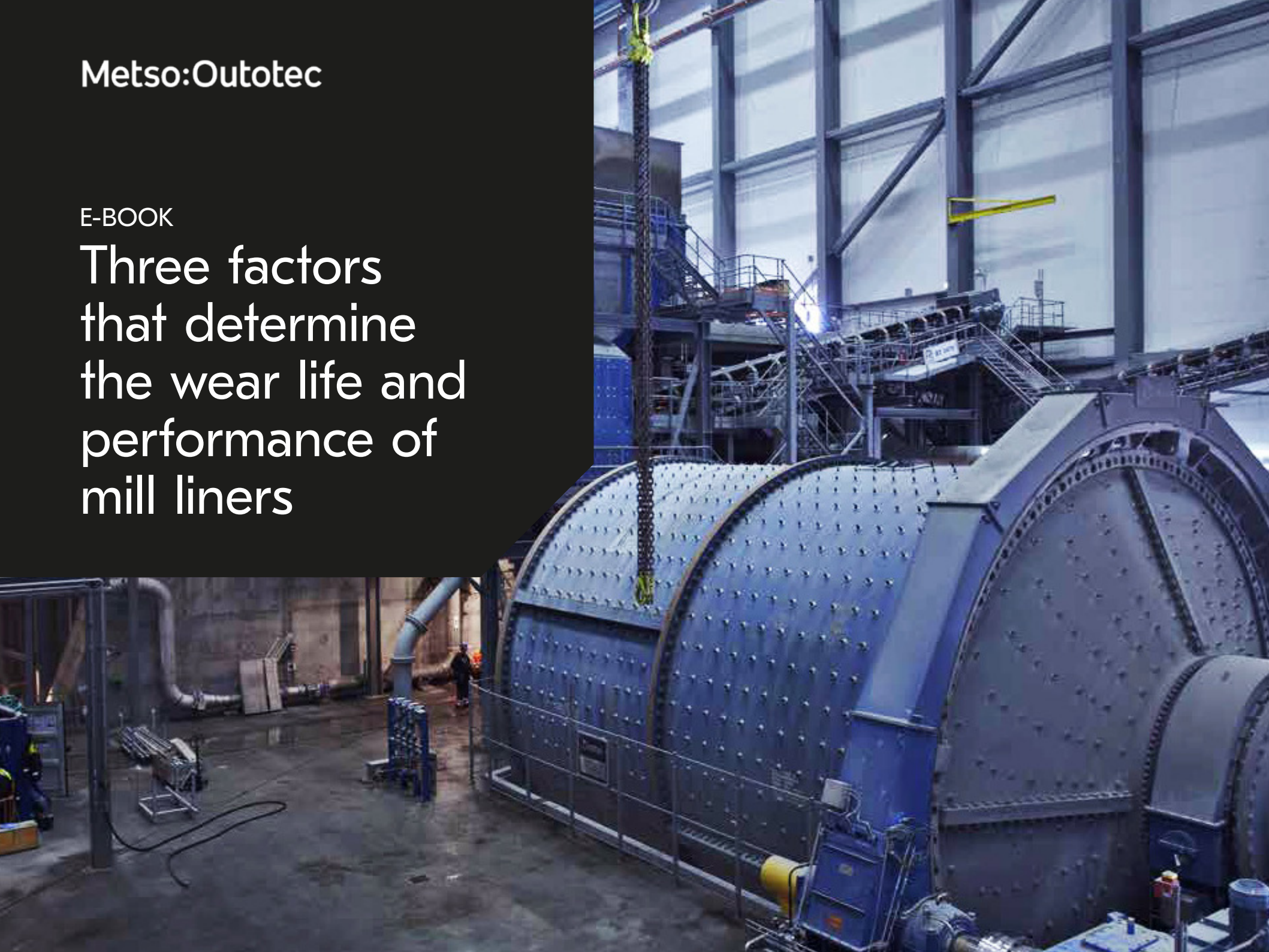


Metso:Outotec

E-BOOK

Three factors that determine the wear life and performance of mill liners



Introduction

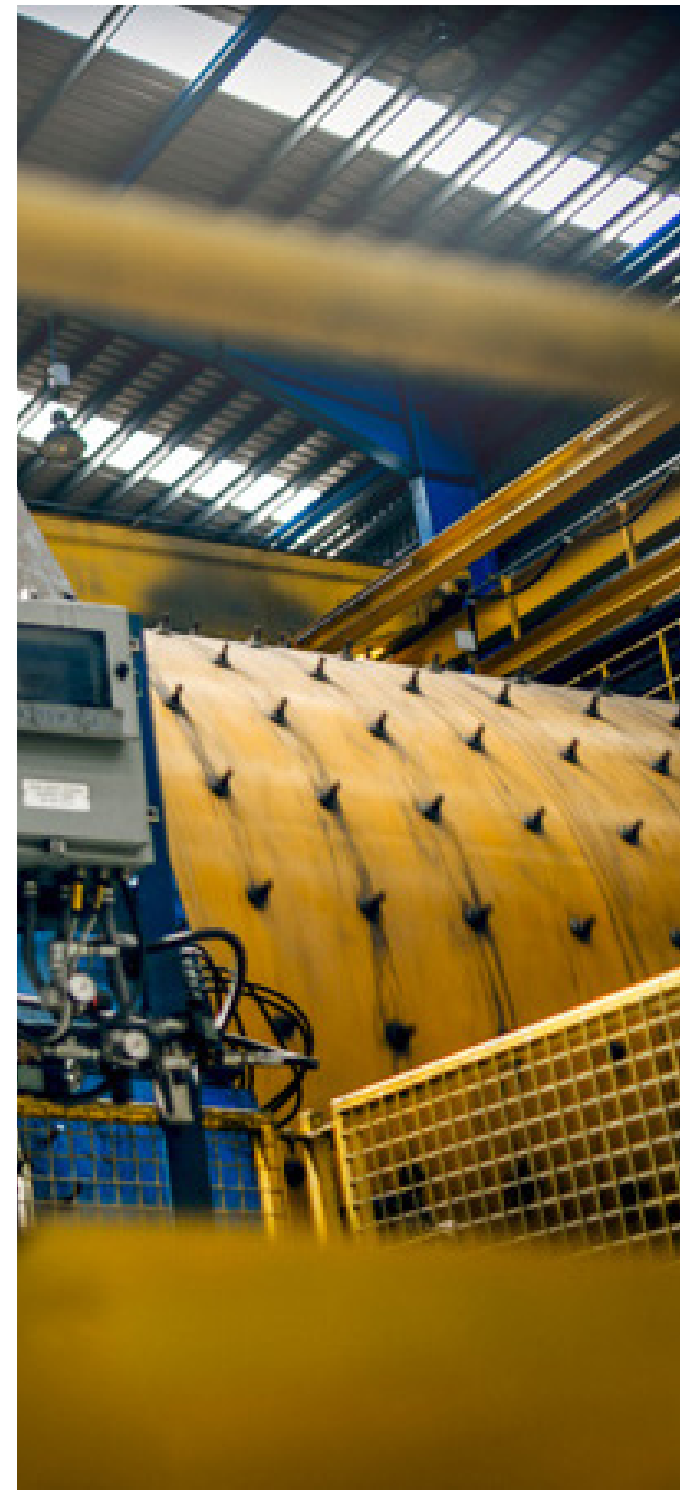
Grinding is one of the key process stages in a mining concentrator. The purpose of comminution is to reduce the size of the ore. The two predominant methods are crushing and grinding.

