DECARBON TECHNOLOGIES

Rothe Erde

Renewable Energy.

engineering.tomorrow.together.

thyssenkrupp

Global strength – local presence.

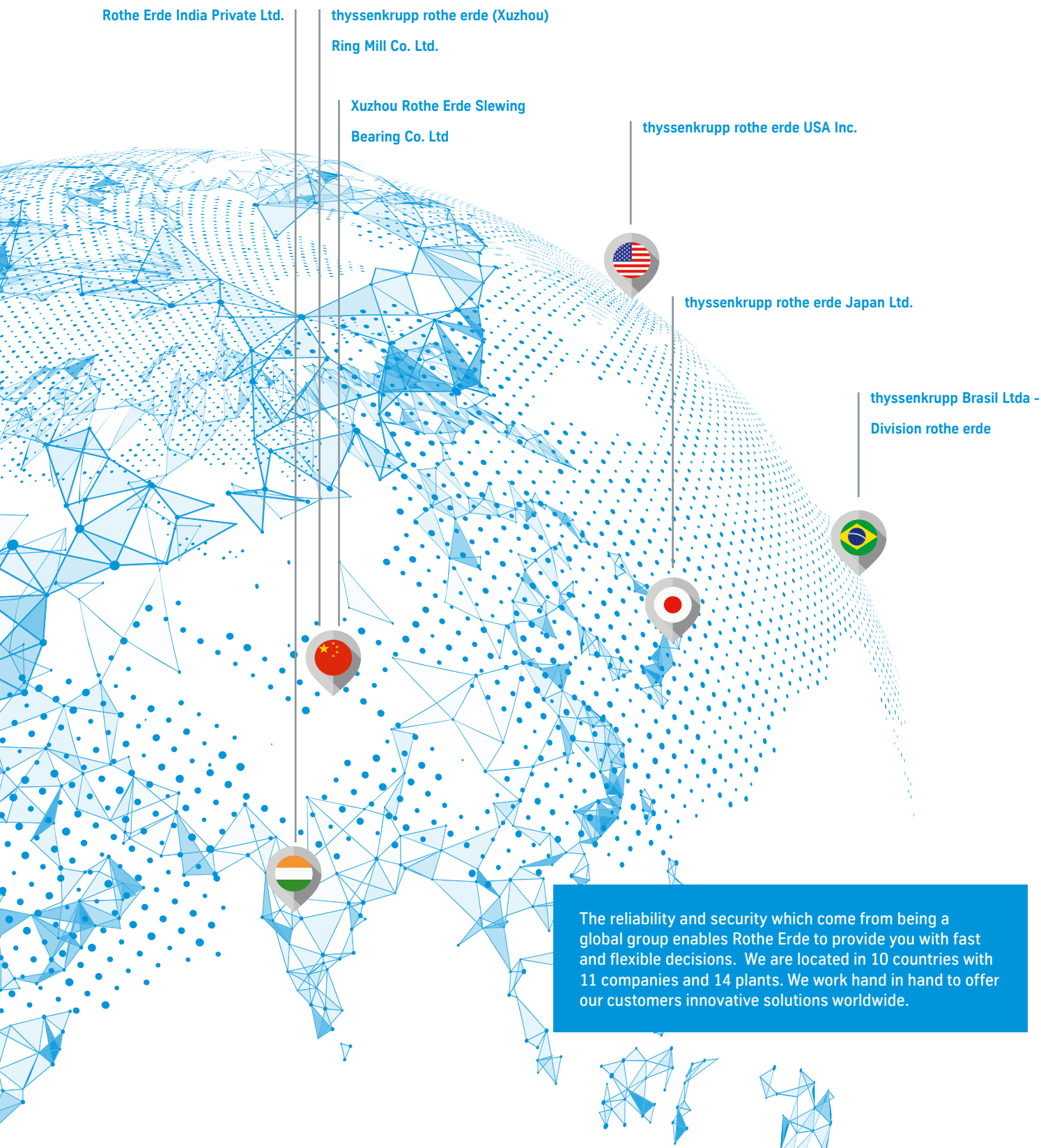
As part of a global group, we are a strong, reliable partner offering you stability and planning certainty for your projects. Our extensive knowledge base in a wide range of applications has made us a global leader.

You can find us where we are needed.

Our global brands rothe erde® slewing bearings, rothe erde® rings, rothe erde® main bearings, psl® rolling bearings and psl® gearbox bearings form the basis of long-standing customer relationships through our wide range of slewing and main bearings, rings and rolling and gearbox bearings and our individualized customer solutions.

