

World's Largest Wind Turbine

GENERATES NEW LARGE-SHAFT BEARING TECHNOLOGY

Sweden-based SKF Group's design of a bearing system for a giant wind turbine with an unusual rotor shaft led to the development of the largest-known CARB® toroidal roller bearing system, as well as to advances in bearing assembly techniques and axial fixation methodology for large bearings.

All wind turbines are large, but the REpower Systems 5M wind turbine is huge.

Manufactured by REpower Systems AG of Hamburg, the 5M towers 120 meters above-ground and produces five megawatts of electrical power. With its three-bladed, 126-meter diameter blade span, the 5M is not only the largest, but also one of the most efficient wind turbines in the world, according to the manufacturer.

Throughout its design phase, the 5M presented significant technical challenges in several different fields. One of the most crucial was the design, manufacture and installation of a bearing system for the 1.5-meter diameter rotor shaft that supports the 130-ton, three-bladed rotor.

"SKF assumed total responsibility for the surrounding design, including the shaft geometry in the bearings area, as well as for all needed tolerances and surface roughnesses and the functional housing design," says Hans-Jurgen Liesegang, SKF account manager for the project.

A new bearing system on a hollow rotor shaft. Though required to support the heavy rotor, the cast iron rotor shaft is hollow. This is to meet weight, cost and performance requirements, all of which were crucial to the design process.

To eliminate the influence of positional- and deflection-related errors, the SKF specialists, in cooperation with



FIG. 1: Wind turbine designers believe that offshore installations are the most energy-productive, but they must be built to withstand the sea's harsh elements.

REpower's designers, developed a system to support the shaft with two bearings. In the non-locating position is an SKF CARB® toroidal roller bearing. The other bearing, in the locating position, is an axially locating, spherical roller bearing. This design affords high load-carrying capacity with the lowest possible bearing and housing weight for a two-bearing arrangement.



FIG. 2: The REpower 5MW turbine, at 120-meters high, is reportedly the largest wind turbine on the planet.

any production batch of bearings, assuming the loading and environment conditions, the same quality of ingredients of the steel, and the same manufacturing processes and quality of manufacturing execution.)

Simulation and calculation tool solves problems. To ensure the bearing system's performance requirements, SKF developed, in partnership with Sweden-based Programming Environments Laboratory (PELAB), its own simulation tool—BEAST—or BEARING Simulation Toolbox. BEAST is a dynamic simulation program that serves as a virtual test rig in the computer. Traditional methods of long and costly experiments on a test rig are replaced by faster and more detailed computer simulations. The program was first used in the development of the SKF line of CARB® bearings, and again in smaller-sized CARB® bearings to evaluate how the inclined shaft in the 5M would influence bearing behavior. The 5M's bearing, with its 1.5-meter inside diameter, weighs 2,700 kg and is the largest of its type ever manufactured by SKF. How a bearing of such magnitude would affect an inclined shaft was an unknown in the early stages of the design process, but the finished product represents beyond-the-envelope bearing design. Because of the bearing size and mounting, further development requiring FEM calculations was needed to determine the interference fit on the hollow cast iron rotor shaft.

Lubricating a 1500-mm diameter bearing. The bearing size also necessitated novel lubrication considerations. The behavior of grease in, for example, a 500-mm diameter bearing is well documented; but not so for a bearing with a diameter of 1,500 mm. Lubrication specialists at SKF needed

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“SKF made all the service duration calculations (for the bearings assembly),” says Liesegang. Calculations included “first L10h calculations based on first-load estimates and the final duration calculation for the Germanischer Lloyd certification based on the given load distribution over time.” (Editor’s note: L10h is an industry standard based upon theoretical expectations of the maximum life expectancy of 90% of

