MARCH 2012

WIND SYSTEMS

FEATURES

DEPARTMENTS

FEATURES

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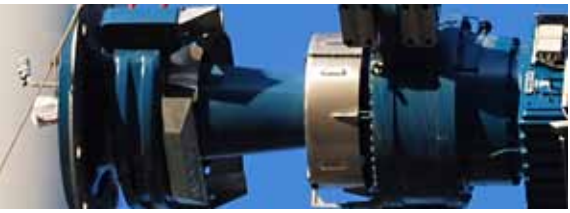

DEPARTMENTS

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EDLETTER

Not long ago I had a conversation with Mark Tomlinson, executive director and CEO of the Society of Manufacturing Engineers (SME). We discussed the importance of industry and academia working together to recruit and educate the employees of the future. You'll read about a perfect example of this type of collaboration in our profile of the Ecotech Institute in this month's issue. Established in 2010, Ecotech is the only entity of its kind, developed specifically to train students wishing to enter the renewable energy market. In addition to its Wind Energy Technology track—a two-year program resulting in an associate's degree—there are eight others in areas such as solar energy and electrical engineering. Curriculum development was guided by the institute's advisory board, representing companies such as Pacific Gas & Electric Co., DeWind, and others. Ecotech is actively marketing these programs, and I would encourage you to do what you can to support these and other efforts aimed toward generating interest in renewable energy as a career. The more we can do to bring wind energy into the mainstream, the more quickly we'll be able to gain greater traction throughout North America.

Just as the Obama Administration announces the opening of new sites for offshore development along the coast of New England, we're pleased to offer "Geotechnical Studies for Offshore Applications" by Robert Mecarini of Alpine Ocean Seismic Survey and Andy Barwise of Gardline Geosciences. Florian Sayer of Fraunhofer IWES Bremerhaven and Felix Kleiner of Henkel AG & Co. teamed up to write "Rotor Blade Reliability," and Gary Meyers and Todd Miller of Seco Tools describe methods for "Decreasing Turbine Weight." Eric Bechhoefer of NRG Systems endorses condition monitoring in "Predicting Gearbox Health," and Greg Knitz of Alignment Supplies provides "A Guide to Wind Turbine Alignment."

I'd like to welcome Matthew A. Lackner, Ph.D., and his colleagues at the University of Massachusetts Amherst (UMASS) Wind Energy Center as our new technology columnists, beginning with a discussion of offshore floating wind turbines, and Chris Martin of Crane Service, Inc., covers wind farm rigging techniques in his construction column. Merritt Brown of Rev1 Renewables concludes a two-part series on safety in his maintenance column, and Mike Graska of the Professional Logistics Group explains why indecision is the enemy of efficiency in his logistics column. Kat McQuade—the new marketing manager at NRG Systems—is our Q&A subject, and you're sure to enjoy her refreshing perspective on a healthy work/life balance.

In closing I would like to thank DMG/Mori Seiki for inviting me to attend their recent Open House at the Deckel Maho facility in Pfronten, Germany. I look forward to sharing news of their exciting new technologies, processes, and machines in upcoming issues of the magazine. All best!

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HEAVY-DUTY HMC FOR MEGA-SIZE PARTS FROM MAG

MAG's modular HMC 1250/1600 Series is engineered for high-precision, high-productivity machining of large aerospace, power generation, pump, valve, and off-road equipment parts. It now includes eight spindle options to suit special-purpose or general machining requirements. The new 6000 and 8000 rpm/46-kW (61.6-hp) tilt-spindles—with +90/-120 degree A-axis travel—joins an all-around 10,000 rpm/ 46-kW (62-hp) spindle, high-speed 24,000 rpm spindle, high-torque 2600 Nm/80-kW (1918 ft lb) spindle and two live spindles (110 or 130 mm diameter). The high-torque spindle is especially suited for hard-metal cutting, while the live spindles extend W-axis reach by up to 800 mm (31.5 in), enabling deep cavity milling to high precision with shorter, more rigid tools. Standard on the live spindle, MAG's exclusive Z-axis thermal compensation software dynamically offsets spindle growth to maintain tight tolerances.

Designed for extreme application flexibility, the HMC 1250/1600 offers maximum 3000 mm (118 in) work-zone swing, and 15,000 kg (33,000 lb) pallet load capacity. Major machine components, including the X-bed, Z-bed and column, are cast ductile iron, with pallets up to 1600 x 2000 mm, headstock and rotary table housings of gray cast iron. Modular design provides a range of machine travels, 60- to 300-tool magazines and two control choices.

Powerful and agile, the new five-axis HMC offers 56 to 100 kW (75 to 133 hp) spindle power, 35 kN (7870 lb) Z-axis thrust, and super-rigid, full-contouring hydrostatic rotary table. The 360,000-position contouring table provides a rigid work platform, while a rugged worm gear drive with clamp securely holds axis position. Rotary table positioning accuracy is 10 arc seconds, repeatable to 5 arc seconds. Positioning accuracy of the tilt-spindle is 4 arc seconds, repeatable to 2 arc seconds.

Meeting industry needs for tighter part tolerances and greater machining accuracies, the HMC Series comes standard with linear scale feedback in X, Y, and Z axes, providing 8 micron (0.0003 in) positioning accuracy and 5 micron (0.0002 in) repeatability. Heavy-duty hardened and ground roller guide ways enable a rapid traverse rate of up to 40 m/min (1575 ipm) with high acc/dec rates, double the load capacity and nearly 10 times the wear life of ball-type ways. The full work zone enclosure is pre-engineered to provide a clean machining environment and includes a doorway for operator access with walkway/platform inside. Learn more by visiting MAG at WESTEC booth #1612 March 27-29 at the Las Angeles Convention Center or going online to www.mag-ias.com.

NEW ONLINE SHIPPING TOOLS FROM BNSF

BNSF Railway has released two new online tools that offer an easier, more effective way for existing and potential customers to compare carload shipping options. The new tools—Carload Shipping Advisor and Serving Carrier Reciprocal Switch Inquiry—allow customers to compare shipping options by price, equipment, and route for multiple origins and destinations.

"All of the features in the Carload Shipping Advisor

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

tool are based on direct customer feedback and designed to meet customer needs," says John Lanigan, BNSF executive vice president and chief marketing officer. "We are confident that providing this upfront visibility to all routing options will save our carload customers time and allow them to more easily plan their shipments."

"Whether planning or pricing their shipment moves, our customers told us that determining if a destination is rail-served is their first step," according to Jo-ann Olsovsky, vice president technology services and CIO. "The new Carload Shipping Advisor and Reciprocal Switch Inquiry allow customers to quickly take that first step by easily verifying whether a shipping origination or destination has rail or transload service."

The new Carload Shipping Advisor tool offers search filters by equipment type or route, and guides to equipment information, including pictures and schematics, to help customers understand the loading requirements and better plan their moves. It also includes features such as the ability to view recent searches, see estimated fuel surcharge, use a type-ahead input form, print/export/email search results, contact a sales representative, and view links to pricing documents.

When planning a shipment, the Reciprocal Switch Inquiry tool now allows customers to validate origins or destinations when not pricing the move. Using a railroad industry-wide file through Railinc, the new tool will now contain all rail-served customer locations in North America. This provides customers with comprehensive visibility to their options. Both of these tools can be accessed under "Customer Tools" on the bnsf.com Customer page at www.bnsf.com/customers. A demo of the tools capabilities can be viewed at www.bnsf.com/customers/demos/carloadshipping-scrsinquiry.html.

BNSF Railway is one of North America's leading freight transportation companies operating on 32,000 route miles of track in 28 states and two Canadian provinces. BNSF and its employees have developed one of the most technologically advanced and efficient railroads in the industry. Learn more at www.bnsf.com.

WIND FARM SUPPORT VESSELS FROM AUSTAL A SUCCESS

Building on its initial success in the renewable energy market, Austal has confirmed a contract for a fourth wind farm support vessel for Turbine Transfers Limited. The order is the first for a new Austal design that will enable safer and more efficient offshore wind turbine service. Welcoming the follow-up order from the UK-based company, Austal Chief Executive Officer Andrew Bellamy says the shipbuilder had continued to refine and enhance its Wind Express vessel range following its launch in mid 2010 as part of a strategy to pursue new commercial vessel markets. "There is clearly an increasing desire in the industry for vessels with enhanced capability, particularly in terms of performance in rough conditions.

This is a challenge that we have already successfully addressed in the ferry and naval markets with our unique trimaran technology. We have now applied that expertise to develop and prove a new hullform that provides a step change in capability for the offshore industry."

The new design combines the seakeeping and fuel efficiency benefits of Austal's trimaran hull configuration with a small waterplane area at rest, to deliver low vessel motions both in transit and when alongside turbines. This enables wind farm personnel to be successfully transferred in considerably higher sea states than is practical with catamarans of similar size. "For offshore wind farm industry operators seeking to maximise productivity and safety in rough seas, this new hullform provides the highest possible levels of seakeeping, passenger comfort and fuel efficiency," Bellamy says.

Managing Director of Turbine Transfers, Captain Mark Meade, said his company was using Austal technology to support the next phase of wind farm development which would see a much larger number of turbines installed farther offshore and in other areas with rougher sea conditions. "To do that we need to be able to transfer further, and in larger waves, while still providing the technicians we carry with comfortable transits and safe turbine step-offs. The extensive analysis and tank testing that Austal has done makes me very confident that this new boat will enable us to do that, and provide us with a competitive advantage."

Bellamy says the new design would improve the viability of offshore wind farms by overcoming the seakeeping limitations of the support vessels currently used in the industry. "To date most wind farms have been relatively close to the coast, and serviceable with fairly basic boats. Now as they move further offshore there is a need for a second generation of vessels that can address the significant challenges this brings. Being able to transport wind turbine technicians comfortably in the rougher sea conditions over longer distances is the key requirement, and we have produced the solution to that need." Learn more at www.austal.com.

SAPA EXTRUSIONS BRINGS "ALUMINOLOGY" TO LIGHT

Sapa Extrusions North America announces the launch of a new marketing campaign to showcase the advanced technical expertise, unprecedented resources, and customer-focused solutions that have made Sapa the world's largest aluminum

extruder. Coining the term Aluminology℠, which is the culmination of these attributes and knowledge, Sapa's new campaign focuses on defining the innovative best practices that have become synonymous with the industry leader.

Along with a new ad campaign, Sapa is soon going live with a promotional Web site that illustrates the broad spectrum of services and capabilities behind Aluminology. The site will expand on Sapa's many capabilities, including design, extrusions, fabrication, finishing, and logistics to highlight the company's technological solutions and customer focus.

"Aluminology exemplifies the very essence of the technology behind our products and of our culture," says Patrick Lawlor, president of Sapa Profiles North America. "We take pride in pushing ourselves and others in the industry to find answers to today's toughest design challenges with the production and use of aluminum. With this new campaign, our goal is to solidify Sapa's role as a leader and innovator in the global aluminum industry."

Sapa's innovative design solutions are improving products for applications that include distribution, automotive, building and construction, commercial and mass transportation (recreational vehicles), defense, electrical, industrial and consumer durables, and renewable energy. As part of the Aluminology campaign, Sapa will announce several new developments in the coming months that demonstrate its technological superiority and advanced capabilities. New applications for key markets and enhanced product performance will be featured.

Sapa Extrusions North America consists of 16 aluminum extrusion plants throughout the U.S. and Canada, boasting the continent's largest plant at its Cressona facility in Pennsylvania. At the forefront of Sapa's cutting-edge product development is its North American Technical Center, housed at the plant in Portland, Oregon. The Technical Center conducts the Sapa Profile Academy, an advanced three-day certification training course that demonstrates opportunities with aluminum to raise skill levels and encourage competition among companies anddesigners.Moreinformationis availableatwww.sapagroup.com.

WIND ENERGY PLAYS INCREASING ROLE IN MEETING ONTARIO POWER DEMAND

Wind energy is playing an increasingly important role in meeting Ontario's demand for electricity, according to the Independent Electricity System Operator's annual release of supply, demand, and price data. Total wind energy production rang in at 3.9 terawatt hours TWh—up substantially from 2.8 TWh in 2010. November 2011 marked the highest monthly wind output ever seen in Ontario, with production in that month alone exceeding 0.56 TWh. In annual terms, wind generation represented 2.6 per cent of total output across all fuel types of 149.9 TWh.

A record level of new wind energy projects were commissioned in both Canada and Ontario in 2011. In 2011 new wind energy projects were built and commissioned in British Columbia, Alberta, Saskatchewan, Manitoba, Ontario, Quebec, New Brunswick, and Nova Scotia. More than 5,000 MW of wind energy projects are already contracted to be built over the next five years.

"Wind energy is proving itself a key partner as Ontario builds a stronger, cleaner, and affordable electricity system. Increased growth of wind energy in Ontario means cleaner air, new jobs and local investments for the communities that host wind energy projects," says Robert Hornung, president of the Canadian Wind Energy Association (CanWEA). "Maintaining Ontario's leadership position will require continued commitments to aggressive targets for wind energy

development and a stable policy framework."

In 2011, the wind energy industry in Canada represented more than $3 billion in new investments that have created 17,000 person years of employment. Canada is now ranked ninth globally in terms of total installed wind energy capacity.

CanWEA is the voice of Canada's wind energy industry, actively promoting the responsible and sustainable growth of wind energy on behalf of its more than 440 members. A national non-profit association, CanWEA serves as Canada's leading source of credible information about wind energy and its social, economic and environmental benefits. To join other global leaders in the wind energy industry, CanWEA believes Canada can and must reach its target of producing 20 per cent or more of the country's electricity from wind by 2025. The document Wind Vision 2025–Powering Canada's Future is available at www.canwea.ca.

