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SEP 2013

Gear Expo 2013 Issue

- Gear/ASM Exhibitor Interviews
- Showstoppers Advertising Section
- Show Map/All Booth Listings

STEM: The New 3 Rs?
How to Inspect a Gearbox

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August 2006
NASA begins development on Mars Science Laboratory Rover(MSL)-later renamed Curiosity.

December 2008 *(date for illustrative purposes only)*
Critical gears are required for MSL's 6 wheels. An American manufacturer is chosen to produce these. KAPP VUS55 is chosen to grind them.

November, 2011
Curiosity launches into space from Cape Canaveral Air Force Station, Florida.

August 6, 2012
Curiosity lands successfully on Mars.

September 2012 - July, 2013
Curiosity collects first samples of material ever drilled from rocks on Mars. Analysis shows evidence of conditions favorable for life in Mars' early history.

Gears good enough for NASA.

Booth 611

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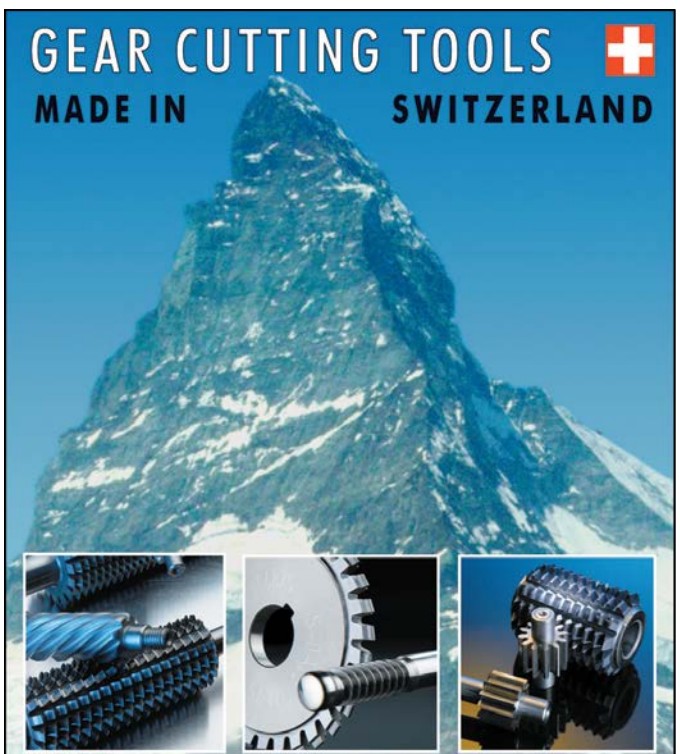

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Vol. 30, No. 6

departments

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Gear hobbing machine LCH 180 two
- Multi-cut strategy with roll/press deburr-chamfering
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Gear hobbing machine LC 180 Chamfer Cut
- High chamfer quality with one-cut hobbing strategy
- Primary hobbing time is done in parallel to chamfering in a second machining position

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GT VIDEOS

Ronson Gears recently released a video of a Corvette shaft being gear cut on one of Ronson's three auto load CNC gear cutting machines. These machines allow the company to produce gearing at a low cost and a higher quality.

Gear Expo Coverage

Additional Gear Expo coverage will be available on Twitter, Facebook and LinkedIn following the show, including product information, educational updates and a Gear Expo recap.

E-Newsletter:

Upcoming E-News topics for *Gear Technology* include the following:

October—Heat Treating
November—Cutting Tools
December—Gear Metrology

Contact *wrs@geartechnology.com* with editorial ideas.

Ask the Expert:

Do you have a question about gear design, manufacturing, heat treating, inspection or assembly? Submit your questions to our panel of experts at: *www.geartechnology.com/asktheexpert.php*

LinkedIn

We like events that cater to both audiences of Gear Technology and Power Transmission Engineering. Check out our LinkedIn page for upcoming trade shows, seminars or educational events like SME's Westec in Los Angeles (October 15-17).

Back to Basics:

Looking for good articles on gear fundamentals? Look no further than the *Gear Technology* Articles Archive. Just go to the home page and type "basics" in the search box.

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Going to Gear Expo

Publisher & Editor-in-Chief
Michael Goldstein

Like many of you in the gear industry, we've been working extremely hard over the past few months getting ready for Gear Expo 2013, which takes place September 17-19 in Indianapolis.

As we put the finishing touches on this issue of the magazine, we're also packing up and getting ready for our exhibit at the show. This year, we'll be in Booth #1123, and we're looking forward to meeting as many of you as possible. Our booth is your rest stop at the show—a place to sit down and relax among friends as you take a break from visiting hundreds of exhibits.

At our booth, we're officially beginning our celebration of 30 years of *Gear Technology*, with some special presentations you won't want to miss. Also, we'll be serving complimentary espresso, cappuccino and latte drinks. We invite you to come and spend a few moments with us, whether you need a boost of caffeine in the morning or you just need a break later in the day and want to take advantage of our comfy couch. Either way, we'll be happy to see you.

We're also putting together an exclusive special event – just for manufacturers of gears and gear drives – the morning of Wednesday, September 18. This unique opportunity, which includes breakfast, will focus on marketing in the gear industry. We'll be taking about the how and why of building your brand and the ways you can make your gears and gear drives stand out from the competition. We'll also make sure you're aware of all the tools we have available to help you with your marketing efforts, including our magazine *Power Transmission Engineering*, which is designed specifically to reach your customers: the buyers of gears, gear drives and mechanical power transmission components. So if your company sells gears or gear drives and you're going to be in Indianapolis during the show, contact Dave Friedman (*dave@geartechnology.com*) for more information (please note: because this event takes place before show hours, an entrance ticket will be required for admittance to the show floor).

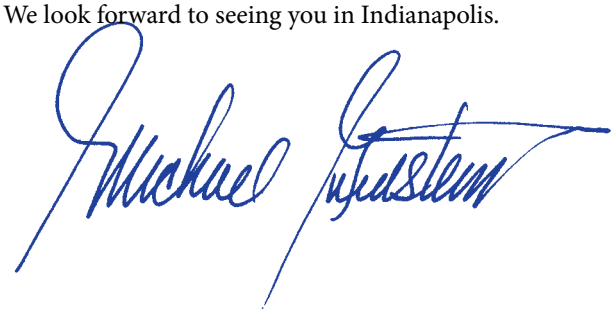
In order to help prepare you for your visit to Indianapolis, we've put together some 48 pages of Gear Expo related information, beginning on page 28. The map and listings will help you get your bearings at the show and identify the booths you want to see. More importantly, our booth previews and Showstopper advertising section will give you a good feel for what you can expect this year.

Once again, our coverage also includes information on the ASM Heat Treating Society Conference and Exhibition, which is co-located with Gear Expo. If you are interested in heat treating services and technology, the coverage begins on page 70.

You can find even more Gear Expo information online in our article archives at *geartechnology.com* and *powertransmission.com*. For example, the August 2013 issue of *Gear Technology* included an overview of the show, interviews with exhibitors about their expectations and coverage of the AGMA Fall Technical Meeting. The August 2013 issue of *Power Transmission Engineering* explored Gear Expo from a gear buyer's perspective, including listings of the gear and gear drive manufacturers who are exhibiting, as well as booth preview for many of them. Both issues also included Showstoppers advertising sections.

As always, Gear Expo will provide great opportunities for everyone in the gear industry, whether you are a supplier of machine tools, a gear manufacturer or a gear buyer. There is no other event that offers the same concentration of gear manufacturing industry knowledge, expertise and technology all in one place. So if gears are any significant part of your business, your company will benefit by your attendance at the show.

We look forward to seeing you in Indianapolis.



P.S. While you're there, please remember to stop by booth #1123 and renew your FREE subscription. You'll be covered for two years, so you won't have to renew again until Gear Expo 2015!

Feedback: Job Shop Lean (ongoing lean series in *Gear Technology* 2013)

Dr. Irani,

Congratulations. Many industries have been slow to implement celluar manufacturing. At the former New Venture Gear, we implemented work cells in 1995. Our work cells were heavily influenced by the design of work cells at Toyota, Mitsubishi, and Aisin A.I. in Japan. We took their design and elevated cell manufacturing to a much higher level. We realized that copying the Japanese layout design would only keep us even with the competition. We began analyzing the manufacturing process and how to revolutionize gear manufacturing.

Gear cutting has traditionally involved using heavy cutting oil. Cutting oil creates hazards itself. It creates slip hazards on the floor. It creates breathing health hazards for employees. It creates environmental hazards as it must be prevented from running off and contaminating the ground water supply and it must be disposed of properly. We had already moved past using heavy gear oil and were utilizing Cimcool water-based coolant, but we still had the same hazards.

We began to envision how we could cut gears without coolant. We were told [at that time] by gear cutting equipment manufacturer Pfauter that it was impractical if not impossible to cut gears without liquid coolants. We were told gear cutting hobs won't hold up to the heat generated from the cutting process without coolant. Despite this advice, our team remained true to the vision.

We brought in engineers from Mitsubishi Heavy Industries in Japan. Mitsubishi had developed a titanium aluminum nitride coating for cutting tools. If one knows anything about machine tools, they know that the coating on a tool performs as a lubricant. Cutting oils are also lubricant but additionally cool the gear that is being cut. By using gear hobs coated with TiAIN, the cutting speed required is approximately four times as fast as conventional gear cutting. Compressed air is utilized to evacuate the chips from the part. The heat goes away with the chip, leaving the gear lukewarm. Dry cutting gears reduces cutting time significantly: a gear that formerly required four minutes to cut with traditional gear cutting practices requires less than a minute to complete dry cutting.

Another major opportunity for improvement in gear manufacturing is to eliminate the damage from material handling while the gear is in a "green state." The damage to gear teeth prior to heat treating results in gearbox noise. The typical solution is to add manpower to grind the nicks off the gear teeth after heat treating. We did a cost analysis and determined that it was more economical to purchase additional heat treat alloy fixtures to load the gears directly onto at the gear cutting process instead of placing the gears into plastic dividers in a shipping container and then having an employee damage the gear teeth as he places them on the alloy fixture in the heat treat department.

Another major improvement we made was the transition from finishing the bores and faces by grinding to hard turning the surfaces with special inserts on CNC turning lathes. We achieved the same micro-finishes by hard turning that we did with the grinding process while eliminating the coolant that had all the hazards I mentioned with cutting oils in gear cutting. We also hard turned all diameters on all shafts instead of grinding.

We eliminated roving inspectors and placed the responsibility of quality upon the cell operator. We still had to verify gear geometry in the gear lab but only after a hob change or after a changeover from one gear part number to another. I mention the changeover because we invested in quick change over fixtures that allowed us to run more than one gear in a work cell. We had no dedicated work cells for any one gear. Since larger gears require heavier gear cutting equipment while smaller gears require less robust equipment, we grouped gears into size categories and routed them to the correct size equipment. This is batch running of gears, but heat treat operations forced batch processing of gears in furnaces anyway. When I left the company, we were working with a company out of Indianapolis on contour hardening of gear teeth utilizing induction hardening. If that process could have been developed, we could have had a true one-piece flow from forging to finished gear process ready for a gearbox assembly.

The most important success factor to our gear cutting was our reliance on machine capability and our TPM system. With capable equipment and scheduled tool change frequencies, the operator always produces a quality part.

For a work cell to be most efficient, the operator must be able to walk the entire cell continuously only stopping to load and unload each machine as he travels around the cell. Never should he be waiting for a machine to finish its cycle. In gear cutting, sometimes a gear has clutch teeth cut on a shaper machine such as a Fellows shaper in addition to the gear cutting operation. Shaping clutch gear teeth is a slower operation,


feature

JOB SHOP LEAN

Ed's Note: This is the fifth article in an eight-part "reality" series on implementing Continuous Improvement at Hoerbiger Corporation. Throughout 2013, Dr. Shahrukh Irani will report on his progress applying the job shop lean strategies he developed during his time at The Ohio State University. These lean methods focus on high-mix, low-volume, small-to-medium enterprises and can easily be applied to most gear manufacturing operations.

Dr. Shahrukh Irani, Director IE Research, Hoerbiger Corporation of America

Design of a Flexible and Lean (FLEAN) Machining Cell: Part 2 (Application)

Job shops may be ill-advised to undertake a complete reorganization into FLEAN (Flexible and Lean) cells. A FLEAN cell would (i) be flexible enough to produce any and all orders for parts that belong in a specific part family and (ii) utilize lean to the maximum extent possible to eliminate waste. For example, FLEAN cells that are implemented in job shops may not allow the perfect one-piece flow that is feasible in assembly cells. Still, due to the proximity between consecutively used machines, small batches of parts can be easily moved by hand or on wheeled carts or on short roller conveyors or using jib cranes. In fact, it is possible that the production volumes and demand stability for many part families simply could not justify dedicating equipment, tooling and personnel to producing any of those families in a stand-alone cell.

FLEAN Cells: Starting Point for Implementing Job Shop Lean

The starting point for implementing job shop lean in a high-mix, low-volume facility is to implement as many FLEAN cells as possible. In fact, management should further support continuous improvement (CI) projects to help each cell become an autonomous business unit (ABU). How? By empowering the team of employees in each cell to manage day-to-day operations and make decisions about allocation of orders to operators, deciding who gets cross-trained on which machines, etc. Those CI projects should be given top priority which seek to eliminate, or at least mitigate, all the

Figure 1 Material Flows in the Current Layout for the MP Cell (MPC).

Figure 2 Material Flows in the Proposed Layout for the MP Cell (MPC).

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so you may have to add an additional shaper into the cell and alternately load each shaper machine each time the operator cycles through the cell.

One of our typical gear cutting cells consisted of the following pieces of equipment: a lathe to turn the rough forging into a gear blank; a gear hobbing machine; a gear teeth chamfering machine; a clutch gear shaper; an oil hole drilling or slot cutting machine; and a washer for cleaning. At the time, we still used coolant on drills and clutch cutting machines because dry cutting had not been perfected at that time. That required the use of a washer in the work cell.

What was unique about our company was that being a joint venture between Chrysler and G.M. we produced the exact same products for both companies. The only difference between the transmissions we provided for each was the bell housing that mounted the transmission to the engine. I left the company two years before the joint venture was dissolved in 2002. I was the first employee hired by the Muncie division after the joint venture agreement was signed in 1990. If you have not adopted the above processes, there is much to be gained by doing so.

Gary Williams
Gdw1007@yahoo.com

Dr. Irani,
Congratulations. All those times we had our heated discussions of lean in job shops, and you have now done exactly what we did between 2006-2008 when I worked for the gearbox manufacturer. Your process is almost verbatim on the "what and how" we rationalized and worked through. Reading your article was like walking through that time period all over again! Our next step was to look at software (like Prasad's system), once our schedulers understood what they were doing well enough to have software do it for them.

Michael Thelen
C.I. Training Manager
mdthelen@bluebunny.com

Feedback: My Gear is Bigger than Your Gear (*Gear Technology* March/April 2013 and reprinted in *Gear Technology India* Q2 2013)

The article "My Gear is Bigger than Your Gear," made interesting reading. It is still debatable as to what criteria qualifies a gear to be BIG. Does it qualify on the basis of diameter, weight or power transmission capability? A very important parameter totally missing in your article is the qualification based on module of the gear. Having spent 25 years in the gear line, I feel that the largest module manufactured in the world should also be a serious contender for the achievement. The module of a gear has a direct relation to diameter and power transmitted. Also, it does not differentiate between a rotating gear and a rack, thereby putting to rest the controversy whether a rack should be considered for such a comparison or not. On checking the Internet, I found the largest module manufactured to be 50, made by David Brown.

P.D. Patiar
Bangalore

How Gear Standards are Written

T.J. "Buzz" Maiuri, Sr. Product/Project Manager, The Gleason Works

Several years ago my friend, colleague and past Technical Division Executive Committee (TDEC) Chairman Doctor Phil Terry (retired chief metallurgist, Lufkin Industries and now owner of P. Terry and Associates) wrote a very good article titled "Raising the Standards" about the AGMA Technical Division and the AGMA TDEC. Doctor Phil's words are still applicable today, and I'd like to revisit some parts of the article with a few updates, as well as explain the AGMA Standard and Information Sheet writing process.

The AGMA mission statement is "To help members compete more effectively in today's global marketplace." A large part of that mission has to do with the standards and information sheets created by the 26 committees in the Technical Division.

The Technical Division of AGMA is overseen by the TDEC. The TDEC has the responsibility to supervise the development and maintenance of AGMA Standards and other technical publications, as well as supervising the division's activities and coordinating them with the Administrative Division. The TDEC also organizes and conducts the annual Fall Technical Meeting.

The TDEC consists of a chairman (myself – T.J. "Buzz" Maiuri of The Gleason Works) and 7 voting members: John B. Amendola, Sr. of Artec Machine Systems; Terry Klaves of Milwaukee Gear Company; Bob Wasilewski of Arrow Gear Company; Dan Phebus of Fairfield Manufacturing Company; Todd Schatzka of Rexnord Corporation; Todd Praneis of Cotta Transmission Company and Bill Hankes of A-C Equipment Services. We meet face to face two to three times a year, once online via WebEx. As necessary, we use conference calls and e-mails throughout the year to take care of any business that needs to be addressed between meetings.

