Hot Technologies to Help Cool the Planet

With global wind turbine demand set to quadruple by the end of the decade, manufacturers are seeking new technologies to ramp up production of gears that can operate in any environment, around the clock, for years to come.

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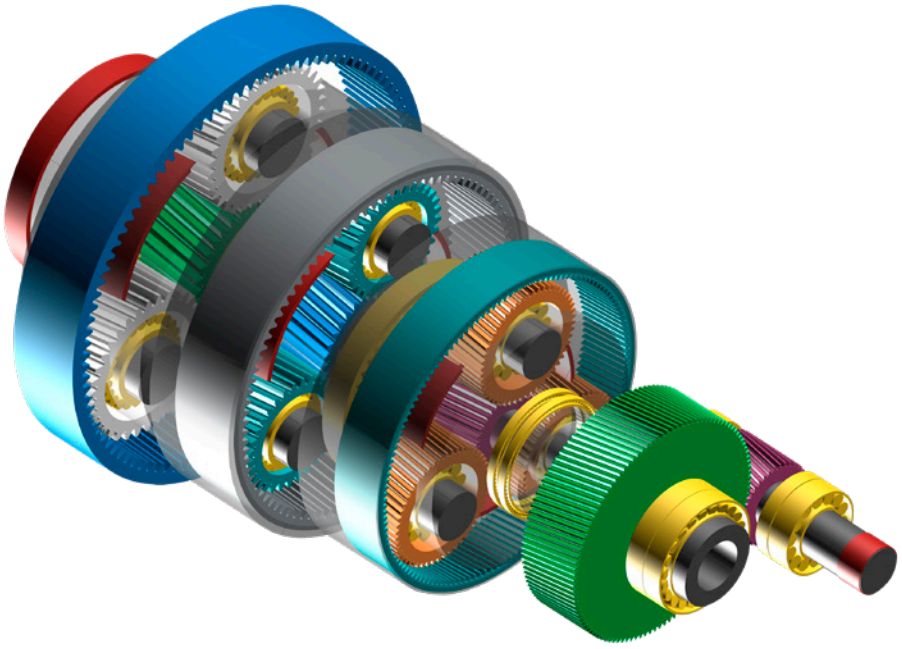
2023 is shaping up to be our planet's hottest year on record, and the wind energy industry is feeling the heat. The GWEC (Global Wind Energy Council) says that the rate of wind turbine installations will need to quadruple globally by the end of the decade if we're to achieve the IRENA's (International Renewable Energy Agency) goal of net zero carbon emissions by 2050—and keep the average annual temperature worldwide from increasing more than the predicted 1.5° C. Fortunately, "net zero" commitments are gathering global momentum. Before year's end, total global windpower is expected to reach a historic milestone of 1 TW of installed capacity, eliminating 1.2 billion tons of CO_2 annually, roughly the equivalent of all the carbon emissions of South America.

These are indeed interesting times for wind turbine manufacturers, now faced with unprecedented demand and backlogs stretching to the horizon. Meeting capacity challenges, while at the same time producing wind turbines that are more efficient and extremely reliable, are the most significant headwinds. In this industry, where the average lifespan of a wind turbine, onshore or offshore, can be 20 years, wear and tear take its toll, and repair and maintenance are very costly. Component quality thus becomes paramount.

Gleason is addressing these challenges with a complete array of solutions for optimizing production of the gears most commonly used in today's windpower gearboxes and, in particular, planetary gears in the 1,200 mm diameter range.

Better By Design

The design of gears and toothing for use in today's high-performance wind turbine main gearboxes poses unique challenges. Wind turbines today are much larger and capable of generating considerably more power than their predecessors. Some stand as tall as the Eiffel Tower and generate 13–15 MW, several times that of the average wind turbine in 2010. Gearbox designs have kept pace, with many more variations for low, medium, and high-speed applications and with one, two, three, or even four stages respectively. This added complexity, and the pressures of producing more power, more efficiently, while at the same time seeking greater reliability, have made it imperative that gear designs first be optimized, and their manufacturability assured well before the first gear is even cut. For that, there's *KISSsoft*. *KISSsoft* is a modular calculation program for the design, optimization, and verification of machine elements. The application ranges from individual elements to the automatic design of complete gearboxes with the add-on system *KISSsys*. It's a critically important tool when considering the challenges, and pressures, facing the wind turbine gearbox designer.