EWEA 2012 ANNUAL EVENT

Focusing on innovation—the major driver of the wind energy industry—tracks will cover six topics from policies and markets to financing grids and science. Bringing together the brightest minds in the industry to exchange the latest knowledge, forge meaningful business relationships and create connections with influential people around the world. The EWEA 2012 Annual Event will build on the huge success of the 2011 edition, which attracted a record-breaking 9,000+ participants, coming from a total of 84 countries. Don't miss the opportunity to:

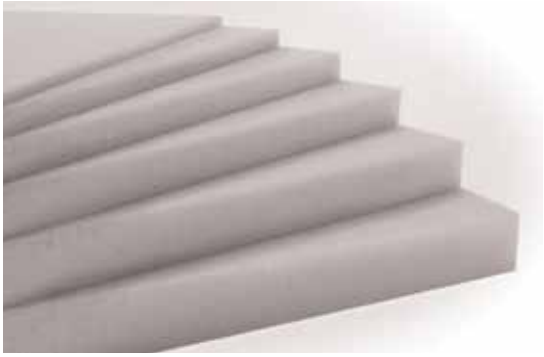
- Discover the latest industry best practices;
- Learn about the latest innovations in over 40 conference sessions;
- Create new business opportunities with global contacts in a flourishing market;
- Network with international leaders shaping tomorrow's energy market;

With over 40 informative sessions, a host of expert industry speakers, lively debates, and new interactive format allowing you to have your say and influence the agenda, the conference will provide you with the latest information and ideas.

With 12,000m^2 of total exhibition space and over 450 exhibiting companies expected, this exhibition is set to be bigger and busier than ever before. Organized by the industry for the industry it is a unique gathering of the industry's top companies, representing the entire supply chain. EWEA 2012 Annual Event is gearing up to be a stimulating arena for dynamic networking and achieving great business performance. see the program online and register at www.ewea.org/annual2012/.

GURIT LAUNCHES NEW G-PET PRODUCT RANGE

Gurit has launched a new range of G-PET structural foam. The new G-PET products are targeting mainly the global



wind turbine blade manufacturing and marine markets. The new range offers a unique combination of properties, including class-leading shear elongation, finer cell size, excellent chemical resistance, and good adhesion, as well as high process temperature resistance. The new G-PET range is available in four new densities—80, 90, 110 and 135 kg/m3—with other densities possible upon request.

G-PET recyclable structural foam is a highly adaptable, thermoplastic foam offering a good balance of mechanical properties, temperature resistance, density and cost. The materials can be used for a wide range of applications and production processes. The new G-PET range comes with varying finishing styles including the following formats and combinations thereof: plain, pin hole, contour scrim, double cut, and vacuum infusion core. Knife cuts are available to minimize resin uptake during infusion. The product is available in standard sheets and tailored kits.

"We are pleased to offer our customers a portfolio of densities for G-PET with best-in-class toughness, a key property for the marine market," says Sam Ang, Gurit's program manager for core materials. "The balance of good properties, temperature stability, and cost addresses the needs of the wind energy market and allows customers in other markets to apply G-PET in a wide array of applications".

In response to the demand for multiple core designs Gurit has extended its structural core product range. This material category now includes PVC, Balsa, and SAN as well as PET core types, all with a distinct range of properties, attributes, and all available in sheet form or as tailored pieces in kit format.

The companies of Gurit Holding AG, Wattwil/Switzerland, are specialized on the development and manufacture of high-end composite materials featuring bespoke physical and chemical characteristics. The comprehensive product range comprises fibre reinforced prepregs, structural foam, gel coats, adhesives, resins, and consumables, as well as certain finished parts, composite process equipment, and tooling. Gurit supplies growth markets in wind energy, tooling, transportation, and marine. The international group has production sites and offices in Switzerland, Germany, the UK, Canada, Spain, Australia, New Zealand, the Untied States, India, China, and Ecuador. Call +44 (0) 1983 828 320 or go online to www.gurit.com.

Chris Martin
Crane Service, Inc.

There is both science and math at the core of all rigging techniques. In this installment we discuss techniques used in wind park construction.

WIND PARK MAINTENANCE, as we learned last month, can be quite the rigging challenge. If we focus on the flip side of the coin, wind park construction, we will see that rigging challenges exist here as well. This month we will take a deeper look behind the scenes of rigging. We are going to learn about rigging concepts that must be taken into consideration for the lift to be safe. Fundamentally, most of the objects we hoist are the same. Their shape, weight, and rigging may change, but the load will always reside under the hook. To safely hoist wind park components, we must always be mindful of this. Each component has a different CG or hoisting requirement to ensure that the component will stay level. This can turn a relatively normal lift into a more-complex procedure. When we hoist a wind tower section, one manufacture requires our rigging to span the whole tower section while another allows the use of two cranes. Before we go deeper into those we need to learn a few rigging basics.

There is science and math at the core of all rigging techniques. It is crucial to learn and understand how sling loadings can drastically change with only a few alterations. Behind the scenes, we have load angle factors that we must consider when lifting wind turbine components. When your slings are perpendicular to a load you have a load angle multiplier (LAM) of 1. Your LAM is determined by the length of the sling divided by the vertical height it covers. Secondly, you multiply that by the weight of the load—we assume the weight is equally distributed between the amount of slings used. Example: if you have two cranes lifting a 50-ton wind tower section, then each of the two slings would have 25 tons of tension. As you decrease the angle of your slings—i.e. go below 90 degrees—your sling tensions increase. If we have the same 50-ton wind tower section and change the angle to 60 degrees, or a LAM of 1.155, the sling tensions increase to approximately 29 tons. Those four extra tons of sling tension on each side can crush, bend, or collapse a wind turbine section in seconds.

To overcome this we have two options, depending on the manufacture of the tower section. The first manufacture will require you to use two cranes in a tandem pick. This ensures that we have a LAM of 1 and cannot collapse the wind tower section. This can be accomplished with a pair of 60-ton cranes. The second manufacture will require us to use one crane. To avoid collapsing the wind tower section we have to use an 80-foot spreader bar to ensure we safely lift the tower section flat. The spreader bar ensures that rigging below the bar is perpendicular to the bar, meaning the odds of crushing the load or bending the load are non-existent. The downside to this is that, instead of two 60-ton cranes, we must use one 300-ton crane. The reason lies in the LAM. When we use multiple slings we always aim for the perfect -60, 60 ,60- triangle in our rigging. This is the safest and easiest way to ensure that our sling tensions are known. The best way to make sure you have a perfect triangle is to have your sling leg span the distance of the load. Herein lies why there is such a drastic change in crane sizes needed to hoist wind tower sections.

When we use one crane we need to have at minimum 80 feet of boom out—this is the length of the rigging and wind tower section. Typically, it will require around 150 feet of boom. When you add the manufacture's safety factor and the amount of boom required because of the rigging lengths, you are now using a 300-ton or better crane. Conversely, if the manufacture allows, we can use two cranes. As stated above, this requires a pair of 60-ton cranes or better.

Crane Service has been in the heavy hoisting and rigging industry for 52 years. We are blessed to have one of the best equipment managers in the business. Fred Hamby, has over 30 years of heavy rigging experience and has traveled the world teaching what he has learned in crane and rigging. Every piece of the hoisting puzzle is crucial, which is why we have a dedicated rigging team that thoroughly goes over our rigging.

Chris Martin is marketing coordinator at Crane Service, Inc. Learn more at www.craneserviceinc.com.

Merritt Brown
Rev1 Power Services, Inc.

With the increase in megawatt output, wind turbines and associated components pose maintenance challenges. Here is the second of a two-part series on the issue.

THIS MONTH WE CONTINUE OUR conversation about safe practices for wind technicians. Inarguably, one of the more demanding tasks of a wind technician is to enter a rotor hub and perform any form of maintenance in this small space. An entirely uncomfortable position for the human body, working in such an area where leverage angles are odd, and where lifting of heavy components presents such a challenging and often difficult day's work, it should be a highlighted area for owners and operators to emphasize improvement to maintenance practices. Some technicians I know will dread the thought of being assigned to a turbine that requires a replacement of the pitch linkage components, knowing there really is no better way to accomplish the task. Or, as other technicians may advise you, bring your Advil on the day you're tasked to replace an accumulator, pitch actuators, or a main pitch motor. These and many other physically demanding uptower tasks are prospects for a continuous improvement program that strives to reduce or eliminate injurious conditions. Some ideas can be borrowed from other industries. For example, heavy hand tool positioning inventions and manipulators are common in many other industries, yet these innovations have yet to be found mainstream in the wind industry, particularly when it comes to working with components or hand tools uptower. Such devices provide special lift assistance when working with heavy materials and can nearly eliminate the physical lifting requirements of the job.

Hand injuries, although often minor, are a leading reported injury from wind technicians. Cuts, bruises, strains, impact stress, pinching, and crushing are all among the penalties of wind turbine maintenance. They can also be avoided. Following a near miss incident at a well-identified and labeled turbine pinch point, I asked a team of technicians to tell me how many of them had experienced such a close call themselves. As they all raised their hands—albeit with all fingers attached—I had to wonder if we had done all we could to address the potential of injury at this point. In the hierarchy of processes for eliminating hazards, engineering a design that completely removes the hazard tops the list, followed by installing guards and safety devices that keep personnel away from the hazard, and finally instituting work processes, labeling, training, and wearing PPE to protect the individual. In the case of this labeled pinch point, the manufacturer has clearly transferred responsibility for safety to the technician who is now required to ensure that their working environment is safe by avoiding injuries due to hazards inherent in the design. Here, it was much more feasible from a manufacturing perspective to install a label than it was to redesign the component or install a guard so that persons working on this turbine would ever be subject to an injury. It results in a critical opportunity for wind project operators to fully assess each situation and understand the fallibility of warning labels. Starting with the assumption that the hazard is real, these labels offer absolutely zero protection from an injury unless a process has been put in place to actually avoid them.

The wind industry presents a unique maintenance environment with special tasks in tight spaces at high elevations. Injuries will affect the profitability of a project by contributing to a loss of wind farm productivity, increasing days away from work and resulting in the possible retraining and hiring of new employees. In laying the groundwork for improving safety on the wind project, owners and operators should listen to those who work on the turbines every day. It is the technician who must don fall protection gear, climb out into the hub, move heavy components in tight areas, and work around electrical and mechanical equipment who is able to most accurately describe the existing work conditions on the turbine. Recording videos of these work processes is a simple idea that will help to identify areas for improvement, provide excellent material for safety training sessions, and also serve as instructional tools for new employees. The technician's actions can be objectively observed and evaluated before and after a corrective process is implemented, and critical feedback can be gathered on which to build an improvement process.

If we look to make safety and health the top priority, then we should start by identifying and correcting current processes that contribute to fatigue and injuries, including redesign options if feasible. In aiming to improve the overall health and safety of our workforce, we should also embrace innovation and develop the best practices that help reduce the exposure to injurious conditions.

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

Offshore floating wind turbines offer a compelling means of harnessing the massive resources available in deeper waters, but you must understand the physics that underlie their behavior.

MOST UTILITY-SCALE WIND TURBINES look the same: three blades, tapering in spanwise chord and twist from root to tip, rotor located upwind relative to the nacelle. This apparent convergence of designed form implies a thorough understanding of the aerodynamically-derived forces acting on a wind turbine. In reality, wind turbine aerodynamics are exceptionally complex. These complexities are further compounded when wind turbines are placed offshore as part of an integrated floating system.

The long-term survivability of floating platforms has been demonstrated by their continued use in the oil and gas industries. Drawing from this precedent, the three dominant offshore floating wind turbine concepts to arise out of the wind industry are the spar-buoy, the tension leg platform (TLP), and the barge. Each platform type possesses inherent positive and negative attributes that play a significant role in floating wind turbine design and siting.

Despite the significant potential benefits of offshore floating wind turbines (OFWTs)—access to better wind resource and increased placement flexibility—there remain significant engineering challenges. Of particular interest is the impact of platform motions on rotor aerodynamics. Some critical questions that must be answered include: What do the additional dynamics of these systems, and the resulting changes in the flow velocity seen by the rotor, mean from an aerodynamic perspective? How will wind turbine performance differ compared to a conventional offshore turbine of similar size? Will platform-motion-induced loading require changes in blade and rotor design? University of Massachusetts researchers at the Wind Energy Center have set out to investigate the aerodynamics of offshore floating wind turbines and answer these important questions.