All TDEC meetings are attended by AGMA headquarters personnel Charlie Fischer – VP Technical Division and Amir Aboutaleb – staff engineer. Joe Franklin Jr. – president of AGMA also attends the meetings, as does the AGMA chairman of the board. The new chairman is Lou Ertel of Overton Chicago Gear Corporation, and the chairman emeritus is Matt Mondek of Reliance Gear Corporation.

Each member of the TDEC is also the liaison to several of the technical committees. As the liaison, he helps the committee chairman evaluate new projects and prepare proposals to the TDEC for the committees, as well as submit progress reports, completed work and committee problems to the TDEC.

The technical committees are responsible for the timely development, maintenance and theoretical accuracy of the technical publications of AGMA. Each committee has a chairman and vice chairman.

Several of the technical committees also serve as the United States Technical Advisory Group to programs within ISO TC 60 and ISO TC 14 (International Organization for Standardization – Technical Committee). The scope for ISO TC 60 is the standardization in the field of gears, including terminology, nominal dimensions, tolerances and tools for manufacturing and control. The scope for ISO TC 14 is the standardization in the field of shafts for machines, their keys and keyways, splines and serrations and their accessories such as couplings, flanges, etc.

AGMA is the secretary of ISO TC 60 and procedurally oversees all the standards programs that are undertaken.

All AGMA standards have the status of being American national standards as defined by the American National Standards Institute (ANSI). To maintain this status, AGMA's Technical Division operations are audited by ANSI every five years to ensure compliance with our own policy and practices, and with ANSI's requirements. The next audit will be in 2014.

There are currently 53 AGMA standards and 30 information sheets.

Information sheets are similar to standards, but are different in a few major ways. ANSI/AGMA standards comprise proven, reliable information. Information sheets, however, often contain material that is still being tested and proven. Information sheets are also a forum for setting new material before the industry so that they can be used and refined. ANSI/AGMA standards require balloting before the entire membership of AGMA, as well as any other interested parties. An information sheet requires only approval of the technical committee that prepared it, and permission to publish from the TDEC. One advantage to preparing an information sheet is that it can be published more quickly, since it does not go through the general ballot process. However, information sheets are not standards and do not carry the authority of consensus standards.

New standards and information sheet projects can originate from within an AGMA technical committee, the AGMA Business Management Executive Committee (BMEC), from AGMA membership, or from sources outside of AGMA.

The whole process from the proposal of a new standard or information sheet to its publication will take some time, and there are a number steps along the way. AGMA headquarters with the guidance of the TDEC has prepared a document titled "Operating Instructions for AGMA Committee Chairmen and Vice Chairman," which outlines the procedures for writing standards and information sheets. As an example, the document contains an extensive flow chart as well as a checklist with 30 task items for standards development. In addition, the manual contains other useful information in the "Policy and Practice Guide" portion of the document. (Note that the TDEC is in the process of reviewing the document for necessary updates to reflect current procedures.)

In brief, the process for a proposed standard will go something like this:

If the proposed standard originates from within a Technical Committee, the proposal will contain a written scope and justification for the standard. It

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will then be directed to the appropriate Committee Liaison on the TDEC.

The TDEC will then review and discuss the proposal, and if approved, the appropriate technical committee will be selected to work on the standard. Through filling of required forms with ANSI, interested parties outside of the AGMA membership body will be notified and invited to comment on the new project.

The technical committee will then create a working draft of the standard. The draft will be reviewed for style, format and metrification by the AGMA Technical Division before distributing it to the members of the committee for review and comments. The committee responsible for the development of the draft will then meet to review and resolve the comments submitted. Following this step, a new draft of the document will be prepared and a request will be made to the TDEC for permission to send the standard out for general ballot. If granted, the standard goes out for general ballot and the ballot comments are resolved by the technical committee. The general ballot list includes interested AGMA member companies, academic and honorary members as well as interested non-AGMA members subject to TDEC approval.

Another revision (if necessary from the ballot comments) is prepared and the technical committee will then recommend, through the TDEC liaison, the approval of the standard for publication.

If the TDEC approves the standard for publication, required forms will be submitted to ANSI to register the new document as an American National Standard and a recommendation will then be made to the Board of Directors to approve publication of the document.

AGMA Standards are reviewed every five years for reaffirmation, revision or withdrawal. AGMA also has a defined procedure involving headquarters, TDEC, and the technical committees for handling requests for interpretation of standards.

Individuals serving on the technical committees and the TDEC are volunteers from member companies. Involvement in AGMA is a win/win situation for everyone — the individuals serving, as well as the companies they are representing, and AGMA. There is no better way to learn about the standards, about the art of gearing and the gearing industry than participating on an AGMA technical committee. You don't have to be an expert to get involved, but I know for a fact that if you do participate on an AGMA committee, you will be working alongside some of the most knowledgeable individuals in the world of gearing.

We are always looking for new people to participate. If you are interested, we encourage you to contact Amir Aboutaleb at *Aboutaleb@agma.org*.

T.J. "Buzz" Maiuri
Sr. Product/Project Manager
The Gleason Works

New Standard for Large Ring Gears for Mills, Kilns

Tom Shumka, Global Inspections-NDT, Inc.

Methods of examining large ring gear teeth to detect surface breaking discontinuities have often been time-consuming and limited in terms of data collected. Methods such as visual and magnetic particle inspection can miss critical discontinuities. However, a new ASTM international standard provides a more effective method for gear examination using eddy current array, a technology that has been widely used but, until now, not standardized.

Eddy current inspection is based on Faraday's electromagnetic induction law. Eddy currents are created through a process called electromagnetic induction. The eddy current array (ECA) was developed just before the 20th century, and the technology provides the ability to drive electronically multiple eddy current coils placed side by side in the same probe assembly. General Electric was the first to use ECA on gearing in the late 1980s. ECA has been used for years in the aircraft and nuclear sectors plus numerous other applications that require fast and accurate surface inspections. This practice will help to standardize the use of this non-destructive testing approach for large ring gear inspections.

To understand operational and production behavior of operational machinery, a robust data collection and examination process must be established. ASTM International Standard E2905 was written for ring gear examinations. This method detects 100 percent of all gear tooth surface discontinuities, larger than 0.015 of an inch. There are two electromagnetic methods that are the basis of this standard: Eddy Current Array (ECA) and Alternating Current Field Measurement (ACFM) ASTM E2261.

Eddy current inspection addresses the need to detect surface breaking discontinuities electronically, and to have the ability to accurately size any surface-breaking cracks found on cast and forged gear and pinion teeth faster and more effectively than other methods. It will scan the addendum, dedendum and root of a gear tooth in 15 seconds. The whole depth of a tooth including the root can be scanned in one pass. This method will benefit both the manufacturer and the aftermarket service sectors.

Prior to the new standard, there were three types of inspections for gearing, besides visual:

1. Magnetic Particle (MT) - ASTM E709. Electromagnetic: Slow process, can miss indications and gear teeth have to be wiped clean to remove any residue.
2. Dye Penetrant (LT) - ASTM E1417: Same issues as Magnetic Particle. At best, these two methods can determine whether a flaw exists, but are unable to provide information on defect severity such as sizing – length and depth.
3. Ultrasonics ASTM A609: Requires couplant — faster than the above two methods, has a "blind" spot for surface, but can see depth.

Enter Eddy Current Inspection

The benefits of eddy current inspection for gear manufacturers include that it is much faster than magnetic particle and dye penetrant as a final inspection. Each tooth flank and root can be scanned in 15 seconds. It allows manufacturing to provide the client with an electronic map of addendum, dedendum and root area of each gear tooth when it leaves the plant.

Benefits for Aftermarket Services

E2905 is an excellent NDT electromagnetic method for the aftermarket service sector.

Cleaning has never been easier. 36' diameter ring gears can be cleaned in less than an hour. There is no need to wipe the gear teeth down after the cleaning, saving numerous person hours.

The method is cleaner, faster, documentable, and covers a larger area in less inspection time. Also it greatly improves probability of detection compared with other non-destructive testing methods used today for gearing applications.

Once the ring gear is inspected and leaves the factory, follow up inspections will deliver consistency, efficiency and standardization, a service valued by customers worldwide.

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The Ease of Ring Gear Cleaning

Over the years, ring gear cleaning using high viscosity, asphaltic-based lubricants has become something to be avoided at all costs. There is now a ring gear cleaning procedure that not only simplifies the cleaning process, but reduces numerous hours of labor. The exception to this is if the lubrication is an oil bath system. In this case, no cleaning is required. The actual time of cleaning a ring gear is under an hour. There is no need to wipe the gear teeth down by hand after inspection to remove residue as in magnetic particle or dye penetrant inspections. The ability to fully visualize the gear teeth is critical for a true gear inspection or audit.

Case Study

An excellent example of the benefits of this method is shown below. The client requested an inspection on a 34' diameter ring gear. Once again, the gear teeth are visually inspected as the teeth are scanned. On tooth 244A, (Figure 13) ECA detected two cracks that could not be visualized.

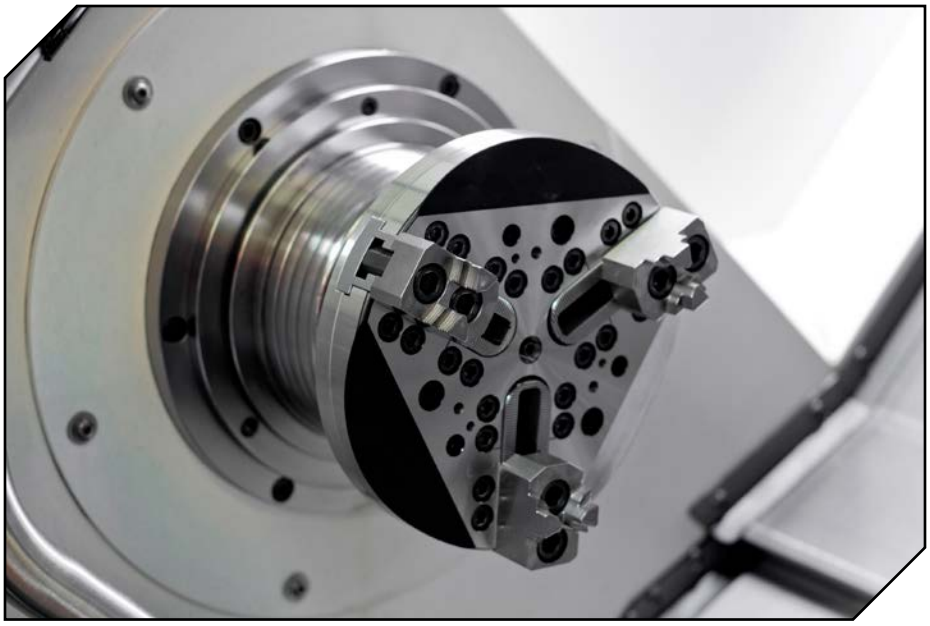
The next step was to size the cracks. Utilizing alternating field current measurement (ACFM), both cracks were sized. The larger crack was sized at 3.63" L×.68" deep. The sizing took less than three minutes. To further validate the characteristics of the crack, MT was used to visualize the crack and to document it. Moving forward, these cracks can be monitored through the inspection hole, on the gear guard, in less than fifteen minutes. Typically this mill would go down for scheduled maintenance four times a year, thus providing a comfort level to the client that any propagation of the cracks can be monitored.

Conclusions

- The inspection can take place alongside other maintenance personnel.
- E2905 will allow SAG and ball mill maintenance planners to reduce the time it takes to perform gear inspections.
- Planners that used to allow 36 hours to perform maintenance and inspect the gear set, now allow 18 to 24 hours for this job.
- It is conceivable to inspect four mills (2×34') and (2×24') in two days.
- This process provides comprehensive and accurate inspection data. This is very important in determining the integrity of the gear set.
- It reduces the reliance on human interpretation using other inspection methods.
- Insurance companies have all acknowledged the benefits of this method.
- This method provides real-time mapping of the inspected region, facilitating data interpretation, improving reliability and probability of detection (POD).
- All of this helps in minimizing catastrophic failures, resulting in reduced maintenance costs and increased uptime.

Hainbuch

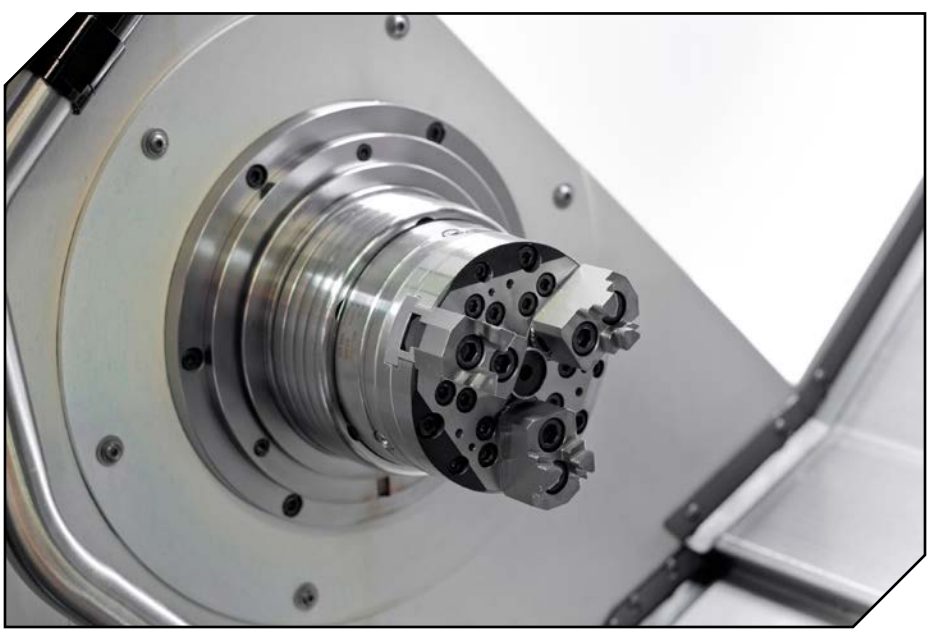
INTRODUCES JAW MODULE GENERATION TECHNOLOGY



Hainbuch presents a jaw module that is small and flexible, that can be quickly changed, and that covers a large clamping range. The result is a quick-change clamping solution for all situations. Mandrels and clamping heads can also be used in the basic unit. The new jaw module completes the circle and gives a new clamping dimension that opens up even more possibilities for users. All this with less weight and a smaller interference contour. In short: ID clamping, OD clamping and jaw clamping all-in-one.

The Hainbuch solution, consisting of a chuck and a jaw module, has nothing in common with the large, heavy, energy sapping big jaws that can be found in many machine shops,where their size is more of an obstacle than an advantage. These heavy chucks put load on the machine spindle and are slow to accelerate and decelerate, losing time and using energy. This takes longer for the part to be produced and hence makes it more expensive and also wears the machine bearings out more quickly. This is squandering of energy and piece rate time in its purest form. Naturally these are costs that today no one can afford or want to pay. Let's assume that someone purchases a lathe/milling machine with spindle taper DIN A2-6 65 mm bar capacity, here the workpiece range is usually diameter of 10 to 200 mm. To cover that range, a machine with a 215 jaw chuck is purchased. However 80 percent of the components are in a clamping range of 100 mm and smaller. And here the dilemma arises that in practice you have to cope with daily: Large clamping device, small workpiece. It is difficult to get all of the tools in place, often the tools will not reach center line and often special tools are required with longer reach, increasing vibration and losing accuracy. Also there is a high risk of collision.

Hainbuch modular solutions use a simple formula: Small workpiece = small clamping solution. Using the new small jaw module, about 80 percent of usual components are covered, and for larger components it can be easily changed over to a large jaw module within 30 seconds. The basic unit is a Spanntop chuck or Toplus chuck, now accepted as an excellent workholding device in its own right. Add to this the jaw module, clamping heads and mandrels; you achieve reliability, accuracy, and safety that traditional jaw chucks lack, especially for ID clamping. Advantages include a simple modular system for fast clamping to a clamping range of 200 mm; availability in two sizes (144, with clamping range from 25–115 mm and 215, with clamping range from 25–200 mm); minimal interference contour; proven technology; optimal utilization of the jaws; flexible, fast and repeatable set-up on clamping head or mandrel clamping; rigid workpiece clamping through the use of clamping head or mandrel; full bar size passage when using the clamping head; suitability for sensitive clamping and delicate components; option to be used as a pick-up chuck on sub spindles; ease of maintenance; resistance to contamination thanks to guideway seal and suitability for stationary use.



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Phone: (414) 358-9550
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Mahr Federal

OFFERS DIVERSE LINE OF CALIPERS

Mahr Federal offers an extremely broad line of MarCal calipers for a wide range of outside, inside, depth, step, and compound measurements. The MarCal line includes standard, special, and universal digital, dial, and mechanical calipers, as well as workshop calipers, depth calipers, and a line of linear machine scales with digital display.

The award-winning MarCal digital caliper line offers a number of advanced features, such as lapped guideways, a reference system that retains the zero position setting, and an increased number of product options and accessories. MarCal digital calipers offer a number of data output options, including wireless, and are available with protection against dust and immersion to class IP67. Advanced electronics provide increased battery life, and the line is available in a wide range of sizes, and blade and anvil configurations.

In addition to calipers with standard jaw designs, the MarCal line also includes a number of specially designed contact tips for measuring special part characteristics, and even jaws with replaceable and configurable contact points. Examples include cylindrically shaped jaws for exploring the wall thickness on cylindrical parts; narrow tipped jaws for measuring small grooves; jaw anvils configured to access recessed grooves, both ID and OD; tapered jaw tips designed to measure center-to-center distances on holes; adjustable height jaws to facilitate stepped measurements; knife-edge jaws with extra reach; and many more.

