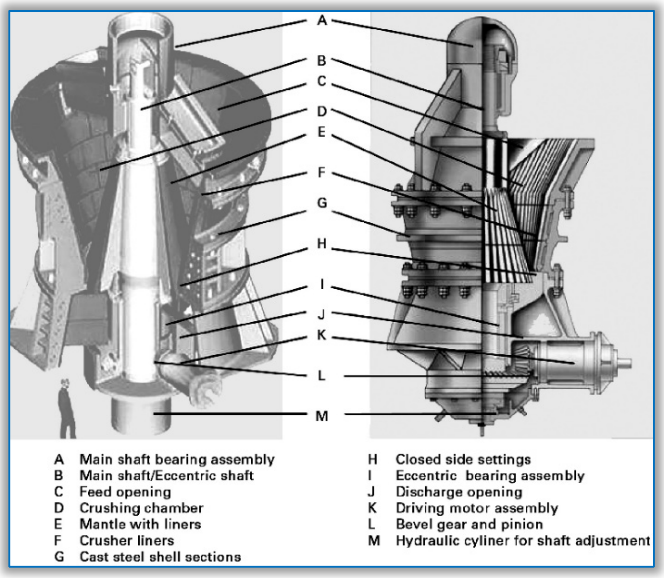

Figure 6. Components of a Cone Crusher

Replacement of wearing parts is usually carried out based on inspection and diagnostics, unlike consumable parts, which are replaced preventively. Typical indicators that replacement is needed include:

- Increased temperature in bearings.
- Elevated noise and vibrations.
- Increased leakage of oil or grease.
- Play or looseness in the shaft assembly.
- Uneven wear of liners.
- Presence of metal particles in oil or grease.
- Excessive clearance between components.

Before any maintenance work, the crusher must be shut down, secured, and completely stopped. The top section of the housing is disassembled, along with any components that obstruct access to the parts being replaced.

REPLACEMENT OF THE MAIN SHIFT

The main shaft is subjected to axial and radial loads and wears slowly over time. However, if cracks, twisting, or excessive clearance occur, the following steps should be taken:

1. Remove the shaft vertically using a hoist.
2. Inspect the conical surfaces, threads, and concave contact points for any damage.
3. Install the new shaft, ensuring it is precisely centered and aligned relative to the eccentric sleeve.
4. Check the clearances with the associated bearings to ensure proper fit and operation.

Proper alignment and clearance verification are critical for safe operation and longevity of the crusher.

Figure 7. Replacement of the Main Shaft

REPLACEMENT OF THE ECCENTRIC BUSH

The eccentric bush enables the eccentric movement of the conical surface. If excessive internal clearance, bearing surface damage, or overheating occurs, replacement of the eccentric bush is required.

During the replacement of tightly fitted components, such as the eccentric bush, small holes are often drilled to reduce pressure between the contact surfaces. These holes allow trapped air or oil—which can create hydraulic pressure during extraction—to escape, thereby reducing frictional forces.

Before installing the new bush, the old one should be measured to ensure it is not deformed. Monitoring the temperature of the components during replacement is also crucial. The eccentric bush is typically cooled to a temperature below ambient to facilitate easier installation, as cooling causes thermal contraction of the metal. This method reduces the risk of mechanical damage to the bearings and the bush itself.

This cooling technique is often combined with slight heating of the bearings to further increase clearance and simplify installation. Cooling of the bush is usually performed using liquid nitrogen or dry ice.

Figure 8. Replacement of the Eccentric Bush

REPLACEMENT OF SLIDING BEARINGS AND BRONZE BUSHINGS

Sliding bearings and bronze bushings serve as load-bearing elements between rotating parts and the stationary housing. Their primary function is to transmit loads with minimal friction. They operate under continuous lubrication.

During replacement, it is crucial to:

— Heat the housing when removing the worn bushing to facilitate extraction.
— Cool the new bushing before installation to allow easier assembly and precise fit.

This thermal adjustment ensures proper seating, reduces the risk of mechanical damage, and maintains optimal alignment for smooth operation.

