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SG 160
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departments

Cover image by David Ropinski

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Klingelnberg

The Höfler cylindrical gear grinding machine Speed Viper focuses on high-productivity generating grinding in large-series manufacturing. Check out a video on its features and capabilities here: *www.geartechnology.com/videos/Cylindrical-Gear-Technology-/*

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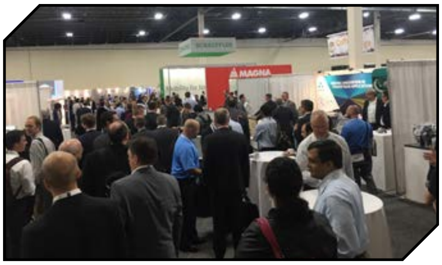
Browse our webpage dedicated to original content prepared by our editors, along with the help of gear industry experts from around the world. (*www.geartechnology.com/tv/*)



Editor's Choice: CTI Symposium 2018 Recap

Read all about the presentations and discussions on the future of the automotive industry as well as the latest transmission and mobility technology that took place at the CTI Symposium in Novi, Michigan: *www.powertransmission.com/blog/on-the-road-to-disruptive-technology/*

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But in many ways, what we're doing goes way beyond the GDPR. Yes, we want to protect your privacy. Yes, we want to use your e-mail address and personal information responsibly. But more importantly, we want to provide you with information that's of value to you, and we want to provide it in the way that makes most sense to you, not us. So we're asking you to confirm that you want the information, and we're asking you to specify how you want to receive it.

More importantly, we're asking you to tell us a little bit about yourself. It's not because we're nosy. It's because the information you provide helps us do our job better. Knowing who you are, where you work and how you're involved with the gear industry helps us craft our magazine, newsletters and websites in a way that appeals to the broadest spectrum of you.

In addition, this is part of a much broader effort on our part to better serve the gear industry. Even though we already have, by far, the broadest reach among publications serving our industry, we're committed to expanding that even further. We're investing heavily in our circulation because we believe very strongly in this industry, and we want to serve as many gear industry professionals as we possibly can. So far our efforts have paid off greatly. In the past month alone, we've grown our requested circulation by 10%, and we're only just beginning. Mind you, we're not just dumping in names to pad the list. We're sending our magazine and e-mail products to more people who want them. And that's our goal.

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The Junker Group

EXTENDS GRINDING MACHINE RANGE WITH CORUNDUM LINE

The Junker Group has extended its range of grinding machines: With its new Zema corundum line, the company is offering efficient solutions for conventional grinding. Versatile, robust, durable — Junker corundum grinding machines fulfill the requirements of series production for a wide range of different workpieces. The CNC grinding machines grind elements such as flanges and journals on crankshafts as well as gear, turbocharger and cardan shafts or spray nozzles with the utmost precision and reliability. In total, the corundum line comprises three models, each of which has different focal points.

The Numerika is designed for the series production of a wide variety of different workpieces — up to a length of 3.50 meters in the biggest model. The cylindrical grinding machine Kargo takes ultra-heavy workpieces such as shafts for generators or electric motors with weights of up to six tons easily in its stride. Rounding off the range are the Flexa corundum grinding machines, which are capable of solving up to three grinding assignments with the utmost precision. Whether internal or external grinding and even thread grinding: The modular design of the robust Flexa series makes it ideal for small and medium-sized production runs.

These corundum grinding machines are the ideal addition to the CBN high-speed grinding machine series from Junker. They come with a robust machine bed, hydrostatic guides and grinding spindles mounted on rolling or hydrostatic bearings as standard. A user-friendly control system comes with all the necessary input masks for precision corundum grinding and excellent surface quality.

Designed for integration into production lines, the corundum grinding machines also come with a high level of automation. At the same time, they offer the flexibility needed for grinding workpiece families: Several types of a workpiece family can be stored in the control system, allowing a quick changeover from one workpiece to another in production. To ensure a trouble-free production sequence, the corundum grinding machines are also equipped with automatic loading and unloading systems.

For more information:
Erwin Junker Machinery, Inc.
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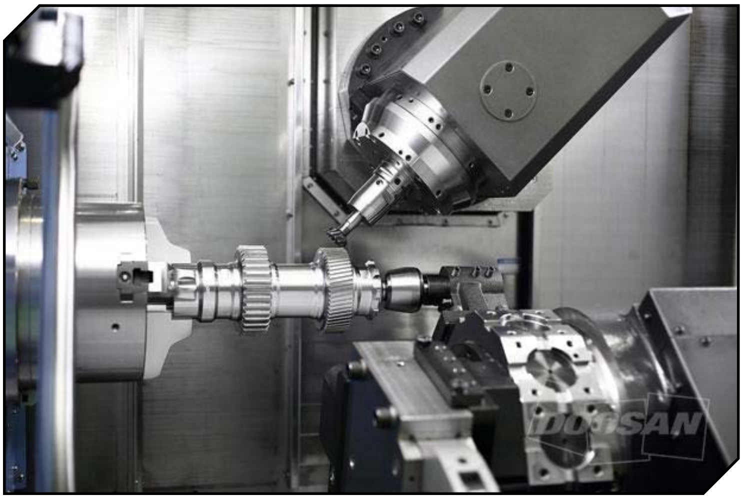
www.junker-usa.com

Doosan Machine Tools America

INCREASES CAPABILITIES OF MULTI-TASKING TURNING CENTERS



If you want to turn out more completed parts on a single machine with less operator time, Doosan has released the PUMA SMX ST series. These super multi-tasking turning centers have axes everywhere. Both left and right spindles are capable of high accuracy C-axis control and the machine can perform various machining functions like turning, milling and synchronized cutting all with a single set-up.

The ST models come with all the advantages and features of the SMX series. For starters, they have high-rigidity machine construction, minimized thermal deformation via oil coolers, an accuracy control feature based on multiple thermal compensation functions and a Y-axis machining area that has been maximized through orthogonal design. Along with the largest machining space

among the same-class machines, they come standard with Doosan's famous ergonomic features that enhance operator convenience and efficient maintenance.

The ST versions include the addition of a lower turret turning/milling function to the existing left and right spindles and B-axis milling function. The turret comes on both of the new SMX ST models: the 10" chuck version (PUMA SMX2600ST) and 12" chuck version (PUMA SMX3100ST). The addition of a lower turret with 12 tool stations allows operators to be even more productive on a single mill turn CNC machine. A static turret is standard, and turret for driven tools is optional, but this lower turret isn't just for tools. Operators can also drop in workholding equipment like steady rests, follow rests, tail stock center and two jaw vises.

The SMX ST series comes with many features. It starts with a full 5-axis multitasking turning and milling machine with a 12,000 rpm milling spindle and 80 tool ATC. Then they added a lower 12 station turret that can offer turning or milling capability while still utilizing the upper milling head to truly multi task.

For more information:
Doosan Machine Tools America
Phone: (973) 618-2500
www.doosanmachinetools.com

GWJ Technology GmbH

INTRODUCES NEW VERSION OF SYSTEMMANAGER

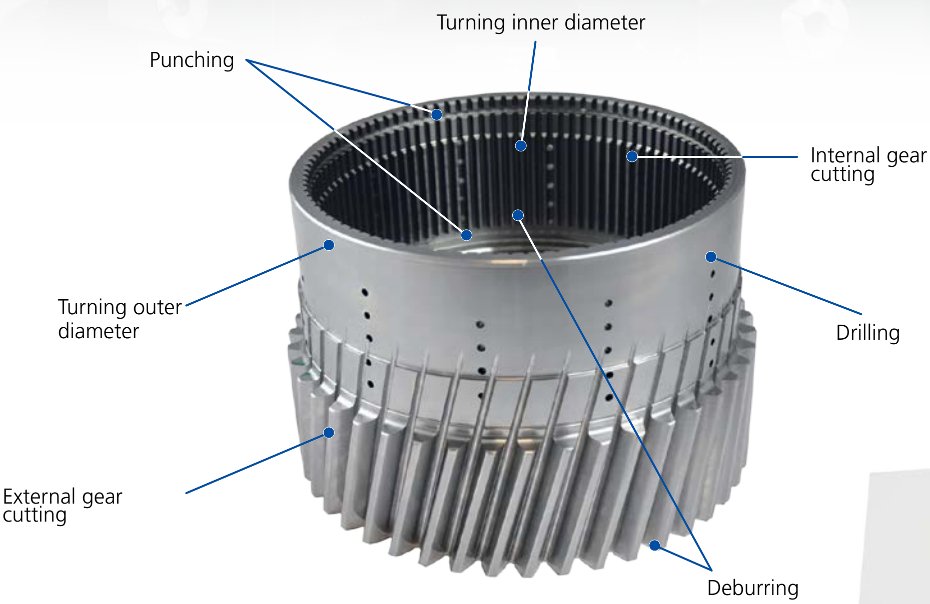
SystemManager is an extension to the web-based calculation software *eAssistant* (web solution) and *TBK*. *SystemManager* is a true software application for complete systems of machine elements, i.e., the software is a coupled FE calculation of multishaft systems with gears as non-linear coupling elements. The new version provides an alternative method of importing and automatically meshing housings and planet carriers. This offers an even better mesh quality and allows a meshing of very complex geometries, for example the geometries of gearbox housings in automotive applications are known to be very complex. The system calculation considers now rotating 3D elastic parts for the calculation of eigenfrequencies (e.g., of planet carriers) using modal reduction.

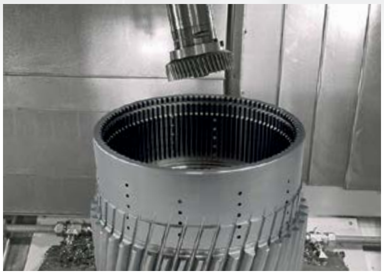
Coupling connections were added in addition to the previous connection types cylindrical gears, planetary gear trains, bevel gears, worm gears and belts. It easily allows to consider hydraulic or electric connections between subsystems. Many small extensions had been added like splitting or merging shafts in addition to copy, shift or mirror options. All bearings types are now drawn with separated inner and outer rings in 2D and 3D views.The animations for 3D mode shapes therefore allow a better understanding of the movement in the bearings. Graphics can be frozen inside the program to allow comparisons and a copy option using the system clipboard was added for graphics for quicker transfer into other documents. The default

POWER SKIVING

Efficiently geared. Completely machined.

The skiving center PITTLER PV315 is the preferred machining solution of a manufacturer of marine transmissions. In search of an integrated solution with several machining processes like turning, drilling, punching, gear cutting as well as deburring the PITTLER PV315 met all his demands. The flexible use of technology allows him to machine the part with a maximum of two chucking processes, thus guaranteeing highest surface qualities. Thanks to the highly efficient gearing technology Power Skiving, the transmission manufacturer can now produce internal and external gearings without changing the setup. At the end of the day, he saved the purchase expenditure of 5 single-process machines plus the time-consuming re-tooling, transport and storage cycles. Just recently, he invested in a second PITTLER PV315.





Efficient production of internal and external gearings in one clamping setup.

PITTLER PV315

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- Integrated tool magazine for complete machining
- Single clamping operation for highest precision

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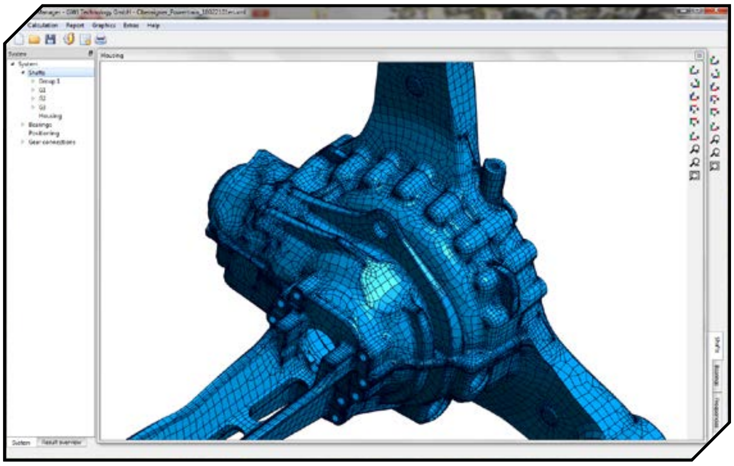

Emuge

INTRODUCES SELF-LOCK SYSTEM FOR THREADING TOOLS

Emuge Corp., a manufacturer of high performance taps, drills, end mills and other rotary tools, has announced its thread making tool quality is available in a Self-Lock integrated locking system. Emuge Self-Lock threading tools offer a high quality alternative in thread locking for vital safety applications in aerospace, medical, communications, transportation industries and more.

The Emuge thread locking feature is integrated in the internal thread, and has a modified profile with a 30 degree ramp surface in the direction of stress which provides the self-locking effect. In an ideal screw connection for high-stress situations, where there is a standard external thread in an Emuge Self-Lock internal thread, the internal thread yields a self-locking screw connection that can be used repeatedly.

"The special profile of the Self-Lock thread allows an even distribution of stress over the entire thread length and therefore eliminates slippage," said Mark Hatch, product director at Emuge Corp. "We are pleased to offer such a safety critical threading solution which results in no stripping of threads and is cost-effective because no additional components are necessary."

Compared with standard threads, the Emuge Self-Lock internal thread shows constant, maximum holding power under dynamic stress. Functions remain in good operation even with repeated loosening and re-tightening of the thread connection. This locking effect is caused by the ramp-shaped surface integrated into the thread profile.

Self-Lock technology results in increased threading tool life for larger thread hole diameters and provides larger tolerances for thread hole diameters. Also, assembly is easy with no assembly errors possible such as forgetting the locking device. To gage Self-Lock threads, Emuge recommends using its two-piece gage system which corresponds to the usual combination of a go/ no-go gage.

Emuge Self-Lock Threading Tools work with standard external threads (screws) with tolerance class "medium". Internal threads can be produced with Emuge taps, cold forming taps or thread mills.

For more information:
Emuge Corp.
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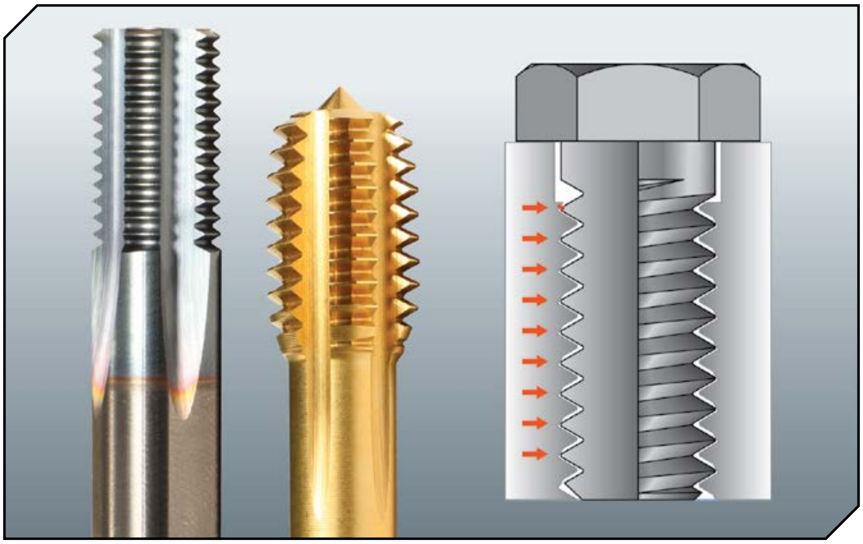
www.emuge.com

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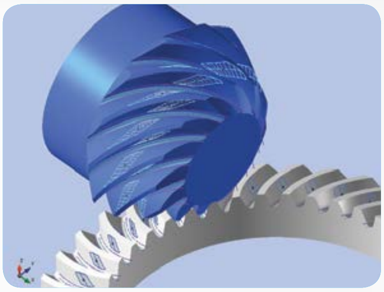
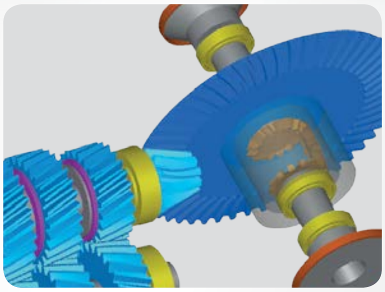




Mahr

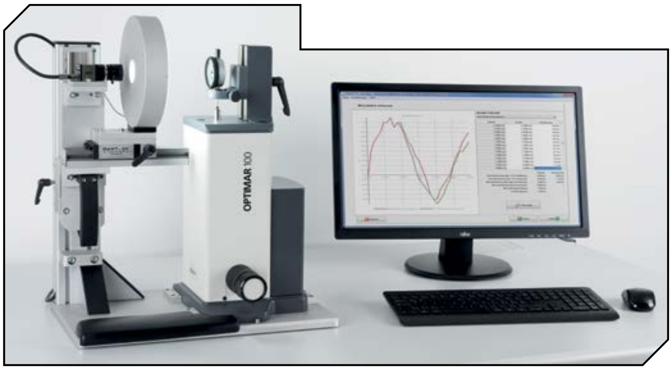
OFFERS OPTIMAR 100 WITH IMAGE PROCESSING

Mahr Inc. recently expanded its Optimar 100, a proven solution for testing dial and digital indicators, test indicators and dial comparators, with image processing for the automated testing of measuring equipment. A new upgrade kit now makes working with the measuring instrument safer and faster: a camera automatically records the indicated values of the test indicators and forwards them to a software for processing. The automated procedure saves time and replaces the exhausting and error-prone reading by the operator.

The hardware and software add-on package provides a cost-efficient way to equip existing measuring stations with Optimar 100 for automated testing. The measuring system, including image processing, is also available as a complete package under the name "Precimar Optimar 100 BV."

The upgrade kit incorporates a USB 3.0 camera for fast image processing, and stable daylight-independent LED illumination along with secure digital identification and reading of digits. The *QMSOFT* software controls the measuring device, evaluates the camera image of the scale or number display of the test object, compares the values with the high accuracy internal reference scale and automatically completes the process of calibrating the product under test. The software also makes it possible to create and store test certificates.

The easy operation of the Optimar 100 with image processing speeds up and facilitates the monitoring of the indicators under test. With the auto-recognition of the vision system, more test items and data points can be recorded faster than with conventional manual methods. Since this is a completely automated inspection system, the operator can be more productive in other operations while the Optimar 100 automatically completes the calibration process. This makes indicator inspection much more economical.



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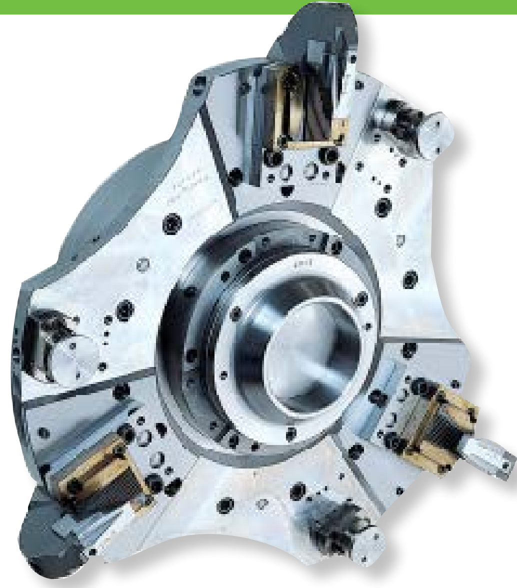
Kitagawa NorthTech

ANNOUNCES SUITE OF AUTOMOTIVE WORKHOLDING SOLUTIONS



Kitagawa NorthTech, Inc., recently announced their suite of automotive industry workholding solutions, which bundles together advanced and custom engineered workholding products ideally suited for automotive industry machining applications. The advanced workholding series are Kitagawa NorthTech advanced chucks and custom fixtures that have been engineered, modified and/or customized to solve part specific machining for a myriad of automotive industry applications, including: camshafts, valves, cylinder pumps and heads, differential cases, brackets, clutches, covers, holders, gears, hubs, pinions, pulleys, rotors, rollers, pistons, chassis components and more.

The suite of automotive industry advanced/engineered chucks and workholding for automotive applications from Kitagawa NorthTech includes:

- DL200 — Dual locking chuck with increased gripping options and easy jaw forming ideal for high volume automotive machining applications.
- PWc and PWTc — 2 or 3 Jaw Power wing chucks with powerful gripping for irregular work pieces and tapered parts. Provides secure gripping for casting and forging applications.
- PU Type Pull Lock Chucks (PU, PUB and PUE) — Draw down chucks for high precision processing available with open center types. High radial gripping forces and strong pullback action allows for stable cutting under heavy load conditions.
- FG Finger Chucks — for high speed turning of 3 jaw wheel chucks for automotive and motorcycle aluminum wheels and 6 jaw chucks for OTR trucking applications.
- Collet Chucks — Short series collet chucks, long series collet chucks, quick change collets chucks and pull back collet chucks.
- Custom Fixtures — Weldment or Casted base custom fixtures for a variety of horizontal and vertical machining applications.

For much information:
Kitagawa NorthTech
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www.kitagawa.com

Cutting Down on Setup Time

With increasingly smaller returns from improving the speed of the actual gear grinding process, improving your setup time has become a primary way to keep improving efficiency. Here's the latest on how you can do that today.

Alex Cannella, Associate Editor

You can speed up setup time with new solutions that reduce or virtually eliminate the need for tools during setup.

With machining time itself having gotten shorter and shorter over the years — to the point where it's starting to see diminishing returns — savvy manufacturers looking for ways to improve efficiency have turned towards setup as one of the most important steps of the manufacturing process to shave time off of.

Everyone approaches the task of reducing setup time differently. Bill Miller, vice president of sales and service at Kapp Technologies, splits his company's solutions between mass production lines and batch manufacturing job shops. It's obvious why job shops that frequently switch between small batch production runs would benefit from improved setup time. Dr. Rolf Schalaster, manager of the competence center for bevel gear grinding at Klingelnberg, predicts that for small batch job shops, setup can even take up to 50 percent of a manufacturer's time. But Miller believes it's also an equally important topic for mass production companies, even if they only set up a machine once or twice a day. Even if you're only grinding the same workpiece repeatedly, grinding tools wear down and need to be swapped out. Workpieces still need to be periodically tested for accuracy. These processes take time, and they can be reduced with the proper tools.

According to Dr. Antoine Türich, director of product management for hard finishing solutions at Gleason, there are four broad categories in which setup time can be reduced: the mechanical work of physically exchanging tools, workholding, and so on; teaching and setting up a particular job before beginning the actual manufacturing; inspecting finished workpieces; and applying the eventual necessary corrections.

There's also a great deal of focus on reducing workplace errors, as they can be one of the greatest sources of lost productivity. Time spent fixing a mistake is time lost not machining.

Different companies have taken a few different strategies to accomplish this. Some make the setup process simpler and provide instructions on how to set up the machine, while others cut out the chance for user error entirely through automation.

Suffice to say that people have come up with a lot of inventive ways to reduce setup time over the years, and we're going to highlight as many of them as possible. While some of these processes are well-known and have been around for a while, they're still constantly evolving and are joined by other newer or less orthodox ideas.