For users who require a high degree of versatility in their calipers, Mahr Federal offers a Universal Digital Caliper design. The MarCal 16 EWV can be used as a standard caliper, but includes a number of special blade tips, anvils and accessories that snap on for measuring a variety of groove and recess configurations. Other standard accessories include a depth measuring bridge, an ID setting gage, a device to determine measuring force, and attachments for measuring threads, balls, serrations and similar geometries. The MarCal Universal Digital Caliper includes all the standard features of the MarCal Digital Caliper line, and comes complete in a special carrying case designed to accommodate all the accessories.

For more information:
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EMAG

OFFERS HEAT SHRINK ASSEMBLY PROCESS

The composite camshaft is still gaining ground in the marketplace. The main reason for this is the considerable weight reduction it brings, compared to its one-piece rival. The composite version is by now also widely used in the HGV sector. However, the main disadvantage of many current assembly processes is the high joining force applied, which creates unacceptable tolerances in positioning and alignment of the cams. By contrast, the patented heat shrink assembly process from EMAG offers a decisive advantage, as it ensures that "ready-to-fit" camshafts, gear shafts and other precision composite units can be produced without problems.

The advantages of the composite camshaft are well known: less expense, less weight, the possibility to use different materials for the various constituent components, greater flexibility in production and the ability to implement new cam geometries, such as negative radii, with ease. The necessary reduction in fuel consumption – and with it those of CO_2 emissions – are easier to achieve with an increasing use of composite camshafts.

Alternative processes for the joining of cam and shaft have one serious disadvantage: the two components cannot be joined with the necessary accuracy to avoid a subsequent finish grinding process. In many cases, the joining of cam to tube is carried out using a form-fit process like press-fitting, knurling and/or spline/serrated gearing. The joining forces required for these processes can deform the components and result in unacceptable tolerances in cam position and orientation.

Heat Shrink Assembly Means Precision Joining

Thermal joining, i.e. the heat shrinking of cam onto tube, ensures that the required tolerances are achieved with a reaction force-free process. The know-how to tightly control the process parameters of "temperature" and "time" — and the mechanical design of the joining equipment — are of the utmost importance in this process.

An optimal combination of robot and special-concept gripping technology allows for fusion gaps of < 15 µm to be achieved safely. The concept's great flexibility allows camshaft designers more freedom in their designs and ensures that the process can also be used for medium batch sizes, where frequent component type changes are the order of the day. The high degree of precision of the composite camshaft drastically reduces the need to subsequently grind the cams or — where precision cams are used — does away with the requirement completely. A further

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advantage of this process lies in the possibility of using different materials for the composite shaft. This includes forged cams, for instance in 100Cr6, or finish-ground cams, even dimensionally accurate sintered cams that do not require a downstream finish-grinding operation. Secondary components, such as bungs and endpieces, can — just like the actual shaft itself — be made of more advantageous materials. All this allows the camshaft to be made to suit the requirements of the engine and to optimize it in terms of load bearing capacity and manufacturing costs.

And Now One Step Further

Where the camshaft needs to be ground after heat shrink assembly, the joining machine can be linked up to a grinder. This is particularly easy when using an EMAG grinding center of the VTC DS Series. With this setup, the joining machine robot transfers the assembled camshaft directly to the loading position on the grinding center. The advantages of this process from EMAG also apply to the machining of other components. When machining gear shafts, ground gears can be joined tightly on the shaft, without needing to account for the grinding wheel overrun at the design stage. It also minimizes the length of the shaft and makes the whole unit more compact.

Maximum Flexibility

The EMAG process is characterized by only a very few machining components being in direct contact with the workpiece. It allows for the machines to be reset in the shortest possible time (typically less than 15 minutes).

Quality Achievements

The heat shrink assembly process offered by EMAG combines flexibility with productivity, while freedom of design and choice of production technologies ensure a short cycle time. While one cam is heat shrinking, the next one is already being preheated. Equipping the heat shrinking machine with a number of preheating units allows for the optimal application of this technology to the task at hand. It is these advantages that may well be the reason why so many firmly established manufacturers of camshafts and other precision assemblies are showing such a great interest in the new process, are asking for machining tests, or are already applying the process under actual production conditions. In the ideal case, the customer will take advantage of the synergy provided by the EMAG Group and ask for a complete concept to be prepared that covers everything from pre-machining to heat shrinking and end machining.

For more information:
EMAG LLC
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Sunnen

HONING MACHINE FOR JOB SHOPS

The new SV-20 honing system is the first competitively priced large-part machine for job-shop part production with a true linear, vertical, servo-stroking system to produce precision bore geometries on compressors, oilfield components, automotive/truck blocks and similar parts. Suitable for job shops and repair facilities, the SV-20 is equipped with a variable-speed 15–550 rpm, 4.1-kW (5.5 hp) spindle motor, powerful enough to drive two-stage, metal-bond, diamond abrasives for short cycle times with high accuracy and minimal labor. The SV-20's linear stroking system keeps the honing tool concentric with the bore throughout the full stroke length to produce a consistent diameter from top to bottom of the bore. The machine's work envelope of 915 mm × 1015 mm (36" × 40"), front-loading design, and weight capacity up to 680 kg (1,500 lb) combine for versatility in processing a wide range of large parts. The SV-20 can be used to hone bores with inside diameters from 19-200 mm (0.75-8.00"). The PLC-controlled SV-20 utilizes a color touch screen, with a toggle switch to jog for fast setup. The swiveling operator panel can be adjusted for viewing from a variety of positions. A hand wheel on the machine allows left/right positioning of the column on its 760-mm (30") X-axis. The machine comes standard with a 208-litre (55-gallon) internal coolant system equipped with two standard canister filters. The SV-20's rotary servo tool feed system can be used with two-stage hone heads to complete roughing and finishing without stone changes for faster processing times. The machine is compatible with all of Sunnen's past and current tooling for CK/CV/SV-series machines, including diamond abrasive hone heads and brushes, GHSS single-stage hone heads with CBN or diamond abrasives and brushes, and GHTS hone heads for two-stage honing with CBN or diamond abrasives. The SV-20 is available with a 400V/50Hz/3Ph or 460V/60Hz/3Ph electrical system. The machine will be featured during Westec, October 15-17 in Los Angeles at Sunnen's booth (#2136).

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Dillon Manufacturing

EXPANDS GRIP JAWS

Dillon Manufacturing, Inc. has expanded their line of full grip jaws to 24 inches in diameter. These cast aluminum (356-T6) wraparound type top jaws can provide minimum jaw force for thin-walled parts and distribute the gripping pressure over more of the workpiece's surface —helping to maintain repetitive accuracy. This type of jaw reduces distortion and provides more friction for drive during turning operations. With close tolerances and concentricity easily maintained, they are suitable for applications such as valves, cylinders, specialty wheels and gears, housings and enclosures, adaptors and connectors, aluminum and steel shells, flanges, retainer rings, and other thin-walled parts such as automotive smog control air pump rotors, gas turbine parts, thin-wall tubing and cylinder liners for diesel engines and more. Dillon full grip top jaws are available from stock to fit chuck sizes ranging from 6 to 24 inch diameter, in both standard height and extra high jaws. They can be adapted to mount both manual and power chucks. Lighter weight Dillon full grip top jaws reduce mechanical stress, for improved machine and tool life.

For more information:
Dillon Manufacturing, Inc.
Phone: (800) 428-1133
www.dillonmfg.com

ITAMCO

RELEASES GLASSWARE APPLICATION

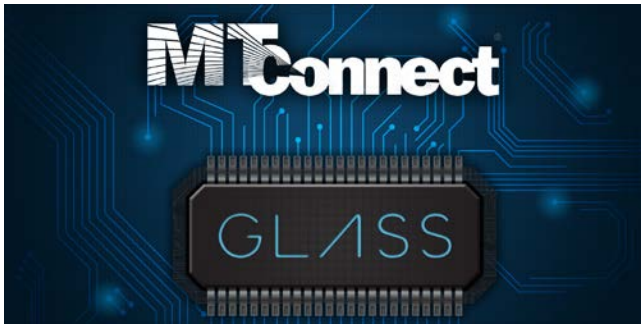
Indiana Technology and Manufacturing Companies (ITAMCO) has released MTConnect + Google Glass, a free Glassware application that monitors machine tools using Google Glass. MTConnect lowers the barriers to manufacturing intelligence, even to as complex a supply-side manufacturing chain as a fortune 500 company. Google Glass—a heads-up display, camera, touchpad, microphone, email and internet connection built into a spectacle frame—coupled with MTConnect functionality, will provide a view into the manufacturing process that until now has been unattainable. The Google Glass user will be liberated from laptops and hand-held smart devices and be able to travel the entire shop floor, gathering and sharing machine data provided by MTConnect, and accessing the internet for more information as he goes. The opportunities inspiring the merger between MTConnect and Google Glass are twofold. The first opportunity is in the

exploitation of augmented reality (AR). AR generates a composite view for the user that is the combination of the real scene, as viewed by the user, and a virtual scene generated by the computer with additional information such as sound, video, graphics, GPS data, or, in this case, manufacturing data via MTConnect. Google Glass becomes a natural extension of MTConnect's view into machines, providing intuitive and user-friendly access to manufacturing data.

The second opportunity lies in the commonalities between MTConnect and Google Glass: the implementation of both is easily achievable, and they are extensible and scalable. Both could be implemented on a small scale and grow with the needs and knowledge base of the facility. Every department in a manufacturing facility benefits from MTConnect + Google Glass, from the shop floor to the management suite. A new machine operator watches YouTube training videos while at the machine, supplementing his training program. Getting and sharing information on the machine and its processes would be as intuitive and non-threatening as using his smartphone or playing a video game. An experienced machine operator sends an email to the maintenance staff as soon as he sees a problem. The CEO travels the shop floor, getting accurate real-time machine data and comparing it to the company's accounting, quality control, sales and engineering data. Project managers evaluate workflow and machine readiness before scheduling future work. They also access 100 percent accurate data and share information with their customers to ensure smooth delivery between vendors. The maintenance staff becomes even more astute at monitoring machines and they respond quicker to problems, while developing stronger preventative maintenance programs. With Google Glass, they can "see" instruction manuals overlaid on the equipment when installing or repairing machinery. The sales staff provides guided Google Glass tours, impressing prospects with the capabilities of the facility and helping them visualize the final product.

Data Streams from MTConnect Agents Directly to Google Glass

Google Glass recognizes the machine tool, grabs appropriate information from MTConnect and parses the MTConnect stream to display it in a user-friendly way for the Google Glass wearer. The user will be able to view the following information from the MTConnect-compatible equipment: power status, emergency stop, alarm/messages, block, controller mode, line, program, execution, path feed-rate, spindle, axis positions, spindle overrides, feed-rate overrides, machine location, part location, and current part status. Also, if there is a camera inside the machine, Google Glass will stream the video to the user and overlay the machine data so the user can compare, analyze and make quick decisions. The user could record and share this data seamlessly with all appropriate parties.



MTConnect + Google Glass will provide a holistic experience of the factory floor that integrates user and machine in a uniquely personal way. The benefits of MTConnect are enhanced due to the faster and more comprehensive delivery method. Google Glass also extends easy-to-understand information to all employees, including administrative and marketing staff who aren't familiar with the shop floor.

For more information:
ITAMCO
Phone: (574) 936-2112
www.itamco.com

Siemens Has Georgia's Schools on Its Mind

Jack McGuinn, Senior Editor

Stephan Richter, publisher of *The Globalist*, an online magazine, in a recent *New York Times* op-ed piece (Sept. 16), serves up Detroit as a national metaphor for what has happened to U.S. manufacturing — and why. Referring to the heady, post-war years of the late 1940s, early 1950s, Richter comments on the country's hard-won — but fleeting — role as the world's No. 1 economic engine.

"But that (manufacturing) dominance was, to a considerable degree, a momentary quirk of history: the absence, in the wake of World War II, of any real competition from other nations. Once foreign competition was re-established, in Europe and Asia, only the superior skills of a nation's workers and a focus on long-term workers' training would allow a country to stay ahead."

He finishes his column with:

"Developing the necessary skills base is not a short-term project. It requires decades of concerted effort on many fronts, by many national, regional and local actors, including collaboration among companies, government, trade associations, schools, colleges and universities. Globalization, in many ways, serves as an early warning system for the changes required in a domestic society. No society should have been better prepared to utilize this tool than the United States, given its traditional — but at least for now largely lost — proclivity to embrace change. That it didn't work out that way is a tragedy of the nation's own making."

The good news is that state legislatures around the country are getting wise to the fact that the country's future — its youngsters — is in jeopardy. For any number of reasons — societal, financial or political — too many of our kids are not learning what they need to know to be viably employable for the type of work that now defines the 21st century workplace. STEM (science, technology, engineering, and mathematics) is the new "Three Rs," and if that strikes dread in the hearts of former English majors, welcome to the Brave New World.

And to help get the job done, the state — behind an initiative of the nonprofit Georgia Foundation for Public Education (GFPE), and supported by the Georgia Department of Education (GaDoE) — has enlisted the willing participation of Siemens USA in developing advanced educational courses for the GFPE's Career Pathways program, charged with training Georgia students using a curriculum based on the employment needs of international companies with facilities in the state.

"We are excited to assist the Georgia educational community with the launch of this educational program," said Helmuth Ludwig, Siemens Industry Sector North America CEO at a press conference announcing the partnership. "This partnership is consistent with our values – responsible, excellent and innovative — and it will promote STEM initiatives throughout the Southeast region of the United States. Through this program, companies like Siemens will be able to identify and develop the next generation of outstanding employees."

GFPE worked with Siemens to develop teaching curriculum for GaDoE's Manufacturing Pathway, based on training materials, manuals and other educational tools used at the company's Drive Technologies manufacturing plant in Alpharetta, Georgia. The associated training materials provided by Siemens are valued at more than $500,000.

The pilot program has been rolled out in South Forsyth High School, where it will be delivered by a teacher that was trained at Siemens. Eventually, the program will also include internships, work-based learning projects and opportunities for overseas cultural experiences for students in Germany.

Of course programs like this don't materialize overnight. It often takes time for legislative bodies to get with the program — like watching an aircraft carrier doing a 180° in harbor. But when a state's most important employers start chirping about not being able to fill high-tech openings, attention is paid.

"(Georgia) House Bill 186 was passed in the spring of 2011, enacting the Career Pathways as part of the state's education policy. During the time the Bill was being debated, a number of CEO's and other business leaders gave feedback to the legislature that they had job openings that were going unfilled in Georgia due to a lack of skilled workers," says Denis Brosnan, principal consultant at Yellow Park Garden and managing director of the Global Workforce Initiative (GWI) for the Georgia Department of Education. "In the months that followed the enactment of HB 186, these business leaders also indicated to members of the legislature and to State Superintendent Dr. John Barge they were willing to assist in the construction and rollout of the Pathways by donating their time, talent and training materials. As a result, in 2012, the legislature enacted the Global Workforce Initiative (GWI) to facilitate cooperation among the business and education communities."

Brosnan was among the many CEO's and other business leaders who worked with officials from the Department of Education, the Technical College System of Georgia, the University System of Georgia, and other governmental agencies to formulate the GWI concept.

Brosnan says "The Career Pathways concept arose out of a nationwide collaboration with other State Departments of Education. Additionally Dr. Barge and his staff further tailored the program by benchmarking innovative programs in

other countries, most notably Germany, France, Finland, and Korea.

"The program was enacted by the Georgia General Assembly in 2011, and the Global Workforce Initiative, an outreach program of the Georgia Foundation for Public Education, a state-chartered not-for-profit corporation, was thereafter created by statute in 2012."

According to Forsyth assistant director for governance and career development coordinator Valery Hall, "The local pilot of the manufacturing curricula developed in cooperation with Siemens began in August at South Forsyth High School. Because the Siemens GWI partnership is designed to afford students who complete the program an opportunity to become employed by Siemens following graduation, it was important to select a school district partner nearby to the Siemens factory in Alpharetta.

"Additionally, Forsyth County Schools has a long history of successful collaborations with the local business community in general and with Siemens in particular, and the district was very enthusiastic about participating in this program."

And while the program does not offer any hands-on manufacturing training on CNCs, gear grinders and the like, it will in fact offer a "manufacturing cluster" that includes a mechatronics path and the STEM cluster with "pathways" in disciplines like engineering, drafting and design.

As for admittance requirements, Hall explains that "students have self-selected, based on career interests, and are designating either engineering or integrated manufacturing, specifically. Students can begin the pathway either in 9th or 10th grade to ensure they will have a work-based learning opportunity by their senior year."

Somewhat ironically, while the clamor for beefed up academics is growing nationally, there is at the same time a

"Forsyth County Schools has a long history of successful collaborations with the local business community in general and with Siemens in particular, and the district was very enthusiastic about participating in this program."

Valery Hall,
Forsyth assistant director for governance and career development coordinator

"The Career Pathways in general—and GWI partnership programs in particular—enable participating students to graduate with a certification in the skill area of their choosing, thereby empowering these students to be immediately employable upon graduation from high school"

Denis Brosnan,
principal consultant at Yellow Park Garden and managing director of the Global Workforce Initiative (GWI) for the Georgia Department of Education

growing recognition that college is not for every kid — that a potentially satisfying career and quality of life awaits bright kids with special skills to match — with or without a degree.