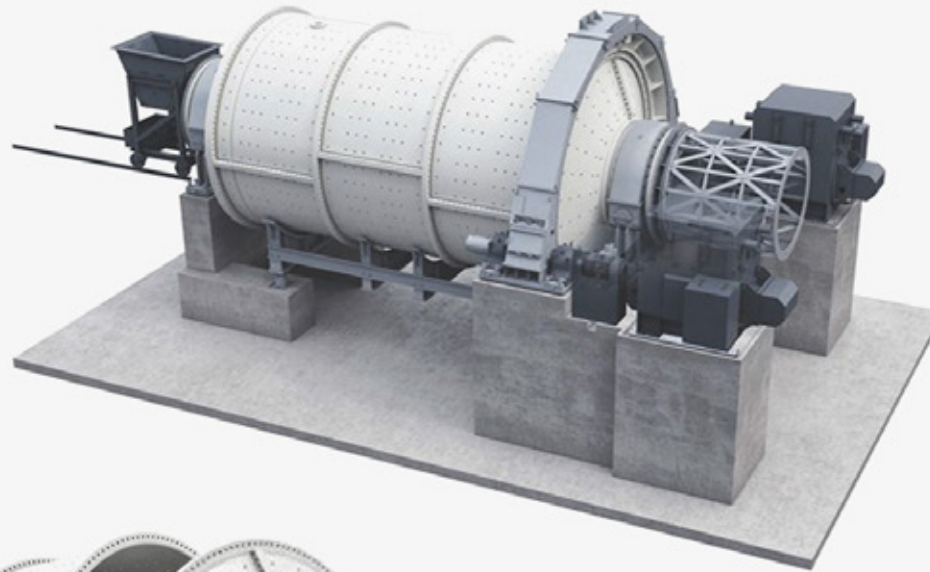
Crushing, the first process step after blasting in the mine, is used to break up coarser ore. This is typically followed by grinding, which reduces the size of the ore to be further refined, and the valuable particles separated. Or, in the case of industrial minerals, used as is.

Grinding is often done in steps: a primary mill grinds the large-sized ore and then a secondary mill grinds the ore from a small size to the desired size. The breakage mechanisms that mills use are impact (for coarse grinding), and attrition and abrasion (for finer sizes). These forces not only grind the rock, but they also subject the mill to substantial wear and tear. Applying these mechanisms in a controlled and efficient way reduces the size of the ore efficiently while protecting the mill.

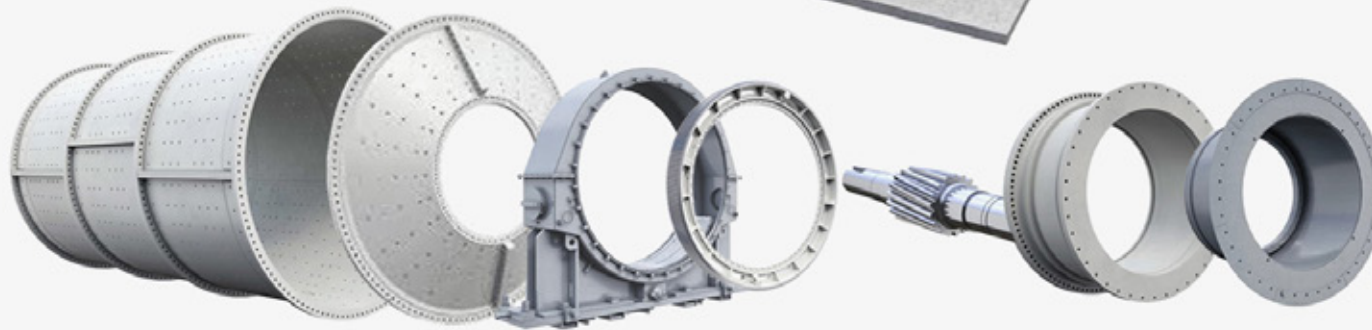


When properly operated and maintained, a grinding mill with an optimized lining design can produce the desired quantities and ore particle-size without damaging the mill itself.





The grinding mill is the heart of a mining concentrator.



This eBook describes the factors that determine wear life and performance of mill liners and how to keep your mill running at optimal performance.

A horizontal mill is the most common type and consists of a cylindrical shell, which is driven by a motor, a pinion shaft, and a gear, and it rotates on bearings. The bigger modern mills have gearless wrap-around motors. Big ore particles and grinding media are fed into the mill body, which rotates and creates a cascading effect.

This results in ore breakage, but it also impacts the mill. A replaceable mill lining protects the mill from wear by absorbing impacts, stress, and other forces. Liners can be made of rubber, metal castings, or a combination of the two.



