

# Premium Technology for the Wind Industry



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As one of the world's leading manufacturers of rolling bearings, linear technology components and steering systems, NSK can be found on nearly every continent with production facilities, sales offices and technology centers.



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## The NSK company

NSK commenced operations as the first Japanese manufacturer of rolling bearings in 1916. Since then, we have been continuously expanding and improving not only our product portfolio but also our range of services for strategic industrial markets across the globe. In this context, we develop technologies in the fields of rolling bearings, linear systems, components for the automotive industry and mechatronic systems.

NSK has 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 America, Europe and Asia are linked together in a global technology network. Here we concentrate not only on the development of innovative technologies, but also on the continuous optimization of quality at every process stage.

NSK's research activities include product design, simulation applications using a variety of analytical systems; development of specialty steel, unique heat treatment and lubricants for rolling bearings. To validate our concepts, our engineers employ state of the art testing capabilities to assure that your designs meet your goals.

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# 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 has built a global reputation for reliability and exceptionally long life.

## The Wind Energy Team

The Wind Energy Team bundles application engineering and service activities to ensure integrated support for our customers in the wind energy segment. Combined with research results from our technology centers, we maximize delivery of technology to the user. Moreover, we use our worldwide network of subsidiaries to ensure global support for our customers. NSK's production operations are extremely flexible thanks to the deployment of the most modern and highly adaptable manufacturing technologies. The same holds true for our test facilities, where we conduct tests on large bearings for wind power plant rotor shafts under a variety of severe operating conditions, monitoring both life and lubrication performance.

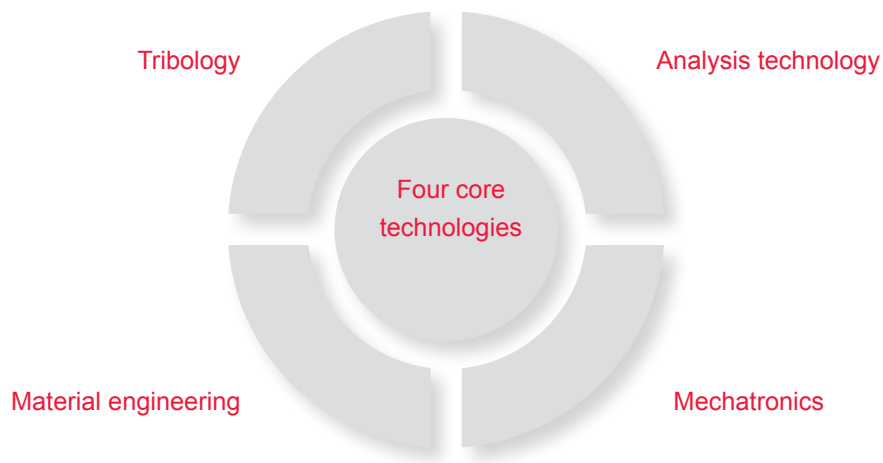
## Advanced Manufacturing Systems

NSK's newest wind energy bearing 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 NSK rolling bearings used in the wind industry. This new facility employs the latest in heat treating, grinding and super finishing equipment. As a result, our customers benefit from excellent quality in all processes and are assured that NSK's products exceed the application requirements. In addition, manufacturing flexibility within the plant allows us to meet your delivery requirements.



# Premium Technology for the Wind Industry

NSK is a leader in the development of rolling bearings that need to be more reliable, longer lasting and robust in extreme environments and applications. At our research centers in Europe, America and Asia, we conduct research and development in four core technology areas:



## › Tribology

Tribology is the science of lubrication, wear and friction in bearings. It is crucial for rolling bearings designed to support axial and radial loads and meet the life requirements of the application. Improvement in lubricants and surface conditions, enable us to develop faster, quieter and longer lasting rolling bearings which are also capable of withstanding the highest possible stresses and speeds. Our engineers' research into this field yields significant advancements to meet the demanding needs of wind applications..