The depth of production we can offer is impressive. All national and international plants are bound, without exception, by the quality concept. Experienced and highly specialized employees with proven know-how work for constant innovation and adhere to the highest quality standards in the world.

Our outstanding position enables us to tackle projects by interdisciplinary approach and to import technology from other sectors. Our company has been a reliable partner to all the manufacturers of wind energy equipment since wind energy was first used.



The reliability and security which come from being a global group enables Rothe Erde to provide you with fast and flexible decisions. We are located in 10 countries with 11 companies and 14 plants. We work hand in hand to offer our customers innovative solutions worldwide.

Wind turbine – onshore and offshore.

Along with innovative solutions for pitch and yaw bearings, the main focus lies on developing main bearings. Rothe Erde has been crucially involved in its role as the global market leader for slewing bearings. Intensive research and development has resulted in the successful deployment of Rothe Erde products in wind energy plants (both onshore and offshore) throughout the world.

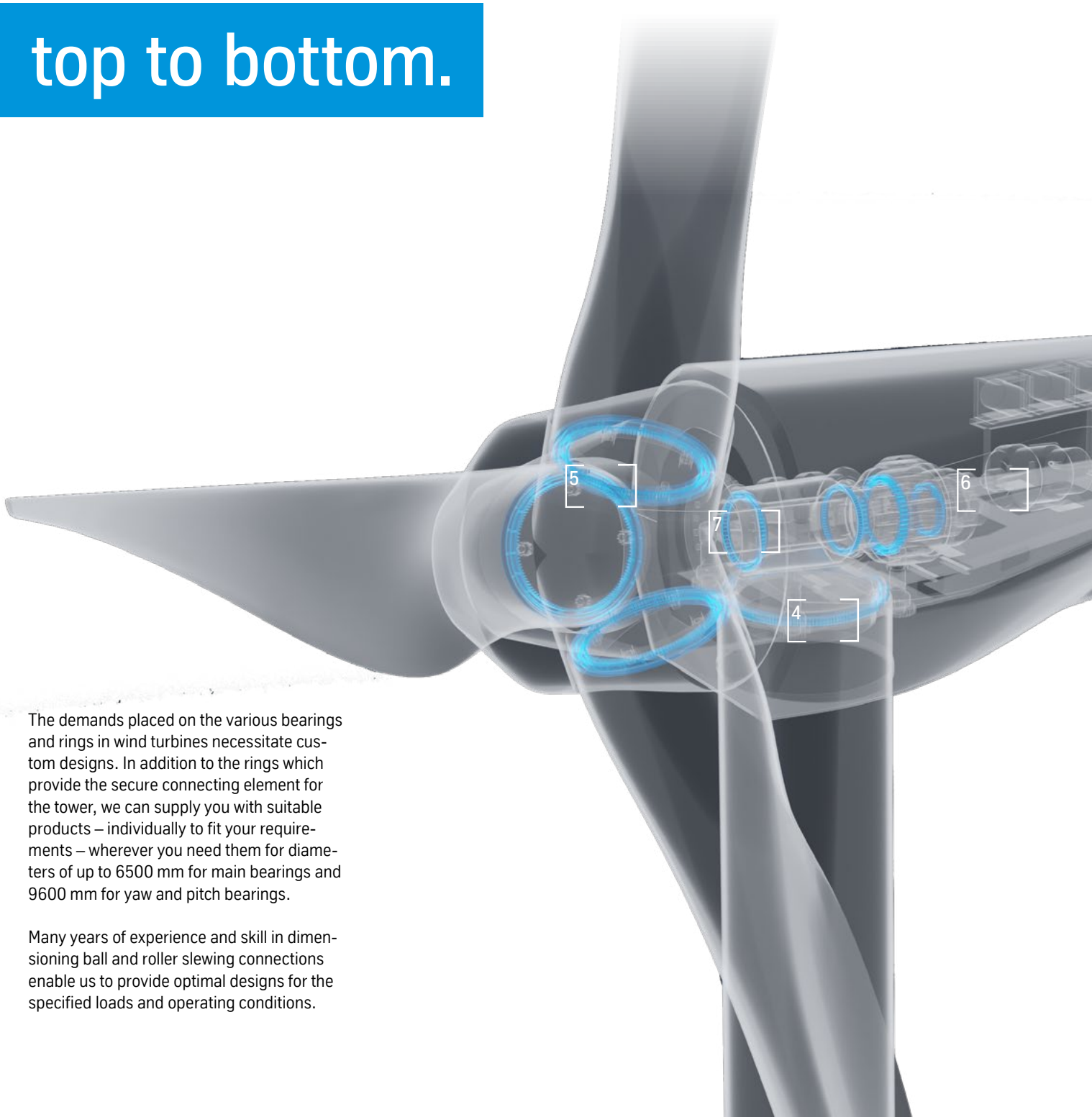
The driving force.

