SUPER-SIZED Quality Control

A Guide to Improving Big Gears

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It's not easy being big.

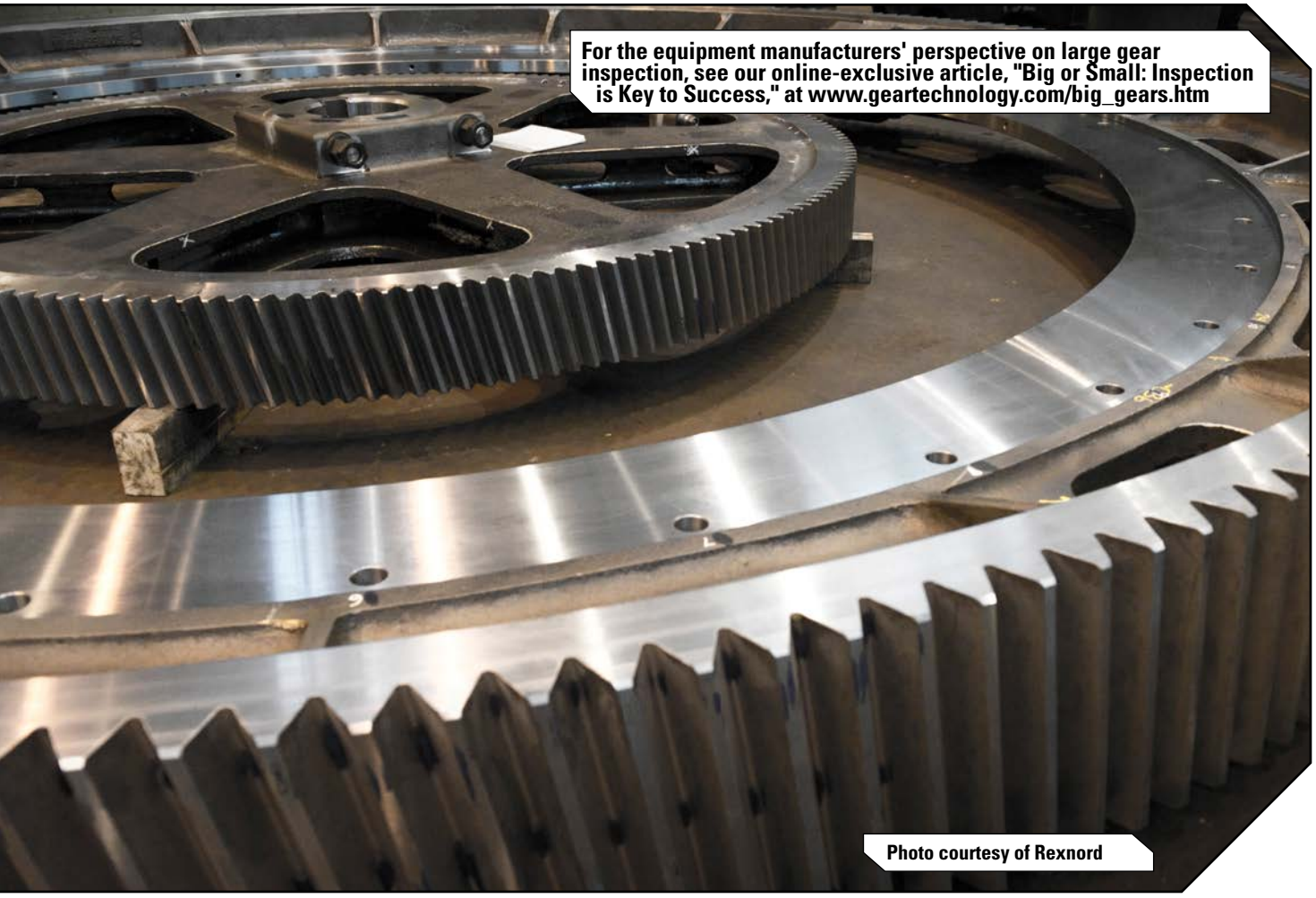
Maybe that's not exactly how the phrase goes, but it's applicable, particularly when discussing the quality requirements of large gears. The size alone promises unique engineering challenges. Those involved in producing large gears continually strive to meet higher quality requirements, adapt to new testing methods and seek out ways to top their own manufacturing capabilities. Seems an awful lot needs to go right in order to achieve the quality requirements necessary to survive in the big gear business.

"In-shop inspections are mandatory," says Fabrice Wavelet, product line manager, Ferry Capitain. "No customer can afford to put a gear into service that is not 100 percent sure/sound. A mining company, for example, can do nothing without a functional driving system on its mill, as 100 percent of the ore is going through it. Failure is not acceptable."