## › Materials Science

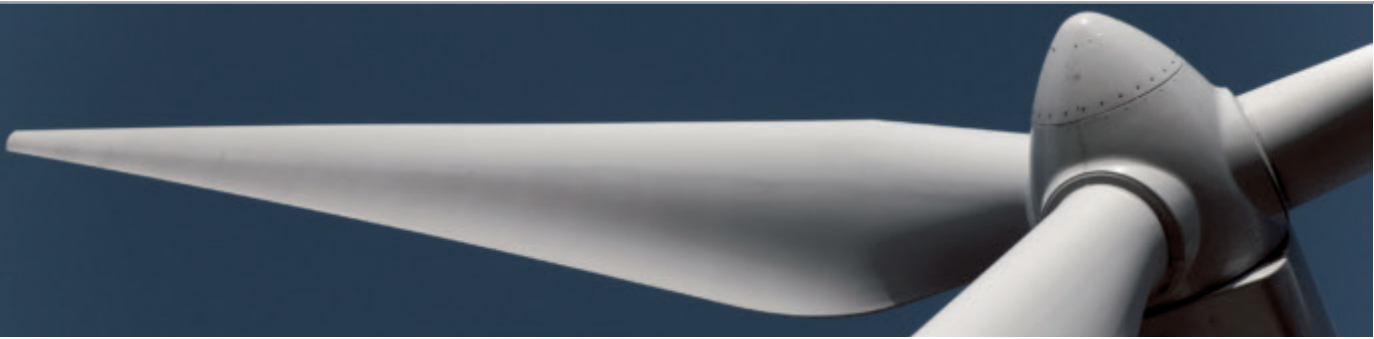
Material Science undergoes continuous development aimed at improving the functionality and strength of rolling bearings. NSK ranks among the leaders. Our research is concentrated in the fields of material composition, heat treatment, performance evaluation and analytical assessment. The results of this research are then applied to new products. As a result, bearings produced by NSK offer the longest life in difficult applications.

## › Analysis technology

In product development, analytical studies, primarily computer simulations, are indispensable. NSK has developed and uses sophisticated programs including, Finite Element Analysis (FEA), to simulate the behavior of bearings under extreme ambient conditions and gain valuable insights into product design. This allows our products to reduce your risk by making them suitable for demanding applications before the challenges of the application cause a redesign.

## › Mechatronics

Mechatronics is the development of machines and machine components that utilize many of NSK's technologies. The combination of mechanics and electronics is creating new, groundbreaking solutions for high-performance engines, control system technology, and biomedical micro-electromechanical systems. Mechatronics also play a role in assembly technology for applications that call for high temperatures, power density and reliability.

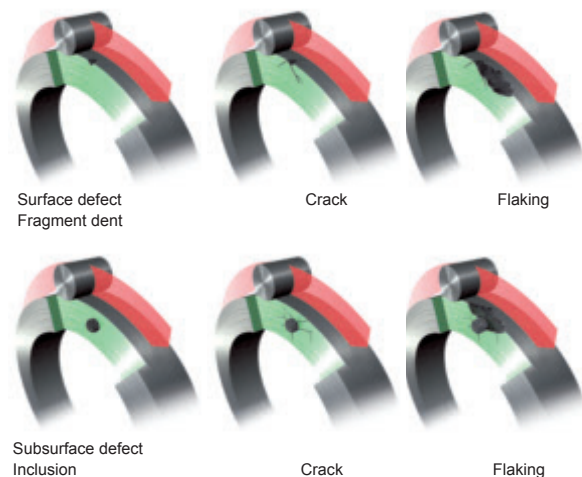


Investments in these four core technologies are really paying off for the wind industry:

### Material engineering

It is well known that the rolling fatigue life of high carbon chromium bearing steel (ASTM 52100, JIS SUJ2) used for rolling bearings is significantly affected by non-metallic inclusions. Life tests show that non-metallic inclusions significantly reduce rolling elements 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 oxides of O, Ti, or S in the steel. Bearings made of Z steel deliver up to 5 times longer service life when compared to conventional vacuum degassed oxides of steel.

### Crack generation from surface and sub-surface defects



Failures arise from both surface and sub-surface defects. Utilization of NSK's material science, understanding of tribology and state of the art production systems reduce that chance that these defects result in bearing failure.

### Super Tough Steel for Wind Applications

Wind gear boxes exhibit unusual failures in certain positions. Super Tough Steel, an NSK proprietary material and heat treatment process, is designed to meet the needs of wind gear boxes. As a result of the higher chromium and retained austenite content, the service life of a bearing made of Super Tough material is up to ten times longer than of one made with standard material. Super Tough steel 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. Super Tough is particularly well suited for certain wind applications where surface distress has led to bearing failure.