Finite resources and rising energy prices constitute a global challenge. At Rothe Erde we are taking on this challenge through our development of pioneering solutions.

With the aim of achieving advances in providing environmentally friendly energy, we are equipping increasingly efficient wind turbine throughout the world, which are now able to compete against fossil energy resources. We at Rothe Erde are a strong, progressive partner in the field of onshore and offshore systems. Our constant search for innovative breakthroughs enables our customers not just to be part of the new energy era but to advance it, and to make crucial contribution to securing a more environmentally friendly future.

The carbon dioxide (CO_2)-free energy gained through wind energy is now ever more important. Germany is not just the leader in this technology, but also uses wind as the top renewable source of energy. The company's commitment to renewable energies has made it a reliable partner to all the important wind turbine manufacturers since the sector came into being.

Wind turbine expertise – from top to bottom.



The demands placed on the various bearings and rings in wind turbines necessitate custom designs. In addition to the rings which provide the secure connecting element for the tower, we can supply you with suitable products – individually to fit your requirements – wherever you need them for diameters of up to 6500 mm for main bearings and 9600 mm for yaw and pitch bearings.

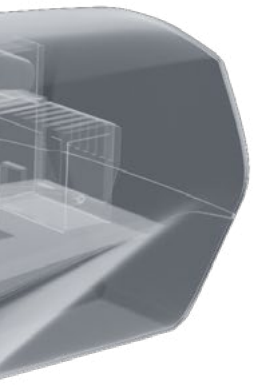
Many years of experience and skill in dimensioning ball and roller slewing connections enable us to provide optimal designs for the specified loads and operating conditions.

[7] Main Bearing

Rothe Erde uses patented production technology to manufacture induction-hardened raceways without soft spots on rothe erde® main bearings. The process is suitable for double-row taper roller bearings and three-row cylindrical roller bearings with diameters up to 6500 mm.

[4] Yaw Bearing

The rothe erde® yaw bearing is used primarily for positional adjustment, keeping the nacelle properly oriented in the wind. Single and double-row four-point contact ball bearings are ideally suited for these applications. Three-row roller bearings are used on MMW scale turbines.



[5] Pitch Bearing

rothe erde® pitch bearings are given a preload with defined torque resistance values during production as a means to prevent unwanted false brinelling. Special UV and ozone resistant double-lip-seals provide optimal protection for the raceway system.

Rotor pitch must be adjustable to produce maximum output from the generator. Pitch bearings in particular have to withstand the continuous load changes. Single and double-row four-point contact ball bearing and three-row roller bearings are ideally suited for these applications.

[1] Foundation bottom flange
[2] Tower flange
[3] Top flange
[4] Yaw bearing
[5] Pitch bearing
[6] Gearbox bearing, disks, spur and ring gears
[7] Main bearing

rothe erde® pitch bearings – Reliable blade pitch adjustment for optimal energy conversion.

Pitch bearings are the connecting elements between the rotor hub and the rotor blade of a wind turbine. To maximize power output from the generator at varying wind speeds, the pitch angle of the rotor blades must be adjustable. The primary functions of pitch bearings are to enable the blades to be adjusted, and to endure the high loads exerted on them.

The pitch bearings are subjected to heavy loads due to continuous load changes. To ensure reliable operation over the service life of the application, the pitch bearings from Rothe Erde are equipped with:

- preloaded raceways,
- wear-resistant cage inserts,
- special ozone and UV-resistant double lip seals and
- integrated internal or external gearing (on request).

Our rothe erde® pitch bearings undergo thorough inspection before delivery using advanced testing methods and efficient analysis tools. These tests provide us with essential data on load-bearing capacity, service life, performance, and operational limits.

Manufacturers of wind turbines face numerous challenges: intense competitive pressure demands ongoing cost reductions and supply chain optimization. Additionally, the trend towards larger wind turbines and their components, such as rotor hubs and blades, results in increased system deformations that can substantially affect the service life and performance of the pitch bearings.

Furthermore, the logistical requirements and transportation costs in the onshore sector are rising significantly due to the size of these components. We have identified these issues and developed a solution: The Pitch Bearing Unit.

