



FAG



Expertise in Bearing Technology and Service for Wind Turbines

SCHAEFFLER GROUP
INDUSTRIAL

Expertise through knowledge and experience

FAG Kugelfischer is the pioneer of the rolling bearing industry. In 1883, Friedrich Fischer designed a ball mill that was the historic start of the rolling bearing industry. INA began its path to success in 1949 with the development of the needle roller and cage assembly by Dr. Georg Schaeffler – a stroke of genius that helped the needle roller bearing to make its breakthrough in industry. Schaeffler Group Industrial with its two strong brands, INA and FAG, today has not only a high performance portfolio in rolling bearings but also, through joint research and development activities, products and services of unsurpassed quality.

For over 30 years, INA and FAG have designed and produced bearing arrangements for wind turbines. Within Schaeffler Group Industrial, the specialists from the business unit “Wind power” work closely with designers, manufacturers and operators of wind turbines. This has resulted in unbeatable know-how: as early as the concept phase, detailed attention is paid to customer requirements. Bearing selection and documentation are backed up by sophisticated calculation methods. Products developed to a mature technical level are optimally matched to the particular task. The range is intelligently rounded off by Condition

Monitoring systems, lubricants, mounting and maintenance tools. In this way, Schaeffler Group Industrial helps to achieve low operating costs for wind turbines.

Core skills

- Wide range of application-specific bearing designs, intensive ongoing product development
- Soundly-based consultancy by experienced engineers
- Optimum application of customer requirements
- State of the art calculation programs such as BEARINX® for optimum product selection
- Comprehensive service for operation including detailed analyses
- Condition Monitoring system recognized by Allianz Insurance
- General and customer-specific training programs
- Worldwide adherence to quality and environmental policy (ISO 9000/ QS 9000, ISO/TS 16949:2002, ISO 14001)



From a single source

A comprehensive range for wind turbines



Rotor shaft: Proven, high performance bearing concepts



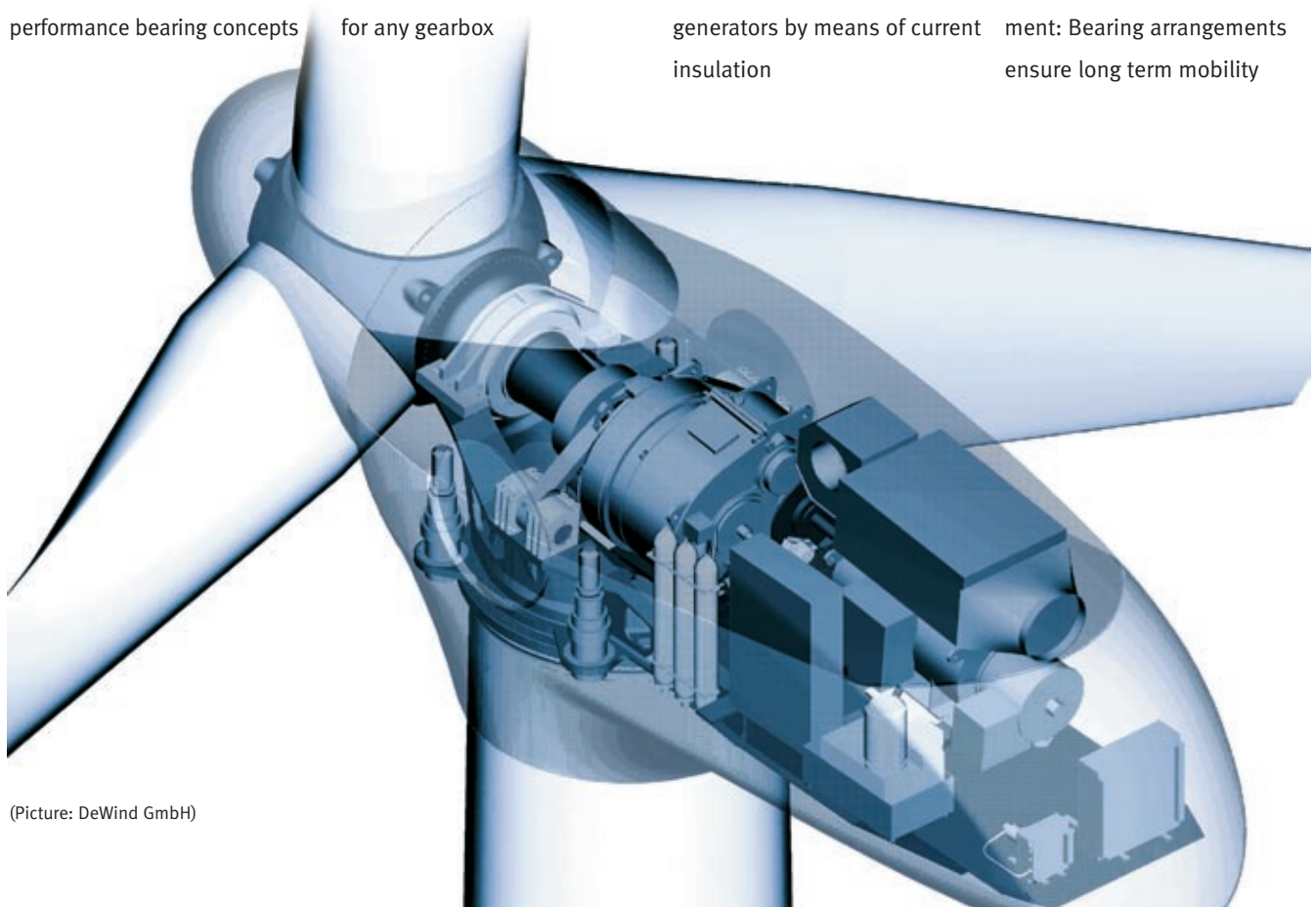
The ideal bearing arrangement for any gearbox



