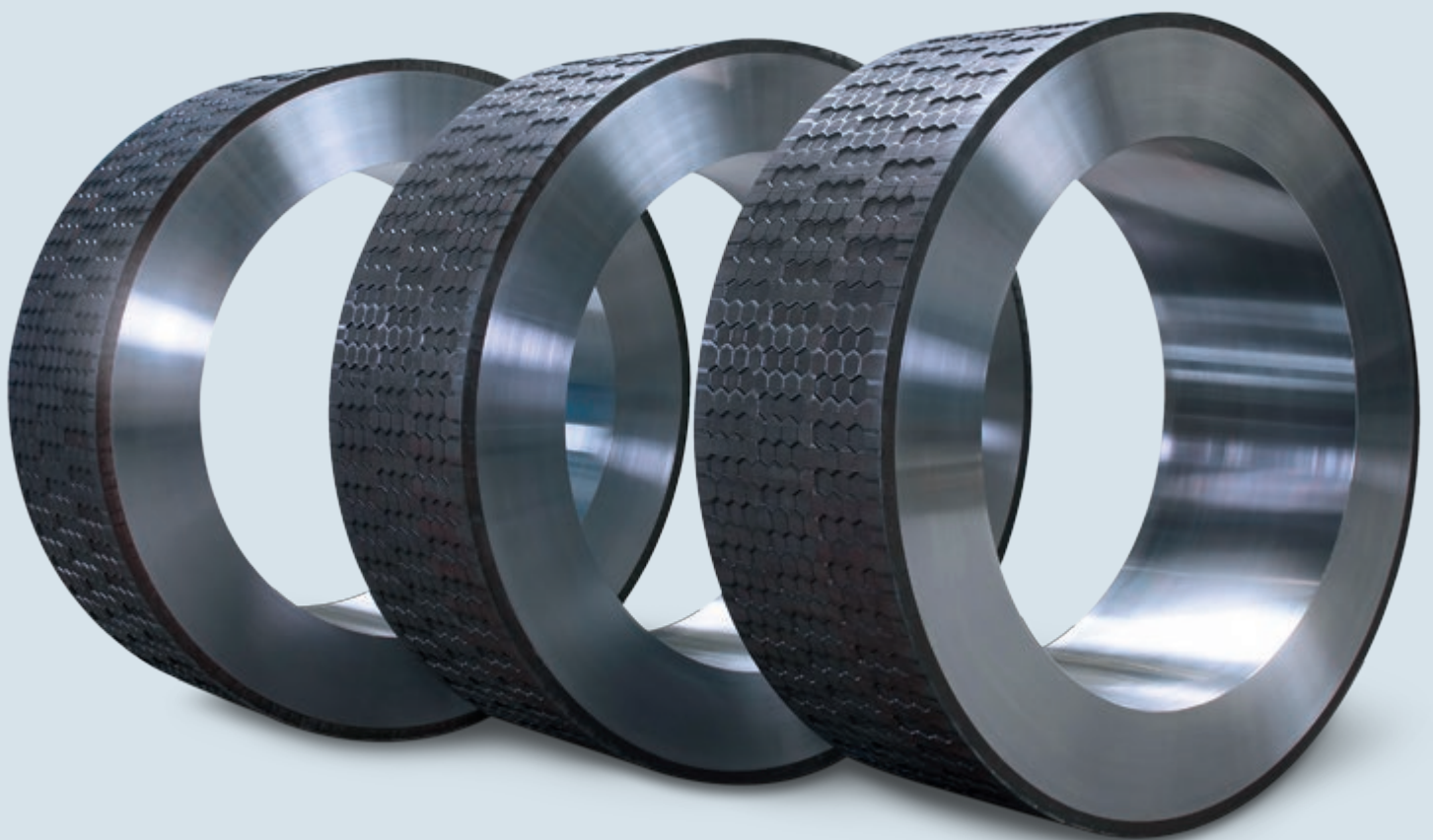


# HEXADUR®

## Wear Protection for the Cement Industry

The Unique Wear Protection Solution



**Köppern**

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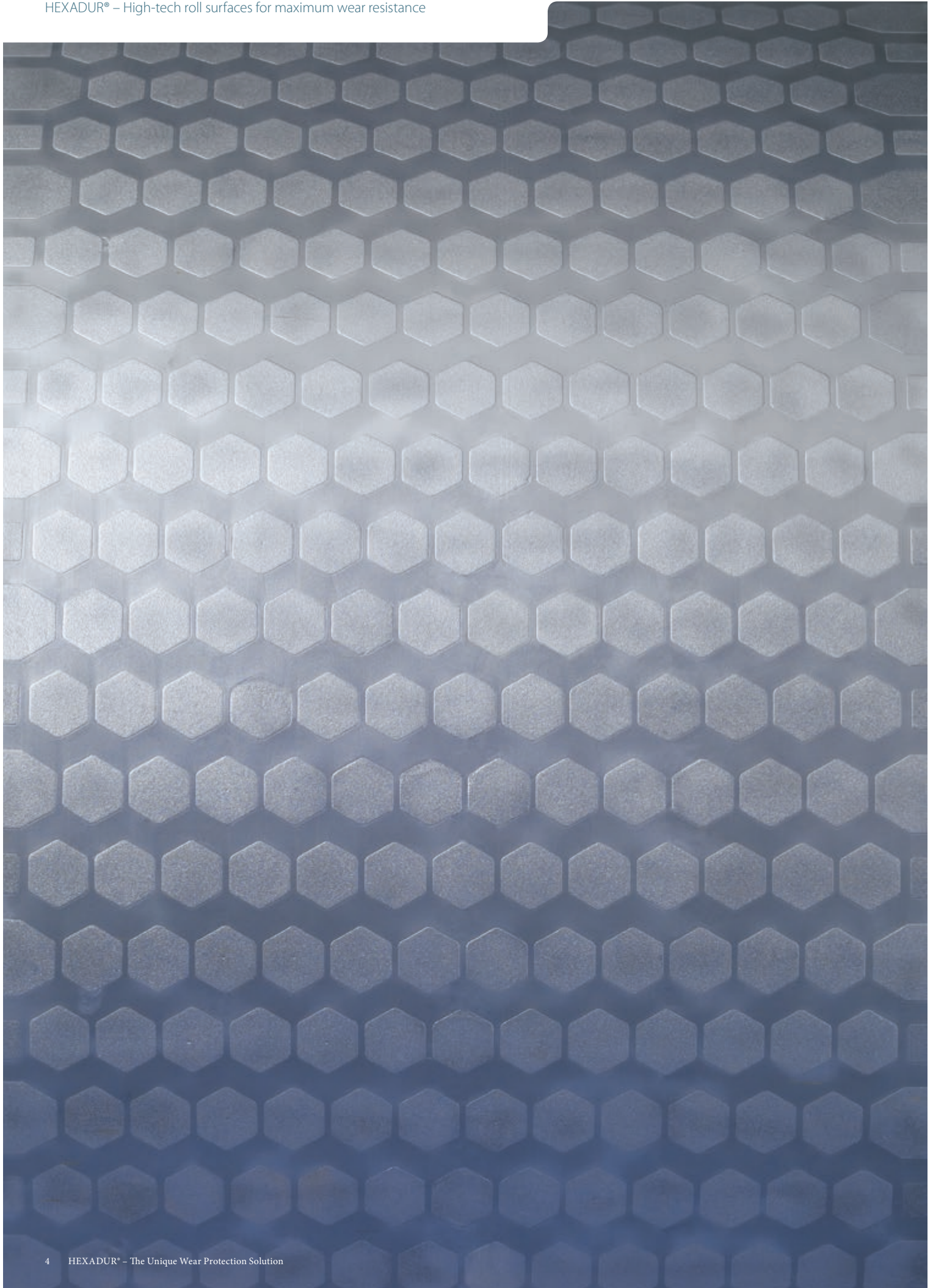
## Contents

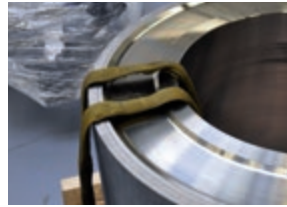
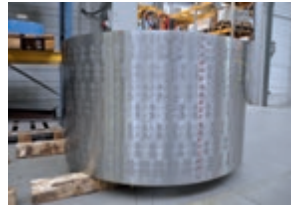
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# Köppern – Specialists in high-pressure comminution for the cement industry





## Experience and Innovation – Cementing Partnerships

Founded in 1898 in Hattingen, Germany, Köppern remains a family-run enterprise reflecting its traditional values of technology leadership and highly dependable manufacturing quality, coupled with a unique regard for the individual needs of its customers. Köppern's global network of subsidiaries provides customized service on all continents.

The company's history is linked to the utilization of roll presses for briquetting and other compaction applications. With the introduction of High Pressure Grinding Rolls (HPGRs) in the 1980s, Köppern successfully expanded into the cement industry, building a strong position through innovative press designs such as the C-Frame® and Hinged-Frame as well as the unique HEXADUR® wear protection system.

These technological advances have resulted in a significant drop in machine downtime caused by wear and repairs. For Köppern's customers, the resulting rise in productivity, along with a parallel increase in grinding efficiency, enables them to compete more successfully in their own market segments.

Based on our experience in raw material and cement grinding and the interfaces between the different process components, Köppern can not only support you with excellent products, but also with comprehensive solutions in greenfield and brownfield projects.