To that point, Brosnan responds that "The Career Pathways in general — and GWI partnership programs in particular — enable participating students to graduate with a certification in the skill area of their choosing, thereby empowering these students to be immediately employable upon graduation from high school. Of course, these students may also then or thereafter continue their schooling by seeking a degree at a technical college or university in that or any other area."

All good so far — but what about scholarships for these kids to help in advancing their budding careers? Do they exist? Whenever bright youngsters are deprived of being all they can be, money is not the root of all evil — *not having it* is what hurts. Brosnan says they are working on it.

"Our work to date in the area of scholarships has been focused on securing funding to enable professional development of teachers and overseas cultural experiences for the students, teachers and business leaders who participate in the GWI. As additional GWI partnerships are brought online, we expect to tie these to new or existing scholarship programs for students who wish to continue their post-secondary education. Our discussions with potential GWI partners have also contemplated employer-sponsored tuition reimbursement programs, and we hope that these become standard features of our GWI solutions prospectively."

One critical positive is that the Pathways programs will soon "graduate" from the Forsyth incubator and spread throughout the Peach State. Hall explains that "Securing the assistance of Siemens in building out the manufacturing curricula is a huge benefit to Georgia. The curricula will be available through the Department of Education for all of the school districts around the state, and assistance will also be available to districts that want to participate in this and other, similar GWI partnerships."

And the state is looking to add on. The Siemens partnership is a keystone of the program, but buy-ins from other companies with high-tech manufacturing credentials looking to give back to the community will help ensure the program's success.

Brosnan: "Through the GFPE's GWI, Georgia has taken the additional step of providing a true public-private partnership utility platform for interested businesses to participate in the construction and roll-out of the Pathway courses. In addition to the social benefits provided by these collaborations, these businesses will benefit by gaining access to talent pools of skilled workers, which will reduce their recruiting, training and retention costs.

"As such, the GWI program is ultimately about filling jobs and growing our communities in Georgia."

For more information:

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Gear Expo Product Preview 2013

Matthew Jaster, Senior Editor

Manufacturing ingenuity will be on-hand in Indianapolis as exhibitors focus on the latest technologies that are changing gear manufacturing. Every two years the gear industry comes together to network with peers, talk shop and learn the latest advancements in gears and gear-related products. Here's a rundown of some of the booths attendees should stop by while roaming the Gear Expo hall (*Ed's Note: For heat treating exhibitors, see additional ASM Heat Treat 2013 coverage on page 70*).

Gleason Corporation

Booth #423

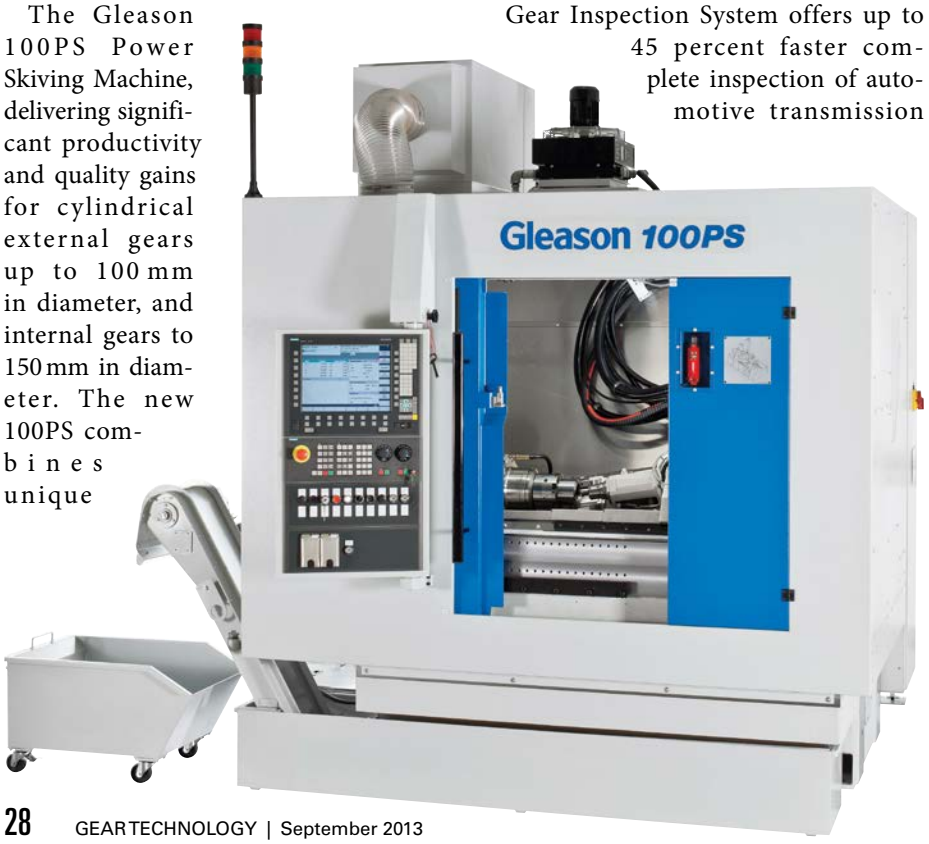
Gleason will introduce a host of advanced new machines, tooling, and global customer support services at Gear Expo 2013, covering a wide array of processes for the complete production and inspection of all types of bevel and cylindrical gears. On display for the first time in North America will be:

The Gleason 100PS Power Skiving Machine, delivering significant productivity and quality gains for cylindrical external gears up to 100 mm in diameter, and internal gears to 150 mm in diameter. The new 100PS combines unique machine, cutting tool and power skiving process expertise to offer users significant performance improvements, particularly in operations where shaping, forming, pressing and broaching are typically used. As compared to shaping, for example, the 100PS can deliver productivity rates as much as eight times higher.

The Gleason Power Skiving process additionally delivers quality levels that are superior to other soft machining processes, with the potential to be used as a 'green' finishing operation.

In addition, the 100PS can be operated both manually and automatically, and easily integrated into production lines with a variety of peripheral equipment, making it an ideal solution for any production volume, any lot size. It's just one of the complete new Gleason PS Power Skiving Series of machines with models available for workpieces as large as 700 mm in diameter.

The Gleason 300GMS Analytical Gear Inspection System offers up to 45 percent faster complete inspection of automotive transmission gears and other smaller gears, gear cutting tools and non-gear parts. The new 300GMS — latest addition to the GMS Series of inspection systems (with models available for gears up to 3,000 mm in diameter) — was developed specifically to meet the needs of automotive transmission gear producers for a faster, more economical solution for complete gear and even non-gear parts inspection. It is the first GMS to feature the new Windows 7-based Gleason *GAMA 3.0* applications software suite which, like its *GAMA 2.0* predecessor, offers users a highly intuitive user interface and simple input screens for programming of workpiece and cutting tool data. Those features, combined with ease of setup, a .NET control system, and movement optimization, reduce the cycle times required for the complete inspection of almost any gear or gear tool by up to 45 percent as compared to Gleason systems running earlier versions of *GAMA*, or competitive products. The 300 GMS also features a new-generation Renishaw 3-D probe head to provide maximum accuracy and flexibility for the complete inspection of all kinds of gears and gear-cutting tools and, in particular, finer pitch gears. The 300GMS is equipped with new ergonomically mounted operator workstations and a Gleason Diagnostic Module — both designed to greatly improve the operator's effectiveness at every stage of the inspection process. The Gleason Diagnostic Module puts a number of powerful tools right at the operator's fingertips, including a 'weather station' to record temperature and humidity, and video telephony, note pad and voice mail messaging capability, enabling the user to capture video, describe a particular programming issue and transmit it over the web to others in the customer's organization or to Gleason for support.



In addition, the 300GMS, like all the systems in the GMS family, offers users the ability to meet a variety of inspection tasks beyond just gear geometry on a single platform, including surface finish and form measurement and even prismatic (CMM) measurement. Visitors will also be introduced to a number of other significant products, technologies and services, including:

Cutting Tools

On display will be advanced new bevel gear cutting tools for cutting and grinding straight, spiral and hypoid bevel gears. For cylindrical gear production, visitors will find a full array of hobs, form relieved milling cutters, shaper cutters, chamfering and deburring tools, shaving cutters, honing tools, coated diamond and CBN grinding wheels, diamond dressing wheels and diamond dressing rolls.

Workholding

Gleason designs and produces a complete series of quick-change, tool-less workholding equipment for bevel gear, cylindrical gear and non-gear production machines. These systems range from the Gleason X-Pandisk systems which automatically align workpieces weighing up to 2,000 kg to reduce changeover time by up to 70 percent, to Quick-Flex and a large variety of quick-change workholding solutions that significantly reduce change-over times for the production of both bevel and cylindrical gears up to 200 mm in diameter. For inspection systems, Gleason offers the high-precision Gleason LeCount expanding mandrels line, renowned for accurate, easy, extremely rapid location of all types of bore parts.

Gleason Global Services

Gleason customers can rely on 250 factory trained service professionals located in over 50 countries throughout the Americas, Europe and Asia, working around the clock to deliver the full range of aftermarket service and support capabilities. Among the most recent of these is the new Gleason Connect 'Remote Service' technology, which enables Gleason service specialists from anywhere in the world to quickly and cost effectively identify, diagnose, repair and monitor products, minimizing costly downtime.

For more information:
Gleason Corporation
Phone: (585) 473-1000
www.gleason.com

Liebherr Gear Technology
Booth #510

The LC 500 universal hobbing machine, providing high machine availability and productivity, as well as flexibility, will be demonstrated at Gear Expo 2013. Market demand for more flexibility was a key factor in the development of the LC 500, which handles workpiece diameters to 500 mm and a maximum module of 12 mm. Liebherr designed the range of LC hobbing machines for universal applications in general mechanical engineering, the commercial vehicle gear industry and construction machinery, as well as their suppliers. Various processing applications can be flexibly performed and optimally configured to satisfy customer requirements, thanks to the one-piece machine bed.

The machine is available in both automatic and manual operation modes — depending on the specific range of requirements. There are a number of specific configuration options beyond

this: from coating and automation as well as drives and cutting heads to additional software modules. "This machine is not off-the-shelf. In addition to flexibility, availability and rigidity during processing characterize the machine concept, even in the event of extremely high cutting parameters. Its flexibility and the broad spectrum of components and batch sizes make it especially appealing to contract manufacturers," said Dr.-Ing. Oliver Winkel, director of application technology, who is responsible for the technological development of gear cutting for Liebherr Verzahntechnik.

Machine Table and Cutting Head

The machines are equipped with fully encapsulated workspaces and spur gears, as well as a highly dynamic, maintenance-free direct drive in the table to deliver premium gear quality. The drive can be a self-cooling spur gear or water-cooled direct drive, based on precision and productivity requirements. Large table bores facilitate the installation of clamping cylinders for workpiece clamping devices.

Different gear ratios for the water-cooled, zero-backlash tool drive mechanism help to achieve the torques required for high performance processing — with rotational speeds up to 3,000 rpm and drive power of up to 27 kW. The tool mount can be made using a hollow shank taper, ISO short taper or collets. An angular gear is available for worm cutting, which is only mounted as an attachment.

Winkel summarizes other features of the machine beyond high productivity and availability: "Taking the LC 500

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GEAREXPO 2013
EXHIBITOR
Booth #823

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as an example, it is easy to distinguish on what this gearing flexibility is based, namely on our ability to produce custom solutions for specific processing tasks. Simply said, customers present us with their components and we build the machines around them."

For more information:
Liebherr Gear Technology, Inc.
Phone: (734) 429-7225
www.liebherr.com

Kapp/Niles

Booth #611

The Kapp Group will be showcasing the Niles ZE 400 machine model, as well as introducing their new product line, R&P Metrology measuring machines. The Niles ZE 400 continues to be one of the most popular compact and economical machines in the gear grinding market due to its versatility to grind internal or external gears, while utilizing both dressable vitrified and non-dressable CBN grinding wheels. It is engineered

for high quality with maximum grinding torque. A stable ductile iron machine bed supports a workpiece of up to 2,650 pounds. The machine comes fully equipped with a tailstock and on-board measuring. It offers advanced productivity features such as rapid pre-grind measurement, which optimizes stock removal and prevents excessive stock removal, for best process safety. Showcased for the first time in North America is Kapp Group's newest product line, R&P Metrology measuring machines. R&P Metrology, a company launched by longtime gear industry professionals Hans Rauth and Christopher Plume, designs and builds gear metrology equipment, concentrating on medium and large parallel axis gears, bevel gears, tools, shafts, bearing rings and 3-D parts. The range starts at approximately 1.0 meter in size. Extended capacity requirements for large applications and customizing are the specialties of R&P Metrology.

Kapp CBN tools for direct grinding, and DIA dressers for grinding and honing are featured as well, and Kapp and Niles application and tool design engineers will be on-site to answer questions about specific applications.

The Kapp Group offers innovative technologies and systems for high precision hard-finishing of gears and profiles. Grinding machines and tools trademarked as Kapp are primarily geared towards the automobile, aerospace, manufacturing and compressor industries. The Niles grinding machines find their applications mainly in the wind energy, rail, drive technology as well as mineral extraction. The Kapp Group encompasses six locations world-wide with about 850 employees. Through continuous research and development, advanced design and manufacturing, as well as superior support, the Kapp Group offers specific solutions for its customers' complex applications.

For more information:
Kapp Technologies
Phone: (303) 447-1130
www.kapp-niles.com

Reishauer

Booth #1041

The inventor of continuous generating gear grinding, Reishauer AG of Wallisellen, Switzerland will be demonstrating the RZ 260. The concept is based on the extremely successful RZ 150 series with several hundred machines installed in plants worldwide. The RZ 260 has not only been increased in size, but also, all relevant components have been adapted to handle higher loads and forces which occur when grinding larger gears. Gears with an outside diameter of 260 mm and modules up to 5 mm can be ground with highest reliability.

An important focus in the design of the machine concept was adaptability to the different production requirements of numerous customers. The machine can be fitted with one or two work spindles. The version with two work spindles is used to minimize the loading times — as introduced with the Reishauer RZ 150. When investment and tooling costs must be minimized or the workpiece handling times are not critical, the RZ 260 with a single work spindle might be a more suitable choice. When grinding gears with space limitations or small lot sizes it might be advantageous to use the changeable profile grinding spindle enabling the use of a small plated or dressable wheel to grind gears with the discontinuous profile method. Both versions of the RZ 260 can be equipped with a fixed or CNC-controlled axis for swiveling the dressing tool. With this option, the flexibility of the dressing

tools can be increased since the same tool can be used for a range of gears as compared to the fixed dresser where the tools are usually workpiece specific.

Like all Reishauer gear grinding machines, the RZ 260 has been developed exclusively for the high demands of the continuous generating gear grinding process, also known as the Reishauer style. All design characteristics that lead to the success of other Reishauer machines have been incorporated in the RZ 260. This includes the Reishauer Generating Module for highest gear quality, Reishauer LNS Low Noise Shifting technology for very low gear noise emissions, Reishauer Twist Control Grinding technology to create defined values for flank twist and the Reishauer HMI for fast change over and set-up times.

For more information:
Reishauer Corporation
Phone: (847) 888-3828
www.reishauer-us.com

Star SU

Booth #901

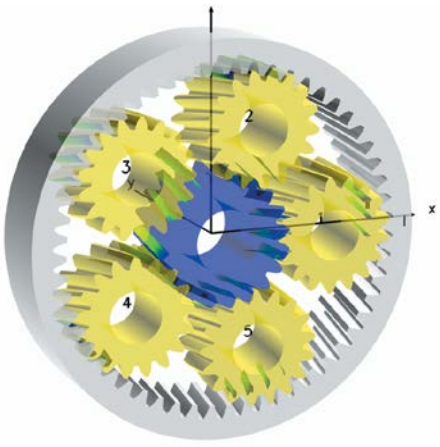
Star SU plans to expand its role as an integration solutions expert for machine tools including workpiece holding, perishable tooling, gaging and automation, according to David Goodfellow, president, Star SU LLC. In Indianapolis, Star SU will fea-

ture the Bourn & Koch 100 H horizontal hobbing machine at Gear Expo.

The Bourn & Koch 100 H can hob splines and geared shafts up to 100 mm in diameter. Mount tools in combinations to cut different gearings on one workpiece or to mill keyways and slots in one tool setup without reclamping. Since the chip conveyor is located directly under the tool spindle, chips are evacuated immediately from the machine to avoid any thermal distortions. In addition, the 100 H can be ordered with automation for machining larger lots. The extended version of the 100 H with a NUM Flexium control can accommodate a workpiece up to 916 mm (36") long and 126 mm (5") in diameter.

The Samputensili G 250 gear grinding machine has been especially developed for very low cycle times and for top-quality and efficient mass production of gears with outside diameters up to 250 mm and shafts with lengths up to 500 mm. The secret behind the machine's efficiency is the dual work spindle concept, which eliminates nonproductive auxiliary times almost completely. By means of the dual work spindles, the loading/unloading process of a workpiece is carried out in masked time, while simultaneously the manufacturing process proceeds on another workpiece. The G 250 can equally use form and worm grinding wheels, both in ceramic and in electroplated CBN. A video presentation of the G 250 will be available at the Star SU booth.

For more information:
Star SU
Phone: (847) 649-1450
www.star-su.com



KISSsoft AG

Booth #717

KISSsoft will be presenting the latest release of the software, Version 03/2013. The latest version of *KISSsoft* incorporates the newest advances in contact analysis for both cylindrical gearing and planetary geared systems.