Choice of mill lining

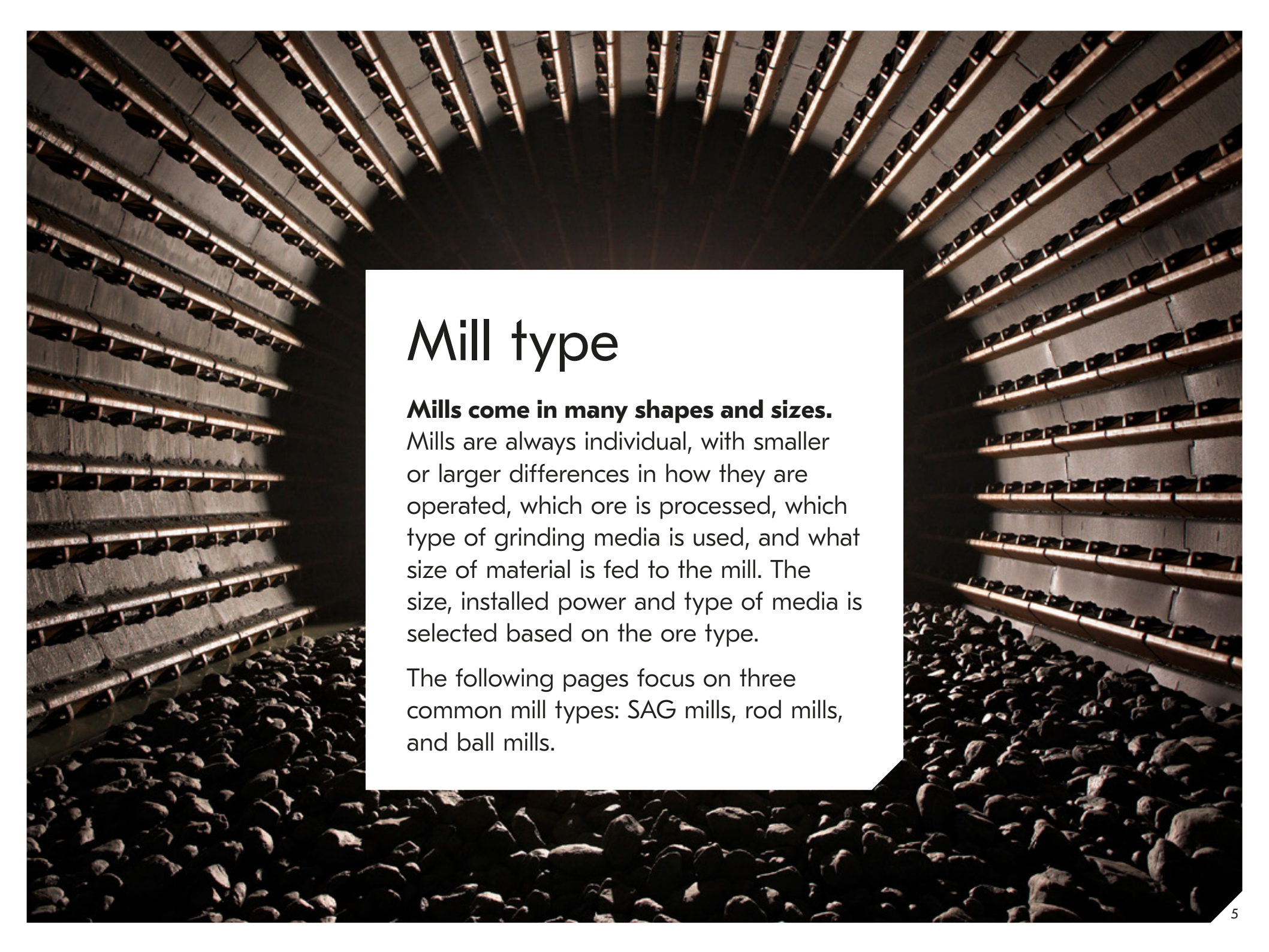
A mill lining should be optimized to suit each specific mill. Choosing an appropriate type of lining and design in terms of lining material, thickness and profile is vital for optimizing mill throughput and total grinding costs.