Reduce the Need for Tools

One common way we can hasten the setup process is to simplify it. After all, the more straightforward something is to setup, the fewer steps and less expertise required, and by extension, the easier and faster the work will be. One primary way machine manufacturers are accomplishing just that is by simplifying the design to reduce the number of tools required to set up a machine.

"Sometimes, you need a whole toolbox with different tools to setup the machine," Türich said. "Our solution now requires just one simple tool, which makes it much faster and easier."

The solution Türich is referring to is Gleason's Genesis GX threaded wheel grinding machine series, a prime example of the idea. Every screw you need to interact with to complete setup has been standardized so that the machine can be completely setup from start to finish with a single Allen wrench. According to Türich, a central focus with the GX was to make sure the machine was as fast and easy to set up as possible, requiring only 10 minutes of setup time to change out the grinding wheel, dressing tool, workholding and gripper inserts before you're ready to get machining.

Gleason can still do one better than that, though. According to Uwe Gaiser, director of product management of bevel gear solutions at Gleason, the process can be as simple as just hitting a button or flipping a switch. Just hit a switch to release and swap out the workholding in a process that takes "just a few seconds" instead of dozens of minutes tightening screws. Combine that with a hydraulic, spring-loaded chucking system, and cutters can be rapidly swapped out with ease.

"We have the same accuracy, but instead of taking 10 minutes, you can do this in 30 seconds depending on the size of the cutter," Gaiser said.

According to Miller, reducing the need for tools can be particularly useful for mass manufacturing because it reduces the need for specialized expertise. In Miller's experience, many larger high-volume manufacturers can have their processes grind to a halt whenever a machine needs to be adjusted as someone runs to fetch an expert. That might sound like a mundane and barely noteworthy issue, but when workpieces can be ground out in seconds or minutes, taking 10-20 minutes to hunt someone down, get them over to the machine and solve the problem can put you behind.

Kapp's KX-100/260 Dynamic machines give high-volume manufacturers a boost by requiring zero hand tools or wrenches to set up, meaning no expertise required. Just put the tool on the flange and the machine handles the rest.

More and more setup processes are becoming entirely automated, both saving time and reducing expertise required to operate the machine.

Automate!

Of course, options like the KX Dynamic series that just lets you plug a tool in and go couldn't exist if the entire process wasn't automated to run itself. Many processes ranging from changing out the clamping device to verifying the runout are fully automated, reducing the amount of time skilled workers have to spend working on a specific machine.

Kapp's advances are only one part of a larger trend towards automation, the latest advances of which are doing their part to help combat the skill gap and reduce setup time as much as possible.

"In a global view, today's machine operators are not necessarily experts on what they have to do like in former days with manually operated mechanical machines," Schalaster said. "We believe that setting up obviously has to be as fast as possible. But in addition, it also has to be as safe as possible since mistakes can quickly lead to time- and money-consuming damages. Therefore, we try to make the system smarter so that the single setup steps are easier, faster and potential sources of error by the operator are avoided."

Gleason's Genesis GX series has multiple new innovations designed to cut down on setup time and simplify the process.

Klingelnberg has developed a number of ways to help machine operators and reduce errors with automation. This can manifest in small quality of life upgrades to existing processes such as how grinding machines won't start a grinding process if the wheel hasn't been reprofiled after loading profile corrections have been finished, or include bigger, standalone solutions such as a smart tooling system.

The tooling system is based around data matrix codes, which each fixture tool in the system comes with. Scan the code and the fixture's geometry gets loaded directly into the machine without any need for input from the technician. Klingelnberg is also working so that in the future, a machine will automatically know the geometry of both new and used wheels immediately after tool changes, reducing the time required to program the machine before it gets to machining.

The tooling system is also currently being implemented to work with Klingelnberg machines' automatic fast profiling program, which minimizes dressing time by automatically determining any necessary reductions of a grinding wheel's length and which areas need to be dressed based on a list of four to six parameters input by a technician. According to Schalaster, Klingelnberg would like to shave that time down even further by implementing the smart tooling system so that technicians won't even need to input the tool's parameters, and can instead just scan the tool and go.

Klingelnberg's tooling fixtures themselves have also seen a few modifications. Most notably, the fixtures can be mounted entirely outside the machine, meaning that the tools for the next job on the machine can be prepped while another job is already running. Once it's time for the next job, it only takes a handful of unscrewed bolts and a few quick steps and the next tool's ready to go. The way Klingelnberg handles its fixtures is just one example of a company-wide focus on another way you can cut down on setup time. Namely...

Do More Outside the Machine

While other companies focus on application-driven solutions or individual steps of the process, Klingelnberg has a taken a unique approach to improving setup time. Schalaster categorizes each element of the setup process as either external setup, which can be done outside the machine while it's working on a previous job, or internal setup, which requires the machine to stop. It's not much of a surprise that many of Klingelnberg's efforts focus on reducing internal setup as much as possible, and they've opted to do so by shifting as much of that labor into external setup processes as possible.

"A decisive issue is to shift as many steps as possible from internal setup time to external setup time," Schalaster said.

One such solution is what Schalaster calls a "one piece oil ring," which is designed for reducing the time required to set up oil pipes and nozzles for your coolant. The idea is for each nozzle to be mounted on a single ring that can be quickly exchanged during setup. Instead of taking time adjusting your nozzles for a new job while the machine is forced to stand idle, you can just swap out pre-adjusted sets of nozzles on each ring and go.

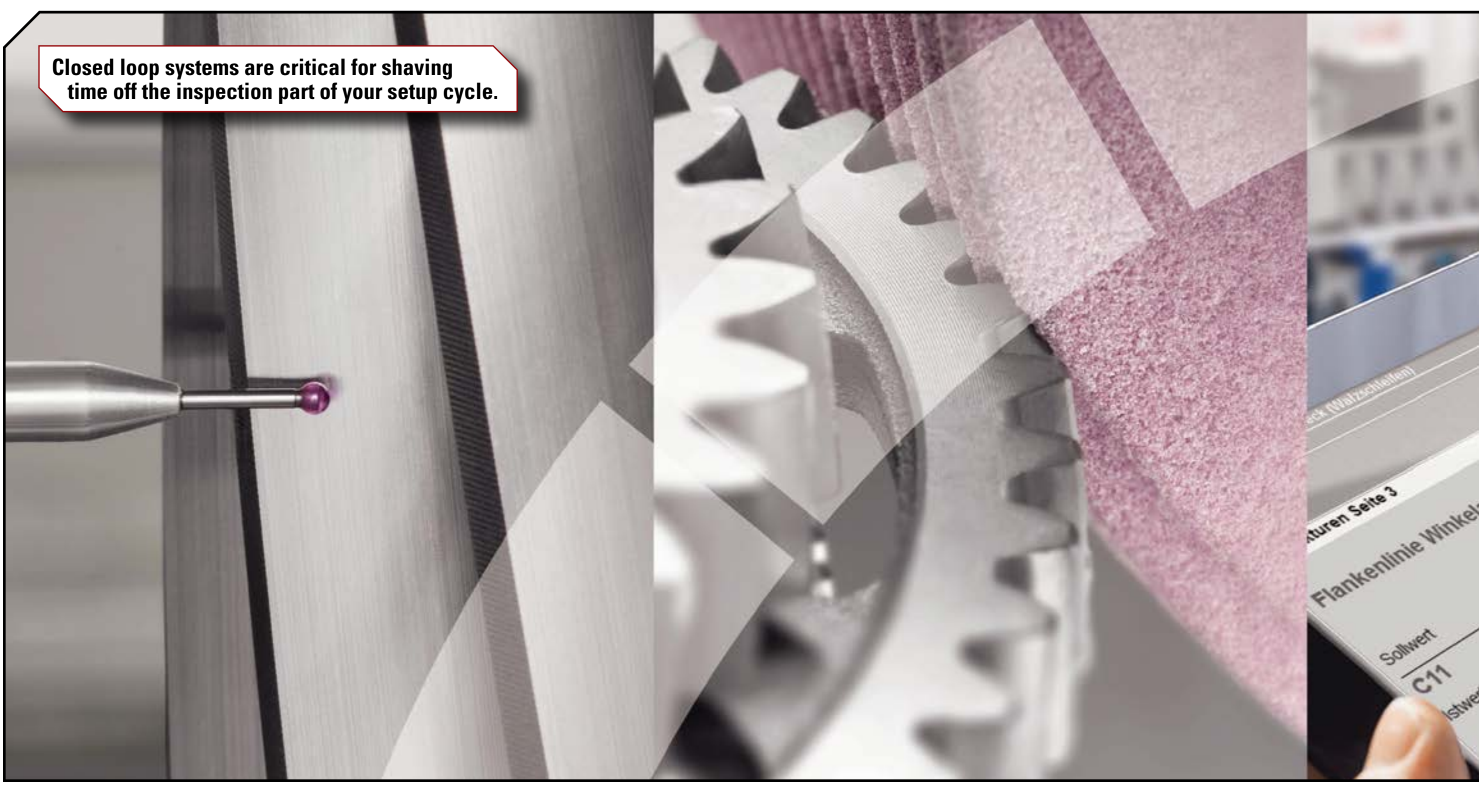
Customers have a few options on how they want to take advantage of the oil rings. Mass manufacturers that only have a machine work on a few different parts can have multiple oil rings that they can slot in and out as each one is needed. For batch manufacturers working on many small projects, however, Klingelnberg also offers a tool trolley that allows you to pre-set an oil ring for the next job while the previous one is still running that can then be slotted in when it's time for the next workpiece.

Get Multitool Machines

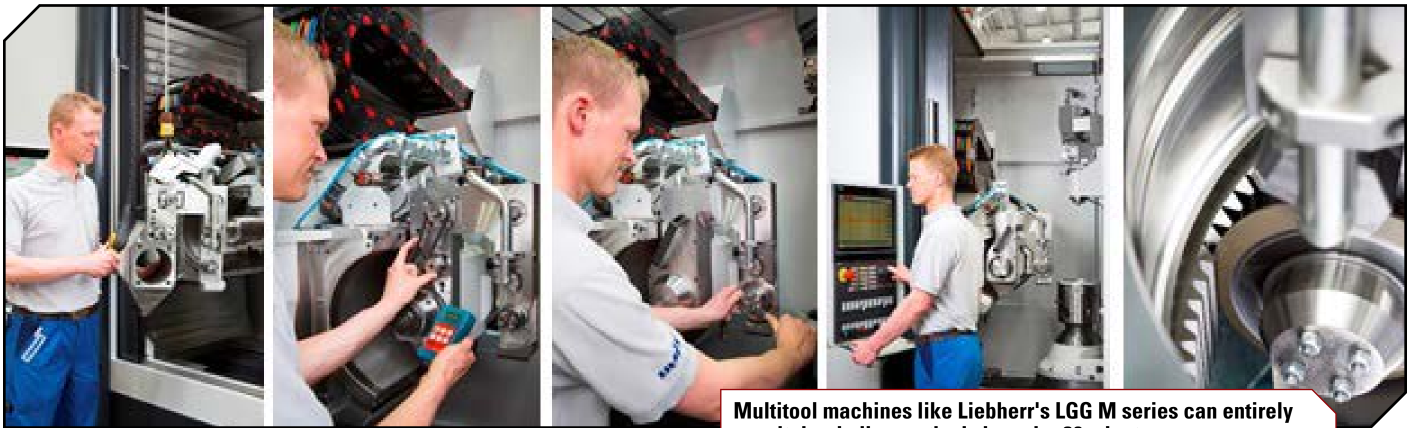
Shifting as many steps as possible to be done outside a machine isn't the only way you can physically cut down on your setup time. You can always get a machine that combines both external and internal grinding, such as Liebherr's LGG 180/280/400 M series, which can switch from generating grinding to internal profile-grinding in less than 30 minutes.

How does Liebherr accomplish this? For one, they make sure the process is simple and easy. The machines' internal grinding arms can be mounted directly onto the external grinding heads. Like with some earlier machines we've highlighted, no hand tools are required to change out parts like inserts or the clamping fixture. Dressing tools are easy to switch out thanks to a hydraulic expanding arbor. A machine mounted jib-crane automatically mounts the internal grinding arms and changes over grinding wheels. And then there's Liebherr's LHGeartec software, which allows the engineer to load any necessary programs for a given project either at the machine or from an external server and can lead the technician through the setup process with its HMI.

Samputensili's SG 160 Sky Grind similarly utilizes both hobbing tools and a grinding wheel in a single machine. The hobbing tool quickly removes most of a workpiece's stock allowance in one pass, then a second pass with the grinding wheel finishes the job. In addition, it can also change workpieces in the same lot in under two seconds, further reducing downtime by shaving off the margins



Closed loop systems are critical for shaving time off the inspection part of your setup cycle.



Multitool machines like Liebherr's LGG M series can entirely switch grinding methods in under 30 minutes.

of time between each individual workpiece's manufacture.

"The part changing time on the Samputensili SG 160 Sky Grind dry grinding machine, and its wet grinding equivalent G-160, have a very quick part change," David Goodfellow, president of Star SU, said. "It is important to change the workpiece in the same lot in product in less than two seconds. This requires high speed machine movements and design changes to realize this important cycle time reduction."

In general, Star SU and its affiliated companies have specialized in improving setup time with servo and hydraulic quick change actuating devices for hobbing, grinding, shaping, shaving and CNC tool and cutter machines. Like a few other solutions tackling setup time that we've described, these quick change devices are run without requiring any hand tools or specialized labor. They've also begun to implement those same quick change components in grippers.

Up Your Software

Improving and iterating upon a machine's software is a pretty common method for reducing setup time. Gleason's Genesis GX series, for example, also features software guidance on its screen that will take even unskilled operators through every step of the setup process, telling them exactly what they need to do. It reduces mistakes and allows less skilled operators to work more quickly, both of which translate to less downtime.

Türich related a common occurrence from when Gleason was showing off their Genesis GX line at open houses where, after demonstrating the feature, visitors would volunteer to try and set the machine up following its instructions and, on the spot, were able to do so.

"They were really impressed with how easy it was and how fast they could learn it by using the software-guided instructions right on the machine," Türich said.

Teach Your Machine

Software can also help improve your setup time by enabling your machine to learn how to do new jobs faster than ever before.

According to Türich, one primary holdup in the setup process is the need to teach a machine new motions. Meshing cycles, initial dressing, adjusting coolant nozzles, calculating the tool position; all of these steps take time and expertise to properly execute, and Gleason has developed software that takes the machine through each of these steps on its own in 10 minutes, prepping it right up until it's time to start machining parts.

"We have taken all these sub-cycles and created a complete new one we call the First Part Cycle," Türich said. "And what this First Part Cycle is doing is going through all the steps which are necessary after the mechanical work until the first workpiece is being ground on the machine. So the machine does everything automatically."

Similarly, you can opt to have your machine remember a job so you don't have to teach it twice in the first place. Gleason offers software for CNC controls that allows their machine to save and remember past settings.

"You can ask after an hour, after a day, after a year," Gaiser said. "If the customer comes back to a specific ratio, it's really just the push of a button to activate that data, activate that machine summary, and you have the same data like you used to have whenever you had the job the last time on the machine."

The benefit of a repeatable setup is self-evident: manufacturers can maintain accuracy and, more importantly, repeatability while greatly reducing setup time by skipping any required calibration.

"If you don't have a repeatable setup, you will have to redevelop the job again…" Gaiser said. "The most preferable way would be to be as close as possible to the part geometry where you had left off the cutting or grinding process whatever time ago."

Streamline Inspection

Unlike with Gleason's other solutions, Türich stressed that much of the inspection process is outside of the company's control. The process isn't fully automated, so there will be variance depending on how quickly a technician works, and there is no solution for two technicians that need to use the same inspection machine at the same time. But looking at it from the opposite angle, streamlining those processes could also lead to improved efficiency. Organizing your workflow so that everyone isn't setting up their machines at the exact same time (and thus needing to inspect workpieces) and would reduce the potential for downtime where your technicians would be sitting around waiting.

One step that Gleason has implemented is a closed-loop system in which a Gleason inspection machine sends the inspection results directly back to the production machine, removing the risk of errors when interpreting results or inputting incorrect values. The production machine compares the actual values with the programmed target values and applies the necessary corrections automatically.

Closed-loop systems aren't necessarily revolutionary today, but they're still an essential tool in reducing your setup time. For example, Klingelnberg's Komet software suite automatically calculates corrections to reduce flank form deviations and remembers past corrections the grinding machine can load on its own. Klingelnberg has been working on expanding the software's applications, most recently translating it to cylindrical gear manufacturing, in addition to already being used for bevel gear grinding. But despite the fact that Komet isn't even a new product and its only recent updates have been to expand its applications, the software suite still recently won an Industry 4.0 award, highlighting just how influential and important closed-loop systems still are.

Norton's Xtrimium grinding wheels can grind and polish a gear without having to be swapped out from the spindle.

Use One Wheel to Grind and Polish

Reducing the time it takes to set up a machine is all well and good, but what if you didn't have to change your setup between jobs to begin with? An option to consider is a grinding wheel that combines two different wheels into one.

For example, Norton | Saint-Gobain has been developing a new line of grinding wheels called Norton Xtrimium that help master the challenges in worm grinding, profile grinding and bevel grinding. The new line includes dual-worm grinding wheels which combine a vitrified bond section to grind and a fine-grit resin bond section to polish the teeth of the gear, delivering an improved surface finish quality to reduce gear noise in the final assembly. The dual-worm wheels can be adapted to existing machines.

"Gear manufacturers are being asked to hold tighter tolerances, improve productivity and improve surface finish," Jennifer Thompson, application engineer at Norton | Saint-Gobain, said. "So instead of having to swap out grinding wheels mid-job for different steps of the process, manufacturers can use the Xtrimium dual-worm gear grinding wheels to rough and finish grind on one spindle to achieve cost and time savings."

Get Your Supplier Involved

A major part of the setup process can be dressing a wheel before getting to the actual grinding. Manufacturers have come up with a few ways of handling this situation, including dressing a second wheel while the first one grinds so it's ready to swap in the instant you need it, but Miller recommends getting your supplier to do the dressing for you. Batch grinders in particular can improve their efficiency by getting their supplier to pre-dress their worms before they even arrive on your doorstep.

"Working together with the supplier, it is possible to get that form much closer to the final form to reduce that time," Miller said.

The idea is to reduce dressing time during manufacturing by essentially having your supplier do some of the work, such as pre-dressing, for you. According to Miller, this can save up to 30-40 minutes of setup time.

Don't Use Just One

Often, many of these solutions are built upon each other, work best alongside each other, or even appear standard together in one machine, such as with Gleason's Genesis GX and Kapp's KX Dynamic. Not every solution is going to fit your specific needs, be they batch manufacturing, mass production, or based on a specific grinding method, but hopefully this has given you a few ideas as to the wide array of options available to take advantage of, and you'll find a few that you can leverage.

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Shake, Rattle and Roll

Software Providers Examine the Dynamic Behavior of Gear Noise

Matthew Jaster, Senior Editor

Some truth about gear noise: Electric motors compared to combustion engines are close to inaudible. For both electric and hybrid vehicles the engine noise that is covering the gear noise is gone, therefore, in low-speeds when tires and wind noise are low, the demands to the gears are much higher concerning noise.

In pure electric cars, gear speeds are typically higher (10,000 rpm vs. 2,000 rpm), which increases the problems with noise, according to Dr. Michael Platten, senior product manager and NVH specialist at Romax Technology. The pressure is on manufacturers to placate gear noise by analyzing data, optimizing gear systems and testing results.

"After decades of optimizing noise of wind turbines and kitchen appliances, the focus switched to electric cars lately. There is now a significant market for battery electric cars, with much higher demands on low-noise gearboxes. In addition, there is always pressure on price in automotive. So, we now need low-cost, low-noise gearboxes," said Dr. Stefan Beermann, CEO at KISSsoft AG.

Meeting Gear Noise Challenges Today

Platten believes there are essentially four main challenges today when looking at gear noise:

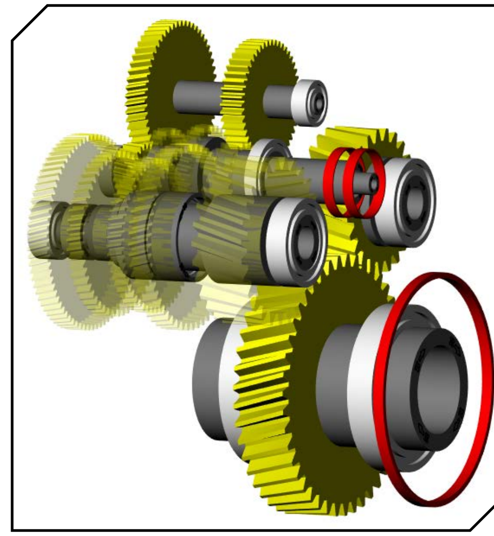
The challenge of reducing product development times and costs while simultaneously meeting the demands of improved noise and vibration quality.

The challenges of electrification in the transportation industry with new powertrain designs and aggressive noise targets.

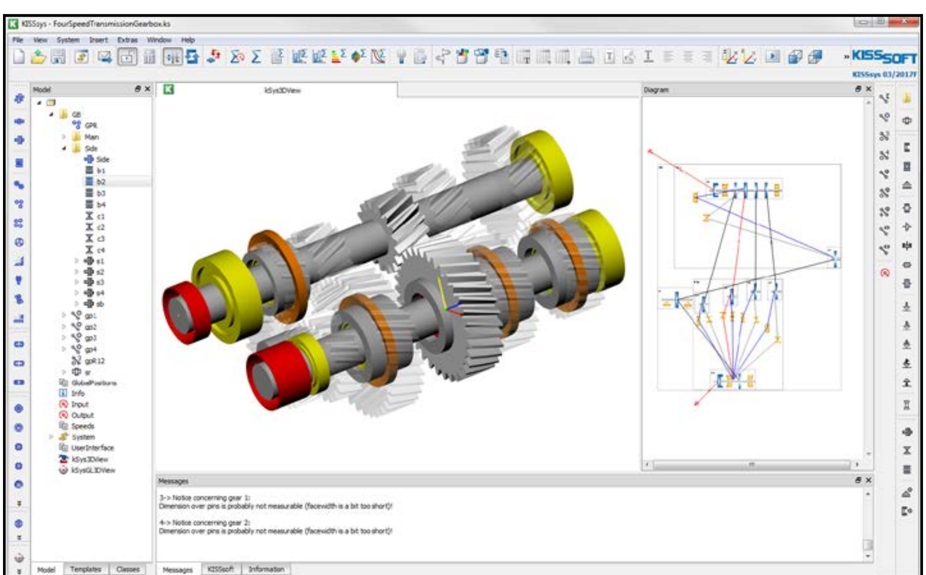
The challenge of understanding the effects of production variability on gear noise and vibration performance.

The challenge to make everything lightweight in automotive and aerospace sectors which is driven by efficiency concerns, but has a significant impact on gear noise and vibration.

As software solutions continue to increase, gear noise can be better evaluated through virtual, predictive and efficiency coverage of the physics in the overall system, according to Christoph Schweiger, team leader of structural dynamics simulation at AVL.



KISSsoft examines the reliability of the system with its software tools.



KISSsys includes assessment functions that evaluate the relevant properties of gear meshes which lead engineers to the best solutions.

