In recent years, manufacturers for wind turbine gearboxes have been challenged with high expectations from OEMs to continuously increase torque density and reduce costs. As rotor sizes have increased, rotational speed has decreased (in view of tip speed limitations related to noise) and design torque for the gearbox has increased proportionally. In view of transport, handling, and assembly limits, gearbox manufacturers are confronted with the need to design higher torque gearboxes in the same design space as previous generations of wind turbines. This explains the growing need for torque density increase, i.e. the ability to transfer higher torque levels through the same outer dimensions.

Challenges to tackle
ZF Wind Power has been working on developing plain bearing concepts as a viable alternative to roller bearings since 2011. A broad study of plain bearing design concepts and materials suitable for different positions in the gearbox was done. It soon became clear that plain bearings are a contributor to
The anticipated need for torque density increase as well as cost reduction.

The main challenge, however, is to find the right choice of materials and design parameters to guarantee smooth operation in all wind turbine loading conditions. Whereas most of the known plain bearing solutions run at a rather constant high speed and relatively low load conditions, the wind turbine loading conditions are quite the opposite, i.e. rather high load in combination with relatively low rotational speed, and a combination of transient conditions, such as start-stops, load reversals, etc.

The main challenges are in the low-speed planetary stage, where the combination of relatively low speeds and the flexible surrounding components can bring the plain bearing into mixed friction conditions.

An in-house test rig to optimise the plain bearing concept

ZF Wind Power was able to successfully develop a first generation of plain bearing concepts, where the designs are characterised by a cautious choice of design parameters, i.e. relatively soft materials (including bronze) operating in moderate pressure regimes. For the planetary stages, the so-called ‘floating sleeve’ design was chosen, i.e. a bronze bushing that freely rotates between the planet pin’s outer surface and the planet wheel’s inner surface. These concepts were thoroughly tested on different levels: material testing specifically in mixed friction conditions, testing on component and sub-system level, as well as gearbox testing on the system test rig and in the field. For the sub-system-level testing, ZF Wind Power developed and built a dedicated test rig which emulates the effect of the gear meshes and deformation of the components in the planetary stage in real size. The rig includes two gearboxes, each with two pinion shafts and a planet gear in between. The two gear meshes simulate the real-size planet environment for the floating sleeve test specimen. A variable hydraulic motor torques the gearboxes and dynamically loads the test specimen.

The behaviour of the test specimen is monitored by a range of sensors. Different design variants of the floating sleeve concept can be tested in a broad variety of running conditions. Simulation models are validated in-depth via this Design of Experiments (DoE) approach, with said validation allowing for optimisations of the plain bearing concept to be done in an iterative way. Several gearboxes incorporating the floating sleeve bearings were tested at the system level using ZF’s in-house dynamic test rig.

The test programme included critical operation points along the power curve, including start/stop, overload, and overspeed conditions. Furthermore, survival states like no-load, rotation under emergency lubrication conditions, and cold chamber tests were performed in a separate test set-up. Finally, several technology demonstrators were put up in the field. Field performance to date has been positive. Inspection results from the disassembled gearboxes that returned from the field after one year of operation were positive overall.

Up to serial production

Technology readiness of these plain bearing concepts is at such a level that steps towards serialisation are now being taken. Current new product developments in the 4 to 5 MW onshore market segment are incorporating the floating sleeve plain bearing concept. Preparation for serial production in terms of the production processes, quality assurance system, and supply chain setup is ongoing.
In view of needed torque density to fit the gearbox into given nacelle dimensions, plain bearings clearly have an advantage over roller bearings in terms of outer dimensions for the same loadability level.

To keep pace with the OEM’s product roadmaps for future wind turbine platform extensions, ZF Wind Power is continuously pushing gearbox developments up the torque density curve. For this, the current plain bearing designs will have to be taken closer to the limits. With a clear focus on the next steps in plain bearing technology for planetary stages, ZF is working on downsizing the plain bearing and planet pin combination for the planet positions through an innovative integration of functions.

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Torque Density Evolution

ZF Wind Power

With more than 120 GW of wind energy installed worldwide, ZF Wind Power is a competent partner, supplying major manufacturers of gear-driven wind turbines with a gearbox output range of up to 9.5 MW power capacity and serving all key wind-power segments.

ZF is determined to be the leading designer, producer, and supplier in geared solutions for onshore and offshore wind turbines and is committed to succeeding in making wind power the most attractive energy source in the future.

With state-of-the-art manufacturing plants and service locations around the world, ZF Wind Power is dedicated to delivering advanced gearbox solutions and services on a global scale, meeting the individual needs of the world’s wind market. Headquartered in Belgium, the company has a global footprint with manufacturing and service presence in Europe, China, India, and the USA. As a continuous innovator, ZF anticipates the trend towards intelligent systems by enabling performance optimisation of the overall wind turbine.

ZF – Putting Wind Energy in Motion.