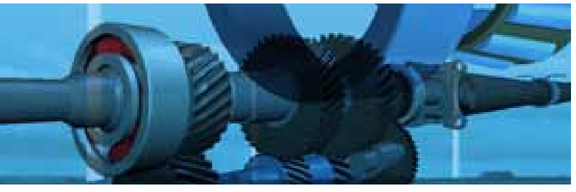
PRE-AWEA WINDPOWER SHOW ISSUE

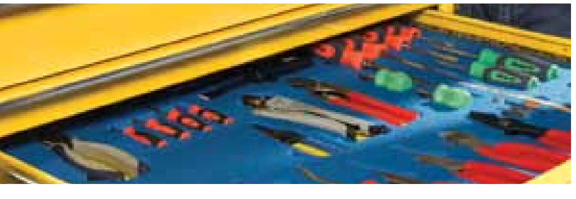
WIND SYSTEMS

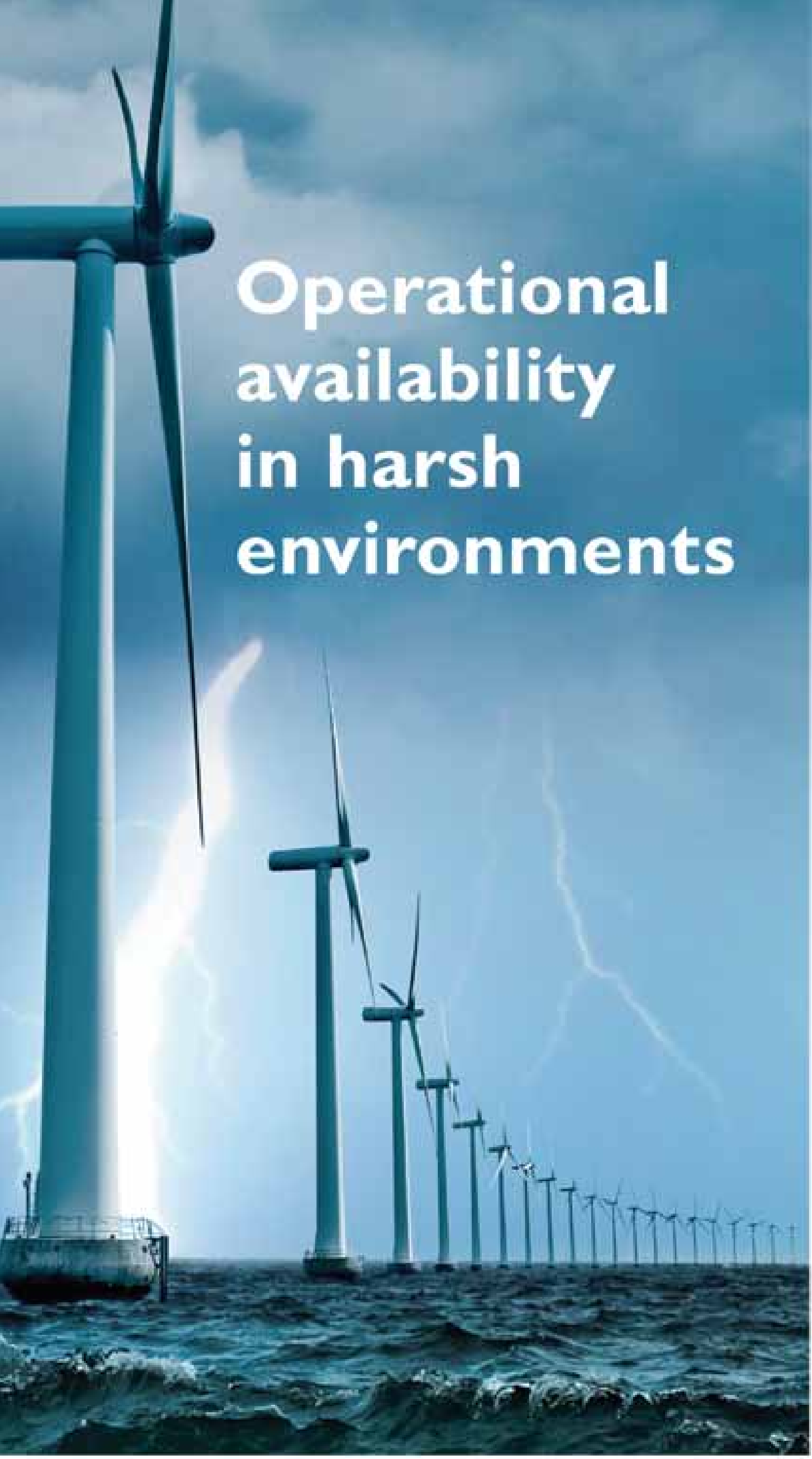
MAY 2012

FEATURES

MAY 2012



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DEPARTMENTS

VOLUME 3 NO. 33

RESOURCES

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EDLETTER

Like you, I've done plenty of work while traveling. I've written lengthy articles while streaking over the Atlantic and edited features in the lobby of the Bellagio in Las Vegas. Maybe that's why I appreciate Mike Graska's logistics columns so much—he's a busy guy, but he always finds a way to honor his commitments. He was the first writer I've worked with to submit a piece written entirely on his iPad during a flight, and he wrote this month's installment in his car during breaks from unloading wind tower sections. I've been amazed by the dedication of so many good people since we launched the magazine three years ago, and that's certainly true of this issue as well.

For instance, Juan C. Serrano and Sandeep Vennam of PPG Industries endorse "Automated Wind Blade Production" in their fine article, and SKF's Greg Zimmerman describes the BEAST in "A Virtual Toolbox of Technologies." Andy Lobo of Snap-on Industrial is a knowledgeable advocate of "Comprehensive Tool Management," and Mike Hayes makes a case for Gleason's new 3000GM analytical gear inspection system in "Inspecting Gears for Wind." Andrew Kusiak and Zijun Zhang of the University of Iowa have contributed "Gearbox Fault Detection," and Don Bridges of the JANA Corp. suggests that you consider "Streamlining Your Maintenance Program." Finally, Mike Moore of Shermco Industries takes an honest look at job prospects in the renewable energy sector in "Seeking a Skilled Workforce."

Even as we increasingly rely on these excellent technologies we shouldn't forget the value of our senses, writes Merritt Brown in his maintenance column, and Matt Lackner of the UMASS Wind Energy Center discusses monopile foundations in his technology column. Chris Martin of Crane Service, Inc., points out the challenges riggers face dealing with wind-speed changes at different heights. In developing our profile of Rockwell Automation—with the assistance of Steve Hessefort, Sarah Larson, Dave Schaetz, Milan Jovanovic, and Damon Sepe—I was impressed by the host of professionals available to service its customers' needs, and by the depth of knowledge it has amassed in its 109-year history. Kevin Coplan—the new president of Capital Safety for North America—is this month's Q&A subject, and I'd like to thank him for taking the time to share his story with me.

Excitement is building for the AWEA WINDPOWER 2012 Conference & Exhibition, to be held June 3-6 in Atlanta, Georgia. Be sure to stop by our booth #6213 to discuss how we can work together in the coming year. All best:

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NEW MEGAFLEX FOR WIND HUB PRODUCTION FROM MAG

Astraeus Wind Energy's MAG MEGAFLEX machining system has passed its initial supplier qualification by completing "Operation 20" metal cutting processes in record time on a Clipper Windpower C96 turbine hub, one of the industry's largest. The unique system simultaneously machines all three blade faces, which enabled it to complete the qualification hub in less than one shift, a first in the industry. "Completing hundreds of features on this hub in such a short time, and meeting the extreme tolerances required, is a world first for U.S. manufacturing technology," according to Astraeus President Jeff Metts. "We should be able to do the industry's simpler hubs in even less time. This is, without a doubt, world-leading technology that no one else can compete with. The system is operational now and we are taking orders, forecasting a capacity of about 1800 hubs per year."

The 18,144-kg (40,000-lb) spherical hub was approximately 3.6 x 3.6 m (12 ft x 12 ft) in size, with a blade bolt circle of about 2.5 m (8.2 ft). Operation 20 for this part included milling the blade faces, drilling and tapping or counter-boring more than 60 39-mm (1.5 in) holes per face, boring and drilling the blade-pitch gear mounting surfaces, and cutting various other features. Tolerances on the part, which was laser inspected after machining, include 0.05 mm (0.002 inch) true position on holes and ±1 degree on angles.

Conceived by MAG in 2009, the MEGAFLEX system's development was funded in part with grants from the Michigan Economic Development Corporation (MEDC), which audited and approved the progress of Astraeus in meeting its performance requirements. MAG developed the entire system on a turnkey basis, including the process concept, programming, machine systems, and tooling package. The patent-pending MEGAFLEX design, which is based on three MAG FTR 5000 floor-type boring mills surrounding a B-axis rotary table, simultaneously machines all three blade faces on a wind turbine hub in one setup, a concept widely used in mass-production of automotive components and small parts. "This is automotive machining technology scaled up an order of magnitude," says Pete Beyer, MAG director of product development. "We are using multiple spindles, specialized tools, and clever process technology to finish a part in one setup in the shortest time possible while maintaining the flexibility to process a family of different hubs."

Concepts borrowed from the automotive industry include offline setup and quick part loading, using a fixture interface plate and a lifting bracket for the workpiece. The interface plate is bolted offline to a locating feature on one side of the casting; the plate then mates with a locating feature on the worktable for fast part setup. The lifting bracket attaches to the top of the part to allow a single crane to transfer

Companies wishing to submit materials for inclusion in this section should contact Sherri Mabry at sherri@windsystemsmag.com. Releases accompanied by color images will be given first consideration.

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the part in and out of the workzone safely and quickly. "These are classic part handling techniques on a gantry-type automotive line that we have adapted for very large parts," Beyer says. "We can setup the next part offline on an interface plate, and quickly exchange a completed part to maximize utilization of the spindles."

As part of the MEGAFLEX design, each machine has a latch-plate interface to accept attachments from a head changing rack. However, for cost economy, the system currently has only one attachment rack, which can be moved for use by any of the machines. Rotation of the worktable allows the machine using the attachments to access all three faces of the part. Synchronous/asynchronous processing is then used to balance out the cutting times and cutting forces of the three spindles when doing similar and dissimilar operations. For more information go to www.mag-ias.com.

NEW REGIONAL SALES MANAGER AT *WIND SYSTEMS* MAGAZINE

Mike Barker has joined *Wind Systems* magazine as regional sales manager, responsible for covering states including North and South Dakota, Nebraska, Kansas, Oklahoma, Texas, Missouri, Arkansas, Louisiana, Mississippi, Tennessee, Kentucky, and Indiana.

A native of Tuscaloosa, Alabama, Barker began his career at Randall Publishing Company in 1988. On moving to Birmingham he joined Vulcan Publications in 1996, where he excelled quickly in management to become publisher of *U.S. Sites & Development* magazine. He has been instrumental in helping to launch industry-leading publications such as *Top Bid, Expansion Solutions,* and *Sports Destination Management.* He is conscientious about providing excellent customer service and takes great pride in developing close relationships with his clients.

"I look forward to getting to know the professionals in the wind energy market," Barker says, "and it is my goal to always offer the very best in customer service to each and every advertiser we feature in the magazine and on our Web site. As a current or potential advertiser in *Wind Systems* magazine, rest assured that my client's best interests will always be my top priority."

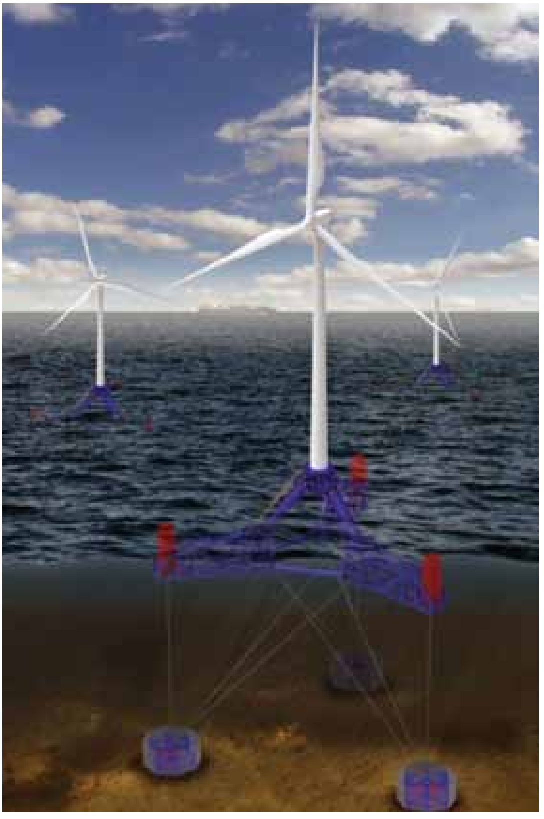
Barker can be reached at (800) 366-2185 x203 or mike@windsystemsmag.com. Also go online to www.windsystemsmag.com

GICON SUCCESSFULLY TESTS FLOATING FOUNDATION FOR OFFSHORE WIND

Floating foundations for the offshore wind industry are increasingly gaining attention and interest within the industry, as well as among government and permitting institutions and also investors. This interest is driven by the conditions found in the U.S. and Japan where the vast majority of offshore wind resources is found in water depths of more than 100 meters. There are also areas in Europe where conventional foundations such as monopiles, tripods, gravity foundations, and jackets are not applicable, especially for planned installations further offshore.

A consortium led by GICON Grossmann Ingenieur Consult GmbH has developed a floating platform solution that addresses the global offshore wind industry's need for floating foundation technology. Unlike other technologies currently under development, the GICON Floating Offshore Foundation (FOF) is not only applicable in deep water but can also be deployed in shallow water depths of 25 meters and deeper. "This versatility addresses a number of key challenges," according to Prof. Jochen Grossmann, owner and CEO of GICON GmbH. "The existing foundation technologies require suitable weather conditions as well as availability of installation vessels. Our FOF can be assembled at shore, including the turbine and then towed with standard tug boats to the deployment site. In addition, floating foundations have less impact on marine life due to reduced construction related noise such as pile driving."

In February 2012 GICON tested the latest design at the Hamburg Ship Model Basin HSVA. A 1:25 scale model was exposed to various wind and wave conditions as well as tow trials to confirm functionality, usability and



load capacity during operation as well as transport. The data acquired during the tank tests validated the various simulations. These tests included the equivalent of a 20-meter "rogue wave" which the structure weathered without any problems. The successful tests are another milestone towards the deployment of a full scale pilot in the German Baltic Sea in 2013.

The GICON FOF is based on the Tension Leg Platform (TLP) principle, which was originally developed for the oil and gas industry. GICON's modular steel structure is equipped with buoyancy elements and moored utilizing vertical as well as diagonal bracing. Since ocean floor conditions vary, a number of different anchoring solutions have been developed as well.

The consortium under GICON's leadership includes the Technical University and Mining Academy Freiberg (Prof. Frank Dahlhaus), Rostock University (Prof. Kaeding), Jaehnig GmbH, Fugro GmbH, Vermessungsbuero Weigt, GLC Gluecksburg Consulting, Institute for Applied Ecology, WPC Wind Power Construction, and wpd Offshore. The consortium's work is also supported by various German Federal as well as German State funding initiatives. Especially the modular construction of the FOF is going to have a very wide economic impact as the supply chain can be optimized for mass

production and include medium size companies. A video showing impressions of the recent tank tests is available at www.gicon.de/en/home/sof-video.html.

GICON is an independent consulting and engineering firm with headquarters in Dresden, Germany and 10 regional offices throughout Germany. The company's interdisciplinary, experienced engineers provide state of the art consulting and planning services for various industrial sectors such as wind power, bio energy and remediation. GICON also have representative and partner offices in Europe and Asia as well as North and South America. Learn more at www.gicon.com.

LEOSPHERE AND NRG SYSTEMS INTRODUCE LIDAR FOR COMPLEX TERRAIN

Leosphere and NRG Systems recently introduced FCR™ (Flow Complexity Recognition), an add-on solution for the WINDCUBE® v2 Lidar Remote Sensor. Supported by WINDCUBE's vertical fifth beam, FCR enables the Lidar to provide precise, bankable data in all terrain types, including complex terrain, with no post-processing or post-correction.

"In complex terrain, all mechanical and remote sensors are prone to higher measurement uncertainty and may introduce measurement bias due to lack of flow homogeneity across the measured volume," says Matthieu Boquet, scientific developments supervisor at Leosphere. "The use of FCR minimizes or even eliminates this bias, allowing WINDCUBE to measure with extreme accuracy and provide bankable data across all terrain types. For the first time, wind energy developers can use the same remote sensor with ease and confidence at all sites, onshore or offshore."

In 2009 Leosphere and NRG Systems formed a global joint venture to expand the use of remote sensing with Lidar in the wind energy industry. Used in wind resource assessment and performance optimization, WINDCUBE v2 is now operating in 20 countries around the world. The joint venture serves customers on all seven continents with sales, service, technical expertise, and support. For more information visit www.lidarwindtechnologies.com.

Leosphere is a leading specialist in the development of lidar technology for atmospheric observations. The company offers turn-key remote sensors that provide real-time tracking and measurement of particles, clouds, and wind. Leosphere's products are used in various applications including, wind energy, climatology, meteorology, and air quality. Learn more at www.leosphere.com.

NRG Systems is an independently owned company that has served the global wind energy industry for 30 years. Its measurement systems and turbine control sensors can be found on every continent in 150 countries, serving electric utilities, renewable

energy developers, turbine manufacturers, research institutes, government agencies, and universities. For more information go online to www.nrgsystems.com.

COMPAXX 900 FOAM CORE SYSTEM FROM DOW

Dow Epoxy, a business unit of The Dow Chemical Company, has introduced the new DOW COMPAXX™ 900 foam core system, which is designed to enable the fabrication of wind blades exceeding 40 meters in length. Dow continues to offer the COMPAXX 700 foam core system for use in wind blades of less than 40 meters.

This latest addition to the COMPAXX line of foam core systems is a structural foam that can help minimize composite weight, which is critical in the production of longer wind blades. The weight savings are made possible by low resin pick-up during fabrication. The foam's small cell size—up to 100 times smaller than cells in chemical blown foams such as PVC—limits the amount of resin that can fill cut cells at the surface. In addition, the closed cell structure of the material prevents penetration of the resin deeper into the foam. Although resin pickup is low, the inherent ductile properties of COMPAXX 900 produce excellent skin-to-core bonds, and composites made with system exhibit excellent fatigue resistance.