### Insulated Rolling Bearings for Wind Turbine Generators

When bearings are exposed to electrical current, e.g. in the generators of wind turbines, electrically insulated rolling bearings are used. These hybrid bearings use ceramic coated rings, or ceramic balls with outstanding performance characteristics that reduce the transfer of electrical currents through the bearing, which could lead to failure. The hybrid bearing is particularly well-suited for use as generator bearings.

NSK uses silicon nitride (Si<sub>3</sub>N<sub>4</sub>) for the rolling elements of hybrid bearings.

### Test Facilities

With the ever increasing demand for higher wind turbine efficiency, power density and performance, custom made bearing designs are essential. NSK develops and tests rolling bearings on application specific test stands to simulate actual operating conditions.

### Rotor shaft bearing test stand

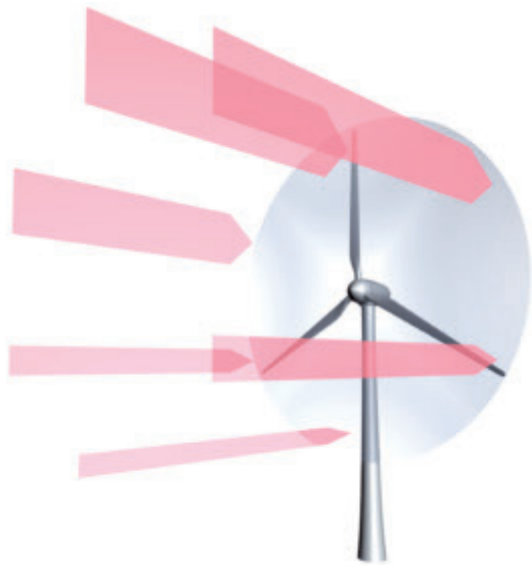
Rolling bearings designed for use in megawatt class turbines are thoroughly analyzed on our test stand. This stand simulates the real life radial and axial loads as well as the severe bending torque moments that have been recorded from operating wind turbines. The results further our understanding of wind applications to assure maximum reliability of NSK's products.

### Test stand for high-speed shaft rolling bearings

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

# Advance Computer Simulation:

NSK's technical experts have developed sophisticated programs that help our customers to better understand the bearings dynamic and static load conditions. NSK's latest developments include optimized methods and calculation programs that increase accuracy for estimating bearing life. Application data, environmental conditions, structural stiffness as well as many influencing factors can be simulated to correctly predict the life of a bearing in a given application. These efforts have led to more reliable designs that meet the needs for all factors that influence bearing life.

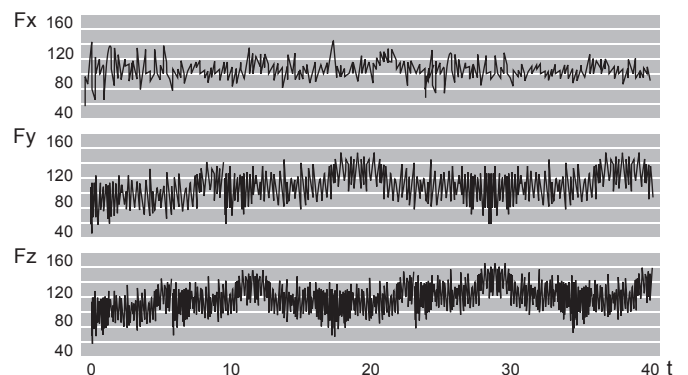
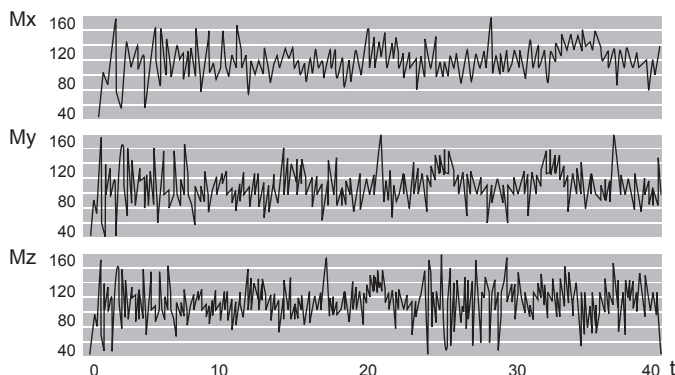


Wind velocity depends on rate, place and time. The excessive wind velocities and resulting dynamic loads dramatically impact the turbine and subassembly designs.