Choosing the correct liner material and design ensures that the mill itself is well protected. It also ensures that maintenance is easy and predictable and mill uptime is maximized. The wrong choice could cause premature wear or liner breakage, which in turn could result in wear to the mill body and unplanned maintenance.

An equally important aspect is grinding performance. A correctly designed lining profile transfers the mill's rotating motion to the ore and media, hence promoting an ideal charge motion in the mill. Different applications require different profiles to provide enough impact and attrition to achieve the desired grinding result.

The following pages feature several factors that must be evaluated to determine the best possible design and material for the lining.

A good lining should wear out, not fall out!



Mill type

Mills come in many shapes and sizes.

Mills are always individual, with smaller or larger differences in how they are operated, which ore is processed, which type of grinding media is used, and what size of material is fed to the mill. The size, installed power and type of media is selected based on the ore type.

The following pages focus on three common mill types: SAG mills, rod mills, and ball mills.

Liner profile

Mills require different liner profiles and designs depending on mill size, speed, charge, charge level, type, size of grinding media, expected service life, and — of course — ore size and properties, such as hardness and abrasiveness.

SAG mill

A SAG mill is usually a primary mill for grinding coarse ore directly from the crushed stockpile. Such application requires a more **aggressive liner profile with high lifter bars and relatively thin intermediate plates**. This provides plenty of traction and lifts the material and media high to ensure enough impact energy to break big lumps of ore.

Rod mill

A rod mill is also a primary mill but with a smaller ore feed size. Grinding is achieved by heavy steel rods tumbling and rolling over each other, breaking the ore particles caught between the rods, so there is no need for an aggressive profile. **The lining should provide enough lift to turn the charge over without causing any actual trajectory.** The lining profile is often of a shiplap or smooth wave type.

Ball mill

Most ball mills, even in primary applications, have a finer ore feed size; this requires some impact but not enough to increase the media consumption or even break the liners. Typically, a ball mill lining has a **more rounded profile, often like a sine wave, and the size of the waves is selected based on the size of grinding media used**. The idea is to achieve a bit of trajectory while ensuring that the charge is compact enough to give high shear energy.



Liner material



Like the liner profile, the liner material is selected to suit the specific mill and process. Aspects to consider include ore abrasiveness, media size, expected impact force on the liner, chemical environment, and temperature. Other aspects to be factored into the equation are liner weight, method of installation, and user preferences.

SAG mill

A SAG mill is almost always a high-impact application. Hence, it is wise to use **tough, impact-resistant materials that are somewhat softer but less brittle** to avoid cracking, chipping, or breaking.

