Turbine Gearbox Inspection: Steady Work in a Shaky Wind Market

Jack McGuinn, Senior Editor

Having outlasted the worldwide Great Recession, the Global Wind Energy Council (GWEC) forecasts a constant growth in wind energy, i.e.: "increase in worldwide capacity to 460,000 MW by 2015."

Europe is a particularly robust market and remains a leading wind power leader—if not in rate of growth (wind energy is arguably a mature industry in Europe), certainly in penetration. The United Kingdom and France are good examples, with the former set to invest 100 billion pounds (> $152 billion American) in wind energy, both on and offshore, the latter progressing to a goal that 10 percent of the country's electrical consumption be wind-generated by 2020.

Here in the United States? Not so hot. According to a recent report by *North American Wind Power* (*nawindpower.com*), "The wind energy industry averted disaster by securing a one-year extension of the production tax credit (PTC) and is likely to benefit from the 'begin construction' language contained in the latest iteration of the incentive. Some companies, including GE, the world's largest wind turbine manufacturer in terms of megawatts installed in 2012, have expressed concerns about where the wind power market is headed for the remainder of 2013, as the PTC's eleventh-hour extension came too late for many firms to resurrect their development plans for this year."

That is so excruciatingly same-o, same-o that we'll leave the market analytics to the experts. We're here to talk about wind turbine gearbox inspection.

And given the highly complex nature of wind turbine gearboxes and their innards, it is little wonder that they are arguably a wind turbine's most endangered component. What heightens that danger is bearing failure. It follows, then, that turbine gearboxes require a good deal of TLC if they are to run dependably without sucking up every available dollar invested in their service warranties. It is really just another take on the old bromide — you can pay me now or you can pay me (much more) later. So a dedicated combination of planned, predictive — whatever you care to call it — maintenance and inspection is significant to gearbox life. And here's another reason that the upkeep on existing wind units is critical. As pointed out above, wind in the U.S. continues to be a relatively unpredictable market, so for sake of demonstrating that wind energy is a winning strategy for the country, it behooves the current players in the market here to ensure that those already installed wind turbines function to their designed capability.

So what's with gearboxes? Why so failure-prone? Reasons typically mentioned include quality-discrepant parts, defective material, faulty design and Mother Nature, with bearings as typically leading the pack in all categories. It has been reported that a wind turbine gearbox is replaced every five to seven years (Source: *DEWI* magazine, No. 39, August 2011). And, although according to Andy Milburn of Milburn Engineering, Inc., a gear consulting company located in Seattle, WA (*andy@milburnengineering.com*), "The typical *design* life (of a turbine) is 20 years," he adds that the real-life experience is that "most turbine manufacturers only offer warranties in the two to five year range."

And then of course there are insurance providers who quote coverage (liability, performance, etc.) rates based in large part upon—*exactly*—previous industry performance.

Toward that end, "I can only speculate that early detection of failures can significantly reduce the cost of repairs, especially if the difference is between deploying a crane to remove the gearbox or repairing it up-tower," says Don Roberts, P.E. and president of DA Roberts, LLC (*don@daroberts-llc.com*). "What has impacted the frequency of gearbox inspections most significantly

Depending on the assignment, rappelling is a valuable part of a wind turbine gearbox inspector's skillset (all photos courtesy NREL/Siemens AG).

is the warranty expiration, which usually occurs between two and five years."

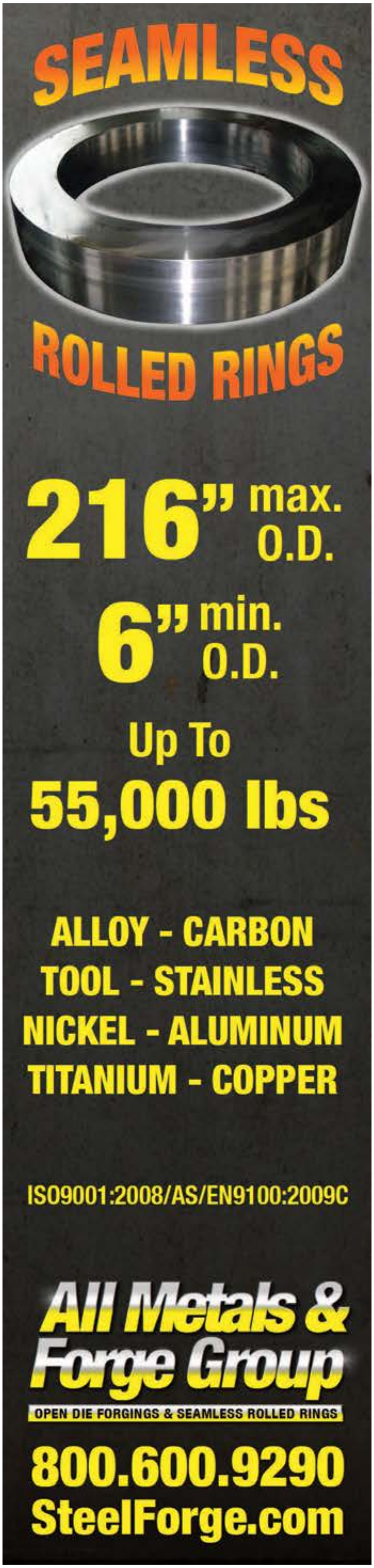
What does a comprehensive wind turbine gearbox inspection require? First, understand that there are four levels of gearbox inspection:

1. Quality assurance audits during manufacturing
2. Operations and maintenance (O&M) inspections
3. Tear-down inspections at end of warranty
4. Tear-down inspections for failure analysis

Trying to address all four in the space allotted here is not possible, so let's address No. 2—O&M inspections.

Given the complexity of the assignment, you wonder how many personnel are needed for the job. Is there, for example, a gear person, a bearings person, a lube expert, etc?

"Up-tower inspections involve two trained technicians who are good with a borescope," says Roberts. "Shop inspections may involve a number of experts, depending upon the nature of



the inspection. For example, gear failure may involve a gear expert, whereas a bearing failure may involve a bearing expert. Oftentimes, in wind energy, the engineering experts are gear and bearing guys. Unique failure modes may require a specialist from a university or manufacturer. Coordination is usually performed by a consulting engineer who is lead on the project, but may not have the highest levels of expertise in each discipline."

And at Spin Trends (a division of Frontier Pro Services; *frontierpro.com*), "My teams use two men," says Darrin McCulloch, vice president. "One highly skilled technician to provide bore scope inspections while the other is present for safety requirements, although typically is also well versed with inspection methodology. Our skilled inspectors are versed with standards, creative best practices of the inspection and author their own in-depth reports."

How long does a gearbox inspection take?

"That's best answered by people doing the inspections, but in my experience it takes about four hours once you get up to speed with a particular model gearbox," Milburn allows.

Or, according to Roberts, "Eight hours for a more thorough inspection looking at all planet bearings and working with custom fixtures to access hard-to-reach locations. More detailed inspection up-tower requires draining of at least some of the oil, maybe 40 liters."

As for the level of experience required to be a good gearbox inspector, it is not acquired easily. As Milburn points out, "There are two aspects to an inspection; the first is observing the condition of the components, and the second is knowing what that condition means and how serious it might impact life. The first part can be learned fairly quickly, but the second will take some time and really requires a lot of experience in failure analysis and forensics."

Anyone in manufacturing is well aware of the latest advances in condition monitoring systems and the savings they can provide. Regular inspection of potential trouble spots and addressing them when they are least expensive is huge; but how does that affect wind gearbox inspection?

"Vibration, wear particle monitoring systems and oil sample or filter element analysis are being used to help inform the scope of borescope inspections up-tower," Roberts informs.

"They have also been successful in early detection of failures, making the verification inspections easier due to less collateral damage within the gearbox," says Shawn Sheng of the NREL (National Renewable Energy


A robust, up-tower gearbox inspection regimen is critical to ensure steady performance.

Laboratory)/National Wind Technology Center (*nrel.gov*).

Spin Trends began using condition monitoring in 2003 while the rest of the industry was still talking about it. Our gearbox inspectors are also CM specialists." However, McCulloch says, CM is often not enough. "Technology such as condition monitoring, oil analysis, particle counters, temperature readings—and even fault logs—do not typically provide enough insight that allows management to make $20,000 to $320,000 decisions." In those cases, McCulloch says, photo documentation of the problem is often required.

And then there is non-destructive testing (NDT). It's a technology that plays a role in turbine gearbox inspection, limited though it may be. (It's a nacelle space issue.) Indeed, while Roberts explains that, "No, (NDT) is not commonly used (up-tower)," Milburn on the other hand says "(NDT is used) not just on gearbox inspections but plays a big part when gearboxes are disassembled for repair." Or, as Charles D. Schultz, PE/chief engineer of Beyta Gear Service (*gearmanx52@gmail.com)* and a *Gear Technology* technical editor points out, "You can use spray-can crack checks and ultrasonic testing up-tower, but magna-flux (NDT) equipment won't fit up there."

Bearings have been fingered as a leading root cause for gearbox failure. But what can be done? How about lubrication, a bearing's best friend?

"There is a huge amount of research on cracked raceways on intermediate and high-speed shaft bearings that may result in changes to current standards or practices," Roberts says. "It is more common to see off-line filtration systems added to reduce the amount and size of wear particles in the gear oil. There are brief discussions on off-line filtration systems in AGMA 6006 or the new IEC/FDIS 61400-4."

"An AWEA (American Wind Energy Association) operation and maintenance (O&M) working group has released recommended practices for changing oil in wind turbines, which is part of the larger set of O&M-recommended practices, available at: *http://www.awea.org/oandm*," says Sheng.