"You're looking at a variety of things happening inside the transmission, for example, when studying gear rattle," Schweiger said in a recent webinar titled Efficiency and NVH Simulations for Transmissions. "There are repeated impacts caused by the movement of free parts (loose gears, synchronizer rings) within their active backlash. Another important driver is the torque fluctuation from the engine. You need to have a gear contact model, study oil resistance, the roller bearings, shaft flexibility and housing flexibility. All of these things must be considered in detail when calculating gear rattle."

KISSsys, for example, is a gearbox design software. Integrated into the software are assessment functions that evaluate the relevant properties of gear meshes, the most important feature being the contact analysis under load which simulates the flank contact over the whole meshing cycle.

"The important influence factors like all involved stiffnesses (tooth, gear body, shaft, bearing, housing), the exact tooth shape, misalignments and tolerances, are taken into account. Based on these assessment functions, optimizations are automated and lead the engineer to the best solutions for their current problems," Beermann said.

To meet the challenge of modelling and simulating the combined electric machine and transmission system, Romax software lets the user build a complete structural model of the full system and analyze the complete dynamic behavior.

"Gear mesh excitation forces are calculated directly in the software and close partnerships with electric machine modelling tools like *MDL Motor-CAD* and *Cobham Opera* allow seamless integration of the electric machine structural model and electromagnetic excitation forces with the transmission model. In this way the effects of the electric machine structure on gear noise can be considered and likewise the effects of the transmission dynamics on the electric machine noise are taken into account," said Platten.

To address the issue of balancing durability and efficiency with noise and vibration performance in the high speed, high duty environment of electric drivelines, Romax's simulation tools provide the ability to analyze and automatically optimize all these performance targets simultaneously. Romax customers like GKN use this within a *Right First Time* development environment to maximize performance and quality of their EV solutions.

"We're moving into a new era of hybrids and electric cars. Genuinely high-performance products demand the effective application of system knowhow from concept to production, so you can find the best possible balance," said Theo Gassmann, vice president, advanced engineering at GKN Driveline.

"The methodology used allows advanced parametric studies to be carried out in an all-in-one approach with *RomaxDESIGNER* to consider the effect of a wide range of design changes on efficiency at the same time as durability and NVH performance," added Dr. Artur Grunwald, supervisor, advanced geared systems calculations, GKN Driveline.

For understanding the role of gear noise within the context of today's new EV chassis designs and the seemingly infinite range of proposed hybrid and EV layouts, Romax works closely not just with gear and transmission engineers, but also with driveline integration and vehicle NVH teams. By linking to other tools like multibody dynamics and whole-vehicle NVH simulators Romax tools are being used by customers to look at gear whine and rattle under dynamic torque loading and predicting directly how designs sound and feel at the driver's ear.

Schweiger at AVL explained the process of determining gear whine and gear rattle in transmissions.

"The NVH Generation and Transfer process typically begins with an excitation mechanism followed by amplification, damping, transfer and then the response, result and assessment. Our research looks at whine and rattle in everything from passenger cars, trucks and tractors to industrial machinery, wind turbines and aircraft transmissions," said Schweiger.

Simulation & Testing

Testing and simulation play an important part of the process even though many interviewed believe that this data is highly subjective and not always guaranteed.

"With simulations the number of prototype tests is reduced. So, there is a huge gain in speed and cost reduction, if the number of tests can be minimized," Beermann said. "Still, noise is a complicated enough issue, that no simulation can give a 100% guarantee that the predicted noise behavior is true. This means that the final step in the development must be a prototype test."

Simulation is critical to ensure the best noise quality from the start. For too long noise and vibration has been considered as "something you do at the end to make it quiet". Continuous simulation during all stages of the design allows engineers to iron out problems before they become problems.

"It is also the main driver in reducing development time and costs by speeding up design time and reducing prototyping cycles. It avoids the need for major remedial noise treatment late in the design when the opportunities for significant design changes are limited," Platten said.

Platten continues, "Of course, testing still plays a role — we can never eliminate prototyping completely — and in the electric vehicle world, we need to be sure that the simulations we are doing actually work by comparing them with real-world noise and vibration tests. Once engineers have the confidence provided by correlation test, then simulation-led design becomes the norm."

Ultimately the "digital twin" concept is what Romax is aiming for, where almost all of the engineering design process for transmissions and drivelines is test-free and the prototyping phase becomes merely a verification exercise. To achieve this, you need to have engineering design processes — not just for noise and vibration — that work across CAE tools, across departments and even between different organizations (OEMs and suppliers, for example).

"Our strategy is to concentrate our efforts as much on streamlining and automating the process as we do on providing simulation technology," Platten added.

A Systematic Approach

Beerman said that during the design phase, a systematic approach asks for a definition of macro parameters first (for gears that would be parameters such as module, number of teeth, pressure angle) and then a refinement by applying micro modifications, like lead and profile modifications for gears.

"Going to the second step too early means blanking out a large field of potentially much better solutions," Beerman said. "For strength, this is often not so critical, but for the higher demands on low noise gears this might cause insurmountable issues."

At Romax, Platten mentioned the "Right First Time" as a philosophy for CAE-led design.

"Nowhere is this more important than in the consideration of noise and vibration. Design decisions made right at the start — like tooth numbers and contact ratios - have the most impact on noise in the end while details like micro-geometry design that are considered later can only really fine-tune what is already set in stone. It is therefore critical that consideration of gear noise is considered systematically from beginning to end," he said.

When dealing with gear noise in transmissions, Schweiger believes there are always tradeoffs. "Areas such as performance, fuel consumption and emissions, temperature and thermal management, packaging, durability and costs can be affected."

It's essentially a balancing act to get the gearbox to run smoothly, quietly and efficiently while reducing costs and energy consumption. You can't focus on one single area to get the best results. The vibration of the entire system comes into play when evaluating noise and performance, according to Schweiger.

So how can you best identify and analyze noise issues when you may be utilizing different people in different departments that are responsible for NVH and durability?

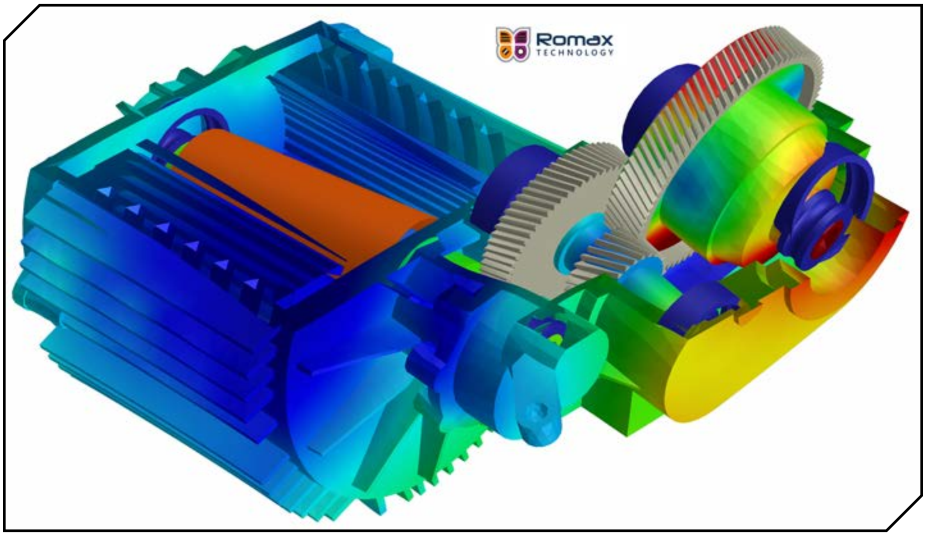
"Those people need to be educated in each other's areas and be provided with the tools that help them to make sure they do no harm to each other's aspects of the design," Platten added. "We must ensure that the processes for modelling and analysis are fast and robustly repeatable."

Selecting the Right Tools

So, the take away here is that it helps if the software toolbox is diverse and the staff is properly trained to utilize it to examine potential noise issues.

KISSsoft, for example, offers public and individual training about methods on how to tackle noise problems with gears.

"And we do noise optimizations for gears ourselves, using these methods. However, it is important to understand, that there is not one optimal way to low noise gears that always works. It is more like an optimization process that might go through several loops. The important part is to understand the mechanisms that generate noise and to know the influence of the parameters controlled by the engineer," Beermann said.



Romax follows a "Right First Time" philosophy for CAE-led design, according to Dr. Michael Platten.

"In KISSsoft, we have integrated tools and algorithms that help with the assessment of gear noise. In addition, we offer interfaces to dedicated vibration software, for deeper analysis. With this, the user gets the best of two worlds, an easy to use gear design software and a software that is specialized on vibrations, but not on gears," he added.

Working alongside the Romax tools for gear whine analysis and electric machine noise, the company also provides interfaces and links to a number of other tools which support design for gear noise and help customers to create integrated and automated CAE processes:

Interfaces for gear contact analysis and transmission error calculation which support our own contact simulations: *OSU Gearlab LDP* for helical gears. *Ansol*, *Gleason CAGE* and *Klinelnberg KIMoS* for bevel and hypoid gears.

Interfaces to FE tools like *MSC Nastran*, *Altair Optistruct*, *Ansys* and *NX Nastran* for pre- and post-processing of components like housings and complex shafts for dynamic simulation of gear noise

Interfaces to acoustic radiation tools like *LMS Virtual.Lab Acoustics*, *MSC Actran* and *Ansol Coustyx*

AVL offers software suites such as *AVL Excite*, software for the simulation of rigid and flexible multi-body dynamics of powertrains. It is a specialized tool that calculates the dynamics, strength, vibration and acoustics of combustion engines, transmissions and conventional or electrified powertrains.

AVL Fire is a CFD simulation tool in the field of combustion analysis. It specializes in the accurate prediction of all IC Engine relevant processes including injection nozzle flow, fuel injection, combustion, emission and exhaust gas aftertreatment. The software also supports the development of electrified powertrains and drivelines.

Collaborate and Innovate

"The best way to meet the multitude of challenges discussed in this article is to tackle issues such as fundamental validation of the methods for simulating gear noise, which have worked previously for conventional drivelines, but which are now being pushed due to increased speed, and the subsequent impact on, for example, gear contact through interactions with tribological factors," Platten said.

Additionally, work is needed to simulate vibration and noise of structures at very high frequencies, where the FE starts to break down, to investigate energy methods which give less detail but provide better ability to make engineering decisions about high frequency behavior and which take into account inherent variabilities at high frequencies.

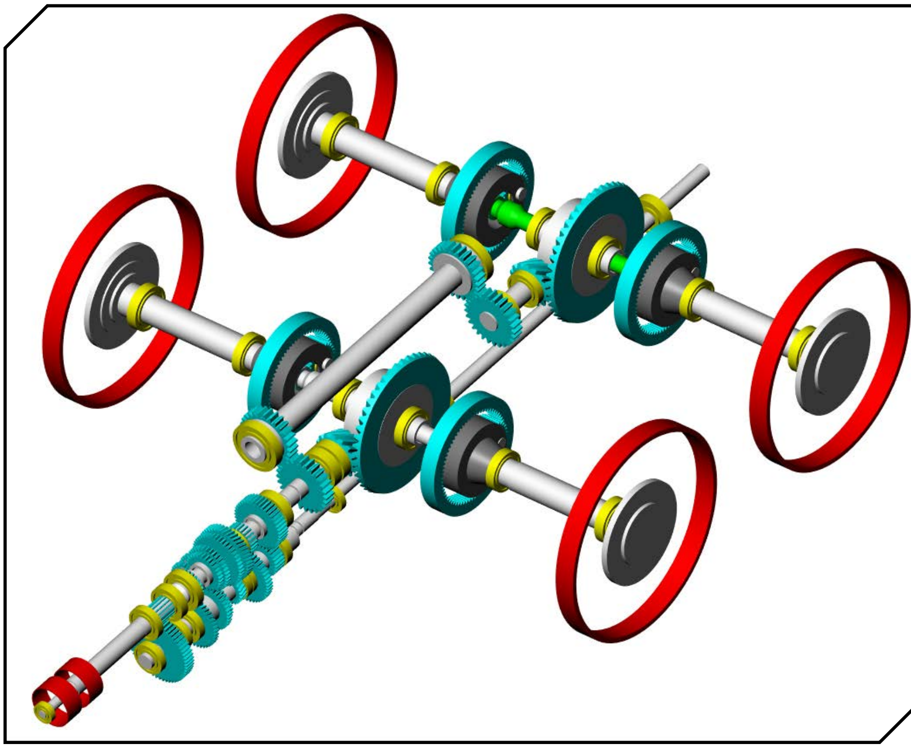
"For gear noise, Romax has worked with the Gear and Power Transmission Research Laboratory for over 10 years. Researchers at Politecnico di Torino and TU Darmstadt have both also published work on their use of Romax software for simulation of gears in novel applications: the former on optimization methodologies for lightweight gears produced by additive manufacturing techniques using *RomaxDESIGNER* simulation, and the latter on investigating novel concepts for range-extended electric vehicles," Platten said.

The outcome of projects with institutions such as Ohio State's Gear Lab or the FZG in Munich often are the basis for standards and also go into commercial software such as *KISSsoft*.

"In the gear world, the topics of strength, efficiency and noise will always benefit from close cooperation between industry and universities," said Beermann.

All in all, gear noise is just one of many design challenges that pop-up in a variety of industrial applications. The automotive industry is a focal point today as we discuss electric vehicles, mobility and new transmission and efficiency requirements. In a few years, there will be another area where software providers will need to develop new innovative, solutions.

Who knew that being quiet could be quite so complicated?



After decades of focusing on gear noise in wind turbines and kitchen appliances, the focus has switched to automotive and vehicle applications, according to Dr. Stefan Beermann at KISSsoft.

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Selecting the Right Tooth Thickness

Email your question — along with your name, job title and company name (if you wish to remain anonymous, no problem) to: *jmcguinn@geartechnology.com*; or submit your question by visiting *geartechnology.com*.

QUESTION

We are currently revising our gear standards and tolerances, and a few problems with the new standard AGMA 2002-C16 have arisen. Firstly, the way to calculate the tooth thickness tolerance seems to need a "manufacturing profile shift coefficient" that isn't specified in the standard; neither is another standard referred to for this coefficient. This tolerance on tooth thickness is needed later to calculate the span width as well as the pin diameter. Furthermore, there seems to be no tolerancing on the major and minor diameters of a gear.

Expert Response provided by John M. Rinaldo. AGMA 2002-C16 does not specify any tolerances; it is up to the designer to select the tooth thickness and tolerance, or maximum and minimum tooth thickness, appropriate for the application. The designer must also select the tolerances for the major and minor diameters of the gear.

Figure 1 Span measurement from AGMA 2002-C16, Figure 7. (All graphics courtesy of AGMA.)

The manufacturing profile shift coefficient — commonly referred to as "the x factor" — is not required by AGMA 2002-C16. In fact, if the manufacturing profile shift is known, the only thing it is used for is to calculate the normal circular tooth thickness at the reference diameter. The standard provides methods to convert not only profile shift coefficients, but almost any other specification of tooth thickness to other ways of specifying tooth thickness or to measurements that can be checked when the parts are manufactured. For example, if the maximum/minimum transverse tooth thickness is specified at a given diameter, equations are provided to find the maximum/minimum normal circular tooth thickness at the reference diameter. Then the maximum/minimum acceptable measurement over balls or any of the other measurements covered can be calculated with the equations provided.

AGMA 2002-C16 also provides methods to determine tooth thickness based on measurements that are indirect. For example, if a span measurement is taken, then the normal circular tooth thickness at the reference diameter can be found using Equation 67.

Although AGMA 2002-C16 does not specify tolerances for tooth thickness, annexes B and C provide guidance on establishing tooth thickness specifications in either the nominal or functional system. The nominal system is more commonly used, and allows measurement over pins or balls or with span. The functional system allows a more direct calculation of expected backlash, but requires the tooth thickness to be measured in relation to the datum axis. Such measurements are typically performed on a double flank tester, a gear measuring machine, or from a datum surface to a single pin or ball.

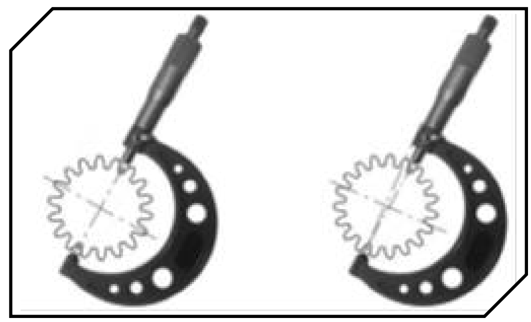

Figure 2 Measurement over balls from AGMA 2002-C16, Figure 10.

Tooth thickness and backlash are intimately related, which is why AGMA 2002-C16 covers both topics in a single standard. In establishing tooth thickness, the goal is generally to ensure that the expected range of backlash will be appropriate for the application. In many applications — particularly when rotation is unidirectional — backlash is not particularly important. In these cases, allowing a wide range of backlash and, therefore, a large tooth thickness tolerance, will keep manufacturing costs down. When tight control of backlash is required, as in indexing applications, then not only does the tooth thickness need to be tightly controlled, but the other gear tolerances may also need to be tighter to allow the tooth thickness tolerance to be met. The gear tooth

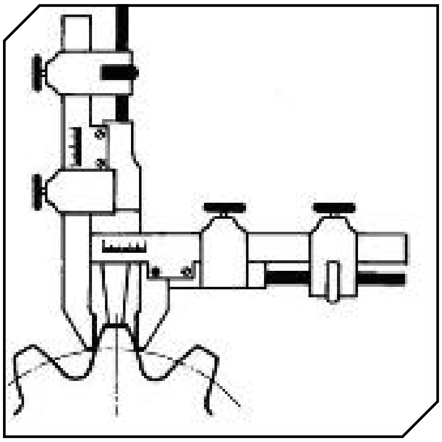

Figure 3 Chordal measurement from AGMA 2002-C16, Figure 21.

thickness measuring method may also need to be carefully chosen, since the method selected can affect both the ability to tightly control the tooth thickness and manufacturing cost. For example, for a large gear a chordal tooth thickness measurement can provide a quick and inexpensive measurement, but unless the radius to the outside diameter has been accurately determined from the datum surfaces, there will be a considerable uncertainty in the calculation of functional tooth thickness. Measurement of pitch on a gear measurement machine will give a direct measurement of functional tooth thickness, but at a high cost. Double flank measurement can be used to quickly measure the functional tooth thickness of all the teeth on a gear, but generally is only applicable to small gears produced in high volumes.

The selection of the appropriate range of tooth thickness is no easier than the selection of any of the myriad other choices the designer faces, such as selecting the appropriate numbers of teeth, the module, the helix angle, the face width, the material and heat treatment and the elemental or composite tolerances.

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Predicting Life on Through Hardened Steel Rack and Pinion for Jacking Applications in the Offshore Industry

Adrian Nowoisky

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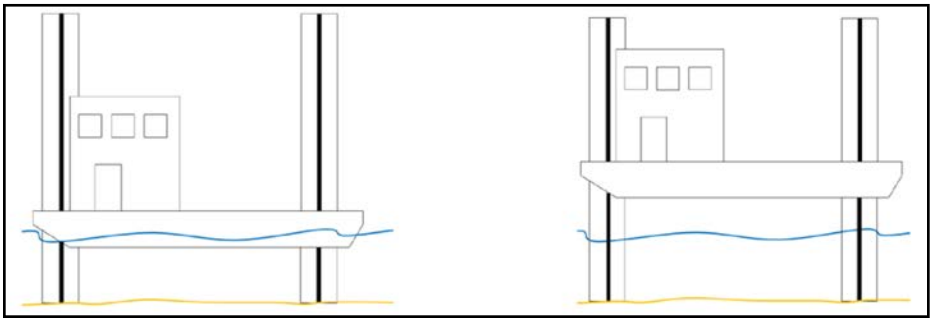

Figure 1 Liftboat illustration.

Introduction in Industry and Application Requirements

Lift boats and jack-up drill rigs are able to self-elevate the hull from sea level. These vessels use either a pin-and-yoke-type jacking system or a rack-and-pinion system to raise or lower the hull. These applications are used for every kind of off-shore service, installation or exploration — mainly in the energy industry. There will be more attention payed to the challenges of the definition and analyzation of a rack-and-pinion-type system. Unlike an enclosed gear mesh, the jacking part is exposed to sea water and other influences in an offshore environment. Only biodegradable grease is used for the rack-and-pinion, depending on the architecture, with an automatic lubrication system. To give an idea of the scope of such gearbox and pinion size, Oerlikon Fairfield is manufacturing its largest gearbox for such vessels with a ratio of 7764:1 and weight of close to 11 metric tons. A matching pinion for this gearbox would have a weight of 3 metric tons and a module of 95–110 mm. In the offshore industry these pinions are made with 7–8 teeth, and a typical pressure angle of 30° for the mechanical benefits known and published (Ref. 1). Designing and sizing a rack-and-pinion system, per AGMA and ISO gear calculation, is challenging when it comes to predicting the gear life on contact stress. The main focus on the gear calculation is to satisfy the root bending strength with sufficient safety margin to the load spectrum. The reason for this is the severity of such failure, perhaps causing loss of the vessel or even lives. The main gear characteristics of a rack-and-pinion application are: low speed, high torque and a low number of load cycles. Furthermore, it can be stated that the contact stress level of a rack-and-pinion is starting where the S-N curve of ISO and AGMA standards end. However, to have confidence in their own gear design and to satisfy the certification body, a different approach must be taken in order to justify the acceptance of such high contact stresses in these unique applications.

Material and mechanical properties typical for this application. The rack material is a high-strength, through-hardened material that is purchased as a cutting process. The rack will be welded to the leg structure that can be 250–300 ft. (76.2–91.4 m) tall for a lift boat. An example of the rack material is ASTM A514 high-strength steel (1.8974 per EU grade). In most applications the material selection is driven by the certifying body and therefore special steel selections are made based on the rules and recommendations of the certification body. The pinion typically is made out of 4340H (1.6511 DIN) as through-hardened material, or some applications use carburized materials such as 1.6587 18CrNiMo7-6 (close to AISI 4320).

For the sizing example given in the following pages, these materials and material properties are used as specified:

	Pinion	Rack
Material:	4340H	ASTM A514 Grade Q
Heat treatment:	Quenched and tempered	Quenched and tempered
Surface Hardness:	36–40 HRC	21–23 HRC
Min. Tensile strength:	160 ksi [1103 N/mm2]	115 ksi [793 N/mm2]
Min. Yield strength:	140 ksi [965 N/mm2]	90 ksi [620 N/mm2]
SN curve:	Steel, Grade 2 HB300 AGMA	Steel, Grade 2 HB200 AGMA
	Through-hardened steel, alloyed	Through-hardened steel, alloyed

max. 8 in. (203.2 mm)-thick steel plate. The teeth geometry is generated in a flame cutting process and smoothed with a grinder. There are racks that undergo a machining process after the flame plate

Operation of a lift boat. As stated, the typical duty for a lift boat is moving to the work area to elevate the hull for more stability (Fig. 1). In Figure 1 two images illustrate the lifting of the hull above sea level. For a solid stand, the legs are designed with pads at the bottom. These pads are supposed to penetrate the sea floor for a more stable stand. This enables the platform to stay firm during operation, as well as in rough weather conditions.