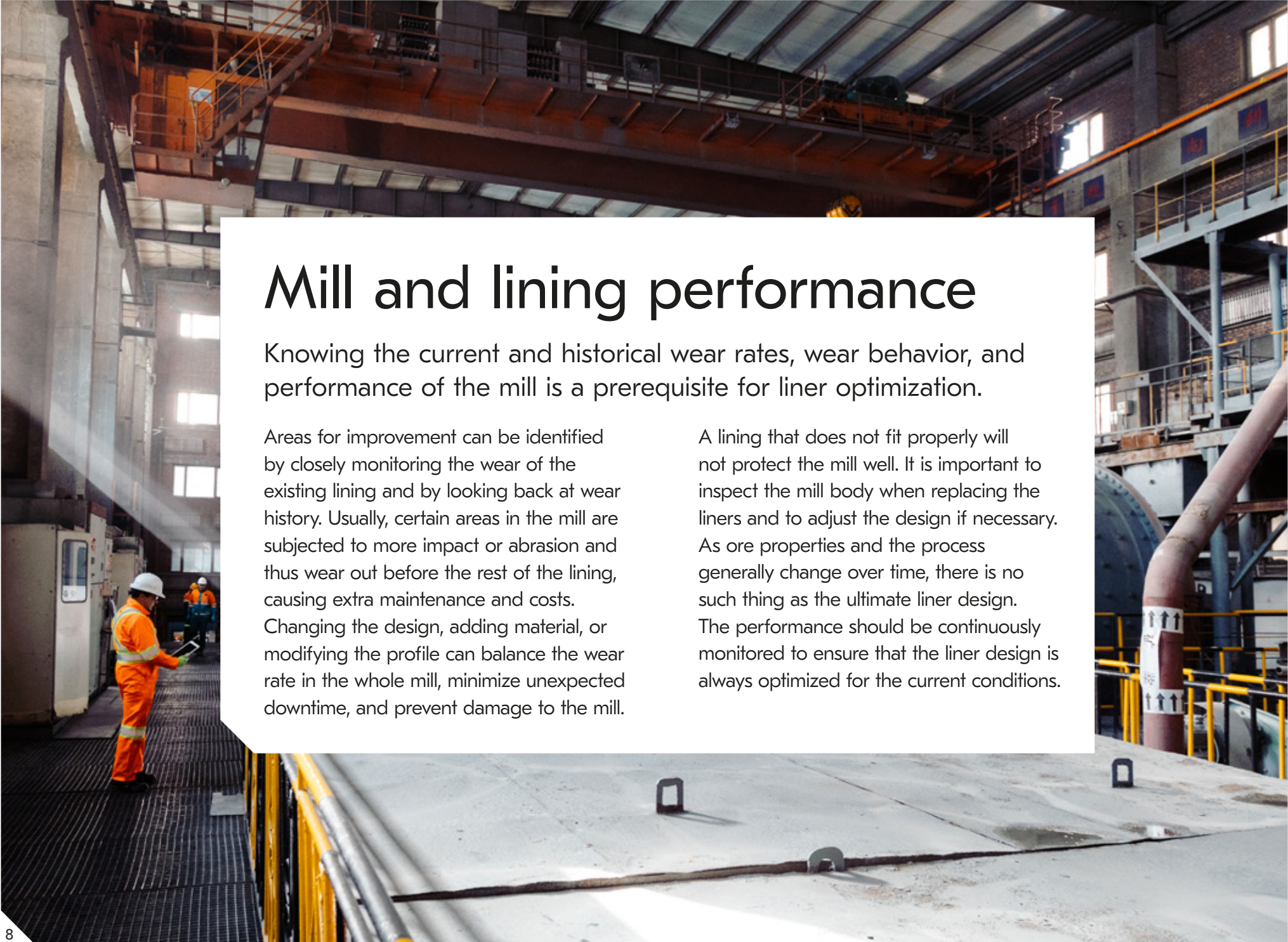
Rubber/steel composite liners are often a good choice as is the range of more impact-resistant cast alloys.

Rod mill

As there should be very little direct impact in rod mills, thanks to the rolling charge motion, and as rod mills are rarely bigger than 4 meters in diameter, it is possible to use **harder, more brittle cast alloys such as cast high-chrome metal liners or composite rubber liners** with hard cast inserts on the mill shell. However, the rods can move sideways and act as battering rams on the heads, so the head liners should always be fully metallic, preferably of a more impact-resistant alloy.

Ball mill

In properly designed and operated overflow ball mills, the shell is protected by the ore and media charge; there should not be any direct media-to-liner impact. **The hardest, most wear-resistant alloys can be used.** Some ball mills are equipped with grate discharge systems. They require softer alloys, as it is difficult to ensure that the charge level remains high, and the liners can be exposed to impact, causing cracking. Rubber or composite liners are also commonly used in ball mills and perform well even in the biggest ball mills, thanks to their shock-absorbing properties.



Mill and lining performance

Knowing the current and historical wear rates, wear behavior, and performance of the mill is a prerequisite for liner optimization.

Areas for improvement can be identified by closely monitoring the wear of the existing lining and by looking back at wear history. Usually, certain areas in the mill are subjected to more impact or abrasion and thus wear out before the rest of the lining, causing extra maintenance and costs. Changing the design, adding material, or modifying the profile can balance the wear rate in the whole mill, minimize unexpected downtime, and prevent damage to the mill.

