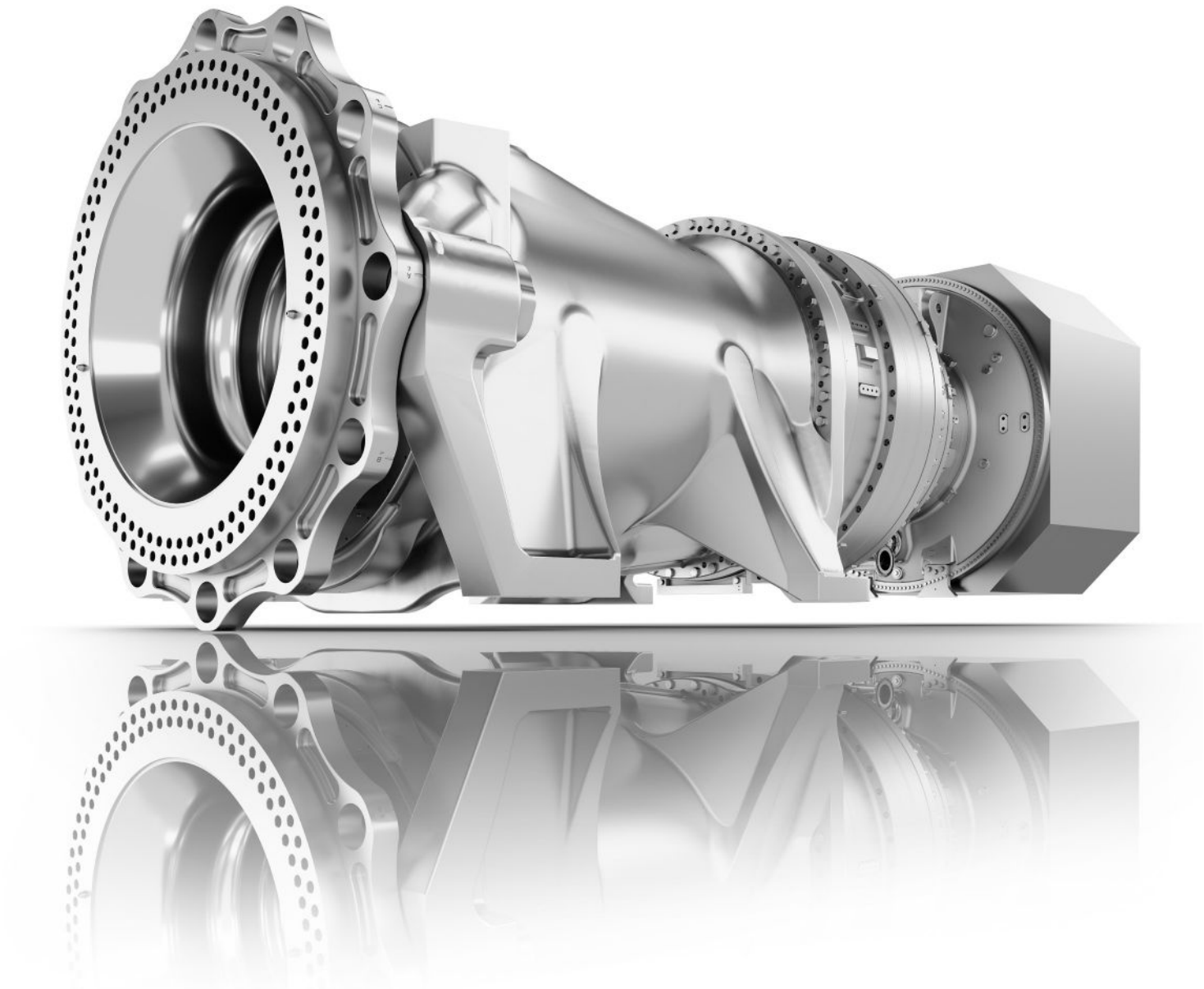


Together with its partners, ZF Wind Power respond to the market evolution with the most powerful complete powertrains

Empowering a sustainable future together

All major regions aim to be climate neutral by 2050. Renewables-based electrification across the economy will be key to this ambition. Wind energy will play an important role in providing clean and competitive power in all major regions. Europe and other regions want faster implementation, putting even more pressure on supply and changing how businesses work together. We must rethink how we create new opportunities to increase competitiveness in this challenge.

Covering market flexibility: from modular gearbox to modular powertrain concepts

Market demands are rapidly changing regarding the pace of introducing new turbine variants, thus bringing flexibility in development to meet market requirements. As a gearbox manufacturer, ZF responded to these early trends back in 2016 by presenting a new modular gearbox platform concept 'SHIFT.' Thanks to standardized building blocks, the platform helps wind turbine manufacturers offer high flexibility in adapting wind turbine designs to changing market requirements while reducing the Levelized Cost of Energy (LCoE).

The market is shifting to a higher gear, and the industry requires higher torque levels. LCoE reduction pressure remains valid. The availability of materials and innovation to upscale wind turbine output is triggering the wind industry to continuously revise its portfolio and roadmaps. The increasing size of powertrains imposes bigger logistical challenges. Cost management shifts from the component to the system level. This opens new opportunities for strategic suppliers to work together with wind turbine manufacturers and offer new solutions in the supply chain. Close cooperation is needed between all stakeholders.