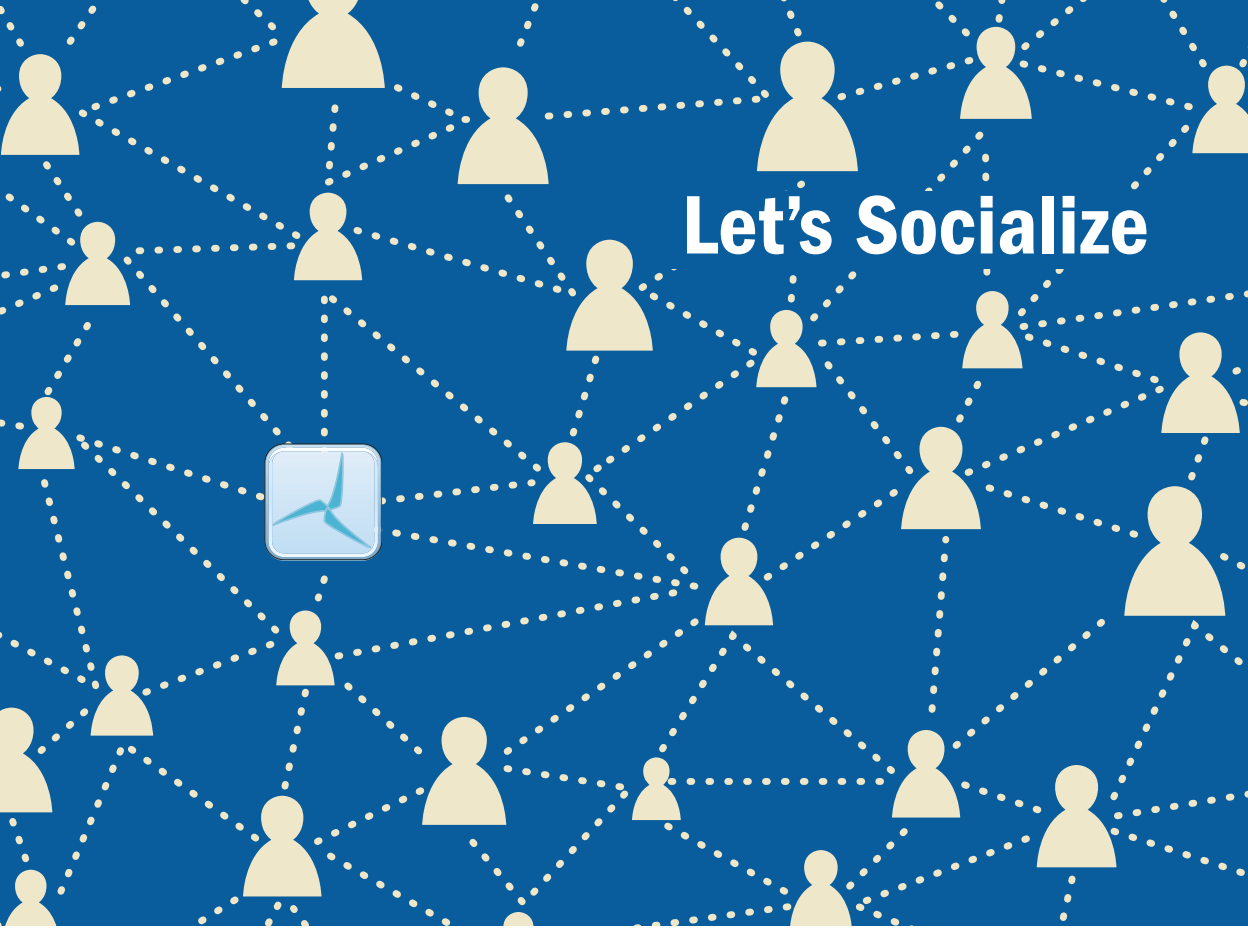
Thomas Sebastian—whose doctoral thesis spurred this work—and I characterized the unique operating conditions that make aerodynamic analysis of OFWTs a challenge via reduced frequency analysis of the NREL 5MW turbine. Platform modes and turbine operating conditions that may result in unsteady flow were identified via a series of aero-elastic simulations and reduced frequency analysis. Additionally, operating conditions that may result in a breakdown of the momentum balance equations were identified for the various platform configurations. This study demonstrated that OFWTs are subjected to significant aerodynamic unsteadiness compared to fixed-bottom offshore turbines, and indicated a need for higher-fidelity aerodynamic analysis approaches.

Momentum balance approaches are conceptually simple, but rely on a number of ad hoc, empirically-derived corrections. Recognizing that the external flow of a wind turbine is nominally inviscid, incompressible, and irrotational permits the use of potential flow methods. These assumptions are global, physically consistent descriptions of the flow rather than experimentally limited extrapolations. Time-marching free vortex wake methods (FVMs), a subset of potential flow, numerically advect the wake lattice, which is composed of Lagrangian markers connected by vortex filaments. This approach has been used for a number of decades, in particular in rotorcraft aerodynamic analysis. Recognizing this, Sebastian and Lackner developed the Wake Induced Dynamics Simulator (WInDS) code, a lifting-line theory (LLT) based FVM developed for OFWTs and validated via comparison to analytical models and experimental data.

WInDS simulations of OFWTs were conducted, using observations from the earlier reduced frequency study to determine which platform modes and operating conditions warranted a closer look. Wake evolution as well as wake-induced loading on the rotor was studied and clearly demonstrated the effect of the platform motions on the wake, which in turn had a significant impact on rotor loading as far as four rotor diameters downstream. Transitions between windmill and quasi-propeller states were also observed. Comparisons to unsteady momentum balance methods indicated that the time lag associated with these approaches is artificially short and that these simple methods may be insufficient for OFWT simulations.

In conclusion, OFWTs offer a compelling technology solution to exploit the massive wind resource available in deeper waters. But to have confidence in the ability of OFWTs to operate reliably and efficiently, it is extremely important to understand the physics that underlie their behavior. In particular, the aerodynamic behavior of these systems is complex, and differs in several important ways from the more easily modeled behavior of fixed bottom and land-based wind turbines. The analysis performed by Sebastian and Lackner quantified how OFWTs aerodynamically differ from fixed bottom turbines, and utilized FVM simulations—of higher fidelity than traditional momentum balance approaches—to investigate the aerodynamic performance of floating wind turbines. The results indicated unique aspects of OFWTs aerodynamics, and future opportunities for improvements in the design and modeling of OFWTs.

Matthew A. Lackner, Ph.D., is an assistant professor of mechanical and industrial engineering at the University of Massachusetts Amherst and a member of its Wind Energy Center. He can be reached at (413) 545-4713 or lackner@ecs.umass.edu. Also visit www.umass.edu/windenergy.



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WIND SYSTEMS

Michael Graska
Professional Logistics Group, Inc.

Planning and preparation are critical to any successful project, but indecision is the enemy of efficiency. Timely decisions keep schedules on track.

THE CONTRACT IS FINALLY SIGNED, and everyone lets out a sigh of relief. Six months of hard negotiations hammered home an agreement. The only problem now is that we only have two months allotted time to start the project ramp up, when even in ideal situations it takes four months. Hey, we got the contract, we can do it! Even though the contract should have been signed three months ago. Sound familiar? For me it's an example of "been there, done that, and even got the t-shirt." I call this the neglected cost of indecision. Every plan, schedule, contract, and project is a decision. It happens on all sizes of projects during the planning and execution. Sometimes the cost is little, but oftentimes it is not. In the above case, the client paid a premium for acquiring materials.

First let me define what I mean by indecision. I am not advocating quick or ill-prepared decisions. My description of indecision is taking too much time in an effort to be too perfect when deciding something. Symptoms are paralysis through anaylsis, looking for every bit of data no matter how relevant, multiple layers of approval, and an over the fence approach method. Let me explain.

This is my favorite: paralysis through analysis. This phenomenon is often indicated by forming a committee to study the issue, or we need more data to absolutely make us comfortable with the decision. I cannot begin to relate how many times in my experience in supply chain management and logistics have I witnessed opportunities die because of this. One of my favorite sayings is "perfection is often the enemy of the good." Especially where good gains more than doing nothing.

Looking for more data can also lead to indecision. Now I am not saying that data and preparation are not important. This is often the key to the right decision. What I am saying is that having too much data, or not the right data, is as bad as not having enough. Searching and waiting for every piece of conceivable information often allows an opportunity to slip through your fingers. I experienced projects getting delayed or even canceled because of waiting on one last piece of information that really did not affect the project. My answer to this problem is "the right information, in the right amount, at the right time."

Can there be too many chefs in the kitchen, as the saying goes? Yes, in some cases. Having too many layers of approval can add time to making the decision; time that could cost money downstream. Drive down the decisions to the proper level. The VP of supply chain should not be making decision that a regional logistics manager should make. I would suggest centralized data and decentralize decision making.

And the last is the "over the fence" method of making a decision. This one is really prevalent in large organizations. It is when one department deals with an issue related to the ultimate decision and throws it over the fence to another department to deal with it, and so forth. By the way, this can also result in what I call "the ping pong affect," going back and forth. This decision making process can be viewed as a series of smaller decisions without regard to the overall decision. It is a suboptimization of the whole process. A far better way is collaboration between departments during the process. Have each interest participate together to provide relevant input. You'd be surprised how this can shorten the amount of time to make a plan, contract, or a project.

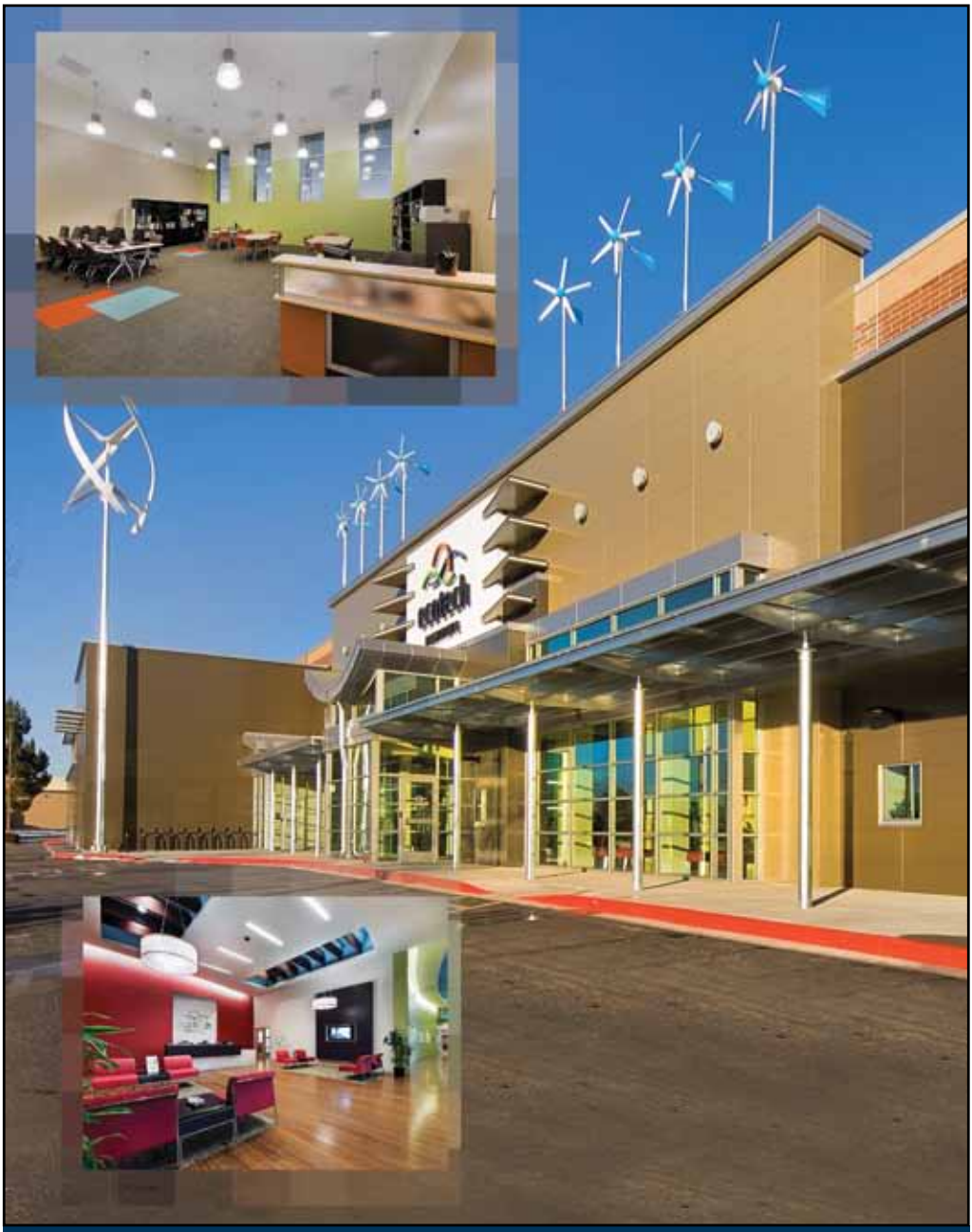
An example of the cost of indecision happened to me when dealing with a large Chinese transportation project a few years back. Our customer just could not decide on a start time for a project and kept refining their decision based on every bit of last minute data they could get their hands on. Opportunities for lowering their transportation cost kept passing them buy. At the last moment they decided to go with their earlier start date, which by the way was their original one. The consequences were much higher cargo rates due to not locking in vessel charters. The cost was so much higher that if they would have made an earlier decision, even with a later start date and storage of the cargo at project site, it would have been far less expensive.

I do believe in thorough planning and preparation. It is vital to a successful project. I subscribe to what I call "incremental justification." If 20 percent of my effort gets me 80 percent of the benefits, is it worth the other 80 percent to gain the last 20 percent? Get the right information, the right amount, and make the decision in a timely manner. That's how you leverage your opportunities. And by the way, I also subscribe to this saying, which is attributed to General Patton during World War II. To paraphrase: "Give me a less than perfect plan aggressively executed over the perfect plan that is poorly executed, and I will win every time."

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

ECOTECH INSTITUTE

By Russ Willcutt



With Wind Energy Technology among the eight academic tracks on offer, this entity is focused on training the renewable energy workforce of the future.

FOR "GREEN" COMPANIES and concerns, Colorado's embrace of renewable energy and sustainable practices provides fertile ground for growth. That was a primary factor behind the Education Corporation of America's decision to base its first Ecotech Institute in Aurora, which is within the Denver metro area, according to Michael Seifert, president. "We began operations in June of 2010 with 52 students, and we're now up to 462 and growing," he says. "We attribute that, in part, to being located in an area with such a passion for green growth and supporting the entrepreneurial spirit."