Loads and duty cycle. The loads are separated in static loads under calm and moderate weather conditions, and combined loads where weather conditions are taken into account to the operational loads. In most cases the certification body is ruling out load cases for review. In the current example, we will review the static loads from:

- Leg operation — lifting and lowering only one leg
- Hull operation — lifting and lowering the complete hull
- Preload operation — extra weight taken into account
- Leg and hull holding — static loads only

And combined loads are taken into account as well, such as:

- Preload holding — hull elevated with extra loads from the environment
- Storm holding — hull is elevated and high waves hit the elevated vessel
- Test load — test load according to certification body rules

Rack-and-pinion geometry. A rack-and-pinion geometry was chosen from the Oerlikon Fairfield product line, since there is a substantial history in service as well as fundamental analytical work done to this system over the time of service and recertification process. The main characteristics of rack-and-pinion system are shown in Table 2.

Analytical Evaluation

This section will show and discuss the results according to gear calculation standards. As well, it will briefly discuss a theory based on Brinell stress to quantify the life of rack-and-pinion systems for the contact life.

ISO 6336 vs. AGMA 2001-D04 root bending stress assessment. The calculation is performed according to ISO 6336: 2006 Method B, and AGMA 2001-D04 root bending stress calculation (Refs. 2–3). It was chosen to use both methods, since the ISO calculation takes a rack or internal gear for root bending stress into account. The differences between each standard will not be discussed further here. The results are showing throughout the load cases high root bending stress. In Figure 2 we see sufficient root bending life for the S-N curves. The root bending stress is still within the limits of the material strength; details of these analyses are shown in Table 3.

Table 1 Example load spectrum

	[in-lbs]	[Nm]	[rpm]	[h]
Leg operation	331,901	37,500	3	750
Hull operation	560,252	63,300	1.5	140
Preload operation	725,761	82,000	0.75	140
Preload holding	858,522	97,000	-	-
Storm holding	1,097,492	124,000	-	-
Test load	1,287,784	145,500	-	-

Table 2 Rack-and-pinion geometry

Description	Symbol	Unit	Pinion	Rack
Normal module	m	mm	28.578	
Normal pressure angle	α_n	DEG	30	
Helix angle	β_n	DEG	0	
Number of teeth	z	1	8	256
Profile shift coefficient	x	1	0.1881	0.0000
Face width	b	mm	165.100	127.000
Tip diameter	d_a	mm	292.100	165.100
Pitch diameter		mm	228.923	144.832
Root form diameter	d_{Nf}	mm	200.746	119.700
Base diameter	d_b	mm	197.993	-
Contact ratio	ε_α	1	1.117	

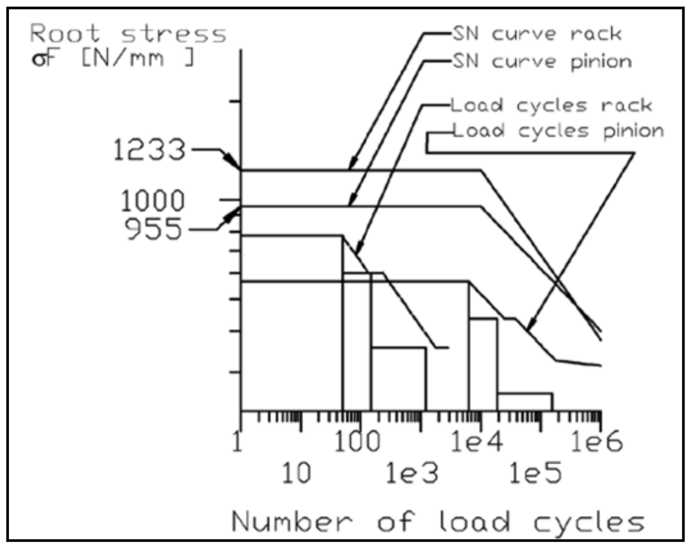

Figure 2 Root bending stress evaluation per ISO 6336.

Table 3 Root bending stress results

	ISO 6336:2006 Method B				AGMA 2001-D04		
	σ_{F_Pinion}		σ_{F_Rack}		S_{t_Pinion}		S_{t_Rack}
	[ksi]	[N/mm²]	[ksi]	[N/mm²]	[ksi]	[N/mm²]	[N/mm²]
Leg operation	37.49	258	51.64	356	35.10	242	-
Hull operation	63.28	436	87.16	601	59.26	409	
Preload operation	81.97	565	112.91	778	76.76	529	
Preload holding	96.96	669	133.57	921	90.80	626	
Storm holding	123.96	855	170.74	1,177	116.08	800	
Test load	145.45	1,003	200.35	1,381	136.21	939	

In comparison, it is significant how much higher the permissible root bending stress is between pinion and rack. In the previous material section of this paper, it was pointed out that the rack material is almost 30% less durable than the pinion. The higher root bending strength can be explained with the calculated notch sensitivity factor Y_{drelT} that with 1.6 is adding significantly to the permissible root bending strength of the rack. It should be pointed out that paying attention to safety on root bending is the most important step in the design process. It is necessary to be aware of required safety factors from certification bodies as published (Ref. 4) or through personal experience.

ISO 6336 vs. AGMA 2001-D04 contact stress assessment. The calculation was done similar to the root bending stress assessment using (Ref. 5) and (Ref. 3) standards. The permissible contact stress for leg operation is specified with σ_{HP_Pinion} = 209.14 ksi (1,442 N/mm²) and σ_{HP_Rack} = 166.79 ksi (1,150 N/mm²) based on ISO 6336-2. Comparing the permissible contact stress with the results in Table 5, we see approximately 1.5 to 3.45 higher contact stress throughout the load spectrum. Figure 3 is showing the appropriate S-N curve with the load spectrum. Here we see the challenge for the gear designer, i.e. — to find appropriate acceptance criteria for the high contact stress. Based on the results, this design would fail due to high contact stress. There are factors in the ISO standard accounting for a work hardening factor Z_W that can increase the permissible contact stress σ_{HP} of an applicable range of 2% to 16%. If taking best-case work hardening factors into account, it will not meet life acceptance criteria per gear calculation standard. However, in this application the work hardening factor will be taken into account with 1.0. If this design has to be submitted to a certification body, how can be these high contact stresses deemed as acceptable for service?

Table 4 Permissible root tooth stress per ISO 6336

Permissible root stress, σ_{FP}	Pinion		Rack	
	[ksi]	[N/mm²]	[ksi]	[N/mm²]
Static loads	79.77	550	178.97	1234
Combined loads	170.27	1174	230.46	1589

Table 5 — Contact stress results

	ISO 6336:2006 Method B		AGMA 2001-D04	
	σ_H		S_c	
	[ksi]	[N/mm²]	[ksi]	[N/mm²]
Leg operation	280.23	1,932	292.54	2,017
Hull operation	364.08	2,510	380.08	2,621
Preload operation	414.39	2,857	432.59	2,983
Preload holding	450.70	3,107	470.50	3,244
Storm holding	509.57	3,513	531.96	3,668
Test load	551.99	3,806	576.24	3,973

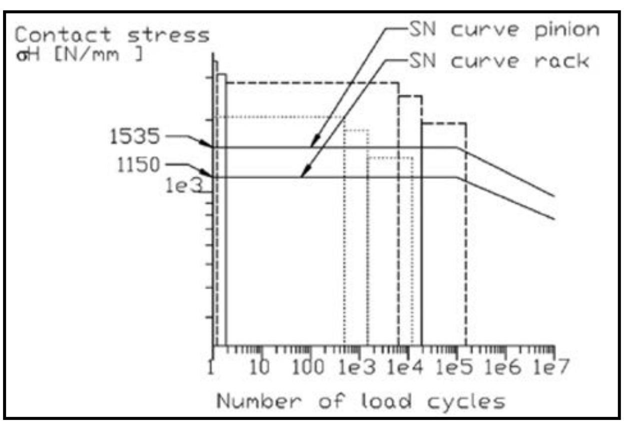

Figure 3 Contact stress for rack-and-pinion.

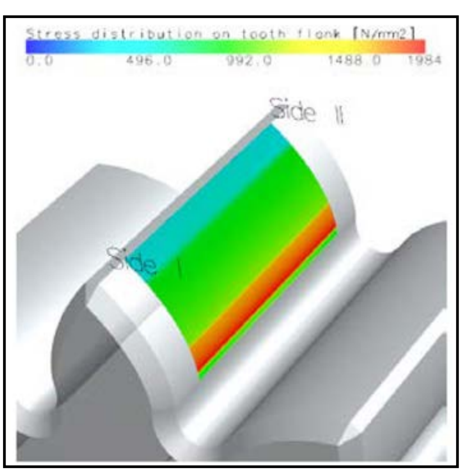

Figure 4 Contact stress for pinion.

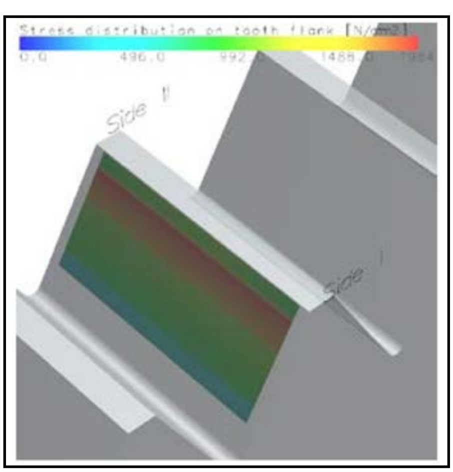

Figure 5 Contact stress for rack.

The contact analyses shown in Figures 4 and 5 assume ideal alignment and surface contact condition. As mentioned in the introduction according to the gear calculation standards of ISO and AGMA, this gear set has a limited life prediction due to high contact stress.

Brinell theory. In 2010 a different approach was published by A.N. Montestruc to evaluate high-contact stress on rack-and-pinion systems in the offshore industry (Ref. 6). This theory is based on the Brinell hardness material test method founded by the Swedish engineer Johan August Brinell in 1900 (Refs. 9–10). The hardness of a given material is evaluated with a spherical test object made out of sinter hard metal and forced into the test material. The plastic deformation in the test material can be evaluated while measuring the plastic-deformed diameter in the test material. Either the indentation or a table (Ref. 7) can be used to build the relationship between impression diameter caused by the test force to calculate the theoretical contact stress that is described as "Brinell stress" by Montestruc and defined in Equation 1:

$$\sigma_{BR} = \frac{F}{\frac{\pi}{4} D_i^2} \quad (1)$$

Brinell stress represents the stress when the material will start to flow. This theory had limitations on material and gear geometry unique to this application, as well as a low number of load cycles, that is less than 10,000. This paper (Ref. 6) is proposing an allowable stress calculated for jacking applications based on the Brinell stress (Ref. 1) while using the factor −0.056 and 1.40 from Figure 17 out of the AGMA standard (Ref. 3). This equation enables the engineer to predict the life of his rack-and-pinion system.

$$\sigma_A = 1.40\,(\sigma_{BR})(N^{-0.056}) \tag{2}$$

As shown in Figure 6, the allowable contact stress is significantly higher than the allowable contact stress out of the ISO or AGMA gear calculation. Due to the low number of cycles the S-N curves are in the linear static area.

This theory was never validated or further investigated by a standardization organization. This approach might be a help to find limits and guidelines for this kind of gear application. This method is mentioned to draw a complete picture of this technical problem.

Numerical Evaluation

FEA will be performed to see how high the von Mises stress is, and how deep the von Mises stress penetrates into the material, as well as whether there is any other stress factor like shear stress that contributes significantly to van Mises stress. Oerlikon Fairfield can perform a linear FEA analysis using ANSYS R18.1 to evaluate this rack and pinion design. It is preferred to carry out in the future a non-linear FEA analysis since experience is showing that this application operates in the stress level of plastic deformation.

Root bending stress validation. To validate the FEA model (Fig. 7) the root bending stress on the pinion will be calculated at severe storm holding. The result of the root bending stress is showing a good correlation. The spread is 5–10% between FEA simulation and standard calculation.

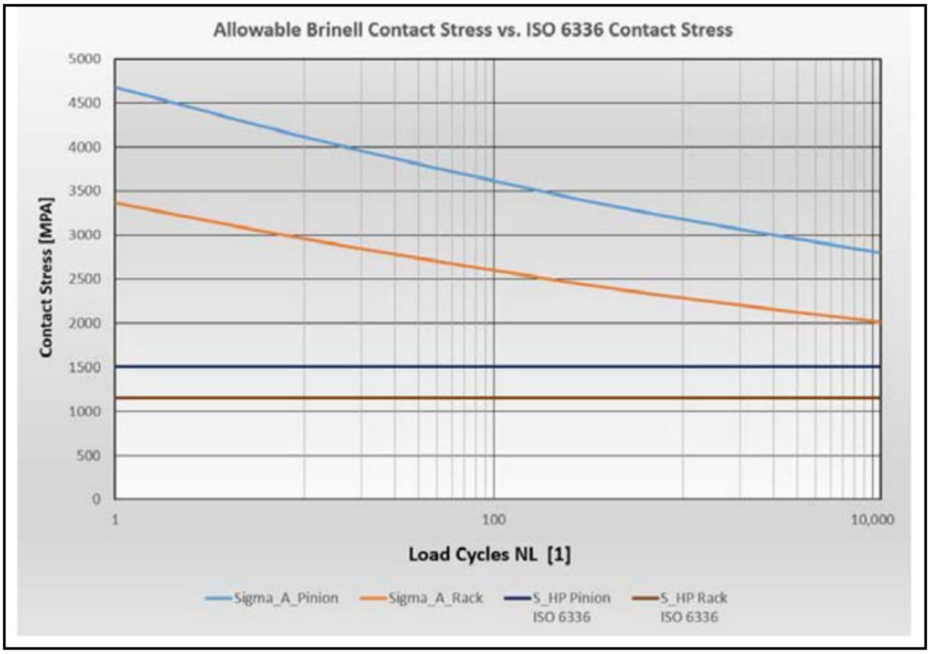

Figure 6 Allowable contact stress for rack-and-pinion.

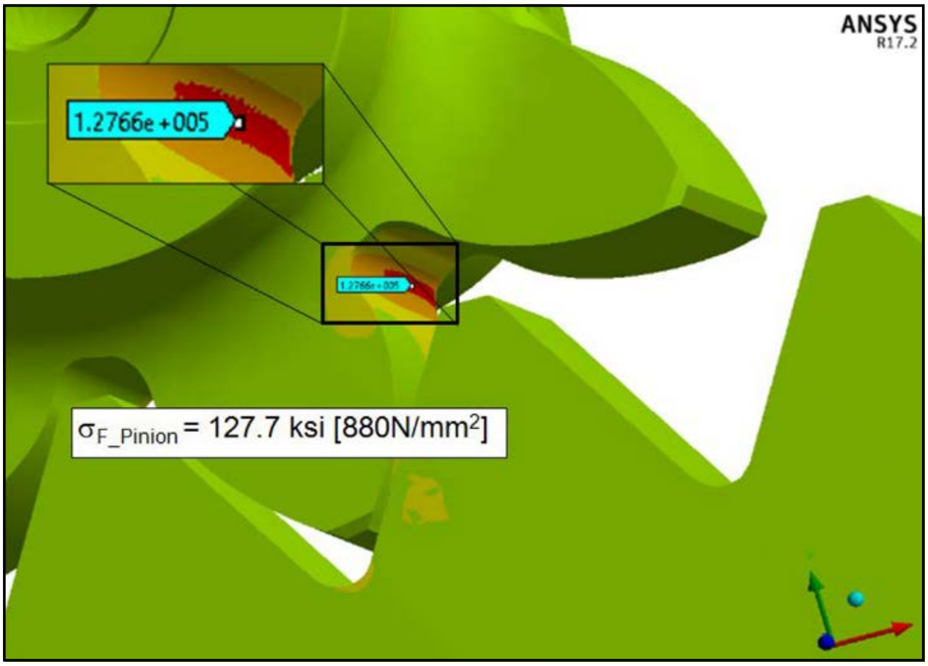

Figure 7 Root stress at the pinion at severe storm load.

Linear FEA at storm holding:

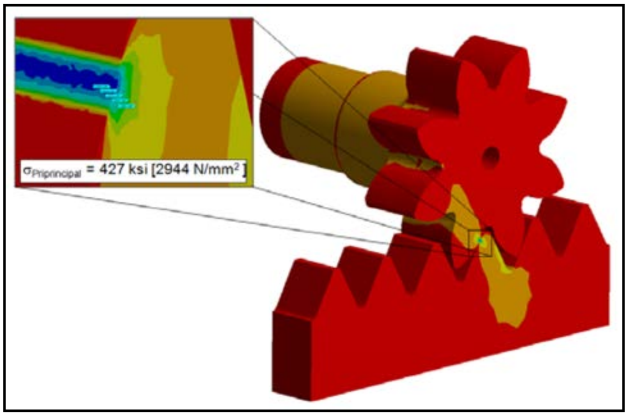

Figure 8 FEA model principal stress.

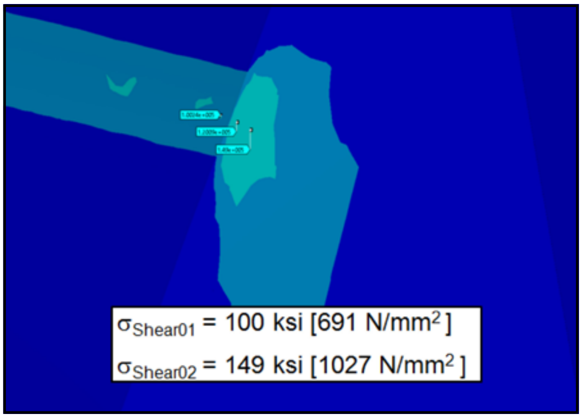

Figure 9 Storm holding shear stress.

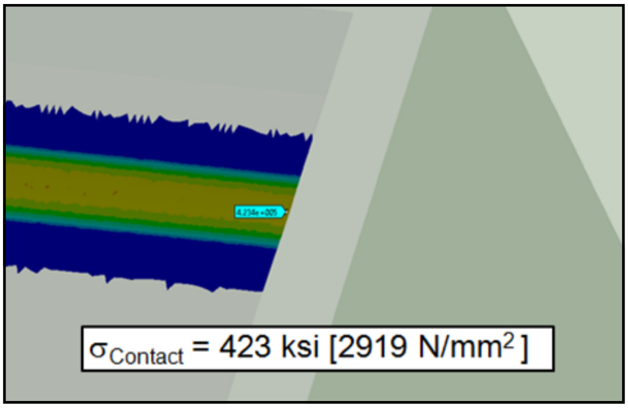

Figure 10 Storm holding contact stress.

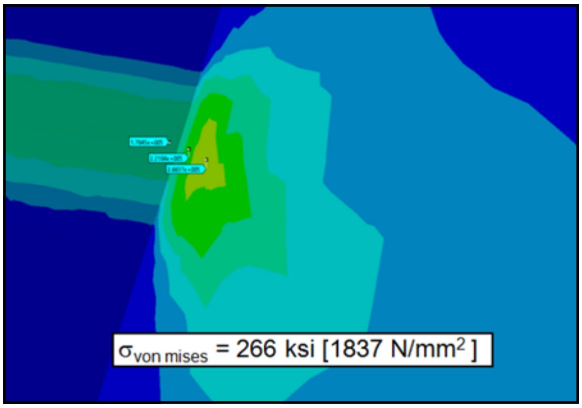

Figure 11 Storm holding von Mises stress.

Linear FEA at preload operation:

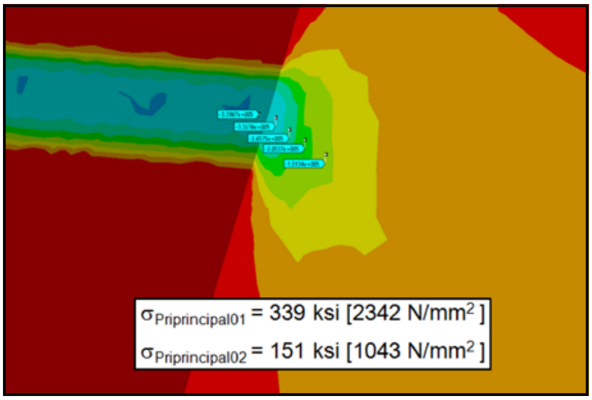

Figure 12 Preload operation principal stress.

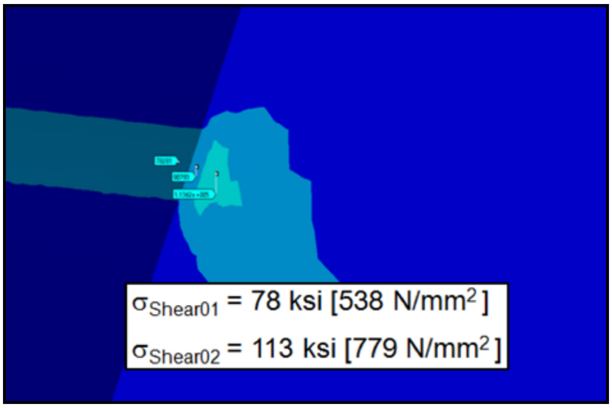

Figure 13 Preload operation shear stress.

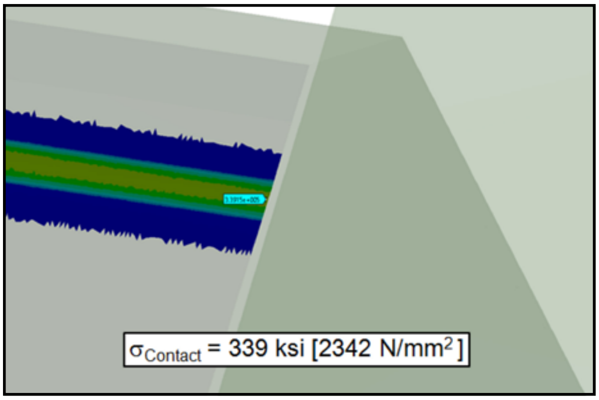

Figure 14 Preload operation contact stress.

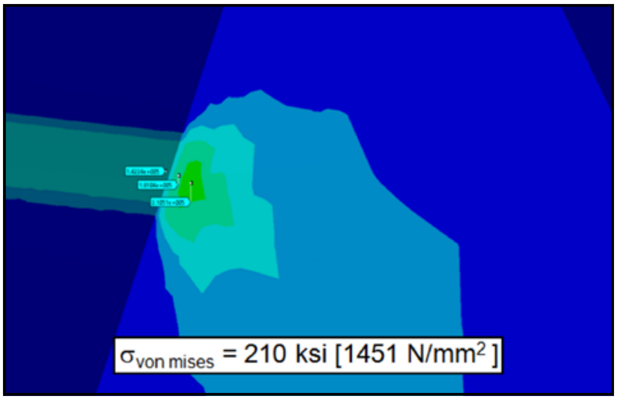

Figure 15 Preload operation von Mises stress.

