Noise and tonality: crucial as onshore goes large

How can powertrain technologies help to unlock onshore areas and raise social acceptance of wind power? Originating in the field of combustion engines, Geislinger successfully entered the wind power market in 2016 with its COMPOWIND® coupling. The robust and durable low-speed shaft coupling (LSSC), made of advanced composites, absorbs virtually all bending moments, or parasitic gearbox loads, and allows the gearbox to be rigidly attached to the main frame.

This is not only important to increase drivetrain reliability and avoid costly gearbox replacements, but also to enable reliable, highly integrated medium-speed drivetrains.

The next milestone in Geislinger's mission to continuously add value to the wind industry has been achieved this year by ramping-up series production for a gearbox-integrated noise, vibration, harshness (NVH) solution. This is to avoid tonalities and disturbing audible tones, originating in the wind turbines' drivetrain.

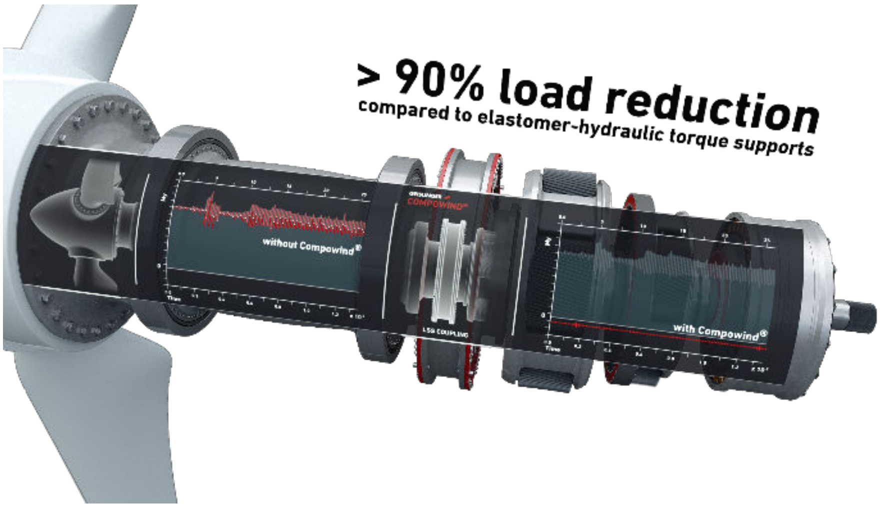
The idea of developing acoustic solutions for wind turbines was derived from long-term experience with sound attenuating products for combustion engines and marine propulsion systems. It was reinforced by the obvious increase in issues with noise and tonalities from wind turbines.

Transfer of combustion engine know-how to wind drivetrains

In combustion engines, most of the engine noise is due to mechanical excitations rather than combustion noise. The torsional vibrations of the camshaft are caused by excitations of the injection pump, leading to gear teeth impact in the gear train between the crankshaft and camshaft.

The energy generated is transferred through the camshaft bearings to the engine structure, which radiates noise. Acoustic tiles on the walls of the engine room and engine covers provide noise reduction to meet regulations.

However, additional costs arise, and engine covers complicate servicing work. Insulating material only dampens the sound path, whereas a torsional vibration damper or a torsional elastic coupling gets down to the root of the problem. Excitations are being mitigated to avoid the generation of structure-borne sound instead of trying to reduce noise after it has already been generated. Transferring this vast experience from internal combustion engines to wind drivetrains opens up uncharted opportunities for tonality-free wind drivetrains.



Growing noise protection requirements

It is not just noise regulations for emissions from European onshore wind parks that are becoming more stringent. Many national regulations for operating wind turbines contain a penalty for wind farm noise with one or more tones, or tonality.

A tremendous advance in blade aerodynamics has gradually reduced sound power levels too. The reduction of this so-called masking energy makes the mechanical noise audible. Noise originating from the drivetrain propagates throughout the entire drivetrain structure and finally to the emitters, like blades, tower, etc.

The need for energy production at low wind speeds, as well as during night time hours, could also lead to increased demand for mitigation measures to avoid tonalities and reduce the overall noise from wind turbines.