While many hail from the surrounding area, national marketing efforts have resulted in classes filled with students from California, Iowa, Tennessee, New Jersey, and other states. In addition to its Wind Energy Technology program—a two-year track resulting in an associate's degree for graduates—the institute also offers Electrical Engineering Technology, Environmental Paralegal, Renewable Energy Technology, Sustainable Interior Design, Energy Efficiency, Environmental Technology, and Solar Energy Technology.

"We sought employer input when we were developing the curriculum for all these programs, including Wind Energy Technology," Seifert says. "It was created to equip graduates with a solid foundation in the fundamentals of renewable energy with an emphasis on understanding the generation and transmission of energy using wind power. Our modern facilities and labs, alongside our small class sizes, really give students the opportunity to apply general theory in real-world applications."

Providing this input—both during curriculum development, and on an ongoing basis—as members of the institute's advisory board are: Abbas Ghassemi, Ph.D., professor of chemical engineering at New Mexico State University and executive director of the Institute of Electrical and Electronics Engineers (IEEE) and WERC: A Consortium for Environmental Education and Technology Development; Alden Zeitz, director of North American operations at the DeWind Co.; Colin M. Coyne, managing principal at the Coyne Group and LEED 2.0 accredited professional lecturer of sustainable enterprise at the Kellogg School of Management, Northwestern University; Craig Mataczynski, chief executive of Renewable Energy Systems Americas and chairman of Ecologic Analytics; Declan Flanagan, president and CEO of Lincoln Renewable Energy LLC; Ghazi Darkazalli, Ph.D., president and CEO of Marian Court College; Janelle Kellman, an attorney with the Pacific Gas and Electric Company; and Timothy Callahan, a partner at the Paul Hastings law firm.

"These individuals and others have gone out of their way to assist with our strategic planning and also to reach out to our students," Seifert says. "We've had panel discussions, for instance, where students were able to ask members of the advisory board questions about their industry, and also about the roles they'll be expected to play once they've completed the program."

Ecotech's career services department also plays a role in identifying internships and helping students develop the "soft skills" they'll need to land a job, including writing effective resumes and being prepared to impress during the interview process. Job leads occur as a result of the institute's close relationship with business both in Colorado and around the country, which also involves conversations about the exact skills that companies need potential employees to possess.

Naming benchmarks of which he is particularly proud, Seifert lists the fact that Ecotech Institute is nationally accredited by the Accrediting Council for Independent Colleges and Schools (ACICS), which is listed as a nationally recognized accrediting agency by the United States Department of Education and is recognized by the Council for Higher Education Accreditation (CHEA). He also mentions Ecotech's recent classification as a LEED (Leadership in Energy and Environmental Design) Gold Certified facility, which is a particular honor given the institute's mission. As a longtime expert in academic administration, however, an upcoming event tops Seifert's list of accomplishments.

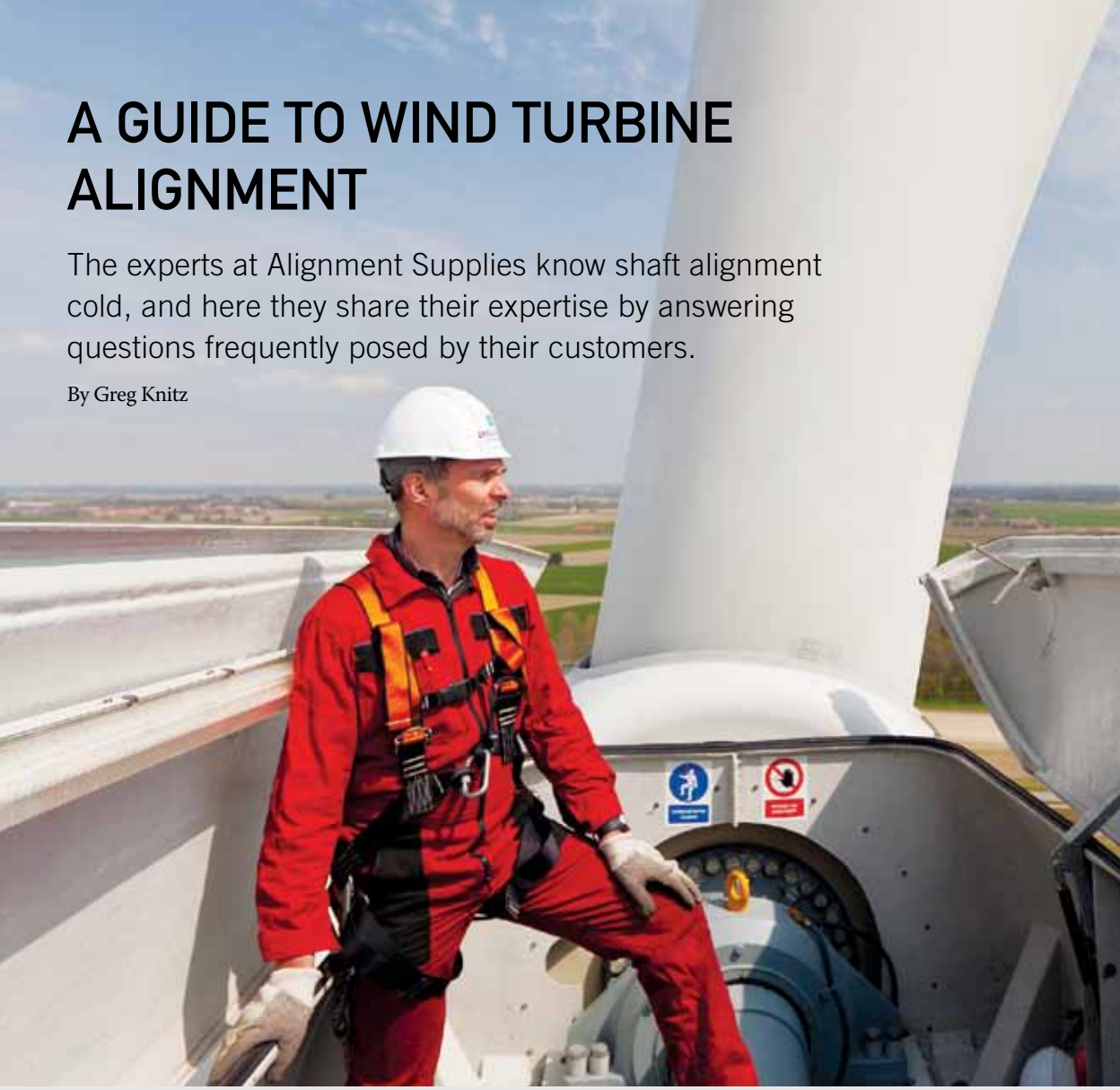
"We will graduate our first class in the Wind Energy Technology program this June," he says, "and that is the ultimate goal for any educator. I am very proud of what we've been able to achieve for our students so far, and I look forward to building our enrollment, programs, and reputation in the coming years. We want to partner with companies involved in all sectors of the renewable energy market, particularly wind, and I welcome queries from anyone who's interested in supporting our work."

Call (877) 326-5576 or go to www.ecotechinstitute.com.

A GUIDE TO WIND TURBINE ALIGNMENT

The experts at Alignment Supplies know shaft alignment cold, and here they share their expertise by answering questions frequently posed by their customers.

By Greg Knitz



Greg Knitz is president of Alignment Supplies, Inc. He can be reached at (419) 887-5890 or gknitz@alignmentsupplies.com. Go online to alignmentsupplies.com.

PRECISION ALIGNMENT IS THE PROCESS of making the two shafts co-linear under normal operating conditions. Properly aligned shafts are able to spin freely and not induce other unwanted forces to the system. These unwanted forces will damage and/or destroy bearings, seals, and couplings, and eventually the gearbox or generator. Precision alignment is recommended by most wind turbine manufacturers for optimal operation and reliability. Generator efficiency can also be affected by misalignment (angular and offset). The following questions—and answers—will help you to enhance the productivity and longevity of your turbine.

What needs to be aligned in a wind turbine?

The shafts of the gearbox and generator need to be aligned. The output bearing of the gearbox and the input bearing of the generator are most likely to suffer damage from misalignment.

When should I perform an alignment in a wind turbine?

An alignment should be performed upon commissioning. The nacelle has traveled a long way, probably by truck, so there is no guarantee that the factory alignment is still good. Anytime a gearbox or generator is replaced, an alignment should be

performed. Because of the movement of the tower and other dynamic forces, a best practice is to recheck the alignment six months after the initial install and a minimum of every year after. Consult your turbine's maintenance manual for recommendations.

What safety precautions are needed for wind turbine alignment?

Safety should be the very first consideration up tower. Check with the turbine manufacturer for specific safety requirements, but generally the brake should be engaged, dead bolts locked, blades pitched at 9:00, and the nacelle up against the wind. Alignment should not be tried in wind speeds ~over 8 m/s.

Does tower movement affect alignment measurements?

All movement can affect the laser measurements. Wind turbines present unique challenges because the gearbox and generator will not always move the same way at the same time. Use a laser measurement system that will allow you to increase the number of readings taken during the recording of each measurement. Five seconds per recording will provide more than enough data for accuracy.

I can only measure at the 6:00 position, not the 12:00 position—what now?

The 12:00 position can be replaced by the 6:00 position in the measurement process using a traditional 9:00-12:00-3:00 measurement method. When this is the case, the vertical movements will be accurate, but opposite (i.e. high will be low, and low will be high). Measuring units (laser/detector) that incorporate inclinometers will usually compensate for the different position automatically, providing accurate readings in the correct direction.

What are the main differences between the three measurement method and limited (40° or 60°) measurement?

Many laser systems employ inclinometers for limited turn or sweep measurement. The inclinometers tell the system where the measuring units are in space so it can make the correct calculations based on the measurement position. Inclinometers will be affected by any movement in the nacelle. This movement can be seen on screen and will affect the measurement. Measurement filters (see question two) will help compensate for this movement. The three measurement method is accomplished by making three static measurements at 9:00, 12:00, and 3:00 when viewing the generator from the rear. This procedure will turn off the inclinometers reducing the effect. The measuring units will still "see" any generator/gearbox movement, but the inclinometers won't add to the effect. The measurement filter can be used to minimize the effect.

Where should the measuring units be positioned during generator movement?

The most accurate readings when moving the generator will be achieved when the measuring units are in the same plane as the movement. When moving the gearbox horizontally, the measuring units should be in the 3:00 position. When moving vertically, the measuring units should be in the 12:00 position. If, for example, you are in the 2:00

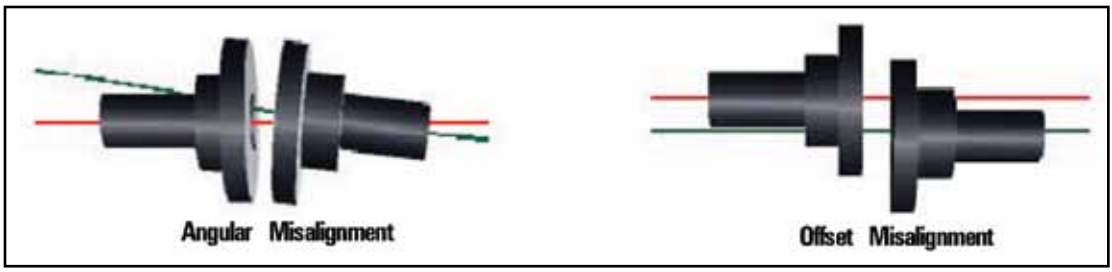


Fig. 1: Angular misalignment at left, and offset misalignment at right.

Offset	Excellent		Acceptable	
rpm	mils	mm	mils	mm
0000-1000	3,0	0,07	5,0	0,13
1000-2000	2,0	0,05	4,0	0,1
2000-3000	1,5	0,03	3,0	0,07
3000-4000	1,0	0,02	2,0	0,05
4000-5000	0,5	0,01	1,5	0,03
5000-6000	<0,5	<0,01	<1,5	<0,03
Angular error				
rpm	mils/"	mm/100	mils/"	mm/100
0000-1000	0,6	0,06	1	0,1
1000-2000	0,5	0,05	0,8	0,08
2000-3000	0,4	0,04	0,7	0,07
3000-4000	0,3	0,03	0,6	0,06
4000-5000	0,2	0,02	0,5	0,05
5000-6000	0,1	0,01	0,4	0,04

Fig. 2: Alignment tolerances.

position when moving horizontally, you will induce error into the readings and, thus, once you are within tolerance, you should re-measure and move again.

What if the brake is in the way at 9:00 and/or 6:00?

In many wind turbines access to 9:00 and 3:00 (and sometimes 12:00) may be prohibited by the brake calipers when using the traditional chain and bracket mounting fixtures. Magnetic fixtures can be used with mounting rods to position the measuring units inside the brake calipers on the brake disc. Care should be taken to ensure that the laser references the centerline of the shaft. The measuring units on either side need to be placed so as to reference their corresponding centerlines.

Should I align with the coupling in or out?

When performing an alignment with the coupling in, you will need to disengage the brake to rotate the shafts. All health and safety standards must be followed in this case. Without the coupling you can use the flange or shaft end to mount the units and turn without disengaging the brake.

How do I decide on alignment tolerances?

Generally, alignment tolerances are determined by the RPM speed of the machine. The speed of the shaft is determined by the gearbox. Depending on the wind available, this speed can vary. The tolerances should be set for the highest allowable speed of the gearbox.

What is dynamic offset and why is it important?

Dynamic offset is caused by the movement of either machine under normal operating conditions. This movement can be caused when temperatures are different from one side of the system to the other. This is called thermal growth. Dynamic offset is caused in a wind turbine when the brake is released and the hub starts to turn. The weight of the system may cause the gearbox to shift upwards (in the vertical direction). When this happens, the shafts of the gearbox and generator are no longer in alignment.

