Magnetic Transmissions Increase Lifespan of Offshore Wind Farms

At Sintex, multiphysics simulation is used to develop and analyze non-contact magnetic couplings. Such systems will offer significantly improved reliability, medium separation, and finding crucial roles in offshore wind turbines and chemical pumping applications.

by ZACK CONRAD

Whether it's an automotive engine, a wind turbine, or something as straightforward as a wristwatch, torque conversion and the transmission of rotational power are important for various technological applications.

Traditionally, transmission is achieved through a series of collinear mechanical gears or shafts that transfer torque and thus power. But mechanical transmission has inherent limitations, namely a susceptibility to friction, wear and tear, and overload because of the continual contact. As the scope of technology continues to expand into more hostile and unforgiving environments, these limitations can be of extreme detriment. In places of limited accessibility and harsh conditions, replacing failed transmissions is a challenging and tremendously costly task.

➾ POWER TRANSFER WITHOUT THE FRICTION

Engineers at Sintex have developed an innovative alternative that provides robustness and reliability: magnetic couplings. The essence of these couplings is that the power transfer is achieved via magnetic forces, rather than mechanical forces, therefore removing contact and wear and tear and drastically improving the lifetime of the transmission system. Power is transmitted through a torque coupling between concentric arrays of permanent magnets (Figure 1). A power source causes one drive to rotate, while the coupling of the magnetic fields between the drives causes the other to rotate with the same speed. This system allows rotational power to be transferred just as in mechanical transmissions but without the friction and risk of overload. If the torque transferred from the motor is too high, the coupling will limit excessive amounts from being applied to the shaft. This limit prevents the shaft from undergoing torque values greater than what it was designed for, thus assuring operation in its intended conditions.

Sintex's noncontact magnetic couplings are ideal for their customers in offshore wind turbines and industries that employ complex pumping systems. Offshore wind farms are becoming increasingly integral with their generation of electricity, but require high levels of reliability in their components because of how difficult these parts are to repair. In individual turbines, magnetic couplings transfer energy from the motor to water pumps that cool the electrical components 24 hours a day. As these offshore systems involve such remote installations, preventative maintenance or repairs are burdensome and expensive, making the reliability of magnetic couplings invaluable. In addition, the air gap between drives easily accommodates the insertion of a separator can (Figure 2), allowing for media separation and closed systems for use in chemical and food industries. Pumping systems that are completely devoid of leakage are critical for the transport, mixing, stirring, and grinding of chemicals and toxic materials.

➾ MAGNETIC COUPLINGS ACROSS INDUSTRIES

Sintex's magnetic couplings are employed in a diverse range of applications and must be individually tailored based on given constraints, which can include weight or material requirements and geometric restrictions. During the design process, engineers need to be able to interchange shapes and materials of magnets to meet their customers' requirements without having to build physical prototypes, as magnetic prototyping is costly and time consuming. In order to save time, Sintex uses multiphysics simulation to characterize configurations and provide virtual prototypes of designs. Flemming Buus Bendixen, a senior magnet specialist at Sintex, has used finite element analysis for twenty years, with COMSOL Multiphysics® as his primary tool of the last decade.

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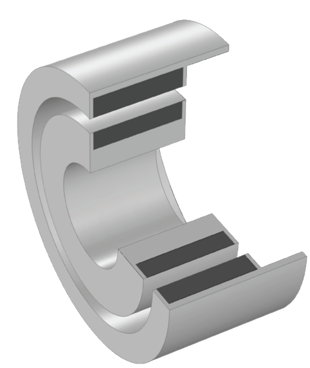
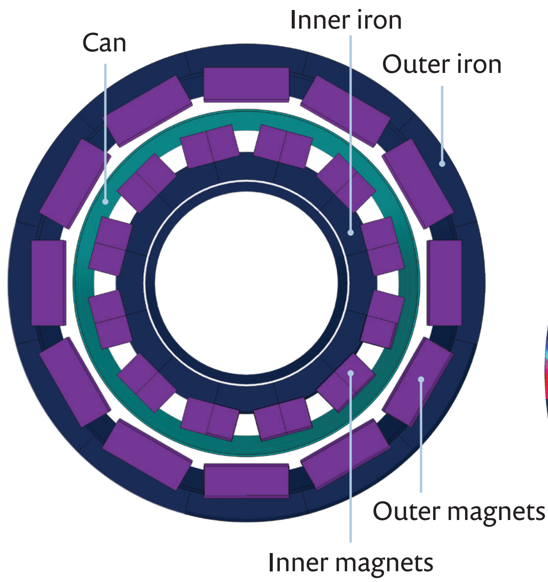


FIGURE 1. Schematic of a magnetic coupling.



