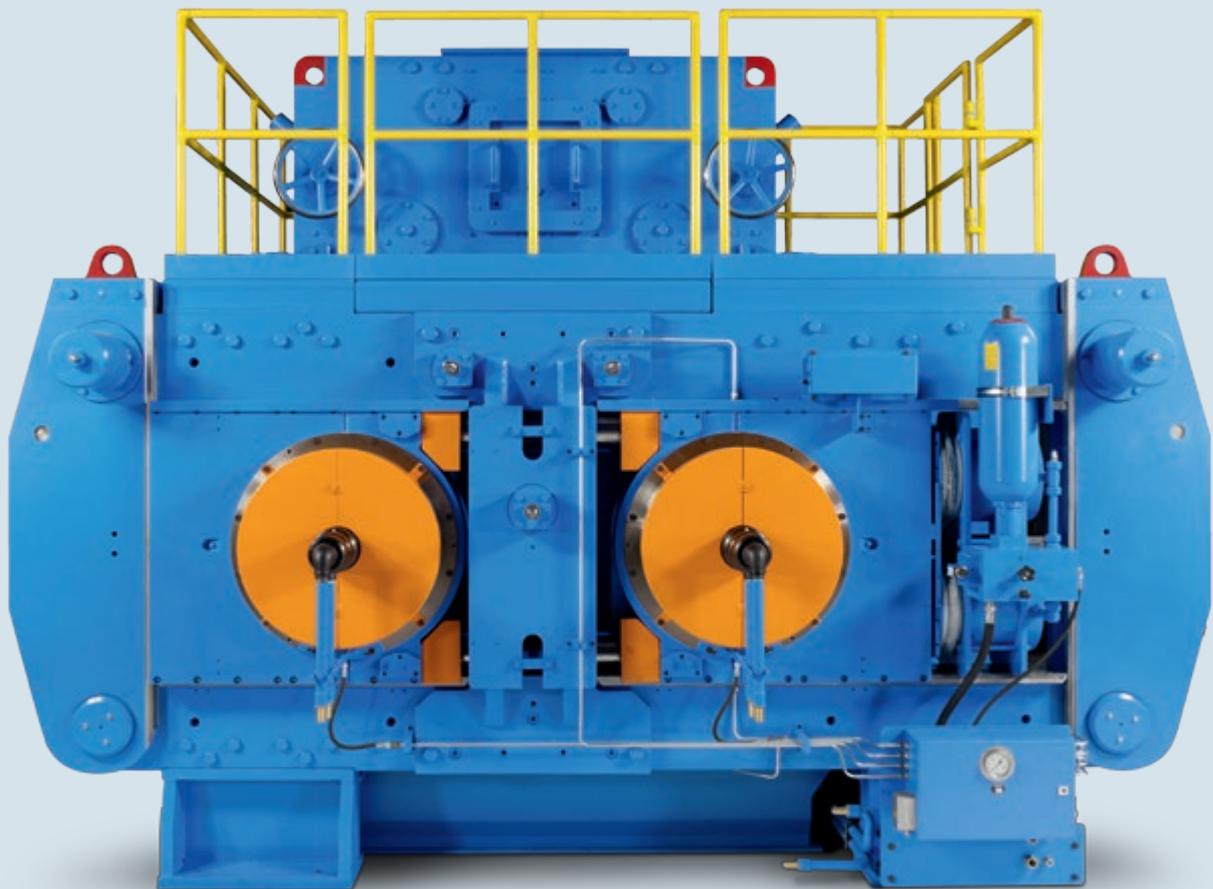


High-Pressure Grinding

Specialists in High-Pressure Comminution



Köppern

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Köppern – Specialists
in engineering,
manufacturing and
technical services for
roll presses and
HPGRs worldwide.





Specialists in High-Pressure Comminution

Founded in 1898 and headquartered with its main manufacturing facilities in Hattingen, Germany, Maschinenfabrik Köppern remains a family-run enterprise reflecting its traditional values of technology leadership, highly dependable manufacturing quality and a unique regard for the individual needs of its customers. Köppern's worldwide network of subsidiaries, including manufacturing plants and engineering offices, provides customer-focused service on all continents.

Köppern's history is linked to the utilization of roll presses for briquetting hard coal. Over the years, the briquetting process has been extended to the agglomeration process, which is relevant for a variety of materials including refractories, fertilizers, chemical products, metallurgical fines and direct reduced iron.