How can I calculate dynamic offset in a wind turbine?

That should be a part of the turbine manufacturer's specification. They know how much the turbine/gearbox will rise or move depending on dynamic forces in different situations. When using a laser alignment tool, make sure it includes a program for Thermal Growth (Dynamic) Compensation.

What is soft foot, and why is it important?

Soft foot is the condition where the machine stands on three feet instead of four. This of course means that the machine is standing unstable on the foundation. Soft foot must be corrected be-

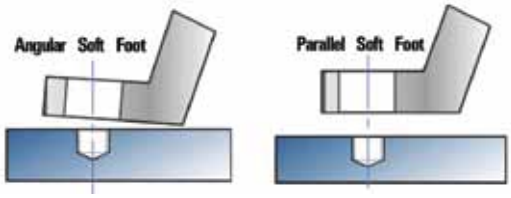


Fig. 3: Angular soft foot at left, and parallel soft foot at right.

fore alignment. A machine with a soft foot condition will continue to move during alignment, making a good job virtually impossible. Because of the generator and gearbox mounting base tolerances, soft foot may not be applicable in generator alignment. Should you find that alignment is extraordinarily difficult, check for soft foot as the culprit.

What other tools will I need?

A good supply of clean shims, feeler gauges to help measure soft foot, micrometers can be used to measure the shim pack, a wire brush is used or cleaning foundations and shims. A good plan and a good tool kit will help prevent the need to go back down tower. When performing an alignment without the coupling, you will need a distance gauge to measure the distance between the flanges. Because many manufacturers are using a carbon fiber coupling that has a tight specification, the axial distance is critical when you align and move the generator.

What should I be concerned about with documentation?

Electronic documentation is the first quality check to ensure that techs have been trained properly and understand how to do alignments that are with in tolerance, ensuring good alignments every time. Good documentation will also help make subsequent jobs go more quickly and easily. O&M companies should be able to provide their customer with a document that shows what was done, who did it and that it was done properly and to tolerance. Documentation should be digital, recordable, and electronically storable. The document should include the final offset and angular misalignment for both the horizontal and vertical direction. Documentation should include the operator and the time and date the alignment performed. The documentation system should also have the ability to record and store any problems or obstacles noted by the technician for future reference. The document should be made available to the technician prior to performing a new alignment.

PREDICTING GEARBOX HEALTH

As is the case with any major capital investment, monitoring the condition of your wind turbine simply makes sense. NRG Systems explores the issue.

By Eric Bechhoefer

Dr. Eric Bechhoefer is lead systems engineer at NRG Systems and an acknowledged specialist in the field of rotor dynamics and wireless sensor technology. Go to www.nrgsystems.com.

AS THE NORTH AMERICAN WIND energy market matures and turbines reach the end of their warranty period, condition-based maintenance (CBM) is generating a great deal of buzz. No matter where a turbine is found, or how long it's been in operation, keeping your finger on the pulse of its internal workings will enhance productivity and increase active service life. Let's begin with a general discussion of CBM techniques before turning to whether or not you're a good candidate, and what you can expect as a return on your investment (ROI).

EXISTING OPTIONS

There are a number of commercial condition monitoring (CM) systems that provide diagnostic capabilities for wind turbine gearboxes. While useful for asset management and logistic support, the current products are deficient in two major areas. First, their ability to define a level of damage is immature (e.g., how bad is bad). Second, these systems have limited ability to predict when a component will go bad (e.g., the damage threshold).

The ability to define a damage threshold is complicated by the metric, or condition indicators (CI), used to identify component health. For all but shaft order 1 vibration—the vibration associated with 1 x the rotation rate of a shaft, which has a physical

meaning—there are rarely defined limits. For example, there is no physical limit for gear CIs such as residual kurtosis, or any other CI. In general, when a CI value is "large" (e.g., residual kurtosis greater than 8) it is assumed that the gear is bad.

Additionally, for many components there is no single CI that works for all failure modes, making it difficult to compare relative failure across components. For bearings there are condition indicators for the inner race, outer race, and roller element. For gears, which have at least six different failure modes, there are numerous CIs that work for some failure modes, but not all. While side band modulation can detect a gear misalignment, it is ineffective for a soft tooth. Similarly, residual RMS (root mean square) work well for gear tooth pitting, but is not effective for an eccentric gear.

LEARNING FROM AEROSPACE

One technique that has been successfully used in aerospace CM systems is the Health Indicator (HI). The HI fuses "n" number of CIs into a single, common indicator of health. For example, the HI can range from 0 to 1, where:

- A nominal component is 0 to 0.5;
- A serviceable component ranges from 0.5 to 0.75;
- A component out of limit ranges from 0.75 to 1, and;
- A component with an HI greater than 1 indicates continued operation would result in collateral damage to other components in the gearbox.

The HI can be designed to have a constant false alarm rate. This is initially set by sampling nominal component data, then using statistical techniques to model the data, account for CI correlation and, ultimately, ensure that a when the HI is greater than 1 it is appropriate to do maintenance. This methodology is useful because, instead of asking the question "when is the component bad," it asks the question "when is the component not good?" It enables operators to see when components are going bad and take proactive steps to avoid more costly damage.

THE VALUE OF PROGNOSTICS

The HI concept facilitates prognostics by enabling maintenance when a component is no longer good. Using the HI, the remaining useful life (RUL) of the component is then simply the estimated time until when the HI is 1. The operator knows that when the HI is 1, it is necessary to do maintenance (because the component is "not good").

The prognostic is also dependent on a fault model. Damage of rotating equipment comes from fatigue, which is a function of torque. It's no surprise that a wind turbine will fail sooner when operating under high loads (e.g., large torques). Paris's Law relates the rate of change of damage (e.g., crack length) to cyclic loading. In most cases the parameters needed for Paris's Law are calculated in the lab. NRG Systems has developed a patent-pending methodology to estimate the unknown parameters by reconstructing them from a state observer. Instead of crack length a surrogate for damage, the HI, is used. By integrating Paris's Law it is possible to estimate the cycles, or time, remaining until the HI is 1.

As a result, this prognostic (or measure of RUL) provides valuable information to operators about

Fig. 1: Gearbox, rotor shaft, and disk brake assembly (Scout Moor Wind Farm Construction).

when components might go bad and under what conditions. This allows for real-time decision making, such as curtailment under high winds to extend the life of a component. Conversely, the RUL can be used to perform opportunistic maintenance. For example, if a maintenance crew were onsite to tend to more costly damage, they could do well-informed preventative maintenance during the same maintenance event, saving time and money down the road.

While these systems aren't there quite yet, there's much we could learn from other industries to continually lower the cost of operations and maintenance and strengthen the competitiveness of wind.

CONSIDERING ROI

Now that we understand the basics of CBM practices and technologies for wind turbines, what is the actual value? Why should you as an owner or operator of wind farms want to spend money on it? The answer is because there is a lot of evidence to suggest that condition-based maintenance can significantly lower operational costs. The question is how to quantify these cost savings.

NREL's Gearbox Reliability Study, among other things, is striving to validate the performance of condition monitoring technologies. Sandia Laboratories has a similar technology program, focused on improving wind turbine performance and reliability to reduce the cost of energy. While NREL's emphasis has been on the gearbox, Sandia has focused on monitoring blade structural loads. Both groups are helping to quantify the performance of CBM practices.

CBM SAVINGS

But how are operational costs reduced? Condition monitoring does not change the design of the turbine, but it can give operators insight into the material condition of the monitored components. This insight can influence maintenance practices and logistics. For example, CBM can give early warning for an imminent generator or gearbox bearing failure. Replacement prior to failure can allow for an uptower repair ($50K) versus a downtower repair where the generator or gearbox must be dropped onsite, repaired, and reinstalled (new gearbox = $250K plus Crane Rental = $150K).

Or CBM can be used to conduct maintenance opportunistically. If the operator needs to bring the crane out for a downtower repair, knowing the condition of all the turbines in a wind farm would allow the opera-

Fig. 2: The nacelle of a wind turbine.

tor to perform maintenance on any other questionable turbines at the same time. This could save the operator from bringing the crane out again for another down-tower event. Additionally, there is the opportunity cost savings of being able to operate the turbine and generate revenue, instead of having a tower offline waiting for a crane.

WORKSHOP EXAMPLES

At a recent AWEA Project Performance & Reliability Workshop, a number of CBM cost-saving metrics were quoted. GE Wind Services announced plans to provide extended 10-year warranties, based in part on installing condition-based maintenance equipment on their 14,000+ fielded 1.5MW machines. This may be due to the reported 10-30 percent reduction in maintenance costs associated with monitored machines.

Other examples of reduction in maintenance costs were presented by Roland Kewitsch of Schenck USA. He gave the first example I have seen of what I would call "active preservation." Based on their condition monitoring system, they found a gearbox in the process of failing. By curtailing production on this machine in high wind conditions, they were able to extend the life of the gearbox by eight months. This facilitated maintenance during the summer, when production is lower and impacts on revenue are less.

IS CBM FOR YOU?

The decision to install CBM is based on a positive return on investment. While most operators agree that CBM greatly reduces operational costs, many existing projects simply have not budgeted the $20K or so per turbine cost to buy and install a system. I would say that as CBM systems mature:

- Operators will learn how to use a CBM system better and the tangible return on investment will increase;
- Insurers and owners will insist on, or provide financial incentives to, install CBM systems prior to commissioning;
- The cost of a CBM system will drop, making the initial investment more attractive.

All of which suggests that there will be many more condition-based maintenance systems installed in the future. As Jean-Marie Robin of 01 dB-Metravib stated, "You simply wouldn't not monitor a 1.5MW industrial machine when the incremental cost of changing a gearbox on a wind turbine can equal a year's profits." I would agree.

ROTOR BLADE RELIABILITY

Component tests help reduce the uncertainties associated with scaling up from pure materials to working structures, especially concerning adhesives used in wind turbine blades.

By Florian Sayer and Felix Kleiner

Florian Sayer leads the working group on material and component testing at the Fraunhofer IWES Bremerhaven and is a member of the competence group rotor blade. Felix Kleiner is adhesive engineering manager at Henkel AG & Co. Go to www.henkelna.com and search "wind power solutions." Also visit www.iwes.fraunhofer.de.

THE WIND ENERGY MARKET has grown dramatically in recent years, with generating capacity in Germany alone increasing from about 1000MW in 2000 to more than 27,000MW in 2010 [1]. This growth has been accompanied by the use of ever-larger rotor blades [2]. The powers given in fig. 1 are not average power values but rather indicate the maximum size of the wind turbines.

Figure 2 shows the structure of modern rotor blades. A distinction is made between non-structural and structural bonded joints, with the majority of rotor blade manufacturers using rotor blade designs with a structurally bonded joint between the blade shells with integrated spar caps and the shear web, resulting in an "I-beam section."

The second design variant has no structural load carrying bond lines. An integral manufactured composite structure takes the loads and the bond line has only to transfer the aerodynamical loads in this structure. The mechanical requirements for an adhesive joint in the "I-beam" construction tend to be higher, as failure of the bonded joint would have a significant effect upon the structural integrity of the blade.

METHODS FOR TESTING COMPONENTS

Rotor blades typically require certification in accordance with the current IEC standard 61400 and related regulations; e.g. Germanischer Lloyd [3]. The certification is

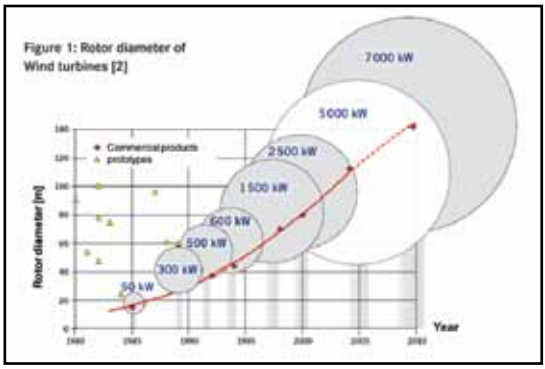


Fig. 1: Rotor diameter of wind turbines [2].

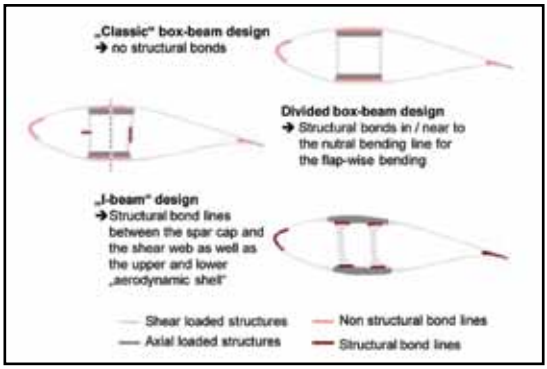


Fig. 2: Typical cross-sections of wind turbine blades.

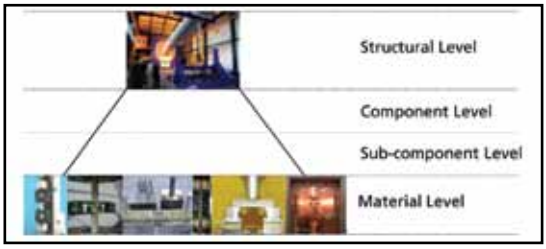


Fig. 3: Test levels for wind turbine blades.

based on static and dynamic material tests, and a full-scale static blade test. Actual stresses in the bond-line—due to stress concentrations and manufacturing variability, for example—are not directly measured in the full-scale blade test. Without a direct measurement, a large safety factor is assumed to minimize risks in the structural bondlines. For example, Germanischer Lloyd (GL) [3] allows maximum shear loads of 7 N/ mm^2 for static loads, yet typical adhesives attain shear strengths of 40 N/mm^2 to 50 N/mm^2. Over 1,000,000 cycles of simulated dynamic fatigue loading, GL specifies a shear stress below $1N/mm^2$.