Extended bearing service life in generators by means of current insulation



Wind tracking and blade adjustment: Bearing arrangements ensure long term mobility



(Picture: DeWind GmbH)



Remote monitoring and diagnosis



Mounting and maintenance

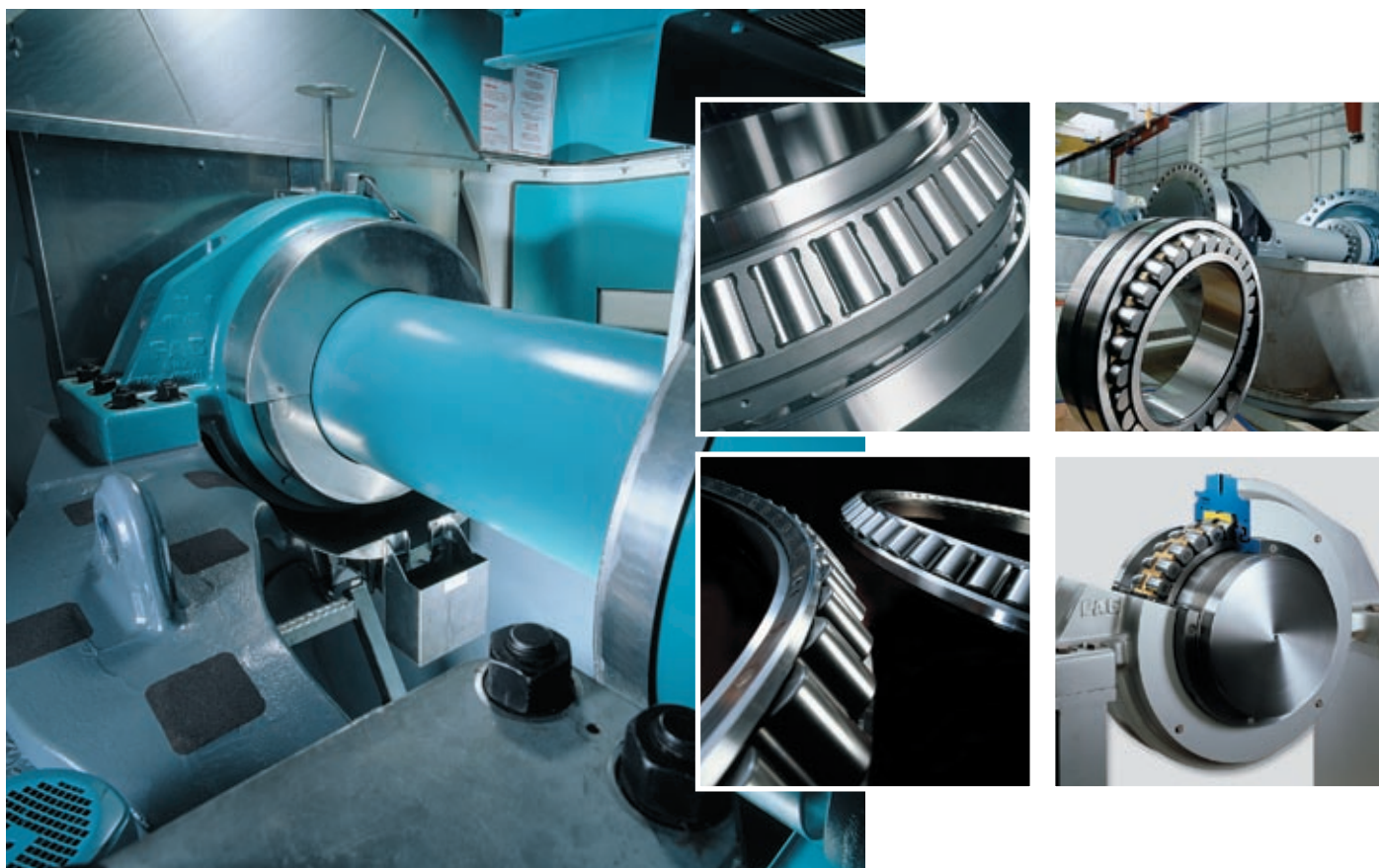


Rolling bearing lubrication – critical for service life



Concentrated knowledge for expert bearing design

Proven, high performance bearing concepts for rotor shafts



In wind turbines, the rotor shaft arrangement is of central importance. This is where all the forces and moments act directly that are induced by the wind. The rolling bearings are subjected to highly dynamic loads and operating conditions. In partnership with customers, the Schaeffler Group engineers develop the most efficient bearing arrangement for each case. Low friction bearings from INA and FAG are used in the power trains of modern turbines throughout the world, from 220 kW to the latest multi-megawatt class.

Shaft bearing arrangement

The classical, repeatedly proven solution consists of a locating/floating bearing arrangement with spherical, cylindrical or tapered roller bearings.

Hub bearing arrangement

The adjusted bearing arrangement contains two tapered roller bearings. The alternative locating/floating arrangement comprises a matched tapered roller bearing and cylindrical roller bearing.

Single bearing concepts

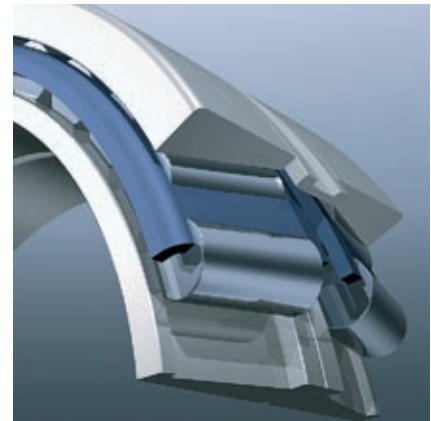
These designs combine the force and moment support functions in a multi-row