Our Solutions

Double four-point bearing

Three-row roller bearing

PBU – The cutting-edge innovation in wind energy from Rothe Erde

- Modularization concept for a variety of pitch bearing designs and variable pitch drive concepts
- Cross-platform standardization of hub and pitch drive
- Reduction in hub size and therefore improved transportation options on the road
- Reduced effort with regard to hub production and assembly
- Enlargement of the blade root diameter for a given hub size
- Plug-and-play solution
- Simplified assembly & testing work on the construction site

Scan the QR code or use the link to learn more about our rothe erde® pitch bearing on our website:

www.thyssenkrupp-rotheerde.com/en/pitch-bearing

Gearbox bearings - Quality-critical components in planetary gearboxes for wind turbines

Gearbox bearings in planetary gearboxes are used to support various gearbox components such as high, intermediate or low-speed shafts, as well as components such as planet carriers and planetary gears.

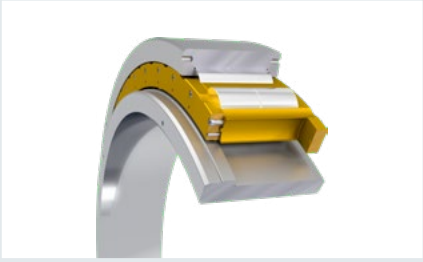
psl® Gearbox bearings are able to withstand the demanding operating conditions in terms of durability, quality and reliability, even in gearboxes with increasingly high power densities.

Cylindrical and tapered roller bearings are the most common models used in wind turbine planetary gearboxes. The tailored bearing design depends on several operational factors such as the load level, the operational speeds and the available space. Generally, single-row or double-row bearings are used for these applications. Cylindrical roller bearings without cages are preferred for slow-running shafts and high operational loads.

Due to the very limited internal space, special bearing solutions with integrated gearing can also be considered, which are characterized by their compact design.

Our Solutions

Double raw (multi-raw) tapered roller bearing



Single-row cylindrical roller bearing

rothe erde® main bearings – Reliable products from one of the world market leaders.

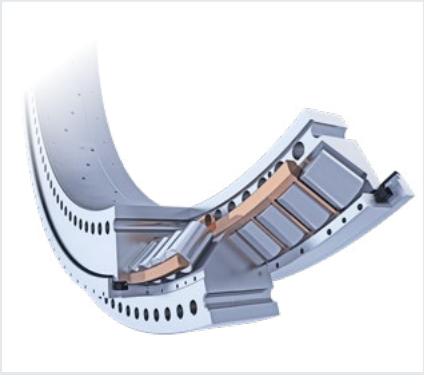
A main bearing must efficiently transmit the torque generated by wind power to the power generator, minimizing energy loss. It must also safely withstand high forces and tilting moments. Thus, the main bearing is the central component of the drive train concept.

Rothe Erde is in close cooperation with our customers, we develop the optimal bearing solution for the rotor shaft with a diameter of up to 6,500 millimeters in the following designs:

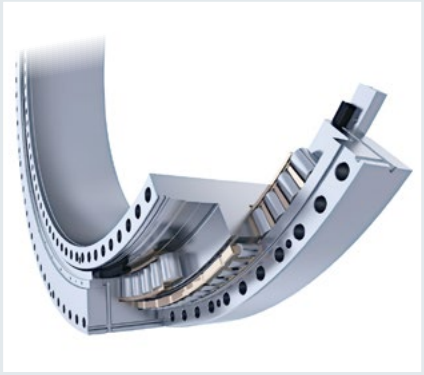
- single-row designs,
- multi-row designs,
- clamped internals,
- bolted internals,
- case-hardened raceways or
- slip-free induction-hardened raceways.

Our rothe erde® main bearings are always put through their paces before delivery: Utilizing the latest test methods and advanced analysis tools, we obtain crucial data on load capacity, service life, performance and utilization limits.

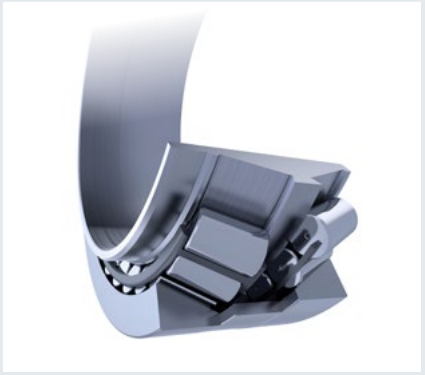
Our Solutions



Two-row tapered roller bearing in O-arrangement



Three-row cylindrical roller bearing



Two-row tapered roller bearing in X-arrangement

TRB-TRB –
The new generation of main bearings

TRB-TRB refers to an adjusted bearing arrangement (also called Main Bearing Arrangement /MBA or Main Bearing Unit / MBU) consisting of two tapered roller bearings (TRB).