Material choice is another element of the mix under constant scrutiny, along with its counterpart industries—heat treating, surface finishing, etc.

"There has been more focus on bearing materials, heat treatment and surface coatings, along with superfinishing surfaces of gear and bearing elements," Roberts confirms.

And according to Milburn, "One particular gearbox manufacturer has experienced a high rate of failures due to inclusions in gear steel. In general I think most wind turbine gearbox manufacturers are specifying steel that is a higher quality than what has been used for industrial gears in the past."

There is also the ever-increasing size—and load assumptions—of today's turbines to consider. How does that relatively recent development affect an inspector's work? Are the measurement and other inspection tools of today adequate to keep abreast of such growth?

"The larger size brings additional sensors and accessories to the gearbox for monitoring and lubrication," says Roberts. "Those systems have a wealth of data that can be extracted by whoever has the monitoring contract, be it OEM, owner, or third party. The inspector does not always have access to that data, but it seems redundant, or even inappropriately matched, for the inspector to supply more sophisticated diagnostic equipment. What is needed, or would be helpful, would be a single-point diagnostic interface (read-only USB) with standardized communications protocols, similar to what the auto industry has developed. Imagine a standard that specified an essential list of data such as repair history, laboratory analysis results, significant events such as grid-loss stops, hours and production since rebuild (not turbine operating hours or production as is now typical). The inspector should be able to pull pertinent inspection snapshot information such as SCADA history for faults or temperatures, oil analysis results, condition monitoring trend lines, service history or log, etc. to a laptop or tablet by browsing or submitting a customized query to the gearbox service database.

As for Milburn, the size issue is more of a manufacturing concern.

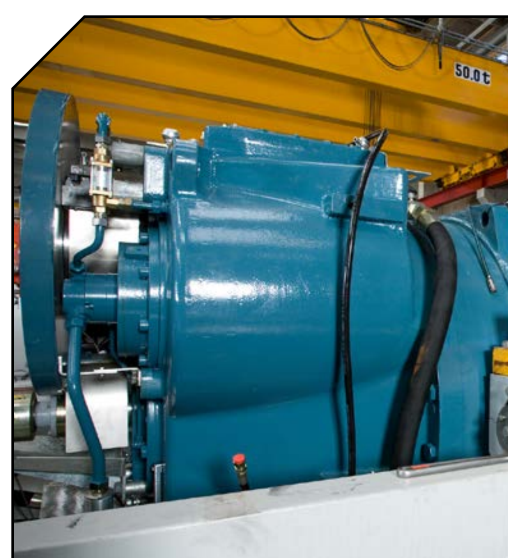
"Size is affecting manufacturing, but so far I don't think it has had much effect on gearbox inspections," he says. "The most used tools for inspection are still human eyes, cameras and borescopes."

Another critical gearbox component is what is known as an "acoustic signature," and every gearbox has one. That signature's noise level maximum is predetermined by regulatory dictates relative to that specific installation. How is that tested in the field?

"All wind turbine gearboxes are full-load tested as part of the manufacturing process," Milburn explains. "Vibration data measured with accelerometers is gathered during the testing. Each gearbox design has acceptance and rejection criteria that determine whether the gearbox is acceptable. The results during testing and initial operation in the field are then used to develop alarm levels for when vibration is monitored during normal operation."

As for acceptable noise levels in Europe (and a few U.S. locations), they are stricter and more prevalent, as determined by population proximity.

"Sound levels are a significant issue in Europe and some parts of the U.S. where the turbines are located closer to human activity," Roberts says. "Therefore, certification testing may include noise signature, which is published with the certification documentation. Noise testing is a very rigorous process performed by certification bodies; IEC 61400–11:2002 or AWEA 9.1–2009 are examples of acoustic noise measurement and analysis stan-



dards. Testing agencies must be accredited in order to provide valid test results."

Finally, a word or two about standards for wind turbine gearboxes. Most reading this are well aware that a standard—in both its implementation and evolution—comes about at a seemingly glacial pace—especially wind turbine standards with an international scope. But what drives the evolution of a standard? That is, what changes that in turn changes the standard? Is a standard, in a sense, always evolving? The answer to the last part of the questions is yes—but not always in a good way.

"A standard is the lowest bar that can be agreed to by consensus with everyone on the committee," says Milburn, adding, "Unfortunately, it does not represent best practice, and company commercial interests can override technical issues."

Adds Schultz, "Standards change because the committee members learn new things in the field or react to ongoing problems from the field. (For example), micropitting research is a hot topic in the wind turbine field right now."

"(A standard's) evolution can be driven by failures, or, due to large representation from industry, from within to improve manufacturing," Roberts explains. "In extreme cases, industry can implement or attempt to implement self-promoting language. Size of equipment in wind energy would be a good example of what is driving changes in the standards. The operating environment, off-shore for example, may also contribute."

Technicians working in a turbine nacelle brought in-shop.

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