rolling bearing. The design as a double row tapered roller bearing is matched to the operating conditions. This also applies to the dimensions; large bearings can be over 400 mm wide and over 3 000 mm in outside diameter.

Rotor bearing housings

Bearing housings calculated using state of the art methods ensure the best possible support of forces and moments with optimum dimensioning. In almost all cases, development is undertaken for specific customer requirements and the housings are matched to the bearings used.

The ideal bearing arrangement for any gearbox



Increasing megawatt ratings require larger and higher capacity gearboxes. The operating conditions for rolling bearings in wind turbine gearboxes cannot be compared with those for static gearboxes. Highly dynamic forces with extreme peak loads and minimal loads, sudden load reversals and widely differing operating temperatures are some of the challenges facing the bearing arrangements. Bearings with high static load safety factor and secure dynamic design according to international design guidelines such as ISO 81 400 are the right solution here.

INA and FAG bearings used: tapered roller bearings, cylindrical roller bearings with cage, full complement cylindrical roller bearings, deep groove ball bearings and four point contact bearings.

New simulation calculations

Deformation of the gearbox housing can place additional load on the bearings. Load peaks can also occur as a result of braking and other influences in turbine control. New simulation calculations of the dynamic behavior of the power train lead to precise load models and

supplement existing models derived from analogies and measurements.