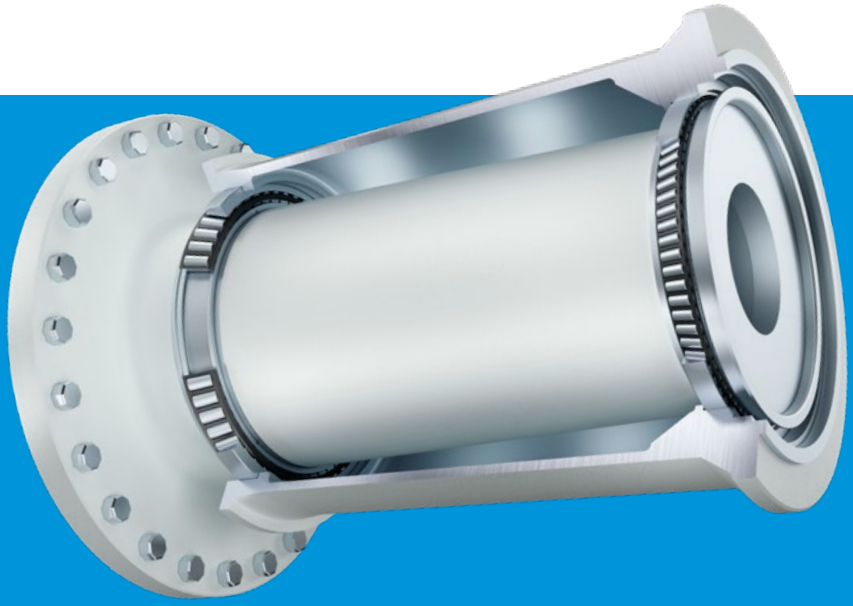
You would like to know: What is a TRB-TRB and when is it beneficial to use one?

Scan the QR code or use the link to learn more about our TRB-TRB on our website:

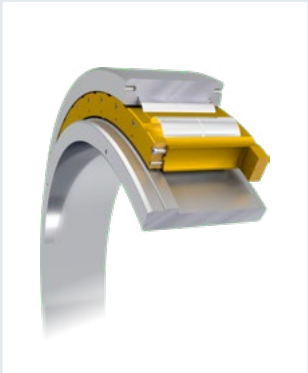
www.thyssenkrupp-rotheerde.com/en/main-bearing

TRB-TRB have the following properties:

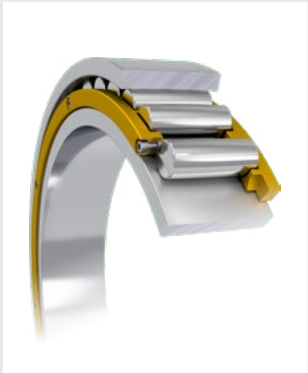
- long service life
- high rigidity
- low torsional resistance
- high load carrying capacity



Single-row tapered roller bearing



Cylindrical roller bearing



Toroidal roller bearing

Spherical roller bearing

Tailored solutions – not run of the mill.

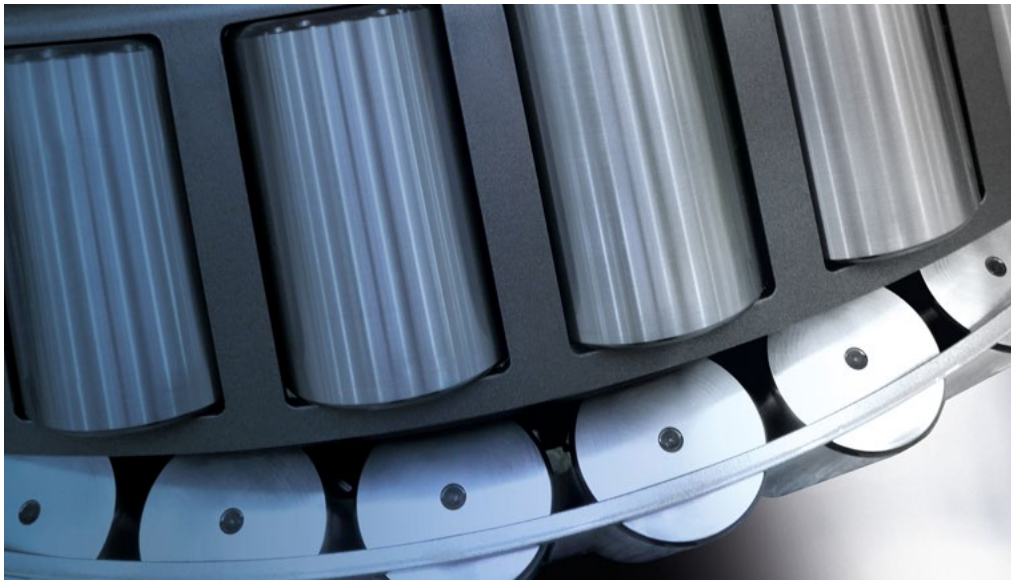
Specialized applications demand individual solutions. Our slewing bearings are developed and manufactured exactly to your requirements. In close consultation with you, we find unique solutions for the construction, material composition and performance.