Further progress came with the introduction of high-pressure comminution in the mid-1980s. This innovative application for the cement and minerals processing industries required a completely new approach to the question of wear protection for roll presses. To meet the new requirements, Köppern developed unique wear protection systems patented under the HEXADUR® brand. Moving to a new production facility in 2002 has enabled Köppern to manufacture even the very largest roll presses required by the industry.

These technological advances have resulted in a significant drop in machine time-outs caused by wear and repairs. For Köppern's customers, the resulting increase in productivity, coupled with a parallel reduction in energy consumption, enables them to compete more successfully in their own market segments.

If you feel that this can be of interest to your company, we would invite you to read on in order to gain more insight into our specialist roll press and HPGR solutions.

The Management Team

The Köppern Chronicle – Focusing on Comminution

- 1898**
Wilhelm Köppern acquires the "Berninghaus-Hütte" in Hattingen, Germany
- 1913**
First exports to England
- 1926**
The company is renamed "Maschinenfabrik Köppern & Co. KG"
- 1954 – 1985**
Further development of roll presses for briquetting and compaction. Addition of new markets
- 1987**
Köppern develops roll presses for the comminution of cement clinker
- 1998**
Development and successful application of the HEXADUR® wear protection system for HPGR surfaces
- 2004**
Development of C-Frame for easier maintenance
- 2005**
First application of Köppern HPGR for goldiferous and diamondiferous ores
- 2006**
HEXADUR® HPGR application in a magnetite concentrator
- 2009**
Redevelopment of the large mill line

Research and Development



Test work materials for grinding: cement clinker, iron ore, blue lead, diamond ore

Value Enhancement

Köppern has a longstanding tradition of close co-operation with high-ranking universities and research organizations, including:

- » the Bergakademie Freiberg, Germany – this technical university assists Köppern in process development research for briquetting, compaction, high-pressure comminution and wear behavior of materials
- » the Ruhr University, Bochum, Germany is mainly involved in wear materials research and development as well as FE calculations for machine parts
- » the RWTH Technical University, Aachen, Germany assists in the field of wear testing of materials
- » the University of British Columbia, Canada is mainly involved in high-pressure comminution research and development.

High-pressure comminution process research is a fundamental element of process design in the mining industry. Köppern has several semi-industrial sized pilot-plant facilities currently installed at the Bergakademie Freiberg, the University of British Columbia and also at research institutions such as Ammtec in Australia and Mintec in South Africa.



Improved Cost-Efficiency

High-pressure grinding roll presses (HPGRs) are emerging as an important comminution technology in the minerals processing industry. The technology has found its key application in the liberation of diamonds and also in primary comminution. Compared with conventional grinding, the HPGR process consumes significantly less energy, which in turn leads to a reduction in operational costs coupled with a positive environmental effect.

Comminution



Cement clinker in three different stages of production: before grinding, flake (the product of HPGR) and the ground product

Energy-Saving Advanced Technology

The energy-efficiency of crushing and grinding processes is becoming an increasingly important issue for both the cement and minerals processing industries. Approximately 37% of electrical energy worldwide is used by industrial sectors, of which the mining industry alone consumes approximately 4%. More than half of this is used in crushing and grinding operations.

Because the softer “paydirt” is running short, the minerals industry is reaching for harder ores. The goods content in the ores is diminishing, placing more emphasis on the importance of energy-efficient crushing and grinding.

In the mid-20th century, roll presses began to be used in a variety of additional industries. These initial applications mainly centered on agglomeration processes in relation to the briquetting and compacting of fine bulk materials. The work of Professor Schönert during the 1970s led to the development of the high-pressure comminution process. One of the main benefits of this process is a reduction in energy requirements for the comminution process when compared with conventional crushing and grinding methods. The application of roll press technology to high-pressure comminution achieved throughput rates that were equal to or better than those produced with conventional equipment.

In addition, there are potential benefits to downstream processes, such as improved kinetics in leaching and flotation due to the unique particle fracture propagation induced by this technology. HPGR circuits, where applicable, offer several potential advantages in comparison to equivalent semi-autogenous grinding circuits, for example lower specific energy consumption, reduced grinding media consumption, smaller machine footprint, shorter equipment lead times, higher machine availability.

This new application gained momentum in the mid-80s, when the first roll presses were installed for the comminution of raw materials for the cement industry – and later also for diamond liberation in the diamond mining industry. Comminution technology has gained popularity steadily since then and today HPGR machines are regarded as state-of-the-art technology in the cement and diamond industries. And the list of applications continues to expand to such industries as iron ore, copper, gold and many more.