Higher operational safety and cost-efficiency with tapered roller bearing units

Ready-to-fit, optimum designs of tapered roller bearing units for high speed gearbox shafts are fitted quickly without errors and reduce the logistics effort required. The internal clearance is matched using adjusted intermediate rings. Load distribution and friction can be optimized by the effect of differing contact angles.

X-life.

Higher cost-effectiveness.

Higher operational reliability.

X-life represents premium products from the brands INA and FAG and gives completely new design opportunities for design engineers.

The use of state-of-the-art manufacturing technologies has resulted in a better, more uniform surface over the whole contact face between the rolling elements and raceway. As a result, there is a significant reduction in the stress conditions present on the rolling

elements and mating track under identical loads. This means:

- reduced friction and
- lower bearing temperatures
- less strain is placed on the lubricant
- a higher basic dynamic load rating
- a higher basic rating life.

Consequently, the operating life of X-life bearings is considerably longer under the same operating conditions. On the other hand, higher loads can be applied while maintaining the same rating life values.

With their optimized characteristics, X-life bearings open up completely new application prospects such as downsizing of the bearing support. Furthermore, the improved price/performance ratio ultimately increases the overall cost-effectiveness of the bearing support.

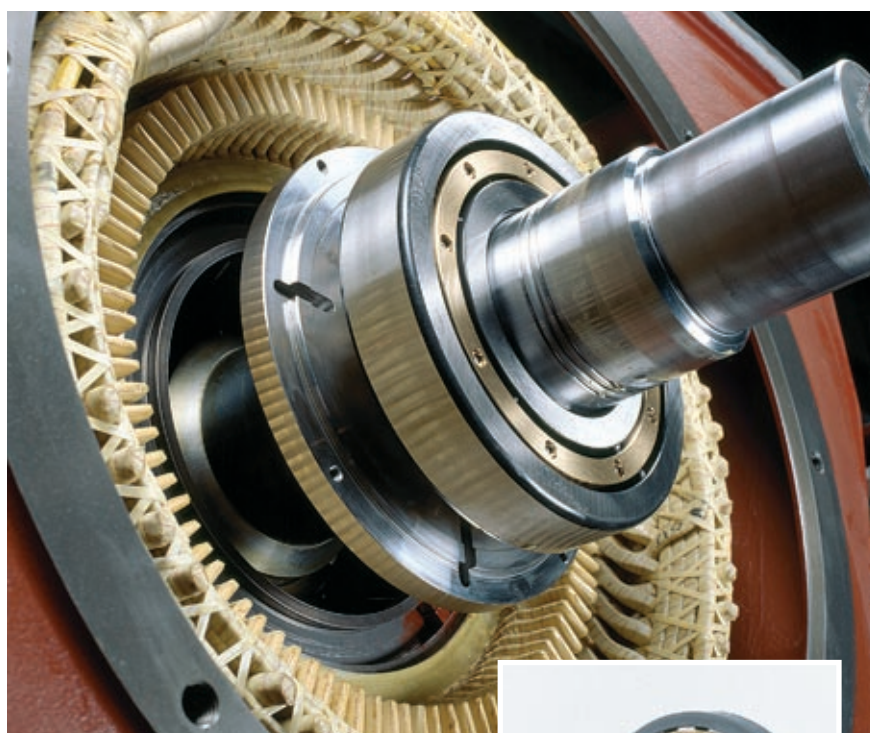


Longer service life by current insulation

A generator operating in the nacelle of a wind turbine is subjected to significantly greater vibration loads than its counterpart on the ground. This additional permanent load has a negative influence on the cages and places a strain on the lubricant. In the design of bearings for a generator, it is not only the speed, size and design that play an important role. Particular attention must be paid to the lubrication and protection against possible current passage. The bearing arrangement of a generator generally contains two deep groove ball bearings or one deep groove ball bearing and one cylindrical roller bearing.