## Classic calculation methods

Conventional calculation methods for determining bearing life are referred to as the catalog method. The bearing industry has agreed to certain calculation methods. These methods can be found in the specification ISO 281. The basic life calculation considers bearing load, speed, load rating and bearing type. The bearing life calculated by the basic calculation is expressed as L<sub>10</sub>. Bearing life calculations need to be much more complex if they are to yield accurate predictions of bearing life and reliable operation for the owners of wind farms. Wind velocity depends on rate, place and time. The excessive wind velocities and resulting dynamic loads dramatically impact the turbine and subassembly designs. 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.

## Wind Load Data





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.

#### State of the art calculations: STIFF

STIFF is NSK's proprietary simulation program. 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 STIFF software program that takes the above mentioned parameters into account along with the exact interior geometry, internal operating clearance and pre-load, deformation of the shaft bearing system, lubrication conditions, load area and the load distribution between rolling elements and raceway. This model divides the rolling elements into lamina sections. A modified service life rating is determined for each lamina section of the rolling element and bearing raceway. This data is then integrated using the application spectrum of the bearing application.

For bearing arrangements in the wind turbine gearbox, the modified service life must be 175,000 hours, i.e. 20 years. The scope of the NSK's STIFF calculation software delivers results that enable rapid parametric analysis and assure that the system design meets the application's life criteria.

#### Advance Computer Analysis of Bearings Applications and Systems

Another example of calculation methods employed by NSK is Finite Element Analysis (FEA). FEA work examines the distribution of stress within the bearing and its support components providing optimum support for many applications. Frequency analysis examines vibration generation of the rolling bearing within the application. From the analysis results, performance and operating characteristics of the bearing system can be understood. Technical Computing Online Service (TCOS), is a collection of calculation programs for the analysis of rolling bearings from a number of perspectives.

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# 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 turbine rotor induces high axial and radial loads in the main bearings, which occur both statically and dynamically. Given such loads, high bearing stiffness is indispensable.

## 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 megawatt class, planetary gear stages are interfaced with spur gear stages. This approach facilitates differential transmissions.

## Oil pump bearings

The gear teeth used to drive the pump exert radial and axial forces.