In facing the challenges of the future, we believe in cementing our partnerships by maintaining our promise of excellence through continued research and customer dialog.

### The Köppern Cement Chronicle

- 1987  
Roll presses for cement clinker comminution
- 1996  
First HEXADUR® installation in cement grinding
- 1998  
First HEXADUR® installation for slag grinding
- 2002  
First installation of macro-profiled HEXADUR® surface
- 2004  
Development of C-Frame® for easier maintenance
- 2005  
First edge-protected HEXADUR® installation
- 2007  
Development of special tile design for slag grinding
- 2011  
New HEXADUR® roll dimensions up to 2,000 mm diameter

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# Conventional HPGR Wear Protection for the Cement Industry



## Today's Situation: Low Entry Prices, but High Running Costs

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### Drawbacks of Conventional Welded Rolls

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- » Cost-intensive plant downtime
- » Frequent maintenance and repair
- » Regular replacement or refurbishment
- » Constantly decreasing efficiency

Following the discovery in the early 1980s that it is possible to save up to 50% energy in cement clinker grinding by using the principle of interparticle comminution, more than 500 high-pressure grinding roll presses (HPGRs) are in use in the cement industry today, mainly for the pre-treatment of ball mill feed. The adoption of high-pressure grinding technology over the last 20 years has already led to significant energy savings as well as reduced costs for wear material.