Current insulation of generator bearings

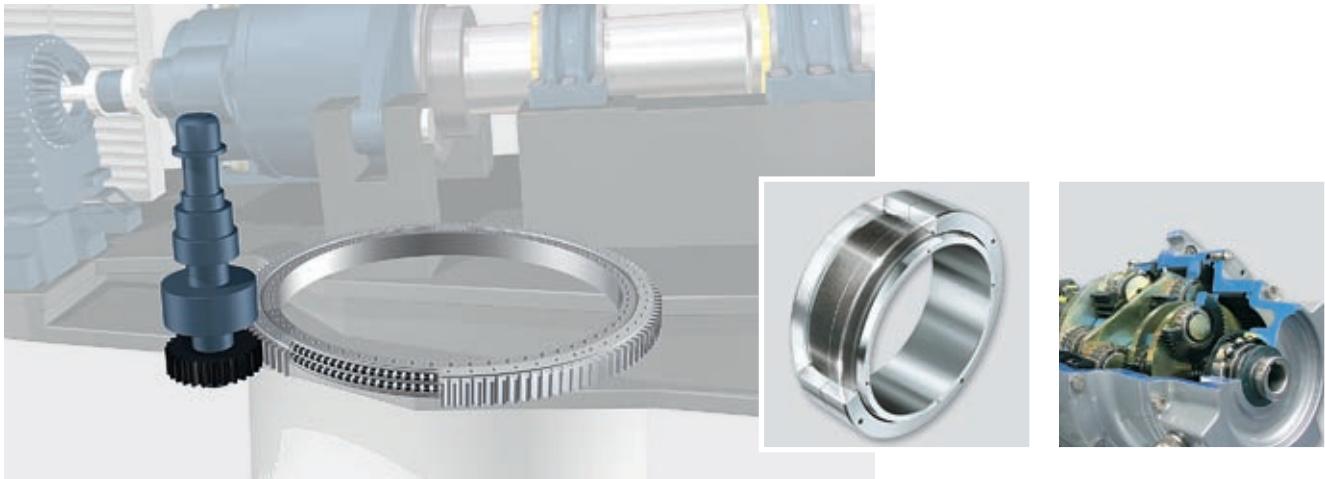
The passage of current in a wind turbine generator can cause serious damage to the raceways of bearing rings in the form of melt craters and false brinelling, leading to enormous repair costs. It is therefore appropriate to take precautions at the planning stage to prevent such damage and failures, thereby helping to save costs. In many cases, it is sufficient to fit current-insulated bearings. Current-insulated bearings are available with coated rolling bearing rings and as hybrid bearings with ceramic rolling elements. The current-insulating, highly wear-resistant layer consists of oxide ceramic and offers protection against a puncture voltage of



up to 1 000 volts, even in a damp environment. Hybrid bearings with ceramic rolling elements allow even higher values. In addition, hybrid bearings give longer grease operating life. They are suitable for high speeds and have good emergency running characteristics. The use of these variants is based on the customer requirements. Conventional bearings can be replaced by current-insulated bearings at any time since the external dimensions are identical.

Wind tracking and blade adjustment

Long-term mobility



Wind turbines must be aligned optimally to the wind in order to prevent extreme loads and to provide the highest possible energy output.

Blade bearing (pitch bearing)

In order to control the power output of the wind turbine, the blade angle is always optimally adjusted to the wind speed via the blade bearing. Very high loads occur in some instances from the dynamic load of the rotor blades. These loads must be transferred securely via the raceways and the screw connections of the blade bearings into the rotor hub. Single or double row four point contact ball bearings with a cage are used here. The bearing can be produced with internal or external gear teeth or without gear teeth depending on the blade adjustment concept of the turbine. A long rating life and a higher level of reliability are achieved by opti-

mally dimensioning the blade bearings and by a maintenance concept specially designed to suit the turbine and the operating conditions.

The blade bearing is also a significant component of the safety concept of a turbine. The blade bearings must ensure that the blades can be reliably and evenly adjusted under all operating conditions.

Tower bearing (azimuth bearing)

A robust slewing ring is required in order to adjust the position of the nacelle to the wind direction. A particularly high level of reliability is achieved due to the slewing ring's generous design. The wind load and the dynamic inertia forces are transferred securely and reliably via the raceways and the screw connectors into the tower head. Single or double row four point contact bearings with external gear teeth are mostly used here.