Materials currently treated in High-Pressure Grinding Rolls

- » Cement clinker
- » Slag
- » Limestone
- » Fine ore/pellet feed
- » Kimberlite
- » Iron ore
- » Coal
- » Molybdenum ore
- » Copper ore
- » Gold ore
- » Basic ceramic materials
- » ...

Increasing costs of electrical energy coupled with the worldwide initiative to reduce CO₂ emissions means that this energy-efficient technology will become indispensable in a wide spectrum of minerals processing applications.

The use of HPGR machines in minerals processing plants requires special attention to these issues:

- » Pilot plant HPGR tests are necessary to evaluate the ore performance and to assess process and energy efficiency
- » Careful assessment of ore body and definition of best/worst-case scenarios
- » HPGR feed preparation is of paramount importance in order to extract the maximum benefit from the technology
- » The treatment of HPGR products and the handling of process recycle materials need to be evaluated

With its HPGR pilot-plant locations and specialist staff spread strategically throughout the world, Köppern is in a unique position to advise and assist customers in assessing the suitability of HPGR for their mining process requirements. The benefits of HPGR in comparison to conventional crushing/grinding circuits will soon become evident:

- » Economic advantages
- » Short-term availability of equipment
- » Shorter installation commissioning time
- » Steady process throughput and the ability to adjust process parameters to changing ore properties
- » No pebble crushing
- » Reliable test work and scale-up

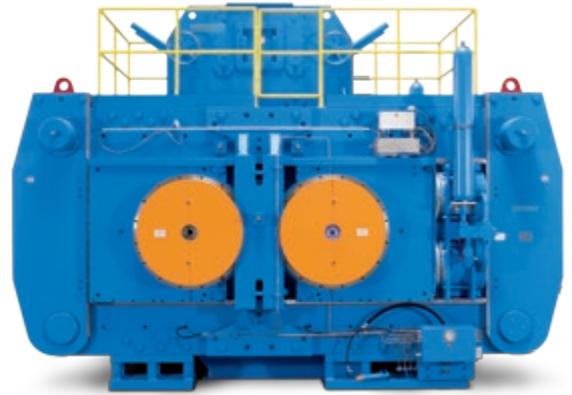


Test Work

Besides its testing facilities, Köppern maintains independent pilot-plant facilities that are available for flowsheet development. In addition, semi-industrial units are available for temporary installation.

High-Pressure Grinding Rolls

Machine type: 750/15-1,300
Application: Clinker grinding
Location: India



Machine Design

The machine is centered around two counter-rotating rolls. These are supported in the frame by spherical roll bearings, which are inherently self-aligning and very robust. In addition to radial loads, the bearings are able to accommodate axial loads acting in both directions, making them insensitive to shaft-skewing during operation.

One of the machine rolls, called the fixed roll, is supported directly on the press frame, whilst the other roll – called floating roll – is supported in the frame by a hydro-pneumatic spring system that allows for horizontal movement of the roll during operation. This movement of the floating roll constitutes the basic principle of high-pressure comminution with a roll press. The extent of the roll movement (roll gap) is a function of the pressing force generated by the hydraulic system in relation to the reaction forces exerted by the processed material. This design feature guarantees that, during the comminution process, all the feed material passes through the roll gap under the same process conditions, thus ensuring that the HPGR output quality remains constant.

The main process control parameter in the HPGR is the specific pressing force applied. This influences the ease with which the comminution process can be controlled and the ability of the machine to respond quickly to operator adjustments. The HPGR drive system is made up of electric motors and planetary gear boxes installed at the drive end of each roll. The gear boxes are connected to a system of torque arms. Depending on the application, an HPGR may be laid out for constant-speed operation or fitted with a variable-speed drive.

The main process control parameters are:

- » process-specific pressing force – this is generated by the hydraulic system and is the main parameter controlling the comminution process (and to a lesser extent the press throughput)
- » roll speed (when a VSD is fitted) – the main parameter controlling the press throughput.

The throughput of an HPGR also depends on the operating gap, which cannot be firmly adjusted for a given machine. This gap is a function of:

- » the press design (roll diameter)
- » feed material characteristics and particle size distribution
- » parameters as listed above.

The pilot-plant test work is normally carried out before implementing the comminution process in order to define these functions.