However, the conventional welded rolls used predominantly today are still subject to rapid and excessive wear when applied to the grinding of cement clinker, particularly if there is a high slag content. Depending on the abrasiveness of the feed material, hard-faced rolls need to be refurbished at regular intervals, in some cases as often as every 2,000 hours. After a certain number of refurbishments, the entire roll has to be replaced due to crack propagations. This severely limits the economical use of conventionally equipped HPGRs due to:

- » cost-intensive downtime of the plant
- » frequent maintenance and repair
- » concave deformation of welded roll surfaces
- » constantly decreasing grinding efficiency
- » negative effect on product quality and throughput
- » frequent roll replacement and refurbishment.



In operation, HPGRs build up a material bed by feeding the material that is to be ground through the gap between two counter-rotating rolls. In doing so, the movable (floating) roll is hydraulically pressed against the material bed and thus against the fixed roll. Forces acting within the material bed cause mechanical interaction, resulting in fracture and the initiation of cracks. Due to the high pressure acting within the gap, the feed material is also densified to an agglomerate (flake). Subsequent deagglomeration of the flake requires only minimal energy. For the same grinding result, the crushing operation utilized in HPGRs requires only about 50% of the energy needed in a conventional ball mill.

But welded crushing tools wear out rapidly because of the high pressure and the friction between feed material and roll surface. The welded surface layers are subject to progressive wear, because they tend to become “softer” with repeated welding of the hardfacing. This leads to irreparable surface failures on welded (hard-faced) rolls, so that the entire crushing tool has to be disposed of.

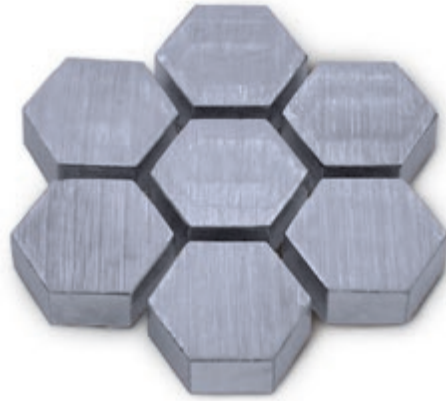
Welded rolls do of course benefit from attractive initial pricing, but their running costs, incurred by high levels of maintenance, refurbishment or early replacement, coupled with plant downtimes and lower longtime grinding performance, make them increasingly uneconomical over time – a challenge that formed the basis for Köppern’s quest for optimal wear protection ...

### The Challenge for Köppern

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The challenge for Köppern was to develop a better wear-resistant roll surface for high-pressure grinding.

# Innovation Leadership



## HEXADUR® Pattern

The use of tool steel or carbide-rich metal matrix composites (MMC) for the hexagonal tiles gives strong wear resistance when grinding abrasive materials.



## HEXADUR® Two-Part Roller Design

Consisting of a roll core and a wear-protected tire

## HEXADUR® – Optimal Wear Protection

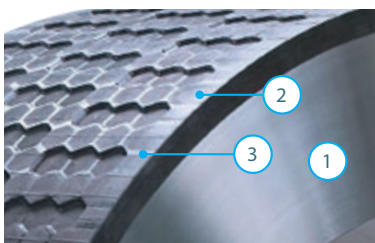
With the inherent disadvantages of conventional HPGRs in mind, Köppern has pioneered the development of a new generation of highly efficient wear protection for HPGRs with the objective of achieving a commercially attractive combination of:

- » long service life
- » uninterrupted availability
- » stable throughput over its service life
- » low operating costs.

Based on years of intensive research and development, the HEXADUR® wear protection system has reached maturity as an optimal solution against roll surface wear.

The two-part design consists of a roll core and a wear-protected tire. Shrink-fitting of the heated tire onto the roll core has proved to be a very reliable method for tire mounting. The multi-material HEXADUR® system has many advantages over conventional HPGR roll surfaces:

- » Small and evenly distributed surface abrasion assures consistent flake production and minimizes maintenance.
- » Consistent material intake and throughput due to the autogenous wear protection layer (see p. 12) ensures constant grinding performance and reliability.
- » The propagation of cracks initiated by welding operations is completely avoided. Thus, roll cores may be reused after the service life of HEXADUR® tires.



## HEXADUR® Multi-Material Wear Protection System

Consisting of a base material (1), wear-resistant HEXADUR® tiles (2) and tough interspace filler material (3) (see p. 12)

These unique features result in:

- » more reliable costing due to a long service life coupled with a low incidence of damage, maintenance and downtime
- » an even usage pattern that provides consistent operational conditions in terms of throughput and grinding efficiency.