The new foam core system exhibits higher static performance than PVC foam due to the continuous extrusion process used to produce DOW COMPAXX™ 900. The process allows very accurate control of cell expansion and produces cells that are homogeneous in size. The result is a material with optimum mass distribution, uniform cell structure, and consistent wall thickness, factors that enable the new foam to outperform core materials with the same density, such as PVC.

Dow says that DOW COMPAXX™ 900 can be used in the shear web, shell, and in all other parts of wind turbine blades where high performance structural foam is required. It is recyclable, and waste material created during the kitting process or panel manufacturing can be recovered. The foam and final composite material can be recycled by grinding and used as filler in other products. Refer to the Material Safety Data sheet for further details on disposal considerations.

According to Gino Francato, business development manager for Dow's wind group, "DOW COMPAXX 900 is the product of Dow chemistry and materials science expertise. DOW COMPAXX foam core systems are advanced materials, engineered specifically for wind blade applications. They can reduce fabrication costs and improve wind blade mechanical performance, which makes them excellent replacements for PVC, SAN, and PET, as well as balsa." Learn more at www.dow.com.

LM WIND POWER BLADES ON WORLD'S LARGEST OFFSHORE TURBINE

LM Wind Power's 73.5-meter blades became the first 70+ meter blades to be installed when Alstom inaugurated the largest offshore wind turbine in the world on March 19 at Carnet in the Loire-Atlantique region of France. The impressive composite structures have been developed specifically for Alstom's Haliade 150-6MW wind turbine in a close collaboration between the two companies to boost energy capture while keeping loads down. The innovative blade design has already been through several rounds of testing before being installed on the turbine in France.

"It was great to see LM blades mounted on the newest and biggest turbine in the world as well as see the excitement this technological leap has made in the offshore world," according to Ian Telford, LM Wind Power vice president of sales and marketing. "Our technology enables us to design and manufacture relatively lighter glass fiber and polyester blades for the length, but above all LM Wind Power has proven ability to handle the industrialization of these blades, which is not easy."

Alstom's Haliade 150-6MW turbine has been EDF-EN/Dong Energy's choice developed in response to a call for tenders launched by the French government that aims to install 3GW of wind turbine power off French shores by 2015. Depending on the results of the tenders to be announced in April, Alstom and LM Wind Power plan to establish a blade manufacturing facility in Cherbourg with the capacity to produce up to 100 sets of 73.5 meter blades a year. Production is planned to start in 2016.

LM Wind Power is the world's leading component supplier to the wind industry, with operations from 13 manufacturing facilities worldwide and more than 140,000 blades produced since 1978. More information is available at www.lmwindpower.com.

PARKER TO LAUNCH STAND-ALONE TWO-PHASE COOLING SYSTEM AT AWEA

As a follow-on to last year's announcement by Parker Hannifin of a "rack-ready" two-phase evaporative cooling system for wind turbine systems, the company has developed a stand-alone configuration of the system as a drop-in replacement to easily retrofit existing wind turbine cooling systems (traditionally air- or water-based). Parker's stand-alone cooling system is fully scalable and available in three configurations with capacity to handle from 25kW-50kW-100 kW and is 50 percent lighter and more compact than legacy air and water cooling systems.

Using the same patented two-phase evaporative precision cooling system as Parker's rack-integrated configuration, the stand-alone system provides a convenient way to "upgrade" the system and greatly

improve wind turbine systems' efficiency and reliability. The Parker cooling system delivers up to 40 percent increase in power throughput and can more than double electronics density in the same space, which is a major benefit in a nacelle or wind tower where space is at a premium. Due to the non-conductive, non-corrosive nature of the coolant, the system is also inherently safer and highly reliable.

The system features Parker's two-phase evaporative precision cooling patented technology, which uses a non-conductive refrigerant in conjunction with a modular cold-plate IGBT design, to circulate in a closed loop. The system includes a small pump to deliver a just enough coolant to the evaporator (usually cold plates) to optimize the heat from the particular device. The vaporized content is then pumped to the system's heat exchanger, where it rejects the heat to the ambient and then condenses back into a liquid, completing and repeating the cycle.

Parker's precision cooling systems are 50 percent lighter and smaller than traditional air and water cooled systems, and fit easily into the nacelle, while enabling up to 40 percent higher throughput from system electronics, and up to twice the density in the same space. All this translates to the overall lower system cost, with inherent safety and simplified maintenance, due to their modular and scalable design. All critical wind turbine systems can benefit from these integrated cooling systems, including the inverter, reactor, and generator as well as other electronics either in the nacelle or in-field containers. Parker's two-phase evaporative precision cooling system is now available in two convenient configurations: the new stand-alone cooling unit, servicing multiple systems with localized cold plate kits (see photo); and the rack-ready integrated design for each wind turbine system (introduced at AWEA Windpower 2011). For more information visit www.parker.com/pc.

NEW HEAD OF BUSINESS DEVELOPMENT AND SALES AT GL GARRAD HASSAN

GL Garrad Hassan has appointed Christoph Thiel as its new head of business development and sales. He will be responsible for managing global sales and business development for GL Garrad Hassan worldwide, working from the head office in Hamburg. He started in his new position on March 1, 2012. "I am really looking forward to speaking with our clients around the world about what GL Garrad Hassan has to offer and how they can benefit from the synergies that are being created through the combined business segments of the GL Group," he says.

"We are very pleased to have Christoph back at GL Garrad Hassan," says Andrew Garrad, president. "His breadth of experience and deep understanding of the market will be extremely valuable in helping us to strengthen GL Garrad Hassan's global presence."

After studying electrical engineering Thiel joined WINDTEST Kaiser-Wilhelm-Koog—now a part of GL Garrad Hassan—in 1998, where he carried out load and power performance measurements on wind turbines. He set up WINDTEST's Spanish subsidiary in Madrid and was based in Spain for almost three years before returning to Germany to build the business development department for measurements and inspections at Kaiser-Wilhelm-Koog. After a short period elsewhere in the wind industry, Thiel has now returned to GL Garrad Hassan.

GL Garrad Hassan is one of the world's largest dedicated renewable energy consultancies and a recognized technical authority on the subject. It offers independent technical and engineering services, products, and training courses to the onshore and offshore wind, wave, tidal, and solar sectors. Although the GL Garrad Hassan name is new, the company has a rich heritage. It is borne of the integration of specialist companies that, united, form the renewable energy consulting division of the GL Group. GL Garrad Hassan is a consulting company; it has no equity stake in any device or project. This rule of operation is central to its philosophy, something which sets it apart from many of its competitors. For further information visit www.gl-garradhassan.com.

Chris Martin
Crane Service, Inc.

Wind speeds change at various heights, making hoisting projects on wind farms particularly challenging. All the more reason to hire experienced operators.

IN PAST MONTHS WE HAVE LEARNED about the maintenance process, rigging techniques, and the different crane types relative to the wind industry. This month we are going to take a look into how the wind speeds change at various heights. The wind speed changes can help reduce wear and tear on the wind components in the air, but it can make hoisting rotors down difficult.

As we know, wind speed increases as we move higher above the ground. For towers below 100 meters in height we can model the change in wind speed logarithmically and constant speed past 100 meters, meaning the wind speed has a great increase as you leave ground level but the slope decreases and almost becomes flat as you approach your 100 meter mark. From 0 to 20 meters the wind speed can change from 0 m/s to 14 m/s, while the change in wind speeds from 35 meters to 100 meters is roughly 2-3 m/s. If we apply this thought to a real world tower we notice something interesting. If we have an 80 meter tower with a 90 meter diameter blade, we can assume that the blade height will vary from 125 meters to 35 meters, 45 meters above the hub height, and 45 meters below the hub height. This puts the blade right at the 35 meter mark to past our 100 meter mark. With that being said, we will only see a wind speed change of about 3 m/s. This can help reduce the wear and tear of gearboxes, blades, and yaw drives. Now, if we push our towers past the 100 meter mark, then the wind speed can be seen as constant and thus further lowering stresses on the blades.

This concept also plays a big part in the hoisting industry, as we learned in previous articles that hoisting wind components can be difficult and tend to be harder when you are near the hub versus closer to the ground. Although this is a true, we cannot underestimate the difficulty of hoisting wind components near the ground. Like we learned above, from the 0 meter to the 20 meter or the 50 foot mark, we can see wind speeds change from 0 m/s to 14 m/s or 0 mph to 30 mph. This can make tailing operations difficult for an operator and his crew. When we are tailing a rotor, our operators and crew have to be in perfect sync and on the same page. As we are lowering the rotor to the ground, the two "rabbit ears" are experiencing different wind speeds than the lower blade. The effect of this can make the sensation of where the blade is moving feel different to each operator, so proper communication between the operators and crew is crucial for a lift like this. You may see the crew on wind parks using taglines to the rabbit-eared blades that are anchored, this also helps combat any rotation of the rotor. To further remain safe while lowering a rotor, we won't work in speeds in excess of 9 m/s or 20 mph for our lattice boom cranes and 10 mph for our hydraulic cranes. This helps ensure that we don't have any issues while we are trying to perform the tandem pick.

When our lattice boom truck cranes or crawler cranes are working in windy conditions, the variation of wind speed at the 35 to 80 meter range can be beneficial in a sense. We now know that the wind speed in this range has a smaller change than the sub 35 meter range. This can actually make the lift more stable because as you are hoisting a gearbox, lid, or nacelle to the ground the wind speed change is very gradual at these heights. This makes the lift smoother, as we aren't experiencing abrupt changes. A good operator can make these lifts appear easy, but in the cab there has to be high level of focus and dedication.

All of our operators are highly trained, experienced operators, and they are certified as well. Most of our operators have surpassed the 20-year mark working in the industry. This allows for us to be very effective in our industry. Couple this with 3D lift planning software from the amazing folks at A1A software, and there isn't any wind project that we can't handle.

Chris Martin is marketing coordinator at Crane Service, Inc. Learn more at www.craneserviceinc.com.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Merritt Brown
Rev1 Power Services, Inc.

In addition to the latest technologies, maintenance professionals can use their physical senses to detect gearbox problems, as this first in a two-part series makes clear.

ARMED WITH SOME EXPERIENCE and a bit of awareness, there are several ways in which a technician can diagnose wind turbine gearbox problems while uptower. Using the physical senses, it becomes relatively straightforward to listen for noises coming from the gearbox, to observe surface damage on the gearing, and to observe the color and smell of the oil. A technician conducting routine maintenance is a first responder and has the ability to evaluate the operating condition of the gearbox through some very simple techniques, even without the use of a borescope or vibration monitoring system.

In conducting end of warranty inspections, we typically find a number of turbine gearboxes with internal gear damage that occurred over a relatively short period of time. While these issues have materialized largely unnoticed by the project owner up to the final turnover inspection, the effect of such irreversible conditions will gravely impact the performance of the gearbox through future years. Proper lubrication and control of contaminants has never been more important both during and after the warranty period. It is expressly the technician's responsibility to avoid contamination during the maintenance of the gearbox, and while contamination can enter gearboxes in a number of ways, you can be assured that whenever the gearbox is opened for inspection, top-off, or repair, a significant opportunity exists for contaminant ingress.

Even though an operating turbine's gearbox might sound normal from the ground, it could be in quite different shape once the inspection covers are pulled and an oil sample is taken. Finding damage—witness marks, in particular—on high-speed gearing can be an indication that a softer-material, slower-moving component is fragmenting and sending metal particulates into the oil system.

We sometimes see gearing surface damage immediately upon pulling covers and then locate the actual source of the contaminant as being a planetary gear or bearing that has progressively failed. Spall, flaking, polishing, fractures, witness marks, and to some degree macro-pitting can all be observed with the naked eye. While these each have different initiators, the technician should be able to assess the severity of the damage and link it to other physical factors during an inspection.

There are some important observations that should be made when an oil sample is taken on a wind turbine gearbox. Odor, color, presence of froth, and sediment fallout tell us several things about the health of the gearbox even before we begin a thorough inspection of the internals. Of course, one needs to start with a clean, clear bottle—it would make little sense to miss an opportunity to immediately observe important oil properties such as color and brightness when your task is to conduct a thorough gearbox inspection.

"Odor, color, presence of froth, and sediment fallout in an oil sample tell us several things about the health of the gearbox even before we begin a thorough inspection."

Sample bottles are available in several materials, and one of the more common types is plastic polyethylene; an opaque material like that of a milk jug. Rather, a project operator focused on uptower diagnosis should always use PET plastic bottles, those that are completely clear and allow for the oil sample to be visually examined upon being taken. This plastic material is compatible with most types of lubricating oils and hydraulic fluids, including synthetics.

The physical properties of gearbox oil—sediment, darkness, brightness, clarity, and color—can be immediately learned from a visual inspection. A sour smell can indicate contamination or excessive degradation. Unusual darkening or solids entrapped in the oil can mean internal contamination. After shaking the sample vigorously, the foam should dissipate from the surface within 10 minutes and air bubbles should disappear in about 15 minutes. If not, this might indicate degradation of the oil's additives. After a rest period the oil should be transparent, and if you're unable to read the print on the cover of this magazine through a clear sample, it is likely an indication that water is emulsified in the oil. We will continue our discussion in the June issue of *Wind Systems* magazine.

Merritt Brown is vice president of Rev1 Renewables, an energy services company supporting wind, solar, and biomass clients worldwide. To learn more call (866) 738-1669 or go online to www.rev1renewables.com.

Matthew A. Lackner, Ph.D.
UMASS Wind Energy Center

Uncertainty in the soil properties can have significant effects on the reliability of offshore wind turbine support structures with monopile foundations.

WHILE OFFSHORE WIND TURBINE technology has evolved from its onshore predecessor, engineering experience in the offshore oil and gas industry has also contributed to the design and analysis methods utilized in offshore wind. In particular, the method utilized in the design of the support structure for an offshore wind turbine (OWT) has its roots in the development of offshore drilling platforms and research into their behavior by the American Petroleum Institute (API) in the 1970s.

Monopiles are by far the most popular foundation type for OWTs, and are likely to continue to be the predominant foundation type in shallow waters. While towers are typically classified and manufactured by the turbine rating, monopile foundations must be uniquely designed for each site due to their strong dependence on local loading and soil characteristics. Unique foundation design is time-consuming and expensive. Moreover, offshore wind turbines operate in a complex and highly variable environment; uncertainties in wind and wave loading and local soil characteristics can be substantial. Uncertainty in OWT design is currently treated by using conservative deterministic methods that can lead to larger (and therefore more expensive) towers and foundations and are not based on the probability that the OWT will exceed design limit states.

Uncertainty associated with the soil stems from the inherent heterogeneity of geomaterials and the difficulty of obtaining accurate in situ measurements of the soil properties. This in spite of the fact that site characterization often calls for at least one boring in the installation area, with more specific site tests per requirement of the applicable design standard.

In recent research, Carswell (a Ph.D. student at UMass Amherst) Arwade, DeGroot, and myself have investigated how soil property uncertainty affects the reliability of offshore wind turbine support structures with monopile foundations. Laterally loaded monopile foundations are typically designed using the p-y method, developed by API, for analysis of the interaction between the monopile and the surrounding soil. The p-y method is based on a distributed-spring model, in which the resistance provided by the soil (p) is defined by a non-linear relationship with the pile lateral displacement (y), and the soil continuum is approximated by a series of discrete springs. The p-y curve appropriate for a particular design and site location varies according to soil classification, soil properties, and soil location in reference to the water table.

The UMass researchers utilized probabilistic reliability analysis to determine the effect of soil properties on the structural response of a monopile in sandy soil. A non-linear quasi-static code was developed that determines the displacement of a monopile foundation under loading utilizing the p-y method. An incremental, load-controlled analysis with 20 distributed soil springs was used to compute the pile-head translations and rotations and an eigenvalue analysis was used to determine the first natural frequency of the monopile. Soil uncertainty was characterized by a probability distribution for a critical soil property, the friction angle (which characterizes the shear strength of the soil), based on measured estimates of variability. Ensembles of random soil property values were generated, and the quasi-static response and natural frequency of the monopile were computed. Two limiting cases were used to characterize the spatial correlation of soil properties at each of the 20 springs: perfect vertical spatial correlation and independent variation. These results allowed the researchers to characterize how soil property uncertainty can propagate to uncertainty in the response of an OWT support structure.

Several important conclusions were made from these analyses: 1) Assuming perfectly correlated soil properties yielded consistently lower reliability than assuming independent variation; 2) As the uncertainty of the soil properties increases, reliability decreases nonlinearly; 3) If the uncertainty in the soil properties are assumed constant, reliability increases linearly with soil density, and; 4) Soil property uncertainty causes the natural frequency to vary by approximately plus or minus 1 percent, which is a fairly small effect and unlikely to result in unwanted resonance.

The overall conclusion of this research demonstrated that uncertainty in soil properties can have important effects on the reliability of monopile foundations. Future designs of offshore monopiles will benefit from incorporating probabilistic design methods so as to properly account for soil property uncertainty and to avoid costly overdesign.

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Michael Graska
Professional Logistics Group, Inc.

Reporting straight from the jobsite, the author relates lessons learned during his career that help keep projects on track.

PROBLEMS, ISSUES, DELAYS, DEADLINES... things that just make your project not to go as planned. This is what I am writing about in this installment of my column, since I am on a project site dealing all of the approve. The last four days working a load-out of wind towers as the project manager have been hectic, and I wanted to catch my impressions will still on the site and share some of the lessons to be learned.

Planning is everything, except when it isn't. Making plans and preparations are important, but being able to adjust and have contingency plans in place is critical. Project cargo is rarely linear in execution. Planning is an absolute must, and this captures 80-90 percent of what needs to be done onsite. It is the 10-20 percent that is unknown that can kill a job. On this particular project I'm I am glad that I had resources lined up just in case something needed to be repaired. One phone call, and I had the issue corrected without loss of time—that's the benefit of planning for things to go wrong.

Keep things moving on a site. Stay ahead of the cargo, and do not let things delay loading. This is the mantra of the project manager, who always needs to be three steps ahead of the action. Let the crews do the immediate work; you need to plan the next steps ahead to keep things moving. Delays equal money, so avoid them at all costs.

Have a mindset to multitask, and delegate as much as possible to allow yourself to solve problems. Many things can happen at once, so understand the difference between "urgent" and "important," because just because something is urgent doesn't mean it's important. Do what is important first. Important things add value, urgent things just keep you busy. Of course, deal with the urgent important things first!

Have staff to back you up. Just because you're onsite doesn't stop e-mails or phone calls from coming in. Have someone who can handle those for you. In our company we always have one senior project manager stay in the office at all times to offer support to field operations. Having an experienced person to cover for you is essential to solving problems and handling critical communications. I cannot count the number of times when that person back in the office was experienced enough to handle a tough problem and take it off of my own plate.