Rotor blade manufacturers, material suppliers, and European research organizations have recognized that there is room between these two extremes for enhancing our understanding of materials and structures. This would allow the reliability of rotor blades to be increased, further optimization of blade designs, and/or reductions in material use. Figure 4 compares the advantages and disadvantages of the test scales shown in fig. 3. The ability to determine SN- lines for structures and study the effect of production faults, material variations, and design adaptations have enormous potential for improving the reliability of bonded joints for rotor blades.

Even though rotor blades are amongst the largest integral fiber composite components that are produced, there are distinct regions of the structure and design that have close similarity. These are, for example: a) rotor blade end section; b) leading edge; c) flange-web design (ply drops in the flanges, flange-web bonded joints); d) sandwich structures, and; e) blade connections (the only blade components currently tested in component tests).

	Blade Tests	Sub-Component	Coupon
Loading	(Realistic)	Simplified	
Defects	Real	Realistic	No
Fatigue Tests	Single test	SN-line	SN-line
Certification	Structure	(No)	Material
Parameter Variation			
– Material	No	Yes	Yes
– Defect	No	Yes	No
– Design	No	Yes	No
Costs	height	medium	low

Fig. 4: Comparison of material, component, and full-scale testing.

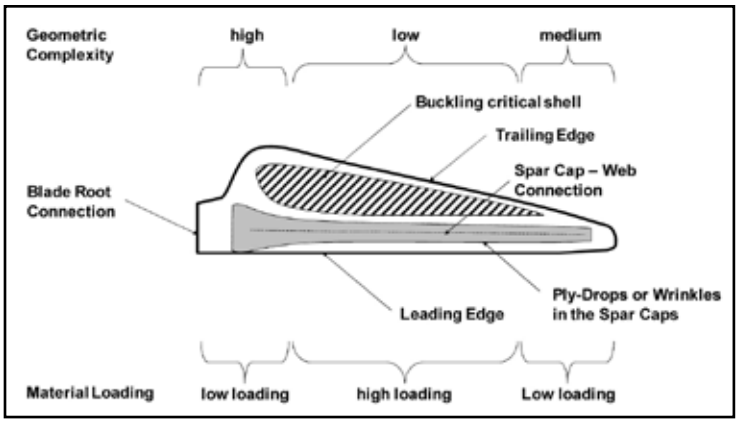
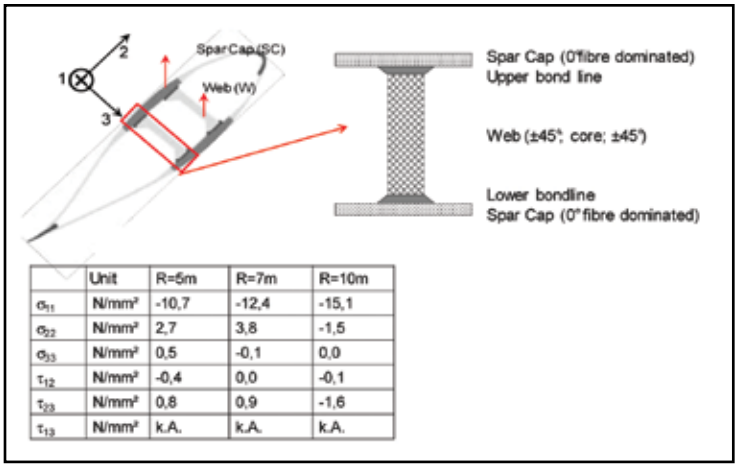


Fig. 5: Rotor blade sections and typical loadings and geometric complexity.



	Unit	R=5m	R=7m	R=10m
σ_{11}	N/mm²	-10,7	-12,4	-15,1
σ_{22}	N/mm²	2,7	3,8	-1,5
σ_{33}	N/mm²	0,5	-0,1	0,0
τ_{12}	N/mm²	-0,4	0,0	-0,1
τ_{23}	N/mm²	0,8	0,9	-1,6
τ_{13}	N/mm²	k.A.	k.A.	k.A.

Fig. 6: Bond line loading in wind turbine blades.

Besides these regions of rotor blades, some of which have to bear very high loads, there are geometrically complex areas of the blade root that are often subject to relatively small loads (fig. 5). Due to the load bearing function of the flange-web joint and the instances of failure and damage observed in operation, this region was chosen in a project between Henkel AG & Co. KgaA, Fraunhofer IWES, as well as in the UpWind project.

STRESSES ON BONDED JOINTS

As part of the OPTIMAT project, T. Philippidis published a report [5] about the loads on a 35 m rotor blade and determined the loads using an experimentally validated FE model. Using this model it is possible to estimate the stresses on the bonded blade joint. For a flange-web joint width between 100 mm and 250 mm a shear stress between 0.825 N/mm² and 0.33 N/mm² is calculated for the blade radius 5 m. The corresponding axial strain is 0.25 percent. Axial stress thus dominates the load on a bonded joint (fig. 6).

Based on these loads, Henkel and Fraunhofer IWES together developed a representative test specimen whose structure is in principle similar to a rotor blade (fig. 6) and induces comparable mechanical stress in the adhesive. One of the test specimen geometries was also used in the EU funded UpWind project [3] because this gave a more realistic state of stress in the adhesive than with the UpWind design used in the project (for example, see [4]).

GEC AND UPWIND BEAMS

The Henkel GEC beam and Henkel UpWind beam shown in fig. 7 have a similar geometric cross-section to a classic I-section, as used today in common blade designs. The beams are supported and loaded by steel bolts that are press fitted and bonded into the beams. In order for the beam loads to be borne by the bolts, these regions are reinforced. The calculated loads on the Henkel UpWind beam are shown in fig. 8. To take account of any differences in blade design and to guarantee conservative results a "safety factor" of two was chosen on the shear stress. A similar load condition was attained in the Henkel GEC beam by varying the flange width.

Macroplast UK 1340 and Macroplast UK 1351 polyurethane structural adhesives were used for the Henkel GEC (fig. 7, left) and Henkel UpWind beams. The two Henkel

Fig. 7: Test setup with Henkel GEC (left) and Henkel Upwind beam (right).

products do not have glass fillers, and are claimed to offer substantial production time saving due to faster cure. Macroplast UK 1351 is a faster-curing system used for bonding components, smaller blades, and repairs. Macroplast UK 1340 has longer open time and higher sag resistance for utility scale blade bonding. In addition, Momentive Epikote Resin MGS Paste 135 G3 glass-filled epoxy adhesive was used as a benchmark reference system for the Henkel UpWind beams [4].

FE BEAM SIMULATION

The measurement of local strain using the beam model is possible with the help of strain gauges or optical methods. Spatially resolved analysis of the load on the adhesive was carried out using computer simulation (fig. 9).

Special modeling tools are then used to simulate the mechanical behavior of fiber composite materials. These are able to effectively show the anisotropic behavior of the individual layers. Material parameters for the laminates are available as validated empirical values or measured values. Such values have been published by Sayer et al. [7]. The mechanical characterization of a structural adhesive requires stress-strain curves determined with pure tensile and shear loads.

The pure load condition for tensile is achieved in accordance with EN ISO 527-2. The pure load condition for shear is achieved using hollow cylinders under torsional loads (DIN EN 14869-1). In combination with suitable experimental boundary conditions, a model can be developed to determine stress and strain in a three-dimensional subcomponent model. The result is an economic assessment tool for the evaluation of different adhesives and bondline geometries.

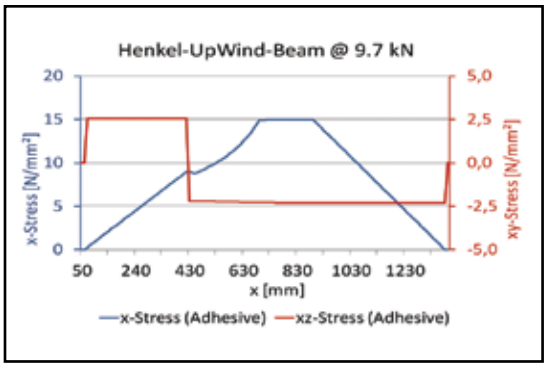


Fig. 8: Calculated loadings in Henkel UpWind beam.

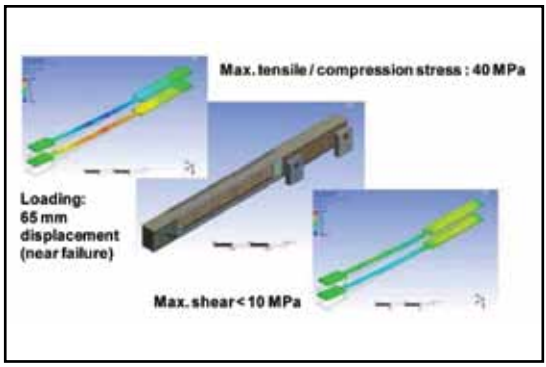


Fig. 9: Stress analysis of Henkel UpWind beam with FE model.

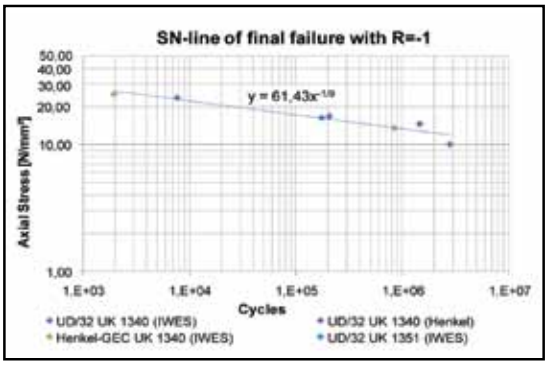


Fig. 10: SN-line of beam tests with Menkel Macroplast adhesive.

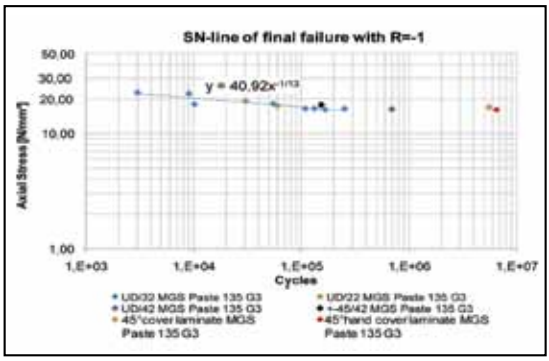


Fig. 11: SN-line of beam tests with Momentive adhesive.

CYCLIC TESTS

In total, six cyclic progressive tests were performed using the Henkel Macroplast UK1340 adhesive: three on the Henkel GEC beam, and three on the Henkel UpWind beam. A further test was carried out using Macroplast UK1351 adhesive. Figure 10 (the maximum axial stress in the adhesive is plotted) shows that the Wöhler exponent κ lies in the region of the standard value of Germanischer Lloyd [3] for a unidirectional laminate.

Figure 11 shows the test results for the Henkel UpWind beam and the Momentive adhesive from the UpWind project (the maximum axial stress in the adhesive is once again plotted here). The Wöhler exponent κ is higher; however the ultimate strength is lower. Differences in the mixing and dispensing process (laboratory methods versus industrial machine mixing) complicate a conclusion about the relative performance of the tested adhesives. Different beam variations were tested with the Momentive adhesive. For example different joint widths were considered and also a thin biaxial stitched glass fabric (840 g/m²) was laminated across the bonded joint. This leads to a slight reduction in the shear stress in the bonded joint (ca. 25 percent for linear calculation).

Significant stress changes in the bonded joint are therefore not expected. On changing the shear stress in the adhesive by varying the width of the bonded joint there were only small changes in the service life (76 percent and 145 percent of the shear stress of the reference shear stress). By laminating over the open part of the bonded joint there was a clear increase in the service life, although the influence on the shear loading of the bond line was comparable to the width increase.

Both the Henkel adhesives and also the Momentive adhesive showed a similar failure behavior (performance should not be compared due to differences in mixing and dispersing technology). First of all cracks formed in the bonded joint, induced by the high axial stress.

These grew across the entire height of the bonded joint and ended at the flange and web laminate. Cracks spread from there to the interface between the laminate and adhesive and led to failure of the structure (fig. 12). It was observed that the density of the axial cracks in the Momentive adhesive was higher than in the Henkel Macroplast adhesive. This could be attributed to normal variations seen in the mixing process.

SUMMARY

Component tests are a worthwhile addition to tests on material and full scale rotor blades level that are currently widely used in the wind power industry. The Henkel UpWind beam design leads to stresses in the adhesive of the flange-web joint that is similar to that in rotor blades. The failure behavior of the adhesives was similar. A pure shear stress, under the tested conditions, had no noteworthy ef-

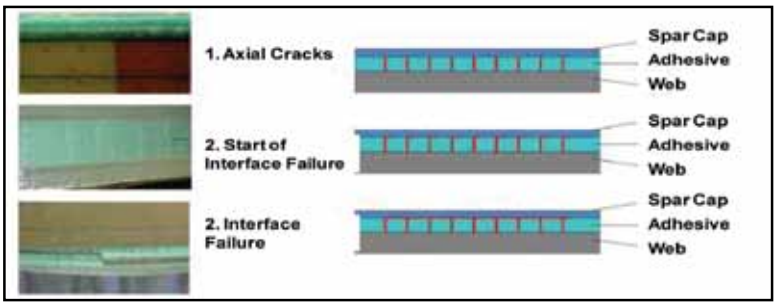


Fig. 12: Exemplary failure development for the investigated adhesives.

fect on the service lives of the test specimens. Cover laminate for the bonded joint led to a significant increase in the service life. As subcomponent beam tests could play a leading role in the future development of adhesives for wind turbines, the objective is now to establish this economic method to assess the performance of adhesives as a standard test for the wind power industry.

