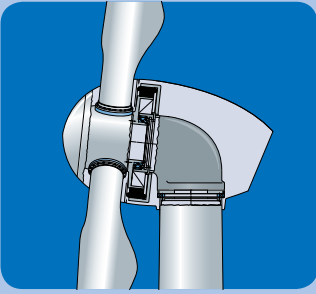


# Nautilus bearing arrangement solution from SKF

Compact design reduces weight, energy loss, and maintenance to improve wind turbine reliability



Big turbine challenges?



# Meet them with the Nautilus solution from SKF

Along with more energy, today's massive, multi-megawatt turbines are generating more problems related to nacelle weight and system reliability, as well as increases in operating and production costs. Accordingly, turbine designers and manufacturers are looking for ways to reduce total weight while increasing component service life.



Photo source: LEITWIND spa

As a result, only the rotor torque is transmitted to the drive train.

Engineered to optimize turbine performance, the Nautilus double row tapered roller bearing from SKF enables all rotor loads to be carried on a single bearing, rather than on a traditional two-bearing arrangement that handles radial and axial loads separately. By doing the work of two bearings, the Nautilus bearing enables designers to integrate the bearing directly between the

The benefits? Nacelle weight and dimensions are reduced dramatically, as are friction and energy loss. The reduction in components and the robust design of the Nautilus double row tapered roller bearing itself combine to lessen drive train loads and improve reliability.

Currently operating in several multi-megawatt models worldwide, the Nautilus single bearing solution has been designed to meet the future needs of multi-megawatt size turbines, onshore or offshore, with or without gearboxes.

Backed by advanced SKF engineering capabilities and a total systems approach that draws on SKF condition monitoring and lubrication systems expertise, the Nautilus is helping manufacturers:

- **Design more compact nacelles**
- **Reduce total nacelle weight**
- **Increase reliability**
- **Reduce maintenance demands**
- **Extend drive train service life**
- **Cut production costs**



# Improving turbine performance and reliability through advanced engineering and materials

## One bearing that can do the work of two

Developed specifically for wind turbines, the Nautilus from SKF is a single bearing solution that carries all the rotor loads, forces and movements, and allows only rotor torque to be transmitted to the drive train. This results in longer drive train service life and higher turbine reliability.



Designed to handle heavy, complex loads, the Nautilus double row tapered roller bearing gives turbine designers the freedom to depart from the

traditional main shaft design and integrate the bearing directly between the machine frame and the hub. Such designs reduce the nacelle's dimensions and weight, which translates into reduced manufacturer's costs. With no main shaft to contend with, engineers have more room to incorporate other innovative design features.

Ideal for multi-megawatt, offshore turbines, Nautilus bearings are compatible with a range of geared and gearless turbine designs. While Nautilus bearings mounted inside the gearbox require oil lubrication, Nautilus bearings mounted outside the gearbox are available in a sealed, grease-lubricated arrangement that provides high performance under the most extreme offshore or cold climate weather conditions.

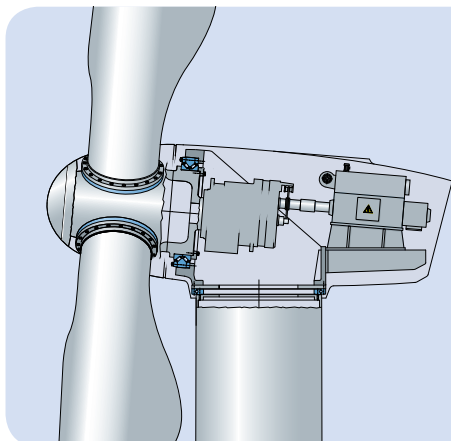
## Greater precision, stiffness and load



In the Nautilus bearing, two rows of tapered rollers, arranged back-to-back, lock the unit axially and deliver extremely high stiffness. The large number of rolling elements enables extreme precision between the raceways and provides extremely high load carrying capacity.

Capable of being preloaded and engineered to optimize turbine performance, the Nautilus has a large diameter that makes it strong enough to withstand yaw and tilt moments. The only forces that reach the generator or the gearbox are torsional.