Empowering a sustainable future together

Together with its partners, ZF innovates with compact and modular designs and supplies the most powerful complete powertrains. In 2020, ZF launched the EnVentus powertrain together with Vestas. With a capacity of 6MW, this complete powertrain was the most powerful onshore powertrain. A few years later, both partners joined forces again and launched the V236-15.0MW powertrain onto the market. With a 15 MW output, the V236-15.0 MW is one of the most powerful gearboxes ever developed for wind turbine use. The torque level is more than three times higher than the EnVentus powertrain.

The first-stage planet carrier incorporates several highly innovative features supporting very compact designs (Torque Density 210 Nm/kg). This planetary stage absorbs the highest input torque; the components are also the largest and have the most mass. Cost savings can be achieved by reducing the outer gearbox diameter and other components, such as a ring gear size, in line with that reduction. The use of compact journal bearings, now a proven mature wind gearbox technology for ZF, is almost a must in these high torque stages. Three stages are now common for larger scale, that are higher rated and/or with larger rotors, wind turbines. The engineers tackled the combined first-stage planet carrier challenges by minimizing internal spacing between the planet gears by switching from a conventional 'outside-in' assembly method to a novel 'inside-out' methodology. This makes it possible to enhance planet carrier stiffness maximally while optimizing carrier and gear-stage mass in a multi-planet stage design.

By introducing the full-scale modular concept at the gearbox level, ZF can now rely on more than seven years of experience in compact and flexible designs that reduce weight and increase output and will further expand this knowledge to create complete powertrains.

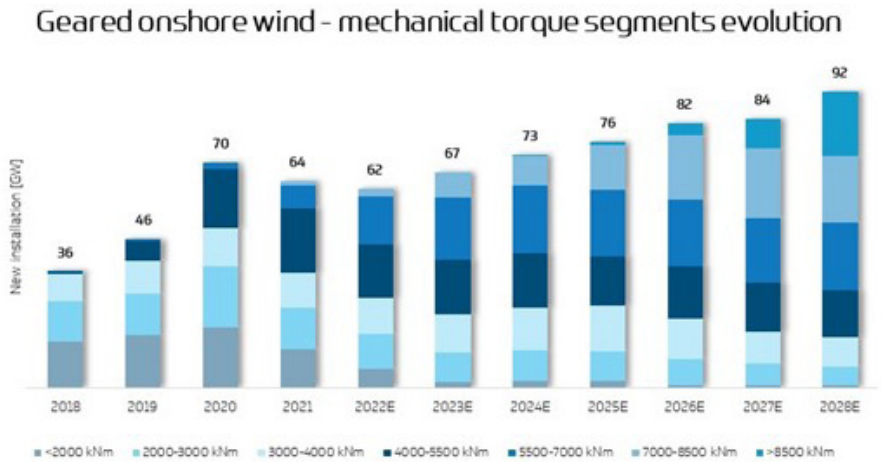
Assembling the future: process modularity

Challenges in R&D are followed by challenges in production processes. ZF aims to reutilize existing and proven production facilities for new designs. Integrating new concepts, additional operations, and bigger products into existing facilities is a challenging process. It requires innovative and new assembly technologies and tools to master the complexity and maintain operational efficiency.

To integrate products on the shop floor, ZF uses advanced software to create a digital twin of the facility before rebuilding the plant and setting up the assembly process. This encompasses all necessary assembly and logistical steps to be virtually predefined, checked in 3D, optimized, and validated. This results in swiftly integrating new processes into the existing manufacturing facilities. The company strives for full modularity of production processes, complete powertrain testing, validation, and pre-commissioning under one roof.