***A windpower gear configuration in* KISSsoft.**

Reducing Failure in the Field

In the low-speed stage (LSS), the extremely low speed in combination with high torque poses the risk of micropitting and tooth flank fracture besides uneven load distribution and flank and root failure. While the latter examples are well manageable and covered in detail in design guidelines, e.g., IEC 61400-4, micropitting and flank fracture rating processes along ISO 6336 series still are somewhat ambiguous and field failures do not always correlate with engineering analysis. Effects of material composition and purity, heat treatment, residual stresses, and shot peening are pronounced in the LSS due to the large part size. However, these effects are difficult to quantify in the gear sizing process, while at the same time, the gear sizing process for the LSS has the highest cost impact. *KISSsoft* gear design software can assist in this process by providing hundreds, even thousands of design candidates for the experienced designer to choose from. With these options, the designer considers absolute ring gear size, torque density, risk of vibration, required hardening depths and so forth. The need to split the input torque into several power paths necessitates the use of four or five or more planets in the LSS instead of only three planets. A simulation or calculation-based estimate for the load sharing among the planets can easily be created, along with the experimental verification thereof.

Optimized for Greater Efficiency

In the intermediate speed stage (ISS), tuning the gearbox ratio is the prime objective along with further lowering the torque for the high-speed stage to be able to handle it. A relatively high ratio asks for a relatively low number of teeth on the sun gear while the pitch tube defines a lower limit for its diameter. Furthermore, the higher circumferential speeds ask for a higher contact ration to mitigate the risk of elevated vibration levels. And for involute gears, a high transverse contact ratio requires a reasonably high number of teeth. Again, requirements are contradictory and algorithms to vary multiple parameters (face width, helix angle, profile shift, tooth profile, root rounding, protuberance, final machining stock, etc.) in a very short time must be calculated. The planet gear size must be chosen such that rolling bearings with rings can be accommodated for while ensuring sufficient material below the root diameter. Technologies, such as raceways, ground into planets or the use of hydrodynamic bearings add both constraints and freedom to the planet gear design.