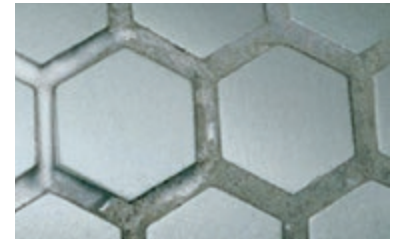
In fact, it is true to say that the more abrasive the material to be ground, the greater the suitability of HEXADUR® – a major advantage for the cement industry:

- » HEXADUR® tires can be fitted to HPGRs of most suppliers.
- » Köppern is able to offer customized solutions for specific applications:
  - different wear-resistant powder-metallurgical surface material compositions
  - different surface profiles
  - made-to-measure rolls up to 2,000 mm in diameter

In the first industrial application at Norcem AS in Norway in 1996, a roll with a HEXADUR® wear protection layer of only 10 mm thickness achieved 16,000 service hours without any maintenance. The abrasion amounted to only about one sixth of the wear thickness and was evenly distributed.

At the same time, a conventional welded (hard-faced) counter-roll wore out completely after only 2,500 hours\*, showing severe signs of wash-out leading to concave deformation. This roll had to be replaced seven times during the same period. Today's advanced HEXADUR® rolls are expected to achieve an even longer service life without maintenance (see references p. 16).

The enhanced wear resistance of HEXADUR® in comparison with a conventional welded wear protection system is visualized in the example below: With an average wear rate of only 0.23 µm per 1,000 revolutions, a HEXADUR® tire can show 14 times less wear than the conventional welded wear protection system.



#### Autogenous Interspace Wear-Protection Layer

The grooves between the tiles fill up with compacted feed material (see p. 12)

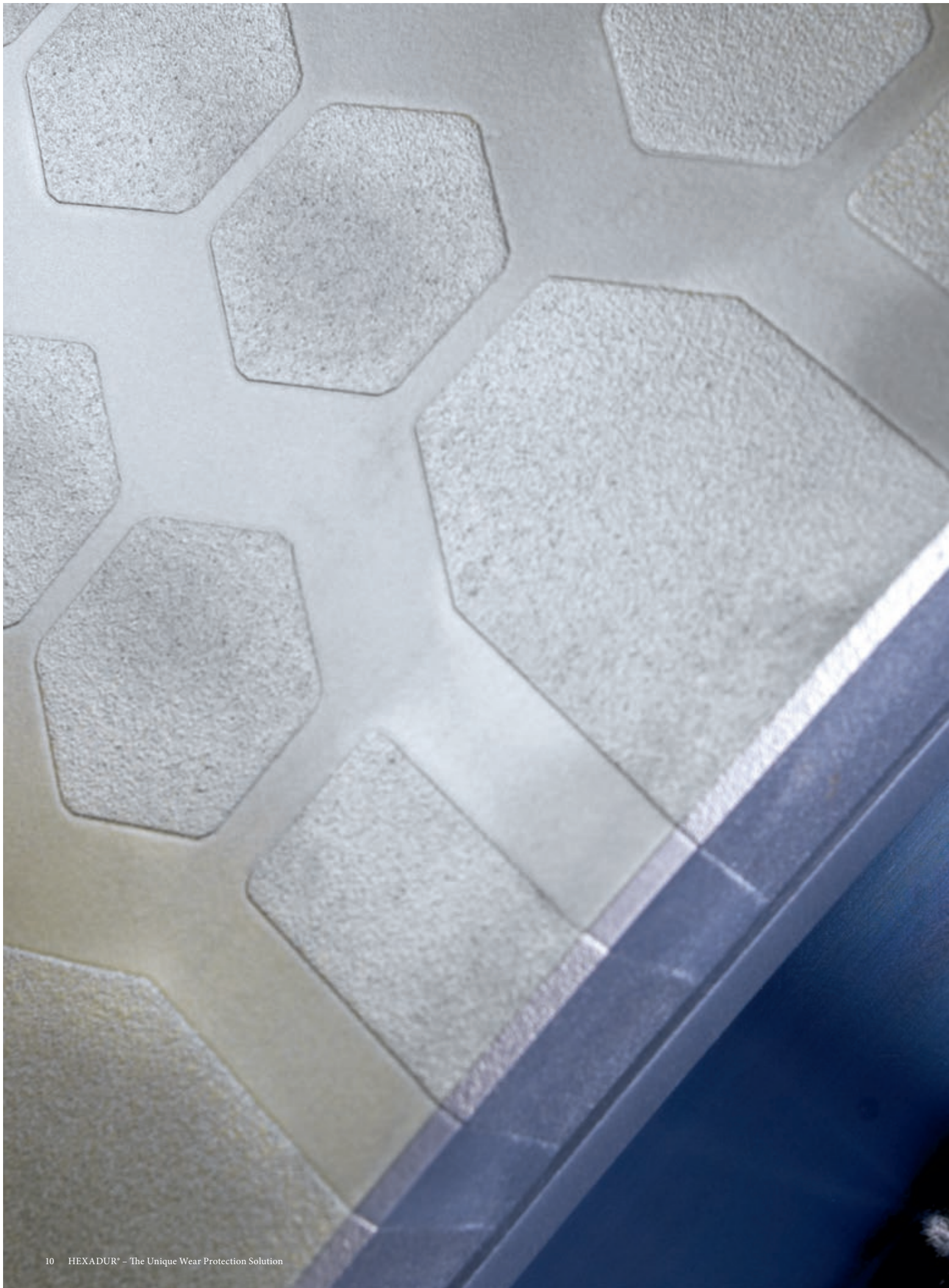
\* Source: A Lifetime of Success in Norway, p. 109, worldcement.com, September 09