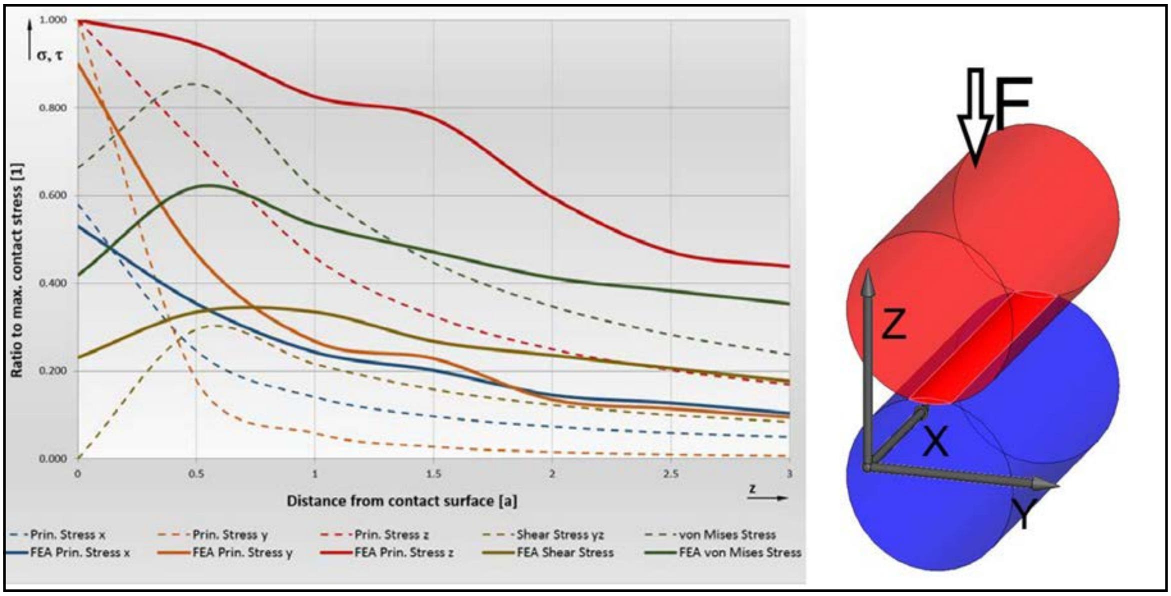

Figure 16 **Stress components below the surface along the load axis (for $\nu = 0.3$).**

For this FEA, more attention is payed to the details of stress directions and depth to the surface to get a better feel for what is happening within the material. For the load cases, storm holding, and maximum preload operation, the results are shown of the FEA calculation in Figures 8–15. And the following details are looked into:

- Figures 8, 12 — principal stress
- Figures 9, 13 — shear stress
- Figures 10, 14 — contact stress
- Figures 11, 15 — von Mises stress

Figure 8 illustrates the rack-and-pinion model, sectioned in the middle of the rack to grasp the centered point of contact. In the FEA model a small crowning was applied to avoid stress peaks on the end of the rack. It can be assumed that this is the highest stressed area that the rack will experience through operation and according to the FEA.

The contact stress calculated with the FEA doesn't correlate as accurately with the analytical calculation as with root bending stress. However, the lower stresses can be reasoned with the area of contact in the FEA model compared to the theoretical line of contact at gear standard calculation. Furthermore, the FEA calculation has not used any applications factors as typically assumed in the gear calculation algorithm.

In fact, the results are giving a good scope to explain what is going on in the rack material and match the Hertzian contact stress distribution theory for two parallel cylinders (Fig. 16) for materials with a Poisson's ratio $\nu = 0.3$ (Ref. 14).

In Figure 16 we can see a fairly good correlation between the FEA principal stresses in the x, y, and z direction, as well as the shear stress. The results of the FEA for the von Mises stress are below the theoretical values, but follow the same pattern. As expected, the principal stresses are high compared to the allowable contact stress defined by gear standards.

Validation and Testing

Since 2003 Oerlikon Fairfield has shipped more than 750 certified gearboxes that are equipped with this particular rack-and-pinion. Together this jacking system is on more than 17 lift boats in service. Up to this writing the rack-and-pinion are working properly and without any known failure due to fatigue or high-contact stresses. The certification body ABS (American Bureau of Shipping) has statically tested the system gearbox and rack-and-pinion before issuing product design approval. The static test is typically defined by ABS and performed under the supervision of surveying engineers. After this test all parts are subjected to non-destructive crack detection to verify the soundness of the system. The acceptance criteria are simple, i.e. — no cracks are allowed after the test is completed. It can therefore be concluded that the rack-and-pinion system has a substantial service experience and is well designed for service.

Conclusion

As pointed out earlier in this presentation, there is a good correlation between FEA results and the contact stress theory for two cylinders for materials with a Poisson's ratio of $\nu = 0.3$. The use of the Brinell theory (Ref. 6) is suitable and appropriate to evaluate rack-and-pinion designs. It is the author's understanding and supposition that the high-contact stresses are starting to deform the rack-and-pinion right away. After a few "run-in" cycles, cold work hardening (Ref. 8) as well as the rack deformation in width and concave shape will retard wear and deformation significantly. After a few runs the rack-and-pinion contact is no longer a line of action; it will become more a "moving contact area" and a "mesh balance" will take place. It is not unusual to see deformation in depth of more than 5 mm (0.2 in.) and width of 15 mm (0.65 in.) on both sides of the rack after test load is applied to rack-and-pinion.

Figures 17–18 show the rack before and after the test load for the ABS certification process. The deformation is so high that it is visible and could be measured with a tape measurement.

Figure 19 (Ref. 11) is showing a rack from a lift-boat removed due to mandatory leg inspection after more than 10 years of service, according to government requirements (Ref. 12). Figure 20 (Ref. 11) is showing a rack with proper lubrication for service. As we can see, the rack teeth are visually deformed and far

Figure 17 Test rack prior to test load.

Figure 18 Test rack post-test load.

Figure 19 Rack removed from hull.

Figure 20 Greased rack for operation.

from an ideal gear mesh — but acceptable for the intended use of lifting and lowering legs and hull. It can be concluded that contact stress per gear calculation up to 456.87 ksi 3150 N/mm^2) are still within the range of a good working rack for low life cycles $400 \leq N \leq 10{,}000$ cycles. Simulation technology becomes a sophisticated tool to predict material and mechanical behavior of rack-and-pinion. In particular, the linear and non-linear FEA can help to understand the contact stress and deformation much better. Engineering judgement and experience are required to determine what can be acceptable and what's not. However, to this day there exist a lot of jacking vessels in the fleet, but there is not the complete understanding of all factors and behavior of the system. It needs more research of these particular applications to gain a better understanding as to why contact stresses of 450 ksi (3102 N/mm^2) for preload operation and 550 ksi (3792 N/mm^2) for test load is working properly in the industry. For the design engineer the main focus should be to satisfy safety on root bending strength for the system. It is preferred to have a jammed system due to deformation, rather than an uncontrolled descent of a lifted hull in open waters. Based on actual events, what a fracture and loss of vessel could mean on such platforms is described (Ref 13). This gives the engineer and certifying bodies a huge responsibility to carefully review their work and ensure the design is properly working in service.

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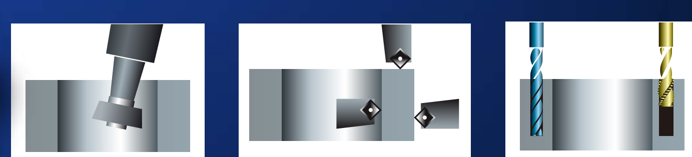

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Human Machine Interface (HMI) in Gear Manufacturing

"Documentation is not a Substitute for an Intuitive Interface"

Yefim Kotlyar

Introduction and Cursory Historical Overview

(*Giving credit where credit is due, the quote contained in this paper's title is attributed to Kenneth Corless.*)

Human machine interfaces (HMI) in the gear industry are continuously influenced by the advances of user interfaces elsewhere in computing. The ever-friendlier and more intuitive interfaces being perpetually enhanced by *Google, Microsoft, Apple, Facebook*, and all other technology leaders are influencing and changing the expectations of the machine users. The machine tools makers are becoming more cognizant of this trend and are making strides to improve their HMIs to meet the changing expectations.

These days gear manufacturing is mostly computerized. While there are still some mechanical gear cutting machines in the field, they are increasingly being phased out, as very few (if any) mechanical machines are being produced today anywhere in the world. As compared to turning and milling, it did take a bit longer for the gear manufacturing industry to fully embrace computerization, but once it did, it never looked back.

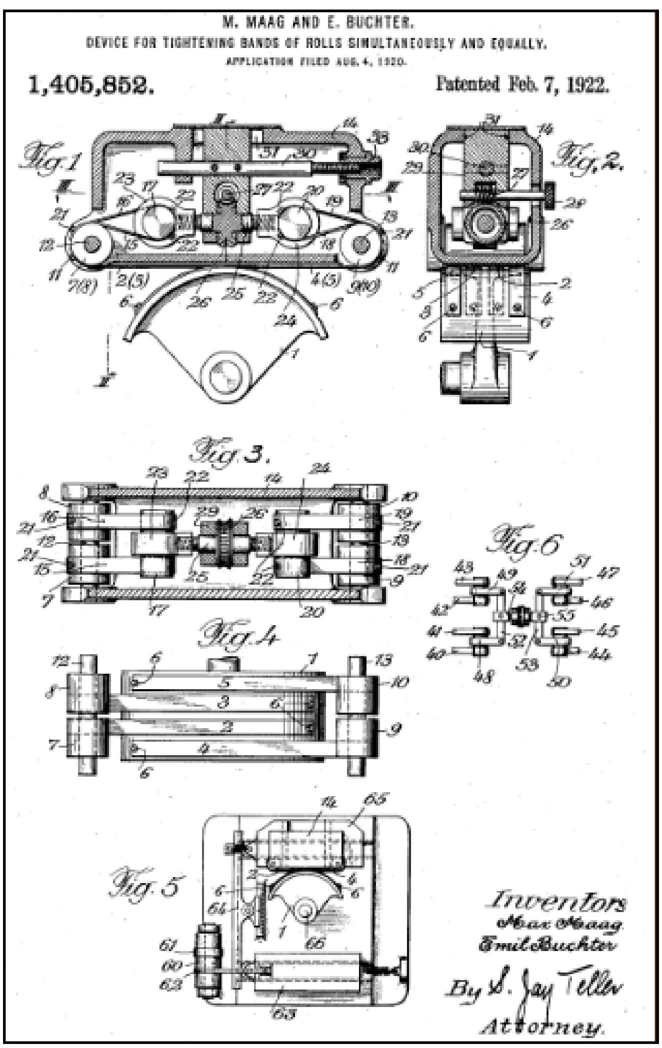

Figure 1 M. Maag & E. Buchter patent for tightening bands of rolls simultaneously and equally, 1920.

During most of the 20th century, improvements of gear manufacturing machinery were centered on perfecting the art of the machine's mechanical foundation, i.e. — increased rigidity; improved accuracy of the axes alignments; introduction of mechanisms for reduction — and even elimination of backlash; introduction of the differential mechanism for cutting helical gears; and introduction of the rolling bands for precision gear grinding (Fig. 1) are just some examples. Also, the use of hydraulics and pneumatics was expanded to support various machine functionalities.

Machine computerization at the end of 20th century brought a new wave of profound and non-stop innovations into the world of gear manufacturing. At the beginning of this computerization process in 1980s and 90s, most of the innovations were driven by computer hardware, i.e. — more powerful, faster controls. But eventually, as Microsoft co-founder Paul Allen said — "Software trumps hardware" — software development has been playing an increasingly greater role in generating new advancements.

The 21st century innovations, whether the expansion of machine functionalities or the elevation of friendliness making the machines easier and therefore faster to set up/operate, are only limited by the imagination of machine users and makers. Thankfully, many users are not shy about verbalizing their imagination and are dispensing new challenges to the machine makers that add fuel to their creative process.

Today, almost anything one can imagine can be mathematically and logically modeled. If an idea can be modeled, it can be turned into a computer code to run the machine.

One side of this unrelenting expansion of machine features, options, and new capabilities is the inevitable expansion of HMI. However, despite the proliferation of features and options, the machine should not be more difficult to operate. Users' high expectations for an intuitive and friendly HMI are cultivated by the likes of, as mentioned, *Google, Microsoft, Apple, Facebook* and many others, i.e. — the expanded possibilities of an app should not necessitate a greater difficulty of use.

A Modern Gear Form Grinding Machine Has Many Functions and Features

Let's look at the example of a contemporary gear form grinding machine that has a lot going on (Fig. 2). While gear grinding

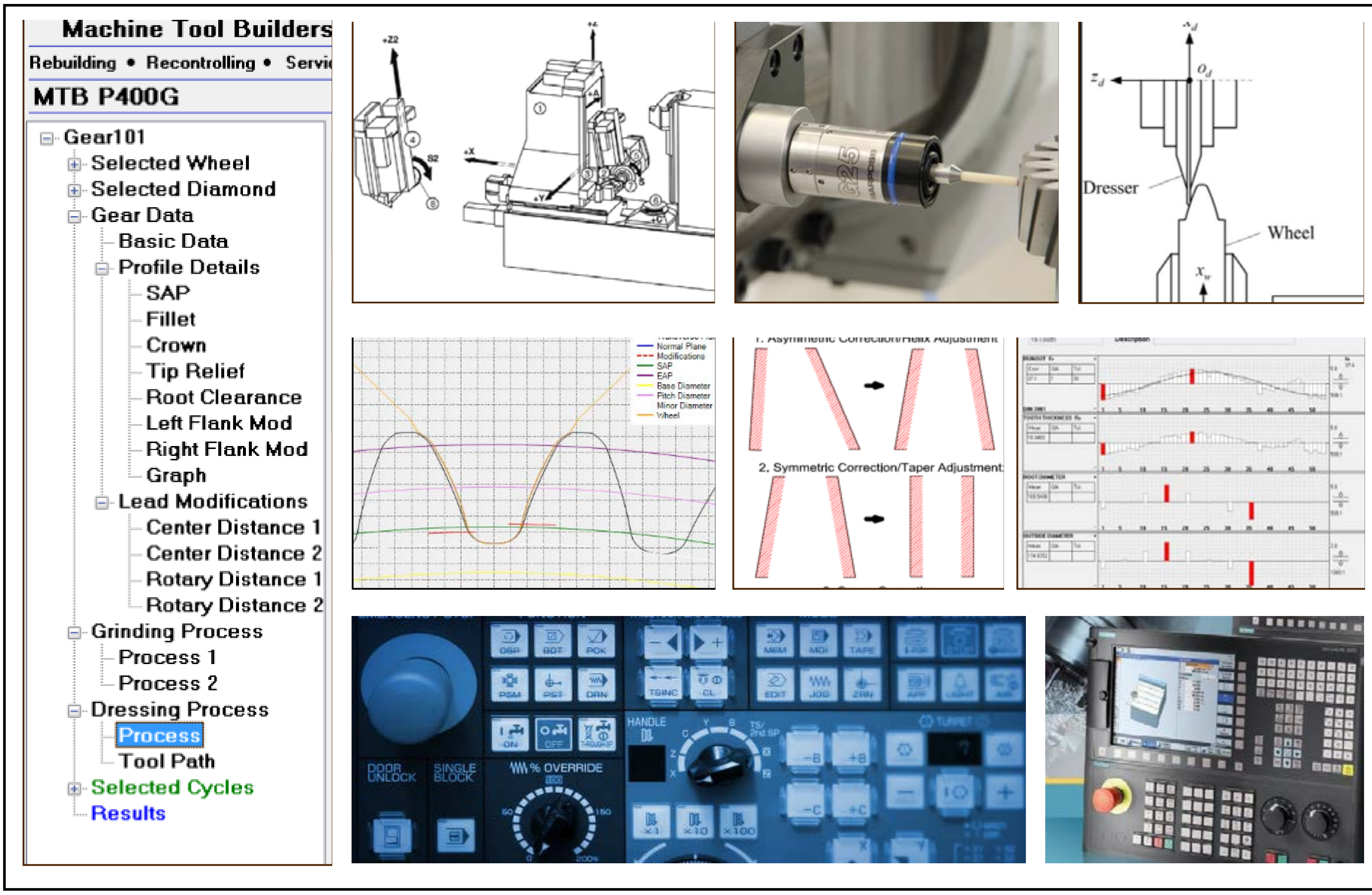

Figure 2 Example of contemporary gear form grinding machine with a lot going on.

is the prime function of the machine, it is only one of its many functions; other supporting functions include:

- On-board dressing of the grinding wheel
- On-board gear inspection and evaluation of inspection results
- Intelligence to make automatic or manual process/setup adjustments based upon on-board inspection results.

All these prime and supporting functions have many data entry fields for the operator to control and to fine tune to ensure proper functionality.

Grinding gears is the main machine function. This function relies on numerous data points defining the basic gear geometry (Fig. 3); profile and lead modifications; the gear axial and angular orientations in relation to the grinding wheel; grinding method; feed and speed rates; number of passes; and many more data points for the "control knobs" to properly complete the task.

Typical features and flexibilities of the form grinding function are:

- Grinding spur and helical gears
- Usage of dressable or non-dressable wheels
- Possibility of grinding two or a single flank at a time
- Profile and lead modifications

On-board dressing is one of the supporting functions. In addition to the basic gear geometry, this function relies on the information about the profile modifications, dressing tool geometry, dressing conditions, and the fine tuning fields to develop optimized dresser passes that minimize dressing time.

Examples of data entry for typical profile modifications and

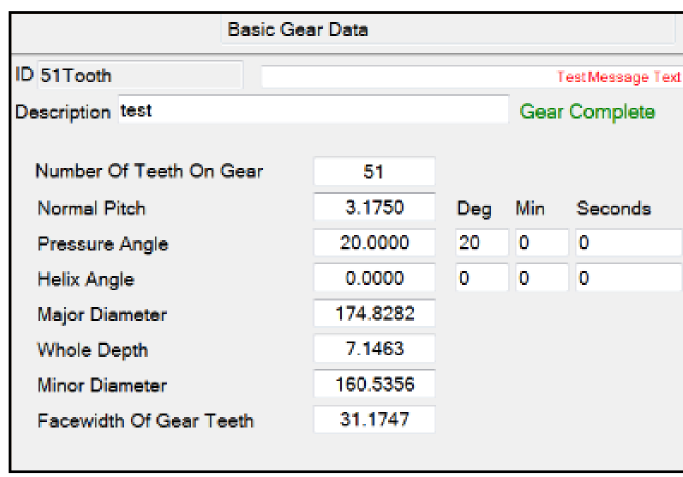

Figure 3 Grinding utilizes numerous data points in defining basic gear geometry.

root geometry (Fig. 4):

- Straight or parabolic tip relief
- Profile crowning
- Point-by-point profile corrections
- SAP or TIF (start of active profile or true involute form)
- Root/fillet radius

Figure 5 depicts an example of the dresser geometry, as this is another critical set of information required for generating precision dressing passes.

Figure 6 depicts a typical geometry definition of a purchased grinding wheel; it is a third set of the information needed for the wheel dressing process. Dressing conditions (Fig. 7) are the fourth set of the information needed for the wheel dressing process.

Based on these four sets of data, the dressing passes are generated. Also, some advanced on-board dressing system may include a capability for optimizing the dressing pass travel for maximum efficiency. Figure 8 represents a visual verification of an optimized, initial dressing pass. The operator has a chance to visually review the optimized dresser passes in order to reduce a chance of a crash and to minimize (or eliminate) the number of wasted passes.

On-board inspection. Today's not only large, but also medium-size gear grinding machines are increasingly being manufactured with an on-board inspection capability. Here are some of the on-board inspection features and capabilities:

- Inspection and evaluation of profile, lead, index, tooth thickness, OD and root diameter
- Automatic tooth finder and stock division
- AGMA/ISO/DIN standard determination and tolerance calculation
- Probe calibration without interrupting part setup

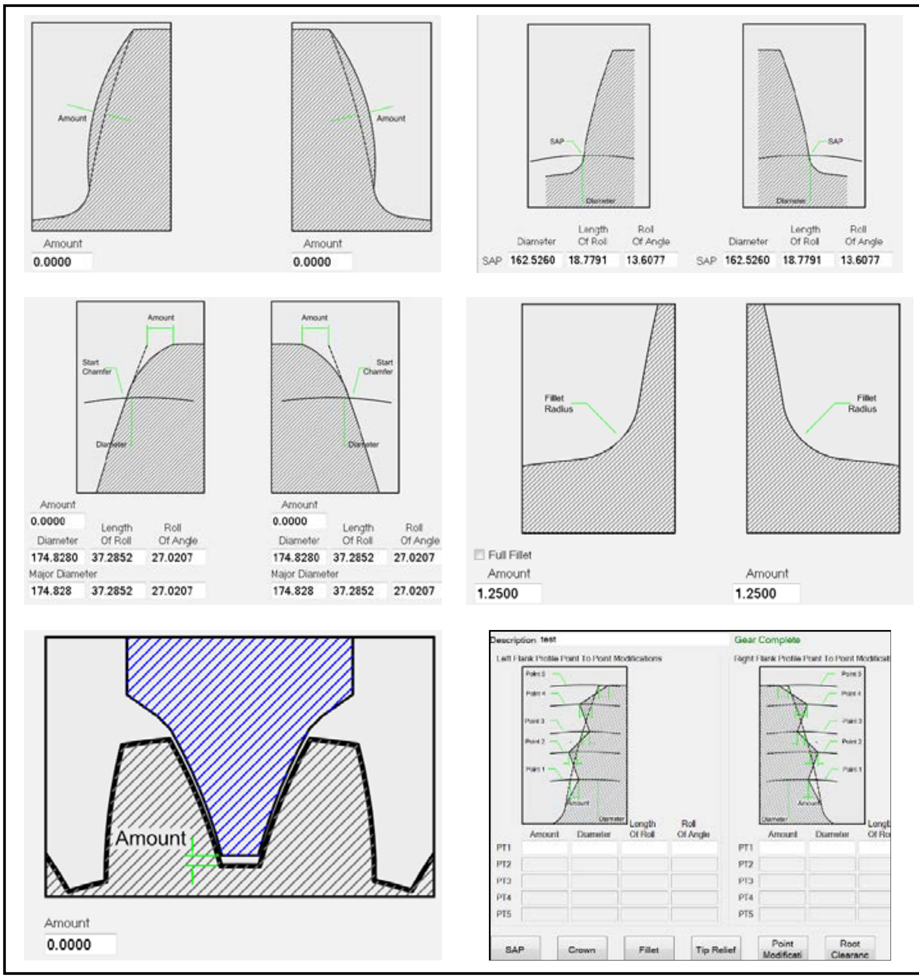

Figure 4 Various profile modifications and other details.

Integrating inspection with setup adjustments. While more grinding machines have features to help operators determine the necessary adjustments based on external inspection, the on-board inspection provides a more fertile soil for automating the setup adjustments for profile, lead and tooth size.