Azimuth drive/pitch drive

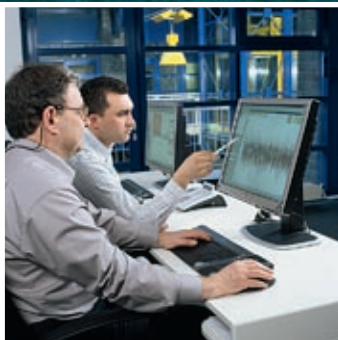
Wind turbines adjust automatically due to active systems. Geared motors and actuators convert the signals from the controller. Schaeffler Group Industrial offers bearing supports for slewing gears for nacelle and blade angle adjustment from one source:

- Input shaft – deep groove ball bearings
- Planet gears – full complement cylindrical roller bearings
- Output shaft – cylindrical roller bearings, spherical roller bearings, tapered roller bearings

Blade adjustment

In addition, the blade angle can be adjusted using electric or hydraulic systems. These use sealed plain bearings with the maintenance-free ELGOGLIDE® fabric, protected against corrosion by means of the Corrotect® plating.

Remote monitoring and diagnosis



Permanent monitoring of rolling bearings operating under hard conditions in wind turbines is a fundamental precondition for better profitability. For INA and FAG, this task is taken up by the experts of the autonomous service company FAG Industrial Services GmbH (FIS).

Online Condition Monitoring by the FAG WiPro system

Online Condition Monitoring – the continuous monitoring of bearings in wind turbines

- prevents unplanned downtime,
- detects emerging damage at an early stage,
- continuously monitors the condition of components,
- specifies emergency cut-off in response to preprogrammed conditions,

- prevents collateral and consequential damage,
- protects individual turbines or complete wind farms.

The WiPro (Wind Turbine Protection System) is tailored to the requirements of the wind energy generation sector and primarily measures vibrations as well as, optionally, torque, temperature, oil quality and other variables. The arrangement of the sensors at critical locations in the nacelle is based on the individual conditions of the turbine. When predetermined threshold values are reached, an alarm is triggered and data are transmitted automatically by landline, wireless or satellite modem to the FIS Service Center. After intensive analysis and detailed in-depth diagnosis, the FIS experts propose specific measures to the customer in order to avoid unplanned downtime and costly consequential damage. Security of planning is increased – replacement of components can be predictively scheduled. Only one system, in conjunction with competent and reliable support, ensures reliable results.

After in-depth checking, the WiPro system has been recognized by Allianz Insurance. Other insurers also apply this benchmark and offer more favorable conditions when the WiPro system is used. The system and the monitoring facility at FIS have been certified by Germanischer Lloyd. Wind turbines of all types can be easily retrofitted with this system.

Mounting and maintenance

Insurance provider rewards WiPro

Allianz Insurance confirms to F'IS that the online Condition Monitoring system WiPro fulfils the requirements of the Allianz Technology Centre (AZT) for Condition Monitoring systems for wind turbines. Allianz Insurance thus recognizes the WiPro system as suitable for condition-oriented maintenance. Alternative agreements may be reached with operators of wind turbines in the insurance variation clauses.



Offline individual measurements

As an alternative route to plant monitoring, F'IS offers individual measurement of vibration and temperature data using mobile diagnostic equipment. This method, for example in the form of half-yearly measurement at the critical machine parts followed by analysis and diagnosis, is a cost-effective alternative despite its well-known limits and is currently still accepted by some insurers as a contractual precondition.

With a wide range of mounting and alignment tools, measuring instruments and lubricants, more efficient work processes can be designed. Thanks to considerable FAG experience and its qualified specialists, F'IS is the expert partner for customer-oriented solutions. The preparation of individual service strategies and practically-based training improves reliability.

If personal intervention is required, highly qualified technicians and engineers are available on site, if necessary only a short while after the call for help. The reconditioning service for rolling bearings offered by F'IS with its short turnaround times, makes a decisive contribution to maintaining continuous availability. This service is provided for rolling bearings from all manufacturers.

Critical factors for service life



In addition to highly developed design and precise manufacturing practice, the reliability and operating life of a bearing is influenced to a large extent by lubrication. Selection of the correct grease, the performance capacity of the oil, the effect of additives, cleanliness in relation to contaminants and adherence to the specified lubrication intervals contribute to determining the quality of the system.

Grease

The main bearings and gearbox bearings in wind turbines are supplied with special Arcanol rolling bearing greases. These greases were developed in partnership with renowned lubricant manufacturers and subjected to comprehensive series of tests before approval. They thus offer consistently high quality and optimum lubrication characteristics. The FIS range includes various lubricators of the Motion Guard series that automatically feed the correct quantity of fresh grease to the lubrication points. Depending on the lubrication system, dispensing times between 1 day and 24 months can be set for up to six lubrication points. As a result, less personnel work is required and security in relation to lubrication of the rolling bearings used is significantly increased.