### Wear Rate of Roll Surfaces in Cement Clinker Grinding

Wear rate (µm / 1,000 revs)



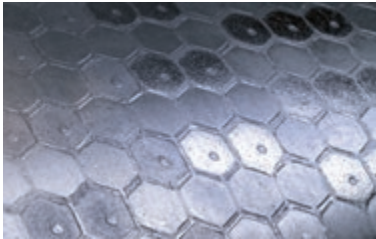
Wear protection	5C-29Cr hardfacing alloy	HEXADUR®
Feed material	Cement clinker	Cement clinker



# Advanced Technology for Cost Efficiency

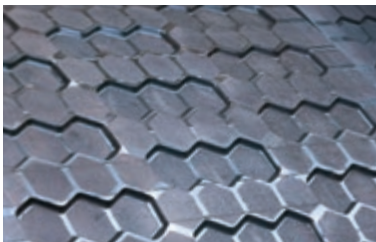
Continuous research and development have led to a unique design and production process that make HEXADUR® tires exceptionally durable. Low operating costs and uninterrupted availability ensure a high return on investment, while the even usage pattern assures stable operational conditions in terms of throughput and grinding efficiency.

# Advanced Technology



## HEXADUR® Surface

HEXADUR® standard surface at delivery



## HEXADUR® Surface

Pre-conditioned surface-design with tiles manufactured to different thicknesses to enhance machine intake right from the start

## HEXADUR® – Unique Design and High-Tech Production

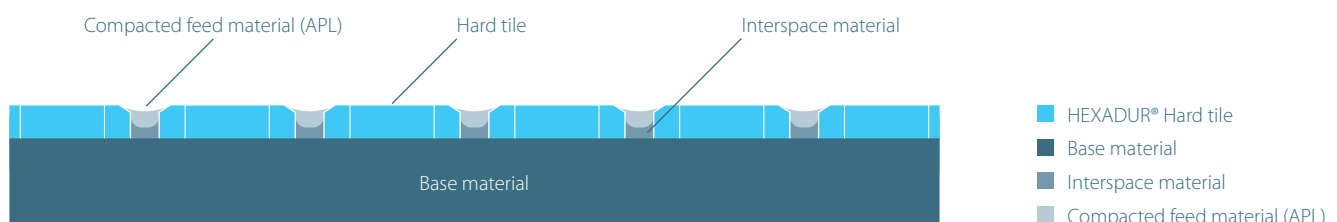
HEXADUR® tires feature a wear-resistant surface with a high content of hard phases in the form of hexagonal tiles of different thicknesses (macro-profiling). The tiles are made of powder-metallurgical tool steel or metal matrix composites (MMC) with strong wear resistance. They are diffusion-bonded onto a high-strength base ring, which results in strong resistance to damage. During operation, the gaps between the tiles wash out slightly and fill up with compacted feed material. This builds up a honeycomb-like autogenous wear protection layer (APL), which also improves intake behavior as well as throughput of the machine by increasing the friction between the tire surface and the feed material.

The softer but tough steel in the gaps between the tiles creates a strong resistance against any local damage extending to neighboring hexagons. Moreover, the tiles are tolerant to minor damage due to their ability to regenerate by smoothing out partial chippings.

As a product of powder metallurgy, HEXADUR® can be custom-designed with respect to the selection of hard-phases and metal matrix in order to suit specific applications. Moreover, the hexagonal tiles can be manufactured to different dimensions, further enhancing surface friction and machine throughput.

HEXADUR® tires can be delivered for various machine sizes of different HPGR suppliers.

## Principle of the HEXADUR® Surface



# Factory Tour

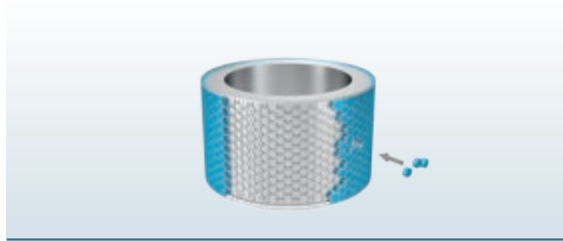
HEXADUR® tires are produced at our ISO 9001-2000 certified production facilities. The main steps of the production process are:

## Base Ring



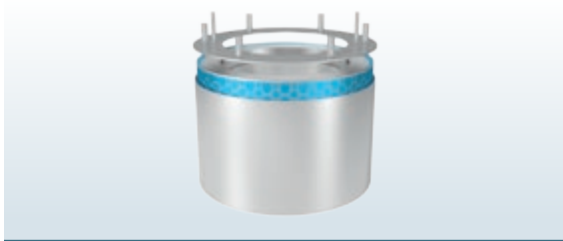
A solid, high-strength, precision-machined steel ring provides the base for the application of the HEXADUR® layer.

## Tile Assembly



The hexagonal tiles are applied to the base ring.