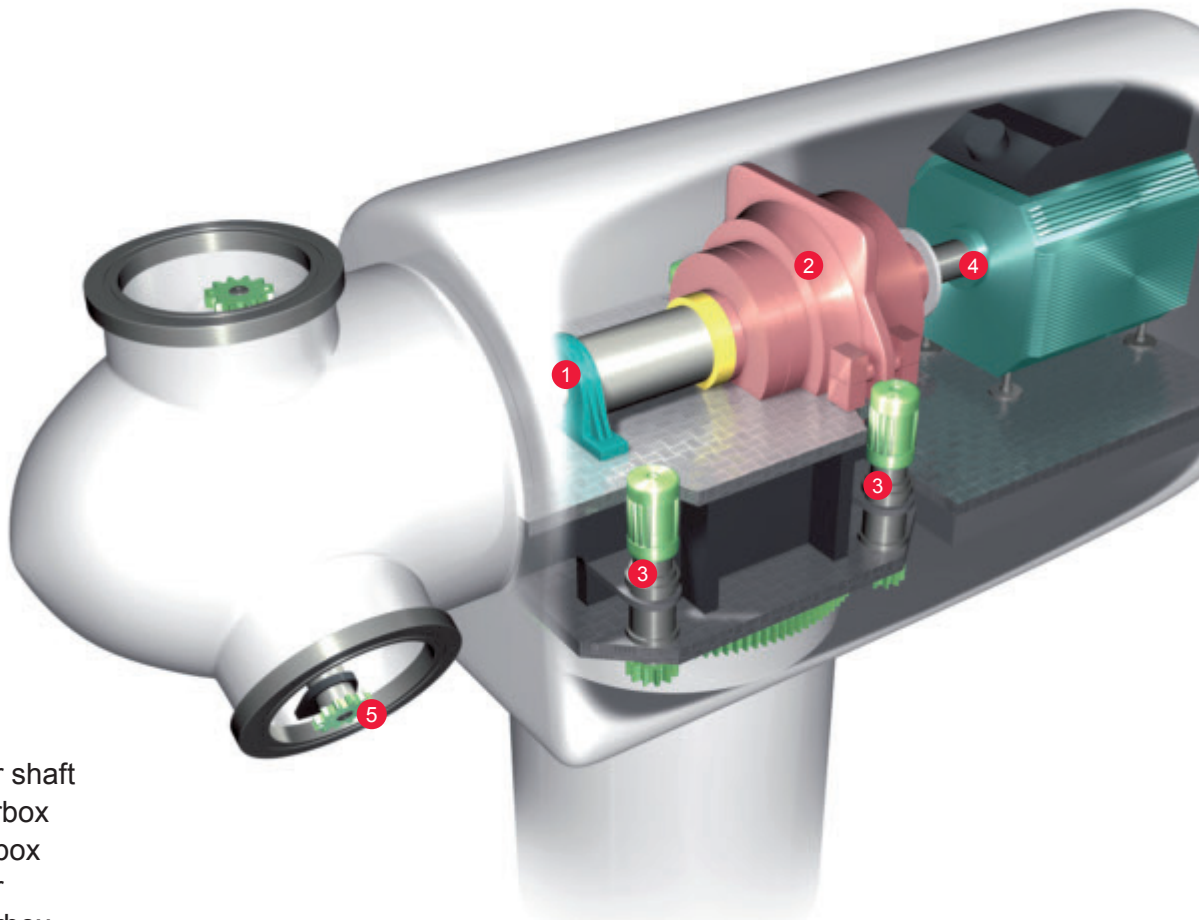
## Generator bearings

Generators primarily use deep groove ball bearings and cylindrical roller bearings. Transmission of electrical current will damage the rolling bearings and shorten their service life. In order to avoid this damage, NSK offers hybrid bearings with ceramic rolling elements for this position.

## Pitch and yaw gearbox bearings

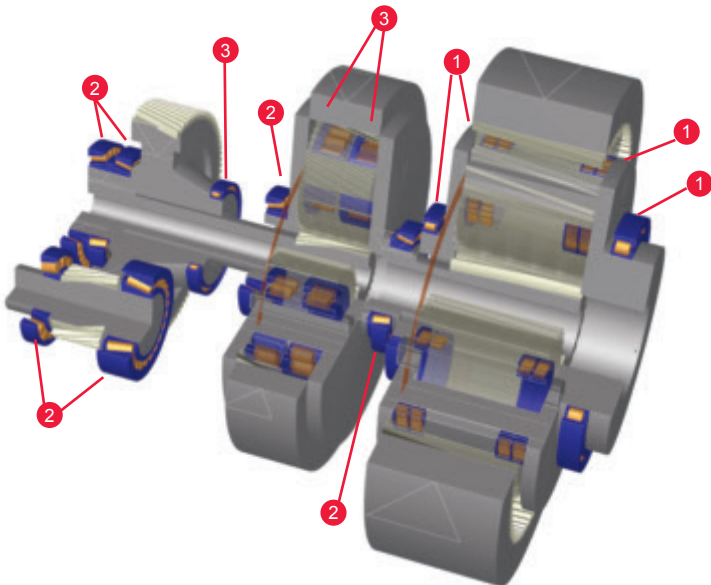
Yaw gearboxes orientate the nacelle to the wind. Pitch gearboxes are required for rotor blade pitch control.





- 1 Main rotor shaft
- 2 Main gearbox
- 3 Yaw gearbox
- 4 Generator
- 5 Pitch gearbox

When selecting a suitable bearing type, the special operating conditions at the respective bearing location are taken into consideration. Our technical experts, using our tools, application knowledge and experience, assure the correct bearing system design for the greatest reliability of the turbine in operation.