Keep a notebook with you at all times, because this is your log of what is happening. Have key numbers to call for assistance listed there, and have key measurements and data at your fingertips. This will keep things moving. Think of it as an extension of your brain. To paraphrase what Albert Einstein once said: "I do not need to know my phone number, I only need to know where to find it."

Projects are difficult, and problems will always arise. Understand that problems will present themselves, and that you are there to solve them. Understand this up front, and it really does make a difference. The best project managers embrace this approach and remain calm during difficulties, knowing that sense of calm reflects on the people working alongside then. One lesson I learned a long time ago is that true character is revealed during stressful times. Under difficult situations remain calm, let the people do their jobs, and resist micromanaging. I see it all the time: managers flying off the handle, ranting at people and thinking such behavior will somehow improve the situation—it doesn't. Keep a sense of humor about you, and remember that things are rarely as bad as they first appear.

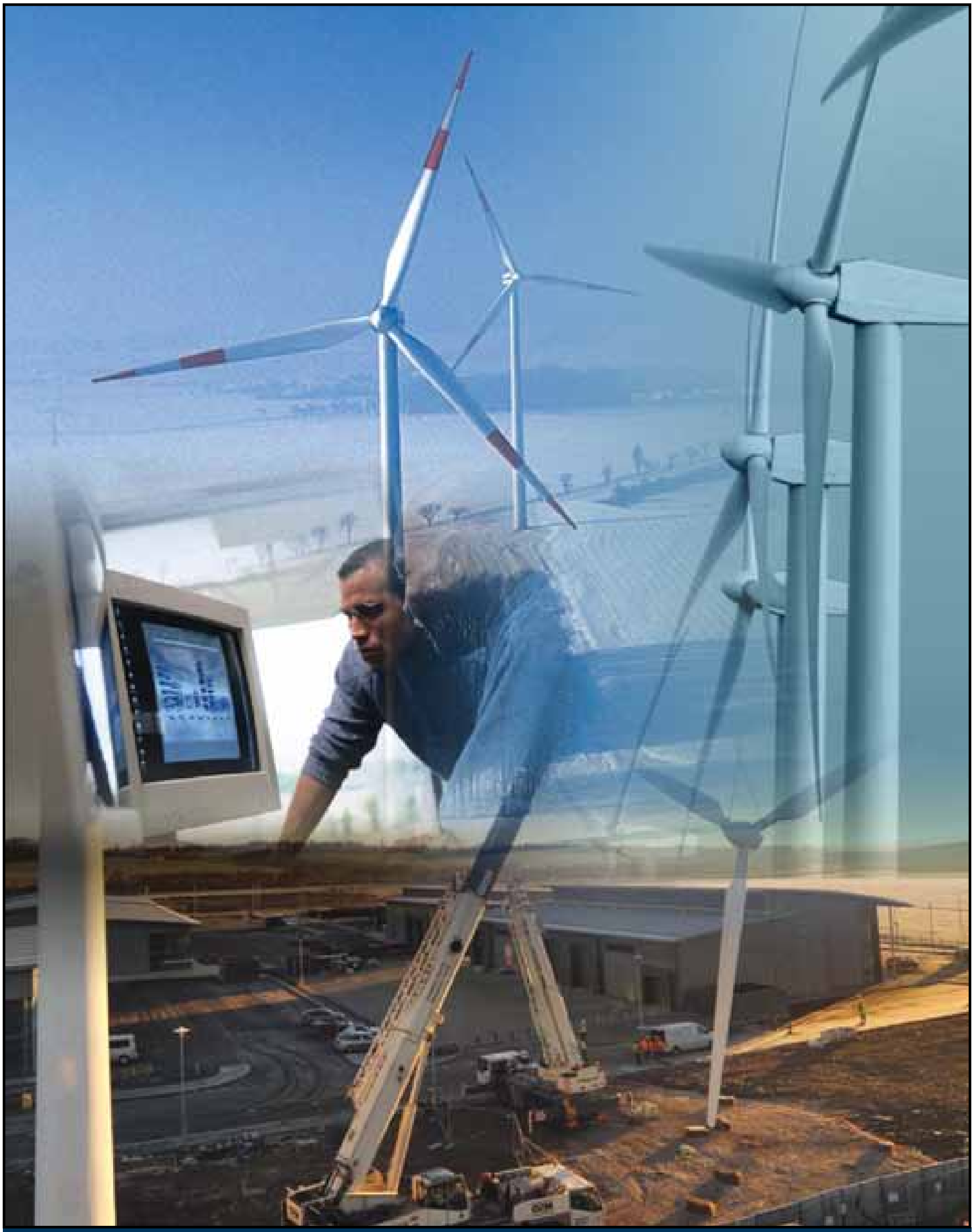
"One lesson I learned a long time ago is that true character is revealed during stressful times. Under difficult situations remain calm, let the people do their jobs, and resist micromanaging."

Which leaves me to my last lesson before I have to get back to work: Leave your ego at home, and recognize that everyone can contribute. Listen to the people doing the work since they often have the best ideas. Encourage them to speak out, and give them credit. More good ideas come from the people doing the actual work than you may realize. I have been fortunate to learn more from them than they have from me.

Michael Graska is project leader with Professional Logistics Group. For more information go online to www.prologisticsgroup.com.

ROCKWELL AUTOMATION

By Russ Willcutt



This company provides integrated safety, control, motion, and vibration monitoring solutions to maximize uptime while protecting your capital investment.

ORIGINALLY KNOWN AS THE Compression Rheostat Company—and launched with an investment of $1,000 by Lynde Bradley and Stanton Allen in 1903—Rockwell Automation has been designing and manufacturing industrial controls and electrical components for more than a century. Along the way it has developed an approach to working with its clients that is particularly fitting for a technology-driven industry such as wind energy.

"We are primarily focused on working closely with OEMs to develop components and systems that complement and integrate with their own designs," according to Damon Sepe, OEM business development manager for North America, "and we're able to provide engineering services to whatever degree is necessary in order to help our customers achieve their goals."

The Engineered Solutions Business (ESB) within Rockwell Automation makes engineers in many specialties available to work with OEMs in developing solutions to the challenges they face. "Once the OEM team has established contact with a new client, it's our job to work up a proposal based on their specific needs," says Steve Hessefort, ESB business unit manager. "That might be an electrical panel that controls the integrated architecture within a wind turbine or some other piece of critical hardware, but we're prepared to work directly from their plans or develop our own, whatever their requirements may be."

Once a design has been approved by the customer and the order placed, that's when Milan Jovanovic's work begins. As a project manager within the ESB group, he describes himself as "a traffic director," coordinating the activities of different players involved in the project. "It's my job to basically act as a coordinator between our development engineers, our salespeople, the customer, and our different manufacturing areas to make sure that the project gets done on time and at the right cost levels," he says. "I'm more or less the single point of contact for any of those groups in terms of trying to answer questions as they arise and make sure the project moves along smoothly."

Of particular importance is the concept of repeatability, according to Sarah Larson, commercial program manager for ESB. "We have teams of marketing and sales professionals who are assigned to work directly with OEMs in different market sectors, such as wind," she explains. "If a turbine manufacturer is in need of a control panel solution, for instance, sales will initiate the contact and our engineers will design a customized panel solution that is repeatable, in that it can be manufactured at one of our facilities located nearest the point of end use."

With new turbine designs constantly being introduced—and with so many leading-edge concepts being developed in the more-mature European wind market—keeping a finger on the pulse of the industry is important. That's where Dave Schaetz comes in. As a global industry technical consultant in the power and energy industries, he plays a number of different roles that result in Rockwell Automation systems being incorporated in current designs while being aware of upcoming trends as well. "On one hand I'm constantly seeking areas that may represent a new market for us, as was the case with wind some years ago," he says. "I learn all I can about the equipment and manufacturing processes involved to see where our existing products might fit, or could be customized to do so. Then I will play a more technical role in terms of setting up training and helping our customers incorporate our products into the equipment they're building."

This level of engagement is embraced by everyone at Rockwell Automation, especially as it increasingly becomes a knowledge resource for the wind industry. By deploying its global technical consultants to work with clients around the world—and engaging in R&D work with both industry and academia—the company provides technology transfer between market platforms: harnessing lessons learned in other forms of energy production to the benefit of the wind industry, for instance. And with a commitment to providing user-friendly solutions, the resulting equipment control solutions are scalable and "plug and play" enabled, using "off the shelf" components that are easy to program and are both reliable and proven. Whether its customers are in need of main turbine controls, pitch and yaw systems, panel fabrication, and even complete wind farm management and control solutions, Rockwell Automation can provide whatever level of service involvement and engineering assistance is required, and its full-service test facility is available for design prove-out as well.

"I think the word that really sums up our approach to market is flexibility," Sepe says. "We have a very close relationship with our customers, using WebEx and Pro/Engineer to collaborate during design, so we're poised to respond immediately to their concerns at any point in the process. We're here to assist our customers all the way from concept to commissioning."

Go online to www.rockwellautomation.com.

AUTOMATED WIND BLADE PRODUCTION

In this article, valuable material benefits that arise from wind blade automation are highlighted by the experts at PPG Industries.

By Juan C. Serrano and Sandeep Vennam

Juan C. Serrano and Sandeep Vennam are with PPG Industries. Go online to www.ppg.com.

NOVEL MATERIAL AND PROCESS technologies for wind blade design and production are critical to increasing the competitiveness of wind power generation. As part of a Department of Energy (DOE)-funded project conducted by PPG Industries (PPG) and MAG Industrial Automation Systems (MAG), the potential of producing fiber glass composite blades using automated manufacturing was evaluated. This paper focuses on the material evaluation and corresponding impact on blade performance as part of the funded study.

During the first stage of the project, a comprehensive review of the DOE composite material database was performed. The results of this review were combined with data from PPG and publicly available information and analyzed for performance characteristics based upon material type[1].

The outcome of this analysis identified state of the art composite material technology and performance characteristics used by wind blade designers. These properties (Table I) were the benchmark for the work performed in the remainder of this study. Some of the key conclusions of the comprehensive database evaluation included:

- Unidirectional, prepreg-based laminates made with E-Glass and epoxy resin have better tensile modulus compared to equivalent infused laminates;

- Tensile modulus values of 47 and 48 GPa have been reported for unidirectional laminates made with E-Glass prepreg and correspond to the highest tensile modulus reported for any E-Glass composites;
- Laminates fabricated with PPG's HYBON® 2026 roving and epoxy resin resulted in higher fatigue performance when compared to laminates produced with other roving inputs.

During the second stage of the project an experiment was conducted to evaluate the effects of fiber diameter, linear density (TEX), and fabric areal weight on material properties. The samples were produced in two distinct reinforcement formats: weft insertion fabrics with 90+ percent of the reinforcement in one direction, and by dry filament winding to mimic the reinforcement packing of a unidirectional prepreg. The glass fiber sizing chemistry and the sizing content was kept constant: PPG's HYBON 2026 multi-compatible roving. The experiment revealed that the roving based factors considered did not have a significant effect on the mechanical properties of the laminates. However, the study showed that the fabric style/architecture and fiber volume fraction achieved using a particular reinforcement had a significant effect on the composite mechanical properties (fig. 1). Furthermore, the elimination of crimp and improvements in fiber alignment as found in resin pre-impregnated rovings can increase overall mechanical performance. A detailed description of these results was reported at a SAMPE Technical Conference in May 2011[2].

Using these findings, the next step was the experimental determination of mechanical properties of currently used non-crimp fabrics. As concluded from the database analysis, a set of composite laminates (uniaxial, biaxial and tri-axial) was produced and tested using the HYBON 2026 roving in commercially available non-crimp fabrics (same fiber orientation within a ply). These results were used as the lower limit considered acceptable for any new material. All laminates were produced with a standard epoxy resin (Momentive Epikote™ MGS L135/Epikure™ MGS RIM H1366) via vacuum assisted resin transfer molding (VARTM).

The evaluation conducted on unidirectional laminates used a dry filament winding process. While not viable for the production of wind blade components, this process was used as an upper boundary for composite laminate performance because it allowed for higher fiber volume fractions[2] than those achieved with today's non-crimp fabric technology. The performance result was expected to be representative of a composite laminate produced through automation.

Four independent epoxy prepreg producers were selected to manufacture the materials. After fabrication according to the laminate schedules, the laminates were laid on a flat tool using either an automated tape laying machine or a fiber placement machine (depending upon the material format requested by MAG) and were molded under vacuum at the recommended temperature defined by the prepreg producers (fig. 2). Table II summarizes the unidirectional (UD) material forms and laminate processes used in the study. Tensile, compressive and fatigue properties were determined for these materials.

The tensile strength of the materials was segmented into three groups. The highest perform-

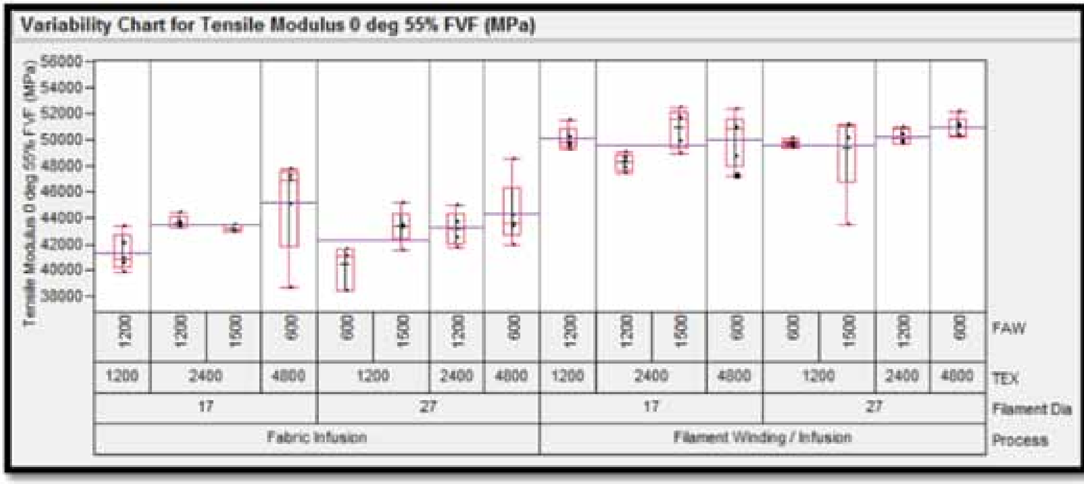


Fig. 1: Tensile Modulus for UD composite laminates produced with weft insertion fabrics and dry filament winding (with varying filament diameter, linear density, and fabric areal weight).

Property	Standard
Tensile strength and tensile modulus in the fiber direction	ISO 527
Tensile strength (perpendicular to the fiber direction)	ISO 527
Tension-tension fatigue performance of composite laminates	ISO 13003
Compressive strength and modulus in the fiber direction	ISO 14126
Fiber volume fraction	ISO 1172
Specific gravity	ISO 1172

Table 1: Identified critical material properties for wind blade composites.

ing material was the dry wound laminate and was considered a "benchmark" because it is not a feasible wind blade manufacturing solution. The second group consisted of one UD towpreg, the UD slit tape, and the UD wide tape laminates. The third group, and lowest performers, consisted of the standard non-crimp fabric widely used for blade production and one UD towpreg material. The statistical comparison of the tensile strength by material form (fig. 3) indicated that modest improvements (0-13 percent, depending on specific material format) in tensile strength can be achieved with the prepreg/automation materials when compared to the standard non-crimp materials commonly used.

The tensile modulus for the diverse material forms is shown in fig. 4. This analysis confirmed that the effect of laminate glass content, driven by the reinforcement format and manufacturing process, has a significant impact on the stiffness of the laminates. All of the UD prepreg/automation material inputs performed significantly better than the non-crimp fabric baseline and were statistically equivalent to the upper bound dry wound infusion laminates. This is a promising finding as it proves that by using automation techniques for laminate production and the state of the art reinforcements, significantly higher stiffness—up to 20 percent, in some cases—can be achieved. Therefore, longer blade lengths and improved energy generation capacity could be realized.

The compressive properties of a composite material greatly depend on the compressive performance of the resin system and fiber alignment. The compressive properties measured in most prepreg/automation materials were statistically equivalent to the standard fabric-based materials utilized in the industry. Similar trends to those observed in the UD laminates were observed with double bias laminates and do not merit additional discussion. The glass transition temperatures for the epoxy resin systems were found to be significantly higher than the infusion epoxy resin Tg.

Fig. 2: Unidirectional towpreg processing in a flat tool via automated fiber placement machine (photo courtesy of MAG).

Representative laminates of all material variants were subjected to tension-tension fatigue to determine the S-N fatigue curve using a servo hydraulic testing machine. The specimens were subjected to various levels of cyclic loading at a rate of 5 Hz with an R value of 0.1 until failure. Figure 5 shows the fatigue performance of the different materials compared to the current non-crimp technology (UD

NCF infusion). While the performance of the dry wound infused laminates was not achieved, it was encouraging to note that both the Towpreg 1 laminate and slit tape laminate performed significantly better than the industry standard.

PREDICTIVE MODELING

To evaluate the impact of the composite laminates on wind blade performance, a full scale finite element blade model was developed. The model used a 33.25m long blade geometry imported from Nu-

Material Form	Laminate Process	Description
UD non-crimp fabric (standard control – lower bound)	Infusionva	Infusion
UD dry wound roving (upper bound)	Infusion	Infusion
UD towpreg 1/prepreg	Fiber Placement/Automation	A single end of 2400 TEX roving is impregnated with B staged epoxy resin; the material is chilled and is helically wound on a 3" cardboard spool.
UD towpreg 2/prepreg	Fiber Placement/Automation	A single end of 2400 TEX roving is impregnated with B staged epoxy resin; the material is chilled and is helically wound on a 3" cardboard spool.
UD wide tape/prepreg	Tape Layup/Automation	Several ends of 2400 TEX roving are brought together in parallel and are impregnated with B staged epoxy resin to produce a 12" wide tape. Interleave PE/siliconized paper film is used to prevent material from adhering to each other and allow for subsequent unwinding in automatic manufacturing.
UD slit tape/prepreg	Fiber Placement/Automation	Several ends of 2400 TEX roving are brought together in parallel and are impregnated with B staged epoxy resin to produce a 4" wide tape. The material is slit and helically wound into 16 - 1/4" slit tape spools in a secondary process. Interleave PE film is used to prevent material from adhering to each other and allow for subsequent unwinding in automatic manufacturing.