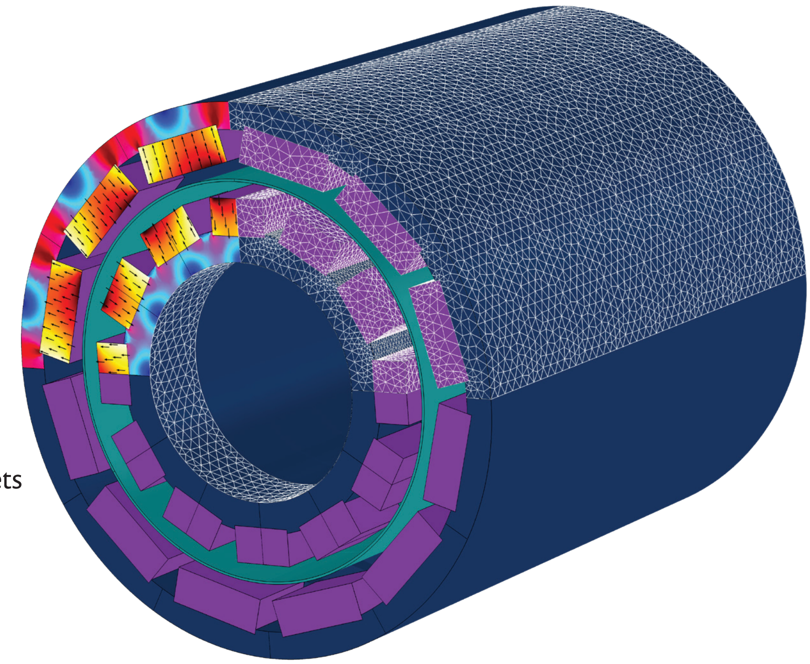


FIGURE 2. Left: Front cross-sectional view of a magnetic coupling. Right: 3D model of a magnetic coupling (the temperature distributions of the magnets, magnetic flux densities through the iron, and mesh are shown).

other," said Bendixen. His team has a plethora of incredibly thorough and complex models and because of the intense verification and validation that the models undergo, the team now places full trust in them. This not only saves time but also reduces the price for customers and allows a greater emphasis to be placed on the finer details.

⇨ ELIMINATING RISK WITH NEW DESIGNS

Using multiphysics simulation Bendixen studies the interactions between the drives of a magnetic coupling and calculates the torque transmission from the outer drive to the inner drive. As the primary purpose of magnetic couplings is to transmit maximum torque and power along an axis, the torque transfer is the most defining characteristic; therefore, it is calculated in multiple ways, including Maxwell's stress tensor, postprocessing integral methods, and the Arkkio method. The analysis is verified through experimentation and has yielded errors as small as 1%, speaking volumes to the accuracy of the model. During the development process of a new design, the model can be used to maximize the torque transferred in a specific configuration.

Since permanent magnets and their fields give rise to numerous secondary effects, Bendixen makes a substantial effort to model them. In metals, such as the steel can in this coupling, eddy currents are generated by the external magnetic fields, resulting in electrical losses. "The shifting north and south poles create voltages across the steel; it conducts electricity and this dissipates energy from the system," explains Bendixen. These are referred to as can losses, which are simulated with post-processing tools in the software, and need to be reduced as much as possible. The team also recently developed a machine that experimentally tests the can losses of designs and confirms the accuracy of their model to a few percent.

"We are dedicated to capturing the truly nonlinear nature of magnetism, and COMSOL allows us to do just that, assuring optimal magnetization of the array," says Bendixen. By employing highly nonlinear hysteresis curves and utilizing their own material temperature dependences for magnetic loading, the simulations (shown above) help prevent the permanent magnets from reaching their critical temperature and becoming irreversibly demagnetized, which is paramount to assuring the reliability of their products. "It is very important to know the temperature that the magnets can withstand, and I can calculate this quite precisely," Bendixen adds. "If the magnets get too hot, they can become partially demagnetized."