The unstoppable trend towards large onshore wind turbines, combined with limits for road transportation and the race to reduce costs is leading to ever higher torque density. Consequently, the ratio of excitation energy versus the mass moment of inertia is shifting, increasing the probability of noise and tonality issues, i.e., wind turbines not complying with noise emission regulations. In other words, the 'damping mass' remains the same, while excitations increase.

All in all, wind turbine and gearbox manufacturers need to explore new technologies to avoid tonalities and noise radiation to meet future regulations and increase energy yield also in urbanized areas.

Drivetrain sounds

Depending on the general architecture of the respective drivetrain and its main modules, wind turbines show some typical eigenmodes. These mode shapes are found in the frequency range up to 250 Hz and do not differ significantly between different wind turbine models.

One of them is a torsional eigenfrequency dominated by the second planetary stage of typical 2- or 3-stages wind turbine gearboxes. This eigenmode is prone to gear mesh excitations and causes the planetary carrier to resonate with the gearbox, resulting in angular acceleration and torsional vibrations.

This is a major source of mechanical sounds, mainly resulting in tonalities and low-frequency noise, propagating through the structural components, like drivetrain, base frame and main shaft hub, before eventually being radiated as tones from blades, tower shells, and other larger surfaces.

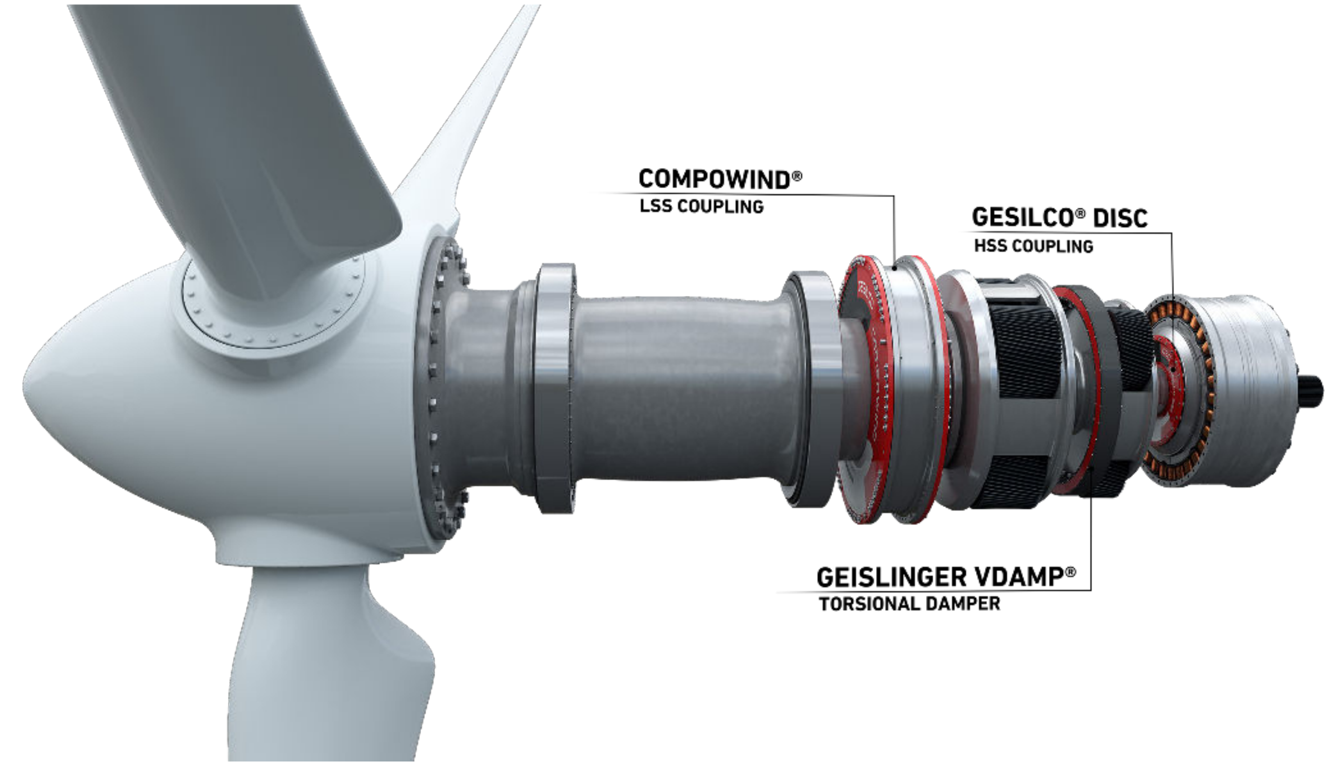
Depending on the excitation levels in combination with the dynamic properties of the structural transfer paths, vibration responses at specific frequencies can be amplified by resonance operation, leading to the radiation of tonal noise or, in the worst case, even degradation of the components' lifetime.