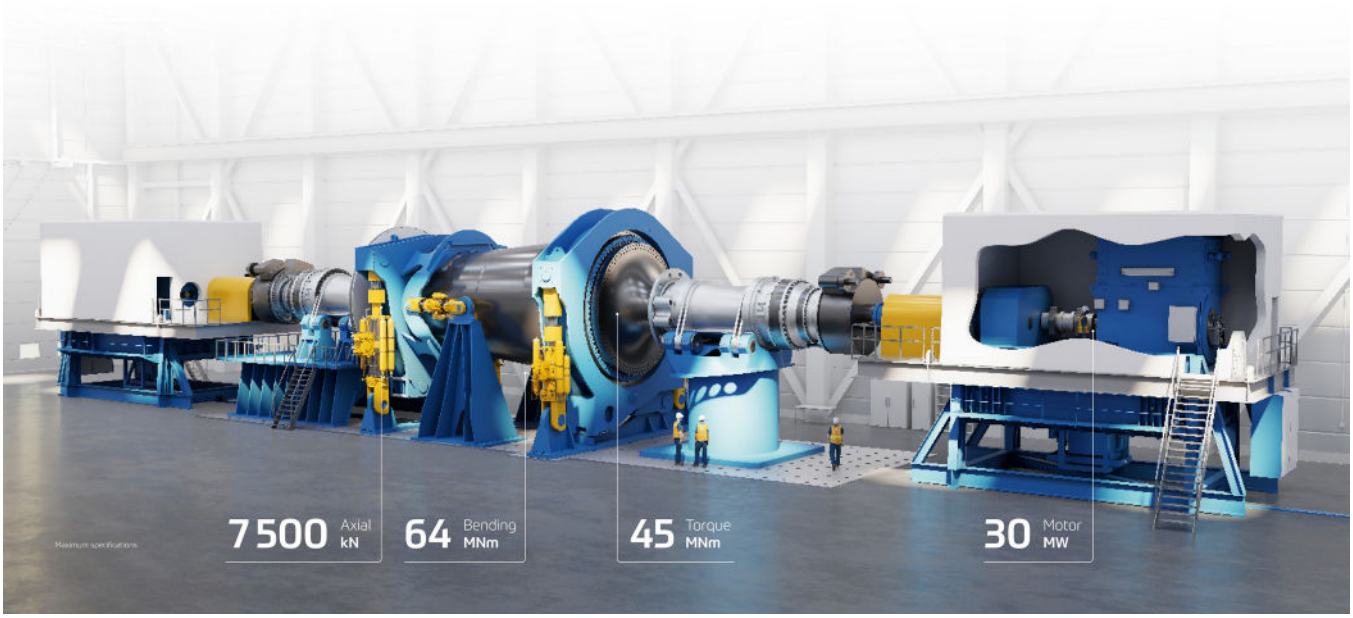
Future-proving growth: extensive in-house validation

With the development and production of the complete 15 MW powertrain, ZF Wind Power proves they are actively preparing for the future. The team is convinced that the evolution and dynamics in the wind market will require a whole new level of testing and validation of modular powertrains that will drive the new generation of wind turbines. In the wind gearbox supply chain, ZF forecasts a continued increase in torque requirements with new onshore developments in the 7,000-8,500 kNm segment and even exceeding 10,000 kNm in the midterm in some markets offshore to double this torque evolution.



ZF Wind Power forecasts a continued increase in torque requirements with new onshore developments in the 7,000-8,500 kNm segment and even exceeding 10,000 kNm in the midterm in some markets

‘With the Test and Prototype Center, ZF Wind takes the validation of future powertrain concepts to a whole new level and sets an industry benchmark.’



The back-to-back 30 MW test bench validates complete powertrain systems for both onshore and offshore turbine applications

As an answer, ZF Wind Power invested in an in-house Test & Prototype Center. Besides the capabilities of prototype assembly, instrumentation, and a wide variety of testing ranging from component testing over no-load testing to (sub-)module testing, the center also boasts the world’s strongest test rig.

This back-to-back 30 MW test bench validates complete powertrain systems for both onshore and offshore wind turbine applications. With a length of sixty meters, the rig will test the functional behavior of the main bearings, the gearbox, and the generator at a system level under real conditions with functional load tests, dynamics, robustness tests, and system integration tests, as well dynamics in torque as non- torque, or bending moments, loading. It covers a maximum torque of 45 MNm, a maximum bending moment of 64 MNm, and a maximum axial force of 7,500 kN. The 30MW motors performing high-torque twisting are positioned at each end of the powertrains under test. Additionally, a specially designed load unit is located between the powertrains and applies the wind loads needed to simulate the varying real-world conditions. Together, the motors and the load unit can simulate the harshest torque loads as well as non-torque loads.

Extensive validation is the foundation of ZF’s innovations. Testing allows containment of the risks inherent to the wind industry and is essential to receive approval from customers, insurers, and certification agencies in order to launch new designs. From this standpoint, ZF is expanding its offering by investing in and driving a culture of standardization and collaboration throughout the industry.

ZF Wind Power has been the market front-runner since 2010 with its self-developed robustness Testing Program, DORoTe (Design Operational Robustness Testing). Now, with the Test and Prototype Center, the back-to-back 30 MW test bench validates complete powertrain systems for both onshore and offshore wind turbine applications. With more than seven years of modular gearbox designs and 20 years of integrated powertrain design experience, the team will be able to produce the next generation of wind turbine powertrains up to 30 MW and accelerate the speed at which the global energy system is being transformed. It demonstrates ZF’s commitment to wind and the strong belief in the future of this renewable energy source.

www.zf.com/windpower

ZF Wind Power

ZF Wind Power is a worldwide leading technology driven manufacturer and service partner in the global wind turbine gearbox industry. The company is leading the high-performance onshore segments with products up to 8000 kNm and first in exceeding 200 Nm/kg torque density in compact modular platform designs.

ZF delivered the world’s first offshore 9.5 MW wind turbine gearbox and delivered, in close cooperation with its partner, the first prototypes of the next generation offshore powertrains. The company has the largest global installed capacity of +8 MW offshore wind turbine gearboxes.

Since they entered the wind industry in 1979, ZF Wind Power has delivered more than 80 000 gearboxes, powering as much as 180 GW, mainly high-performance wind turbines, covering almost 25 percent of the total installed capacity of geared-driven wind turbines worldwide. With its partners the company constantly invests in the wind market to empower a sustainable future together.