To cater for this we have different designs, hardening processes and configurations available – which have all been subjected to intensive testing and proven in field throughout the world

We believe that solutions should be designed to fit the customer's requirements from planning to manufacture and beyond. As a global group in 10 countries with 11 companies and 14 plants, we are able to maintain close contact with our customers by virtue of our local presence. Through decades of expertise gained in the wind energy sector, we are capable of finding efficient and innovative solutions in cooperation with you.

Rothe Erde relies on APQP4Wind to minimize risks. APQP4Wind is an initiative of the Danish Wind Industry Association and leading wind turbine manufacturers for the transparent implementation of customer requirements within the development, planning, and production processes.

The aim is to reliably meet customer requirements even before the product enters into series production. APQP (Advanced Product Quality Planning) originated in the automotive industry, where it was established as a standard. With APQP4Wind, this standard is adapted to the special requirements of the wind industry and significantly lower volumes. Rothe Erde has been one of APQP4Wind's first component suppliers since its inception in 2017 and has been working to establish the standard ever since. Requirements of APQP4Wind were successively implemented and the employees were fully trained.



At the beginning is the raw material steel - but not all steels are the same. Only individuals with the relevant knowledge of materials can recognize and make full use of all the technical options.

Production chain – all from one source.

With us, you choose a partner capable of covering the entire production chain. From raw materials to the finished product, all-the main components of the slewing bearings are manufactured in-house.

For the manufacture of our slewing bearings we only use steels whose suitability for the respective application has been proven beyond a doubt. Inspections are made throughout the entire production chain. The steel used is of the highest purity with minimal oxygen and sulphur content in order to prevent long-term material fatigue. In the case of large-dimension bearings and rings this secures the optimal combination of hardness and fracture strength. Once we have selected and manufactured the correct material, our rolling mills manufacture the rings. These rings form the basis for further production stages of machining through to finishing and assembly.

In addition to rings we manufacture all the other components, such as balls, rollers and cages at our plants. This guarantees very strict quality control and traceability throughout the entire production process. In addition, the great vertical production range enables lead times to be shortened considerably with the accompanying improvement in planning ability. Knowledge of the materials and components, their properties and composition guarantees innovative results which can be achieved in close collaboration with the customer. This ensures that you will receive complete solutions from a single source, with all require-ments catered for, right down to the smallest detail.

Only individuals who are able to view the entire production chain in detail are capable of providing you with effective advice to satisfy your requirements. With this knowledge we are able to assist and advise our customers through all project phases from initial advice on planning the system to its construction and ins-tallation. Our services continue after shipment has taken place. Trained and experienced service inspectors are available to assist you with all questions.

Hard shell – tough core.

Our employees use specially developed hardening processes to give our slewing bearings, roller bearings, slew drives and rings a very high surface hardness. This ensures a long service life for our products. Our specialists also adapt the hardening depth to the application. This means that our bearings and rings can also withstand extreme loads and are optimized for all areas of application.

Our plants offer a full range of thermochemical and inductive processes to achieve the desired results. Targeted carburization and austempering lead to optimal material characteristics from the required hardness to the correct toughness. Cooling processes then achieve an obvious reduction in the retained austenite and eliminate possible weaknesses throughout the entire raceway geometry.

Specific sections of certain workpieces can even be provided with different, and hence exactly suitable, hardening profiles using non-slip induction hardening, and this can be done on diameters of up to 6500 mm.