CAD Engineering

Köppern design engineers use modern 3D CAD software. An efficient EDP network connects CAD engineering with NC-programming and CNC-controlled machine tools and equipment.



Designed for easy maintenance and repair to provide maximum operational availability

Machine Frame

Hinged Frame

The steel structure of the press frame is designed to absorb all the pressing forces, thus avoiding their transmission to the press foundation. The press frame is bolted together to avoid any welded joints being exposed to pressing forces. Köppern has developed and patented the hinged-frame design in order to facilitate the rapid exchange of worn surfaces and minimize maintenance shutdowns.

C-Frame®

In response to industry requirements, Köppern has created and developed an enhanced solution for the hinged-frame mechanism and roll exchange process of an HPGR. The new C-Frame® HPGR design concept makes maintenance easier and reduces maintenance costs. The C-Frame® design allows access to both rolls from one side of the machine only and satisfies industry requirements without compromising the already proven Köppern hinged-frame design for rapid roll exchange. The C-Frame® is ideal for use in both mineral and cement industry applications, especially for high wear applications where downtimes are critical.

Tools

Most HPGRs in the cement industry have solid rolls made of weldable steel, forged into their final shape in order to provide good mechanical properties. Different types of hard-face alloys are used as wear protection. By simply re-welding the surface, the rolls can usually be refurbished several times before the whole roll has to be replaced. Today however, almost all HPGRs for grinding applications of minerals are equipped with tires. In comparison to solid rolls, tires can withstand higher mechanical loads. Tire-shaft solutions are used in combination with well-proven wear protection systems such as hard-facing or the HEXADUR® system from Köppern.

Cheek Plates

Cheek plates are used to seal the working gap between the rolls at their edges. These wear parts consist of a base plate of mild steel with wear protection applied at the overlapping areas of the roll edges and at the roll nip. These wear parts are made of materials with extreme wear resistance and pressed against the rolls with a constant force generated by spring packets.



Design of Rolls

Rolls of different designs are available for specific applications:

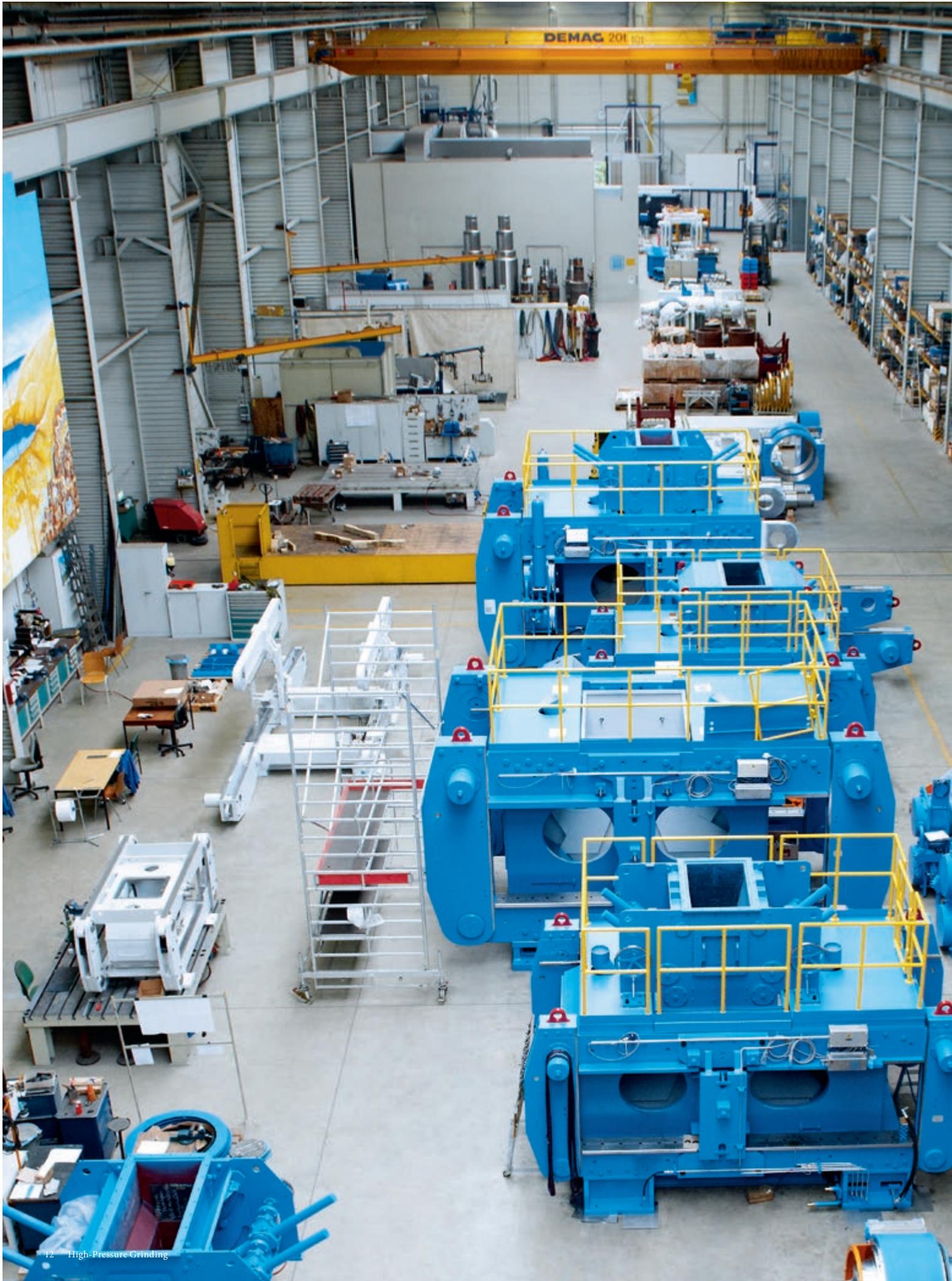
- » Solid Rolls
- » Rolls with tires

The following wear resistant linings can be provided:

- » Welded hard-facings
- » Cast metal linings
- » Composite steel
- » HEXADUR® – Köppern's proprietary wear protection



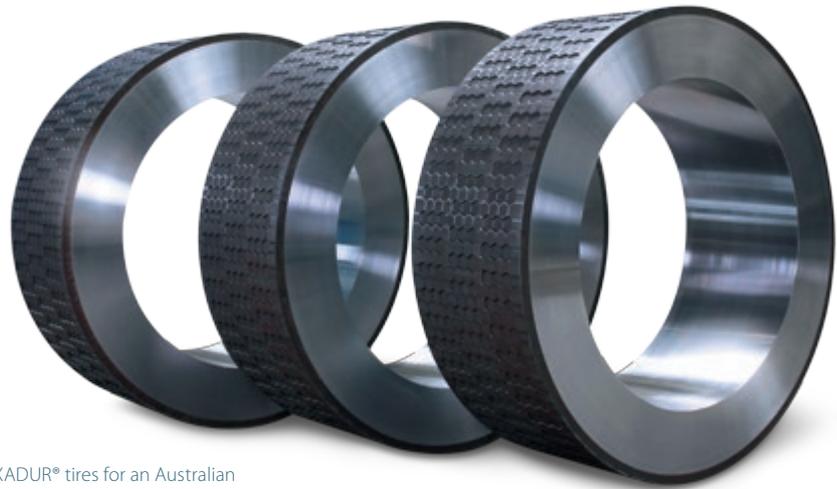
Positioning of cheek plates



Innovation Leadership

Following the success with roll presses for briquetting and compaction, Köppern developed new and innovative solutions that have revolutionized the productivity of the crushing and grinding process for many materials. Keeping the basic concept – converting fine materials into agglomerates by applying high pressures between two counter-rotating rolls – in mind, Köppern found that inter-particle comminution in a material bed is the ideal solution for the crushing and grinding requirements for many materials. Initially introduced for clinker and slag grinding in the cement industry, high-pressure comminution has now made its way into the hard ore and minerals sector. Whilst contradictory at first sight, the roll press as a single-machine technology can be successfully applied in both agglomeration as well as size reduction.

Wear Protection



HEXADUR® tires for an Australian iron ore application



HEXADUR® Pattern

The use of carbide-rich metal matrix composites (MMC) for the hexagonal tiles gives high wear resistance even when grinding extremely abrasive materials.



TETRADUR® Pattern

Modified surface design to meet specific demands in mineral applications.

DURUNIT®

Closed surface coating produced by powder metallurgy for third-party applications.

HEXADUR® – the Unique Solution

A high level of operational availability for continuous, trouble-free plant operation is a key feature of Köppern HPGRs. As wear surface replacement is the main cause of machine downtime, Köppern has taken a major step with the unique base-frame concept in achieving an adequate lifetime for roll surfaces and speeding up roll replacement procedures.