Manufactured with "clean" steel at state-of-the-art SKF production facilities, the Nautilus bearing combines advanced materials and optimized design to help increase turbine reliability, maintenance intervals and service life in even the harshest offshore operating environments.



In this arrangement, the Nautilus rotor bearing replaces the bearings used for a conventional two-point suspension and the necessary separate housings or a joint bearing housing. The Nautilus bearing is separated from the gearbox by a short rotor shaft and is directly connected to the nacelle main frame. This arrangement provides a compact, lightweight and stiff drive train design that is suitable for turbine sizes in the multi-megawatt range.



# bility through

## Segmented PEEK cage minimizes contact forces

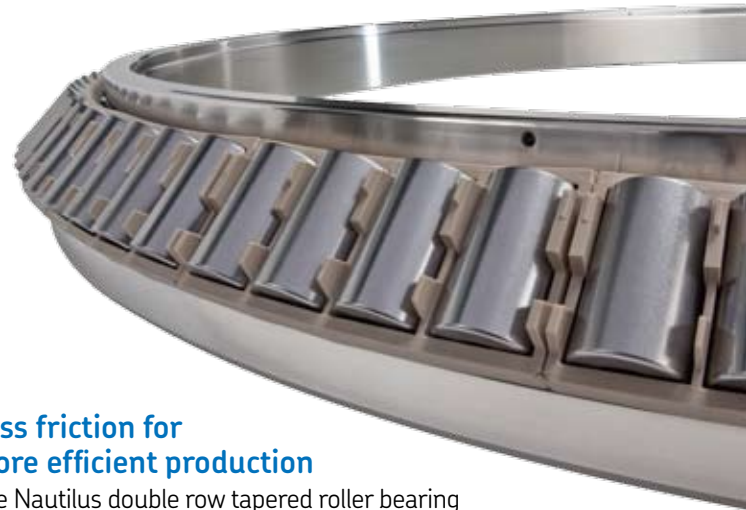
Constructed from the advanced polyetheretherketone polymer, or PEEK for short, the Nautilus cage is segmented to make it more flexible and to minimize contact forces and friction.



The segmented cage also means there are no additional cage forces to add to normal internal bearing forces. So it can operate in a flexible

environment with pre-load, lending stiffness to the drive train and the surrounding structure.

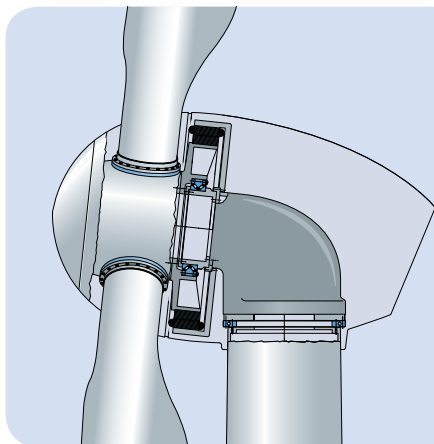
Along with the optimized cage geometry, the segmentation also improves the roller guiding, providing optimized load distribution among the rollers. Additionally, the window-type cage made of PEEK material provides extremely low friction and makes the bearing less sensitive to inadequate lubrication conditions, resulting in less wear. Therefore it is possible to use either grease or oil to lubricate the Nautilus bearing.



## Less friction for more efficient production

The Nautilus double row tapered roller bearing combines precision-manufactured clean steel, PEEK cages and optimized designs to reduce friction significantly.

The single bearing Nautilus solution easily outperforms traditional two-bearing arrangements, cutting friction loss to provide greater power output. Out in the real world, this means turbines can take full advantage of even the lightest winds. Reduced friction also means lubricants last longer, helping to extend lubrication maintenance intervals and improve reliability.



In this arrangement, the Nautilus bearing's inner ring is directly connected to the nacelle main frame instead of the long and flexible axis of traditional gearless designs. This main bearing arrangement enables a very stiff design and exact guidance of the generator air vent. Dynamic rotor loads are directly transmitted into the main frame of the nacelle.

This arrangement is also possible with a rotating inner ring instead, where the outer ring is flanged to the nacelle main frame.