Additionally, the draft of the new plastic strength analysis standard (VDI 2736) is implemented. Furthermore, a lot of other helpful features for an optimal gear calculation are available now.

Additionally, *KISSsoft* covers a very broad range of applications in one package, even with one user interface. So regardless in which state of the design process the engineer is, he/she can use the same tool. A strong point in *KISSsoft* is the optimizations which are conducted on all levels, for single parameters, for parameter sets, or for complete systems of machine elements. And the program can be customized in many regards. This covers the input (default settings, data base contents), the output (reports), the calculation procedures (customer specific rules that are asserted during the calculations) and of course the installation.

"In addition to these technical points, KISSsoft AG has gained a very good reputation concerning gear knowledge," says Dr. Stefan Beermann, CEO of KISSsoft AG. "This is a very important point for a customer when he/she decides which software package to rely on. We try to measure up to these high expectations by joining the committees for the standards, conducting scientific conferences, conducting general trainings about gear knowledge, providing excellent support and so on."

Beermann continues, "Nothing replaces personal contact, particularly in our industry. Many things are easiest to discuss face to face. Bring your gear design problems to booth 717 and see how KISSsoft can help solve them. Dr. Kissling and I, founders of KISSsoft will be on hand to answer all of your questions."

Software demonstrations will be presented through the day.

For more information:
KISSsoft AG
Phone: +(41) 55 254 20 50
www.kisssoft.ag

Emuge Corp.

Booth #505

Emuge Corp., a manufacturer of precision workholding devices for many industries, offers a comprehensive line of clamping solutions. Emuge's workholding division specializes in providing highly accurate, almost maintenance-free customized solutions for applications from low volume job shops to high volume automotive production environments. "Our workholding group stays close to our customers to learn about their unique challenges and production environments. Doing so helps us develop the best solutions for their applications," said David Jones, precision workholding manager at Emuge Corp.

With its expanding-bush design, Emuge's System SG is used in many machining operations such as hobbing, shaping and shaving for gear production, as well as milling and inspection. The System SG's large surface area contact with the workpiece provides a clamping solution which is very rigid, accurate and repeatable.

The high precision System SP is used not only to clamp workpieces but also to clamp tools. By applying an axial force, the clamping sleeves move in the direction of the force and expand radially. This eliminates the clearance between clamping sleeve and body, and between

clamping sleeve and workpiece. System SP achieves concentricity of < 0.002 mm (corresponding to < 0.0001 inch).

For workpieces that have a short clamping base or for diameters with a very large tolerance, Emuge offers the System SZ. By applying an axial force, a slitted collet is radially expanded by a cone. Simultaneously an axial movement occurs, clamping the workpiece.

When the eccentricity between pitch circle and seating bore is very small, diaphragm clamping System SM is suitable. It allows clamping of the gear wheel at the pitch circle for machining the seating bore. The gear wheel is clamped in both axial and radial directions.

System SH is a solution if there is not enough room for a mechanical clamping system and for clamping long, thin-walled workpieces or a number of similar workpieces. System SH is a closed system which uses hydraulic pressure to clamp the workpieces.

For more information:
Emuge Corp.
Phone: (800) 323-3013
www.emuge.com

Norton Abrasives
Booth #1153

Norton Abrasives, a brand of Saint-Gobain, has developed and launched Norton Vitrium3, the next generation of bonded abrasives products, engineered for maximum performance and cost savings in precision grinding. An entirely new abrasives platform, Norton Vitrium3 features a patent-pending bond technology developed by the Saint-Gobain Abrasives R&D team. This bond features an exclusive chemistry that promotes excellent grain adhesion, resulting in improved product versatility across a wide range of applications. Substantial performance improvements with Norton Vitrium3 are now attainable in all Norton abrasive grains, from proprietary Norton Quantum ceramic alumina to conventional aluminum oxide.

"Whether the goal is to reduce total cost per part, increase throughput, or improve workpiece quality, Norton Vitrium3 is re-shaping the world of precision grinding to meet these needs," said Scott Leonard, director of product management at Norton Abrasives. "This

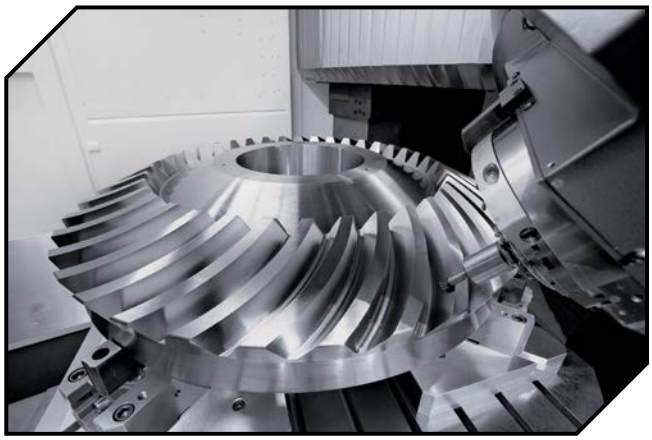
new technology will allow significant increases in production and also introduces the possibility of grinding instead of conventional machining on some operations."

For more information:
Norton (Saint-Gobain)
Phone: (508) 795-2833
www.nortonabrasives.com

DMG/Mori Seiki

Booth #631

DMG/Mori Seiki will demonstrate its full gear machining technology portfolio, with a focus on *gearMILL* software and the InvoMilling process, at Gear Expo. The InvoMilling process will be demonstrated on the NT series multitasking machines and NLX Series (three-axis lathe) machines. The five-axis gear-machining capability will be demonstrated on the DMU series machines and NT machines. In addition to newly developed processes, traditional gear-machining processes such as hobbing, gashing and broaching will be on display on NLX (three-axis lathe) machines. A variety of gears, such as spiral bevels, spur, helical and internal gears, will be machined on these platforms.



"The demonstrations center around the flexibility of the machines to offer the customer a choice of gear machining process based on day-to-day scenarios," says Nitin Chaphalkar, manager of advanced solution development. The demonstrations will emphasize benefits of multitasking machines such as simple change overs between parts, yielding increased throughput in small and medium batch production.

In addition to the demonstrations, Chaphalkar will conduct two presentations at the Solutions Center portion of the event. On Tuesday, Sept. 17 at 10:30 a.m., he will discuss bevel and spiral bevel gear-manufacturing technologies and gear grinding. The presentation will discuss applications for these methods and the software necessary. It will cover gear grinding and methods of surface heat-treating the gear teeth in the multitasking machine. The second presentation on Thursday, Sept. 19 at 10:30 a.m. will focus on universal gear milling machines and new methods for manufacturing gears, including InvoMilling. Chaphalkar will talk about using the multitasking machines for machining gears not only with conventional processes including hobbing, shaping and five-axis machining, but also with new processes such as InvoMilling.

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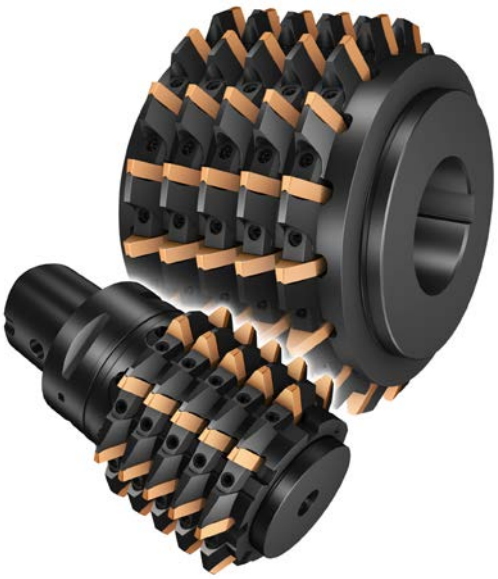
Sandvik Coromant
Booth #335

Sandvik Coromant will focus on the ongoing shift in gear manufacturing technology during Gear Expo. For an operation that has been reasonably consistent for about a century, there have been a lot of exciting technological advancements in recent years. Whether you're running a traditional, dedicated machine for large batches, doing smaller, one-off batches and prototypes on your multitask machine, or anything in between, stop by booth 335 to check out the next generation of gear milling solutions.

One focus area will be CoroMill 176, an innovative indexable insert cutter for productive gear wheel hobbing. CoroMill 176 is a more cost-efficient alternative to regrindable high speed steel (HSS) hobs and is designed for gears in the module range 3 to 10. Its ability to reach higher cutting speeds combined with user-friendly insert changing will reduce cycle times to a fraction versus high speed steel tooling, making it the high productivity gear milling choice for large volume gear facilities.



The new CoroMill 172 full form disc cutter is another area of emphasis. It offers a versatile and timesaving solution for milling of high-quality gear profiles, splines and racks. Thanks to the new indexable carbide insert technology and a powerful iLock interface, the component can be machined in flexible non-dedicated machines, such as multi-task machines and machining centers, as well as in hobbing and gashing machines. This makes the CoroMill 172 a truly flexible choice that has application on a wide array of operations and has shown particular value in the production of splines.

And the InvoMilling (patent pending) process is a unique approach to milling spur and helical gears using indexable insert cutters. InvoMilling opens up new, cost-efficient ways to produce geared components without dedicated hobbing machines. Since complete components can now be machined with just one set-up in a single 5-axis machine, overall production lead-times can be reduced dramatically as waiting for expensive hob cutters is not required. One InvoMilling cutter is capable of producing multiple module or DP sizes. Also, eliminating a hobbing operation dramatically shortens the value stream and overall work in process. And the new generation of indexable carbide insert gear cutters will increase cutting data

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EMAG LLC

Booth #315

With the VL 5, EMAG has created a customized solution that makes a positive impression in handling the heavy stresses exerted on the tools and machine during hard turning. One example is its machine base made of Mineralit, a polymer concrete with a vibration resistance eight times better then cast iron. "A vibration resistant machine leads to an improved surface finish on all workpieces it machines, which also leads to an improvement in tool life," says Peter Loetzner, CEO of EMAG. The vertical design is another feature that ensures an economical process, with the work spindle and the workpiece located above the tool. This offers suitable chip flow conditions, with the material removed being taken out of the machine by a chip conveyor. All guideways are located above and away from the machining, keeping them safe from any chips or dirt. This increases the component accuracy and reduces the maintenance effort.

Another important quality feature of the vertical turning centers from EMAG is their integral automation. They all use a conveyor belt with prisms that hold the raw parts in place. The conveyor belt moves the workpieces directly into the pick-up station, where they are picked up by the work spindle and then machined. Workpiece changeovers are very fast, because the distance traveled between the loading and machining position is only 550 mm. This leads to a massive shortening of the time between machining processes.

The possibilities offered by hard turning on the fully automated, vertical turning machines from EMAG is best shown by the example of a gear production for a sub-supplier to the automotive industry. The VL 5s run by the customer produce a total of eight different gears for a dual-clutch transmission system. Following the hardening process, the workpieces are pre-turned on the machine, to remove the hardened top layer. This is followed by a synchronous ring being welded onto the workpiece away from the VL 5. The workpiece is then returned to the EMAG machine and finish-turned. Before the customer had the VLs, he performed comparable operations on grinders.

"This company started investing in the VL 5 machines for their hard turning process, because the investment costs were so much lower," adds Loetzner. "Hard turning on the VL 5 is in no way inferior to the old grinding process; and the machining times are noticeably shorter," he explains further.

When can hard turning successfully replace the grinding process in the machining of a component surface? "That depends on a number of factors. One important factor is the desired surface texture. We help guide our customers and give them our opinion on the best way to proceed," explains Loetzner, "and when hard turning is possible, it often becomes first choice." Apart from lower investment costs, many users are also impressed by the elimination of the grinding operations. On the VL, the turned part can be finish-machined in a single setup. It is no longer necessary to take it to another machine for finishing. The result: the output level of the whole production increases considerably.

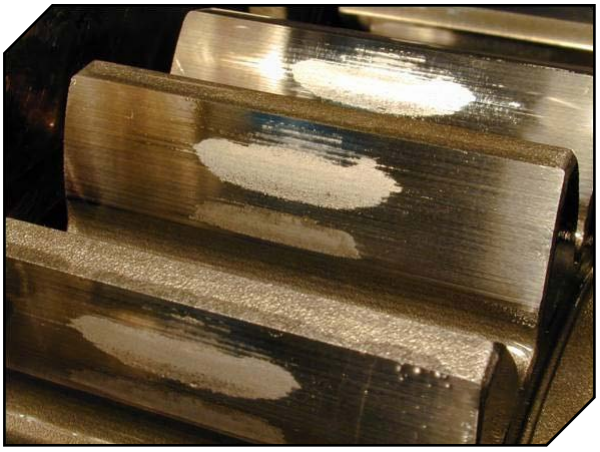
The turning specialists from EMAG have already delivered a total of 3,500 VL machines. The know-how this has provided is something the new user also profits from. "Our design team familiarizes themselves with customer demands. This ensures that the strengths of our machines are targeted on what is required by customers." The types and numbers of components that can be produced on these vertical turning machines are very diverse. Toothed components, such as gears and crown wheels, can be produced with the same efficiency as bearing rings. "The system can be adapted to suit any batch size and is very impressive with its short cycle times and high component quality. If the VL 5 allows you to eliminate a whole process stage, the user will be able to enjoy an unbeatable cost advantage," emphasizes Loetzner.

For more information:
EMAG LLC
Phone: (248) 477-7440
www.emag.com

Dontyne

Booth #1052

Genesis Partners has developed and tested a non-involute tooth form that projects up to a 40 percent improvement in various physical and performance parameters of a gear pair compared to the equivalent involute. A distinct advantage of this new tooth form is that it utilizes the existing gear manufacturing asset base. Under an exclusive agreement Dontyne Systems has programmed the Genesis Partners source code to not only design and rate Convoloid pairs and compare them directly with involute pairs, but also provide the protocols to easily craft these designs to optimize many of the gear parameters influencing successful gearing applications. The confluence of the well-developed specialties of these two firms provides timely, efficient, and comprehensive analysis prior to the machining, testing and inspection of hardware—a breakthrough in the future of gearing power density and cost reduction.



The relative size reduction for Convoloid over optimized involute equivalent for same ratio and face width translate into large benefits in production cost and power density as well as operating life. Dontyne Systems has completed both design and loaded tooth contact analysis modules for the Convoloid gear form. Parameters such as stress, load, efficiency and transmission error can be calculated. These can be used to investigate the performance of a design including the effect of center distance variation and misalignment. The problems associated with this type of conformal gearing are not as acute as an experienced gear designer might intuitively expect. Potential problems such as stress concentrations, micropitting, and vibration can be treated by surface modification, in the same way as an involute gear form often is, to achieve optimum operation. The software enables the user to quickly establish whether the Convoloid solution

is appropriate to provide an advantage over the involute for a given application under specific operating conditions. Further modules to simulate manufacturing and inspection — linking directly to production equipment — are close to completion.

This technology has been aimed initially at the wind turbine industry during its development. As the understanding of the limitations has increased through software analysis, then the confidence in the product applicability has grown such that many industries are ready to investigate the operating characteristics of non-involute designs as never before. This new calculation is exclusive to Dontyne Systems. Genesis Partners will be giving a talk in the Solutions Center on the development and testing of this technology entitled "Convoloid—The Future of Power Density and Cost Reduction," scheduled for 9/17/2013 at 3:00 p.m. The presentation will also include some results from the new analysis software. The potential for this design software or design service can be discussed in more detail at the Dontyne System Booth 1052.

Micro-Erosion: Propagation of Micropitting

The ISO 15144 Method A and B for micropitting have been implemented in Dontyne Systems' *Gear Production Suite* for some time now. The standard is fairly restricted, only giving indication of the risk of micropitting which could be based over a 16 to 70 hour test. It does not state whether micropitting will continue to develop with time or stop (as will be the case sometimes) and further whether this is actually detrimental to the operation of the gear. This may lead some gears to be scrapped and development programs halted pending redesign when it may not be necessary, leading to costly and wasteful delays. Dontyne has been working with Dave Barnett (Gears Made Easy) to implement a calculation which looks at the longer term micro-erosion (model of the propagation of micro pitting) and the influence on operating characteristics under load. The calculation procedure itself has been has been explained in previous AGMA FTM presentations and more recently in a Voices piece (*Gear Technology* November/December 2011). The new method has been experimentally validated and it is believed can contribute to the understanding and development of a more complete model of gear behavior for more efficient design and production. Significantly, it can also look at the implications on life due to surface modification. This new calculation is unique to Dontyne Systems and can be demonstrated at the Gear Expo Booth 1052.

For more information:
Dontyne Systems Limited
Phone: +(44) 191 206 4021
www.dontynesystems.com

Hainbuch

Booth #600

Changing over from O.D. clamping to I.D. clamping without disassembling the base clamping device is done in a matter of two minutes with the Hainbuch modular system. With Mando Adapt, just place the mandrel in the mounted clamping device. It's a great time-savings solution, not to mention that Mando Adapt is extremely rigid and precise.

Mandrel type 213: This mandrel type

is suitable for small clamping diameters and extremely slender mandrel bodies. In comparison with the Mando T211 with draw bolt, the segmented clamping bushing is not released via ejector pins in the mandrel body; rather it is coupled in on the upper end of the draw bolt. Thanks to this trick, the mandrel body can be implemented with even more rigidity. That's why this mandrel type is in such demand, particularly for gear cutting applications where interrupted cuts are on the daily agenda. The vulcanized segmented clamping bushings are supplied as a clamping unit mounted on the draw bolt and thus can be conveniently changed. For greater clamping diameter, you can also change the segmented clamping bushings individually through the use of two-piece draw bolts.