Köppern wear protection systems are characterized by the roll design and the type of surface applied. Two different roll designs have been successfully demonstrated in operation, namely solid rolls and rolls with tires.

For effective surface wear protection, the following solutions are available for various types of rolls:

- » Deposit welding – multiple layers of deposit welding are applied to the surface
- » Cast-hard layers – the wear parts are either made entirely of carbide, or their outer layer consists of cast material with a high carbide content
- » Stud lining – metal carbide pins are inserted into the roll surface. Compressed material accumulates between the pin pattern, resulting in additional autogenous wear protection
- » HEXADUR® – a system exclusively developed by Köppern initially for use in high-pressure comminution processes and now successfully used in briquetting and compaction applications under the brand name RESIDUR®

HEXADUR® tires feature a wear-resistant surface with a high content of hard phases in the form of tiles. During operation, the spaces between the tiles erode and fill with pressed material, thus leading to additional autogenous wear protection and optimizing the material intake into the press nip.

As a product of powder metallurgy, HEXADUR® can be custom-designed regarding the selection of hard-phases and matrix in order to suit specific applications.

The hexagonal tiles can be manufactured to different thicknesses – this further enhances surface friction and machine throughput. The wear thickness of the protection layer can also be adjusted.



HEXADUR® standard surface and electrochemically machined, preconditioned surface



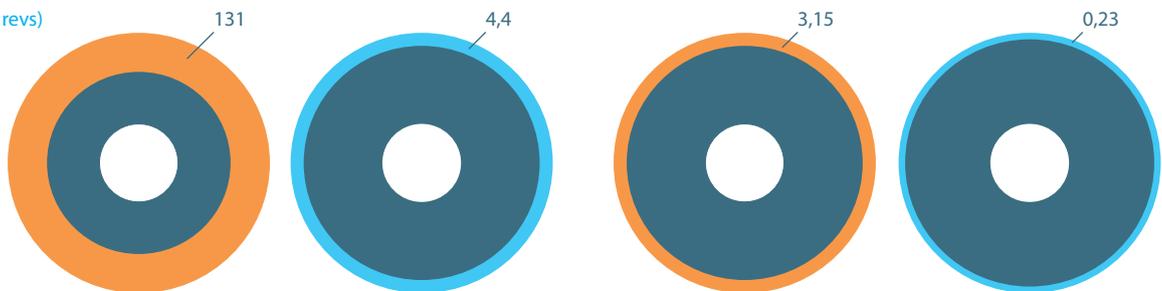
Built-up autogenous wear-protection layer

The hard, wear-resistant tiles are diffusion-bonded in a high-strength material, resulting in a much greater resistance to damage caused by oversized feed particles and/or tramp materials in comparison with other wear protection systems. A number of applications in the comminution of extremely hard cement clinker have demonstrated substantial lifetimes for the roll surfaces.

As the cost efficiency of a roll press is closely related to the wear performance of its rolls, it is appropriate to make a cost comparison. Whilst a HEXADUR® tire is clearly more expensive when compared with welded wear protection systems, the higher lining cost is offset by a significantly longer service life. Along with additional cost savings due to less maintenance and shut-down time, this makes the HEXADUR® system, which can be fitted to all makes of HPGR, commercially very attractive.

Wear Rate of a Roll Surface – in Mineral Processing / in Cement Clinker Processing

Wear rate ($\mu\text{m} / 1,000 \text{ revs}$)



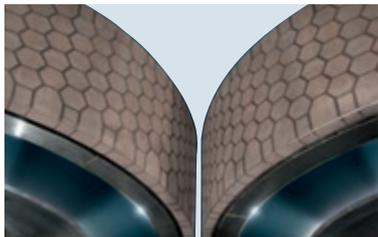
Scale	30	1	14	1
Wear protection	5C-29Cr Hard facing alloy	HEXADUR®	5C-29Cr Hard facing alloy	HEXADUR®
Feed material	Kimberlite	Kimberlite	Cement clinker	Cement clinker

Fields of Application



Products gained using HPGRs, for example cement, diamonds and gold

High-Pressure Grinding Rolls



Rolls with HEXADUR® tires – view inside the working gap.