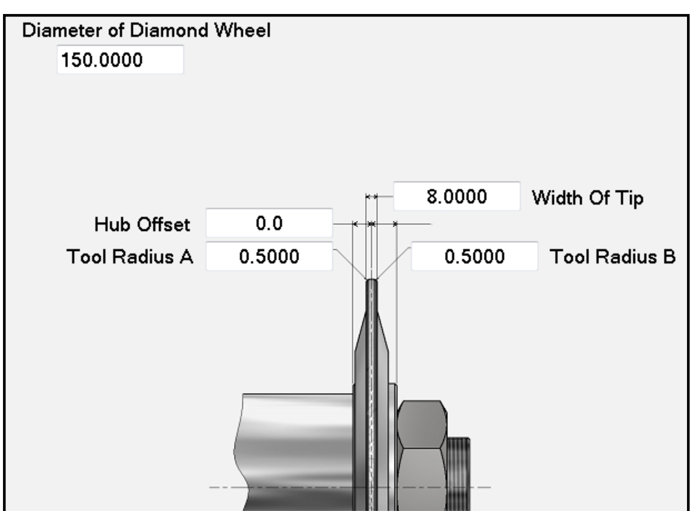

Figure 5 Example of dresser geometry — another critical set of information required for generating precision dressing passes.

The Prominence of Human Machine Interface (HMI)

With so many different capabilities, functions, features, and fine tuning "knobs," how does the operator "connect the dots"? How does the operator achieve a situational awareness (SA), i.e. — what do I do next? How do operators maintain their sanity? What makes the machines easy to use?

The trends in gear manufacturing (for making the machine easier to use) are no different than what is happening in computing elsewhere. Computer functionality is becoming more and more accessible to people without an advanced computer education. Our smart phones (that are basically pocket computers with many software features) today are so much more complex and more capable than earlier computers. Yet, thanks to more intuitive and friendlier user interfaces (UIs), billions of people easily navigate smart phones today. In contrast, only a few elite professionals were able to navigate earlier computers that were significantly less capable and less powerful.

HMI or UI are just different names for the same concept, i.e. — means for a human/user to interact and control a machine or a computerized process. HMI bears the prime responsibility for the operator experience and for making the functionality of the machine explicable.

Typical Wheel (Norton)

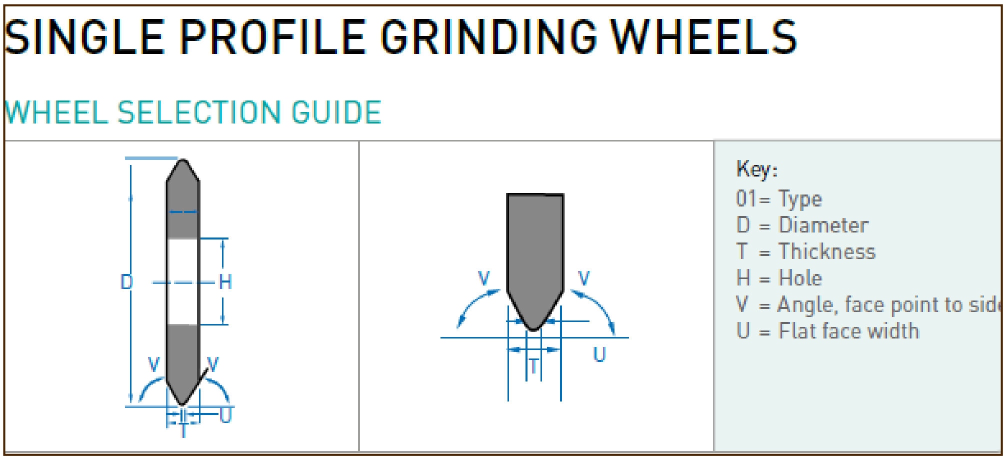

Figure 6 Typical geometry definition of purchased grinding wheel — the third set of information needed for wheel dressing process.

How to Design an Intuitive HMI/UI

Everett McKay, the author of *"UI is Communication: How to Design Intuitive, User-Centered Interfaces by Focusing on Effective Communication,"* says that an intuitive interface should include an appropriate combination of the following:

- ***Affordance.*** The UI provides visual clues that indicate what it is going to do. Users don't have to experiment or deduce the interaction. Affordances are based on real-world experiences or standard UI conventions.
- ***Expectation***. The UI delivers expected and predictable results with no surprises. User expectations are based on labels, real-world experiences, or standard UI conventions.
- ***Efficiency***. The UI enables users to perform actions with minimal effort. If the intention is clear, the UI delivers the expected results the first time so that users don't have to repeat the action (perhaps with variations) to get what they want.
- ***Responsiveness***. The UI gives clear, immediate feedback to indicate an action is taking place, and whether it was either successful or unsuccessful.
- ***Forgiveness.*** If users make a mistake, they need the ability to fix or undo the action with ease.
- ***Explorability***. Users can navigate throughout the UI without fear of penalty or unintended consequences, without getting lost.

Data Entry

Data entry is one of the first things the operator needs to do when starting a new grinding project. A gear grinding machine with on-board dressing, on-board inspection, and built-in intelligence for setup corrections requires a cornucopia of data, e.g. — basic gear data; modification data; dressing data; inspection data; grinding data; and so on. Below are some of the data entry principles that would make it easier and more intuitive for the operator.

- ***Minimum data entry.*** While every grinding project requires

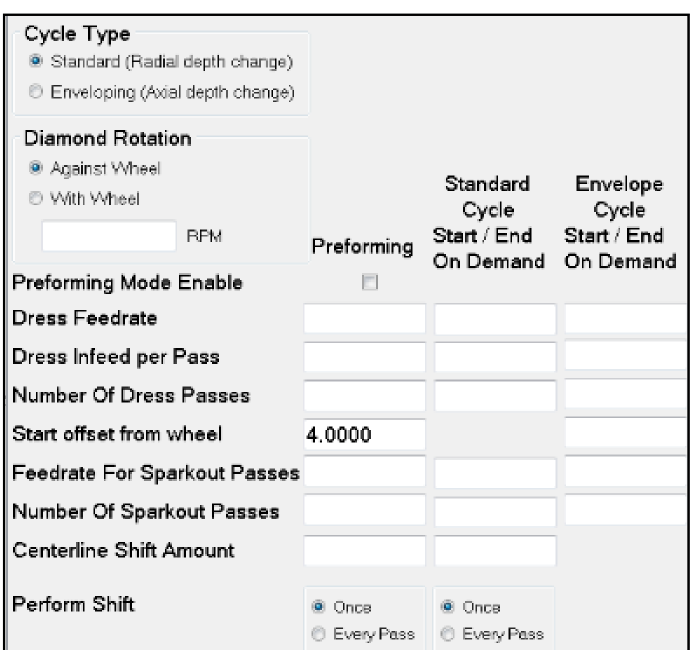

Figure 7 Dressing conditions are the fourth set of information needed for wheel dressing process.

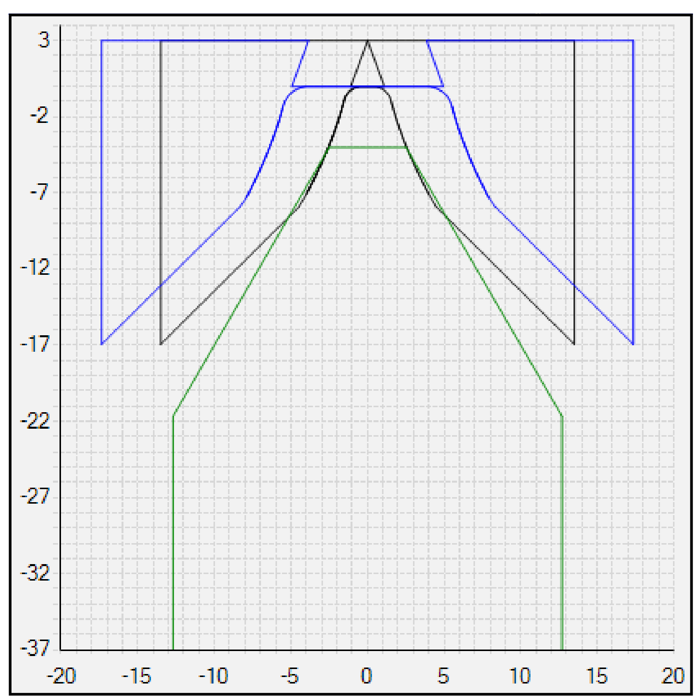

Figure 8 Visual verification of an optimized, initial dressing pass.

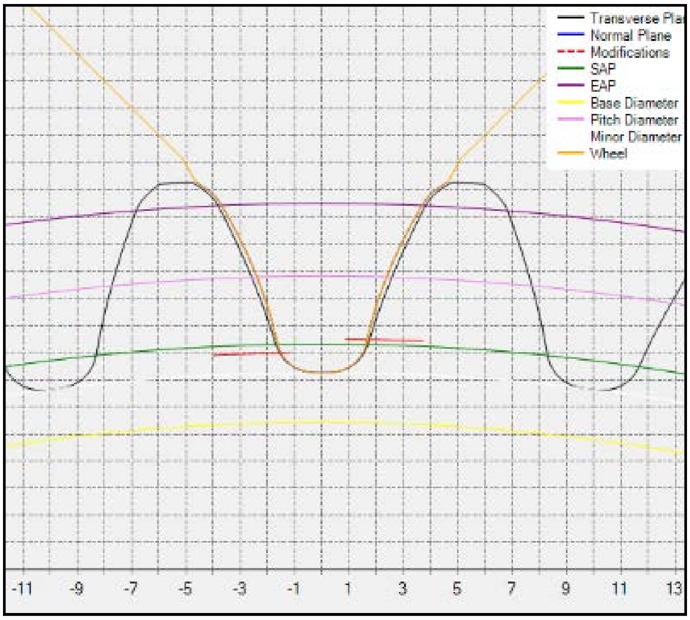

Figure 9 Gear teeth with profile modifications.

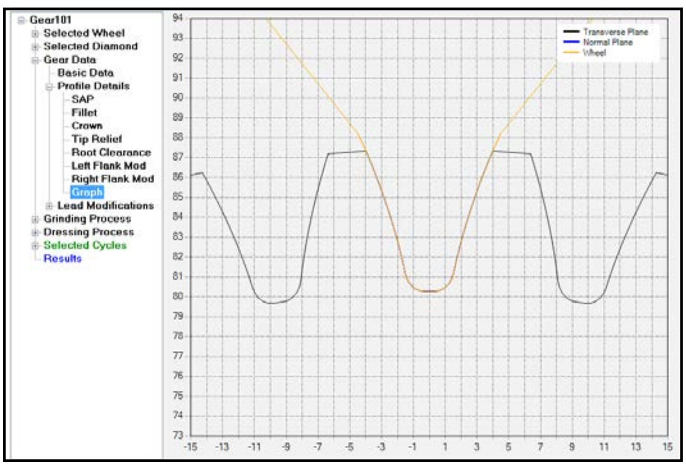

Figure 10 Gear teeth without profile modifications.

hundreds of gear geometry and process data entry fields, there are probably a dozen that "must" be provided by the operator. For example, only the basic gear geometry data is required to be entered in order to start a "plain vanilla" gear tooth grinding.

- ***Defaults***. Availability of friendly defaults for all additional gear geometry fields can dramatically speed up the data entry and the entire setup process. However, the user is always in charge and should be able to update any defaults that are calculated and displayed.
- ***User-centered.*** The data entry interface should satisfy different traditions for the geometry specs, standards, and other company-specific preferences for gear specs; for example, angle vs. length of roll, or diameter, tooth thickness vs. span or DOP, and metric/inch switchable at any time.
- ***Forgiveness.*** Automatic reconciling of any interdependent fields (e.g. decimal degrees vs. min.; and sec., tooth thickness vs. DOP and span; length of roll vs. angle and diameter, etc.) The user should be able to see all calculated references, such as base circle and lead, that were not entered but were critical characteristics for proper functionality.

Figure 3 shows an example of the minimum basic gear data entry; there are only seven data entry fields. All other gear geometry characteristics — with the exception of modifications and root radius — can be derived from the basic gear data. An operator should not have to update additional data entry fields, unless the profile (Fig. 4) or lead modifications (Figs. 11–12) are required.

Visual Gear Data Verification

Visual data verification transforms the numerical data entered into a scaled pictorial gear representation, thus delivering an extra level of confidence and allowing the operator to quickly detect mistakes and typos. Figures 9 and 10 depict examples of gear teeth with and without profile modifications respectively. Normal (and transverse in case of helical gears) representations of the grinding wheel geometry can be superimposed and viewed on both figures.

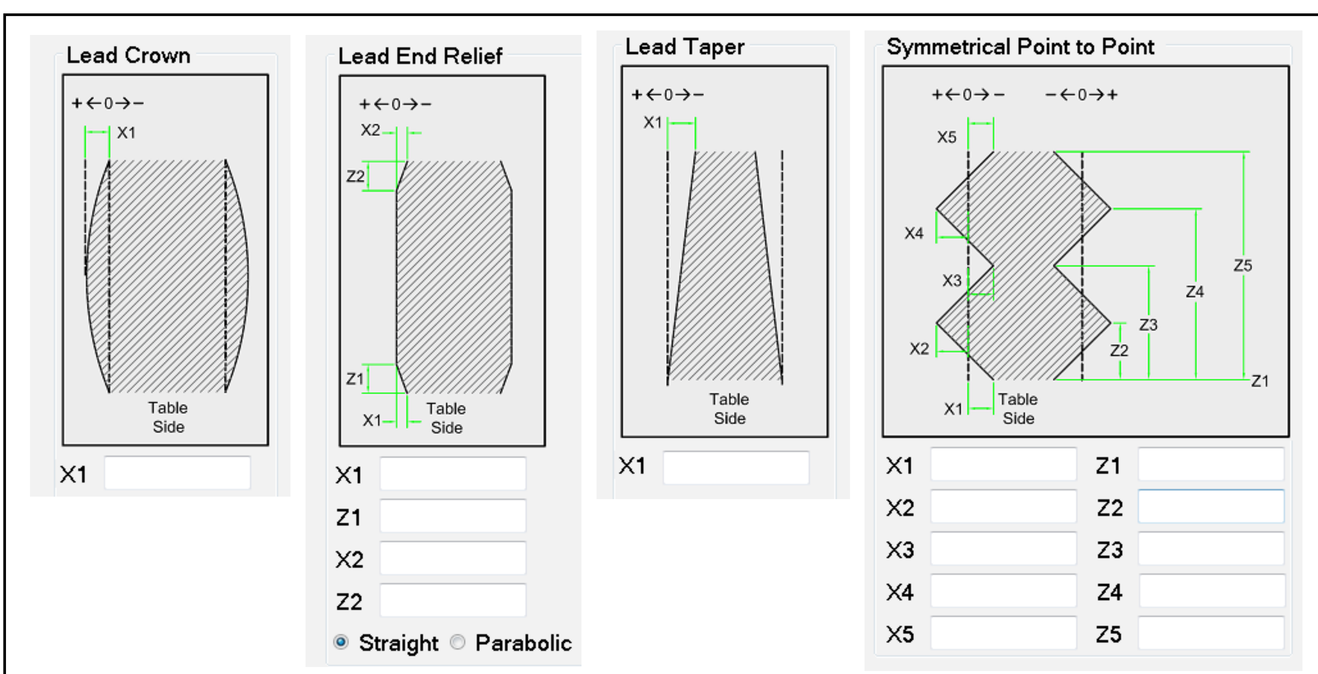

Figure 11 Symmetric lead modification.

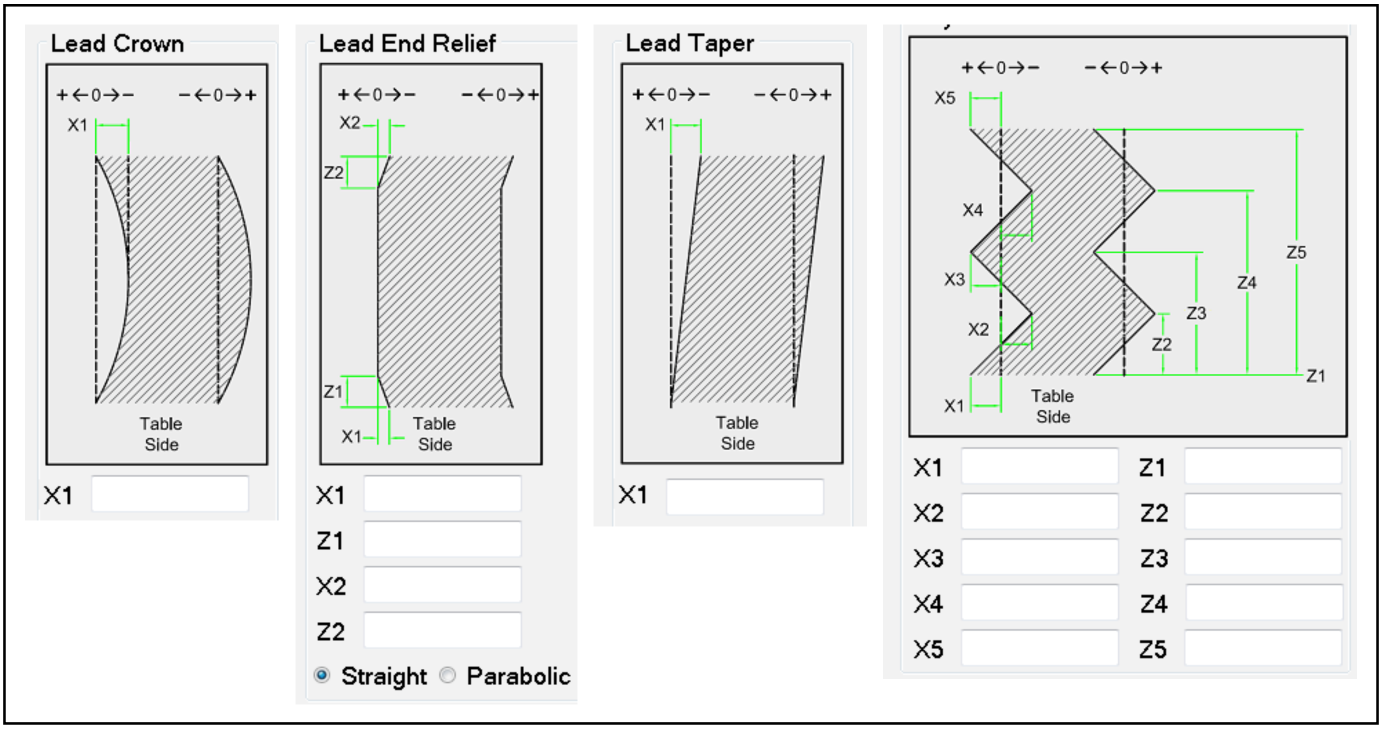

Figure 12 Asymmetric lead modification.

Some Principles of a Good Graphic Design

Graphics are very powerful tools for brief and clear communication. It is not uncommon for a gear grinding (or other gear manufacturing) machine to have an HMI that utilizes graphical communication for the data entry fields. Paul Gruhn's *Good Graphic Design Concepts/Visual Clues* lists some principles of a good graphic design.

- Grouping: related items are kept together (e.g., all symmetric lead modifications)
- Contrast: things that are different should look different
- Alignment: every element has some visual connection
- Proximity: things that belong together are placed together
- Repetition: repeat visual elements

Figures 11 and 12 are examples of applications of these principles for designing data entry pages for symmetric and asymmetric lead modifications. Graphics provide visual explanation for achieving symmetric lead modifications by adding delta X-axis (center distance) travel in relation to Z axis (axial travel). Asymmetric lead modifications are achieved by adding delta C-axis travel (table rotation) in relation to Z (axial travel).

On-Board Gear Inspection

A contemporary gear grinding machine can have an on-board inspection with a plethora of inspection and evaluation capabilities. Figure 13 depicts a scanning probe installed on a form gear grinding machine. Every inspected feature requires numerous data entry fields that define the inspection and evaluation parameters. However, a friendly and an intuitive HMI can have the intelligence to default most, if not all, of the data inspection requirements based on the basic gear data. Of course the operator should be able to review all defaults and update them, if desired. Below is an incomplete list of a typical on-board inspection and evaluation capabilities on a gear grinding (or cutting) machine.

Figure 13 Scanning probe installed on a form gear grinding machine.

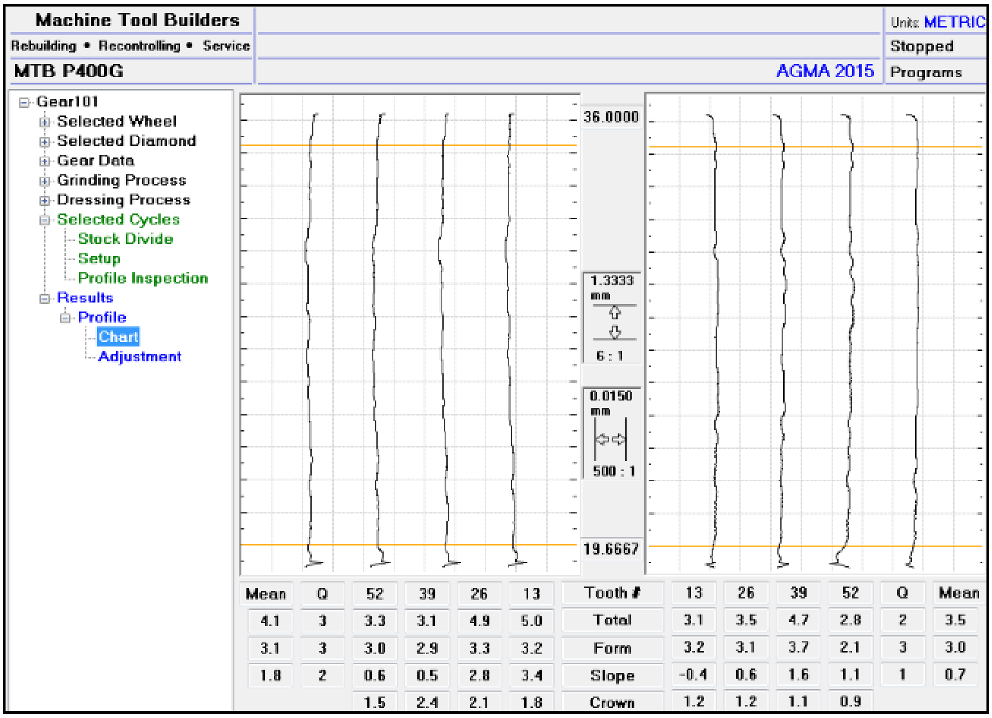

Figure 14 Example of profile inspection and evaluation.