For more information:
Hainbuch America Corp.
Phone: (414) 358-9550
www.hainbuch.com

Mitsubishi Heavy Industries America

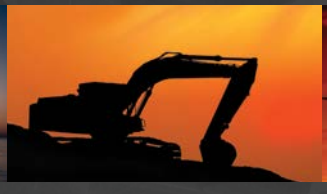
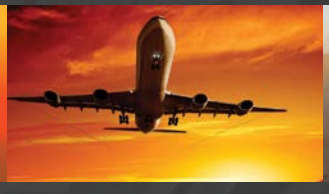
Booth #909

Mitsubishi will proudly be showcasing two machines at Gear Expo 2013. Making its debut in North America, a revamped design of the ever popular Model ST40 advanced programmable lead guide shaper will demonstrate the capability to program internal and external gears with crown or taper through the use of a newly developed NC relieving mechanism. The ST40A machine is also equipped with a quick return stroke function, which greatly shortens machining times for wide face width gears. This machine will be dry cutting one component of a cluster gear.

Additionally at Gear Expo, Mitsubishi will be demonstrating an automated gear cell which includes a palletized conveyor paired with a Model GE15A dry-cut gear hobbing machine. On the GE15A,

Our Gears Work
Around The Clock, Around The World

High Performance, Higher Quality Gears

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AGMA

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GEAREXPO The Worldwide Gear Industry Event 2018

(Booth 800)

Mitsubishi will demonstrate a timing function which is beneficial for skive hobbing or timing a gear to another feature on the workpiece. Also exhibiting their capabilities in the Mitsubishi booth will be Federal Broach and Machine Company. Mitsubishi and Federal will have industry experts on hand throughout Gear Expo to offer solutions to the many manufacturing challenges that attendees will bring.

For more information:
Mitsubishi Heavy Industries America
Phone: (248) 669-6136
www.mitsubishigearcenter.com

Ingersoll Cutting Tools
Booth #235

Ingersoll will be exhibiting the latest advancements in its gear machining tools. Whether it's hobbing, gashing, shaping, or CNC machining, be sure to visit booth #235 to see what's new in indexable insert gear machining tools. "We will have our industry experts in the booth, and are eager to discuss your particular gear cutting needs and applications," says Frank Berardi, gear machining product manager. "Our new line of Radial Insert Hobs will be a major focus at the show. The radial hob is designed primarily for smaller module gears. It is available in 1-Start, 2-Start and 3-Starts, and in screw down or wedge style insert mounting.

Additionally, there will also be a live demo in Liebherr's booth (510) featuring the Module 7, Radial Hob on a Liebherr LC500 machine. "We will also have the latest designs in positive and negative geometry gashers for internal and external gears, as well as our indexable insert shapers, which have been extremely successful in roughing applications, reducing cycle times as much as 50 percent in many cases," Berardi adds.

For more information:
Ingersoll Cutting Tools
Phone: (815) 387-6600
info@ingersoll-imc.com
www.ingersoll-imc.com

Klingelnberg AG
Booth #323

With the acquisition of the core business of Höfler Maschinenbau GmbH in 2012, Klingelnberg expanded its product portfolio with the addition of gear manufacturing machines for cylindrical gears, thereby strengthening its position as a single-source system supplier. The company's origins date back to 1863. In 1993, Oerlikon Geartec AG in Zurich was acquired and a new generation of bevel gear cutting machines, the C-Series, was developed. Within this product range, Klingelnberg introduced the dry-cutting process for spiral bevel gears in 1997. The service offering also includes machines for grinding, lapping and testing of bevel gears. The Klingelnberg precision measuring centers (P-Series) are used for dimension, form, and position measurements of gears and axially symmetrical components, such as tools, gears of all types, and gear components measuring several meters in diameter. During Gear Expo, Klingelnberg will be exhibiting the P 40 precision measuring center for the automotive, aviation, precision engineering and industrial construction industries. The P 40 offers a maximum workpiece diameter up to 400 mm, weight up to 300 kg and a vertical measuring range up to 550 mm. Additionally, it offers gear measurements as well as dimension, shape and position of axially symmetrical high-precision components of any kind, roughness measurement on tooth flanks; manifold options for testing of drive components in the automotive industry such as: clutch gears, sprockets, beveloid gears as well as camshafts and crankshafts; maximum precision and repeatability of measuring results; excellent mechanical basic precision and modern compensation strategies and easy operation with a graphical user interface.

For more information:
Klingelnberg America, Inc.
Phone: (734) 470-6278
usa.sales@klingelnberg.com
www.klingelnberg.com

James Engineering
Booth #701

James Engineering is introducing its 2014 line of systems. These systems are a culmination of 30 plus years of experience and refinements. "Our 2014 lineup allows the customers to increase productivity, reduce setup times, increase operator multitasking, increase machine uptime, reduce scrap, and most importantly reduce the cost per part," says Scott Richards, vice president at James Engineering. "We have focused so heavily on these attributes that our company-wide Return on Investment (ROI) is 1.5 years."

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LWT-3080

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LFG-3540

Universal Gear Tool Grinding Machine

LUG-3040

Gear Cutting Tools

Headquarters
Luren Precision Co., Ltd.
No.1-1, Li-Hsin 1st Rd, Hsinchu Science Park,
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PHONE : +886-3-578-6767
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Luren Precision Chicago Co., Ltd.
707 Remington Road, Suite 1,
Schaumburg, IL 60173, USA
PHONE : 1-847-882-1388
FAX : 1-847-882-1933
Email : Gerald_kuo@luren.com.tw
darian@lurenchicago.com

GEAR EXPO 2018
Booth#1101

Today, James Engineering focuses on flow, setups, and ergonomics. "Our automatic wheel wear compensation, for example, can wear a four inch outside diameter grinding wheel down to one and one half inches without a single setup change. We can wear the wheel from beginning to end with a 10 percent variance in both chamfer angle and size. Many conventional machines can only wear down a half inch radius before they need to make a setup change. These conventional machines may make up to three setup changes to achieve the same minor diameter our systems can. In some cases these conventional machines cannot wear a wheel down that small and simply discard it. Discarding a wheel prematurely is a horrible waste of money and time."

Additionally, James Engineering recently introduced a patented 25,000 rpm, one horse power, hydraulic chamfer motor. "This motor is 80 percent more efficient than the compressed air motors, has a longer life span, and is silent. When these figures are combined it equates to a massive ROI, which in many cases, justifies the purchase of our most expensive systems within six months."

Richards continues, "We offer what is arguably the most comprehensive line of deburring systems on the market. We have expanded our range of systems to encompass manually operated systems, guaranteed setup systems, zero-setup systems, fully automated systems, and high pressure water deburring systems. These systems have the physical ability to deburr gears from fractions of an inch to 400 inches outside diameter and infinite lengths."

James Engineering will be sharing a booth with Sinto Surface Treatment at Gear Expo.

For more information:
James Engineering
Phone: (303) 444-6787
www.james-engineering.com

Hydra-Lock

Booth #640

Hydra-Lock features its patented Conform-A-Chuck and Conform-A-Arbor workholding solutions designed to adapt to an out-of-round OD or ID and securely grip that diameter to enable boring, honing, grinding, or other machining operations without changing the original free state shape of the part. This unique technology provides solutions for the unlimited combinations of machining found in today's gear making applications.

The Conform-A products rely upon a unique plastic material called Hydra-Fibre. This allows the chuck or arbor to easily expand (up to .125" depending upon size) and adjust in order to hold thin-walled and out-of-round components without rounding. The Conform-A products are able to locate on a rough machined surface and establish an average center line. By locating on the entire surface, the chuck is able to support the weak component area and withstand tool pressure. Resulting accuracies of the operation are typically within +.001".

Conform-A-Chucks and Conform-A-Arbors can be developed in any size to meet the application with either a direct pressure or a self-contained hydraulic system. Conform-A-Chucks can be designed to produce either bell-mouthed, straight or choke condition at the skirt end. Conform-A-Arbors feature retractable stops so that the end face of the part may be machined square and ID chamfered during the same cycle during which the OD is turned.

For more information:
Hydra-Lock
Phone: (800) 634-6973
www.hydralock.com

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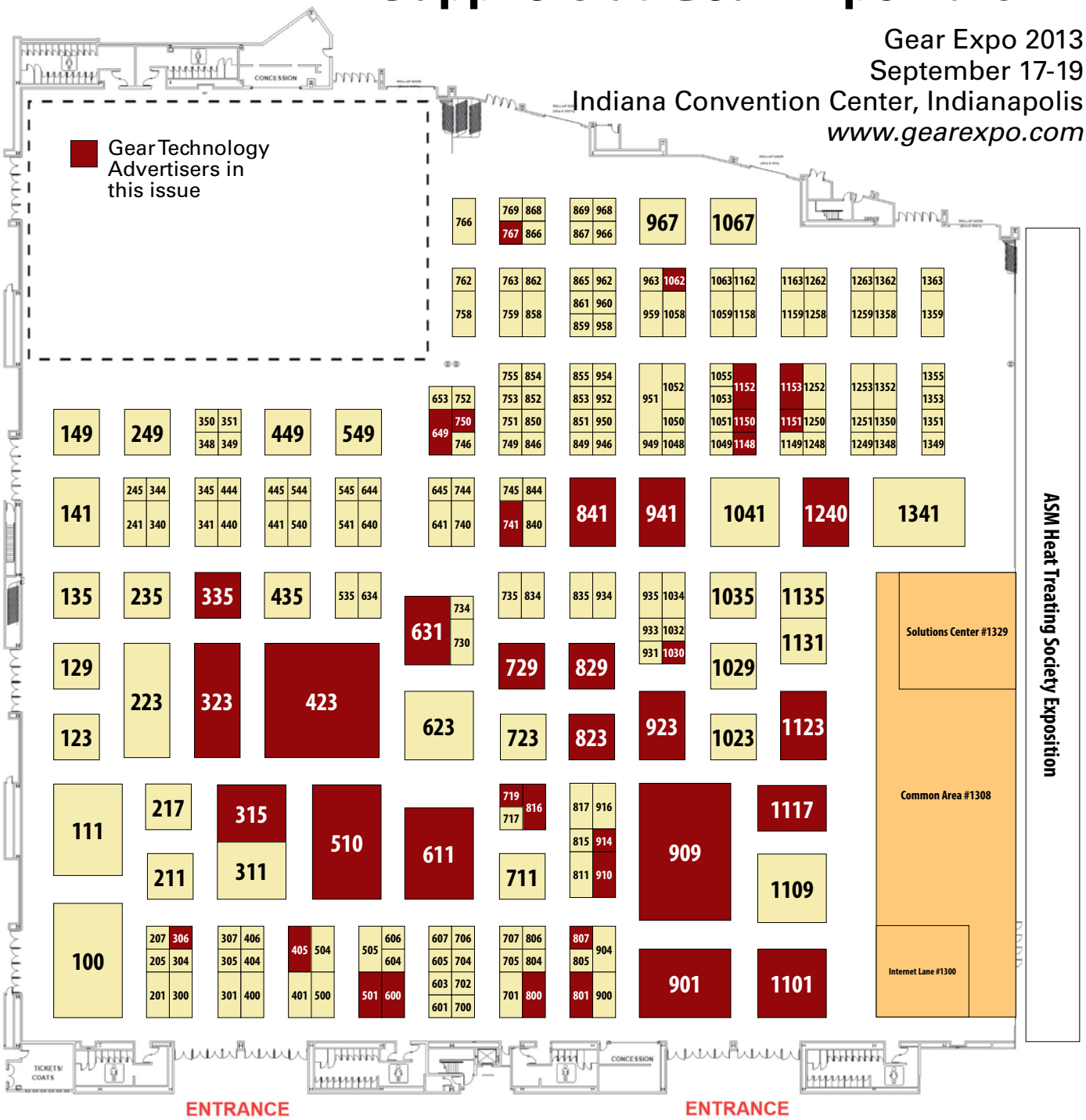

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SANDVIK Coromant

See us at Gear Expo, Booth 335
Sept. 17-19, Indiana Convention Center, Indianapolis, IN

COMPANY	BOOTH #
3M (see our ad on p. 35)	**941**
A A Gear & Manufacturing	1252
ABA-PGT Inc.	1048
Accurate Specialties Inc.	350
Acme Wire Products Co. Inc.	1355
ADF Systems Ltd.	835
AGMA	1109
ALD Thermal Treatment, Inc.	817
ALD-Holcroft Vacuum Technologies Co. (see our ad on p. 75)	**816**
American Gear Tools/American Broach & Machine Co.	1163
American Stress Technologies, Inc. (see our ad on p. 66, 87)	**306**
Ancon Gear & Instrument Corporation	207
Arrow Gear Company (see our ad on p. 53)	**801**
Artec Machine Systems	815
Ash Gear & Supply	1251
Banyan Global Technologies	749
Bevel Gears India Pvt. Ltd. (see our ad on p. 106)	**706**
Big C: Dino-Lite Scopes	963
Bishop Steering Technology, Inc.	245
Bodycote Thermal Processing	859
Bohle Machine Tools, Inc. (see our ad on p. 63)	**1152**
Bohler - Uddeholm Corporation	1050
Bowmar LLC	404
Brad Foote Gear Works, Inc.	641
Brelie Gear Co.	406
Breton SpA	1058
Broach Masters/Universal Gear Co. (see our ad on p. 15)	**405**
Broaching Machine Specialties	1349
Broadway Gear (see our ad on p. 62)	**914**
C & B Machinery	1158
Canton Drop Forge	934
Capstan Atlantic	500
Carl Zeiss Industrial Metrology	759
CCE	745
Ceramtec NA	135
Chamfermatic Inc.	601
Changzhou Kangning Forging Co., Ltd.	855
China Machinery Industrial Products Co. Ltd.	704
Chongqing Xinxing Tongyong Drivetrain Co. Ltd.	952
Cincinnati Gearing Systems (see our ad on p. 85)	**829**
Circle Gear and Machine Company (see our ad on p. 111)	**605**
CJMT USA	1062
Cleveland Deburring Machine Company	1352
Clifford-Jacobs Forging Company, Inc.	916
CNC Design Pty. Ltd.	933
Columbia Gear Corporation	730
Comtorgage Corporation (see our ad on p. 38)	**1150**
Creative Automation Inc.	806
CSR Qishuyan Institute Co., Ltd.	1353
Custom Gear & Machine, Inc.	1055
CW Bearing USA, Inc.	1358
Dalian Running Engineering Company Limited	205
Delta Gear (see our ad on p. 45)	**800**
Des-Case	935
Deutsche Messe Worldwide (see our ad on p. 61)	**1162**
DixiTech CNC	1135

COMPANY	BOOTH #
DMG Mori Seiki USA (see our ad on p. 49, 60)	**631**
Dontyne Systems Limited	1052
DTR Corporation (see our ad on p. 30)	**741**
EES Gear GmbH	854
Eldec Induction, LLC	1035
Eltro Services, Inc.	863
EM Gear LLC	1350
EMAG LLC (see our ad on p. 27, 66)	**315**
Emuge Corporation	505
Engineered Abrasives	811
Engineered Tools Corporation	504
Erasteel	307
Erwin Junker Machinery Inc.	1131
Euro-Tech Corp.	301
Excel Gear, Inc. (see our ad on p. 11, 65)	**1148**
Fabco Automotive	351
First Gear	900
Flame Metals	734
Foerster Instruments Inc.	445
Forest City Gear Company (see our ad on p. 7, 67)	**923**
Forging Industry Association	769
FPM Heat Treating	348
Gardner Business Media	959
Gear Resource Technologies, Inc. (see our ad on p. 60)	**750**
Gear Solutions Magazine	549
***Gear Technology* and *Power Transmission Engineering* Magazines (see our ad on p. 67)**	**1123**
GearKing, Inc. (see our ad on p. 59)	**719**
GearWorld North America	435
Gibbs Machinery Company	300
Gleason Corporation (see our ad on p. 56-57, 64)	**423**
GMTK - USA	535
Great Lakes Gear Technologies, Inc.	223
Great Taiwan Gear Ltd.	904
Hainbuch America Corp. (see our ad on p. 25, 60)	**600**
Hangzhou Jie Drive Technology Co. Ltd.	805
Hangzhou Xingda Machinery CO., Ltd.	544
Hanik Corporation	305
Hankook Precision Ind. Co., Ltd.	123
Hans-Juergen Geiger Maschinen-Vertrieb GmbH (see our ad on p. 74)	**910**
Härterei Reese Bochum GmbH	763
HobSource Inc.	702
Hoffmann Filter Corporation	1253
HST Otomotiv Imalat Sanayi ve Ticaret A.S.	1023
Hydra-Lock Corporation	640
Hy-Pro Filtration	341
Industrial Machinery Digest	766
Ingersoll Cutting Tools	235
Innovative Rack & Gear Co.	606
Interstate Tool Corporation	755
Involute Gear & Machine Company (see our ad on p. 22, 61)	**1240**
Ionic Technologies, Inc.	967
Jiangsu Chixiang Precision Gear Co., Ltd.	866
Jiangyin Fangyuan Ringlike Forging & Flange Co., Ltd.	705
Jiangyin Nangong Forging Co. Ltd.	950
JRM International Inc.	735