The advantages:

- Fully automatic and almost maintenance-free
- Precise grease quantities, no undersupply or oversupply
- Extended bearing life
- Higher cost-effectiveness due to economical, environmentally-friendly metering

Oil

Recirculating oil lubrication with a filter offers the optimum supply of lubricant to the contact points. In condition monitoring of important oil parameters such as operating temperature, contamination, water content and viscosity, the filter should also be included.

Modern simulation and calculation programs

From the entire system right down to the rolling contacts

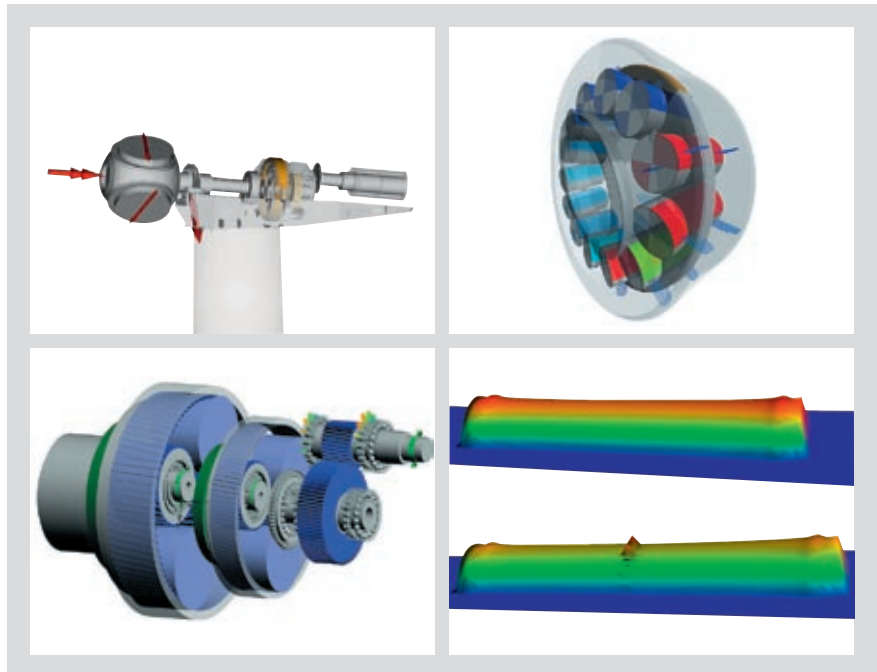
High costs are associated with the failure of a wind turbine. This means that all influencing factors must be considered in the best possible manner as early as the planning and design phase. We use the most up-to-date simulation and calculation programs in order to ensure optimum product selection.

Multi-body simulation

The dynamic behavior of the entire wind turbine is mapped with hybrid, multi-body simulation (MBS). Individual components of the drive train and the entire turbine design can be improved in the development phase using this model.

BEARINX®

The software BEARINX® can be used to model and calculate all bearing types, complex shafts, shaft systems and even complete gearboxes. The support reactions, the internal loads in the rolling bearings, the comparative stresses of the shafts and the most important parameters are calculated and presented in tabular and diagrammatic form. Obviously, the internal load distribution in the bearing is also calculated precisely – including contact pressure taking account of the rolling element profile. Based on the individual rolling contact loads, BEARINX® determines the calculated bearing life more precisely than ever before.



With BEARINX®-online our customers can calculate complex shaft systems with several bearing supports from the convenience of their office.

FEM

For even more detailed analysis, FEM can be used to determine the influence of the adjacent construction on the rolling bearings and vice versa.

CABA

The MBS software CABA3D enables the dynamic analysis of rolling bearings. Taking account of all the degrees of freedom, the force and movement

curves of the rolling elements and rings are determined, from which results (e.g. for frictional energy) can be calculated for each time period. CABA3D can thus be used, for example, to calculate the frictional energy transmitted and the acceleration behavior of the rolling elements when they enter the load zone.

Telos

Individual rolling contacts can be examined with the 3D simulation program Telos. Any rolling contacts under general lubrication conditions can be considered and it is possible to differentiate between plated and unplated bearing components.

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