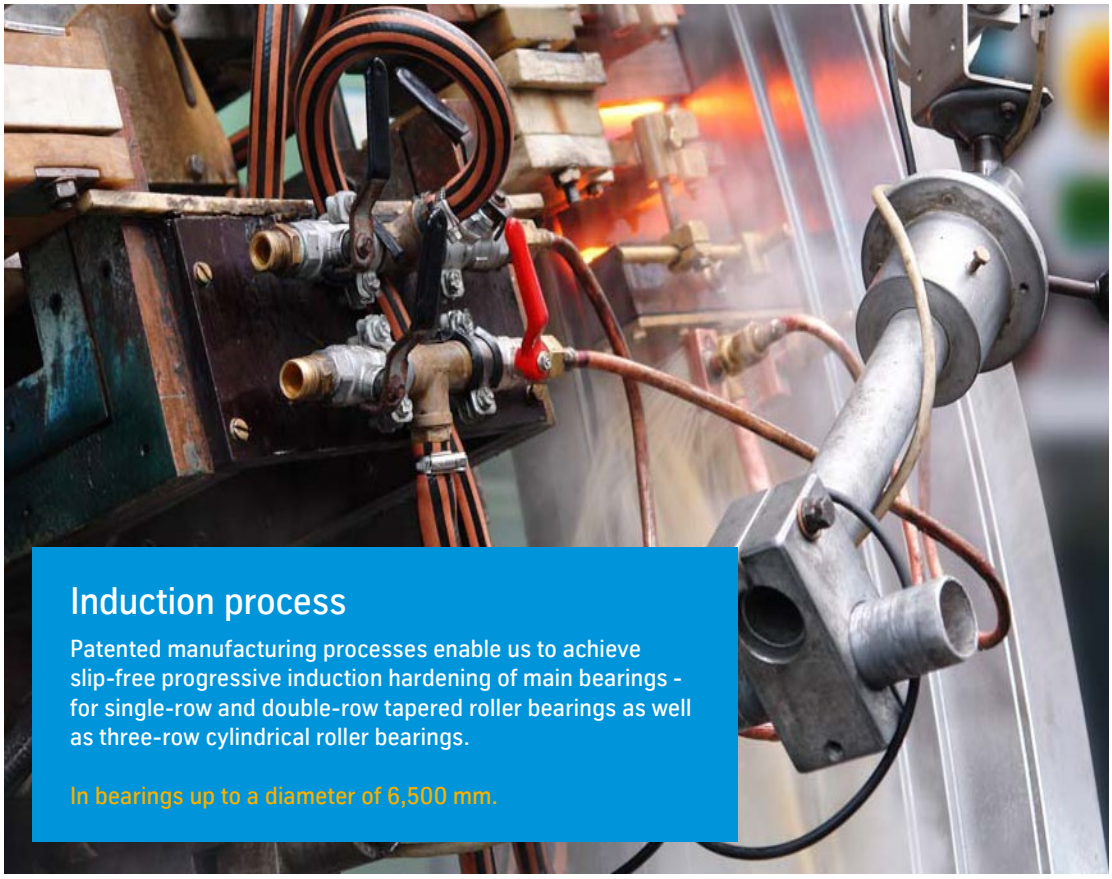
Case-hardening

We harden entire bearings through targeted carburizing and a controlled cooling process.

Through-hardening

After heat treatment, rapid and controlled cooling takes place. Depending on the cooling process, a martensitic or bainitic structure is created in the entire bearing.

In bearings up to a diameter of 4,000 mm.



Induction process

Patented manufacturing processes enable us to achieve slip-free progressive induction hardening of main bearings - for single-row and double-row tapered roller bearings as well as three-row cylindrical roller bearings.

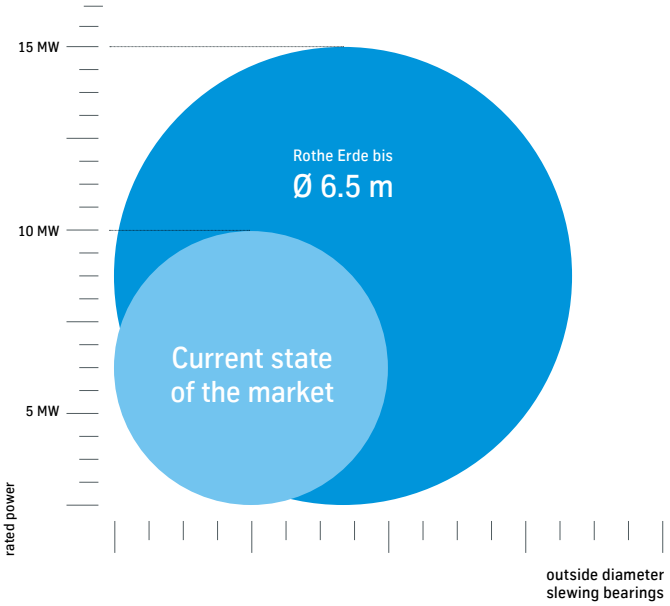
In bearings up to a diameter of 6,500 mm.

Commitment to quality – we meet customer requirements.