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GEOTECHNICAL STUDIES FOR OFFSHORE APPLICATIONS

Offshore wind infrastructure studies off European coastlines serve as valuable references for geotechnical efforts in North American waters.

By Robert Mecarini and Andy Barwise

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GEOTECHNICAL SURVEYS PHYSICALLY sample or test the seabed characteristics so developers can ensure the optimal placement of offshore wind farm turbine, substation, and cabling infrastructure. By the time a project requires geotechnical data it has already traversed several stages, including desktop, baseline, environmental, marine mammal observation, hydrographic, and geophysical studies, so stakeholders have significant investments tied up in their leaseholds. As the tasks that comprise geotechnical studies represent the largest single investment in the site characterization process, they require extensive experience in marine operations and equipment, particularly as projects move from the shallow-water regions that comprise the bulk of offshore farms around the world to increasingly deeper waters.

Though marine wind projects in North America are moving forward, the United States still doesn't have a production turbine in the water and has yet to institute a federal Renewable Energy Standard (RES) or the long-term production tax credits that will encourage the level of investment needed to drive the sector. On the regulatory front, BOEM and other agency regulations are works in progress, but agencies have stated their intentions to

collaborate and use existing multidiscipline data to streamline permitting guidelines where applicable. When these financial and regulatory issues are eventually addressed, the U.S. will need to play catch-up.

The good news is that U.S. developers can turn to offshore geotechnical work in Europe and elsewhere to inform their own wind energy efforts. To speed the tempo needed to stay competitive on an international scale and reap the economic and environmental benefits that offshore wind promises, North American contractors can incorporate the hard-won lessons learned collecting geotechnical data for overseas offshore wind projects, as well as from oil and gas projects worldwide. The offshore O&G industry has spent decades incrementally improving geotechnical techniques to develop optimum specifications and equipment, which have been further tested and modified over the last several years for offshore wind installations off Europe. Though the vast majority of wind projects has thus far been in shallower waters, deepwater O&G specs and continuing lessons from overseas wind farm work can serve as very valuable tools for projects progressing off the East Coast, in the Great Lakes, and in the Gulf of Mexico.

These synergies were a key driver behind United Kingdom-based Gardline Ltd.'s acquisition of New Jersey-based Alpine Ocean Seismic Survey in 2009. Working in the offshore wind sector for more than a decade, Gardline has completed more than 140 renewables projects and is currently involved with five of the U.K.'s nine Round Three efforts. Alpine, working alongside Gardline Geosciences, adds the complex geotechnical piece to its existing portfolio of marine services to offer one-stop, turnkey data collection solutions for North America's burgeoning offshore wind sector, giving the company access to the kind of equipment and experience needed to tackle geotechnical work in nearshore, transitional depths, and deepwater projects. With expertise gained from more than 50 years in marine projects, Alpine brings localized knowledge of the U.S. market and regulations, long-standing associations with state and federal agencies, and relationships with other domestic contractors that simplify project coordination.

GEOPHYSICAL INFORMS GEOTECHNICAL

The efficiency and quality of a geotechnical campaign is closely tied to the success of the geophysical data collection operation that precedes it. The high-resolution geophysical (HRG) studies that acoustically map seabed features—seafloor topography, bathymetry, stratigraphy, archaeological elements, hazards, and other characteristics—enable the design of a geotechnical study that targets locations that will yield the most representative physical samples and in-situ measurements needed to determine the viability of proposed infrastructure sites. Geotechnical studies examine soil structure and other attributes that, combined with geophysical findings, create the geological model needed to establish engineering parameters for turbine foundations, substations, cable burial trenches, and other infrastructure.

According to estimates, geophysical, geological, and geotechnical studies comprise on average more than three quarters of the total cost of site characterization investigations. With comprehensive geophysical data gathered and analyzed,

geotechnical contractors can—where regulations allow—reduce the number of points that have to be physically sampled or drilled, thereby trimming the cost and time of their effort. Further, with a single experienced marine contractor handling both disciplines, developers can alleviate concerns that a geotechnical outfit working independently of the geophysical provider will perform unnecessary work. Beyond getting a geotechnical design that best complements the geophysical data collected, stakeholders also ensure they get smooth transitions between survey phases, accountability, and a single point of coordination, keeping costs and timelines more reasonable than those sometimes seen when multiple contractors are involved (fig. 1).

In the U.K., for example, offshore wind farm regulations allow contractors to rely more on less-costly geophysical surveys to target optimum—rather than overly redundant—test sites for their geotechnical studies. U.K. guidelines regulating geotechnical designs are geology- and consultant-dependent, an approach that can streamline the extensive amount of work required. Based on their geophysical data analysis, for example, North Sea contractors can reduce the number of conventional soil boring samples they take by relying more heavily on seabed cone penetration testing (CPT), which can be less expensive and provide better coverage than conventional drilling. As agencies elsewhere see satisfactory outcomes from an approach that gives more credence to comprehensive geophysical campaigns, they're more likely to consolidate their own regulations to more efficiently get critical infrastructure in the water and operational.

In the U.S., BOEM guidelines currently require CPT and soil borings for each turbine foundation pile and substation. However, as projects progress around the world, geosciences contractors may be able to leverage successful outcomes from overseas efforts to work with BOEM to ease regulations as agencies have in the U.K. With such evidence, BOEM may deem its blanket regulations for this kind of activity to be excessive, and allow U.S. contractors to leverage vetted geophysical data to reduce the number of locations where they must supplement CPT with standard soil borings. In the mid-Atlantic region of the East Coast's Outer Continental Shelf (OCS), for example, the geology generally isn't highly varied, which can obviate the need to conduct conventional borings in every location, reducing survey time, costs, and permitting cycles.

EQUIPMENT SELECTION SUITS THE PROJECT

The equipment used for a marine geotechnical campaign depends on water depths and ground

conditions, as well as the region's regulatory requirements, making ready access to a depth and breadth of tools that span a wide range of project types a key differentiator. Geotechnical specialists should be capable of deploying the following technologies:

Cone penetration testing (CPT) units: CPTs are versatile devices used for in-situ soil tests, typically the first step in a geotechnical campaign. CPTs capture data continuously or at specified depths on such geotechnical parameters as soil density, shear strength, and consolidation rates. During penetration, the forces on the cone and the unit's friction sleeve and pore pressure transducers are measured and transmitted to topside data-logging software. For work in North American waters, contractors should be able to choose from a number of units designed for specific applications and penetration depths, ranging from lightweight mini-CPTs (with penetration up to 10m) to such equipment as Wheeldrive ROSON units (with penetrations up to 40m), Neptune 3000 and 5000 units (10m and 20m, respectively), and wireline CPTs, which enable downhole tests to be performed and guarantee CPT data to the final depth of the borehole.

CPTs provide more accurate, calibrated, and fully traceable in-situ information on the geotechnical properties of the soil than standard penetration tests (SPTs), which are more commonly used for land projects and involve counting how many blows (blow counts) of a standardized weight it takes the drill string to penetrate a set distance. Data captured through CPTs can be analyzed onboard in realtime, unlike physical samples that require offshore or onshore laboratory testing.

Seabed samplers: For seabed sampling for such infrastructure studies as cable route surveys, geotechnical contractors utilize a range of samplers. A provider should have at its disposal:

- High-power and specialty vibrocorers;
- Hydraulic clamshell grabs for bulk samples;
- Box corers for minimal impact sampling of surface soils.

Heave compensation drill rigs: For deeper-water wind farm projects, geotechnical data acquisition requires the use of heave compensated drilling rigs. These systems provide three-meter heave compensation, allowing drilling to continue undisturbed in rougher marine conditions where waves that lift the drilling vessel likewise raise a stationary drill, potentially ruining the sample or damaging the rig. They can be permanently installed on dedicated drill vessels, and are also available in containerized packages so they can be used on third-party

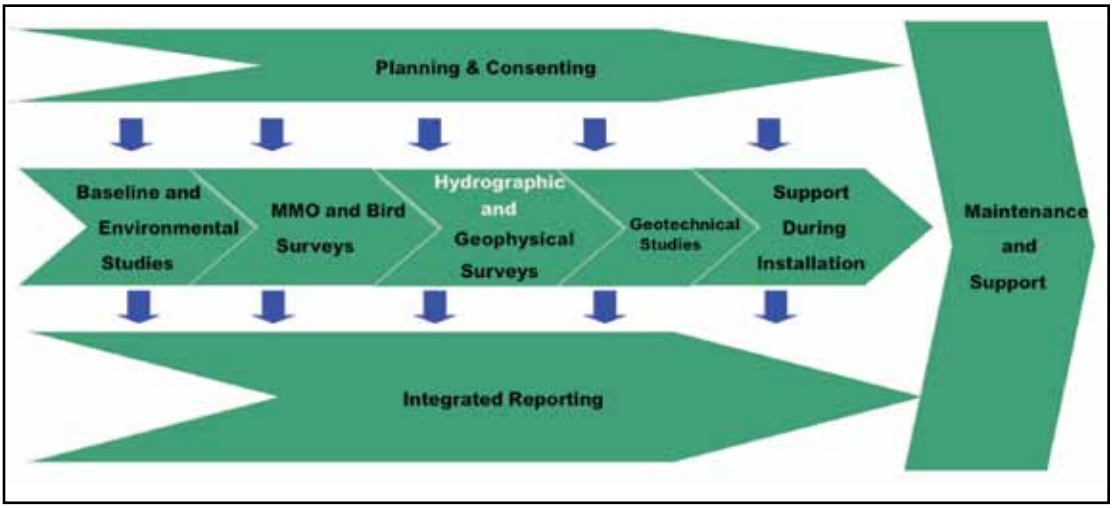

Fig. 1: Site characterization for an offshore wind project requires a comprehensive dataset that includes desktop, baseline, environmental, MMO, hydrographic, geophysical, and geotechnical studies.

vessels, where ideally, they are operated through a moon pool, or if necessary, through side-mount installation.

For offshore renewables projects, heave compensation rigs should be capable of drilling in water depths up to 1,000 meters, enabling them to be deployed for drilling, sampling, and downhole CPT efforts for a range of wind farm sites. These systems can also perform downhole geophysics studies—performed in completed boreholes to calculate additional important attributes related to depth—and can incorporate onboard data and analysis capabilities. For leaseholds in deeper waters, developers should consider contractors with these rigs in their arsenal, ensuring the extensive experience required to deploy them for various applications.

VESSEL VERSATILITY

As the majority of the wind farm work in the North Sea and in U.S. waters to date has been nearshore, geotechnical contractors have relied to a great extent on smaller niche and jack-up vessels, often opting to mount land-based truck-mounted rigs for drilling purposes. Under the right conditions and supervision, this combination is effective and cost-efficient, but it is limited in application.

On the vessel side, jack-ups revealed their limitations for wind farm geotechnical site investigations in early North Sea efforts. Testing for wind turbine sites naturally means working in windy areas, and unlike specialized vessels, stationary platforms aren't optimized to handle the resulting marine conditions. Further, research teams with stationary jack-ups can only test in the area within range of the vessel before mobilizing to a new location, a more arduous process with jack-ups than in moving a dynamic positioning (DP) or anchored vessel. This remobilization process doesn't easily accommodate the need to work in the tight timeframes when weather conditions are suitable, a leading factor dictating offshore data collection. In addition, smaller jack-ups don't have adequate living accommodations, so personnel must be continually transported from ship to shore and back.

On the equipment side of the equation, there are also HSE (health, safety, and environment) issues to consider when using land-based drilling equipment on jack-ups. Relatively few drilling operators whose expertise is in land-based projects have the experience required to conduct drilling safely, effectively, and efficiently offshore. Further, the effectiveness of this vessel/drill rig combination is limited to shallower waters under calm conditions. For projects farther offshore, contractors must rely on marine options designed for harsher conditions, both for effective operations and safety reasons. Expertise in these challenging environments is important as projects progress in the Northeast, where most of the geotechnical drilling to date has been on inland waterways rather than offshore, where conditions are far less predictable.

In deeper waters, a heave compensated rig is the superior drill choice. The point where contractors should consider moving to this kind of rig is when water depths reach 60 to 70 feet. Some jack-ups, especially those available on the East Coast of the U.S., aren't large enough to perform safely or adequately beyond these depths. Although larger jack-ups working in the Gulf of Mexico can operate in deeper waters, the costs of mobilization from the Gulf to the Northeast, coupled with the higher costs of leasing a bigger vessel, make it more effective and equally economical to use heave compen-

sation equipment on a properly configured drill ship.

Though the bulk of U.S. offshore wind development to date has largely been in water depths ranging from less than 60 to around 160 feet, it's just a matter of time before efforts move to deeper areas. If developers are planning a small test turbine array in shallow water, heave compensated equipment isn't necessary, but if they're intending to place hundreds of turbines in deeper waters, it's much more effective to choose a heave compensated system mounted on a dedicated DP vessel to take advantage of strong seakeeping performance, onboard real-time data analysis capabilities, dry and wet laboratories for sample processing, and accommodations for extended periods at sea.

> "When developers contract with a geotechnical services provider whose expertise is in offshore operations, they ensure they get personnel with experience sampling and drilling in a dynamic marine environment."