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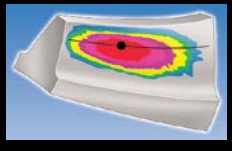

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COMPANY	BOOTH #
Kapp Group (see our ad on p. 3)	**611**
KH Gears	958
Kisssoft USA LLC	717
Klingelnberg (see our ad on the back cover)	**323**
Koepfer America, LLC	311
Liebherr Gear Technology, Inc. (see our ad on p. 5, 62)	**510**
Ludeca Inc.	1049
Luren Precision Chicago Co., Ltd. (see our ad on p. 47)	**1101**
Machine Tool Builders Inc. (see our ad on p. 107)	**841**
Mackeil Ispat & Forging Ltd.	1034
Magnetic Inspection Laboratory	948
Marposs Corporation	340
Mazak Corporation	111
Metal Improvement Company	604
MicroTek Finishing LLC	1249
Mijno Precision Gearing	762
Mitsubishi Heavy Industries America, Inc. Machine Tool Division (see our ad on p. 8)	**909**
Mitsubishi Materials USA Corp. (see our ad on p. 26)	**649**
ML Lubrication USA, Inc.	1362
Mohawk Machinery Inc.	931
MSC Software	344
Nanjing Sinergy Transmission Machinery Company	966
New England Gear	1029
Nichiei Co. Ltd.	644
Norton/Saint-Gobain (see our ad on p. 65, 89)	**1153**
Oelheld U.S., Inc. (see our ad on p. 59)	**767**
Oerlikon Drive Systems (see our ad on p. 63)	**1117**
Parker Industries, Inc.	129
Patriot Forge Co.	867
Paulo Products Co.	804
PECO - Process Equipment Company (see our ad on p. 37)	**729**
PECO - Process Equipment Company (see our ad on p. 37)	**501**
Peening Technologies	653
Perry Technology Corporation	201
Positrol Workholding	1262
Power Electric	758
Precision Gage Company, Inc.	740
Preco, Inc.	1359
Presrite Corporation (see our ad on p. 31)	**823**
Proto Manufacturing Inc. (see our ad on p. 21)	**1348**
Pulstec Industrial Co. Ltd.	1363
QC American, LLC	1067
Qijiang Heavy Duty Truck Gear Co. Ltd.	954
R.P. Machine Enterprises, Inc.	623
Rave Gears	951
Raycar Gear & Machine Co.	1149
Redin Production Machine	400
Reishauer Corporation	1041
Reliance Gear Corp.	858
REM Surface Engineering	217
Riley Gear Corporation	634
Riten Industries Inc.	401
Rockford Heat Treaters Inc.	1032
Rolled Threads Unlimited	349
Romax Technology Inc. (see our ad on p. 64)	**607**

COMPANY	BOOTH #
Roto-Flo & U.S. Gear Tools	211
RUF Briquetting Systems	1351
Russell, Holbrook & Henderson	707
S.L. Munson & Co.	711
Saacke North America, LLC	852
Sandvik Coromant (see our ad on p. 51)	**335**
Schunk	545
Scientific Forming Technologies Corporation	1159
Scot Forge	862
Seitz LLC	861
Shanghai Bearing Imp. & Exp. Co., Ltd.	851
Shanthi Gears Ltd.	241
Shinway Transmissions Co. Ltd.	345
Shyi Chang Enterprise Co. Ltd.	960
Sinto Surface Treatment	701
Six Star Machinery Co., Ltd.	645
Smart Manufacturing Technology	304
Specialty Steel Treating	541
Speedgrip - Cameron - Madison	1059
Spencer Pettus Machine Co.	444
Stace-Allen Chucks, Inc.	1263
Stack Metallurgical Services, Inc.	1248
Star SU, LLC (see our ad on p. IFC-1, 29, 61, 110)	**901**
STD Precision Gear	753
Taiwan United Gear Co., Ltd.	962
Taiyuan Heavy Industry Co., Ltd.	540
Techna-Tool Inc.	440
Tecsia Lubricants USA	844
The Modal Shop, Inc.	949
Therm Tech of Waukesha	744
Thermotech, Inc.	846
Thors, LLC	1250
Ticona Engineering Polymers (see our ad on p. 55)	**1030**
Tokyo Technical Instruments Inc. (see our ad on p. 18)	**807**
Toolink Engineering Inc.	723
TSA America LLC	834
United Gear & Assembly, Inc.	850
Vancouver Gear Works	1063
Viking Forge Corp.	700
Virgo Communications & Exhibitions	1051
Walker Forge, Inc.	746
Weko Geartechnologies Ltd.	441
Wenzel (see our ad on p. 62)	**510**
Western Pegasus	449
Whitmore/Air Sentry	752
Wiseton Industries	603
World Class Plastics	868
Wuxi Bele Industry Co. Ltd.	853
Yager Gear Enterprise Co., Ltd. (see our ad on p. 110)	**1151**
YLH Machinery Parts, Inc.	968
Zhejiang Kiyo Gears Co. Ltd.	1259
Zhejiang Powerbelt Co. Ltd.	849
ZVL/ZKL Bearings Corporation	840

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GUR® ultra-high molecular weight polyethylene (UHMW-PE)
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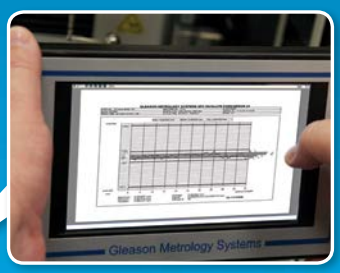
- ✓ Fine pitch measurement



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Gear Expo
September 17-19
ASM Heat Treating Society Conference and Exposition
September 16-18
Indiana Convention Center, Indianapolis

New Technology Roll Call

Exhibitors target heat treat advancements at ASM/Gear Expo

Matthew Jaster, Senior Editor

Heat Treat 2013
27th ASM Heat Treating Society Conference and Exposition
September 16-18, 2013
Indiana Convention Center, Indianapolis
www.asminternational.org/content/Events/heattreat

The ASM Heat Treating Society Conference and Exposition is once again co-located with AGMA's Gear Expo. This year's show celebrates the 100th anniversary of the ASM Heat Treating Society, which began as the Steel Treaters Club in Detroit.

In addition to a comprehensive technical program, the conference will include three special "Heat Treating Master Series" sessions that will focus on heat treating pioneers whose research transformed heat treating technology. The sessions will include lectures by current experts in the heat treating field on the contributions and impact of past heat treating giants Walter Jominy, Marcus Grossmann and Edwin Northrup.

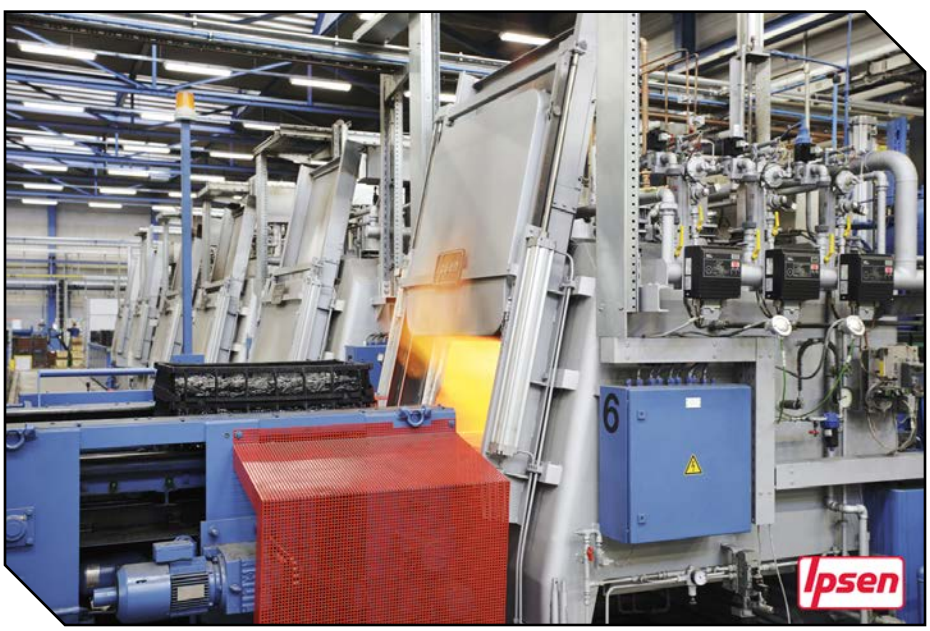
The technical program runs from September 16-18, but the exhibition hall is open only Tuesday, September 17 (9 a.m. until 6 p.m.) and Wednesday, September 18 (9 a.m. until 5 p.m.). Note that the Gear Expo portion of the exhibition hall is open one additional day— Thursday, September 19.

For more information, visit *www.asminternational.org/content/Events/heattreat.*

Co-located once again with Gear Expo is Heat Treat 2013, the 27th ASM Heat Treating Society Conference and Exposition. ASM welcomes innovators, influencers and decision makers in the heat treating industry for a mix of education, technology and networking opportunities. Above all else, the exposition floor is an opportunity for gear and heat treat attendees to discuss the technologies that are changing the industry in 2013. *Gear Technology* asked heat treat exhibitors from both show floors (Gear Expo/ASM) to discuss some of the key heat treat products that will be on display in Indianapolis. Many exhibitors will also be presenting educational sessions during the show.

"The ASM Heat Treat/Gear Expo 2013 show will be a great experience for those who visit our booth. They will have the chance to interact with Ipsen in a fun way, and maybe even win some prizes, while learning about our specific offerings in equipment, controls and service, as well as our new product developments and our global support network," says Geoffrey Somary, president and CEO at Ipsen. "We will be featuring some exciting new technologies for gear manufacturers and we will have experts available to offer in depth information on those new technologies and product offerings."

These featured technologies cover a vast range of Ipsen's premium vacuum and atmosphere product lines including, but not limited to, the AvaC process for vacuum carburizing with acetylene, ideal for incorporation into their TurboTreater and vacuum oil or gas quench furnaces, and Atlas integral-quench atmosphere furnace. Additionally, furnaces well-suited for low-pressure carburizing, such as the Turbo2 Treater, will also be represented.



Additionally, at the ASM conference surrounding the show, Ipsen will present two topics of interest to the gear industry entitled "Redefining Quenching Technology" and "Bright Tempering: Achieving High-Quality Appearance During Tempering" where experts will discuss a new set of definitions for gas quenching and describe how to reduce cycle time while increasing uniformity through the use of both vacuum and convection heating, respectively.

Inductoheat, Inc. will again be highlighting the latest advancements in induction heating technology and introducing attendees to the new Statipower IFP (Independent Frequency & Power) power supply.

"Specifics of gear geometry demand a particular process control algorithm of induction hardening. In the past, the process control recipe was limited to an available variation of power and frequency vs. heat time. Recent innovations bring unique ability of novel inverters

to independently control both power and frequency during static hardening or scan hardening operations, which optimizes electromagnetic and thermal conditions at initial, intermittent and final stages of tooth hardening," says Dr. Valery Rudnev, director of science and technology for Inductoheat.

"As an example the Statipower IFP inverter provides the ability to independently change during heating cycle, the frequency and power. This capability represents the long-awaiting dream of commercial induction heat treaters, since it provides the greatest process flexibility. Statipower IFP is a uniquely designed IGBT-type power supply oriented for induction surface hardening applications, allowing independently adjustable frequency via CNC-program in a 5-40 kHz frequency range and power in the range of 10-360 kW. This concept substantially expands heat treat equipment capabilities for processing parts by programming power and/or frequency changes *on the fly*, optimizing hardening gears of different modules with various tooth geometries," he adds.

On Monday, September 16th, Rudnev will be giving his presentation titled, "Novel User-Friendly Computer Modeling for Induction Heating and Heat Treating." The presentation number is 34660 and it will take place from 10:30 a.m. to 11:00 a.m. In addition, Robert Madeira, vice president of heat treating, Inductoheat Inc. will be giving his presentation titled, "Induction Hardening of Steel and Cast Iron Components." The presentation number is 34661 and it will take place from 9:00 a.m. to 9:30 a.m.

Surface Combustion boasts more than 645 patents and 75 registered trademarks and will be showing off a few of its technical accomplishments during the show. "Surface Combustion offers one of the most complete lines of heat treating equipment for gear manufacturers. This includes vacuum processing, atmosphere processing, carburizing and nitriding, including designs from small batch systems to fully automated high volume continuous furnace systems," says John Gottschalk, director engineered products at Surface Combustion, Inc.

Eldec LLC will be featuring new heat treating solutions for gears and shafts. "We are introducing the MIND-M, a compact induction heat treating system that you will want to see for your lean production requirements," says Mark Davis, sales engineer at Eldec. "The Eldec MIND-M is the compact, *smaller sibling* of the full-featured MIND Modular Induction Hardening System from Eldec. The eldec MIND-M Flexible

Integrated System is a complete, integrated, lean system for your induction hardening application — or any other induction heat treating process for low-volume parts. The energy source is integrated into the machine base with active coolant and quench system (if needed)."

The MIND-M can be transported "as is," featuring the smallest footprint of any complete system up to 150 kW Medium Frequency (MF) or 30 kW High Frequency (HF). The spacious working area allows for different modules and workholding devices to be freely positioned. This creates flexibility for various work parts and applications.

ALD-Holcroft will be discussing both its ModulTherm and SyncroTherm processes during the show. The ModulTherm allows power consumption to resemble actual production levels instead of full power and SyncroTherm offers one-piece-flow that can keep pace with gear cutting equipment or can be operated as a high speed, small batch furnace. "Holcroft will be providing an 'open tap' each afternoon of the Gear Expo," says Bill Gornicki, VP sales and marketing for ALD-Holcroft. "We encourage all participants to stop by for a cold beer and open discussion on heat treatment of gears."

Solar Manufacturing will present a full-scale display of its new and improved 2IQ production vacuum furnace. Its innovative design gives fast, powerful quenching with the low resistance and high efficiency gas flow. A 150 hp motor drives a high-speed turbine fan to recirculate the quench gas straight through the water-to-gas heat exchanger and then into the hot zone at high velocity. Tapered graphite gas nozzles are specifically directed at the workload for optimal cooling. The high-tech Solar PowerSave Hot Zone reduces heat loss and operating expenses.

Raytek, a provider of infrared thermometry, recently enhanced its modular MI3 system by adding new communication boxes for integrating the digital temperature sensors into the control level. In addition to Profibus and Modbus units, and a version with four galvanically isolated analog outputs, new options include a robust die-cast zinc housing and 6TE DIN rail housing. The new Profinet boxes are suitable for time-critical applications as they can transmit data to a higher-level PLC in real time. The Ethernet version features a 64 MB data logger that can store up to 24 days of recorded data at a 1 s saving interval. It supports TCP/IP4 and, based on an integrated HTTP server, provides its own landing page with direct access to the temperature data, as well as product information and manuals via any standard internet browser. A user-friendly control panel and a large LCD display facilitate on-the-spot configuration of functions, such as peak and valley hold, as well as intelligent averaging.

The *Datatemp Multidrop* software for remote operation and configuration is available free of charge. The MI3 system entails minimum commissioning costs per measurement point since up to eight sensors can be connected to one communication box. Users can choose freely from the whole MI3 program: all sensors and boxes are compatible. Automatic head detection enables comfortable plug and play. Various spectral models, high data quality, and the wide temperature range from –40 to 1,800°C (3,272°F) make the MI3 system a solution for many applications, especially in process monitoring. Raytek Corporation will be presenting "Every Plant Needs an Ally" at the Solutions Center at 3:00 p.m. Wednesday, September 18th.

Nitrex Metal Inc. began with a range of gas nitriding technologies but through the years the company has developed other heat treating processes and product lines. R&D efforts in technologies, equipment and process controls include software development, safety measures and the design and implementation of environmental protection equipment. During the ASM show, Jack Kalucki and Dimitri Koshel will present "Influence of Steel Surface Conditions on the Nitrogen Uptake during Gaseous Nitriding Process" from 8:00 – 10:00 a.m. on Tuesday September 17th.

Known for the Internal Quench Furnace with Beaver Ram transfer system, BeaverMatic's product line includes temper furnaces, washers, endothermic gas generators, box furnaces, pit furnaces, continuous roller hearth and pushers, carbottom furnaces, and tip up furnaces.

The equipment is designed and manufactured to meet customer's specific process, throughput, time line, and budget for the aerospace, automotive, agriculture, defense, energy, power transmission, medical, petroleum, and transportation industries.

Today, BeaverMatic's commitment to extensive in-house capabilities assures customers product quality and dependability. BeaverMatic's in-house capabilities start in the design engineering department and continue with layout, bending, cutting welding, assembly and finishing. The latest tooling and fabrication equipment promotes volume in-house production, while preserving attention to such details as removing sharp edges from metal surfaces. Rigid control over the quality of basic parts, components and assemblies is one of the many advantages that BeaverMatic customers know and appreciate.

BeaverMatic will feature the various Internal Quench Furnace configurations currently available. Known for its reliability since the early 1960s which it was first introduced, this furnace has a unique design concept that focuses on three basic objectives: 1) ease of operation, 2) maximum uptime, and 3) the ability to meet specific customer needs. The company will also feature the original Jack Beavers IQF with Rams as well as the Straight Through Single- and Two-Chamber IQFs and In/Out IQFs with Push-Push Load Transfer Mechanisms.