- 1 Full complement cylindrical roller bearings for low speed and high radial loads
- 2 Tapered roller bearings for ultrahigh loads and components
- 3 Cylindrical roller bearings for high speed and high loads, functioning as a floating bearing



### Deep groove ball bearings

#### Suitability

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

#### Applications

- › Gearbox
- › Generator

#### Designs

- › Cage made of steel, solid brass or plastic
- › Electrically insulated roller bearings
- › Outer diameters up to 2400 mm



### Spherical roller bearings

#### Suitability

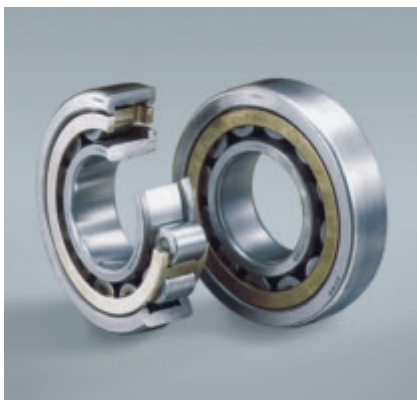
- › Very high radial loads
- › Axial loads in both directions
- › Able to misalign
- › Medium speeds

#### Applications

- › Gearbox
- › Rotor shaft

#### Designs

- › Cage made of steel or solid brass
- › High Performance Standard (HPS™), designs with higher load ratings and extended speed range
- › Optimized NSK design of rollers and cage for large rotor shaft bearing arrangements
- › Outer diameters up to 2400 mm



### Cylindrical roller bearings

#### Suitability

- › High radial loads
- › High speeds

#### Applications

- › Gearbox
- › Generator
- › Rotor shaft

#### Designs

- › Full complement
- › Multi-row
- › EM (solid brass cage) and EW (steel cage) series with higher load ratings
- › New Higher capacity designs
- › Outer diameters up to 2400 mm



### Four-point contact ball bearings

#### Suitability

- › High axial loads in both directions
- › Medium speeds

#### Applications

- › Gearbox

#### Design

- › Brass cage
- › 35° contact angle



### Taper roller bearings

#### Suitability

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

#### Applications

- › Gearbox
- › Rotor shaft

#### Design

- › Metric and inch dimensions
- › NSK high capacity HR tapered roller bearings with higher load rating
- › NSK cage design optimized for large tapered roller bearings installed in planetary carriers
- › Steel cage
- › Segmented plastic cage for inner diameters of more than 1000 mm
- › Outer diameters up to 2400 mm



## Worldwide Sales Offices

**NSK Ltd. - Headquarters, Tokyo, Japan** [www.nsk.com](http://www.nsk.com)  
 Americas & Europe Department tel: 03-3779-7120  
 Asia Marketing & Sales Department tel: 03-3779-7121

**Africa**  
**South Africa:**  
 NSK South Africa (Pty) Ltd.  
 Johannesburg tel: (011) 458 3600

**Asia and Oceania**  
**Australia:** [www.nskaustralia.com.au](http://www.nskaustralia.com.au)  
 NSK Australia Pty. Ltd.  
 Melbourne tel: (03) 9764-8302

**China:**  
 NSK Hong Kong Ltd.  
 Hong Kong tel: 2739-9933  
 Kunshan NSK Co., Ltd.  
 Kunshan tel: 0520-7305654  
 Guizhou HS NSK Bearings Co., Ltd.  
 Anshun tel: 0853-3521505  
 NSK (Shanghai) Trading Co., Ltd.  
 Shanghai tel: 021-62099051  
 NSK representative office  
 Beijing tel: 010-6590-8161  
 NSK representative office  
 Shanghai tel: 21-6209-9051  
 NSK representative office  
 Guangzhou tel: 020-8732-0583  
 NSK representative office  
 Anshun tel: 0853-3522522

**India:**  
 Rane NASTECH Ltd.  
 Chennai tel: 04114-65313, 65314, 65365, 66002  
 NSK representative office  
 Chennai tel: 044-4334732

**Indonesia:**  
 P.T. NSK Bearings Manufacturing Indonesia  
 Jakarta tel: 021-898-0155

**Korea:**  
 NSK Korea Co., Ltd.  
 Seoul tel: 02-3287-0300  
 NSK Korea Co., Ltd., Changwon Plant  
 Changwon tel: 0551-287-6001