Table 2: Material forms and processes evaluated for technical feasibility assessment.

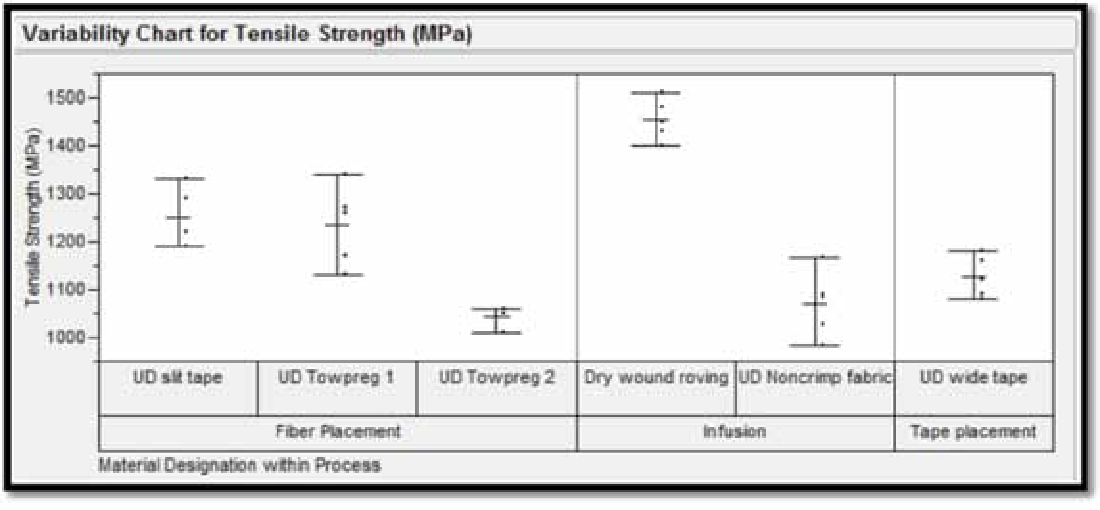


Fig. 3: Tensile strength (MPa) vs. material designation for UD laminates.

Rotor Radius (R)	35m
Blade Length (L)	33.25m
Max. Chord	2.8m
Max. Chord Location (% of R)	25
Twist	10.5^0
Weight of the Blade	4733 Kg
Number of Airfoil Stations	6
Airfoil Sections Type	Circle, S818,S825,S826

Table 3: Blade model specifications[3].

Layer #	Material	Thickness
1	Gel coat	0.51 mm
2	Random mat	0.38 mm
3	Tri-axial fabric	0.89 mm
4 0%-15% c 15%-50% c 50%-85% c	Balsa Spar Cap Mixture Balsa	0.5% c Specified % t/c 1.0 % c
5	Tri-axial Fabric	0.89 mm

Table 4: Blade structural shell material definition[3].

merical Manufacturing and Design (NuMAD) software, which was originally developed by Sandia National Laboratories into an finite element analysis (FEA) platform using ANSYS® software. The model included detailed laminate and material information based on a composite shell element formulation for the prediction of stresses and deformations. The blade model specifications are outlined in Table III and IV and are documented in detail in the National Renewable Energy Laboratory (NREL) report (NREL/SR-500-29492)[3] and correspond to a three-blade wind turbine with rotor radius of 35m and tip speed ratio of 7 for a generation capacity of 1.5MW.

All pre-processing of the 3D FEA, model geometry creation (fig. 6), material designation (Table IV and V), meshing, and boundary condition definition was done using NuMAD software. The blade model wire frame geometry is shown in fig. 7.

For the model, the spar cap consisted of alternating layers of tri-axial (CDB340) and unidirectional fabrics (A260). The tri-axial fabric was composed of 50 percent $\pm 45^0$ and 50 percent 0^0 fibers. The spar cap mixture laminate had 70 percent unidirectional and 3 percent tri-axial fabrics by weight. Although changes were implemented to the spar cap, no changes were performed on the root or shear web sections from the NREL design. The material models described in Tables IV and V were assigned to the blade 3D model in NuMAD. The 3D model generated in NuMAD was analyzed in ANSYS using a composite shell element (SHELL281, fig. 8). SHELL281 is an eight-node structural shell with 6 degrees of freedom at each node (translations and rotations in X, Y, and Z axes).

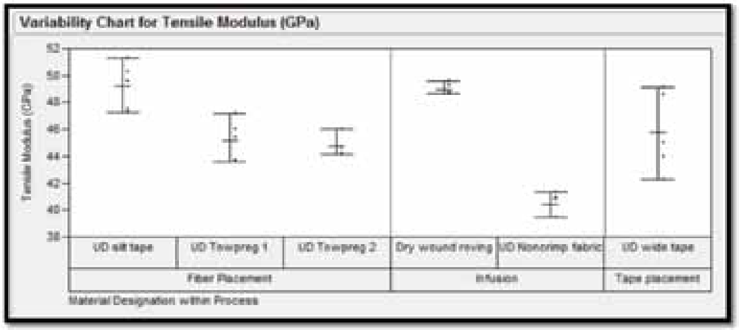


Fig. 4: Tensile modulus (GPa) vs. material designation (UD laminates).

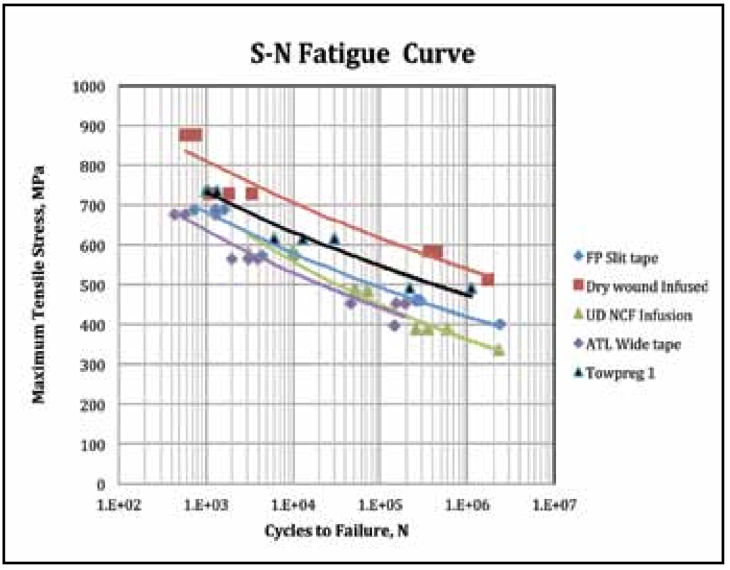


Fig. 5: Fatigue performance of automation materials and non-crimp fabric based laminates..

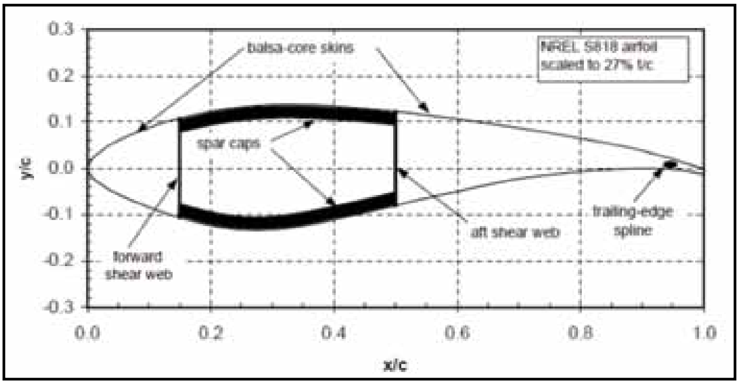


Fig. 6: Blade geometry cross section[3].

Using the ANSYS GUI environment, a master node was defined at the tip of the blade and coupled to the blade tip edge nodes. A static load of 1,000 kg was applied at the master node, acting vertically downwards along the Y-axis of the model coordinate system, inducing flap-wise deformation to the blade. A dummy load was selected to characterize the stiffness of the blade and had no relation to the actual aero-elastic loads expected to be endured during blade service. The model was also used to calculate the weight of the different sections of the blade.

Using the baseline model, the material properties of the blade were replaced with state of the art properties from the UD prepreg using HYBON 2026 roving input and other E-glass offerings from PPG. The maximum displacement occurred at the blade tip in the flap wise direction. The weight of the new blade was calculated as 5237 kg, due to the increased fiber weight fraction of the unidirectional composite.

The focus of the modeling efforts shifted to the impact of the mechanical properties of the evaluated materials on blade weight and energy generation capacity. For this purpose, the blade model was scaled to generate a 40m, 3MW blade. The experimentally determined mechanical properties from the analysis were used to design equivalent stiffness blades, using the highest performing automation materials. The total calculated blade weights from the FEA model and the blade lengths are summarized as follows:

Case 1: The spar cap of the blade is produced with UD prepreg while keeping the remaining blade materials constant. The blade can be made 4 percent lighter while maintaining the stiffness of the baseline 40m blade.

Case 2: The complete blade is made by prepreg/automation using automated fiber placement.

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Property	A260 UD	CDB340 Tri-axial	Spar Cap Mixture (70% UD and 30% tri-axial)	Random Mat	Balsa	Gel Coat	Fill Epoxy
Ex (GPa)	31	24.2	27.1	9.65	2.07	3.44	2.76
Ey (GPa)	7.59	8.97	8.35	9.65	2.07	3.44	2.76
Gxy (GPa)	3.52	4.97	4.7	3.86	0.14	1.38	1.1
Vxy	0.31	0.39	0.37	0.3	0.22	0.3	0.3
Vf	0.4	0.4	0.4	-	N/A	N/A	N/A
wf	0.61	0.61	0.61	-	N/A	N/A	N/A
Density (g/cm^3)	1.70	1.70	1.70	1.67	0.144	1.23	1.15

Table 5: Preliminary blade material properties[1].

The blade has a 5 percent weight savings compared to the baseline due to the increased stiffness provided by the pre-impregnated materials.

Case 3: The blade is produced with pre-impregnated rovings using automated fiber placement but the blade length is increased without increasing tip deflection. The resulting blade is heavier, but energy generation capacity was increased by approximately 6 percent.

Case 4: The spar cap is made using automation but the blade length was increased to match the stiffness of the baseline. The blade length increased to 40.8m and resulted in an energy generation capacity increase of approximately 4 percent.

CONCLUSION

Materials suitable for automation were evaluated and composite laminates made using those materials demonstrated significant improvements in laminate strength, stiffness and fatigue life as compared to existing materials.

The automated fiber placement process was found to be a technically feasible alternative to resin infusion to produce equivalent or higher performing composites. The potential for higher strength, stiffness and durability compared to current materials used for the production of blades was shown.

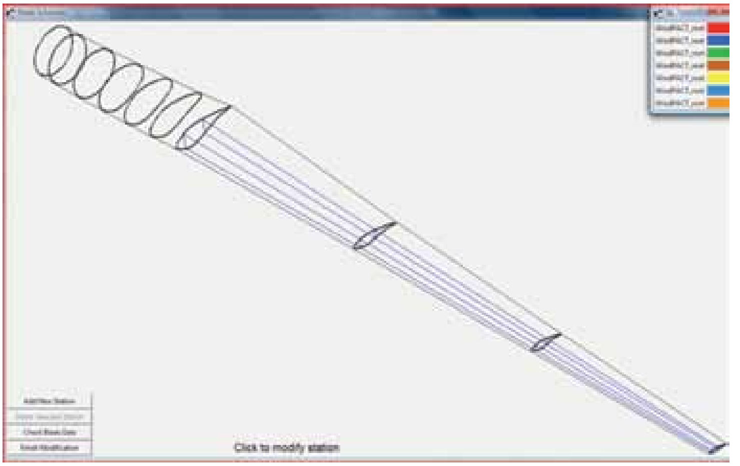

Fig. 7: Blade wire frame geometry in NUMAD.

The materials designated as Towpreg 1 and slit tape processed via automated fiber placement resulted in increased performance and are recommended as technology capable or that requiring minor development for further evaluation. A manufacturing trial on a scaled wind blade component is recommended at this point as these materials have proven capable of increased mechanical properties against the benchmark materials and were found to be amenable to automated processing.

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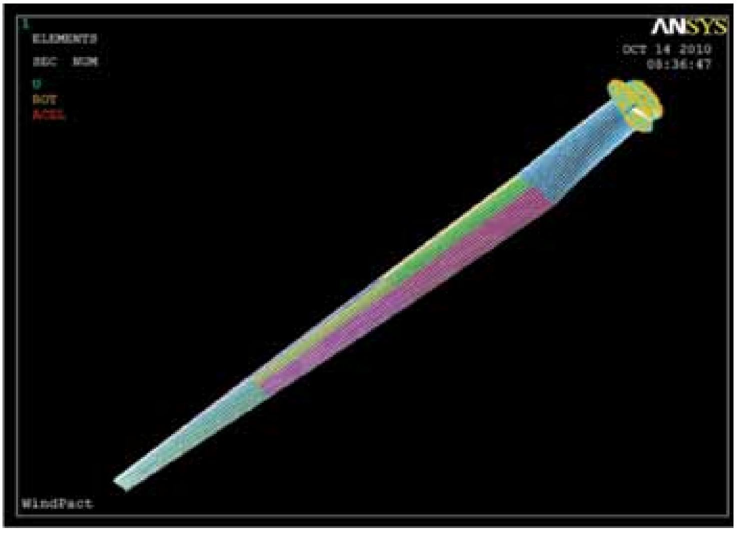

Fig. 8: Blade finite element model boundary conditions

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STREAMLINING YOUR MAINTENANCE PROGRAM

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By Don Bridges

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A FEW YEARS AGO A MAJOR OPERATOR signed a deal to operate wind farms at several locations over a multi-year period. The farms would then be turned over to a local authority once the initial service period ended. Near the end of the operator's service period, it was determined that all of the maintenance plans and procedures would need to be conveyed to the local authorities.

The only problem was, there was no maintenance plan in place and no procedures had been documented. All that existed were piles of repair tickets that listed the scheduled and unscheduled work that had been done over the past several years—that and the combined knowledge of the maintenance staff, which was filed in the 8" space between their ears. With some outside help, the operator was able to analyze the repair tickets and build the required documentation needed to complete their contractual requirements.

A better approach would have been to develop and implement operational strategies from the beginning that mitigate (or eliminate) the effects of unplanned maintenance events. Achieving the correct balance of scheduled and unscheduled maintenance is an ongoing quest that evolves as equipment wears and economic conditions merit. Organizing technical information (typically procedures and schematics) in a way that is easy for the field technician to comprehend and utilize—regardless of the

specific machinery being maintained—is critical to the success of the operation.

In this article we will walk through the high-level basics of defining a maintenance program and see how the operator used this approach to meet their needs. We will discuss how to:

- Organize your procedural information in a universal manner;
- Incorporate simplified English in technical documentation;
- Understand organizational objectives and determine the correct balance between scheduled and unscheduled maintenance;
- Manage spares inventory while increasing your part availability, and;
- Implement technology that allows maintainers to work more efficiently.

Fig. 1: Advance preparation streamlines maintenance programs.

ORGANIZATION

The first step is to determine how your technical data will be organized so you can find the information you need efficiently. Unfortunately, there are no universally adopted standards as to how technical information is organized in the wind power industry. Instead of reinventing the wheel, the operator in our story structured their technical information similar to what is used by the commercial air transport industry (Kinnison, 2004). The information is laid out so that the top-level assembly (tower platform) is divided into major components (tower, nacelle, electrical systems, etc.), and these components are divided into subassemblies. For example, the gearbox cooler is a component of the nacelle. Subassemblies can be further divided into components (gearbox fan, gearbox motor, gearbox radiator, etc.). The process is repeated until the lowest repairable unit is reached. At that level, the specific information can be provided that is applicable to that unit. These may include description information, inspection tasks, repair tasks, and servicing tasks.

The organization of information is relevant for any tower platform, regardless of the manufacturer or design. This allows the maintenance staff to locate the correct information quickly regardless of the manufacturer, and enables the staff responsible for updating technical information to know exactly where the revised information belongs.

KEEP IT SIMPLE

Once the information is organized, it needs to be written in a manner that makes it easy to use and maintain. Simplified Technical English (STE) is one approach that helps improve the readability and portability of your information.

The objective of Simplified Technical English (STE) is clear, unambiguous writing. Developed primarily for non-native English speakers, it is also known to improve the readability of maintenance text for native speakers. STE does not attempt to define English grammar or prescribe correct English.

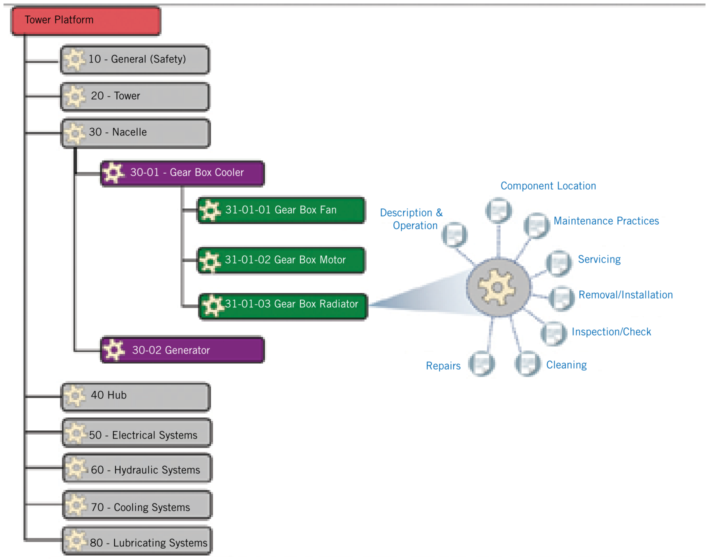


Fig. 2: An organizational structure for maintenance programs.

This type of writing standard is also known as a controlled language because it restricts grammar, style, and vocabulary to a subset of the English language. The main characteristics of the STE standard are: simplified grammar and style rules; a limited set of approved vocabulary with one word having only one meaning; a thesaurus of frequently used terms, technical nouns, verbs, and suggested alternatives, and; guidelines for adding new technical words to the approved vocabulary.

STE attempts to limit the range of English, and many of its rules are recommendations found in technical writing textbooks. For example, STE requires writers to use the active voice, use articles wherever possible, use simple verb tenses, use language consistently, avoid lengthy compound words, and use relatively short sentences. Companies in several industries—manufacturing, mining, oil exploration and software development, for example—have produced their own controlled-language writing standards (Works, 2005). Here is an example, with the "original" text: Place the water heater in a clean, dry location as near as practical to the area of greatest heated water demand. Long un-insulated hot water lines can waste energy and water. Clearance for accessibility to permit inspection and servicing such as removing heating elements or checking controls must be provided.