# Real world experience, real world solu



With big turbines, often in difficult-to-access locations, maintenance and reliability are big issues. With decades of industry experience and expertise in many areas affecting turbine performance, SKF can provide a wide range of products and services to help you achieve your reliability goals. These include:

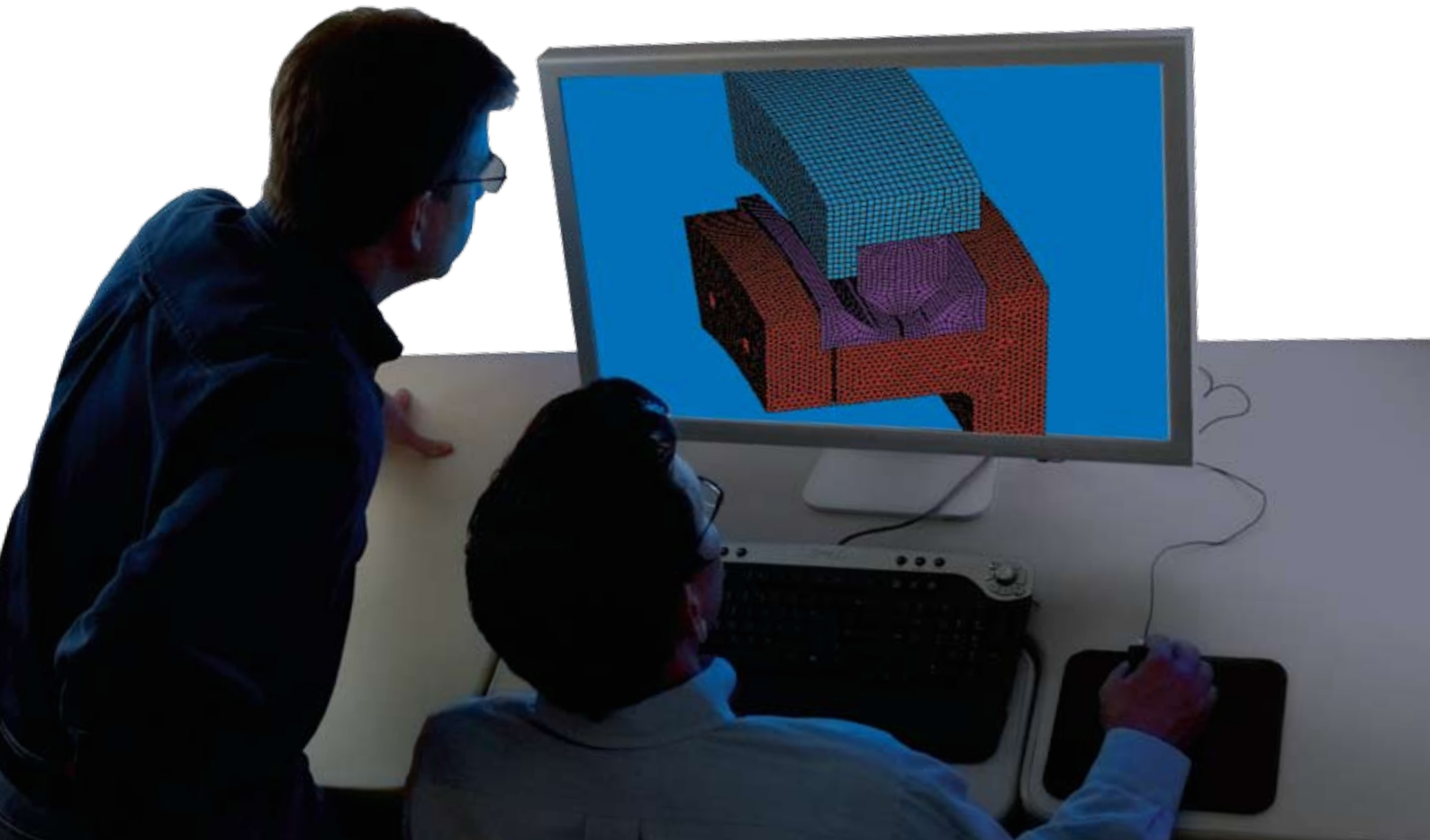
## SKF Engineering Consultancy Services

Incorporating more than 100 years of rotating machinery expertise, SKF Engineering Consultancy Services can help make sure that a new Nautilus-equipped turbine will be “right” from the start.