A lining that does not fit properly will not protect the mill well. It is important to inspect the mill body when replacing the liners and to adjust the design if necessary. As ore properties and the process generally change over time, there is no such thing as the ultimate liner design. The performance should be continuously monitored to ensure that the liner design is always optimized for the current conditions.

Predicting liner performance

It has traditionally been difficult to know exactly what goes on inside a grinding mill during operation. The latest developments in 3D discrete element modeling (DEM) simulations have changed that. An advanced wear-progression model can predict the performance of a lining with extreme accuracy, and the model can be calibrated using wear-monitoring data to further optimize the liner design.

Simulations



The liner designs can be tested to ensure that they not only wear in a reliable and predictable way, but also contribute to the mill's grinding efficiency, save energy, and maximize throughput.

Generic DEM software is available on the market, but the best results can be obtained with customized simulation software that uses specific algorithms created on the basis of grinding process know-how. This allows for the identification of potential problem areas and solutions already at the design stage.

Shell simulation

A program that uses the actual lining design and real process input to simulate the charge motion and the impact and shear energy occurring inside the mill. Alternative lining designs (shape, dimensions, volume of materials) can be compared to find the optimal trajectory for each individual mill and process conditions.

Wear simulation

The wear-progression model predicts the performance of the lining reliably and accurately and can be calibrated using wear-monitoring data (3D scanning, wear history) to further optimize the liner design. This output can also be used to calibrate 3D DEM models to simulate the wear progression of new designs.

Discharge end simulation

A tool to study the flow and forces inside a mill discharge system. Enables the detection of pinch points, reasons for back flow or recirculation, and identification of areas where shear forces are high enough to potentially cause excessive wear. The discharge system has a high potential for optimization and this tool helps to find the best design for each mill.

A photograph of two workers in a grinding mill. They are wearing hard hats, safety glasses, and work clothes. One worker is holding a dark, rounded object, likely a grinding media ball. The background shows the interior of a large mill with a circular opening and a bright light source. The number '2.' is overlaid in the top left corner.

2.

Regular mill inspections

What you can't see can hurt your mill. A clear understanding of the complete health of your mill can improve maintenance planning and avoid unwanted downtime and costs.

A stable process, a good and up-to-date lining design, and a well-established inspection plan significantly reduce the risk of permanent damage to the equipment.

The environment in a grinding mill is tough. It is subjected to huge forces, and it is filled with water, hard ore, and grinding media. Sometimes the temperature is high, the pH values are high or low, and there are process chemicals and chlorides present in the process. For various reasons, mills are sometimes operated outside the normal operating parameters. This can subject the mill lining and the mill itself to higher stress, impact, and corrosion.

Mills and liners should be regularly inspected using the proper tools and methods to avoid problems. The intervals vary from mill to mill. Frequent inspections are important when a new mill is starting operations, after a major change in design, or when the mill has been operated outside the normal parameters; then a suitable and safe schedule to follow can be determined. Most mills are typically inspected 4-6 times a year, but a shorter life cycle of the lining can require additional inspections.



What to look for during a mill inspection?

All mills are individual and some liner components may be more critical than others. Regular inspections make it possible to identify these critical components and make future inspections easier.

Inside the mill:

- Remaining profile and thickness of the liner
- Uneven wear of adjacent liners
- Status of grate plates
- Cracked or broken liners
- Impact marks or deformed liners
- Uneven spacing or severe packing between liners
- Charge level and foreign objects in the mill (tramp metal, pieces of crusher plates, excavator teeth etc.).
- During a mill relining, the rubber backing of the old liners and the inside of the actual mill body should be inspected and repaired if necessary.

Outside the mill:

- Leaking or broken liner bolts
- Broken mill flange bolts
- Cracks, or dents in the mill body
- Leaking man doors.



How to inspect a mill?

There are many methods to inspecting a mill lining. The method used depends on the requirements and the availability of measuring equipment. While in many cases simpler methods will suffice, **a 3D scan is the only way to capture the entire mill lining geometry.**

The scanner will capture everything above the charge. The 3D scan cloud can be further analyzed and used for very comprehensive studies of the liner profile and a comparison with the original liner geometry.