Resolve tonalities by torsional vibration mitigation

Recently, Geislinger has conducted several studies on various gearbox-integrated powertrain products, e.g. torsionally elastic couplings and torsional dampers to mitigate tonalities, followed by technology and product developments in close cooperation with wind turbine and gearbox manufacturers. Two examples are described below, limited of course to protect the intellectual property rights and confidentiality of our partners and customers.

The Geislinger VDAMP® is a viscous damper consisting of an inertia ring coupled to a housing by a special, highly viscous silicone oil. Torsional vibrations result in an angular offset between these elements, applying shear load to the silicone oil, converting the vibration energy into heat, and transferring it to the ambient.

By selecting the oil viscosity from a range of available products and designing the dimensions of the internal shear gaps, the

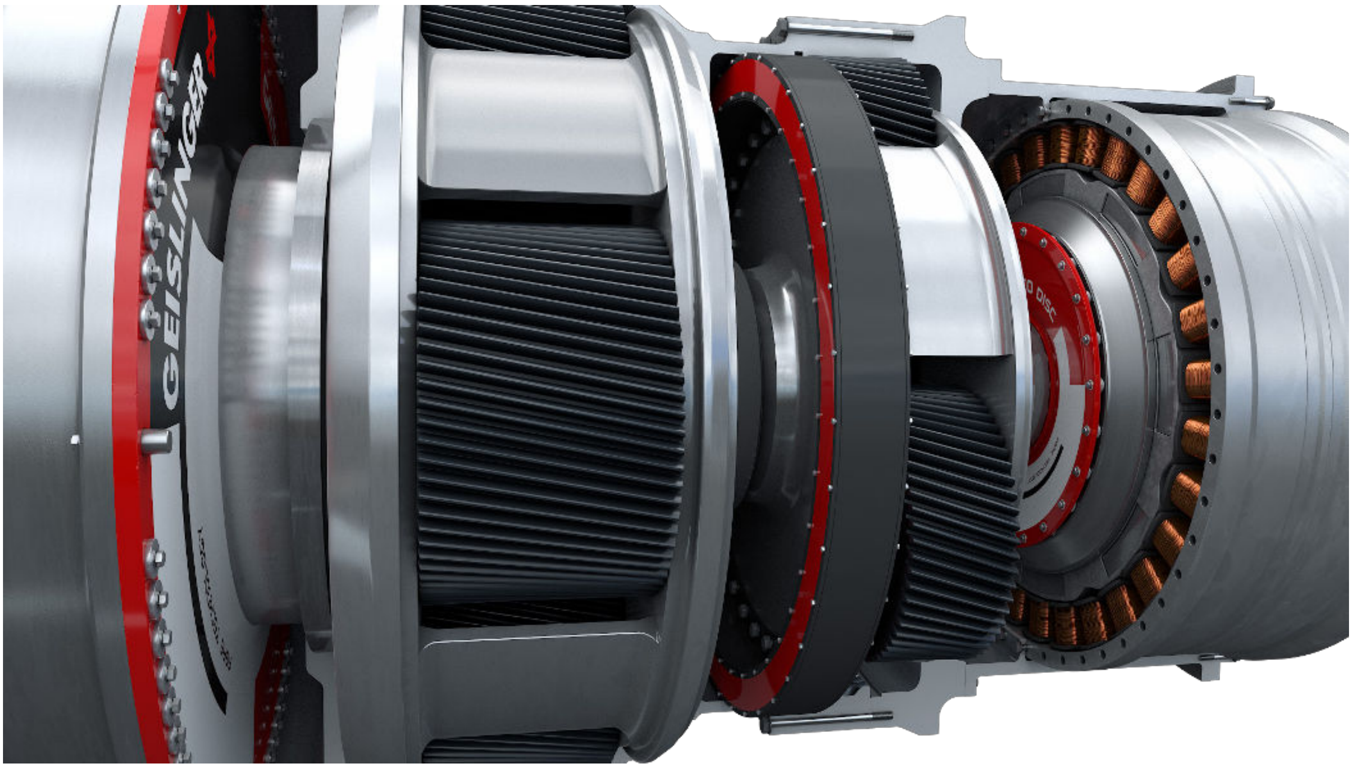


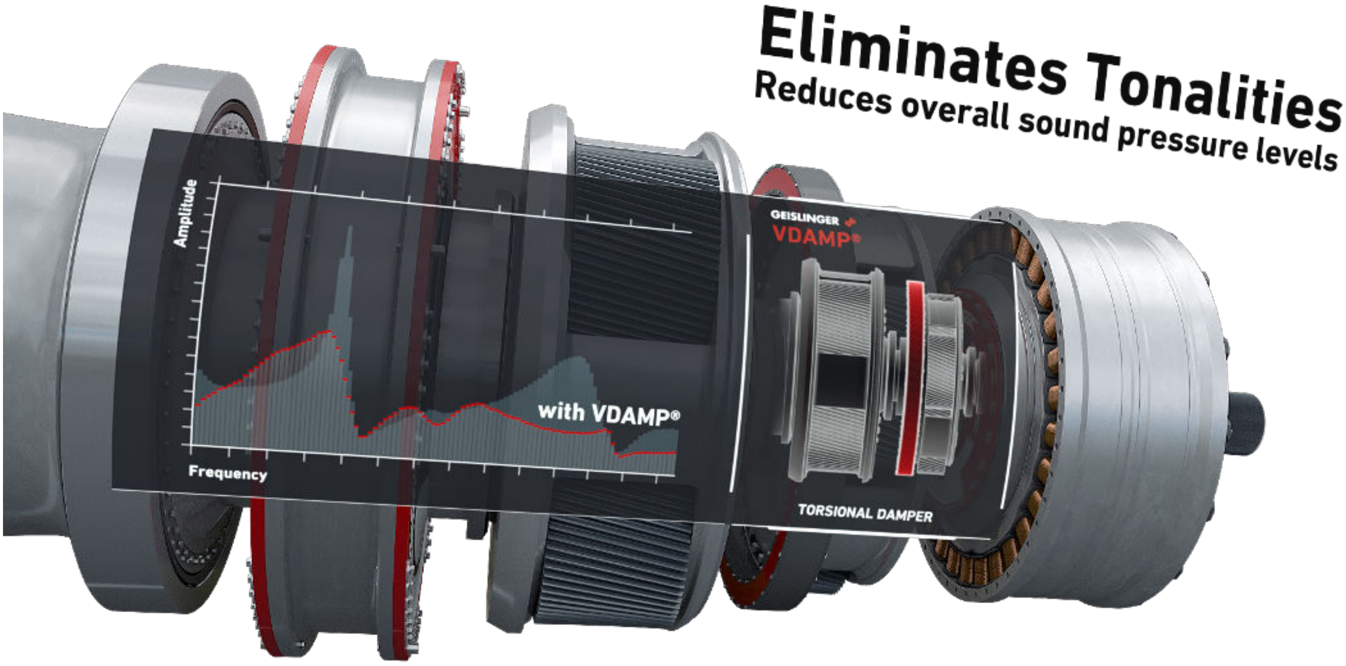
damper can be tuned to achieve a maximum damping effect on the drivetrain. A viscous damper is attached directly on the planet carrier, very close to the main noise source of the drivetrain. The broadband damping effect effectively reduces the amplitude in the main frequency area, corresponding to -5 dB and more depending on the available installation space.