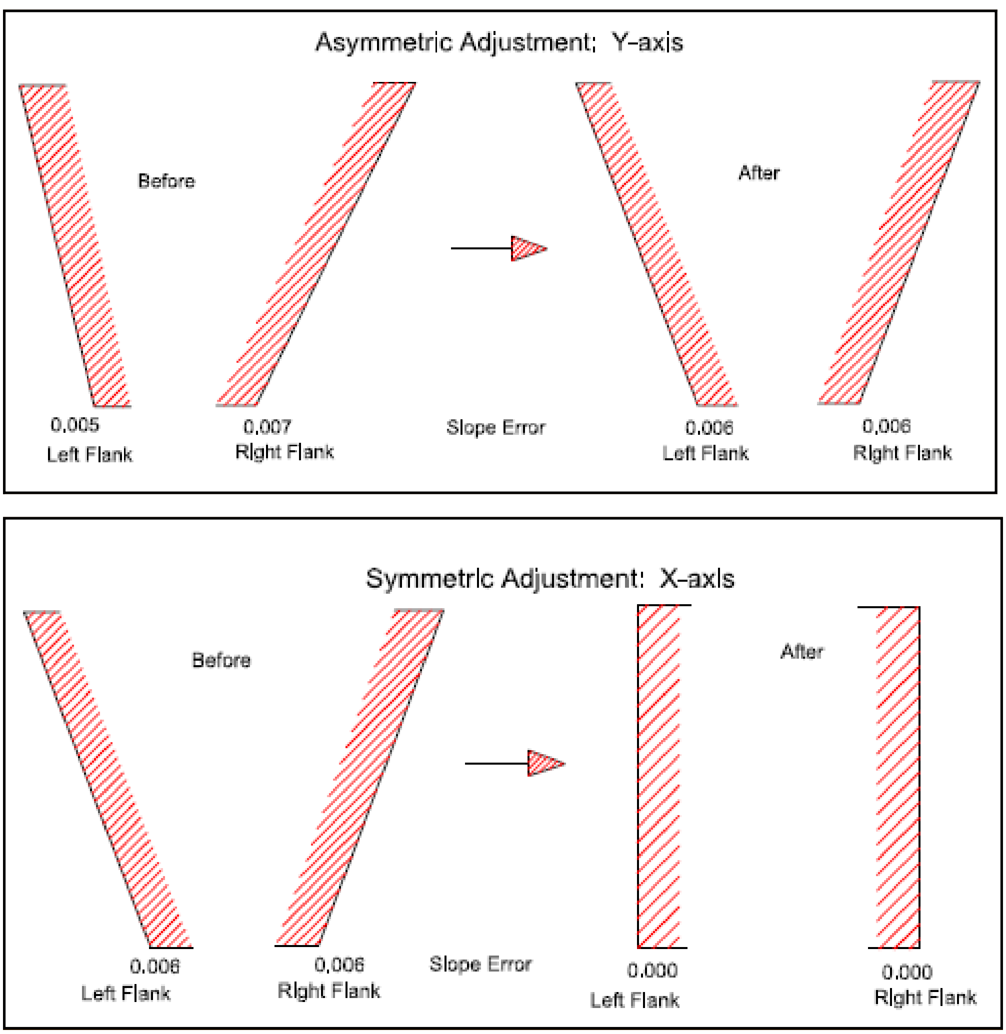

Figure 15 Profile slope setup adjustment in two steps: symmetric and asymmetric.

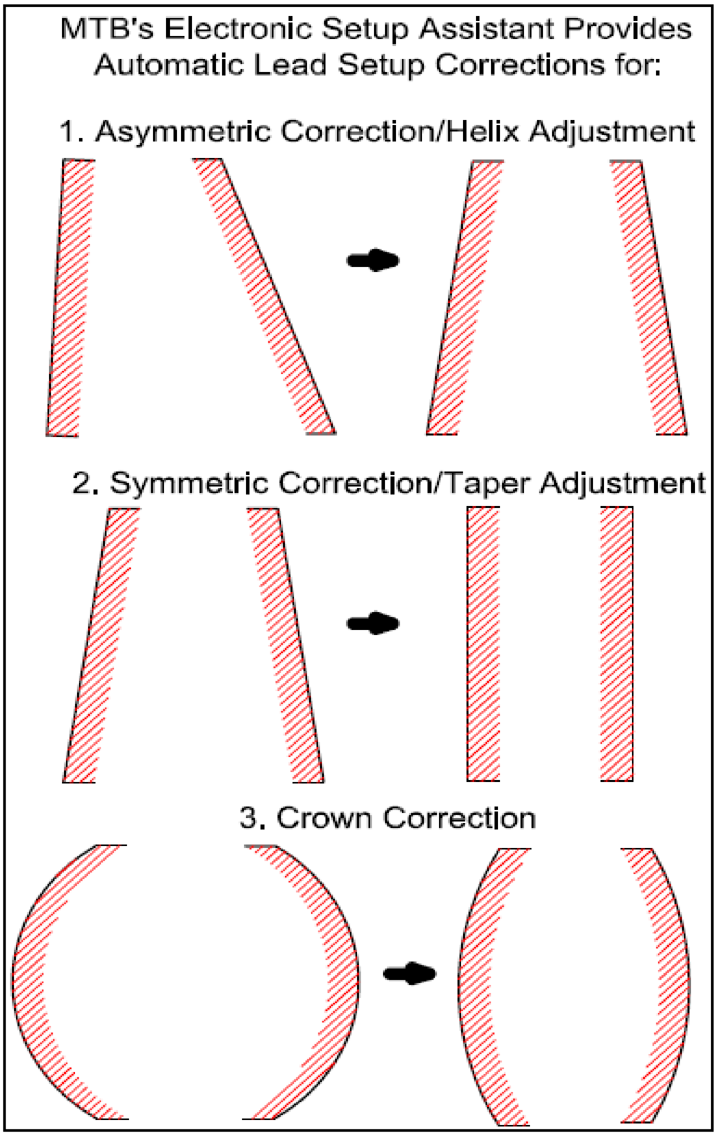

Figure 16 Lead setup adjustments are conceptually similar to the profile.

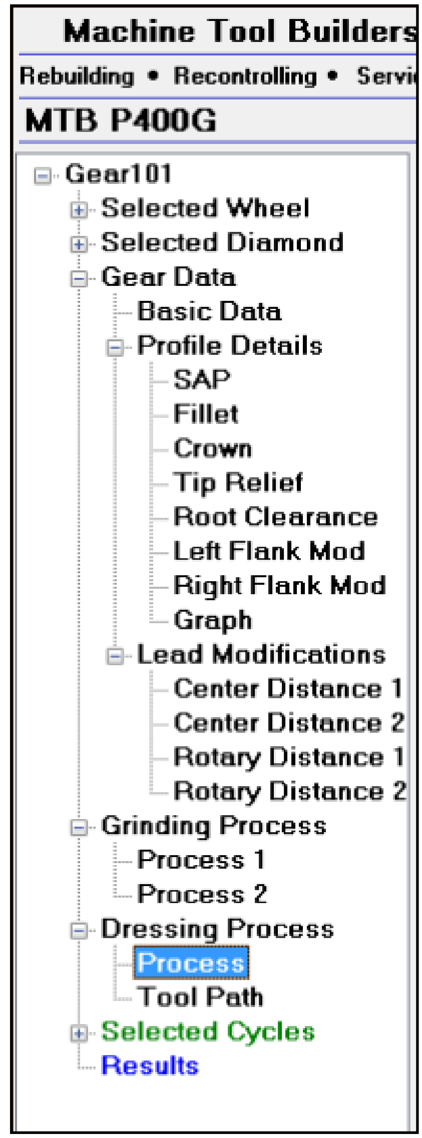

Figure 17 Tree project structure (without the right pane) with expanded notes.

On-board gear inspection and evaluation features:

- Profile: total/slope/form/modifications
- Lead: total/slope/form/modifications
- Index: pitch/spacing/runout
- Tooth thickness/DOP/span
- Tip and root diameters
- AGMA/DIN/ISO
- Tolerance band/K-chart

Additional on-board inspection and evaluation features:

- Auto average stock divisions
- Axes alignment mapping
- Automated setup adjustments — MTB setup assistant

A modern on-board inspection feature includes most, if not all, the inspection and evaluation capabilities of a traditional gear measuring center. An example of the profile inspection and evaluation is depicted in Figure 14.

Setup Adjustments

One particularly exciting HMI feature is built-in intelligence for setup corrections.

One of the most helpful outcomes of the on-board gear inspection and evaluation is that the system can use the inspection results to determine all the necessary setup adjustments. This opens up a possibility for either automated or manual setup adjustments of profile, lead, and tooth thickness features.

- One way to make profile slope setup adjustments is to break it down into two steps: symmetric and asymmetric adjustments (Fig. 15). The asymmetric adjustment is achieved by shifting the tangential axis (Y-axis) and the symmetric by adjusting the center distance (X-axis) between the gear and the dressing wheel. This can be accomplished in an automatic mode or semi-automatic mode when the operator would be selecting (Yes/No) for including the adjustments.
- Lead setup adjustments are conceptually similar to the profile (Fig. 16); it is typically broken down into two steps: symmetric and asymmetric. The asymmetric adjustment (helix) is achieved by refining the synchronization of table rotation (C-axis) and axial travel (Z-axis). The symmetric adjustment (taper) is achieved by refining the synchronization of X and Z axes. The lead crown correction can be combined with symmetric and asymmetric corrections. Based on the crown

inspection results, the X-axis and Z-axis synchronization can be further refined.

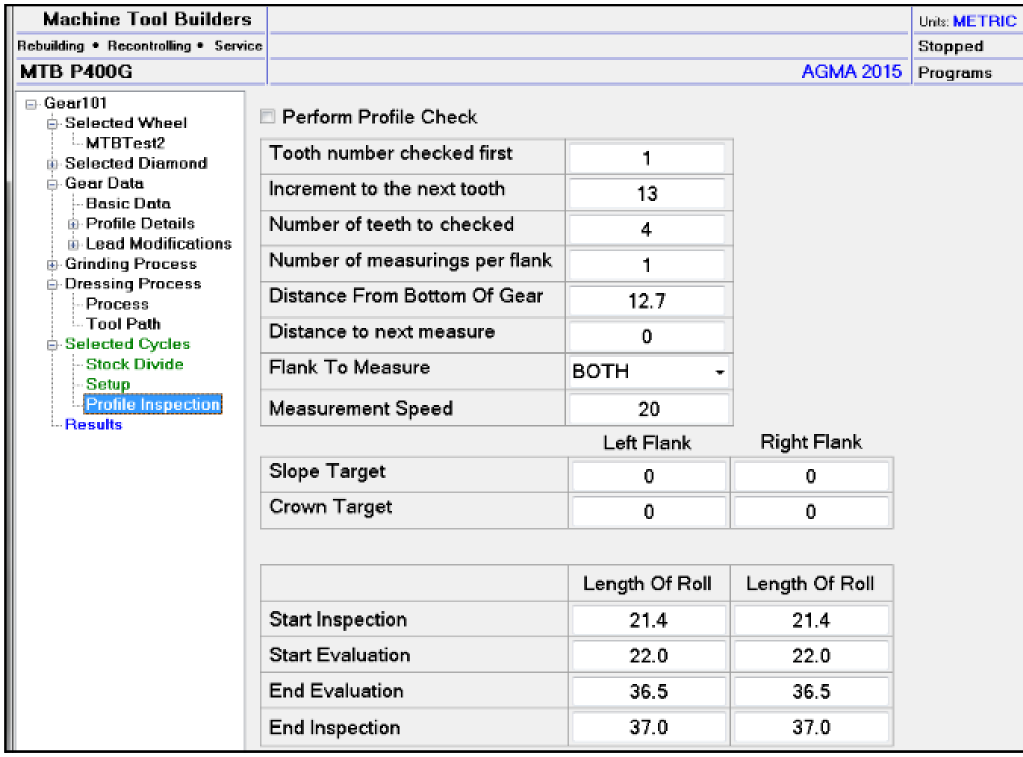

Figure 18 Example of profile inspection details via project tree profile inspection node.

Situational Awareness or Navigating the Gear Grinding Project

An intuitive navigation through the gear grinding project is a very important facet of the HMI. A familiar project tree structure (used in a wide variety of computer applications) enables the user to easily move through many data screens. A project tree structure also provides consistent means for viewing and editing every single detail on the right pane of the project while seeing the "big picture" of the entire project on the left pane. Grinding project comprises:

- Grinding wheel
- Diamond/dressing wheel
- Gear
- Grinding process
- Dressing process
- Selected cycles (orientation — aligning of the grinding wheel with gear tooth, grinding, inspection, adjustments)
- Results of inspection
- Setup adjustments recommendations

Grinding project tree can include familiar navigational features such as:

- Collapsing/expanding nodes in the project tree
- Adding/removing/sequencing grinding process items (orientation, dressing, grinding, inspection)

A tree project structure (without the right pane) with some expanded notes is shown (Fig. 17). The operator may collapse or expand each node at will. Figure 18 depicts an example of the profile inspection details as viewed by clicking on the project tree "profile inspection" node.

Conclusion

Once again, HMI bears the prime responsibility for the operator experience and for making the functionality of the machine explicable and intuitive. With friendlier and more intuitive HMIs that have default features, minimum data entry requirement, visual verification, and easier navigation, users are now empowered with both a more pleasant experience and a setup time reduction.

The author would like to express his gratitude to John Waxler for his assistance in preparing the supporting graphics and for converting the math models into computer codes.

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Standard Samples for Grinder Burn Etch Testing

Jonathan R. Crow and Michael A. Pershing

Introduction

Surface temper etch inspection ("acid etch" testing) for thermal damage as a result of hard finishing (typically, grinding) operations is the most prevalent inspection method in gear manufacturing. The acid etch method relies on contrast in color, resulting from nitric acid severity of attack on thermally affected areas vs. those areas that are not thermally affected. There are known issues with maintaining proper nitric acid baths, HCl baths, wash baths, and rinse baths. Assurance that an acid etch system and method is working correctly requires a standard sample. This paper discusses a unique method of producing a sample that has a very consistent amount of thermal damage. Multiple degrees of burn are applied to the sample to ensure that the etch inspection can detect all levels of potential burn on the piece parts. The sample can then be reliably used to test an acid etch system and method to ensure the proper amount of contrast for threshold levels of thermal damage. The developed sample, with standardized burns, may be processed through the etch tanks at frequent intervals (or even simultaneously with piece parts) to ensure the etch system is able to detect any burn that may be present on the actual piece parts. The method of producing the sample is described here, as are methods of quality control using the standard.

Hardened gears — subsequently hard finished (typically via hard grinding) — can be subjected to thermal damage known as "grinder burn." This undesirable thermal damage occurs if hard grinding variables are not carefully controlled. The thermal damage resulting from grinder burn affects near-surface metallurgical properties and can result in reduced gear life or even premature failures. The harmful effects depend on the degree of thermal damage present and can include reduced hardness, increased hardness, harmful change in residual stress state, and even cracking in more severe cases. Detection of this burn is critical in any quality control plan for hard ground gears.

Although various methods are utilized to detect grinding burn, many gear manufacturers continue to utilize one of several varieties of surface temper etch inspection methods (herein called "acid etching"). Acid etching has been utilized for many years with successful implementation in many industries that utilize hard grinding. Other NDE methods are also utilized, such as Barkhausen noise, which have been beneficial but also difficult to implement economically and without confident correlation of results. For this reason acid etching is the most common method.

Several international standards exist for grind burn acid etching (Refs. 1–2). Exact processes vary, but all generally use some combination of pre-cleaners, etching acids, rinses, and rust preventive steps (Fig. 1) to create a detectable visual contrast on any

Figure 1 Series of tanks for acid etching in a gear manufacturing facility.

Figure 2 Example of burned gear after going through the acid etch series of tanks; dark areas show "temper-back," with some visible cracking.

burned areas of the ground surface (Fig. 2). Regardless of the method used, the detection of damage is visual — and therefore extremely dependent on careful control of the etching processing variables to achieve an acceptable result. After burned parts are acid etched, differing degrees of grinder burn are visually discernable and differ in appearance and therefore simultaneously provide guidance on both the presence and severity of burn. In order to assure that the acid etching procedure and system is working well, a standardization sample is desired to ensure adequate controls over all of the variables encountered in acid etching.

"Grinder burn" is a blanket term that encompasses varying degrees of thermal damage, and etching is used to indicate both the presence and severity of any burn present. After etching, an undamaged part will be a uniform light gray color. Areas heated enough to cause excessive tempering will etch darker than this uniform light gray and will appear between a darker shade of gray or even black, depending on severity of temperature exposure. This type of damage is commonly called "over-tempering," "temper-back," or simply "tempering." The most severe type of burn occurs when the thermal exposure due to grinding damage exceeds the material's austenitizing temperature, and is commonly called "re-hardening." Re-hardened areas etch white against the gray background and are typically surrounded by an intermediate temperature exposure area, etching black or gray (temper-back). A burned gear could therefore have varying mixtures of black, dark gray, light gray, and even white areas after etching, depending on the severity of burn present. For visual detection, any burn must exhibit sufficient contrast against this palette of a uniform gray. For any etching process, developing this contrast between damaged and undamaged areas is of paramount importance.

Background

There are many variables to control in an acid etch process in order to properly detect grinder burn. Typically, control of the acid etching process is accomplished through careful control over all measureable process inputs, i.e. — immersion time, bath temperatures, bath concentrations and many others. Loss of control of any of these variables can create false-positive or false-negative burn detections — depending on the nature of the error — causing unnecessary rework, scrap, or even customer quality excursions. Setting of control limits for each of these variables is typically based on experience and past practice, which creates the highest possible visual contrast, balanced with the minimized part damage and material removal from the parts. Establishing control ranges for these various process inputs is difficult. In fact, limits may even be established that are more demanding than the process requires, simply in an effort to ensure a semblance of process control. Further, there are several important variables that are much more difficult to quantify (part cleanliness and bath cleanliness, for example) that are not easily measured or quantified in a production environment. The sample described herein bypasses these limitations of conventional process controls and presents a known burn to the process to ultimately test the level of detectability produced by the entire etching process.

Multiple standards (ISO 14014 and AMS 2649) (Refs. 1–2) refer to the need of the creation of pre-burned samples to aid in verification of etch process performance; but creation of these samples is out of scope of these documents, therefore they lack any detail about how to create them. While creating deliberate grind burn on a test sample is certainly possible with a grinding wheel, the repeatability of any type of such a process is likely to be low. Replication of a consistent level of thermal damage is desirable for sample distribution among various facilities in an organization, for example. Creating varying levels of thermal damage on a prepared test sample is possible in a repeatable fashion and is the focus of this paper.

Discussion and Future Work

Ideally, a single test sample could be created that would show different levels of tempering or thermal effect. In order to emulate the thermal effects of grinding damage, a laser was used to create a specimen with exact and differing levels of tempering or heat throughout one specimen. Laser heat treatment of sample plates, consisting of similar material and heat treatment as the subject parts, is the proposed solution to the desire for a single standard test piece. Laser heat treating is an attractive option because of its ability to create multiple levels of thermal damage on the same part with the same process in a single part setup. Additionally, the heat input is controllable over a range of heat inputs. Using this method, a single sample may be thermally exposed over a range of temperatures, emulating varying levels of grinder burn within the same part. Of particular usefulness, this process may be repeated on multiple samples, creating multiple 'standardization' samples that may be used in differing acid etching processes. Such samples could even be run at the same time as the parts being analyzed, thus providing a record of acceptable etching performance.

Since the sample was developed in conjunction with carburized and hardened gear manufacturing, the standardization sample was similarly carburized and hardened with a similar material. The same standardization approach would work with gears hardened by various other means, provided the test samples were manufactured from a similar material and heat treat combination as the audited parts.

Figure 3 is a simple drawing of the proposed sample. This plate is first carburized and hardened to an effective case of approximately 3 mm and a good surface carbon plateau of 0.8–0.9% C. The plates are then very carefully surface ground to remove approximately 100 microns of material. This minimum stock removal is important to ensure removal of the shallow layer of non-martensitic transformation products (NMTP) from the carburized case that would otherwise interfere with accurate visual inspection after etching (Fig. 4). During grinding, parts were repeatedly etched to ensure no grinding burn was occurring and the surface grind process was in control. Parts were not etched after the final grinding pass to ensure a consistent surface finish and reflectance necessary for subsequent laser heat treating.

Laser heat treating was then utilized to create at least three different degrees of burn damage — complete re-hardening, heavy tempering, and light tempering, with intermediate levels applied as space allowed on the surface of the sample (Fig. 5). Once the cycle was established, it was easily replicated to create many identical samples. Both sides of a given plate may be laser heat treated, providing two surfaces for inspection if desired. There

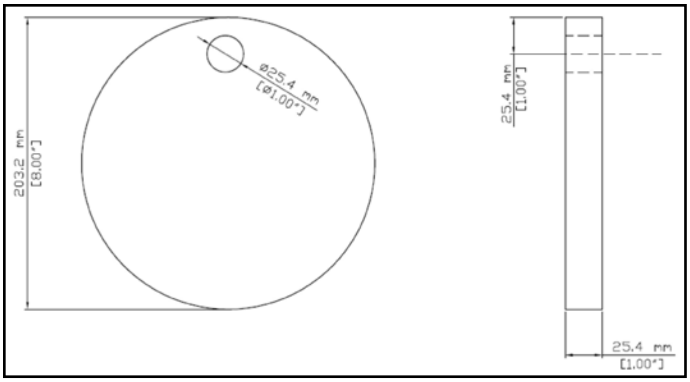

Figure 3 Drawing showing dimensions of the round plate that is carburized, hardened, and lightly ground and then laser heat treated.

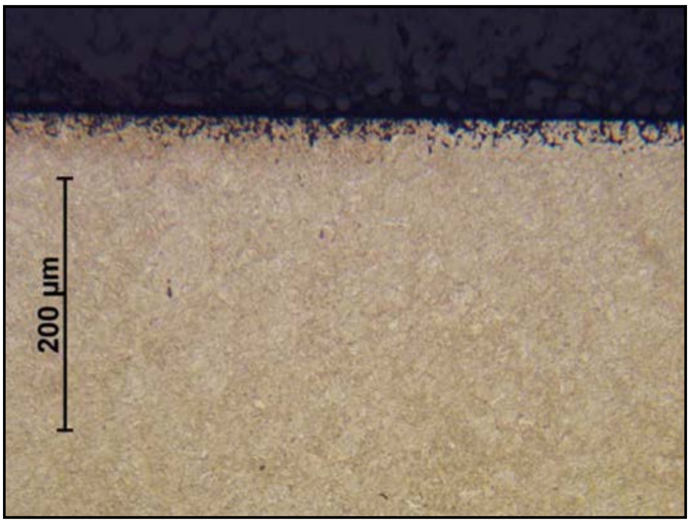

Figure 4 Non-martensitic transformation products at the surface of the plate after carburize and harden. Removal by grinding is necessary to keep steady temper-back color effects. The grinding must be done carefully so there is no thermal damage.

Figure 5 The standard sample as it appears after a good acid etch.

are different ways to make the samples, in terms of the laser heat treat pattern. The samples may be sectioned into smaller pieces as desired. Various lasers and settings could be utilized to produce the sample. For this work, a 4,000W direct diode laser was utilized (880 nm wavelength, continuous wave).