Visual inspections are also important, as the human eye can notice things that the scanner may miss, such as small cracks, evidence of heavy impact, the shape of deformations, and things that are not in the scanner's line of sight like attachments, the interior of the discharge system, and trunnion liners.

Measuring reference thicknesses of a few liners will help to validate the analysis of the scan cloud. Taking pictures to further detail and document interesting observations is always recommended. The points of interest should be marked on the photos for easy identification.

It is also important to gather data and information about the process and the mill's general performance.

All of this information can then be used to better predict the remaining wear life of the liners, to develop and optimize the next generation of liners, to extend the service life to fit the maintenance cycles, to minimize weight and cost, and to increase the overall performance of the mill.



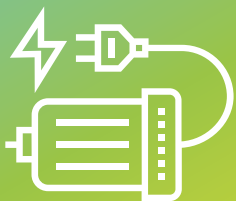
Mill operation

Choosing the design and material of an optimized mill lining is always based on known facts about the way the mill is or will be operated. Changes in operation — whether small and slow over a long period or major changes — must be identified to ensure the lining will perform well under the changed conditions. Failing to identify the changes can lead to premature wear or even unplanned downtime.

It is not unusual for operating parameters to change over time. In a new mine, the surface ore is soft and easy to grind but gradually gets harder the deeper the mine goes. Changes in the process are also common. Set points are changed, equipment is replaced, or new equipment is added, all of which can lead to a different way to operate the mill.

Changes in production rates are not uncommon and operators try to maximize utilization of their existing equipment. These changes could necessitate a mill liner redesign; therefore, it is recommended to validate the process data on a regular basis and whenever there is a known change in the process.

Some of the most important parameters to monitor are listed on the following page.



Energy required to grind the ore

It is important to monitor changes in the Work Index (WI), which specifies the typical amount of energy needed to grind the ore under certain conditions. The actual specific energy consumption per ton varies depending on the hardness and toughness of the ore, and it can also indicate efficiency.



Abrasion index

The abrasion index indicates how abrasive a particular ore is. A change to a higher index value means a higher liner wear-rate. The abrasiveness of the ore depends on the hardness of the ore, the amount of silica in the ore, and the shape of the crushed particles when ground.



Throughput

If throughput increases, the wear rate per hour increases, since the liners are subjected to more big and sharp ore particles. A higher throughput might not always cause a higher wear rate per ground ton or a higher cost per ton, but you will most likely have to replace the liner earlier than planned.



Particle-size distribution

Coarser ore generally means higher wear. A bigger feed size leads to shorter mill liner wear-life and a poor ore-size distribution can cause loss of grinding efficiency. The size and composition of the grinding media charge also depends on the size distribution.



Mill filling or total charge level

The grinding charge (the ore and the media) protects the liners from direct impact. If the levels are too low, the wear rate will increase. If they are too high, the mill may not grind efficiently.



Mill speed

The profile of the lining is selected based on a balance between mill speed and charge level. If the speed increases, a higher charge trajectory causes more impact on the liners, potentially increasing the consumption of liners and grinding media. Extreme impacts can cause the liners to break. A higher speed also means higher energy consumption, so it is desirable to operate at the lowest possible speed that provides the ideal charge motion.

As described in this eBook, there are many factors that can influence the wear life and performance of mill liners and, ultimately, your mill.

Choosing the correct liner profile and material based on validated information and historical data, doing regular inspections to monitor liner performance and mill status, and ensuring the stability of the process can extend the service life of your equipment. It also maximizes mill uptime by avoiding unplanned maintenance, and it helps to ensure that planned maintenance is performed efficiently, and spare parts are delivered on time. To summarize: it helps you to get the most out of your equipment — and for a long time!

Metso Outotec offers high-quality grinding equipment and highly optimized liners. We can also provide various expertise services, including site inspections. We do comprehensive process audits designed to assess your requirements based on your specific process and objectives.

Contact us to take your grinding process to the next level:
mogroup.com/mill-liners

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