MOTION & CONTROL™

NSK

PREMIUM TECHNOLOGY FOR THE WIND INDUSTRY

As one of the world's leading manufacturers of rolling bearings, linear technology components and steering systems, we can be found on almost every continent – with production facilities, sales offices and technology centres – because our customers appreciate short decision-making channels, prompt deliveries and local service.

The NSK company

NSK commenced operations as the first Japanese manufacturer of rolling bearings back in 1916. Ever since, we have been continuously expanding and improving not only our product portfolio but also our range of services for various industrial sectors. In this context, we develop technologies in the fields of rolling bearings, linear systems, components for the automotive industry and mechatronic systems. We have been supplying rolling bearings for wind turbines since the late 1980s. Today our products are rotating all over the world and are moving us closer to our goal: zero energy loss from friction. Our research and production facilities in Europe, America and Asia are linked together in a global technology network. Here we concentrate not only on the development of new technologies, but also on the continuous optimisation of quality – at every process stage.

Among other things, our research activities include product design, simulation applications using a variety of analytical systems and the development of different steels and lubricants for rolling bearings.

Individually tailored solutions without compromising on quality.

Wind turbines generate electricity under adverse and constantly changing conditions, both on- and offshore. Efficient power generation demands top performance from every component – especially bearings. NSK bearings have built a global reputation on dependability, resistance to heat and seizure, exceptionally long life and environmentally sound design.

Service-oriented organisation – the Wind Energy Team

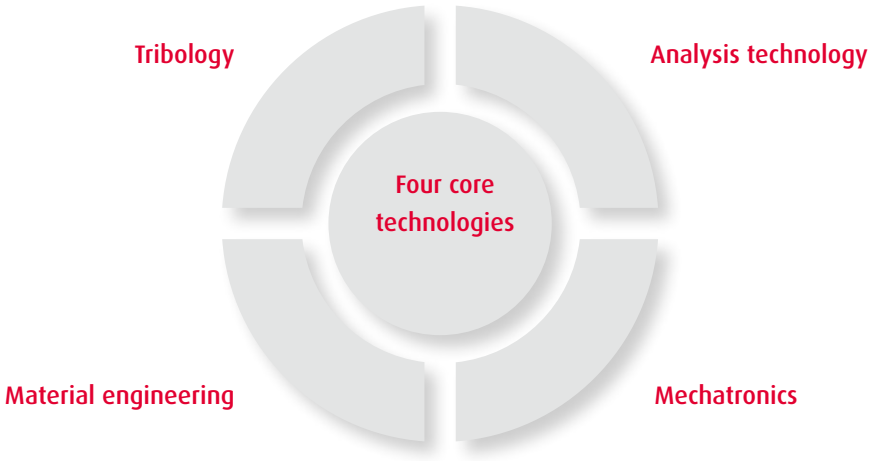
The Wind Energy Team bundles sales and application engineering activities to ensure integrated support for our customers in the wind energy sector. The results of research from our technology centres are combined here under one roof. Moreover, we use our worldwide network of subsidiaries to ensure global support for our customers. The production operations are extremely flexible thanks to the deployment of highly adaptable manufacturing technology. The same holds true for our test rigs, where we can also conduct tests on large and giant bearings for wind power plant rotor shafts under a variety of conditions.

Expanded production capacities

An additional plant was opened in the summer of 2008 in Fujisawa, Japan, in order to be optimally prepared for our customers' increasing demand for large bearings. This state-of-the-art and eco-friendly factory produces a large share of the NSK rolling bearings used in the wind industry. Excellent quality in all processes and a high degree of flexibility are our guiding principles in this regard.

Premium technology for the wind industry.

NSK is among the leaders when it comes to the development of rolling bearings that are even more reliable, longer lasting and robust – even at high speeds. In our research centres in Europe, America and Asia, we conduct research and development in four core technology areas:

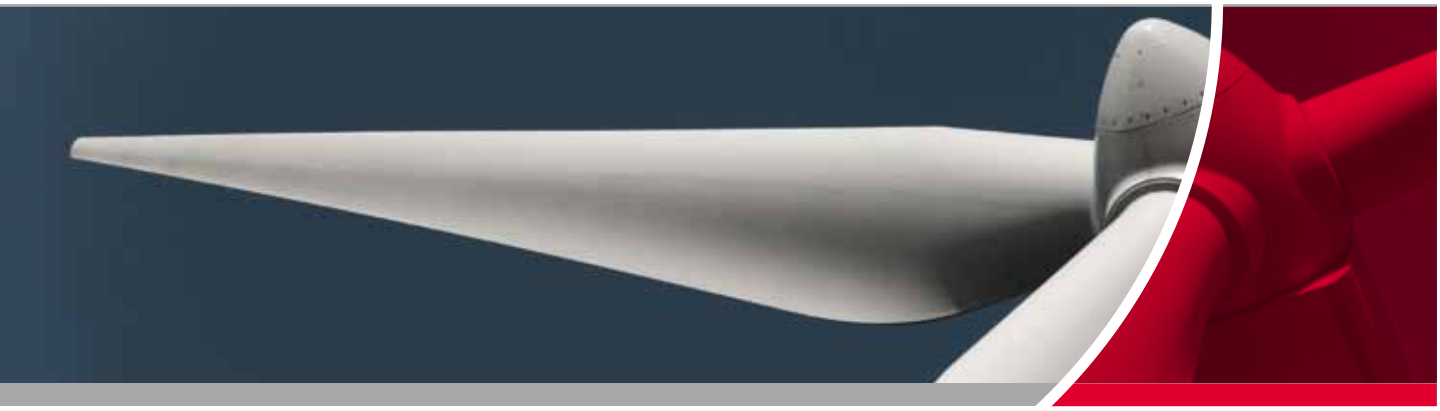


› **Tribology**
Lubrication is crucial for rolling bearings designed to support linear and rotary motion. Improved lubricant formulations and surface treatment processes enable us to develop even faster, quieter and longer-lasting rolling bearings which are also capable of withstanding the highest possible stresses.

› **Material engineering**
Materials science is undergoing continuous further development aimed at improving the functionality and strength of rolling bearings. And NSK ranks among the leaders. Our research is concentrated in the fields of material composition, heat treatment, performance evaluation and analytical assessment. The results of this research are then applied to new products.

› **Analysis technology**
In product development, analytical studies – primarily computer simulations – are indispensable. We use them to simulate the behaviour of products under extreme ambient conditions and gain valuable insights relative to product design and manufacturing processes.

› **Mechatronics**
Mechatronics – This combination of mechanics and electronics is creating new, groundbreaking solutions for high-performance engines, control system technology, precision sensors and biomedical micro-electro-mechanical systems. Mechatronics also play a role in assembly technology for applications that call for high temperatures, power density and reliability.



Investments in these four core technologies are really paying off for the wind industry:

Material engineering

It is well known that the rolling fatigue life of high carbon chromium bearing steel (SAE52100, SUJ2) used for rolling bearings is significantly affected by non-metallic inclusions. Life tests show that oxide non-metallic inclusions exert a particularly adverse affect on rolling fatigue life. Z Steel, with lower oxide non-metallic inclusions, exhibits improved performance. Z Steel is produced by reducing non-metallic inclusions, oxides and other inclusions such as Ti, or S, inside the steel. Bearings made of this steel deliver significantly extended service life, up to 1.8 times longer, compared to conventional vacuum degassed steel. Super Tough (Super TF): As a result of the higher chromium and residual austenite content, the service life of a bearing made of Super TF material is up to ten times longer than for one made of standard material. Super TF technology can be used in a wide range of bearing designs, including cylindrical roller bearings, taper roller bearings, spherical roller bearings, deep groove ball bearings and angular contact ball bearings.

Electrically insulated rolling bearings

In cases where standard bearings are exposed to electrical corrosion, e.g. in the generators of wind turbines, rolling bearings with ceramic coating or hybrid bearings are used. With ceramic-coated rolling bearings from NSK, the ceramic is applied by plasma spraying to achieve secure bonding to the bearing steel. The ceramic coating is covered with an acrylic resin that ensures high electrical resistance. Hybrid bearings that use ceramic balls feature outstanding performance characteristics, such as thermal resistance, longer service life, light weight and low thermal expansion. Moreover, the ceramic balls are not electrically conductive. This makes these hybrid bearings also particularly well-suited for use as generator bearings. We use the ceramic material silicon nitride (Si3N4) for the rolling elements in hybrid bearings.

Test rigs

With the constantly increasing performance of today's wind turbines, tailor-made bearing designs are essential. NSK tests the properties of these rolling bearings on application-specific test rigs that simulate actual operating conditions.

Rotor shaft bearing test stand

Rolling bearings designed for use in multi-megawatt turbines can be thoroughly analysed on this test stand. Radial and axial loads and bending torques can be applied, whereby the loads can act statically and dynamically.