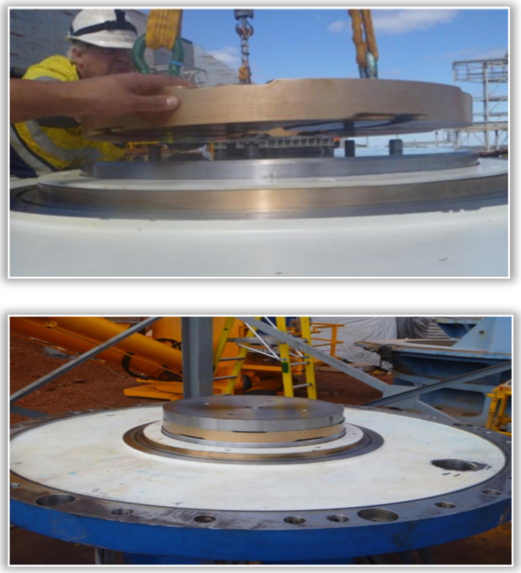

Figure 9. Replacement of Sliding Bearings and Bronze Bushings

REPLACEMENT OF SEALS AND RINGS

Seals and rings are used to prevent leakage of oil and grease, as well as to protect internal components from dust, mud, and particles from the crushed material. They are typically made from rubber, Teflon, or polyurethane, and operate under high pressure and temperature. Over time, seals can allow lubricant to escape and dust to enter the bearings and sleeves, at which point they must be replaced to ensure proper functioning and prevent damage to the crusher components.

REPLACEMENT OF GEARS

The gear transmission is crucial for the operation of a cone crusher, as it transfers power from the motor or gearbox to the eccentric assembly. Over time, gear teeth wear down, leading to improper meshing and increased backlash. When these conditions occur, it is necessary to replace the gears to maintain efficient and safe operation of the crusher.

Figures 10. Gear Replacement

Figures 14 and 15 illustrate the process of replacing the gears of a cone crusher, showing how the old gear is removed and the new one is precisely installed in the drive assembly to ensure proper gear alignment, minimal backlash, and an optimal contact pattern for torque transmission.

REPLACEMENT OF HYDRAULIC SYSTEM COMPONENTS

The hydraulic system in crushers serves multiple key functions, including overload protection, raising and lowering the crusher mantle, and adjusting the crusher’s discharge opening. Replacement involves changing individual components that are worn, damaged, or no longer functioning within tolerance limits. Replacement is required when issues such as loss of system pressure, oil leakage from cylinders, uneven mantle movement, or operational irregularities are detected. Components typically replaced in the hydraulic system include: hydraulic cylinders, valves and manifolds, pumps, hydraulic pipes, and the hydraulic reservoir.

INSULATION OF MACHINE COMPONENTS

In the operation of machinery in the mining industry, where working conditions involve high humidity, temperatures, dust, vibrations, and impact loads, insulation of machine components plays a key role in preserving functionality, extending service life, and reducing the risk of failures.

Insulation does not only mean thermal insulation, but also protection against external factors, electrical insulation, and mechanical protection of vital machine parts.

Insulation also refers to preventing direct contact of personnel with hazardous parts and zones of the crusher during operation. The crusher must be enclosed with physical barriers, clearly marking danger zones. Access to service points should be controlled, with safety locks that can only be unlocked when the crusher is at a standstill.

During maintenance, power must be switched off and the system locked to prevent accidental start-up. Modern systems allow remote control of crushers, reducing the need for operators to be physically present near hazardous areas.

CONCLUSION

Cone crushers represent one of the most efficient and important types of crushers in the modern mining industry. Their structural design, mode of operation, and integrated systems enable high reliability, long service life, and easy maintenance, but only under proper operation and timely servicing.

Considering that the entire production process relies on their uninterrupted operation, any downtime of the crusher directly leads to a halt of the entire production line. The consequences include loss of working hours, reduced capacity, and interruptions in the supply to subsequent process stages, and direct financial losses. Therefore, continuous, stable, and reliable operation of the crusher is crucial for the productivity and economic efficiency of a mining and processing plant.

The operation of a cone crusher depends not only on the quality of its design but also on qualified personnel, good technical practices, and regular monitoring of all subsystems. An integrated approach to the mechanical, hydraulic, and lubrication aspects of the crusher forms the foundation for stable, safe, and long-term operation under the most demanding industrial conditions.

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