Drawing on application experience ranging from the earliest wind turbines to the latest designs, SKF engineers can help you avoid design and development setbacks and identify more profitable approaches.

By applying Finite Element Method calculations, for example, we can help you define bearing pre-load, related service life and bearing contact stresses during all load cases. Using an SKF “virtual” test rig, we can also simulate different operating conditions of multi-megawatt wind turbines. These simulations can include testing different materials, operating temperatures of different positions and the results of lubricant starvation.

While evaluating these calculations, SKF engineers will also help you consider the effects of surrounding components, as well as the optimum roller size to maximize service life and reliability. In this way, we can help you achieve a “best fit for application.”



# tions

## SKF condition monitoring



SKF WindCon is an easy-to-manage, online condition monitoring system that helps reduce operating costs. Easily installed on all turbine sizes and types, on land or at sea, the system continuously monitors single units or entire farms to reliably predict the need for maintenance tasks. Using vibration sensors mounted directly on the Nautilus bearing, as well as access to the turbine control system, SKF WindCon collects,

analyzes and compiles a range of operating data. In addition to the early detection of faults, the collected data can be also used to perform root cause failure analysis.

## SKF automatic lubrication



Keeping a Nautilus bearing properly lubricated with an automatic lubrication system can reduce maintenance needs and, by helping to avoid over-greasing, also minimizes environmental impact. Developed specifically for wind turbines, the SKF WindLub centralized automatic lubrication system delivers the exact quantity of the appropriate lubricant at the right positions at the right time for all rotating equipment. The system also helps to extend the turbine's

service life and reduce operational and lubricant costs. SKF WindLub easily integrates with SKF WindCon to further simplify maintenance and enhance reliability. The combination provides operators with a complete overview of the lubrication system.

## SKF greases

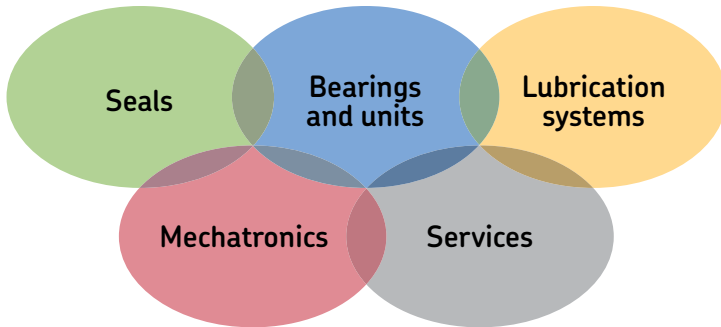
SKF offers a range of bearing greases that provide proper lubrication, both when the turbine is operating or in standstill mode. SKF greases have excellent water and corrosion resistance, superior performance at low starting torque and have high thermal and mechanical stability. SKF application specialists can help you select the grease best suited to your application requirements.



Advanced SKF sealing solutions provide excellent lubricant retention and contaminant exclusion, protecting both the bearing and the environment.

The Nautilus bearing sealing solutions have outstanding ozone and abrasion resistance characteristics, resulting in highly reliable sealing performance and extended service life. For easy on-site installation, the seals are available in a split version and are supplied with a kit for joining them on-site.

With decades of expertise in material properties and seal designs, SKF can support your design team in selecting or developing effective sealing solutions for your application.



### The Power of Knowledge Engineering

Drawing on five areas of competence and application-specific expertise amassed over more than 100 years, SKF brings innovative solutions to OEMs and production facilities in every major industry worldwide. These five competence areas include bearings and units, seals, lubrication systems, mechatronics (combining mechanics and electronics into intelligent systems), and a wide range of services, from 3-D computer modelling to advanced condition monitoring and reliability and asset management services. A global presence provides SKF customers uniform quality standards and worldwide product availability.

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