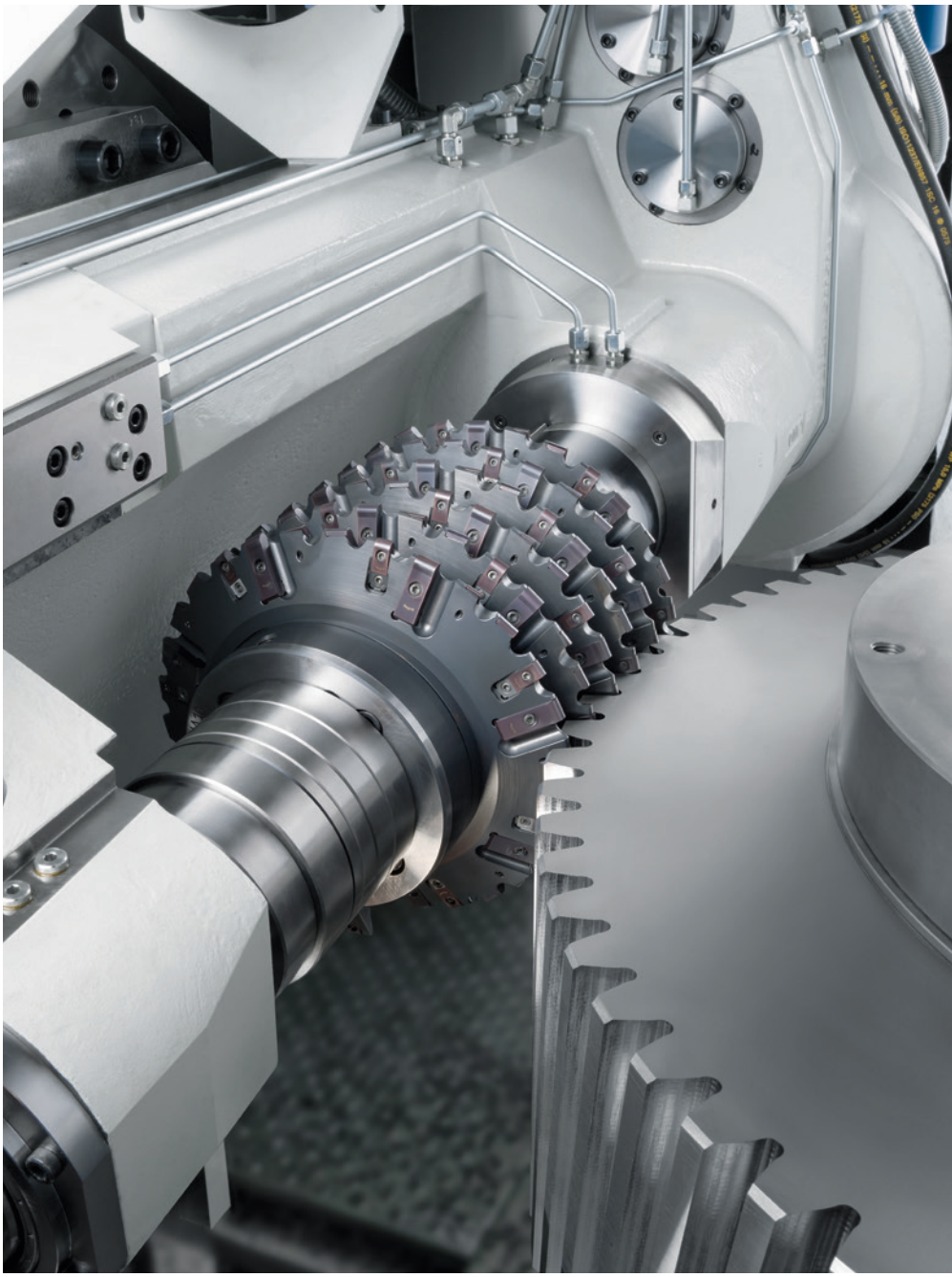
Extending Service Life by Years

Finally, the high-speed stage (HSS) reaches cycle numbers well into the high cycle fatigue range where experimental S-N curves are hard to come by. The gear rating for near infinite life much depends on the material purity, quality control and lubrication. The failure mode to base the gear design mode is pitting and the forementioned parameters are to some extent considered in the life calculations. Software based life and failure probability calculation are commonly based on load duration distribution type spectra but may nowadays also be based on torque versus time data directly. The effect of torque reversals may be considered for the flank and root rating modifications of the damage accumulation method, e.g., the use of "Haibach modification" should be considered. Finally, the Loaded Tooth Contact analysis and assessment of the transmission error in the HSS and its spectrum is an integral part of the gear design, targeting low mesh force amplitudes and pronounced higher orders in its spectrum. For all of the above, *KISSsoft* provides the gear designer with powerful tools to speed and help optimize this complex design process.

A Cut Above

Significant savings in production time, and improvements in windpower gear quality are now possible downstream in the manufacturing process as well, with the all-purpose Gleason P Series hobbing machines and the Gleason Titan hobbing machine series, combining maximum productivity and precision. For the planetary gears, external hobbing machines up to 1,200 mm workpiece size are used, with or without automation. These machines are also used for production of the sun gear shafts. For the larger internal gears, hobbing machines in the three-to-four-meter range, with powerful internal milling heads for profile milling, are necessary. All these machines need to offer maximum productivity for both rough and finish cutting.

The Gleason P-Series of hobbing machines seem almost tailor-made for the requirements of these gears. Wide guideways, with hydraulically preloaded guides, are used in combination with a separate linear guide and backlash-free roller bearing assembly to ensure precise, repeatable slide movements at any feed rate. The use of hydrostatic table bearings combined with the proven zero-backlash double worm index drive guarantees precise table travel and maximum face and radial runout accuracies for the worktable. With the Gleason Titan series, a machine concept for high performance external wind planetary and sun gear cutting is now available. Patented guideways ensure high performance when dry or wet cutting. The guideways, a combination of slideway and antifriction guideway, provide the ideal combination of stiffness and damping characteristics to help ensure substantially higher productivity and improved gear-cutting quality. Direct driven tables with



Opti-Cut Hobs (and Gear Gashers) maximize metal removal rates and cutting speeds by employing indexable carbide insert technology.

hydrostatic bearings offer new performance levels.

With both machine series, several hob head options for external and internal gear cutting are offered. Depending on the module and gear size, solid HSS hobs or Opti-Cut Hobs (and Gear Gashers) with carbide inserts can be used. The Opti-Cut design guarantees maximum metal removal rates and cutting speeds by employing indexable carbide insert technology. By eliminating the need to resharpen the tool, Opti-Cut Hobs achieve more consistent tool life and saves on the time-consuming resharpening process. Opti-Cut Hobs are available in a variety of cutter body sizes and geometries for gear milling or hobbing.

With today's higher volume production requirements for planetary gears, reductions in nonproductive load/unload and workpiece clamping times are critically important. Gleason offers a range of flexible automation and workholding solutions, all working together to make significant reductions in nonproductive time. For example, with the X-Pandisk system, workpieces weighing up to 2,000 kg can be centered and clamped automatically, thus taking significant time out of the typical process needed for an operator to manually set up and dial in workpieces of this size.

The Zero Point Clamping is intended for larger workpieces weighing up to 8,000 kg, including the pallet. Here, the setup of the clamping devices and the workpieces takes place in parallel during machining. This allows optimum quality to be achieved with minimum setup times.

In conjunction with these workholding solutions, nonproductive time can be further reduced by loading/unloading in parallel to machining using automation solutions now available for even the larger hobbing machines. These include pallet changer systems and 2-station ring loaders for disc parts.

The X-Pandisk system can handle workpieces weighing up to 2,000 kg and can be centered and clamped automatically—taking hours out of the typical manual process for operators to set up and dial in workpieces of this size.

