



Expertise in Bearing Technology and Service for Wind Turbines

Expertise through knowledge and experience

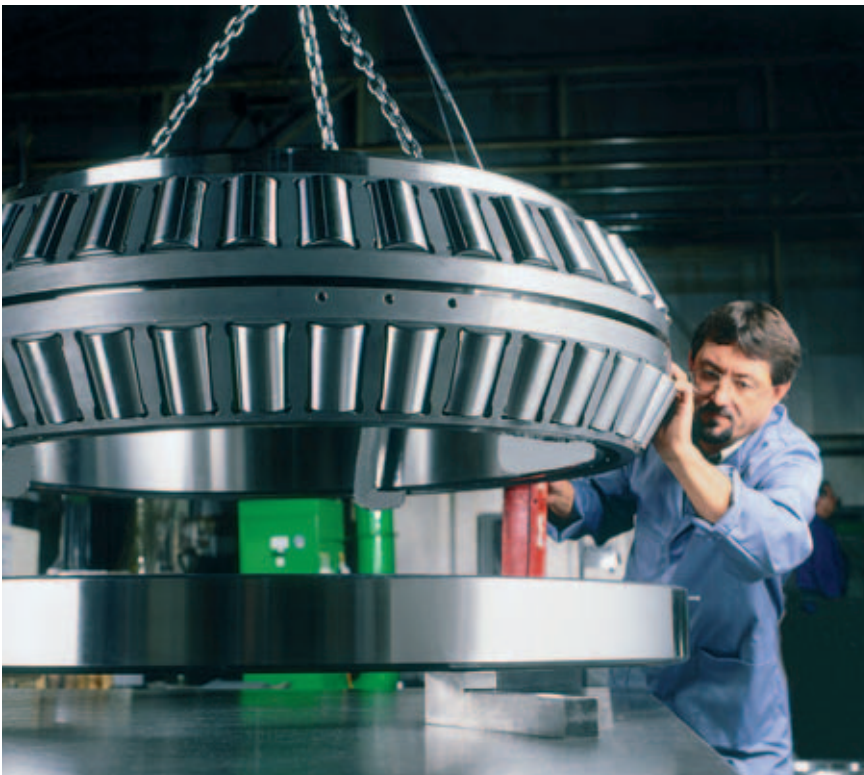
FAG Kugelfischer is the pioneer of the rolling bearing industry. In 1883, Friedrich Fischer designed a ball mill that was the historic start of the rolling bearing industry. INA began its path to success in 1949 with the development of the needle roller and cage assembly by Dr. Georg Schaeffler – a stroke of genius that helped the needle roller bearing to make its breakthrough in industry. The 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 25 years, INA and FAG have designed and produced bearing arrangements for wind turbines. Within Schaeffler Group Industrial, the specialists from the market sector “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 recognised 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