And the same content in STE: Put the water heater in a clean, dry location near the area where you use the most hot water. If the hot water lines are long and are not insulated, you will use too much energy and water. For inspection and servicing, make sure that you have access to the heating elements and controls.

Besides readability, STE offers a business advantage when creating documentation that will be translated into a number of languages. As the text volume is typically reduced by at least 20 percent and the remaining text becomes more repetitive, the use of STE normally results in 30-40 percent less translation cost. In addition, STE will reduce the number of unique terms and improve translation quality and consistency. The graph shows typical results of rewriting standard English into STE (Wijma, 2012).

Text in STE is easier to understand and may not even require translation. Where translation is needed, STE helps to drastically reduce translation cost and time-to-market, as it effectively eliminates redundant words and improves consistency. With the ever-increasing number of languages that companies need to deal with, these savings add up quickly. Con-

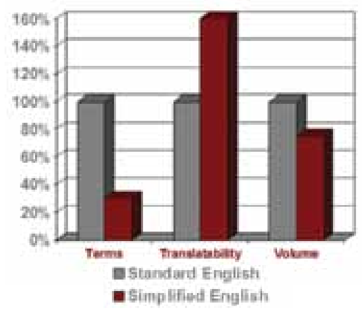


Fig. 3: The advantages of using Simplified Technical English (STE) are readily apparent.

tent is easier to validate, technical writers will be more productive, and fewer iterations and less rework will be required.

STRIKING A BALANCE

There are some industries where unscheduled maintenance is associated with catastrophes. Air travel is one. There is no road shoulder at 30,000 feet. Nuclear power is another. Thankfully we are not in the brokerage operations market, where the cost of downtime is reported to be $107,500 per minute (Marquis, 2006). For the wind power industry, unscheduled maintenance is a bad event, but it's also something that can be managed.

Scheduled maintenance, while allowing the operator to avert part failure, almost always results in premature part replacement. Unscheduled maintenance results in parts being replaced only once full part life has been utilized. Unplanned failures are a problem not because of the repair costs, but because of the downstream effect of loss of energy production. This makes it difficult to arrive at a cost estimate that is both accurate and believable.

Applying industrial engineering concepts allows the operator to evaluate items such as costs and likelihood of downtime, and the cost of purchasing parts with higher reliability or having spare sub-assemblies available (which have a cost on the shelf). In some cases an operator will have a database of thousands of repairs that can be analyzed to prevent future failures before they occur through planned maintenance and condition based maintenance programs. These programs are designed to preserve and restore equipment reliability by replacing worn components before they fail. Preventive maintenance activities include partial or complete overhauls at specified periods, oil changes, lubrication and so on. In addition, workers can record equipment deterioration so they know to replace or repair worn parts before they cause system failure.

SPARE PARTS

The inventory of maintenance items includes all the replacement parts for machines, for tools, and for company-supplied finite-lived employee equipment such as safety glasses. This category excludes items used in manufacturing, such as washers or bolts, and this category includes consumable items for cleaning or safety, such as solvents. Maintenance storeroom management has three major goals:

• To have the item that is needed;
• To supply that item when needed, and;
• To control the overall cost of keeping items in stock.

As an example, suppose that an oil pump is typically replaced twice a year, but only when it "fails," rather than on a pre-emptive maintenance schedule. That tower's production will stop until the pump is replaced. If it is out of stock, there will be a significant delay in returning the tower to production. If a replacement pump is listed in the inventory, but misplaced, there is still a delay. Now suppose the response to this scenario is that a dozen pumps are purchased, with some stored near the machine and more in the storeroom. That expense represents a six-year supply. If we assume some of those pumps will be misplaced in the ensuing years, part of this investment still represents a loss of production time at best, and inventory cost if the missing pumps are never found.

One key recommendation is to consider a computerized inventory management system for the maintenance supplies. This should integrate the purchasing, storage, and stock-release functions so the system tracks pending orders, expense authorizations, where items are stored, and to whom the items are released. For scheduled maintenance, the demand for repair parts will be known in advance. Ensure that the storeroom workers are given sufficient notice of the maintenance schedule so they may pick the items and prepare maintenance "shopping carts" for each tower. This streamlines the workload for the storeroom staff, and it leads to fewer errors (Olofsson, 2011).

IMPLEMENTING TECHNOLOGY

Perhaps the hardest part of a maintenance program is knowing when to invest in your maintenance staff through training and when to invest in tools through technology. Most organizations realize that training is required when implementing new concepts. What few organizations do well is monitor mistakes in order to better understand when training would have improved the efficiency of the maintenance staff. If similar mistakes are being repeated across the staff, training classes can reinforce best practices or clarify information.

This is an area where technology can help training. Some electronic technical manuals have a functionality that allows end users to add their comments about technical information, typically a task or procedure. In many cases the task can be improved by leveraging the knowledge of the people doing the task in a field environment, and this functionality allows that feedback. But in some cases the added suggestion is not what the person who originally developed the task had in mind. For instance, an employee suggested using a broomstick to rotate a very delicate compressor assembly to assist in the inspection. In reality, the broomstick could introduce nicks and dents to the compressor blades. There were two results of this well-meaning feedback: a warning was added to not use foreign objects (like a broomstick) to rotate the compressor; and a training session was conducted to alert the maintenance staff as to why this was not an approved maintenance method.

As a side note, the employee who made the suggestion was actually rewarded with a gift certificate for making the suggestion. Not because it was a good idea; it wasn't. But because he was using the system to leverage his experience.

One way to get the most from your training budget is to record videos of processes that warrant it. This is likely to be the case when it is difficult to do the process correctly, or it is a common to many processes. Just as some electronic technical manuals have a "knowledge manager" that allows for field feedback, there is also the capability to embed training videos and 3D model browsers into technical documentation. Try getting a piece of paper to play a video.

While most maintenance staff will attempt to memorize procedures because of repetition or convenience, it's difficult to memorize all the part numbers associated with scheduled maintenance tasks, and impossible for unscheduled maintenance tasks. This is what makes the Illustrated Parts Catalog (IPC) a critical piece of technical information. But even with an updated IPC, identification and ordering of spare parts can be a trouble spot. Maintenance is often delayed when the wrong parts are ordered because part numbers are identified or entered incorrectly. Use of an electronic parts catalog provides a point-and-click functionality where part numbers are automatically inserted into a shopping cart. Implementers of this technology report that creating a parts list via an electronic shopping cart is 35 percent faster than manual entry into a form, and ordering errors are reduced by more than 20 percent.

SUMMARY

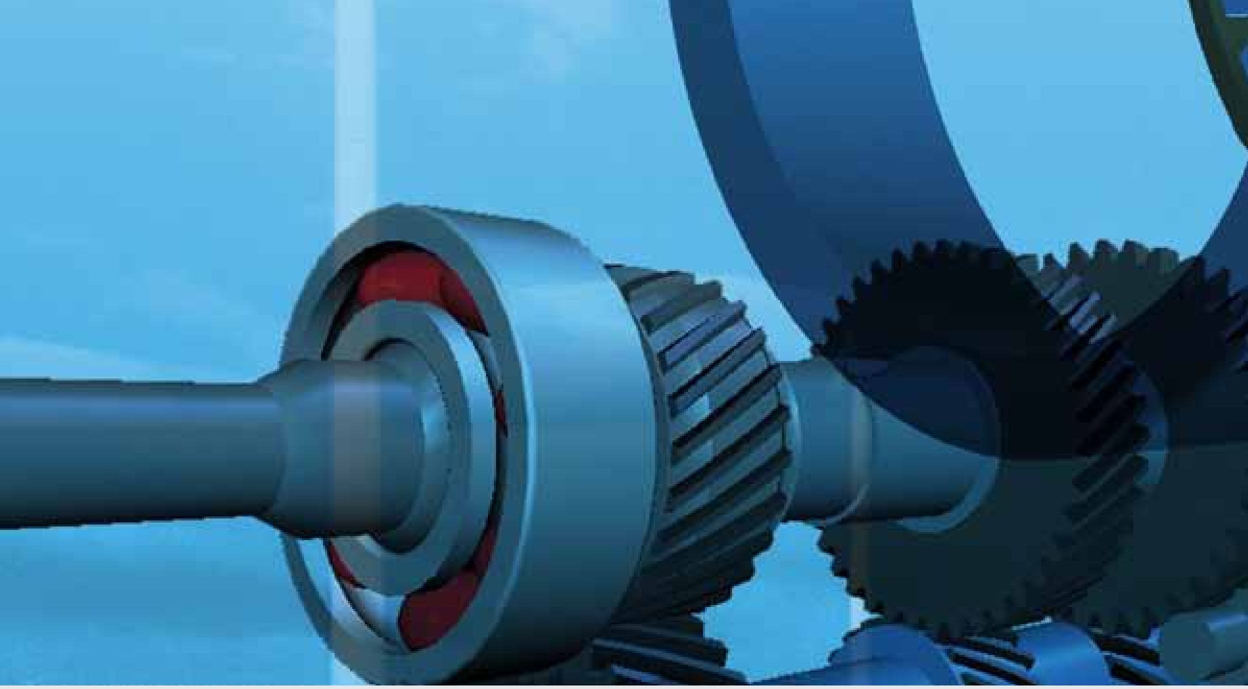
While some organizations look at their documentation as a "necessary evil" at best, in reality it can be the foundation of an efficient maintenance program that maximizes uptime and reliability and can strengthen the organization. By implementing a consistent organization and structure to your technical information, managers provide your staff a head start in finding the information they need consistently, regardless of the equipment being maintained. Implementing STE allows even the most inexperienced maintainer to more easily comprehend complex task. Building a maintenance plan that factors scheduled and unscheduled maintenance with organizational needs can save money by avoiding unnecessary maintenance. Determining which spare parts to stock—and where they should be stored—will help make parts inventory lean and efficient. Likewise, knowing when and how to leverage technology will keep a workforce on the cutting edge without being gashed by not having the information foundation in place.

And what about the operator with the eleventh-hour requirement for maintenance plans and procedures? They were delivered on time, with the information well organized and unambiguous.

A VIRTUAL TOOLBOX OF TECHNOLOGIES

The BEAST tool from SKF simulates the behavior of a complete bearing, including cages, using a fully three-dimensional specialized tribological contact model.

By Greg Zimmerman



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TRADITIONAL DESIGN AND VERIFICATION procedures in developing a new product or improving upon existing technology can be time consuming, costly, and in some cases physically impractical or risky in the field. Typically, many disciplines will be involved in the iteration loop from concept to product launch and the number of prototype and test iterations can become staggering. The application of advanced computer simulation techniques—"virtual simulation" or "virtual testing"—can help shorten the process (and enable verification and evaluation of designs at an early stage when all options are open), reduce a need for prototyping, troubleshoot for root causes when components fail and, ultimately, optimize a system's overall performance and reliability.

Challenge: A major wind turbine manufacturer was in the process of designing a large turbine with an objective to sustain a 20-year lifecycle. The design team additionally sought documentation that the mainshaft bearing and housing arrangement would fulfill requirements of international certification bodies active in the wind industry.

Solution: Enlisting extensive experience in bearing system structural fatigue analysis and applying proprietary virtual simulation technology with the capability to evaluate the dynamic behavior of rolling bearings,

SKF engineering consultants conducted a highly accurate analysis of the turbine housing, including bearing and mainframe interaction. Detailed results enabled engineers to assess the design from a system fatigue perspective and generate valuable input for future design improvements without the need to develop a prototype (or wait for 20 years to ascertain actual lifecycle performance of the turbine).

Results: Analysis confirmed the main bearing housing design would meet extreme load and fatigue-load conditions and that the design would not lead to premature bearing failure over the required 20-year service life. Supporting documentation was compiled to apply for formal international certification of the design.

SIMULATING DYNAMIC BEHAVIOR

Rolling element bearings are a bridge between rotating and static parts and often are a key element for the behavior of the complete application. They consist of an inner ring, outer ring, and a set of rolling elements (balls or rollers). Most rolling bearings also have a cage (or cages) and a few types feature a guide ring. Most commercial simulation tools offer a bearing "representation," usually sidelining the cage or describing in simplified models.

The dynamic phenomena that occur in rolling bearings require specialized simulation tools for evaluation. SKF has been developing simulation tools to analyze bearing and bearing systems for more than 40 years. The first tools focused on an accurate representation of a bearing by itself and were greatly limited by the computational power available.

Today's tools allow for the accurate representation of not only the bearing, but of the complete system such as a gearbox. The SKF tool, called BEAST (for Bearing Simulation Tool), simulates the behavior of complete bearing, including cages, using a fully three-dimensional, specialized tribological contact model (which also accounts for the effects of small-scale geometric variations, such as surface roughness).

This simulation program additionally builds upon or otherwise augments commercial CADS/FEA/CFD systems enabling importing and exporting of system information that may or may not be required for an accurate description of the bearing dynamics. SKF BEAST utilizes fully transient models (generating results over a time domain), compensating for flexibility in bearing geometry (for accurate bearing load calculations), and accommodating all bearing types to develop accurate and detailed bearing models (with geometry based on exact manufacturing data).

UNLEASHING THE BEAST

BEAST is based on multi-body techniques and with special focus on contact problems. It allows for studies of dynamic behavior of all bearing components to be carried out under general loading conditions. This includes the forces on (and motions of) the cage, skew, and tilt behavior of rollers and the skidding of balls.

Principal output data from BEAST relates to the movements of all bearing components, the contact forces between the components, and the forces with the environment. Additionally, detailed data from the contacts are produced (for example, power loss, lubricant film thickness, pressure distribution, slip-speed distribution, and wear).

The output data can be studied in several ways. Animation of bearing components can serve as a good visual starting point (and motions can be magnified for more clarity). Force or velocity vectors can be added to

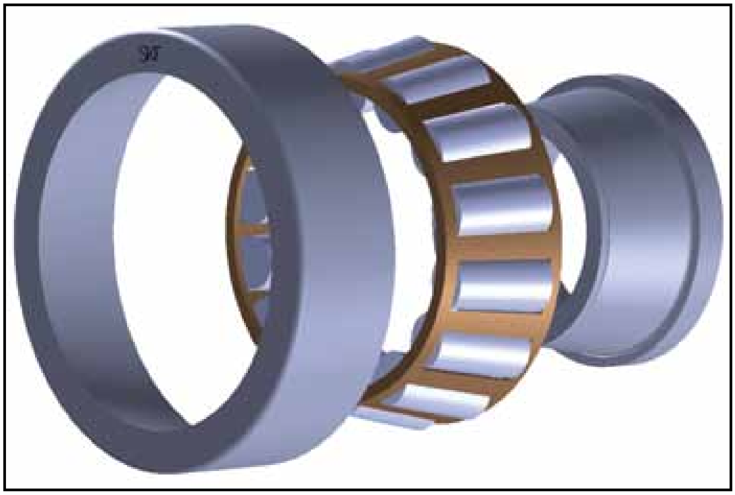


Fig. 1: A BEAST solution simulation.

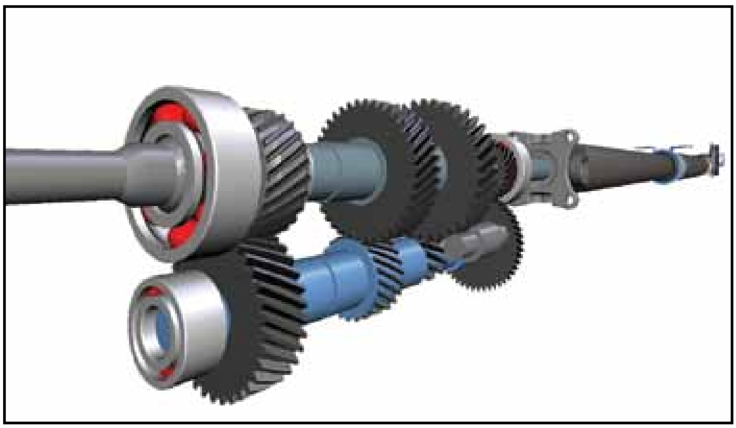


Fig. 2: Design verification.

the animation. Some parameters, such as contact pressure or slip velocities, can be displayed as three-dimensional images on the bodies or on parametric surfaces. All output data can be reviewed in more detail using graphical formats.

The integration of Design for Six Sigma (DfSS) into the modeling process introduces a framework for optimized evaluation of selected bearing arrangements. Utilizing the DfSS process enables a structured approach and toolbox to identify critical to performance operating parameters.

The performance of bearings will be influenced by many different system design and operating parameters. Some can be controlled during operation, while others cannot but may have a significant impact on system performance. One example of combining virtual simulation and DfSS is to generate a virtual design of experiments (DoE). Through a statistical analysis of DoE results, the robustness of a bearing system can be ascertained along with the influences that design parameters exert on performance.

In a design of experiments, different calculation runs will be made to rank the parameters in terms of their influence on the bearing's performance. The model allows many more parameters to be analyzed independently compared with physical assembly and testing. This type of analysis can help optimize system settings to

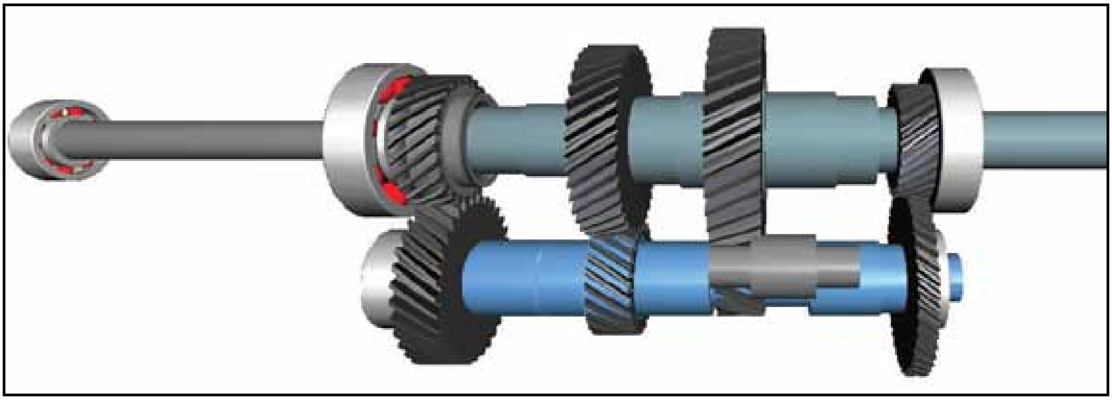


Fig. 3: Orpheus transmission.

increase robustness and reduce performance variability. Such models can help designers narrow their choices and evaluate the various options early in the design process or beyond. Designers can strategically factor in different parameters and tolerances to understand how they will impact overall performance without use of a prototype or physical testing. As a particular example, friction and thermal models can provide an accurate temperature prediction that can help in determining bearing life and clearance, lubrication intervals and conditions, and proper lubricant selection, among other purposes.