A Geislinger coupling is a robust all-steel product with a tunable mechanical stiffness and hydrodynamic damping. Unlike a damper, a coupling is transmitting torque and is separating the torsional system into two tuned subsystems by introducing elasticity to the torque path.

For this reason, vibratory torques can hardly be transmitted. Vibrations are reduced, and the noise transfer is attenuated significantly. The damping properties of the coupling further reduce the resonance amplitudes. The basic idea of integrating a coupling into the gearwheel of the third stage, or parallel stage, is derived from the proven solution of camshaft couplings in combustion engines to reduce engine sounds.

Simulation results show the magnitude of the





shift in natural frequencies and lead to amplitude reductions of up to 50% and more, even if the coupling is not located directly at the excitation source.

Outlook

A third option to mitigate noise and avoid tonalities was developed in close cooperation with a wind turbine OEM and gearbox manufacturer. The solution is based on Geislinger's GESILCO® product line, i.e. on fatigue-resistant and maintenance-free couplings and driveshafts made of advanced composites.
The technology development will be completed in the fourth quarter of this year.

Simulation, test bench and field-testing results have confirmed the high potential of this solution and, together with its high degree of integration into the system, it is very likely to be a new technology with excellent prospects for the near future. The timing is just perfect against the background of a massive growth of wind power to be expected by 2024, 2025 at the latest. Due to confidentiality obligations, further information can only be disclosed towards the end of this year, followed by several publications in early 2023.

Finally, Geislinger has recently initiated studies in close cooperation with a renown German Institute to verify the effect of a composite LSSC, Geislinger COMPOWIND®, on noise transmission, respectively tonality mitigation: Until now, low-speed shaft couplings have been used on big offshore machines to increase reliability and avoid costly gearbox exchanges.

With the strong trend towards using integrated medium-speed drivetrains for the next generation of big onshore wind turbines, drivetrain development engineers will be faced with two major challenges. Firstly, impermissible gearbox loads, or parasitic forces, due to the stiff, integrated design without the use of elastic torque supports and. And with tonality issues, also because of omitting elastic elements, but also due to the ever-increasing torque density, the ratio of the damping mass to the excitation energy shrinks down to a magnitude, where additional tonality mitigation technology is desperately needed.

Gearbox integrated solutions were described in detail in the main part of this article. Nevertheless, tonalities can be efficiently eliminated by decoupling the excitations in the drivetrain from the sound-emitting surfaces of the wind turbine. In addition to the well-known behaviour regarding the decoupling of non-torque rotor loads from the drivetrain, the influence of a LSSC on the structure-borne sound propagation inside an integrated drivetrain is investigated.

Geislinger GmbH: a pioneer in torsional vibration technology

Founded in 1958 by L. R. Geislinger, the young engineering consultancy firm developed a torsional elastic coupling along with calculation methods for the reproduction of torsional vibrations in internal combustion engines. Back then, the tunable, all-steel torsional elastic coupling was a game changer to the marine propulsion industry.

Ten years later, in 1969, the Geislinger torsional damper was introduced to the market. Both products have been continuously developed further and are still representing the backbone of the Austrian technology company.

In the early 1990s Geislinger developed a lightweight, fatigue-resistant, and maintenance-free elastic coupling based on advanced composites. The first product was introduced to the market in 1995, followed by the first composite shaft to propel fast, light-weight vessels. Today, the composite product line is known to the marine propulsion industry as Geislinger GESILCO® couplings and shaft lines.

Innovation and engineering expertise were the foundation of Geislinger and still today, research and development play a vital role in the philosophy of the company:

Approximately 10% of the turnover is reinvested in this key segment year after year. The company, headquartered in Salzburg, Austria, is being run in the third generation by Cornelius and Matthias Geislinger, together with Torsten Philipp. Adrian Geislinger, the fourth generation, joined the company in April last year.

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