case study

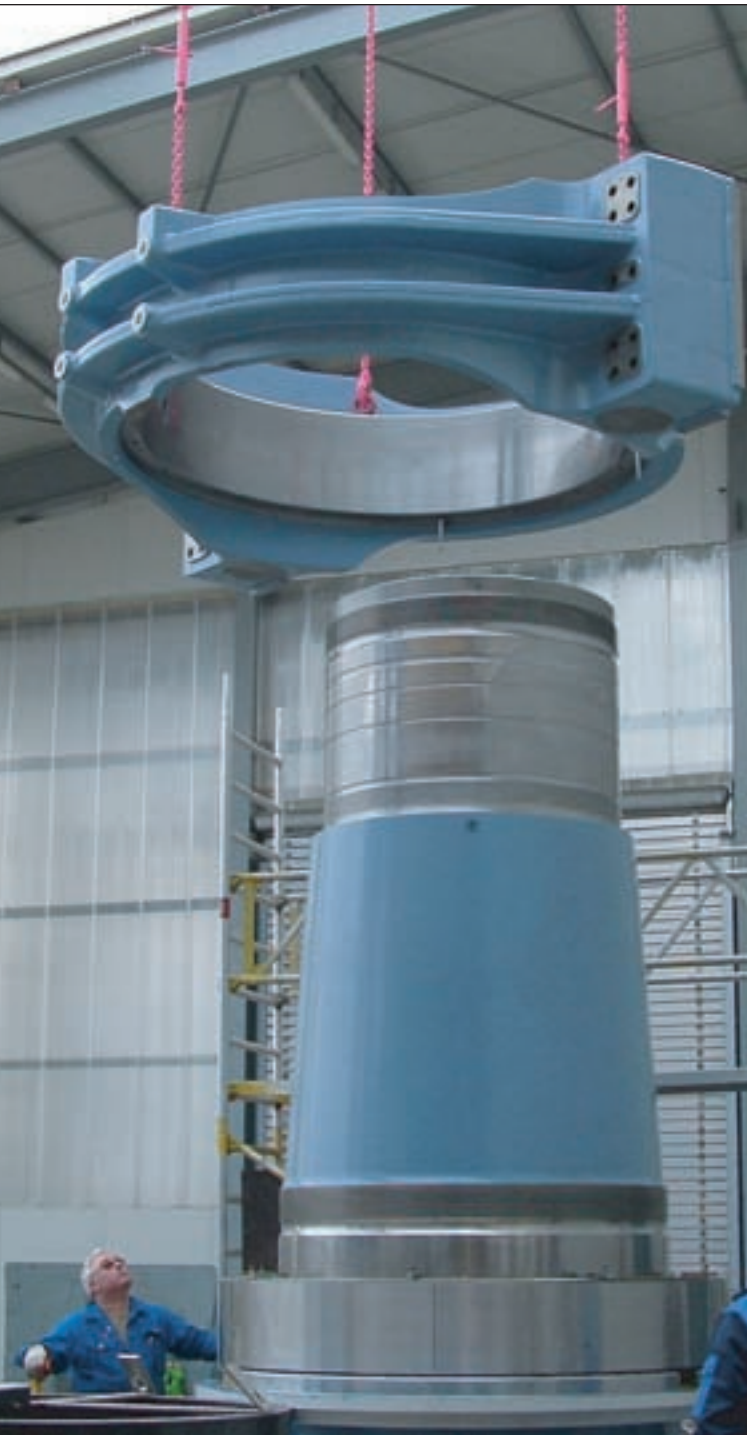


FIG. 3: The 8,000 kg housing is carefully lowered onto the CARB® bearing encompassing a cast iron hollow shaft. The shaft must support the 130-ton rotor.

to determine whether grease distribution in a 1.5-meter bearing would cover all the relevant surfaces, or would gravity pull the grease to the bottom of the housing. Answers to those questions resulted in the housing being designed to cover oil lubrication as well as grease. But later inspections have shown dependable lubrication coverage, thus allowing for a simpler housing cover.

Induction heater for bearing assembly. Another challenge for the bearing specialists was to overcome difficulties during assembly and installation of the two huge rotor shaft bearings. For one, there were no commercially available induction heaters that could uniformly heat the 2,700-kg CARB® bearing and the 3,320-kg spherical roller. So when the time came for the bearings and their two 8,000-kg housings to be heated for correct assembly and installation, SKF designed and had built a 1,000-kVA (kilo volts x amps = watts) induction heater.

Also, because the weight of the roller set in the CARB® bearing is almost 800 kg, it had to be specially clamped during heat-up and assembly. Without induced safe-clamping, the weight of the roller set would make the rollers clamp loosely between the inner and outer ring, which could damage the raceways. (Normal, loose clamping also occurs in standard-size bearings mounted vertically, but because the weight is so much less, it is not a consideration.)


Axial fixation of the bearings presented another major challenge. Fixation is usually done by shaft nuts, but the shaft in the 5M turbine has a diameter of 1.5 meters. The frictional moment on a thread of this diameter is enormous. The problem was solved by design of an outsized, safety split nut—the largest ever made. Dubbed the “HMS lock nut,” its most notable feature is that it does not require a keyway in the shaft, thus resulting in a more robust design and reduced manufacturing costs. The system is easy to mount and open for maintenance and repair, and there are no problems with fretting corrosion when dismounting.

Destined for a life at sea. The first 5M wind turbine was erected in Germany at the coastal city of Brunsbittel; it came on-stream in 2005 as a pilot project to evaluate the total turbine design. The location was based on the conviction by the designers of the 5M that wind at sea is a much better source of power than wind on land. They believe that because wind speed at sea is typically slightly higher, and the wind frequency decidedly greater, you can harness twice as much electricity from wind at sea as from on land. Consequently, the Brunsbittel installation serves as a beta test site in anticipation of the series installation of 5M turbines out at sea.

Indeed, the first proposed site is 25 kilometers from the Scottish coast, in 44 meters of water. The site is part of the Talisman DOWNWIND project supported by the European Union.

Because the 5M was designed for operation in harsh environments, exceptional care was required in the design, manufacture and installation of the rotor shaft bearing system. Beyond its protection against corrosion, redundancy in many components, and continuous electronic monitoring of critical components, the 5M turbine has a rotor shaft bearing system that has been engineered for long-term reliability.

For REpower, partnering with SKF was an easy strategic decision.

“SKF is known worldwide as the bearing company with new ideas like CARB® and HMS-nuts, and WindCon (machine condition monitoring system),” says REpower’s Carsten Eusterbarkey, the project’s development engineer. “They are a global player and will help REpower to build up production and joint ventures all around the world.” 

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FIG. 4: Positioning the CARB® bearing system onto the custom-designed induction heater.



FIG. 5: The CARB® toroidal roller bearing being clamped prior to heating.