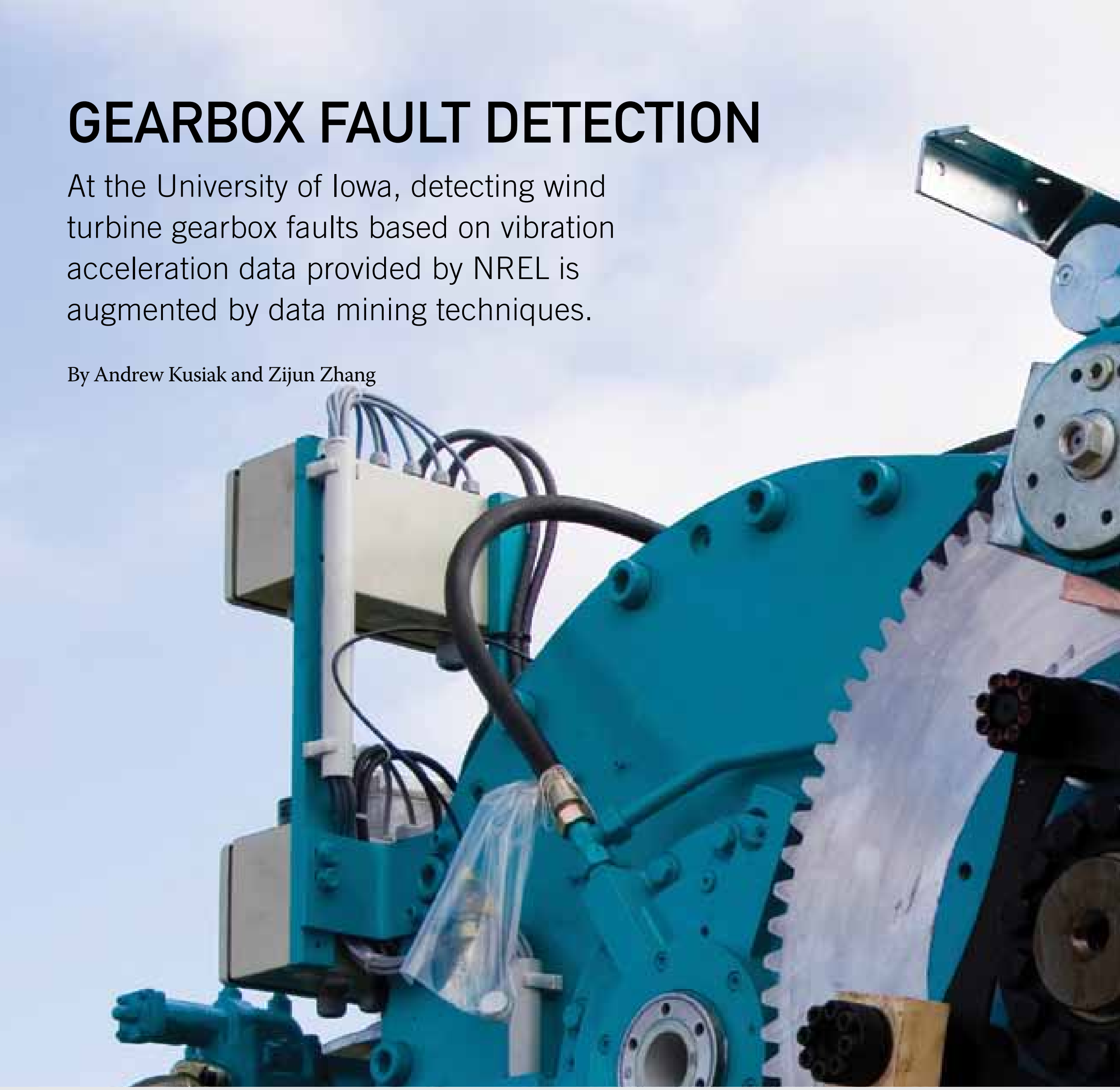
FINAL NOTE

While virtual simulation and testing cannot necessarily replace all physical testing and prototyping, technologies offer a practical methodology to investigate parameters and test conditions too difficult to achieve otherwise. Along the way, the number of iterations on the road to a viable design can be reduced significantly. In the near future, advances in computers and simulation technology can be expected to increase capabilities and provide designers with even keener insights into how bearings and systems can (and should) perform.

GEARBOX FAULT DETECTION

At the University of Iowa, detecting wind turbine gearbox faults based on vibration acceleration data provided by NREL is augmented by data mining techniques.

By Andrew Kusiak and Zijun Zhang



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THE WIND INDUSTRY HAS EXPERIENCED a rapid expansion. As wind farms are aging, their operations and maintenance issues are gaining in significance. The wind industry has been affected by failures of wind turbine components such as main bearings, gearboxes, and generators. Replacement of failed components results in the high cost in energy production. Therefore, research in fault identification and condition monitoring is warranted. In this study, detecting wind turbine gearbox faults based on vibration acceleration data provided by the National Renewable Energy Laboratory (NREL) has been investigated. Data mining methods [1, 2] are applied to identify the faults in the time domain.

NREL GEARBOX TEST FACILITY

The data used in this research originate from a damaged gearbox of a test wind turbine. The gearbox was retested at the Dynamometer Test Facility (DTF) at NREL. To retest the gearbox, the complete nacelle, and the drive train of the test wind turbine were installed at the DTF. The nacelle was hard fixed to the floor without hub, rotor, and yaw bearing. Figure 1 shows the diagram of DTF.

The gearbox included three stages: low-speed stage (LSST), intermediate-speed stage (ISST), and high-speed stage (HSST). It was instrumented with over 125 sensors. Figure 2 shows the side view of the gearbox. As

shown in fig. 2, the LSS is connected to the rotor and the HSS is connected to the generator.

To investigate the root cause of the gearbox damage and conduct the fault identification analysis, vibration data needed to be collected. Therefore, 12 accelerometers were mounted on the outside of the gearbox, generator, and main bearing to measure the vibration acceleration. Vibration data measured by all 12 accelerometers were collected at 40 kHz using a high-speed data acquisition system. Besides the vibration data, the corresponding torque of the low-speed shaft and the generator speed were recorded. The direction of the drive train vibration acceleration is described as a three-dimensional coordinate system and sensed by accelerometers. The origin of the coordinate system is the intersection of the planet carrier rotation axis and the plane cutting the torque arm cylinder in half along their length. The x-axis describes the system acceleration along the main shaft axis and the downwind side, and the y-axis represents the vibration acceleration direction, which is horizontally perpendicular to the x-axis. The z-axis is orthogonal to the x- and y-axes. Figure 3 illustrates the coordinate system of the vibration acceleration. Although the vibration acceleration of the system is depicted by a three-dimensional coordinate system, the mounted accelerometers can only sense one or two directions of acceleration. Table 1 presents the locations of the accelerometers, the measured directions of vibration acceleration and the units of the recorded data. Figure 4 illustrates the locations of 12 accelerometers.

Three test cases are conducted by NREL. In Case 1 the nominal speed of the high-speed shaft is set to 1800 rpm and the electricity power is set to 25 percent of the rated power. In Case 2 the nominal speed of the high-speed shaft is the same as in Case 1, but the electricity power is set to 50 percent of the rated power. This indicates that the torque in Case 2 is twice the amount of torque in Case 1. In Case 3 the generator speed is 1200 rpm and the torque is at 25 percent. The test length of all cases is the same, 10 min.

DATA PROCESSING

To analyze the gearbox vibration in the time domain, jerk is utilized. Jerk describes the rate of acceleration change, and it is often used to indicate the excitement of vibration. For the high-frequency vibration acceleration data in Section 2, the jerk is approximated in (1).

$$\vec{J} \approx \frac{a_t - a_{t-T}}{T}$$

where J is jerk, a is acceleration, t is the time index, and T represents the sampling interval.

Since the sampling frequency is high (i.e., 40 kHz), the number of data points within 10 min length is large. Therefore, vibration, the high-frequency jerk data (40 kHz), is then converted into much lower-frequency data (1/15 Hz) by computing the mean of jerk at 15-s intervals. The standard deviation and the maximum value of the jerk data in each 15-s interval are also computed.

FAULT IDENTIFICATION METHODOLOGY

In this section, clustering analysis [1] is utilized to investigate the failed components in the gearbox. Clustering analysis is an unsupervised method of data analysis. Clustering algorithms group observations into clusters by evaluating similarities among the observed data. The component failure can be identified by examining the pattern similarity of the jerk data measured by accelerometers mounted at different locations of the drivetrain.

The clustering analysis aims at grouping data from 12 sensors using the jerk data. The time series of the

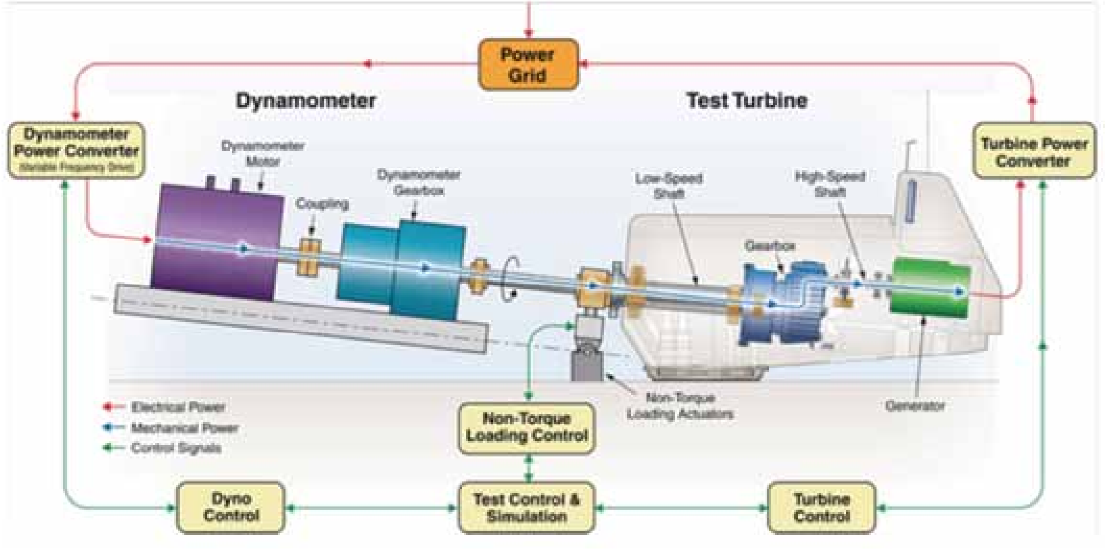

Fig. 1: Diagram of NREL 2.5-MW dynamometer test facility (Courtesy of NREL).

jerk described in the previous section are utilized in the clustering analysis. The k-means algorithm [3] is modified in this study to establish clusters. In the original version of k-means algorithm, the number of clusters, k, should be arbitrarily set by the analyst. In this study, a clustering cost function is introduced to evaluate the cluster quality with k.

The results of clustering analysis for Cases 1 and 2 are the same and illustrated by fig. 5. As shown there, the 12 accelerometers are classified to three clusters according to the modified k-means algorithm. In Cluster 1, most of the sensors sense the vibration acceleration of the gearbox low-speed stage. Cluster 2 contains data from two sensors that monitor the acceleration of the

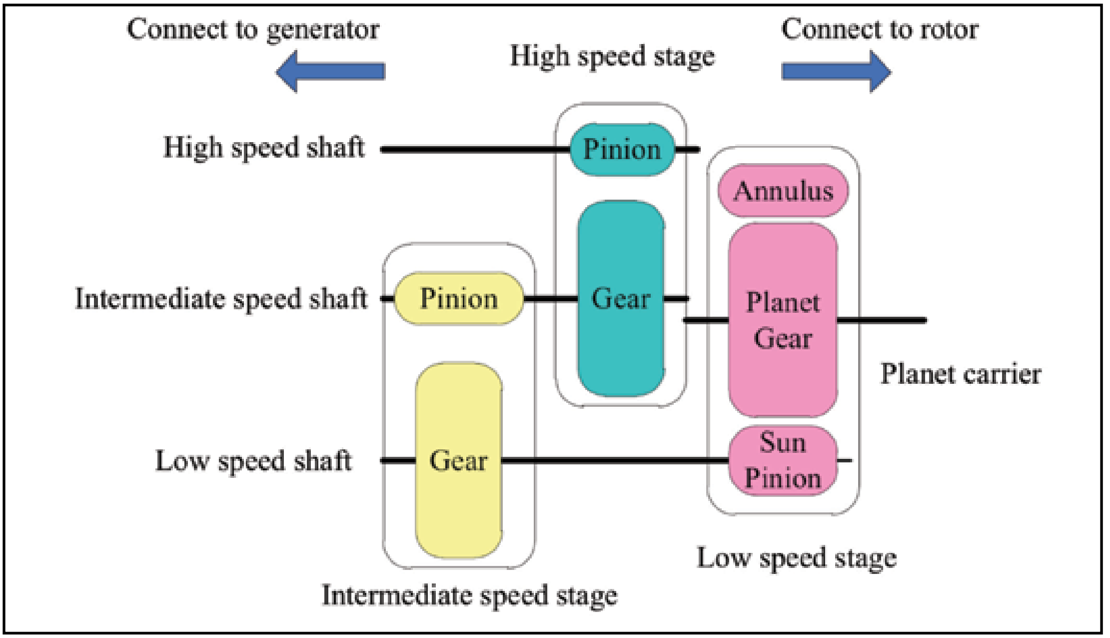

Fig. 2: Structure of the gearbox.

main bearing. Sensors that measure the vibration acceleration in the intermediate- and high-speed stage make Cluster 3. To further analyze the data in the three clusters, the Euclidean distance between the centroids of clusters is calculated. The shorter the distance, the more similar the two clusters are. Figure 6 demonstrates the cluster distances for Cases 1 and 2, respectively.

Since the gearbox test experi-

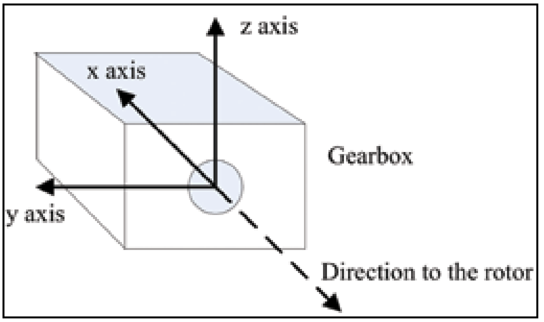

Fig. 3: Vibration coordinate system.

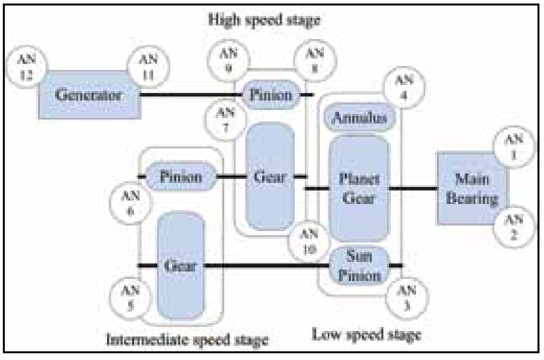

Fig. 4: Location of the accelerometers.

ment was conducted to examine the failure components of the gearbox, the vibration of the main bearing was considered as normal in this research. In Case 1 of fig. 6, the distance between the centroids of Cluster 1 and Cluster 2 is 2.31 while the distance between the centroids of Cluster 3 and Cluster 2 is 5.72. The Case 2 demonstrated in fig. 6 presents a similar result. Based on the results in fig. 6, the components sensed by the accelerometers in Cluster 3 are considered to be primarily failed because the distance between Cluster 1 and Cluster 2 is small. Some components sensed by the sensors in Cluster 1 are also considered as failed since the vibration data from the two sensors installed for monitoring the same stage belong to two different clusters.

CONCLUSION

In this article vibration acceleration data of an impaired wind turbine gearbox provided by NREL were analyzed to identify the faulty stage of the gearbox. In the analysis the vibration acceleration data were transformed to the change rate of vibration acceleration. The correlation coefficient analysis and modified k-means clustering approach were introduced to identify the faulty stage of the gearbox. The suspected faulty stages of the gearbox were proved after the inspection of the gearbox by disassembling.

Sensor	Symbol	Location	Plus Acceleration Direction	Unit
Accelerometer No. 1	AN1	Main bearing radial	+Z and -Y	m/s^2
Accelerometer No. 2	AN2	Main bearing radial	-X	m/s^2
Accelerometer No. 3	AN3	Ring gear radial 6 o'clock	-Z	m/s^2
Accelerometer No. 4	AN4	Ring gear radial 12 o'clock	+Z	m/s^2
Accelerometer No. 5	AN5	Low-speed shaft radial	+Y and -Z	m/s^2
Accelerometer No. 6	AN6	Intermediate-speed shaft radial	+Y and -Z	m/s^2
Accelerometer No. 7	AN7	High-speed shaft radial	+Y and +Z	m/s^2
Accelerometer No. 8	AN8	High-speed shaft upwind bearing radial	+Z	m/s^2
Accelerometer No. 9	AN9	High-speed shaft downwind bearing radial	+Z	m/s^2
Accelerometer No. 10	AN10	Carrier downwind radial	+Y	m/s^2
Accelerometer No. 11	AN11	Generator upwind radial	+Z and -Y	m/s^2
Accelerometer No. 12	AN12	Generator downwind axial	+Z and -Y	m/s^2
Generator Speed	w	Encoder on high-speed shaft	Null	rpm
Low-Speed Shaft Torque	π	Strain gauges on low-speed shaft	Null	kNm

Table 1: Location and description of the sensors.