Depending on project parameters, heave compensated drilling rigs can be permanently mounted on specialized vessels or temporarily installed on multi-role vessels and barges. In the U.S. it's important for both project suitability and local stakeholder interests—given the strong business emphasis on using local providers—that companies have geotechnical equipment that can be mounted on third-party barges and other vessels to employ local companies as part of a project.

When developers contract with a geotechnical services provider whose expertise is in offshore operations, they ensure they get personnel with experience sampling and drilling in a dynamic marine environment, who understand the risks, safety requirements, and specific data attributes needed to design and conduct acquisition efforts. With this approach, even if the project is far-reaching and calls for using land-based equipment on jack-ups nearshore and marine-optimized technologies and DP vessels in deeper water, the marine contractor can coordinate the entire operation and ensure quality control throughout the project. The geotechnical campaign is consequently much more likely to be completed successfully without encountering the kinds of problems that can bring a project to a costly and damaging halt.

DECREASING TURBINE WEIGHT

According to Seco Tools, the U.S. should follow Europe's lead in embracing efficient machining practices that decrease wind component weight and increase efficiency.

By Gary Meyers and Todd Miller

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WIND ENERGY IS ONE OF THE WORLD'S fastest-growing sources of energy. According to a 2011 report provided by the World Wind Energy Association, China, the United States, Germany, Spain, and India were the top five wind power markets by total capacity in 2010. When it comes to producing wind turbine components as efficiently and inexpensively as some of these countries, however, the United States tends to lag behind. Why is that, and what can be done?

EMBRACING EFFICIENCY

Europe, for example, is capable of producing wind turbine components at much more affordable levels than the United States. The Europeans follow the mindset that they will invest in the right equipment to make these components as quickly and cost effectively as possible. In fact, they use large, high-powered machines to achieve fast metal removal rates and shorter cycle times.

The United States has not been able to mimic Europe's efficient machining practices because not enough incentive funding exists for wind turbine manufacturers to want to move forward in improving their processes. For example, the oil and gas industry receives higher tax incentives than wind power. Furthermore, wind power manufacturers must renew

Fig. 1: Seco's Double Octomill features 16 cutting edges and provides excellent cost effectiveness.

their federal subsidies on an annual basis, making it difficult for them to gauge how stable the wind industry is going to be from one year to the next.

The current reality in the United States is that several wind turbine manufacturers have evolved from automotive-type companies who are continuing to utilize their existing machine tool equipment to produce turbine components. These machines are older, slower, and less powerful than what Europe is using to machine their parts. To put it in perspective, Europeans can produce a wind turbine rotor hub in four to five hours, whereas it takes a U.S. manufacturer eight or more hours. All the while, OEMs are putting a lot of pressure on American manufacturers to reduce manufacturing costs.

MATERIALS MATTER

On a brighter note, some U.S. manufacturers are contemplating the use of lighter, stronger materials such as carbon fiber, compacted graphite iron (CGI), aluminum, and titanium alloy to lower the cost of industrial wind turbines. After all, the heavier the wind turbine, the more costly it is to produce, transport, and install.

The larger OEMs, in particular, are actively looking into materials with improved strength-to-weight ratio for wind turbines out on the ocean. Offshore turbines tend to be a lot larger than those on land, and installation is a lot more difficult and expensive. Therefore, being able to reduce their weight is a big deal. Should this become a successful trend, more manufacturers of land wind turbines will be apt to follow suit.

Consider the land-based 5MW wind turbine of today, which weighs more than 1.1 million pounds, with the nacelle, rotor hub, and blades accounting for most of the weight. If manufacturers started making these three main wind turbine components out of lighter material, they could probably cut the weight of the 5MW in half. As a result, the tower portion—which typically weighs several hundred tons—can undergo a considerable weight reduction because it would only have to support approximately 551,000 pounds instead of over a million. Furthermore, the wind turbine's foundation could also see a decrease in size.

Today, wind turbine blades are typically made of fiberglass and assembled by hand. If manufacturers transitioned over to carbon fiber materials and invested in a CNC process, the weight of the blades would decrease by about 70 percent and their strength and consistency levels would improve overall. However, carbon fiber costs more: a fact that deserves attention when looking at the overall savings of building a complete wind turbine. It's also important to note that manufacturers can't reduce the size of the blades to save money because the area of the blades that "catches" the wind must remain the same size.

Rotor hubs are currently made of ductile cast iron. However, a better alternative exists with compacted graphite iron because of its improved strength-to-weight ratio. It features mechanical and physical properties between those of ductile and gray irons. CGI's graphite particles are short and thick, resulting in stronger adhesion between the graphite and iron for greater tensile strength. Such properties make CGI more resilient to mechanical and chemical fatigue and are highly favored in applications ranging from high-speed rail train disc brakes to engine blocks. And because of its benefits, several wind tur-

bine manufacturers are starting to have rotor hub test pieces made out of CGI.

ATTRACTIVE ALLOYS

Aluminum is another material the wind turbine industry is considering for manufacturing rotor hubs because it is approximately ⅓ the weight of steel and provides corrosion resistance. Titanium alloy is another choice that offers excellent strength-to-weight ratio, but it comes at a higher price. Therefore, when looking to reduce rotor hub weight through CGI, aluminum or titanium alloy, manufacturers need to evaluate which material will offer the best overall weight, strength and price ratio for their operations.

Although manufacturers can reduce the actual size of the rotor hub to eliminate weight, the hub still has to be able to withstand strong wind forces and successfully transfer the torque to the mainshaft/gearbox or generator on a direct drive system. Therefore, choosing a lighter, stronger material to produce the rotor hub is more likely the best option in terms of weight reduction.

When looking to reduce the weight of ancillary wind turbine components such as bearings, the bearing house, shaft, and gearbox, manufacturers need to go through the same weight, strength, and price ration routine to see what material is going to reap the best benefits for their businesses.

Beyond the wind turbine itself, when manufacturers reduce the weight of turbine components, they are also lessening their manufacturing efforts. For example, the size of the equipment they use—from machines to forklifts—doesn't have to be as large to accommodate such hefty parts.

CUTTING EDGES

There are, however, some challenges when transitioning over to some of the lighter, stronger materials. For example, if a shop is currently machining rotor hubs made of ductile cast iron and wants to start using aluminum, the shop would need to update its tooling, reprogram its parts for different cutting techniques, and adjust its speeds and feeds for the tooling. Another challenge is the hazardous dust that comes with machining carbon fiber materials. Shops would need to have special equipment to keep the carbon fiber particles from contaminating the air.

But for those wind component manufacturers ready to start a weight-loss trend, Seco has extensive experience in working with carbon fiber, compacted graphite iron, aluminum, and titanium alloy. After all, the company's cutting tools have long played a role in machining these weight-reducing materials within the aerospace and power generation markets.

Such cutting tools include Seco's Turbo square shoulder mill. Available in four different insert sizes, the Turbo offers improved tool life and precision by optimizing cutting properties that reduce heat generation and cutting forces. Another ideal milling solution is the company's Double Octomill™ that features 16 cutting edges and provides excellent cost effectiveness. It handles roughing and finishing by accurately positioning its inserts inside the cutter body pockets using high-speed steel location pins that offer easy and secure indexing. The Double Octomill also provides extremely fast metal removal rates and can greatly reduce cycle times when machining a wind turbine component. Additionally, some of Seco's cutting geometries are free cutting, which is important because they increase stability in long-reach applications, which are common in wind turbine component manufacturing.

Fig. 2: A Seco Perfomax indexable insert drill in action.

STEADY SYSTEMS

When tackling long-reach applications, Seco's patented Steadyline™ vibration dampening system, made of high tensile steel, improves the dynamic rigidity of milling assemblies. In a typical long overhang milling operation, the Steadyline provides increased tool life as well as performs twice as fast as a classic system. Steadyline shell mill holders are available in a wide range of types and sizes, including cylindrical, conically strengthened, HSK, Seco-Capto, DIN, BT, and CAT.

Other relevant Seco tools for the wind power industry include a complete range of drilling, reaming, and boring tools such as Feedmax™ solid carbide drills and Perfomax® indexable insert drills, X-fix™ large diameter, multi-tooth reamers, and the Graflex® boring bar system of various lengths and diameters. In fact, with its wide variety of holemaking tools Seco offers the widest boring range on the market, covering the entire 0.12" to 84.843" diameter range with complete precision.

While Seco can optimize most machining operations with its comprehensive tooling portfolio, the company can also provide turbine manufacturers with custom tooling solutions that maximize their unique wind power operations.

PRODUCTION PARTNER

For those just getting started in the wind turbine component industry, Seco offers a Component Engineering Tooling (CET) program that takes a comprehensive approach to process design and improvement that ensures the best possible operational results. As part of the program, the CET team—which consists of expert engineers—conducts technology evaluations to ensure a company's manufacturing process incorporates the most suitable equipment. Functional testing can also take place inside one of Seco labs to prove out a machining solution prior to implementation. The Seco team then executes an integration plan of the selected equipment, including technical support and training, implementation of the system, run-off tests, and documentation of potential savings. Several wind customers have taken advantage of this program and managed to save time and money before any parts hit the manufacturing floor.

Current wind turbine component manufacturers looking to improve their productivity and profitability via their existing operations are encouraged to take advantage of Seco's Productivity and Cost Analysis (PCA), which represents a total evaluation of a manufacturing process using Seco's unique software program. The PCA begins with Seco working closely with a manufacturer's employees to understand and benchmark the company's current efforts. The software program allows Seco to verify and gain a baseline of any type of component. In fact, the software goes step-by-step with each tool and process as a way to put together a "snapshot" of an entire manufacturing process. Seco then draws upon the expertise of its global resources to identify, investigate and prove out recommendations for reducing costs, increasing throughput and maximizing efficiency. Typical results from a fully executed PCA include cost reductions of up to 30 percent and productivity increases of up to 40 percent. Manufacturers can also tailor a PCA to meet a specific need, from assessing a single machining application to evaluating workflow throughout the company's entire facility.

SUMMARY

Wind is among the most affordable renewable energy resource on the planet. However, in order to cost-effectively cultivate more wind farms in the United States, a trend toward using more efficient equipment and weight-reducing materials in the development of wind turbine components must first occur. Manufacturers should know they are not alone in such a movement, however, because Seco is ready to help them pave the way with its optimized machining solutions.

ADINDEX

Katherine McQuade
marketing manager/NRG Systems

TELL US HOW YOU CAME TO JOIN NRG SYSTEMS.

My husband and I are committed to environmental stewardship and sustainability. We wanted to start an organic farm, but we were living in New Hampshire where it's difficult to find nice, flat ground and tillable soil. We found exactly what we were looking for in Vermont, and we purchased 28 acres where we're now growing organic apples, pears, blueberries, grapes, currants, and gooseberries. Our tagline is "Farming for the Future," and we're even using glass panes from old structures instead of plastic in the greenhouse we're building. My husband started working on the farm full-time, and I continued to commute to my job in New Hampshire for as long as I could but it was just too far away, so I began the process of finding employment in the Vermont area. I had a great job, though, so when I started looking around I didn't want to transition from a really great position into something that was less than inspirational and challenging. As I've progressed through my career the alignment of my employer's values with my own has become increasingly important to me. I'm currently working on my doctorate, and my dissertation focus is on the leadership of sustainable companies, which is how I became familiar with NRG Systems. This company is completely self-sufficient, very focused on the environment, and it practices what it preaches. Not everyone does that.

I UNDERSTAND THAT YOU'VE WORKED FOR SOME REAL MARKET LEADERS ALONG THE WAY.

That's right, I've been extremely lucky in that regard. I studied education at Boston University, but I soon found that teaching three year-olds wasn't for me, so I took a typing test and went to work for a computer company. Then I joined Hewlett Packard, starting as a technical writer and working my way up to a manager in the marketing department. During that time I earned my MBA from Rivier College in New Hampshire, and even took a side job teaching in the MBA program at the University of Massachusetts in the evenings. When Hewlett Packard was split into two companies I decided to go with Agilent Technologies, helping develop new channels to market their wireless cell phone test equipment. From there I went to work for Hypertherm for six years as a marketing manager, helping to identify international marketing opportunities for their mechanized business line. I've been in marketing for a long time, and one of my core strengths is that I have primarily worked on the development side, being involved in launching new products. I enjoy being out there in the world talking with customers, and then translating their needs into specifications that engineers can use to develop new products.

WHAT DO YOU HOPE TO ACHIEVE IN YOUR NEW POSITION WITH NRG SYSTEMS?

I come from a strong background of educators, and even though I'm involved in business I see the key role of marketing as educational outreach. Just as marketers are the liaison between customers and engineers, we're also taking knowledge from engineering and translating it into tangible, meaningful material for the sales staff and, ultimately, the end user. I've always viewed those of us in marketing as the "go-betweens," and I believe that it's our job to translate and educate. Another thing I bring to the table is my experience working with big companies like Hewlett Packard that employ hundreds of thousands of people and have robust structures. This experience can benefit smaller companies that are experiencing tremendous bursts of growth, such as NRG Systems. As you've mentioned, I've always tended to work for market leaders. Now, working for a leader in the wind industry, part of my role is to educate the market. We are an important resource for the wind industry at large, and thought leaders in helping the market to grow and evolve.

SOUNDS LIKE YOU'VE ACHIEVED THAT WORK/LIFE BALANCE YOU MENTIONED.

I'm just working toward it like everybody else, but I feel like I'm closer than I've ever been. I'm surrounded by people who share my concerns about protecting the environment, and I'm involved in a market that will lead to a cleaner, more-sustainable future. I'm really looking forward to merging my professional background and personal interests into supporting the important work that NRG Systems is doing.

Call (802) 482-2255 or go online to www.nrgsystems.com.

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more information about these and other new solutions.

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