Test stand for high-speed shaft rolling bearings

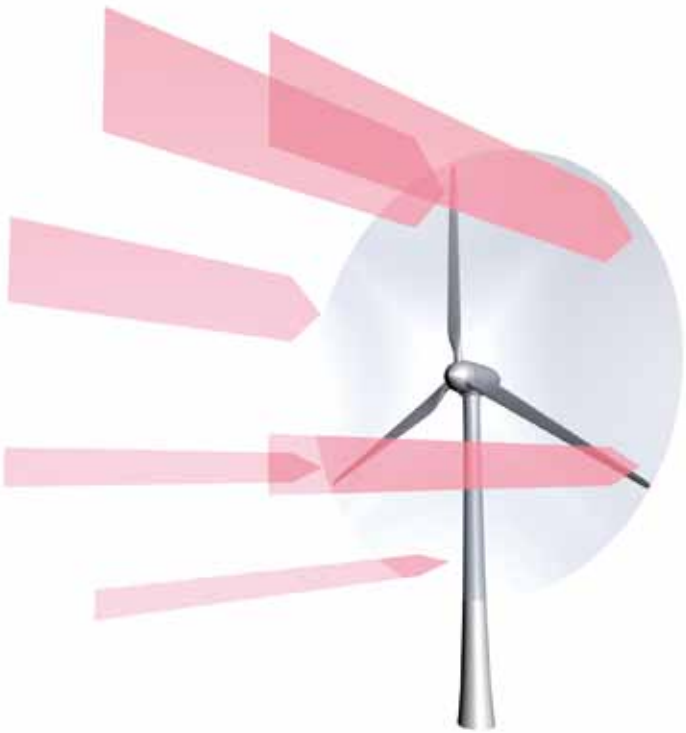
The rolling bearings used on the high-speed shaft can be tested on a specifically designed test rig. Just as with the rotor shaft bearing test stand, static and dynamic forces as well as torques can be applied to the rolling bearing.

Formation of damage on the surface

Formation of damage below the surface

A further invention: STIFF

Having selected the bearing type, the next step is to determine the required bearing size and bearing design to come to a solution that considers all aspects for high capacity and efficient design. One criterion is of paramount significance: estimating bearing life.

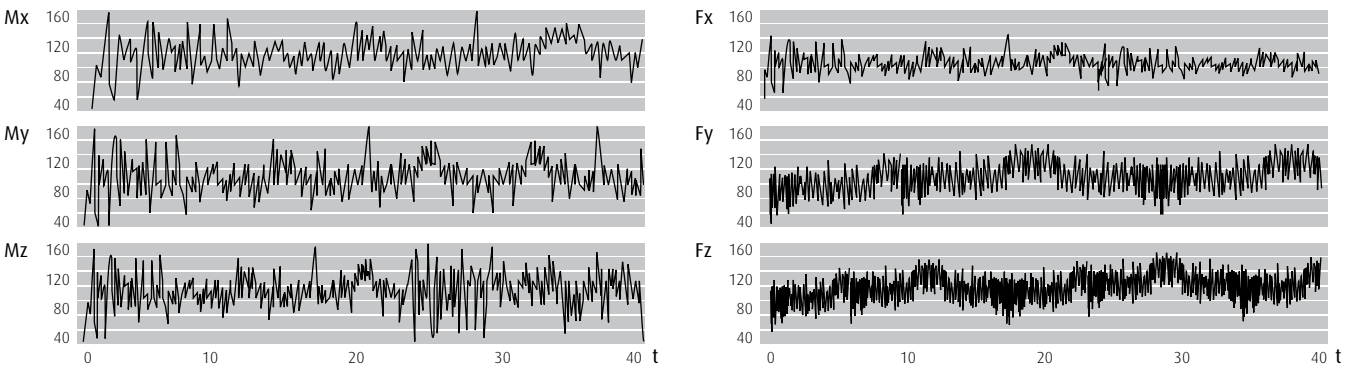


Wind velocity depends on rate, place and time, and results in considerable dynamic load impacts affecting the wind turbine as well as subassemblies, including the rolling bearings.

For a long time experts have been aware of the fact that many features need to be considered for an estimation to be reliable. NSK's latest developments include optimised methods and calculation procedures that increase accuracy for estimating bearing life.

Classic calculation methods

Conventional standardised calculation methods for determining bearing life are also referred to as the catalogue method. These are stipulated in ISO 281. The parameters involved are: bearing load, speed, load rating and bearing type. The bearing life figures that result are: L10 or L10h.