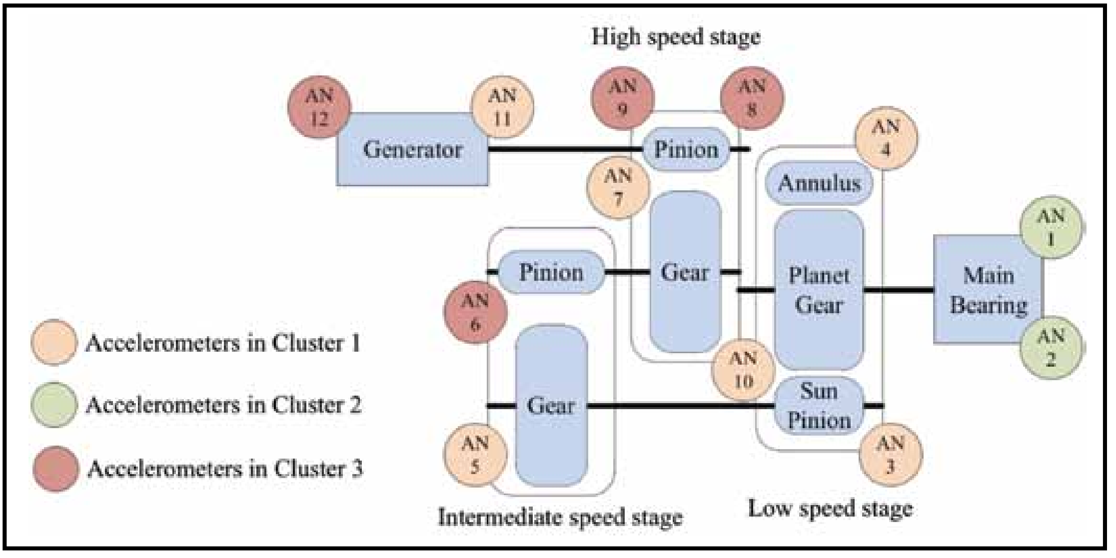

Fig. 5: Clustering results of Case 1 and Case 2.

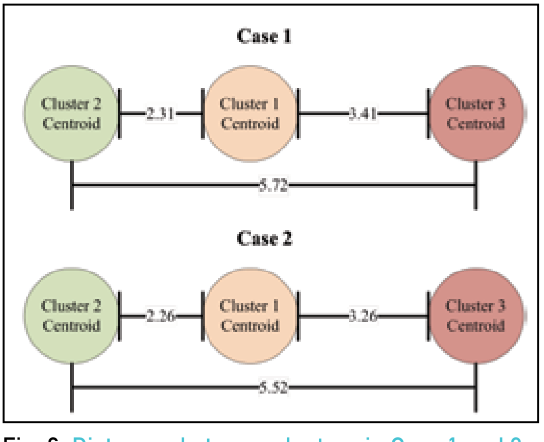

Fig. 6: Distances between clusters in Case 1 and 2.

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INSPECTING GEARS FOR WIND

The new 3000GM analytical gear inspection system from Gleason helps its global wind customers achieve faster, more-accurate gear production.

By Mike Hayes

Mike Hayes represents Gleason. More information is available at www.gleason.com. Also visit www.breviniwind.com and www.guibe.com.

WITH SOME 60,000 OF ITS WIND TURBINE pitch and yaw systems installed worldwide, the Brevini Group is no stranger to wind power. Yet today the stakes, and opportunities, have never been greater. With the establishment of its Brevini Wind division—and a $90-million, 100,000 square-foot, ultramodern factory in Yorktown, Indiana—Brevini has entered the main wind turbine gearbox business in a big way. It's expected that as many as 40,000 new wind turbines could be deployed in North America by 2015, and many will be equipped with a new generation of lighter, more-efficient, and highly reliable Brevini main gearboxes ranging in size from 0.9 to 3.5MW capacity. So when Brevini Wind USA Director of Facility Operations Dale Harder learned that a Gleason 3000GMM analytical gear inspection system was going into the new factory's QC room, he couldn't have been more pleased.

"Many of us have had experience in the past with M&M Precision, which ultimately became Gleason Metrology Systems, so the brand is highly respected," he says. "We have established very ambitious quality and throughput objectives for the large internal ring gears and sun and planetary gears we're producing here for these new gearboxes, so you can imagine the very important role gear inspection is playing."

Fig. 1: Brevini Wind USA gears up for fast-growing North American wind turbine demand with a new ultra-modern $90 million, 100,000 sq. ft. factory in Yorktown, IN USA.

Fig. 2: New Gleason P 2400 large hobbing (top) and profile grinding machines (bottom) perform complete cutting and hard finishing operations on a new generation of very high quality internal ring gears, sun and planetary gears for Brevini's main drive gear boxes.

QUALITY IS CRITICAL

A critical driver of gear quality standards at Brevini is of course the need for exceptional gearbox reliability. Wind turbine installations are often in inaccessible areas and operating in adverse conditions that make repair and maintenance both difficult and expensive. Increasingly important is the need for quiet-running wind turbines, particularly for wind towers in close proximity to populated areas. Despite their size (Brevini internal ring gears are as large as 2.2 meters in diameter with 400 mm face widths and weigh upwards of 3,000+ kg), part prints call for Brevini gears to be made to ISO Grade 6 or better, all with surface finishes to Rz 3 µm. Mr. Harder says his two new Gleason P 1600 and P 2400 Hobbers and two P 1600 G and P 2400 G Profile Grinders are easily achieving these levels, and better. The challenge, he says, is ensuring that inspection keeps up with production. "We're keen on demonstrating, both internally and to our customers, that our new processes can achieve the highest quality levels, which

Fig. 3: New Gleason 3000GMM analytical gear inspection system speeds and simplifies the critical quality verification process for any gear, enabling Brevini to keep pace with its new gear production machines.

Fig. 4: "Stirring in" setup time is greatly reduced with Gleason's Journal Reference software, which takes minutes, even hours out of the time usually required to 'true up' large gears manually.

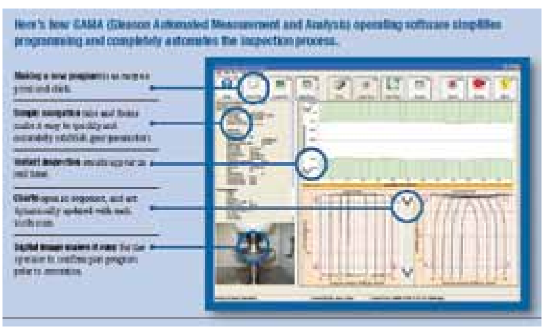

Fig. 5: Here's how GAMA (Gleason Automated Measurement and Analysis, operating software simpifies programming and automates the inspection process.

puts the burden on our gear inspection system," says Mr. Harder. "That's what we really like about the new 3000GMM. If you can read a part print, you're practically ready to set up the part and run the machine. It's that fast and easy."

A STIRRING EXPERIENCE

For example, Harder says that the initial "stirring in" of the part during setup is traditionally one of the most time-consuming stages of the large gear inspection process. In the case of a two or three ton internal ring gear this can consume a considerable amount of time, with several people delicately lower the part onto the worktable and work to manually "true it up"—a painstaking process of moving part datums incrementally until they're zeroed in precisely to a pre-established starting point. But the 3000GMM eliminates much of this setup time with its "journal reference" software. This allows the operator to simply position the part anywhere to within 10 mm of the desired location—something most operators can "eyeball"—and then the journal reference software takes it from there. It automatically probes to determine the actual location of a datum such as the OD, takes a radial and axial measurement, and corrects for the new zero location so that no additional stirring in time is required. Harder says it's just one of the many features available to his operators through the system's extremely friendly user interface called GAMA, a software suite designed to greatly simplify the inspection process. It's particularly easy to learn and use, with a highly intuitive Windows-based graphical user interface and a host of features including help menus, language translation, multiple security levels, and even online support. Several other important features stand out as well, including:

- A solid granite base, providing considerably more stability for, say, a 3,000+ kg gear than competitive models with cast-iron bases. Its Meehanite® cast iron slide assemblies provide vastly better damping characteristics as well.
- The use of the Renishaw® SP80H probe, which is an advanced 3D scanning probe that's light years ahead of older model scanning probes. It acquires data faster and more accurately on even the most complex gear tooth profiles and features industry leading probe axis travels—X axis is plus or minus 1.5 mm; Y and Z axes are plus or minus 2.5 mm—with each axis driven on 20 nanometer resolution glass scales for exceptional measuring accuracies.

Finally, Gleason's localized service and support network has been instrumental in the successful startup of the new technology. Gleason Metrology Systems, based in Dayton, Ohio, is in relatively close proximity to the Brevini plant and has provided onsite technical expertise and application support throughout the installation and launch period.

"The 3000GMM is the perfect complement to the highly productive Gleason machines," Harder explains. "Those of us employed here with Brevini Wind clearly realize what a unique opportunity we have been presented with. We are very fortunate to work for a company that is willing to make the significant investments

Fig. 6: Talleres Guibe's New Gleason 2000GMS performs the complete inspection of increasingly complex gear geometries up to 25% faster, while meeting VDI/VDE Class 1 specifications.

necessary to provide us with such tremendous gear manufacturing and inspection capabilities.

"Additionally, we are also very fortunate that Gleason has proven itself to be a very dependable partner in our startup efforts by providing us with the necessary training and applications assistance that allows us to utilize these latest technologies in the most proficient ways," he says. "The most demanding of our gear manufacturing applications have been easily accommodated although the level of experience amongst our workforce with large gear manufacturing in the beginning was quite minimal.

"Our manufacturing team is extremely pleased with the simplicity of setting up and operating all of the Gleason equipment," Harder says. "I don't know how Gleason could have made this any better for our particular situation."

GAINS IN SPAIN

It might surprise you to learn that Spain is the world's fourth biggest producer of wind energy, right after the United States, Germany, and China, with an installed capacity of 19,959MW at the end of 2010. And the number of wind turbine installations in Spain is expected to rise. For companies like special gear and gear reducer manufacturer Talleres Guibe, situated in the heart of northern Spain's industrial region of Irura, Guipuzcoa, that's good news.

But according to company officials, the enormous productivity and quality gains made possible with new Gleason grinder installations were being limited by the deficiencies found in the company's large gear inspection system. This older system was suddenly rendered almost completely obsolete, since its measurement capabilities were far below the exceptional accuracy levels achievable on the new Gleason machines. Furthermore,

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spare parts and service for the old system were almost nonexistent. As a result, large gear inspection would now have to be performed elsewhere, adding to cost and delivery time; neither of which was acceptable to Talleres Guibe or its customers.

No wonder Talleres Guibe is so excited about their new Gleason 2000GMS analytical gear inspection system. With a 2-meter workpiece diameter capacity, the new 2000GMS can handle almost any gear produced at Talleres Guibe. Better yet, it performs the complete inspection of today's increasingly complex gear geometries up to 25 percent faster, while meeting VDI/VDE Class 1 specifications.

POWERED BY GAMA

Equipped with a new and improved GAMA 2.0 applications suite of software, the GMS series is unquestionably the easiest and most intuitive system of its kind to operate, empowering even less experienced operators with the ability to inspect any gear faster and more efficiently. GAMA 2.0 puts a host of powerful new features right at the fingertips of the operator, creating a simple and intuitive human/machine interface to improve their performance.

For example, the process of creating a new program is as easy as point and click, and it can be done in just minutes in a few easy steps, and regardless of the operator's level of experience or the gear or gear cutting tool type. This even includes an "unknown" gear, where parameters aren't defined and even a drawing might not exist. The operator simply selects from a list of typical machine configurations, enters a part number, and clicks the "create" button. Once the necessary fields are filled out with pertinent gear data, special tests required for highly modified gear profiles and geometry, and the type of analysis required, GAMA 2.0 does the rest. It draws from a suite of applications software supporting the complete topographical inspection and prismatic measurement of any rotationally symmetrical workpiece, including cylindrical, bevel, conical and cycloid gears, shaper and shaving cutters, hobs, bevel blades, rotors, etc., and the programming process is complete. In addition, the human/machine interface has been further enhanced on the new GMS series with a newly-designed operator work station, which puts the operator in a better position to quickly, easily, and more comfortably perform tasks.

Also available is a unique handheld remote pendant workstation that allows the operator to be productive anywhere and is also ideal for large gears and particularly complex part setups. This remote pendant control comes complete with video telephony support, Internet connection, touchscreen input, and a host of other important features.

SEEKING A SKILLED WORKFORCE

As the Boomers retire, how do we begin building the renewable energy workforce of the future? Early outreach is key, according to Shermco Industries.

By Mike Moore

Mike Moore is vice president of sales for Shermco Industries. For more information please visit www.shermco.com.

THE NATIONAL UNEMPLOYMENT RATE is currently at 8.3 percent. The unemployment rate has been at or above 8.8 percent for the past 28 months. The underemployment rate has remained between 15.7 and 17.4 percent since the spring of 2009, and it currently stands at 16.1 percent. Additionally, the current skilled workforce is losing its qualified and experienced workers. On average 10,000 senior, experienced, knowledgeable, qualified workers will turn 65 years of age every day for the next 20 years, and as the 73 million folks leave the marketplace so goes their skills, talents, knowledge, and inherent trade techniques. With these kinds of numbers who would ever have thought that there was a very large unmet demand for skilled labor, or that the need for skilled labor would be in a niche marker sector like wind energy?

Since the end of World War II there has been an appreciating decline in skilled workers. This decline has grown immensely as the American economic engine has revved up. The Baby Boomers numbering in the ballpark of 73 million folks were the largest contributor to the skilled labor pool, but not large enough to meet the demands in the industry. The following generations of "X" and emerging generation of "Y" have not met the demand of the industry to date.

THE BABY BOOMERS

By definition, a Baby Boomer is someone who was born between the years 1946 and 1964. As of right now Boomers are between the ages of 44 and 62. The Boomer generations are the folks who built and motivated the American economy for the last 60 years. Their social, cultural, and economic impact on the United States has been unprecedented in its history and is currently the single largest economic group in the United States today. The Boomers' "work hard, play hard" mentality allowed them to have one of the highest discretionary income levels than any other age group, and it accounts for 45 percent of all consumer demand. As these Boomers retire and leave the workforce, the demands that they place on the goods and services producers and service providers will create some challenges as there are fewer folks to produce and service the retiring boomer society.

However, the Boomers have not saved very effectively for retirement, and some may be retiring early or moving into a less demanding working pattern, working less rigid jobs, playing golf on weekends, and dining at leisure all while still possessing their skills, talents, knowledge, and inherent trade techniques from a lifetime of hard work and no one to pass these skillsets on to. The exit of the Baby Boomer generation compounds an already looming crisis with the lack of qualified and skilled workers that has existed over the last 30 years. Skill levels in the U.S. workforce have stagnated, with Americans 25-34 years of age who do not possess the higher skills that their Baby Boomer parents do.

> "Students in high school who are beginning to consider career choices need to know that there are career opportunities in renewable energy."

GENERATION X

The 46 million "X Generation" of sons and daughters of the Boomers did not wholly move into the skilled trade sectors, but instead went to college, sought professional degrees, jobs, and technical assignments, overall making much less income than their Boomer parents. They are officially the first generation to challenge the notion that that each generation will be better off than the one that preceded it. The study "Economic Mobility: Is the American Dream Alive and Well?" focuses on the income of males 30-39 in 2004 (those born April, 1964 – March, 1974) and is based on Census/BLS CPS March supplement data. The study, which was released on May 25, 2007, emphasized that in real dollars this generation's men made less (by 12 percent) than their fathers had at that same age in 1974, thus reversing a historical trend. The study also suggests that per-year increases in the portion of father/son family household income generated by fathers/sons have slowed (from an average of 0.9 to 0.3 percent), barely keeping pace with inflation, though increases in overall father/son family household income are progressively higher each year because more women are entering the workplace, contributing to family household income.

In the next five years the X generation will make up the largest majority of the workforce in America, replacing the roughly 20 million skilled Boomers with only a third of the skilled workforce required to support the demands for goods and services. The balance of the X generation will continue to work in the professional services sector.

GENERATION Y

The roughly 80 million "Y Generation" folks entering the workforce today are the most technologically diverse generation in American history, but they barely make the global top 10 of educated and trainable workers. America is no longer a skill-abundant country compared with an increasing share of the rest of the world. As a result, in the coming decade America will face broad and substantial skill shortages.

The Y generation prefers to work independently with self-directed projects, responding to learning that provides interaction with their colleagues. They prefer more structure, direction, and social interaction. This generation is polite, believes in manners, adheres to strict moral code, and believes in civic action, but it also places a high value on making money—more than any other previous generation—and they see education as a means to this goal. Like the X generation before them, they seek professional careers. Studies predict that Generation Y will switch jobs frequently and will not have the passion for "the company" that older and more career established employees do. With the global booming numbers of Y generational workers added to the employment pool, economic prospects for the Y generation look bleak due to the late 2000 recession and a youth unemployment rate in the U.S. reaching a record level of close to 20 percent at the end of 2010.

As the Boomers exit, the X generation tries to fill the gap while the Y generation is looking to find a professional work environment. The question arises; Who is going physically move this country forward in the next 10-20 years?

RENEWABLES AND LABOR

The resurgence of renewable energy installations possesses the potential to be a very large source of job creation. This virtually renewed industry demands highly skilled electrical and mechanical construction workers, heavy machinery operators, and professionals with a wide range of skills from chemistry, engineering, and physics to design, build, install, and maintain the infrastructure at these sites.

Since "skilled and qualified" workers of renewable infrastructure did not exist in any great numbers, the labor was pulled from the general skilled trades and the declining energy sectors to construct and maintain these sites. Because wind farms require permanent employees to maintain and operate them, wind energy produces jobs at different levels, in operation as well as in wind turbine component manufacturing and construction. These jobs, unlike other high-paying jobs in technology-based industries, are widely available in rural areas where wind farms are located.

These new jobs will require the personnel to interact with the equipment, either as a direct employee or a contractor and the ever-increasing regulatory component of the U.S. government is placing critical demands for protecting workers in the renewable energy sector, hence the ability to learn, adapt, and understand job-site hazards is a must.

“The resurgence of renewable energy installations possesses the potential to be a very large source of job creation, demanding electrical and mechanical construction workers, heavy machinery operators, and professionals with a wide range of skills.”

HUMAN RESOURCES

Unskilled native-born Americans do tend to compete with unskilled workers in the jobs marketplace, but the skilled workforce is still a challenge that has yet to be met for the growing immigrant labor pool.

The Y generation moving into the workforce may not be as motivated to take skilled labor, or “hands-on” jobs, due to their ability to easily seek education beyond high school and pursue professional careers where their income levels will be same as their X generation counterparts. It remains to be seen where this generation will end up, but whatever the outcome working long distances from home in remote isolated areas with limited communications and long workdays far away from social circles may create a challenge in retaining these folks. Since much of these renewable resources are

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constructed and installed in very rural areas many workers are leaving the ranch and farm to work in the industry. Many are pursuing educational opportunities from community colleges and universities that are developing renewable energy programs that offer a general education in wind, solar, and biomass engineering and maintenance technologies.