"The quality of large gears takes technical expertise, years of experience and proper equipment," says William Quinn, business development lead, mill products at Rexnord. "Improvements in materials, lubrication and gear quality levels have made positive impacts in the life of today's large gears. Modern gear cutting and grinding machines need to be met with equally advanced geometric inspection equipment."

"With higher accuracies of the gearing we can extend the lifetime of the equipment," says Holger Fritz, product manager mill gearing, Hofmann Engineering. "To be able to determine higher qualities, the measuring equipment has to be a minimum of one accuracy level higher than the item that is being inspected. This is a challenge for the future and we're working hard to improve the inspection methods and one day might have a minimum big gear (above eight meters) quality level of AGMA 12."

"While it's always good to improve the quality of large gears, the current requirements are *already* impressive thanks to ASTM A609 and ASTM E709 or E1444," adds Wavelet. "The same requirements for a 3 m gear and for a 10 m gear makes the 10 m gear of a comparatively higher



For the equipment manufacturers' perspective on large gear inspection, see our online-exclusive article, "Big or Small: Inspection is Key to Success," at www.geartechnology.com/big_gears.htm

Photo courtesy of Rexnord

quality, simply because casting such a heavy part (more than 20 tons a segment, finished weight) has nothing to do with casting a 3-ton segment."

Tools of the Trade

What's the best way to inspect these large gears? According to our big gear experts, it's a combination of many different tools.

"Hofmann Engineering is using laser trackers for the dimensional inspection on big mill gears and portable CMM arms to determine the form on the involute and the lead line," Fritz says. "For the pitch we use a special D&P pitch tester. But the ultimate test is still the mesh test of a precision ground mill pinion that is measured on a CMM together with the mill gear. Mill pinions are always measured on a gear CMM machine."

He adds that before they even start machining at Hofmann they use ultrasonic units and magnetic particle units to determine the quality of the material or of the welds.

"Varying challenges exist depending on the inspection required; in-process nondestructive inspections can be done with relative ease in the manufacturing environment. Once the gear is in operation, the same type of nondestructive testing can take a significant amount of time—from a couple hours to multiple days. Usually this involves shut down, removing guarding, and cleaning the area to be inspected of lubricant," Quinn says.

Other operational inspections can be completed continuously or with ease, such as vibration monitoring, lubrication testing, and infrared temperature monitoring," says Quinn. "In-process non-destructive testing is done primarily with magnetic particle inspection and ultrasonic inspection. Complex geometry in large gears can present challenges to ultrasonic inspection, but with skilled technicians and control processes we can overcome these."

For field inspections, infrared thermometers and cameras, and multi-axis vibration monitoring equipment with read out capability make continuous monitoring relatively straightforward. "More in depth field inspections of the gear may involve using a MAAG TMA gear checker to check pitch, magnetic particle inspection with a hand yoke, and standard ultrasonic inspection equipment," Quinn adds.

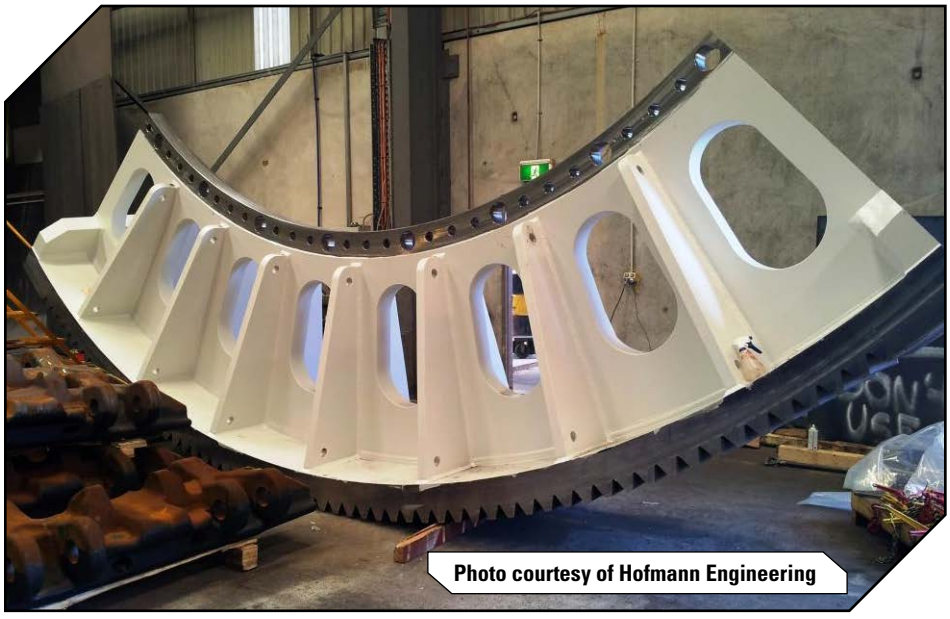


Photo courtesy of Hofmann Engineering

"The development of UT Phased Array and of Eddy Current (classical or Phased Array) is of the highest interest for us. These techniques have been successfully used on site, allowing an interesting time saving compared to the classical methods, but they are not economical on large surfaces and in-process inspections … for the moment," Wavelet says.