Bendixen takes further advantage of the flexibility of multiphysics simulation having imported Sintex's library of magnetic materials, allowing for a vast array of custom magnetic configurations.

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➩ THE EASY BUTTON FOR SIMULATION EXPERTISE

Once Sintex was comfortable with the level of complexity in their models, the next step was to broaden their usage and make them more accessible to non-simulation experts. Previously, when sales representatives and other colleagues that were not versed in simulation techniques needed to run tests on designs, they went to Bendixen to have all of the calculations done.

Bendixen created simulation apps based on his multiphysics models and found productivity and convenience of simulation at an all-time high. Sintex currently employs ten different simulation apps with up to twenty different users. The apps are created directly in COMSOL Multiphysics® through the Application Builder tool and can then be accessed via a web browser by connecting to COMSOL Server™. The simplified user interface and straightforward deployment provide ease of use to all of their employees. Select customers are even given access to these apps and their computational power. "I built the apps because some of my colleagues are not so skilled in simulation software and would like to do some system testing and simulations by themselves, and the apps enable them to easily do this," Bendixen says.

Simulation apps allow the user to vary parameters without having to alter the underlying computational model. "Sales people can change dimensions and perform simulations while they're on the phone with clients to verify agreement with their specifications within minutes," says Bendixen. But despite the simplicity of the interface, there is still extensive flexibility to be innovative with design iterations. Sintex's apps let the user adjust both geometric and magnetic parameters. The model then calculates the critical temperatures of the magnets, remanence distributions, magnetic field flux densities, torque, and can losses. Figure 4 is an example of an app that simulates the eddy currents generated in the separator can. These currents can then be used to calculate the resulting power loss. Now, people at all stages of development can contribute to the design process and help maximize reliability in their products.

FIGURE 3. Standard magnetic couplings.

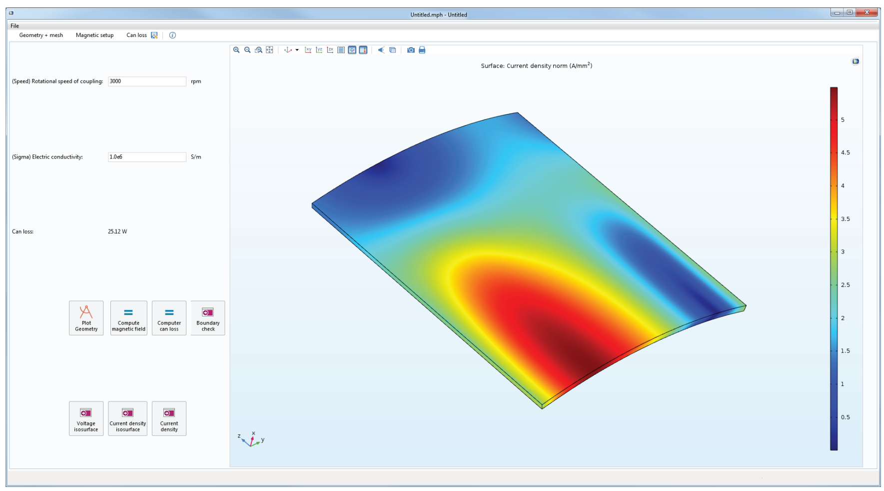

FIGURE 4. This portion of the simulation app models the induced eddy current density in the can and calculates the resulting energy loss.

➩ LOOKING AHEAD

Sintex is also developing a novel magnetic reluctance gear, which will expand the application range of gears in general. In addition to offering reliable, noncontact magnetic transmission of torque, these gears can alter the speed or torque between drives, allowing for mechanical advantages to be created with fixed gearing ratios. In a unique design feature, these gears will incorporate a single permanent magnet with a magnetization parallel to the shafts, greatly simplifying assembly and enabling a high degree of customization. And with simulation apps involving more people in the analysis process, Bendixen can spend more time making consistent improvements to all of Sintex's magnetic technologies. ❖

Flemming Buus Bendixen, a senior magnet specialist at Sintex.