Faster Grinding, Greater Reliability

With quality requirements now at levels rarely seen for gears of this size, hard finish grinding is mandatory. How best to deliver fine finishing, but without creating a costly production bottleneck—and adding significantly to cost? At Gleason, we've addressed this production conundrum with several new profile grinding solutions.

1200G Profile Grinding Machine

With 1,300 mm axial travel, the new 1200G covers the applications most common in this size range. For the large profile depths and high grinding performance required in wind power applications, then a performance grinding head with powerful 150 Nm torque and maximum wheel diameter of 450 mm is available. The grinding head can cover up to 80 mm profile depth, sufficient for the typical windpower gear. The 1200G's axial speed, particularly critical to ensuring short grinding times, is 10 m/min, exceeding the performance of competitive machines by up to 66%. Optionally, even 14.5 m/min is available, setting a new benchmark in this class.

Additionally, the design of the direct drive table allows for high dynamics and, through use of Gleason's proprietary Auto Servo Tuning (AST), the capability to handle a wide variety of workpiece sizes, weights and inertias.

Finally, the 1200G has an integrated inspection device for testing external and internal gears right on the machine, thus saving precious time as compared to transporting these parts to the quality lab. The inspection data can be evaluated according to all common industry standards.

Titan Profile Grinding Machines

The Titan Grinding Machines offer the ideal combination of high-performance grinding with best-in-class surface finishes. Through the use of the unique tool changer, it is no longer necessary to compromise with a single grinding wheel suitable for both roughing and finishing. Instead, individual grinding wheels can be used that are adapted to the specific tasks of roughing and finishing. This results in higher productivity, better surface finishes, and at the same time greater process reliability.

Titan's modular design covers machine models ranging from the 1200G to 1600G, with up to 1,600 mm workpiece diameter, 1,600 mm axial travel, module 40 mm, and a 100 mm maximum profile depth. For the profile grinding of windpower gears ranging in size from 1,600 mm up to 4,000 mm in diameter, Gleason offers its P-series. The P4000G, for example, is particularly well suited for hard finishing larger internal ring gears.

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All of these series give customers their choice of different grinding heads for external and internal grinding to cover any production requirement.

Most importantly, both the 1200G and Titan are designed to take precious minutes, even hours, out of cycle times by greatly reducing typical nonproductive time. For example:

Runout and Wobble Compensation

Time-consuming manual alignment of large and heavy workpieces on the machine table can be significantly shortened with patented runout and wobble compensation. A measuring probe detects the eccentricity position of the clamped workpiece on one or two measuring planes and compensates both the wobble and the runout of the workpiece during grinding. This feature ensures high precision with significantly reduced loading time.

Stock-Specific Grinding

Stock-specific grinding avoids air grinding caused by possible hardening distortions, especially during the first grinding strokes. During the tooth centering process, the stock allowance distribution around the circumference of the gear is determined and grinding is performed only where material removal is expected.

A(X) and Degressive Infeed Strategies

Innovative infeed strategies such as the patented A(X) and Degressive Infeed result in significantly better and uniform material removal along the entire profile during all grinding strokes, leading to much more effective and reliable material removal. This results in shorter grinding times, better wear behavior of the grinding wheel, and higher process reliability to avoid grinding burn.

Smart Dressing

Costly, time-consuming basic dressing for initial profiling or reprofiling of a grinding wheel is greatly reduced by the use of "Smart Dressing." The innovative software function ensures that dressing only takes place on the necessary grinding wheel areas.

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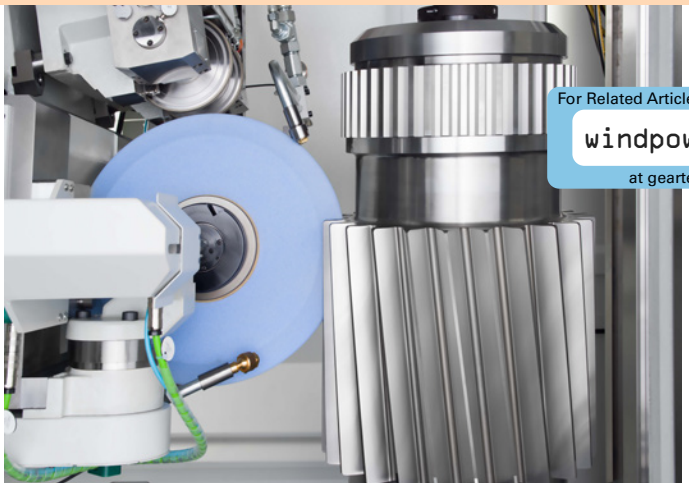

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New profile grinding solutions are the key to meeting the quality and reliability required of today's windpower gears, while at the same time reducing cycle times.