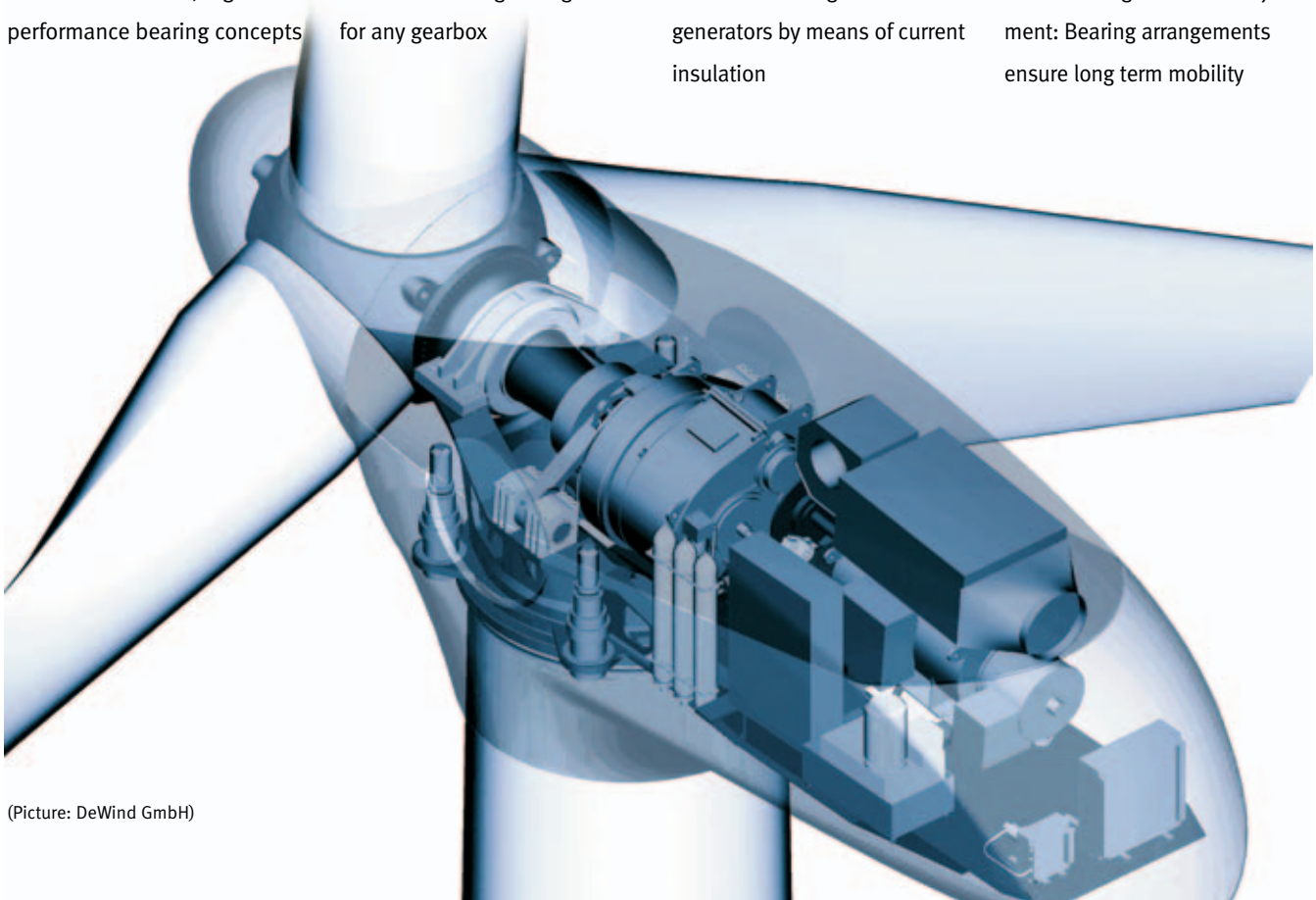
The ideal bearing arrangement for any gearbox



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)