## Capsule Assembly



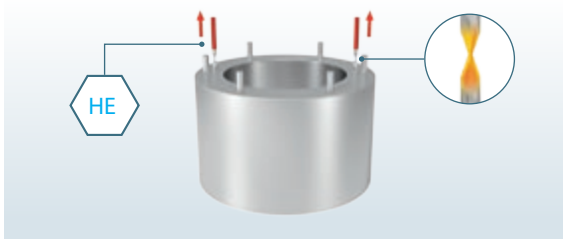
The ring is transferred into a sheet-metal capsule. The gas-tight lid is welded onto the capsule.

## Powder Filling



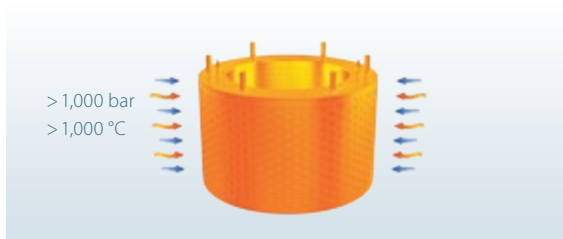
Homogenized metal powder is filled into the capsule and densified on a vibration table. This powder forms the tough interspace material.

## Evacuating and Sealing



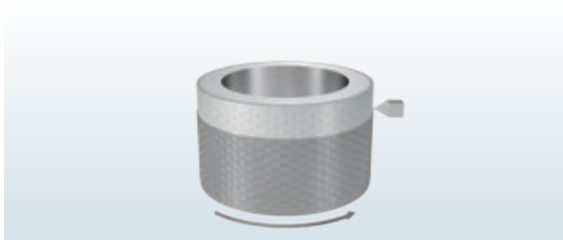
The gas-tight capsule is evacuated. Tightness is checked using a helium leakage test.

## Hot Isostatic Pressing (HIP)



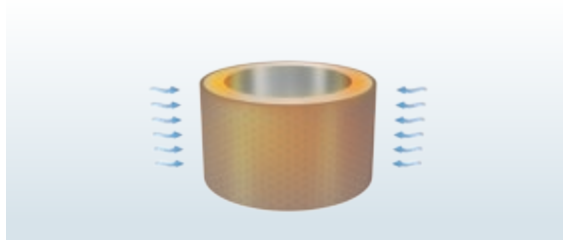
The compound body is then exposed to high temperature and pressure (HIP technology).

## Removing the Capsule



The capsule is removed by machining on a vertical lathe.

## Hardening



The required final material properties are achieved by heating the HEXADUR® tire to approx. 1,000 °C followed by rapid quenching.

Finally, the inner diameter of the HEXADUR® tire is machined to the exact dimension for shrink-fitting onto the roll core.

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# Focus on Cost Efficiency



## HEXADUR® – A Sound Investment for your Business

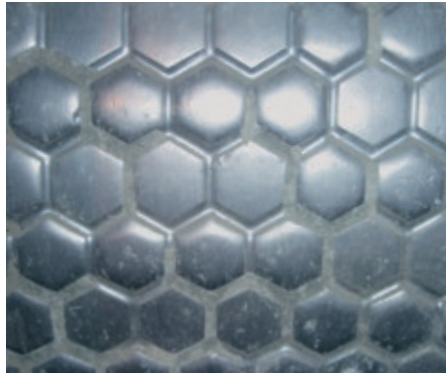
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Uninterrupted HPGR availability is of paramount importance to cement makers. Therefore they expect a technically reliable and cost-effective wear protection solution that maintains proper operation even under severe service conditions.

For the comminution of cement clinker as well as other highly abrasive feed materials, such as slag, the HEXADUR® wear protection solution ensures a substantially extended, uninterrupted service life in comparison to conventional hardfacing or wear-resistant castings.

Due to the complex manufacturing process, the initial costs (CAPEX) for HEXADUR® rolls are higher than for welded rolls. However, during their significantly longer service life, HEXADUR® rolls generate considerable cost savings due to their very low wear rate. They also benefit from their even usage pattern, which provides consistent operational conditions in terms of throughput and grinding efficiency.

The higher entry costs of the HEXADUR® system are therefore more than compensated by cost savings over time (OPEX) resulting from maintenance- and trouble-free operation. The diagram on page 15 illustrates the comparative cost efficiency of a HEXADUR®-protected HPGR in relation to a welded roll.