Once a consistent set of samples has been created, it is ready to be utilized as a part of the quality control around the acid etch process. A sample can be processed in a given acid tank as an audit of etching performance. The sample may be run periodically (i.e., 1×/shift, 1×/4 hours, etc.) or even run side-by-side with especially critical piece parts. Samples may also be cleaned and re-used multiple times. Re-use frequency is dependent on etch cycle specifics (concentration, immersion time), but re-use of samples up to 20 times has been observed. While cleaning via abrasive pad between etching runs was used for these studies, any cleaning method that minimizes stock removal and returns the part to a shiny, pre-etching appearance is acceptable. After too many etching cycles, the more aggressive acid attack in the burned areas eventually creates observable pitting on the surface of the sample, at which point it should be discarded and replaced. Pictures may also be kept of etching performance of the test sample from each etching cycle as an additional record of process performance.

Both Type I errors (α-Risk, Producer Risk) and Type II errors (β-risk, Consumer Risk) can occur with grind burn etching processes if variables are not closely controlled. The test samples can help to avoid either type of error but are particularly effective in avoiding Type II errors. In a scenario without use of the sample, the etch tank could be completely ineffective in detecting burn, and be unknown to the inspector. In this case, the inspector could unknowingly release burned parts to a customer. Using the described 'standard' samples now allows the inspector to be sure that the tank performance is adequate to detect the necessary ranges of burn severity.

The samples are also particularly useful to assess potential changes to the acid etch procedure. Changes to chemical types, suppliers, or concentrations are sometimes necessary or desired, and there may be questions about the process remaining effective or equivalent to the previous procedure. These samples provide a method for judging the effectiveness and equivalence of these changes.

Conclusions / Summary

- A standard sample was created to standardize and "master" the performance of a given etch tank and process.
- The sample ensures that differing levels of thermal damage can be detected by using laser heat treatment to create areas of re-hardening, heavy tempering, and light tempering — all on the same sample piece.
- A single standard sample piece can be reused multiple times.
- The sample is effective for use in daily quality control or in evaluating potential acid etch procedure changes.

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1. ISO 14014. , 2009, "Acid Etch Testing," ISO Std. 1596–992, 2009.
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AGMA/ABMA

ANNUAL MEETING HIGHLIGHTS

More than 300 executives gathered in late April to connect and network with peers at the 2018 AGMA/ABMA Annual Meeting in Naples, Florida. Here are some of the highlights during the event:

Lifetime Achievement Award

The American Gear Manufacturers Association (AGMA) presented **David Goodfellow**, president of Star SU, with the AGMA Lifetime Achievement award. This award is presented to someone who has demonstrated dedication and leadership for the advancement of the gear industry and AGMA, exemplified superior vision and exceptional knowledge that has been shared with colleagues and achieved admiration and respect of peers.

"David has gone above and beyond for the gear industry and has been a true leader to all of us in manufacturing," said James Bregi, chairman of the AGMA Board of Directors. "He has generously given his time and resources to help in the advancement of AGMA and its members."

Goodfellow began his career in gears after serving in the U.S. Army and attending Syracuse University. He was eventually named president of American Pfauter in 1981. Most notably, Goodfelllow was instrumental in the introduction of the wafer hob concept and the advancement of high-speed gear hobbing while with American Pfauter and Pfauter Maag Cutting Tools.

"David's name is synonymous with expertise and leadership in our industry worldwide," Jeff Lawton of Star Cutter Company noted in his nomination. "For nearly 50 years, David has impacted those around him as a colleague and mentor and most importantly, as a leader."

Goodfellow was part of the visionary leaders in the creation of the Gear Expo tradeshow. Additionally, he has been an ambassador to the international companies assisting in the transition of AGMA to becoming a global leader for gear manufacturers.

Chairman's Award

The American Gear Manufacturers Association (AGMA) presented **Jack Masseth** of Meritor, Inc., with the AGMA Chairman's award. This award is presented to a recipient that has contributed greatly to the gear industry and has gone above and beyond the call of duty to support innovation and advancement through AGMA.

Masseth graduated from Rochester Institute of Technology in Mechanical Engineering and began his career at The Gleason Works. After 13 years of applications engineering he moved to Dana in Fort Wayne, Indiana and work for 14 years as chief engineer, gear engineering and development. From there he moved to American Axle and Manufacturing and then to his current position at Meritor.

"Jack is a great example of what this award represents," said James Bregi, chairman of the AGMA Board of Directors. "His dedication to the gear industry and leadership throughout the years to AGMA is something we all hope to strive for."

Masseth is an active member on the Vehicle Gearing Committee, Gear Efficiency Committee, the Gear Accuracy Committee and the Emerging Technology Committee. Jack was also instrumental in helping AGMA begin the Strategic Resource Network or SRN. This group has played an important part in attracting new leaders to AGMA.

Next Generation Award

The American Gear Manufacturers Association (AGMA) presented **Maeve McGoff**, sales and marketing coordinator at Cincinnati Gearing Systems, with the AGMA Next Generation award. This award is presented to someone who, while early in their career, is an emerging contributor, innovator and leader in the gear industry. A Next Generation award recipient demonstrates hard work and acts as a role model for others while having a positive impact on AGMA.

McGoff has seven years in the gear industry and has excelled in bringing a strong online presence to her company through re-branding, graphic design and video. Her energy and determination to bring innovation to manufacturing has been demonstrated through her active role in attending AGMA events and working to deliver value in modern platforms through social media and digital marketing.

"Her advertising and promotional methods not only informs and delivers value in a factual sense, they are also creative and appealing for a common consumer," explained Patrick Potter, director of sales with Cincinnati Gearing Systems. "Maeve has brought Cincinnati Gearing systems to the forefront of modern marketing. . .it is easier for CGS to connect to the younger generation and hopefully close the age gap in the workforce."

McGoff will be joining AGMA committees and has already provided many photos for AGMA events and the epicyclic committee.

The American Gear Manufacturers Association (AGMA) also announced Benjamin Sheen, gear engineering specialist at Eaton — vehicle group has been awarded the AGMA Next Generation award.

Sheen has aided the gear industry through innovative solutions and intellectual property generation, increased gear manufacturing productivity by introducing state-of-the-art processes and mentored young engineers at manufacturing plants and centers for developing the next generation. He was responsible for managing the installation of six robotic lines at Eaton, which increased their manufacturing productivity.

"Ben has been instrumental to advance gear technology within Eaton," Carlos Wink wrote in his nomination. "He is a role model for Eaton's global gear team, inspiring others to follow his steps as an innovator and engineering leader."

Sheen is a member of the AGMA Vehicle Gearing Committee and has taken five courses with AGMA to earn his Advanced Gear Engineering Certificate. Sheen has also presented at the AGMA Fall Technical Meeting where his paper was later published in *Gear Technology* magazine in July 2016.

AGMA Foundation Receives Donation for Scholarship Award

The American Gear Manufacturers Association (AGMA) Foundation received a $100,000 donation from Linda and Bipin Doshi, formerly of Schafer Industries. The announcement to endow a scholarship award through the AGMA Foundation was made to members at the 2018 AGMA/ABMA Annual Meeting in Naples, Florida last week. The $100,000 donation is the largest single gift ever received in the AGMA Foundation's 22 year history. The Doshis have been very active leaders with AGMA and AGMA Foundation Boards for many years. With this endowment, the AGMA Foundation will annually grant a, "Linda and Bipin Doshi Scholarship" to a top scholarship applicant. The AGMA Foundation annually grants scholarships to students who are planning in a career in the gear industry, or in power transmission as it relates to the gear industry. Technical/Associate level students are eligible for $2,500 scholarship awards, while Undergraduate and Graduate students are eligible for $5,000 awards. The first "Linda and Bipin Doshi Scholarship" will be granted in August 2019. "This generous gift will make a real difference in the lives of many students, and will provide the gear industry with a strong talent pool," says Cindy Bennett, executive director of the AGMA Foundation. "The future of the AGMA Foundation Scholarship program depends upon the generosity of donors such as Mr. and Mrs. Doshi. The Linda and Bipin Doshi Scholarship Endowment will grow and perpetuate excellence in the gear industry for many years to come." (*www.agma.org*)

Klingelnberg

SHOWCASES HIGH-PRODUCTION GENERATING GRINDING IN GERMANY

From April 18 to 19, 2018, international experts from the automotive industry were inspired by the system supplier's industry-specific solutions at Klingelnberg's Ettlingen Oberweier plant. In keeping with the theme of "High-production generating grinding in large-scale production — quiet gearing with Klingelnberg Industry 4.0 solutions," the main attraction of the event was the market launch of the Speed Viper² cylindrical gear generating grinding machine featuring the dual-spindle concept. On either side stood additional exhibits from the Höfler cylindrical gear and Oerlikon bevel gear machine lines, precision measuring centers from Klingelnberg and innovative production concepts such as Smart Tooling and Closed Loop. A winner of the iF-Design Award, the Speed Viper cylindrical gear generating grinding machine was developed by Klingelnberg with a special focus on high-production generating grinding. The innovative machine concept was presented to a large audience for the first time at EMO 2017 in Hanover, Germany. The solution provider took the opportunity of this two-day workshop to present further innovations to its customers in a targeted, application-centered setting. The dual-spindle concept of the Speed Viper² is especially designed to meet the productivity requirements of the automotive industry and its suppliers. Whereas the single-spindle machines offer high versatility and short set-up times, the dual-spindle machines are designed for large-scale production and minimal cycle times. In a number of interesting live demonstrations, over 100 gear experts from throughout Europe, Asia and the USA had an opportunity during the two-day event to design their own generating grinding process on the single- and dual-spindle machines on display: Speed Viper 300, Speed Viper 180 and Speed Viper² 80.

Cylindrical gear production in the Industry 4.0 concept

The innovative production philosophy manifested in the Speed Viper establishes a solid basis for quiet gearing in the Industry 4.0 production environment. This is because the Speed Viper works with Klingelnberg precision measuring centers in the fully automatic, corrective Closed Loop. The experts from Klingelnberg presented this technology using the P 40 precision measuring center on display. And Smart Tooling, the digital tool management system from Klingelnberg, ensures outstanding quality management throughout the process, since it provides a precise overview of the tool status at any time — another key component of the Industry 4.0 concept.

Greater versatility on the shop floor

In the presentation areas at the Ettlingen plant, workshop participants were also able to see for themselves what efficiency gains can be achieved in gear production thanks to modern technology. For example, in addition to the well-known and established bevel gear methods for large-scale production, the Oerlikon C 30 bevel gear cutting machine can also be used for machining cylindrical gears. As a complete machine tool, the Höfler TM 65 likewise surpasses virtually every competitor when it comes to versatility due to its ability to produce any type of complex gear bodies from bar stock in a complete machining process.

Interesting talks in a relaxed atmosphere

A series of timely talks on interesting technological topics rounded off the direct impressions participants gained from the machines on site. Participants also took advantage of the opportunity to address specific issues with the gear specialists from Klingelnberg and to discuss application questions in a practical setting. (*www.klingelnberg.com*)

Gleason

INAUGURATES NEW TECHNOLOGY AND MANUFACTURING CENTER IN SWITZERLAND

On April 19th, Gleason held a grand opening ceremony for its new facility in Studen, Switzerland. Many important customers from across the world attended the event which also included product and technology demonstrations.

The Gleason-Pfauter Studen organization has approximately 120 employees and focuses on the design and manufacturing of gear hobbing, gear power skiving and gear profile grinding machines all of which are typically equipped with automation solutions. Its products are shipped globally to a variety of industries including automotive, power tools and aerospace, to name a few.

The Gleason-Pfauter operation located in Studen has grown rapidly in recent years necessitating a move to a larger building to accommodate its expanding volume of business. The new advanced manufacturing facility extends the company's office space by 30% and machine assembly capacity by almost 60% compared to the previous premises. The assembly area has been optimized for effective material flow and the building was designed with energy efficiency and maintaining a low carbon footprint as high priorities.

Rudolf Moser, general manager of Gleason-Pfauter Studen, said "New technologies, including power skiving, are driving great interest and business opportunities from our customer base. Our success is a credit to our employees. Through their efforts our business continues to grow each year. Our new factory will create an even better environment to further develop new products and technologies and continue producing highest quality machines." (*www.gleason.com*)

Forest City Gear

ADDS DIRECTOR OF SALES

Forest City Gear has hired **Erik J. Spurling** as director of sales to oversee the activities of the company's network of direct and independent sales representatives nationwide, and to lead sales strategies that meet the growing demands of a wide and diverse customer base throughout the world's gear-making industries.

Spurling brings a wealth of sales and marketing experience and a deep familiarity with all facets of inside and outside sales and customer service processes, along with a strong background in manufacturing. This background, combined with his extensive sales and marketing leadership skills, made him an ideal candidate for the new position, says Wendy Young. "Manufacturing the world's best gears has always been the company's focus — Erik will help to elevate our sales efforts to that same level," says Young. "Our sales force, and the customers they serve, will benefit greatly from new strategies and methodologies that make the sales process faster and more efficient."

(*forestcitygear.com*)

June 12–15—HxGN Live 2018 Las Vegas, Nevada. HxGN LIVE is for manufacturers seeking to learn more about process automation, closed-loop manufacturing, and connecting CAE, CAD, CAM and metrology technology via the digital thread. The conference stages more than 120,000 sq. ft. of Hexagon technologies, nearly 500 sessions and 60+ exhibiting sponsors. The Zone technology expo features the digital thread at work as a common communication framework with feedback loops that embed continuous improvement into the product lifecycle. HxGN SMART Quality, Hexagon's online quality data and measurement resource management platform, is one of the prime tech highlights in The Zone. The innovative solution delivers information automation to quality management, so manufacturers and quality control professionals can shape smarter workflows and actively improve efficiency and productivity. For more information, visit *hexagonMI.com*.

June 17–20—PowderMet 2018 San Antonio, Texas. PowderMet2018 is the International Conference on Powder Metallurgy & Particulate Materials. The conference will feature over 200 worldwide PM industry experts presenting on PM, particulate materials, and metal additive manufacturing. The event includes extended exhibit hall hours, student poster sessions, evening networking events and the return of the co-located program AMPM2018, featuring worldwide industry experts presenting on the latest developments in the fast-growing field of metal additive manufacturing. AMPM2018 also hosts a 100+ exhibitor trade show in conjunction with PowderMet2018. "Metal AM is a natural fit for MPIF as we have supported the PM industry for nearly 75 years. We're excited to offer an expanded AMPM conference that allows for more time for the transfer of technology, and to expose the metal AM sector to the greater PM industry through access to both AMPM and PowderMet conferences," said James P. Adams, executive director/CEO of the MPIF. For more information, visit *AMPM2018.org* and *PowderMet2018.org*.

June 27–28—Dritev 2018 Bonn, Germany. Increased CO_2 discussions, sustainable mobility and electrified drives: The automotive transmission world is changing. Why the understanding of the transmission changes, how it is to be understood as part of the overall powertrain and why cross-component know-how becomes more and more important are the subjects of the Dritev in Bonn. Attendees can expect more than 1,500 developers, around 100 international exhibitors and 80 specialist lectures on one of the world's largest networking platforms for powertrain and transmission development. Thus, Dritev seamlessly connects to the long-standing tradition of the VDI Congress "Drivetrain for Vehicles." At the heart of the event is its selected technical program, which reflects the current challenges and developments in the transmission world. The program includes subjects such as the transmission topology for electrified powertrains and current concepts for automatic transmissions and e-axes. In these, the individual components motor, axle and gear are integrated in one element. For more information, visit *www.dritev.com*.

July 23–27—2018 Coordinate Metrology Society Conference Reno, Nevada. Designed to empower a rapidly evolving profession, the CMSC attracts metrology practitioners, quality control managers, manufacturing executives, scientists, students and educators. Attendees will find enriching, informative opportunities to learn about technology achievements, network with high-level master users, and get an overall picture of the state of the metrology industry. The conference is renowned for its original, expert-level technical papers and presentations covering the successful use of measurement and inspection technologies, industry best practices, new applications and innovations emerging in the field. The CMS Executive Board peer reviews all technical papers and publishes top selections in its prestigious, high-impact Journal of the CMSC. For more information, visit *www.cmsc.org*.

July 30-August 2–CAR Management Briefing Seminars Grand Traverse Resort, Traverse City, Michigan. Initiated by the University of Michigan in 1965, the first Center for Automotive Research Management Briefing Seminars (CAR MBS) hosted only 30 people. When the industry was at its highest number of employment, the event grew to attract more than 1,400 attendees annually from more than 35 states and 15 countries–representing industry, academia, media and the government. CAR MBS leads the industry in providing a context for auto industry stakeholders to discuss critical issues and emerging trends while fostering new industry relationships in daily networking sessions. Seminars include targeted sessions on manufacturing strategy, vehicle lightweighting, connected and automated vehicles, advanced powertrain, supply chain, sales forecasting, purchasing, talent and designing for technology. For more information, visit *www.cargroup.org*.

August 7-9–Ipsen U Cherry Valley, Illinois. Throughout the course, attendees are able to learn about an extensive range of topics - from an introduction to vacuum and atmosphere furnaces to heat treating, furnace controls, subsystems, maintenance and more. They will also be able to view the different furnace components firsthand while learning how they affect other parts of the furnace and/or specific processes, take part in one-on-one discussions with Ipsen experts, participate in a leak detection demonstration, and tour Ipsen's facility. The Ipsen U classroom features comfortable seating for up to 36 attendees, as well as integrated technology with a large smartboard and two additional monitors for interactive presentations and demonstrations. Register today for an upcoming 2018 Ipsen U course at *www.IpsenUSA.com/IpsenU*.

August 6-8–SAE Fundamentals of Modern Vehicle Transmissions Seminar Troy, Michigan. Starting with a look at the transmission's primary function — to couple the engine to the driveline and provide torque ratios between the two — this updated and expanded seminar covers the latest transmission systems designed to achieve the most efficient engine operation. Current designs, the components and subsystems used, their functional modes, how they operate, and the inter-relationships will be discussed. For more information, visit *www.sae.org/learn/content/99018/*.

September 10-15–IMTS 2018 Chicago, Illinois. More than 115,000 industrial decision-makers attend the International Manufacturing Technology Show to get ideas and find answers to their manufacturing problems. They will see new technology demonstrated in areas like aerospace, automotive, machine shop, medical and power generation. The IMTS Conference Program will focus on six topics in 2018 including Process Innovations, Alternative Manufacturing, Plant Operations, Automation, Quality and Industry 4.0/IIoT. Co-located shows include Hannover Messe USA: Integrated Automation, Motion & Drives, Surface Technology, ComVac and Industrial Supply. The Smartforce Student Summit will once again promote student and educator attendance and other familiar attractions such as AMT's Emerging Technology Center will highlight the latest manufacturing technologies. For more information, visit *www.imts.com*.

Setting a Hundred-Year Standard

Remembering Panhard and Levassor, the company that invented the first manual transmission.

Alex Cannella, Associate Editor

20th century French automobile company Panhard and Levassor were always unconventional. Sometimes, their deviations from the norm didn't quite pan out. For example, one car, the Panhard and Levassor Dynamic, featured the driver seat in the middle of the car, with passengers on either side, for a few years before the design was scrapped as awkward and impractical.

But while Panhard and Levassor's innovations sometimes ended in a few evolutionary dead ends, some also resulted in a lot of the automotive industry's first big steps that are still standard practice today.

They were the first to start mounting the engine on the front of the car. Before the turn of the 20th century, when automobiles were more still mostly motor buggies, the engine was often mounted behind the driver's seat. Levassor, the designer of the duo the company was named after, had been frustrated by previous, unsuccessful automotive designs that followed in the common rear-engine tradition of the day. So instead, he mounted a Daimler-patented 1.2 liter V-twin engine to the front of the car and connected it to a rear-wheel drive to work, a setup known as the Système Panhard. Even if you don't know it by name, you're no doubt familiar with it. After all, a lot of modern cars have been built on its basic principles.

Panhard and Levassor's Système Panhard might be the company's most well-known concept, remembered for the many firsts it brought to automobile design that have become ubiquitous today. But the Système Panhard also contained a world first that is of particular interest to us gear folk. Levassor replaced the then-traditional belt drives with the world's first ever manual transmission and clutch on an automobile.

It was just a simple three-speed sliding gear transmission that could never hold a candle to anything on the market today. But the Système Panhard's transmission was the dominant design up until 1928, when Cadillac innovated upon it with the synchromesh transmission, and conceptually, it remains the embryonic foundation for many of the basic principles for most transmissions we build today.

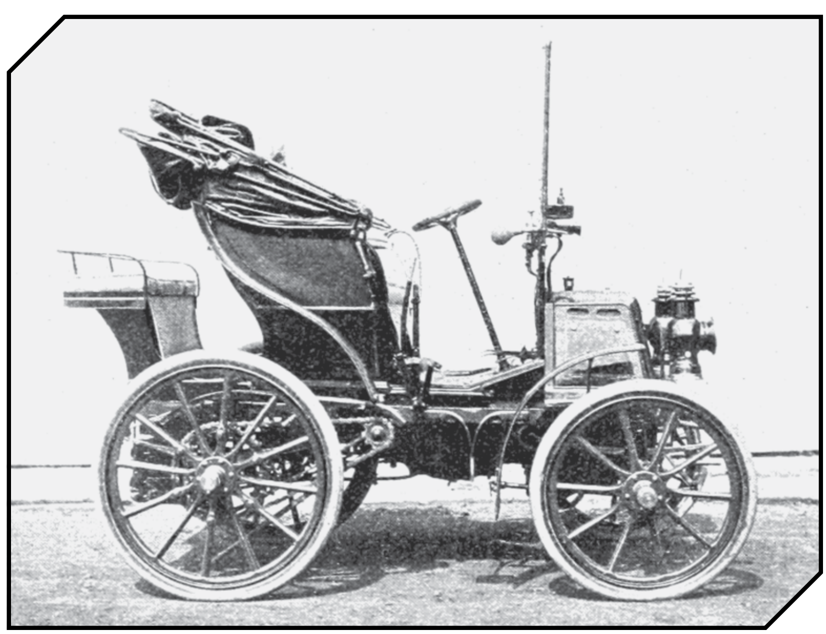
Within a decade, the Système Panhard had been adopted by most major car manufacturers, including Daimler themselves, as well as their main competitor at the time, Benz. Levassor himself went on to popularize his system's design by driving his own cars on several cross country races, most notably winning a 730-mile race from Paris to Bordeaux and back, before the hobby ultimately claimed his life in 1897 in a fatal racing accident. Panhard, the other mind of the pair, would pass on, as well, a decade later.

The company's innovations didn't stop after its two founders had passed, however. Most notably, they eventually developed the "Panhard rod," an early suspension rod that you can still find on some cars today.

But here again, Panhard and Levassor the company continued to put out less well-known innovations for transmission systems. It was never anything huge or flashy, but fundamental steps forward towards what we commonly recognize today as a modern transmission. Enclosed gearboxes in 1895. Quadrant changing four-speed transmissions in 1903. Gated manual shifts in 1910. The list goes on, and certainly isn't limited to just transmission technology.

After WWII, Levassor's name was eventually dropped from the company title, and Panhard continued making cars until 1967. The company's glory days as a trendsetter well behind it, it was absorbed by Citroën and has been bouncing around since until it most recently ended up in the hands of Renault Trucks Defense, part of the Volvo Group.

Ironically, the trends the company set have outlasted the company itself, and will continue to do so long into the future. But that's no reason to forget the names of both the company and the inventors that created the foundation for the modern automobile: Panhard and Levassor.



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