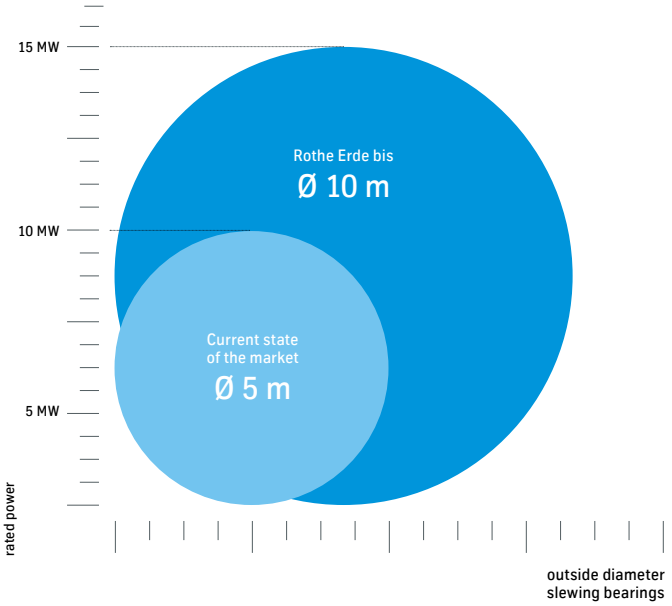
R&D Center

Rothe Erde owns one of the world's largest R&D facilities to ensureim-portant testing can be carried out quickly and efficiently.

Production possibilities for main bearings



Production possibilities for pitch bearings



While the growth of wind turbine size has brought the established processes and technologies close to their limits, Rothe Erde has steadily continued developing its bearing concepts.

The bearing concepts at Rothe Erde are continuously being developed further. For example, both the inner and outer ring of bolted main bearings can be bolted to the adjoining construction.

Prior to shipping, our slewing bearings are thoroughly tested in every possible aspect. The latest testing methods and efficient forms of analysis offer valuable clues to stability, service life, performance and load limits. The tests are performed in the full-size plant under realistic conditions, with thorough inspection of the individual components.

Environmental factors such as temperature and air humidity are included in the tests. We are able to examine the slewing bearings on a scale of 1:1 under conditions approxmating reality using a number of in-house pitch and main bearing test benches.
To include new developments for systems in the multi-megawatt class,Rothe Erde was careful to increase its production capacity at an early stage.

This is where we test the future.

In order to test our products as realistically as possible and thus minimize the risk for our customers, we rely on tests with real companion structures on a scale of 1:1. In addition to several rotor bearing test benches, a new pitch bearing test bench considerably expands our possibilities.

There, we receive the possibility to test the next generation of pitch bearings by using an original hub and an original blade of an off-shore wind turbine. This includes all designs as well as the challenges for systems >10 MW. It is possible to simulate the required service life within months. With these opportunities, Rothe Erde has developed a test center that is unique worldwide. In addition to testing the specific components, the results are directly incorporated into our calculation methods and thus serve as validation for all rothe erde® pitch, yaw, and main bearings.

Additionally, we investigate and improve the structural behavior and lubricant compatibility of our products on site, thus providing you the bearings of the next generation.

End-to-end service for maximum safety.

From installation, inspection, maintenance and refurbishment, to training courses, our service concept covers the entire spectrum. It is divided into three areas:

In-house service

We take care of inspection and refurbishment work on your bearings in our factories, independent of the manufacturer. With additional services such as in the preparation of installation, lubrication and maintenance instructions, as well as lubricant analyses, we enable you to handle the bearings professionally and safely.

Proactive service

In addition to the actual work on slewing bearings, we develop service concepts for you, analyze the condition of the bearings in your application, and provide you with detailed reports. Our customized service concept can include elements such as training and service reminders.

On-site service

We can also carry out all of the specified work on your premises. On request, we can provide supervision during the installation or exchange of the bearings in your system.

Scan the QR code or use the link to learn more about our Service on our website:

www.thyssenkrupp-rotheerde.com/en/service

Flexibility

As we see it, being flexible means consistently implementing our customer's wishes and requirements. We tackle every task that you set us professionally, cost-effectively and on time. Our service team not only takes care of slewing bearings manufactured in-house, but also inspects, maintains and repairs all your bearings, regardless of the manufacturer. We can also optimize previously installed bearings on request.

International profile

We're there for you wherever you need us. We currently have seven service locations in Europe, the USA, Brazil, China, India and Japan, and are continuously expanding our network. You benefit from a fast response time, usually within 24 hours.

Experience

We have decades of experience not only in bearing design and manufacture, but also in inspections, maintenance and refurbishment. Our service team experts work for our customers worldwide. We also have qualified personnel who can handle special tasks, such as work on offshore systems, wind energy and special technology.

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