"The question regarding the most useful inspection can't really be answered as all the above mentioned inspections are necessary to prove that we manufactured a top quality gear," Fritz adds.

Why are so many different inspection requirements necessary for big gears?

"The size of the items in question," Fritz says. "Temperatures for example have a big impact on the final sizes and a temperature controlled environment is necessary."

Also, large gears today imply large module and consequently, large rim thickness, particularly when talking about foundry. "I suppose it is the same thing with forgings or plate; the main challenge is to maintain the high quality level required into such parts. For a gear module 36 in cast steel (something that was exceptional 10 years ago and usual today), the as-cast gear rim is easily wider than 220 mm, considering both the machining stock and the riser deformations. Avoiding internal indications as small as 5 cm^2 in this outer rim is the highest challenge a foundry is confronted with today," says Wavelet.

Such defects have to be avoided or the foundry undertakes the risk of having the part rejected.

"This is where the experience and the knowledge come into the equation, whether the gear is in steel or in ductile iron. The number of foundries capable of doing small gears (i.e. 3 m) in cast steel or ductile iron is high throughout the world. The number of foundries capable of producing the largest and most powerful gears today can be counted on the fingers of one hand," Wavelet says.

Although size matters, the inspection techniques (ultrasonic or magnetic particle) are identical for small and large gears… as well as the quality requirements.

"These techniques are reliable and repeatable when used by qualified personnel. The type of products being made for narrow markets use in-house inspection people. This is what we do in Ferry Capitain. All our inspection personnel are qualified ISO 9712 / Cofrend level 2 (at least equivalent to ASNT level 2) for UT, MPI, dye penetrant test and radiography, although these two last techniques are not commonly used on gears. Use of classical techniques, rather than the UT Phased Array, for example, is still justified as this saves time in production, while the equipment is economical. We believe at Ferry Capitain that the new techniques, including UT Phased array, are of the most interest, but for expertise, not production control," Wavelet says.

"Magnetic particle inspection is still the industry standard for checking sur-

face discontinuities; it is widely used and acceptance criteria are clearly defined by manufacturers and industry standards," adds Quinn. "Ultrasonic inspection is the accepted method for checking subsurface discontinuities. Continuous temperature monitoring, lubrication testing, and vibration monitoring are still the most beneficial inspections that can be performed in the field. Monitoring these parameters over time and tracking deviations from baseline readings quickly allow a user to identify potential problems."

One wonders how much time these techniques take from a quality control perspective.

"It really depends on the type of inspection being performed. In-process ultrasonic testing of our largest ring gears can take up to 7 hours; magnetic particle inspection of the teeth can run up to 3 hours per segment," Quinn says. "Field inspections consisting of contact checks and root clearance measurements can take from 4 to 8 hours. More involved inspections are usually scheduled during planned shut downs and can last from a couple days to a week plus."

Big Gear Standards

One area that continues to play a vital role in the inspection process is the gear standards. Whether it's AGMA, ISO, DIN or any others, they need to be updated and modified regularly to keep up with demand.

Fritz at Hofmann Engineering believes AGMA standards cover most of the inspections. "It would be good if they would have chapters about mesh test results, surface finishes and general guidelines for dimension tolerance. As a gear designer/manufacturer you know all about these things, but most third-party inspectors want to have some documentation/recommendation of an AGMA standard referring exactly to these points," Fritz says.

"AGMA 6014, and especially the next version, which should be issued sometime next year, addresses all the inspections and quality requirements large gears need to respect. We, at Ferry Capitain, have developed an intensive R&D program on materials and defects with the aim to be able to quantify the influence of surface or internal defects on the service life," Wavelet says. "The number and concentration of indications do not matter to us as one defect is enough to ruin a complete gear and compromise the driving function of it. Then, the size of a unique defect, and its location, are the parameter to be considered. A better understanding of the nature of the defect and its influence on the service behavior is what we are working on today."

Quinn at Rexnord agrees that the standards work but tweaks are in order.

"AGMA 6014 addresses magnetic particle, ultrasonic, as well as geometric inspections required during the processing of large gearing. The annex contains essential operational inspections and recommended frequency for large gears, recommending lube analysis, vibration monitoring, infrared alignment, visual inspection, gear joint tightness, pictures, contact pattern and root clearance. (But) the AGMA standard does not directly address nondestructive field inspection of ring gears," Quinn says.

Pushing the Technology Forward

What's next for inspecting big gears? What can the industry look forward to in the near future? Hofmann, Rexnord and Ferry Capitain all have ideas. The technology and the machines will grow, according to Fritz.