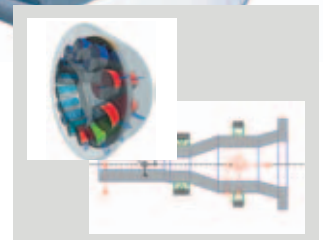
Remote monitoring and diagnosis



Mounting and maintenance

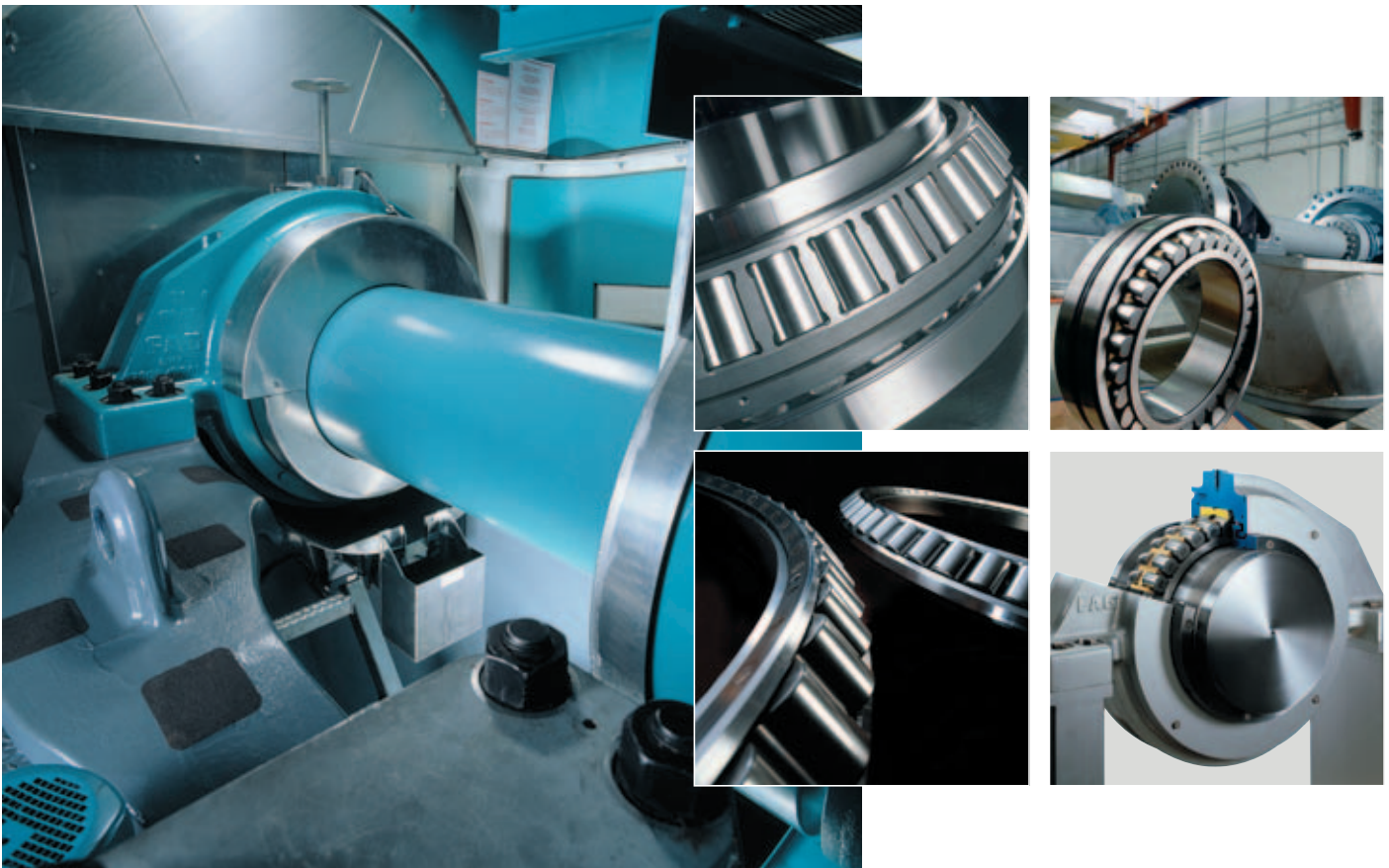


Rolling bearing lubrication – critical for service life



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.

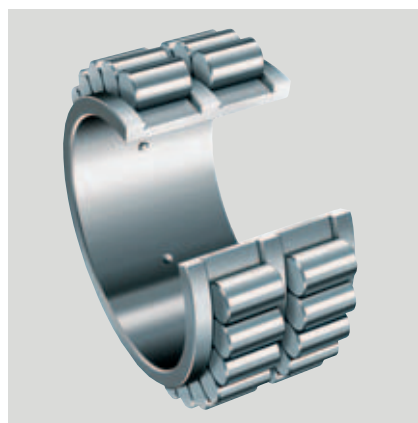
Rotor bearing housings

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



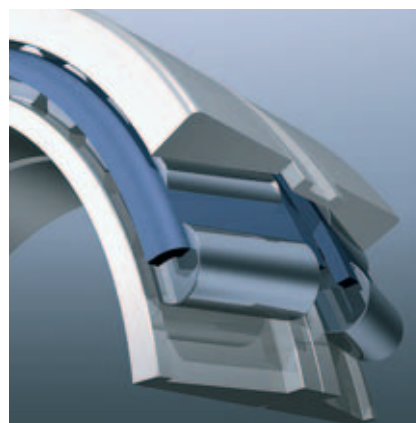
Increasing megawatt ratings require larger and higher capacity gearboxes. The operating conditions for rolling bearings in wind turbine gearboxes cannot be compared with those for static gearboxes. Highly dynamic forces with extreme peak loads and minimal loads, sudden load reversals and widely differing 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 AGMA 6006-A03 are the right solution here.



INA and FAG bearings used: tapered roller bearings, cylindrical roller bearings with cage, full complement cylindrical roller bearings, spherical 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 behaviour 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 optimised by the effect of differing contact angles.

Quality has a name: X-life

X-life represents premium products from INA and FAG. Products with increased operating life far beyond conventional values.