HPGR technology is based on a concept very similar to Köppern's traditionally successful roll presses for briquetting and compaction, which have been in use across the globe for many years. Continuous development of innovative wear protection materials, press frames, drive trains and hydraulic systems has paved the way for Köppern's entry into the cement, minerals and mining industries. Here, the roll press is used to grind coarse feed material by applying a high pressure between the rolls.

During high-pressure comminution, feed material is in effect compacted to a dense flake through exposure to relatively high pressures. After de-agglomeration, this flake normally shows a substantial amount of completed or incipient cracking of the material particles. The process requires considerably less energy input compared to conventional crushers and mills, due to:

- » relatively uniform loading of the material in the compression zone
- » very short retention time
- » minimal energy requirement for material transport in the HPGR.

Key features of Köppern's HPGRs include:

- » superior machine design, ensuring process reliability and ease of maintenance
- » highly developed wear protection systems providing long service life and steady operation
- » control systems to monitor, adjust and optimize the comminution process.

These technological advances have resulted in a significant drop in machine time-outs caused by wear and repairs. For Köppern's customers, the resulting increase in productivity, coupled with a parallel reduction in energy consumption, enables them to compete more successfully in their own market segments.

Whilst high-pressure comminution is already a well-accepted and proven technology in the cement industry, it has also increasingly penetrated niche applications in the processes of diamond liberation and iron ore pellet feed preparation. Other ores and minerals that are suitable

Ores

In the ore dressing and minerals industry worldwide, approximately 130 machines have been installed so far. Today HPGRs are almost standard in every new diamond plant project. They quickly replaced the tertiary crushers once it had been established a greater amount of fines are produced and the working gaps are larger. This led to a reduction in diamond breakage and an increase in the value of the diamonds recovered.

It has also been noted that particle size reduction by compression only, as practised in the HPGR, generates residual micro-cracks in the crushed product, with potential benefits to the separation kinetics of downstream processes such as flotation and leaching. This evidence of micro-cracking in the HPGR product can have two potential advantages over e.g. SAG mill product in downstream processing. In the first instance, the Bond ball mill work index of the HPGR product is reduced, facilitating lower energy requirements, higher ball mill throughput and a potential for finer grind in the downstream ball mill grinding circuit. In the second instance, current tests relating to the increased incidence of micro-cracking in the HPGR product versus the SAG product are expected to result in enhanced process kinetics, for example in the cyanide leaching of gold. First attempts to apply HPGRs in the gold ore industry were made in 1996.

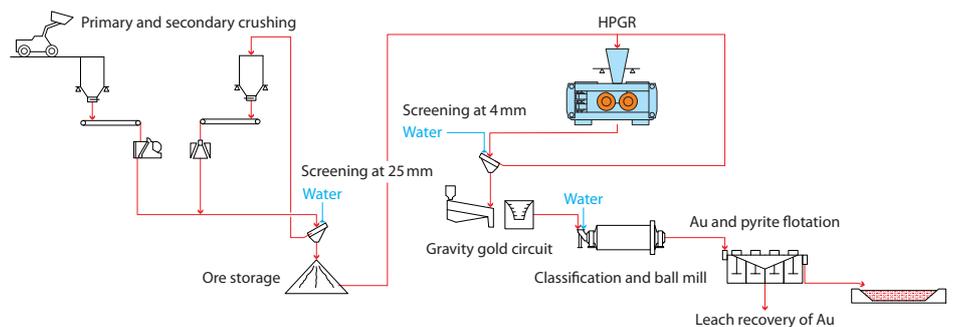
In the iron ore industry, HPGRs were first applied in 1994. The machines were initially used to grind relatively fine ore in pre-treatment plants for pellet feed, resulting in an increase in the throughput of pellet plants of up to 30%. Moreover, the moisture for balling could be reduced.

Since 1997, roll presses are also being used for grinding coarse iron and pebbles – surplus pebble material in an iron ore mine is re-crushed by means of HPGRs in order to increase the throughput of a concentrator line.

A particular application relates to a new coal-based DRI process, in which an HPGR is used to grind iron ore as feed material for a briquetting plant. In copper mining, the first successful application for HPGRs in hard ore crushing was established in 1999.

Key issues for the successful application of Köppern roll presses in hard ore grinding are advantages in process technology, low maintenance costs and a significantly reduced level of machine time-outs caused by wear and repairs.

Gold Ore Grinding with HPGR





A History of Quality

As a family-run German company with a long and successful history, Köppern has built up an enviable reputation for end-to-end quality and dependability, which continues to be reflected in our technological development, manufacturing processes, finished products and customer service.