"I know of an eight-meter machine so far but I know that there are plans to build bigger machines. The challenge of big gear measurements will be to measure the much tighter tolerances of AGMA 12 or 13 on 15 m gears," Fritz says.

"The development of computer-assisted are not economically viable for in-shop inspection and for Eddy Current. It is thus probable Eddy Current will take over MPI in the close future, as this technique is easy, fast and reliable. As for

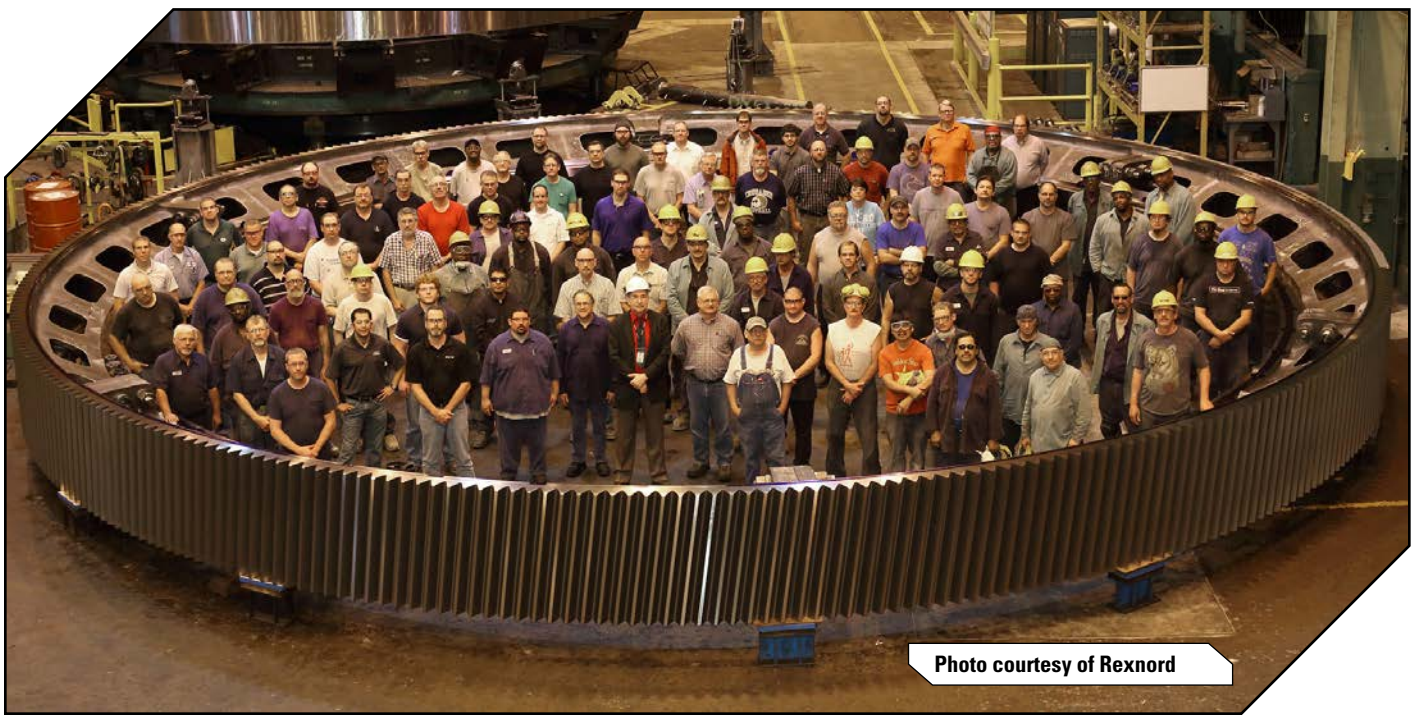


Photo courtesy of Rexnord

UT Phased Array, the only question that inspection equipment manufacturers have to solve is the question of probes: they have to be reliable, economical and adaptable to all kinds of materials, surface finish and size," Wavelet says.

"Improvements in continuous monitoring system analysis will offer faster indication of distress, helping plant personnel to make necessary adjustments and avoid costly downtime. Condition monitoring/analysis systems allow the user to identify a problem in one area before it has an adverse effect on equipment in another. Eddy current inspection is likely to gain ground as a quick and thorough way to check for surface discontinuities in ring gears, allowing the user to log a permanent record (map) for future reference. Phased array will gain wider acceptance as an improved method for inspecting subsurface defects as acceptance criteria are established and validated in the large gearing industry," Quinn says.

The technology is changing when it comes to inspecting large gears. Manufacturers of these components will be the first to tell you there are no shortcuts. Good news for those looking for the highest quality components for a massive application.

Photo courtesy of Ferry Capitain

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