As with any resource, skilled labor will be in higher demand, which in turn will drive wages higher and demands for repairs, testing, and power generation equipment maintenance will push the skilled worker from employment with the renewable sites directly to contractors and suppliers. As these wages increase, so will labor rates for the services offered by electrical installers and repairmen. Eventually the annual incomes of skilled workers will match or outpace those of the professional worker.

If we want to build a skilled workforce in sufficient numbers to fill the jobs in the growing renewable energy industries, we will have to start before college. Students in high school who are beginning to consider career choices need to know that there are career opportunities in renewable energy. They also need to understand what workers in the renewable industries actually do on a daily basis to get a realistic idea of whether or not a job in renewable energy is right for them. That could be accomplished through internships for high school students as well as "job shadowing" opportunities during which students spend time with workers on the job, witnessing firsthand the skills and responsibilities those jobs require. To complete the process of ensuring that renewable energy firms have an adequate pool of skilled labor, we must build a strong "skill pipeline" from high school into college and to the workplace to provide an adequate number of skilled applicants for every type of position.

As the renewable market grows, opportunity will grow with it. This opportunity will be rich, with high-paying jobs that will have to compete for the qualified and skilled workers that choose to stay on their tools. Though the possibilities are endless for the Y generation to move into the skilled trades, it does not appear with the current trending to be the case anytime soon. The answer in the short term to who will fill the skilled trades' gap may lie with international workers who possess similar skills, training and qualifications very similar to that of the native-born American counterparts.

Whatever the generational case may be, there are unfilled skilled jobs available in the renewable energy market sector, as well as those service providers who install, maintain, and repair the unique equipment that generates power from the wind and the sun—but you must be qualified to answer the call.

COMPREHENSIVE TOOL MANAGEMENT

A comprehensive tool management system includes organization, visibility, security, trackability, and accountability. Snap-on Industrial can help.

By Andy Lobo

Andy Lobo is director of product management and development at Snap-on Industrial. He can be reached at (262) 656-4702 or andrew.r.lobo@snapon.com. Also visit www.snapon.com.

IT'S REMARKABLE HOW TOOLS and equipment can suddenly grow legs and walk off a wind farm or jobsite. A lost or missing tool may not seem like all that big of a deal, or a lot of money for that matter. But when a jobsite starts losing multiple tools, the replacement costs—not to mention the lost productivity—can quickly add up.

Tool manufacturers are leading the charge to help eliminate the growth of those legs and keep tools and equipment on the jobsite where they belong. A comprehensive tool management system includes organization, visibility, security, trackability, and accountability. Different applications and needs require different answers, from very low-tech solutions such as foam cutouts to visually identify if a tool is missing all the way to digital imaging software to track tool movement in real time. When implemented correctly, these jobsite tool management strategies provide an effective way to reduce tool loss, improve worker productivity, and ultimately save money.

LOW-TECH SOLUTIONS

Certainly the idea of using foam cutouts in a tool box as a way to visually inspect for any missing tools isn't a new concept, but it is effective. Imagine trying to find a 19mm socket in a box in which tools are scattered

Fig. 1: An example of Snap-on's customized foam insert.

throughout several drawers with no semblance of order. You may eventually locate the socket, but it could take awhile. A box with no organization also poses an inviting target to someone looking to take a tool home. Who's going to know if that 19mm socket is missing from a box with tools that's an unorganized mess? If the socket has been removed, and the next person is hunting through the box looking for it, the time wasted searching for it is keeping him from performing his job. That's lost productivity.

Boxes with foam do provide an extra layer of security in preventing tool loss. A person is going to think twice before considering taking a tool home knowing that an empty foam cutout is showing the evidence of a missing tool. Foam also aids in alerting someone of a tool left behind on the jobsite. A quick scan of the drawers can reveal any missing tools that may have been inadvertently left behind on the job, which can then be retrieved.

While using foam is a low-tech solution for tool control, the process of foam creation has come a long way from the days of tracing and cutting by hand. Some manufacturers cut foam to their customers' exact specifications. One way to do this is for customers to lay out tools in a mock drawer with a camera positioned over it. The drawer is pre-sized to fit their existing tool boxes. They then arrange tools in the mock drawer to their liking, and take a photo of the layout. The process is repeated for each drawer. Once the photos are taken, they are sent to the manufacturer, where the photos are converted to a CAD drawing and fed into a CNC cut machine, and cut to the exact layout of the tools in the pictures. The foam drawers are ready to use and are cut precisely to fit their existing tools.

Another low-tech solution to tool control is using pre-made tool kits on the job site. Again, the concept of creating a kit for a specific job is nothing new, but what is different is the ability to add tool control to that kit to help ensure each tool is returned following the job.

Many companies that have created kits often include all the necessary tools to accomplish a task, but they are thrown into a bag or pouch and distributed to the technician at the tool crib. These tools can mistakenly get left behind because there's no way of truly knowing if all the tools are in the pouch unless they're counted. This is an inefficient process that may be skipped on the jobsite.

The better solution is a mobile mini tool chest that offers tool control. These types of boxes can be kitted to contain tools to perform specific maintenance out on a jobsite, but have drawers with foam for tool control. They're designed with different configurations to meet different applications: two two-inch drawers plus six one-inch drawers, or three two-inch drawers plus four one-inch drawers. The drawers can be opened

Fig. 2: High-tech tool boxes can be accessed with bar codes.

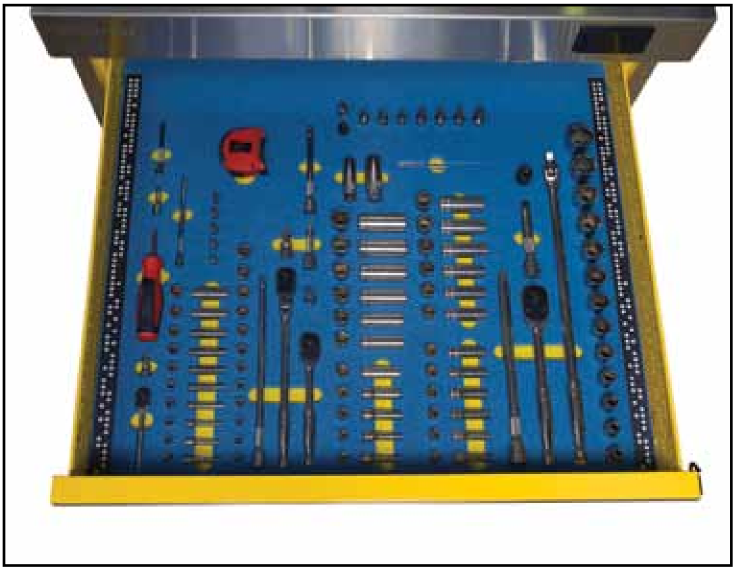

Fig. 3: Tools are assigned to the individual removing them from the box.

without having to flip the box over on its side.

The box has wheels so it can be pulled by hand, and the drawers open and close on slides and rails and can be fully secured when not in use. Portable tool chests are ideal for applications where maintenance is being performed on more remote jobsites away from the tool crib.

Another was to prevent tool loss is simply through color. While shiny chrome tools can pose an attractive target to someone with sticky fingers, tools are available in a dull, black finish. It's not to say that black-colored tools don't walk away from tool boxes as well, it's just another way for companies to reduce the appeal of tool theft.

HIGH-TECH SOLUTIONS

Technology has greatly improved tool control to the point where a supervisor, miles from a jobsite, can track which tools are being used, and who is using them. For many tool boxes, keys are becoming a thing of the past. Tool boxes today can be accessed by someone using a badge with a bar code. Not only can a box be set up to allow specific people to access it, but there is now an electronic paper trail of a date stamp of when the box was accessed. This way, any lost or missing tools can be traced back to the person that last accessed them. Using an electronic badge to access tools does cut down on tool theft as boxes are more secure; only those persons authorized to use the box have access to it.

Beyond bar-code entry, software is now available to fully track which tools have been removed and returned to a box using a scanner. Here's how it works: Once a person scans their credentials to gain access to the box, any tools removed are scanned by a handheld device that captures pertinent information about that tool. For instances where multiple people are accessing the same box, any tools removed are tagged to that specific individual. Tools and equipment can be marked for single use or in quantity.

For example, if a kit has been developed containing 20 tools, it can be scanned as one item to save time. All returning tools are scanned to ensure full accountability.

The latest adaptation of this type of technology is the use of digital imaging to track and monitor tools. Digital imaging removes the need to manually scan tools as cameras mounted inside the tool box scans the drawers each time the box is accessed, recording the removal and return of tools. Additionally, software keeps track of information and can transmit data via wireless or a cable Ethernet connection to a computer for further accountability.

These tool boxes, which can hold up to 750 tools, come equipped with an LCD monitor attached to the top to give technicians a visual view of the tool activity he is using from the box. Each time a drawer is open and tools are removed, the system scans the drawer and documents which tools have been removed. The box is also voice activated and announces which tools have been removed. When tools are returned, the system scans the opened drawer again and checks off which ones have been returned and both visually and audibly alerts the technician on the status of each tool. If a tool has been placed in the wrong foam cutout in the drawer, the voice alerts the technician to the discrepancy.

The system, along with its tracking software, can also monitor calibration cycles of tools such as torque wrenches. Another benefit of this type of box is that it reduces the need for tool crib attendants during late-night shifts when maintenance needs to be performed but an attendant may not be available. Essentially the box acts as its own tool crib as multiple users can be set up to access the box with each user's actions being tracked.

These more high-tech technologies are useful in those industries such as wind, natural resources, and aerospace where tool control is a prime concern. Leaving a tool behind in a wind tower could pose a threat to the operation of the tur-

Fig. 4: Tough tool kits from Snap-on stand up to any environment.

Fig. 5: Arriving onsite, mobile tool boxes help keep tools orderly and handy.

bine, not to mention the time wasted to go and recover the missing tool. Monitoring tools saves money and improves efficiencies.

MOBILE TOOL CRIB

For some applications in the wind industry where it may be more advantageous to bring the crib and its tool control directly to the jobsite, a mobile tool crib may be the answer. A mobile tool crib can be preloaded with thousands of tools and shipped directly to a remote job site and be fully operational in just a few days. When the job is finished, the crib can be loaded onto a tractor trailer and moved to the next site. This cost-saving move reduces tool costs by bringing the tools to the workers when needed.

Mobile tool cribs, which can be staffed with an attendant from a tool manufacturer, offers the same level of tool control and accountability as the technology found in individual boxes. These cribs are designed to be quickly deployed to remote locations and put tools into the hands of workers on a jobsite, yet at the same time using tool control technology to eliminate lost tools and save money.

When a new mobile tool crib is set up on a jobsite, the first thing the attendant accomplishes is entering each worker into the tool tracking software and assigning each of them a bar code. A quick scan of the employee's barcode, followed by a scan of the tool accurately tracks the equipment that has left the crib and who's responsible for it. This setup can be done by a designated employee, or some suppliers will even provide a trained tool crib attendant to manage the mobile tool crib onsite. Modular in design, mobile tool cribs range between 20 and 40 feet in length, include storage and control systems, cabinets, and shelving, plus electrical components that include lighting, air conditioning, and electronic entry systems. A mobile tool crib isn't the answer for every application, but for those companies operating multiple jobsites it can become an efficient, cost-saving tactic to supplying and tracking tools for workers.

As systems and components become more complex, tooling will need to keep pace by providing the right solutions for technicians to get the job done correctly. That's why it's becoming more important to control those tools and keep them on the jobsite ready for use. There are several ways companies can go about implementing a tool control program. Consulting with a tool manufacturer to review your application, needs, and expectations is the best way to proceed in obtaining a tool control program that will provide the best return on your investment.

AWEA WINDPOWER CONFERENCE & EXHIBITION 2012
Atlanta, GA June 3–6

SUNDAY, JUNE 3

INDUSTRY ESSENTIALS PROGRAMS

MONDAY, JUNE 4

8:30 am – 10:00 am	**WINDPOWER 2012 – Welcome and Opening Session** (Open to all attendees)				
	Market Updates Track	**Project Development Track**	**Transmission Track**	**Resource Assessment Track**	**Community & Distributed Wind Track**
10:30 am – 12:00 pm	Post 2012 Wind Market Assessment: Supply, Demand & Cost	Development in a Seasoned Market: Where Do We Go From Here?	Opening Scientific Session: The Science of the Wind Industry	Critical Topics Currently Influencing Resource Assessment	Community Wind: A Diversified and Promising Sector
1:30 pm – 3:00 pm	Road Map to Wind Development in the Southeast	POWER SESSION: International Wind Energy Update	Operation Transmission: Plugging Wind into America	Modeling and Measurement – Current Advances in the State-Of-The-Art (Scientific)	Economic Value of Distributed Wind
3:30 pm – 5:00 pm	Decisive Policy: Expanding the U.S. Wind Energy Industry	International Markets for Wind Power – Growth and Expansion	Technical Challenges for Wind Plant Interconnections	Prepare for the Best: Resource Assessment at 100 GW	Real World Impacts of Distributed Wind

TUESDAY, JUNE 5

8:30 am – 10:00 am	**General Session** (Open to all attendees)				
	Finance Track	**Siting Track**	**Utility Track**	**Supply Chain Track**	**Turbine Design Track**
10:30 am – 12:00 pm	State and Regional Policy Demand Drivers for Wind	Siting Impact Assessments: Addressing Pre- and Post-Construction Due Diligence	Critical Wind Power Topics for Electric Utilities	On Land and In the Water – What Does the Future Hold for Construction, Transportation and Logistics	Wind Turbine Gear Design
1:30 pm – 3:00 pm	Project Finance Market Update and Outlook	Eagles and Bats: The Intersection of Policy and Science	Long-Term Wind Power Contracts and State Policies	Wind Turbine Supply Chain Opportunities and Challenges	Full-Scale Wind Turbine Testing and Validation
3:30 pm – 5:00 pm	How to Finance Projects in Development	Community Toolbox: Overcome Wind Energy Opposition at the Community Level	Utility Strategies for Wind Power – Case Studies	The Role of Wind Power in Economic Development and Jobs Creation	Wind Turbine Blade Structural Design, Analysis, and Manufacturing (Scientific)

WEDNESDAY, JUNE 6

	Offshore Track	**Wind Deployment Track**	**Integration Track**	**Turbine Performance Track**	**Turbine Track**
8:30 am – 10:00 am	Offshore Wind: Can We Create a Viable Market in the U.S.?	How Does your EHS Program Measure Up?	Investigating Advanced Wind Forecasting Techniques (Scientific)	Power Performance-Observations from the Field	Large Wind Turbine Manufacturer Forum Part 1
10:30 am – 12:00 pm	Integrated Risks for Offshore Wind: A Broad-Based Research Perspective	Laying the Foundation for a Strong Workforce	Grid Integration of Wind: Solving the Technical and Economic Challenges	Performance and Reliability (Scientific)	Large Wind Turbine Manufacturer Forum Part 2
1:30 pm – 3:00 pm	Innovative Research in Offshore Wind Technologies (Scientific)	Emerging Applications and Issues for Wind Power	Expanding the Science behind Wind Integration Analysis (Scientific)	Turbine Reliability - Lessons from the Real World	Drivetrain Technology Options

Program subject to change without notice.

ADINDEX

Kevin Coplan
president /North America, Capital Safety

CONGRATULATIONS ON YOUR PROMOTION. TELL US ABOUT YOUR BACKGROUND WITH THE COMPANY.

Thank you, this is a very exciting point in my career with the company. I started working at Capital Safety when I was 19 years old, and over the years I've worked my way up through a wide variety of positions, with many of them focused on sales. I was named vice president of sales in 2006, and then in January of this year I was promoted to the position of president of the North American region. So I've amassed a great deal of institutional knowledge over the past 26 years, and I'm honored to have the opportunity to apply that experience to the continued success and growth of the geographic areas I'm responsible for.

I CAN'T IMAGINE A BETTER WAY OF PREPARING YOURSELF FOR THIS POSITION THAN THE PROCESS YOU'VE DESCRIBED.

You're right, it's been great to have the opportunity to gain so much in-depth, hands-on experience over the years, and that's something we really value here at Capital Safety. We have a Sales Trainee Program, in fact, where we bring someone in who's either early in their sales career of just out of college, and they spend anywhere from three to six months working in every functional area of our business. We make this investment in our employees because once they're actually representing the company to our customers we want to make sure they've built the products, as well as inspected, tested, and even packaged them for shipping. We've had a lot of success with this program since it was launched about six years ago, and we've been very pleased with the members of the armed forces who've joined us and gone through this training program as well.

TELL US A LITTLE ABOUT THE COMPANY'S GLOBAL FOOTPRINT AND MARKET INVOLVEMENT.

Capital Safety truly is a global company, with more than 20 dedicated locations around the world throughout North and South America, Europe, Slovakia, Australia, and Singapore. We employ approximately 1,200 people, and we have about 7,000 distributors worldwide. Construction is probably the largest market we serve, in addition to oil and gas, transportation, utilities, telecommunications, mining, and wind energy, of course.

WHEN DID CAPITAL SAFETY GET INVOLVED IN THE WIND ENERGY INDUSTRY?

As manufacturer of the Lad-Saf system, which was designed to fit on a fixed ladder to provide continuous fall protection for climbers, Capital Safety naturally became involved in the North American wind industry quite early, basically when the first turbines were being erected in California. The product found its way into job specifications, and it really became the norm on the jobsite. As the wind industry really began to expand in the mid 2000s, that's when we began developing more-specialized products for wind technicians and other workers. We realized they needed harnesses and fall-protection devices that could withstand tough environments and still allow for movement in tight spaces. Working with OEMs around the world—and with the guidance of Oliver Hirschfelder, our global wind energy director—we now have a line of wind-specific products under the DB-SALA and Protecta brands. They include the Lad-Saf powered and manual climb assist devices, the FORCE2 Shockwave wind energy lanyard, and the ExoFit line of climbing harnesses, among many other devices and accessories. We also offer training on all of these devices, which we'll either conduct onsite or at our training centers in Canada, Mexico, or one of our two U.S. locations in Texas and Minnesota. Not only do we train on the equipment, we also address things like rescue techniques in case has fallen or become ill on the job. We're lucky to be located here in Minnesota, which is a great wind market and gives us access to technicians who are in the field every day. That helps us with new product development, as do our activities overseas, where we have experience with devices used in offshore applications, which is just now gaining traction here in the United States. So we are committed to the wind energy industry, and we're here to help make sure it grows and evolves in a safe and productive way.

Call (800) 328-6146, e-mail solutions@capitalsafety.com, or go online to www.capitalsafety.com.