References

Cement

Founded in 1898, Köppern remains a family-run enterprise reflecting its traditional values of technology leadership, highly dependable manufacturing quality and a unique regard for the individual needs of its customers.

Slovakia



Material: Cement Clinker, Slag
 Type & size: 750/15-1,300
 Capacity in t/h: 710
 Tool size in mm: 1,500x1,300

Sri Lanka



Material: Cement Clinker, Slag, Gypsum
 Type & size: 630/17-1,100
 Capacity in t/h: 650
 Tool size in mm: 1,700x1,100

Thailand



Material: Cement Clinker, Gypsum
 Type & size: 850/21-1,300
 Capacity in t/h: 1,640
 Tool size in mm: 2,100x1,300

India



Material: Limestone
 Type & size: 630/15-1,000
 Capacity in t/h: 500
 Tool size in mm: 1,500x1,000

Selection of Worldwide References relating to Cement

Country	Material	Type & size	Capacity in t/h	Tool size in mm
India	Cement Clinker, Slag	630/12-1,200	496	1,200x1,200
India	Cement Clinker, Gypsum	750/15-1,300	750	1,500x1,300
Indonesia	Cement Clinker	92/10-765	260	1,000x765
Spain	Lime Stone	500/10-930	270	1,000x930
Turkey	Cement Clinker, Slag, Gypsum	750/14-1,400	1,200	1,400x1,400
USA	Cement Clinker, Gypsum, Recycled Material	880/21-1,300	1,200	2,100x1,300

Ores

Our worldwide network of subsidiaries, including manufacturing plants and engineering offices, provides customer-focused specialist services from pilot-plant test work to operator training on all continents.

Australia



Material: Vanadium Ore
 Type & size: 92/14-1,400
 Capacity in t/h: 575
 Tool size in mm: 1,400x 1,400

Australia



Material: Iron Ore
 Type & size: 630/14-1,400
 Capacity in t/h: 1,500
 Tool size in mm: 1,400x 1,400

Australia



Material: Gold Ore
 Type & size: 72/10-500
 Capacity in t/h: 100
 Tool size in mm: 1,000x 500

China



Material: Iron Ore
 Type & size: 630/17-1,400
 Capacity in t/h: 1,360
 Tool size in mm: 1,700x 1,400

Selection of Worldwide References relating to Ores

Country	Material	Type & size	Capacity in t/h	Tool size in mm
Canada	Kimberlite	72/12-600	135	1,200x600
China	Molybdenum Ore	500/15-1,000	556	1,500x1,000
China	Iron Ore	500/15-1,000	400	1,500x1,000
Russian Federation	Kimberlite	500/15-1,300	350	1,500x1,300
South Africa	Kimberlite	52/10-230	50	1,000x230
USA	Iron Ore	630/15-1,000	451	1,500x1,000

Customer Service

Köppern Service Worldwide

Our specialist services cover pilot-plant test work, plant audits, process layout, engineering, supply of complete grinding plants or key equipment, supervision of installation and commissioning as well as training.

Köppern operates service centers at strategic locations throughout the world to ensure a rapid response to customer requirements for spare parts, maintenance and repair services. Experienced personnel from either the Köppern HQ in Germany or any of its subsidiaries can be dispatched to our customers' sites at any time.

Please contact us for further information.

Headquarters

- » Maschinenfabrik Köppern GmbH & Co. KG (Hattingen, Germany)

Köppern Subsidiaries with Sales and Service Offices

- » Köppern Entwicklungs-GmbH (Hattingen, Germany)
- » Köppern Aufbereitungstechnik GmbH & Co. KG (Freiberg, Germany)
- » Köppern Equipment Inc. (Charlotte, USA)
- » Maquinarias Koeppern Venezuela C.A. (Puerto Ordaz, Venezuela)
- » Köppern-Maco Services Pvt. Ltd. (Kolkata, India)
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- » Koeppern Service Canada Inc. (Saskatoon, Canada)

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- » Mexico
- » Paraguay
- » Russia
- » South Africa
- » Spain
- » Ukraine
- » Uruguay



Customer Focus – Worldwide

Sales and Service Offices

Place your confidence in our worldwide network of service centers and engineering offices. Köppern offers a comprehensive range of customer-focused services starting with process consulting for either your greenfield project or your existing plant update.

- Köppern Headquarters, Hattingen
- Köppern Subsidiary with Sales and Service Offices
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