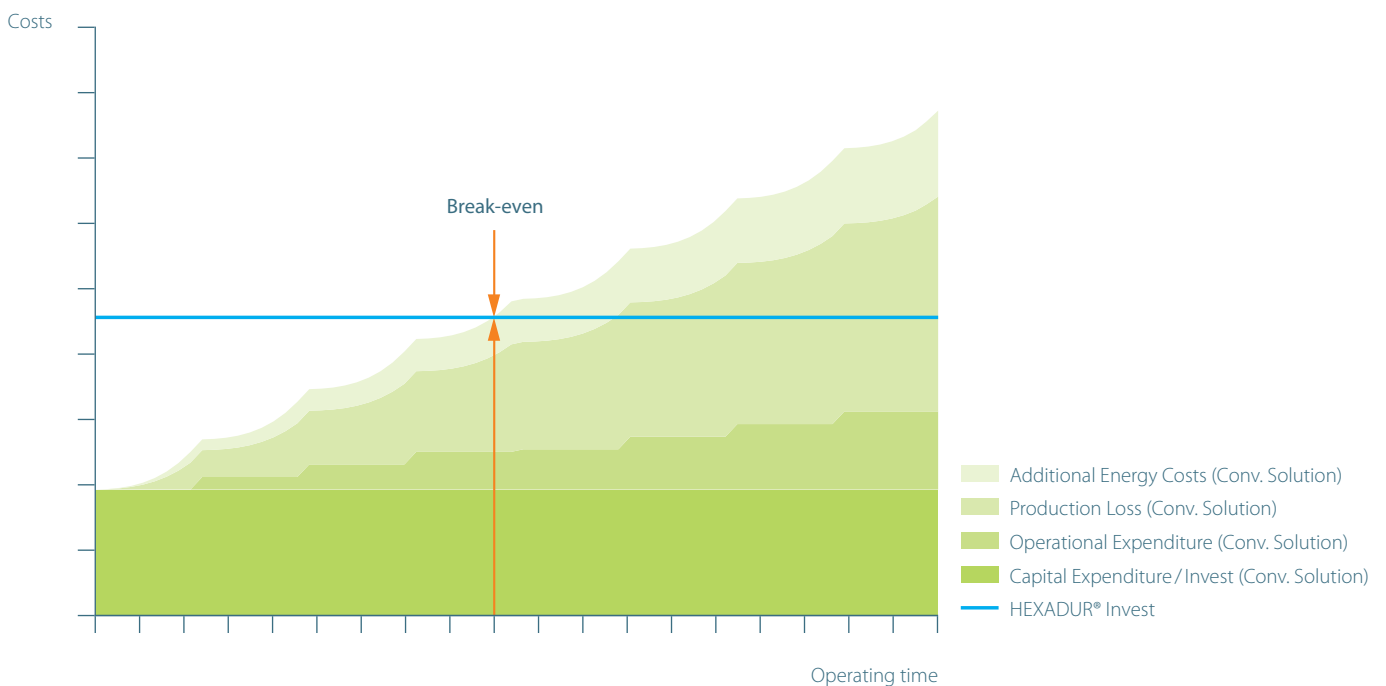


Welded (hard-faced) roll surface after 2,500 hours of service (left) and HEXADUR®-protected surface after surpassing 50,000 hours of service (right)

At Norcem AS, maintenance-free operation of HEXADUR® rolls in cement grinding has provided convincing proof of concept for this wear protection system. It has been shown that costs can be reduced by up to 75% over time through full operational availability over a prolonged period.

In 2010, the HEXADUR® tires surpassed 60,000 service hours without any maintenance, and a service life of more than 70,000 hours was then expected. In this particular case the service life of HEXADUR® rolls exceeds that of welded (hard-faced) rolls by a factor of 25 to 30. In a number of other applications in Europe, North America and Asia, the same factor of 10 and more has been achieved and is still increasing.