- Improved product characteristics,

lower noise, easier to maintain and high load capacity individual and system solutions, often exceeding the requirements

- Improved price/performance ratio
- Training programmes for defect-free

fitting and dismantling, plus correct selection and supply of the right lubricant

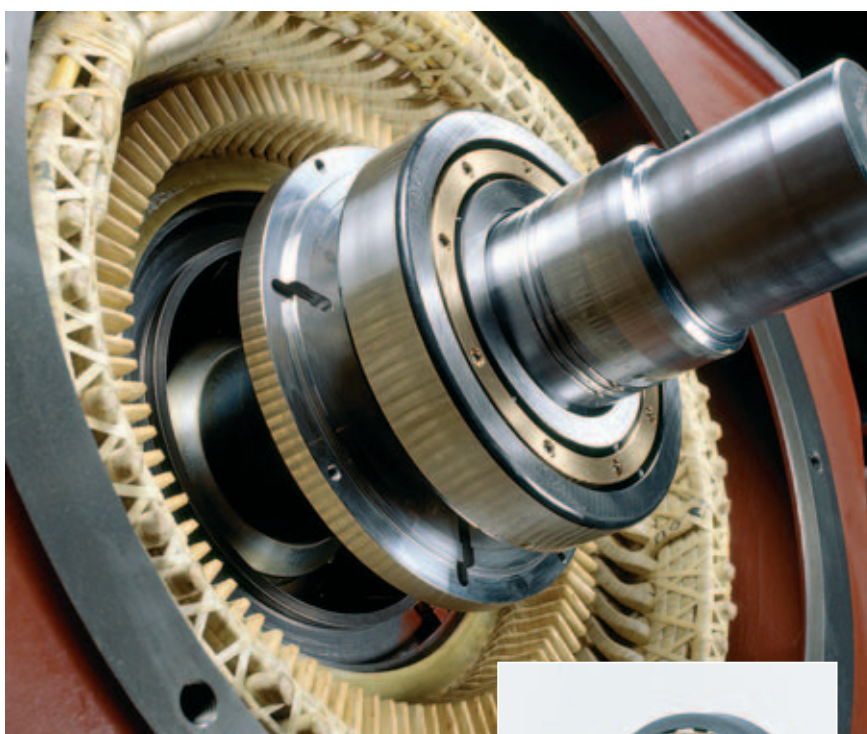


Longer service life by current insulation

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 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.

Tracking the wind, adjusting the blades

Long term mobility

Wind turbines must – like sailing ships – be aligned optimally to the wind in order to prevent extreme loads and allow cost-effective operation.

Azimuth drive

Geared motors and actuators convert the signals from the controller. With high sensitivity and over the long term – with bearings from INA and FAG.

The Schaeffler Group offers bearing arrangements for slewing gears for nacelle adjustment from a single source: Input shaft – deep groove ball bearings
Planets – full complement cylindrical roller bearings
roller bearings

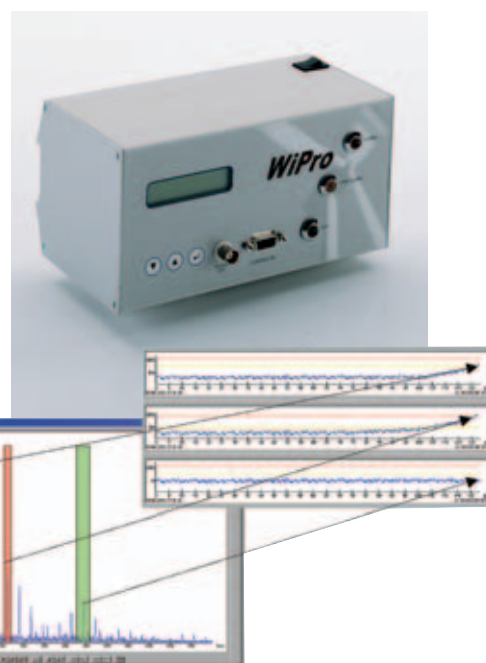
Output shaft – cylindrical roller bearings, spherical roller bearings, tapered roller bearings

Blade adjustment

The rotor blade angle is adjusted by electric or hydraulic drives. These use sealed ELGES 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.