Planet gears are often thin-walled, highly stressed machine elements. Evaluation of planet gear deformation can be used to adapt the inner geometry of the bearing arrangement in a way that achieves uniform load distribution, thereby increasing bearing service life.

Innovation: STIFF

In ISO 281, annex 4, the calculation of modified service life rating is based on simplified rolling bearing geometry. In order to increase the accuracy of the results of these calculations, NSK has developed the so-called STIFF software is a program that takes the abovementioned parameters into account along with the exact interior geometry, operating clearance and pre-load, deformation of the shaft bearing system, load area and the load distribution between rolling elements and raceway. This model divides the rolling elements into cross sections. A modified service-life rating is determined for each cross section. These data are then integrated using the time components for each instance of loading.

For bearing arrangements in the gearboxes of wind turbines, the modified service life must be 175,000 hours, i.e. 20 years. The scope of the calculation software is impressive and the application delivers results that enable rapid parametric analysis. The system also makes it possible to save time when testing special rolling bearing adaptations.

Practical tools

Another example of calculation methods employed by NSK is FEM analysis. Finite Element analysis examines the distribution of stress factors within the bearing and its components and thus provides optimum support for non-standard applications.

Frequency analysis, on the other hand, examines noise generation of the rolling bearing within the application. From the analysis results performance and operating characteristics of the bearing system can be understood.

The TCOS (Technical Compating Online Service) is a collection of calculation programs for the online analysis and calculation of rolling bearings from a large number of perspectives.

Every solution calls for the right products.

Whether for the main drive stage or accessories, our broad product range delivers precise solutions for a wide variety of applications.

Rotor shaft main bearings

The rotor induces high axial and radial loads in the main bearings, which occur both statically and dynamically. Given such loads as these, high bearing stiffness is indispensable. Spherical, cylindrical and taper roller bearings mounted either in the classic fixed end/loose end bearing arrangement or in a floating bearing arrangement are particularly well-suited for this application.

Main gearbox bearings

A variety of gearbox arrangements have been implemented for wind turbines in recent years. Megawatt-class systems often combine a planet gear stage with multiple spur gear stages. In today's multi-megawatt class, planetary gear stages are connected with spur gear stages. This approach also facilitates differential transmissions. Deep groove ball bearings, spherical roller bearings, cylindrical roller bearings, taper roller bearings and four-point contact ball bearings are used, depending on the location of the bearing.

Oil pump bearings

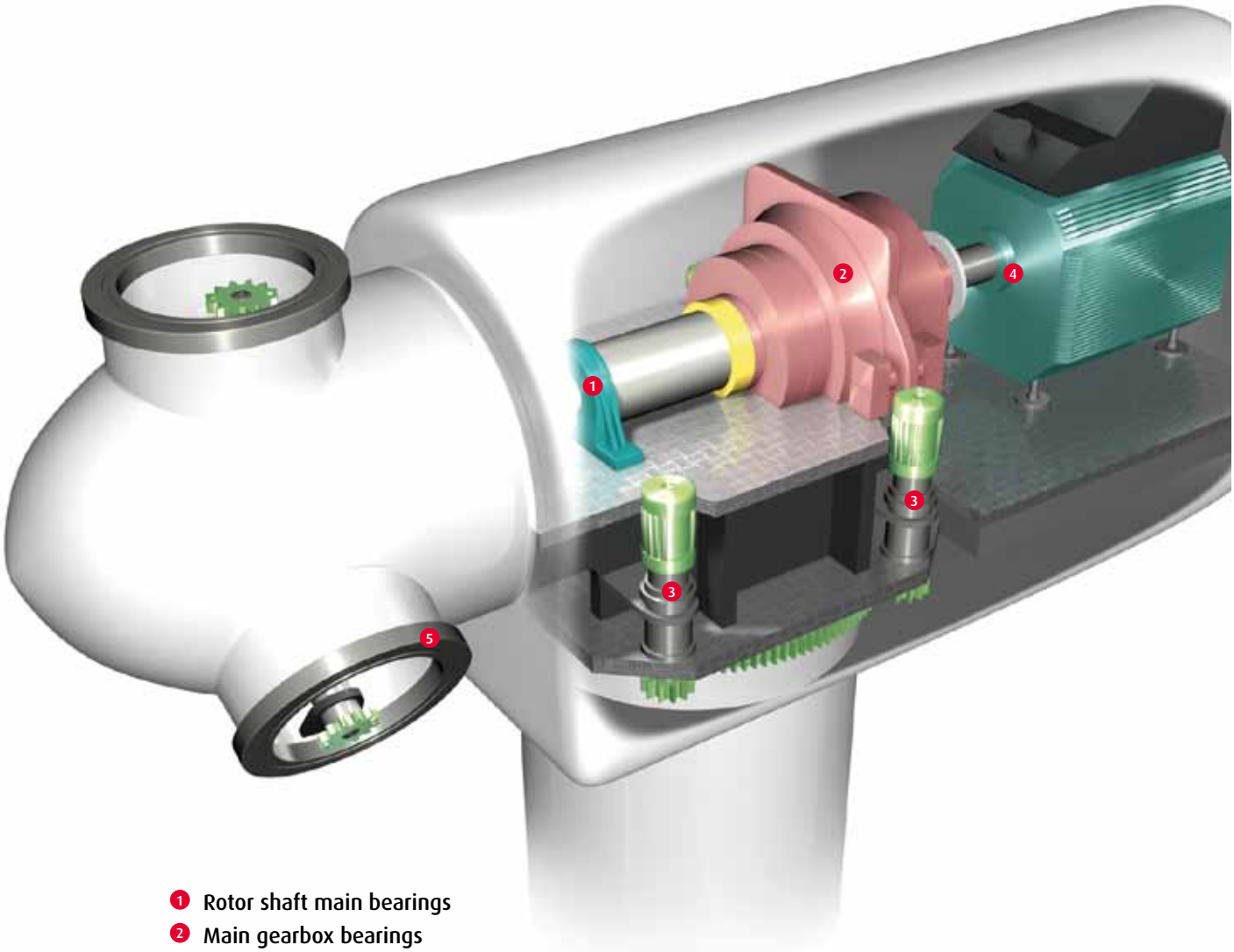
The gear teeth used to drive the pump exert radial and axial forces on the deep groove ball bearings, cylindrical roller bearings or taper roller bearings in this application.