**Malaysia:**  
 NSK Bearings (Malaysia) Sdn. Bhd.  
 Kuala Lumpur tel: 03-7958-4396  
 NSK Micro Precision (M) Sdn. Bhd.  
 Kuala Lumpur tel: 03-961-6288

**New Zealand:** [www.nsk-rhp.co.nz](http://www.nsk-rhp.co.nz)  
 NSK New Zealand Ltd.  
 Auckland tel: (09) 276-4992

**Philippines:**  
 NSK representative office  
 Manila tel: 02-759-6246

**Singapore:**  
 NSK International (Singapore) Pte Ltd.  
 Singapore tel: (65) 273 0357  
 NSK Singapore (Pte) Ltd.  
 Singapore tel: (65) 278 1711

**Taiwan:**  
 Taiwan NSK Precision Co., Ltd.  
 Taipei tel: 02-2591-0656

**Thailand:**  
 NSK Bearings (Thailand) Co., Ltd.  
 Bangkok tel: 02-6412150-58  
 NSK Safety Technology (Thailand) Co., Ltd.  
 Chonburi tel: (038) 214-317-8  
 Siam NASTECH Co., Ltd.  
 Chachoengsao tel: (038) 522-343-350

**Europe**  
**NSK Europe Ltd. (European Headquarters)** [www.eu.nsk.com](http://www.eu.nsk.com)  
 Maidenhead, England tel: 0162-850-9800

**France:**  
 NSK France S.A.  
 Paris tel: 01 30 57 39 39

**Germany:**  
 NSK Deutschland GmbH  
 Düsseldorf tel: 02102-481-0  
 NSK Steering Systems Europe Ltd.  
 Stuttgart tel: 0771-79082-277

**Netherlands:**  
 Neuweg Fertigung GmbH  
 Munderkingen tel: 07393-540

**Italy:**  
 NSK Italia S.P.A.  
 Milano tel: 02-995-191

**Poland:**  
 NSK Europe Ltd. Warsaw Liaison Office  
 Warsaw tel: 48-22-645-1525, 1526

**Czech Republic:**  
 NSK Iskra S.A.  
 Kielce tel: 48-41-366-6111

**Spain:**  
 NSK Spain S.A.  
 Barcelona tel: 93-575-4041

**Turkey:**  
 NSK Bearings Middle East Trading Co., Ltd.  
 Istanbul tel: 90-216-442-7106

**United Kingdom:**  
 NSK Bearings Europe Ltd.  
 Peterlee, England tel: 0191-586-6111  
 NSK European Technology Co., Ltd.  
 Ruddington, England tel: 0115-940-5409  
 NSK UK Ltd.  
 Newark, England tel: 0163-660-5123  
 NSK Steering Systems Europe Ltd.  
 Coventry, England tel: 024-76-588588

**North and South America**  
**NSK Americas, Inc. (American Headquarters)**  
 Ann Arbor, Michigan, U.S.A. tel: 734-913-7500

**Argentina:**  
 NSK Argentina SRL  
 Buenos Aires tel: 011-4762-6556  
[www.br.nsk.com](http://www.br.nsk.com)

**Brazil:**  
 NSK Brasil Ltda.  
 São Paulo tel: 011-3269-4700  
[www.ca.nsk.com](http://www.ca.nsk.com)

**Canada:**  
 NSK Canada Inc.  
 Toronto tel: 905-890-0740

**Mexico:**  
 NSK Rodamientos Mexicana, S.A. de C.V.  
 Mexico City tel: 5-390-4312

**United States of America:** [www.us.nsk.com](http://www.us.nsk.com)  
 NSK Corporation  
 Ann Arbor, Michigan tel: 734-913-7500  
 Sales Offices:  
 Ann Arbor, Michigan tel: 734-913-7500  
 Santa Fe Springs, California tel: 562-968-1000

NSK American Technical Center  
 Ann Arbor, Michigan tel: 734-913-7500  
 NSK Precision America, Inc. [www.npa.nsk.com](http://www.npa.nsk.com)  
 Franklin, Indiana tel: 317-738-5038

NSS America  
 Bennington, Vermont tel: 802-442-5448  
 NSK Latin America Inc. [www.la.nsk.com](http://www.la.nsk.com)  
 Miami, Florida tel: (305) 477-0605

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