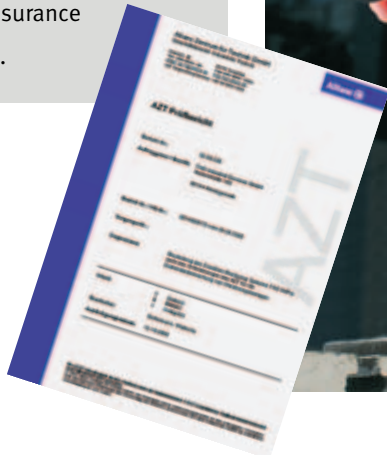
The WiPro (Wind Turbine Protection System) is tailored to the requirements of the wind energy generation sector and primarily measures vibrations as well as, optionally, torque, temperature, oil quality and other variables. The arrangement of the sensors at critical locations in the nacelle is based on the individual conditions of the turbine. When predetermined threshold values are reached, an alarm is triggered and data are transmitted automatically by landline, wire-

less 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 recognised by Allianz Insurance AG. Other insurers also apply this benchmark and offer more favourable 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 AG confirms to FIS that the online Condition Monitoring system WiPro fulfils the requirements of the Allianz Technology Centre (AZT) for Condition Monitoring systems for wind turbines. Allianz thus recognises 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, FIS 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, FIS 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 en-

gineers are available on site, if necessary only a short while after the call for help.

The reconditioning service for rolling bearings offered by FIS with its short turnaround times, makes a decisive contribution to maintaining continuous availability. This service is provided for rolling bearings from all manufacturers.

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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.

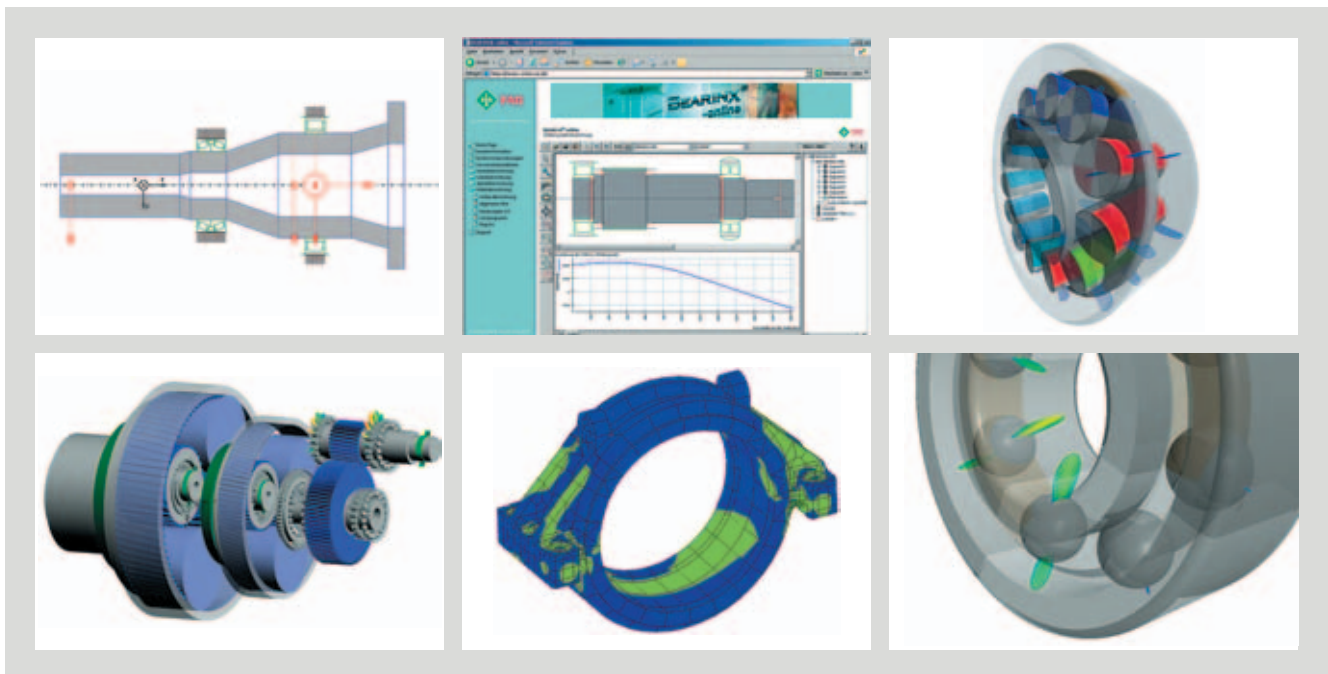
The advantages:

- 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.

Concentrated knowledge for expert bearing design



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. With BEARINX®, stress can be presented taking account of shaft flexing and the elastic behaviour of rolling bearings.

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.

BEARINX®-online

With BEARINX®-online our customers can calculate complex shaft systems with several bearing supports from the convenience of their office. The input files used by BEARINX®-online are fully compatible with BEARINX®. This makes communication with our application engineers considerably easier.

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 MKS 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.

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