Generator bearings

Generators primarily use deep groove ball bearings and cylindrical roller bearings. Transmission of electrical current can damage the rolling bearings and shorten their service life. In order to avoid this damage, the use of insulated rolling bearings should be considered. We offer hybrid bearings with ceramic rolling elements as well as coated rolling bearings where an insulating coating has been applied to the outer rings.

Pitch and yaw gearbox bearings

Yaw gearboxes turn the nacelle into the wind or away from it. Pitch gearboxes are required for rotor blade adjustment. Deep groove ball bearings, cylindrical roller bearings, spherical roller bearings and taper roller bearings are typically installed in these gearboxes.



1. Rotor shaft main bearings
2. Main gearbox bearings
3. Yaw gearbox bearings for tower adjustment
4. Generator bearings
5. Pitch gearbox bearings

Deep groove ball bearings

Suitability

- Low to medium radial loads
- Smaller axial loads in both directions
- Very high speeds

Applications

- Gearbox bearings
- Generator bearings

Design

- Cage made of steel, solid brass or plastic
- Electrically insulated roller bearings
- Outer diameters up to 2500 mm

Spherical roller bearing

Suitability

- Very high radial loads
- Axial loads in both directions
- Medium speeds

Applications

- Gearbox bearings
- Rotor shaft bearings

Design

- Cage made of steel or solid brass
- HPS™ (High Performance Series) with higher load ratings and extended speed range
- Optimised NSK design of rollers and cage for large rotor shaft bearing arrangements
- Outer diameters up to 2500 mm

Cylindrical roller bearing

Suitability

- High radial loads
- For small to medium axial stresses in one or both directions, depending on the type of construction
- High speeds

Applications

- Gearbox bearings
- Generator bearings
- Rotor shaft bearings

Design

- Full complement
- Multi-row
- EM (solid brass cage) and EW (steel cage) series with higher load ratings
- Newly developed high-capacity rolling bearings with load ratings beyond those of the EM and EW series
- Outer diameters up to 2500 mm

Four-point contact ball bearing

Suitability

- High axial loads in both directions
- Medium speeds

Applications

- Gearbox bearings

Design

- Brass cage
- Various pressure angles

Taper roller bearing

Suitability

- High radial and axial loads in one direction
- Axial loads in both directions when arranged in pairs
- Medium speeds

Applications

- Gearbox bearings
- Rotor shaft bearings

Design

- Metric and imperial dimensions
- Patented NSK HR taper roller bearings with higher load rating
- NSK cage design optimised for large taper roller bearings installed in planetary carriers
- Steel cage
- Segmented plastic cage for inner diameters of more than 1000 mm
- Outer diameters up to 2500 mm

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