### Total Cost Comparison – Conventional Solution vs. HEXADUR®



# References

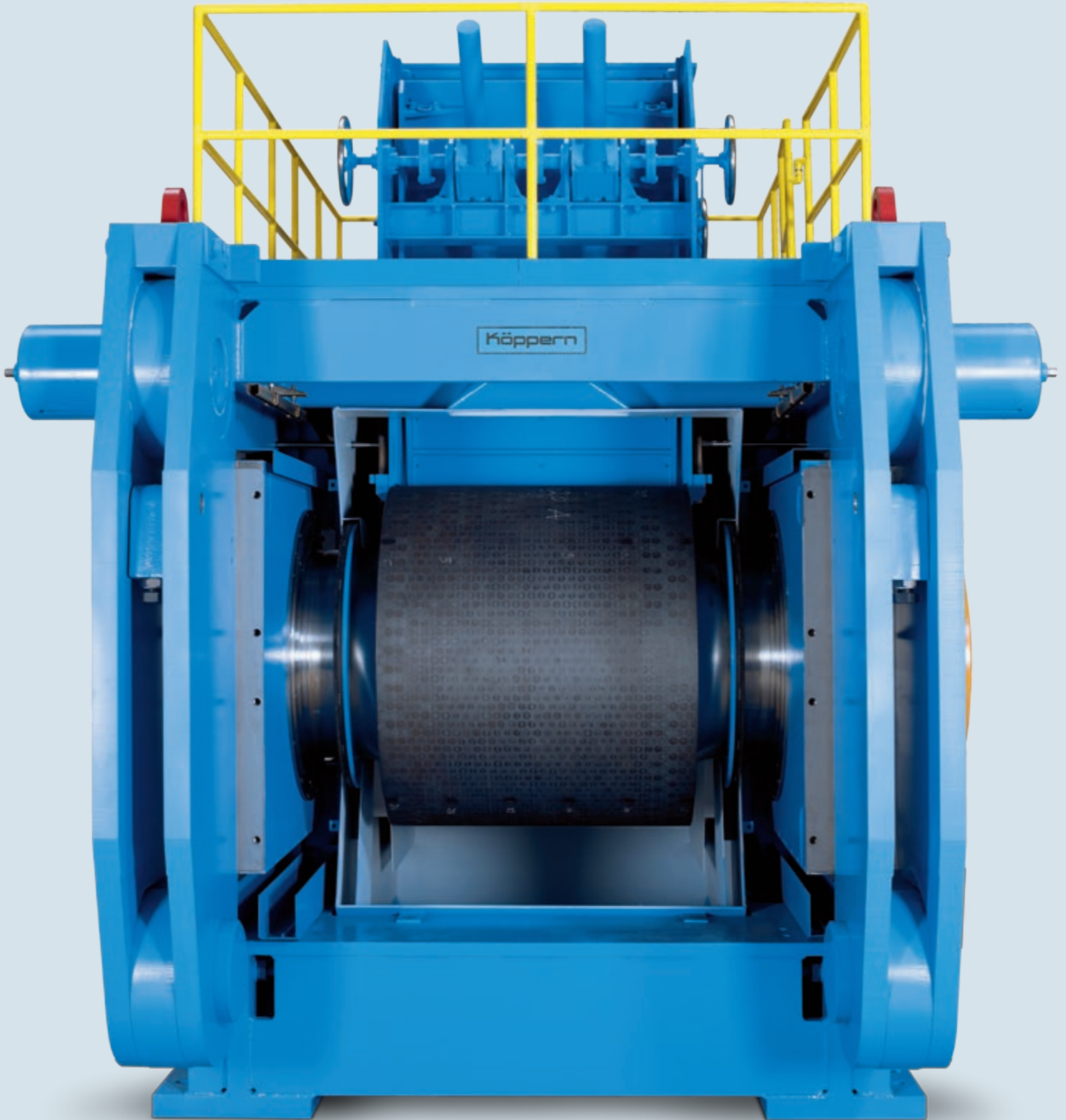
## Established Throughout the World

Since its launch in 1996, Köppern's unique HEXADUR® wear protection solution for high-pressure grinding rolls in the cement industry has established itself on three major continents, and is currently being introduced into the South American market.

Our customer community for HEXADUR® tires, for use on Köppern's or other suppliers' high-pressure grinding installations, has ordered a total of more than 200 tires and is growing rapidly. Below is a selection of references where customers are already benefiting from a significantly higher consistency in operational conditions for their cement and slag applications in combination with an extremely long service life of the wear-protected tires.

### Selection of Cement Industry References

Country	Material	Roll size outer dia. x inner dia. x width in mm	HPGR supplier	Hours of operation up to 02/2014	Number of HPGRs	First HEXADUR® installation
<b>Europe</b>						
Norway	Clinker	1,000 x 710 x 930	Köppern	75,000	1	1996
Austria	Clinker/Slag	1,000 x 600 x 630	Other	43,000	1	2001
Germany	Clinker	1,400 x 950 x 1,200	Other	76,000	2	2001
Italy	Clinker	1,400 x 1,000 x 660	Other	> 33,000	1	2003
Austria	Clinker	1,000 x 690 x 380	Other	30,230	1	2008
Slovakia	Clinker/Slag	1,500 x 1,030 x 1,300	Köppern	10,464	1	2011
Suisse	Clinker	1,150 x 765 x 630	Other	> 8,000	1	2012
Germany	Clinker	1,400 x 1,000 x 530	Other	> 10,000	1	2012
France	Clinker/Slag	1,000 x 690 x 380	Other	Ordered	1	2014
<b>Asia</b>						
India	Clinker	1,200 x 840 x 1,200	Köppern	40,500	2	1999
India	Clinker/Slag	1,200 x 840 x 1,200	Köppern	43,000	2	2002
India	Clinker	1,200 x 840 x 1,200	Köppern	23,000	1	2003
India	Clinker	1,500 x 1,030 x 1,300	Köppern	> 20,000	2	2010
Indonesia	Clinker	1,000 x 710 x 765	Köppern	> 14,000	1	2011
India	Clinker	1,500 x 1,030 x 1,300	Köppern	> 3,500	1	2012
Saudi Arabia	Clinker	1,500 x 1,030 x 1,300	Köppern	> 2,500	2	2013
Philippines	Clinker	1,500 x 1,030 x 800	Other	Ordered	1	2014
Thailand	Clinker	1,220 x 765 x 760	Other	Ordered	1	2015
Thailand	Clinker	1,524 x 1,030 x 965	Other	Ordered	1	2015
Thailand	Clinker	1,200 x 840 x 1,200	Köppern	Ordered	2	2015
Thailand	Clinker	1,000 x 710 x 930	Köppern	Ordered	1	2015
<b>America</b>						
Canada	Clinker	1,220 x 900 x 765	Other	18,000	1	2000
USA	Clinker	1,150 x 780 x 1,000	Other	> 31,000	1	2009
Mexico	Limestone	1,000 x 690 x 380	Other	> 5,450	1	2012
Mexico	Clinker	1,410 x 950 x 525	Other	> 4,700	1	2013
Peru	Clinker	1,150 x 780 x 1,000	Other	> 5,000	1	2013
Colombia	Clinker	1,700 x 1,150 x 1,400	Other	Ordered	1	2014



HEXADUR® (1,500 mm outer dia. x 1,300 mm width) in a Köppern HPGR – ready for dispatch to India (roll cover removed)

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# Customer Service

## Köppern Service Worldwide

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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)
- » Koeppern Machinery Australia Pty. Ltd. (Perth, Australia)
- » Koeppern China Holding GmbH (Beijing, China)
- » Koeppern Service Canada Inc. (Saskatoon, Canada)

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- » 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
- ▲ Köppern Workshops
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