Partnering Up for Education

The Solutions Center will offer industry presentations throughout the week focusing on real world problem solving

for specific manufacturing techniques, products and technologies. Topics on the heat treat side include atmosphere troubleshooting, practical applications of heat treat process modeling, flame-hardening in the 21st century, real time carburizing, heat treatment of steel alloys and more. The Technical Program will include topics on brazing, cryogenics, emerging technology, induction heating, nitriding and carburizing, quenching, vacuum technology and equipment innovations, to name a few. (Please note that the presentations and programs are subject to change prior to the show).

Once again, ASM and Gear Expo will offer a joint education course that begins with gear materials in the morning and heat treatment in the afternoon. Additionally, plans have already been confirmed for Gear Expo and Heat Treat to collaborate once again for the 2015 show, according to Jenny Blackford, AGMA director of marketing and communications. "This has been a successful collaboration so far and we'd like to continue to work with the ASM in the future."

Industry presentations throughout the week at the Solution Center will give attendees the opportunity to see the latest manufacturing technologies and techniques from both the heat treat and gear industries.

"I really like the addition of the heat treatment exposition," says Tony Werschky, sales manager and partner for Delta Gear. "The two expos complement each other well and we truly have an interest in expanding our knowledge of the heat treat process. We have many times considered adding heat treatment to our core competency. The majority of our gears are heat treated and the new technology for heat treatment is ever changing."

For more information:

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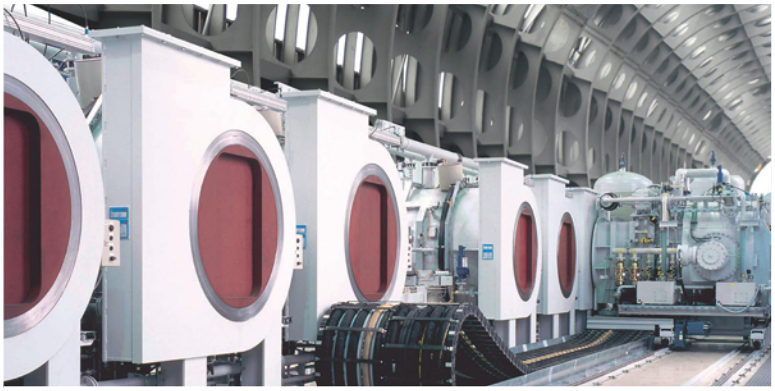

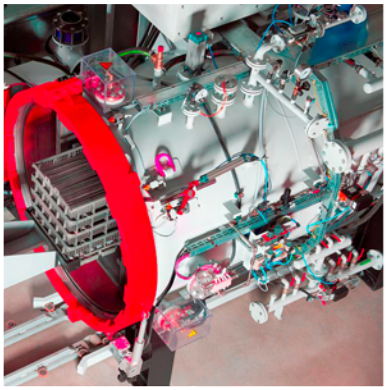

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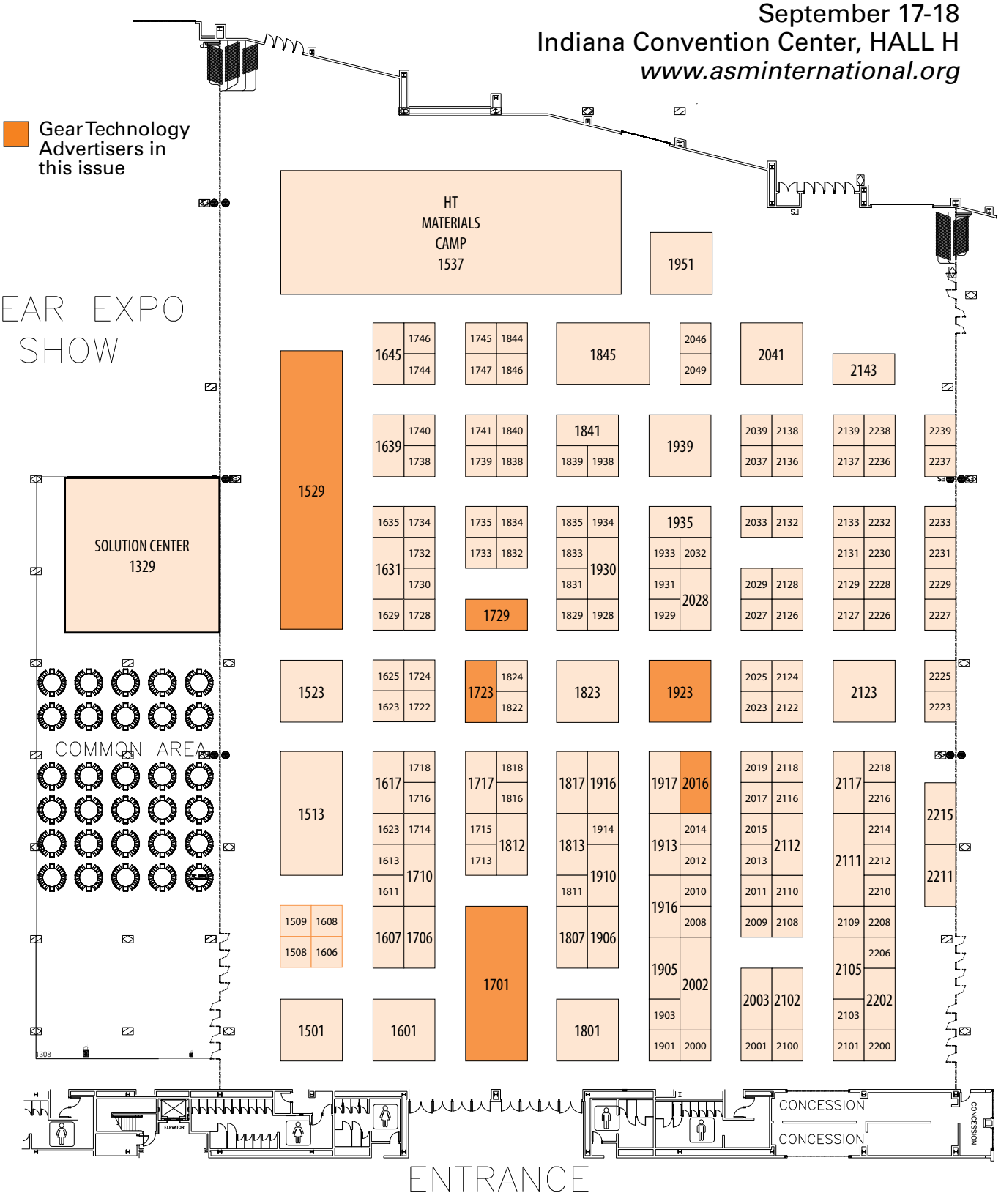

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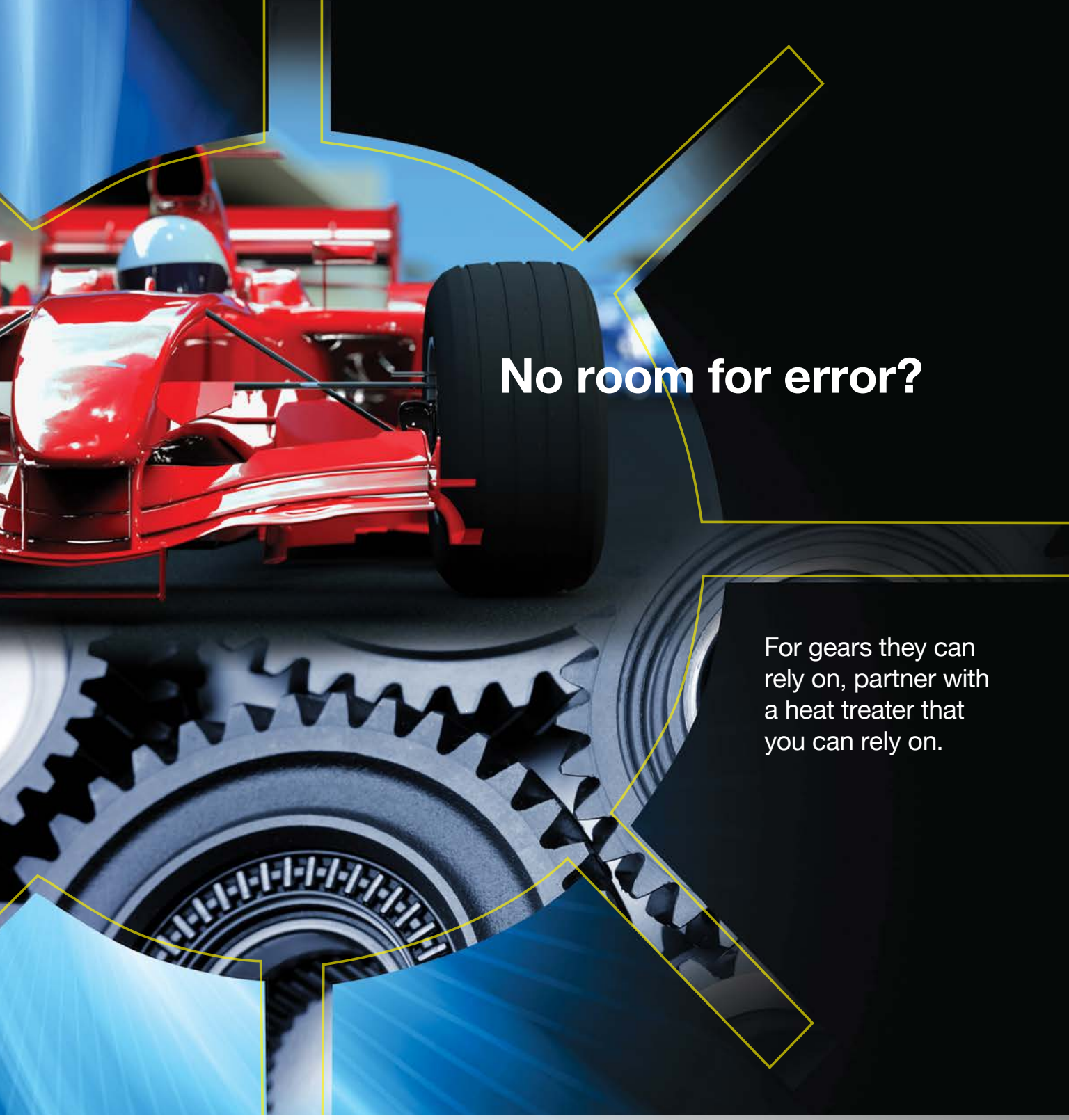

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How to Inspect a Gearbox

Jane Muller and Robert Errichello

(Gear Technology *thanks Noria Corporation and* Machinery Lubrication *magazine for permission to reprint this article.)*

Although a comprehensive on-site gearbox inspection is desirable in many situations, there may be constraints that limit the extent of the inspection such as cost, time, accessibility and qualified personnel.

Cost and shutdown time might be perceived as prohibitive by management, but catching a problem in its earliest stages can save time and money in the long run. While it may seem too difficult to do a comprehensive inspection, a simple visual inspection of gear contact patterns through an inspection port can prevent future catastrophic failures. If in-house inspection expertise is not available, an expert can be hired to perform the inspection and train personnel.

Overcoming constraints in order to allow an inspection can help to extend gearbox life and avoid catastrophic failure. This might also save time, money, injury to personnel and damage to adjacent equipment.

This article describes the equipment and techniques necessary to perform an on-site gearbox inspection.

Getting Prepared: Good Housekeeping is Essential

Before beginning an inspection, prepare an inspection form for documenting your observations. It should be designed for your specific application. Next, assemble the necessary equipment (see sidebar on page 14).

There are several sources of gearbox contamination, including those that are built-in, internally generated, ingressed, and added during maintenance. Many gearboxes operate in dirty environments. Therefore, good housekeeping methods should be used during inspections. Areas around inspection ports and other openings should be cleaned before they are opened. Inspectors should take care not to drop anything into the gearbox. Shirt pockets should be empty and tools should be stored in a tool belt. Ports should never be left open during breaks and should be closed and secured after the inspection is complete.

Walk-around visual inspection. You should perform a thorough external examination before the gearbox inspection port is opened. Use an inspection form to record important data that would otherwise be lost once cleaning is completed. For example, before cleaning the exterior of the gear housing, inspect it for signs of overheating, corrosion, contamination, oil leaks and damage. Measure the tightening torque of structural fasteners that carry significant loads, such as torque arm bolts. Look for evidence of movement, including cracked paint or fretting corrosion at structural interfaces. Note the condition of the fasteners and inspect load-bearing surfaces of components for fretting corrosion or other evidence of movement.

Detecting Overheating

The following are signs of overheating:

- Smoke from shafts, seals or breathers

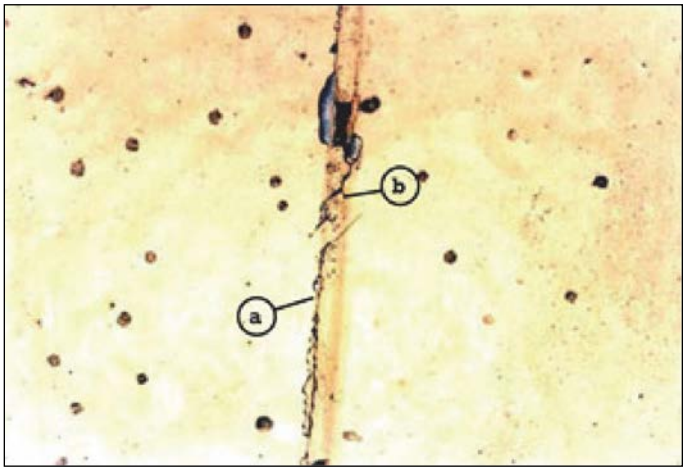

Figure 1 Cracked paint at torque arm interface indicates movement; a = 45° direction of cracks; b = suggests component on right moved downward, relative to component on left.

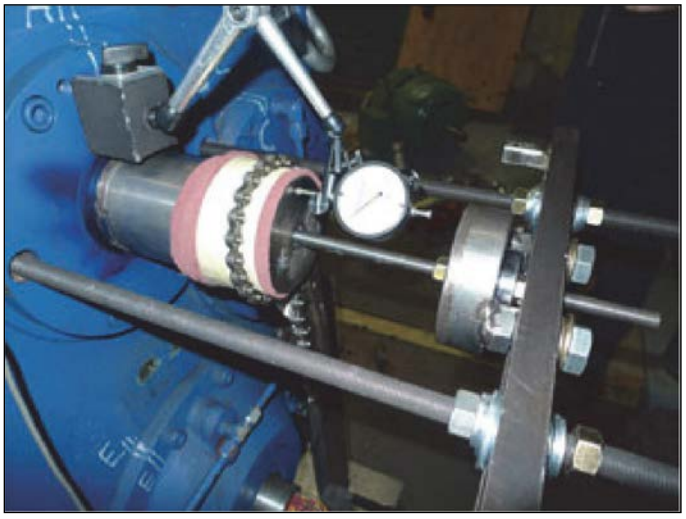

Figure 2 Fixture used for measuring shaft endplay.

Figure 3 Severe misalignment can cause macropitting on helical pinion gears.

- Discolored or burnt paint on housings
- Water sprayed on the housing or shafts evaporates quickly, boils or crackles
- Temper colors on unpainted surfaces
- Melted plastic components, such as shipping plugs
- Low oil level in sight glass or on dipstick
- Dark oil in sight glass or on dipstick
- Foam in sight glass
- Water in sight glass or sludge on filter element (may indicate oil cooler failure)
- Metal chips on magnetic plugs, chip detectors or filters (may denote gear or bearing failure caused by overheating)

Methods for Inspecting a Gearbox Visual walk-around
- Visual inspection through inspection ports
- Borescope inspection
- Measure temperature
  - Thermometers
  - Resistance temperature detector (RTD) probes
  - Thermography
- Measure oil pressure
- Measure sound and vibration
- Inspect filter elements Inspect magnetic debris collectors
- On-site analysis of lubricant
- Laboratory analysis of lubricant
- Magnetic particle inspection of gears
- Dye penetrant inspection of gears
- Documenting gear condition
  - Written
  - Sketches
  - Photography
  - Contact patterns

***To help you detect overheating, use this checklist*:**
- Visually inspect the gearbox exterior for signs of overheating.
- Record temperatures from gearbox thermometers, thermocouples or resistance temperature detectors (RTDs).
- Measure oil sump temperature.
- For pressure-fed systems with an oil cooler, measure temperature at the gearbox oil inlet and outlet, as well as the cooler water inlet and outlet.
- Estimate gearbox housing and shaft temperatures using water spray.
- Survey the gearbox housing temperature by touching it with the palm of your hand and using temperature-sensitive paint, crayons and labels, or a digital thermometer probe.
- Check the gearbox housing temperature using an infrared thermometer or infrared imaging camera.
- Analyze gearbox oil for signs of oxidation or thermal degradation using on-site and laboratory tests.
- Analyze gearbox oil using particle counters, spectrometric analysis and ferrography to detect wear debris.
- Inspect internal gearbox components through inspection ports for signs of overheating, misalignment, inadequate backlash, inadequate bearing endplay or oil oxidation.
- Measure gearbox sound and vibration and compare to allowable limits.

Inspect the breather. The breather should be located in a clean, non-pressurized area away from contaminants. It should include a filter and desiccant to prevent ingress of dust and water. Also, ensure that the breather is shielded from water during wash-downs.

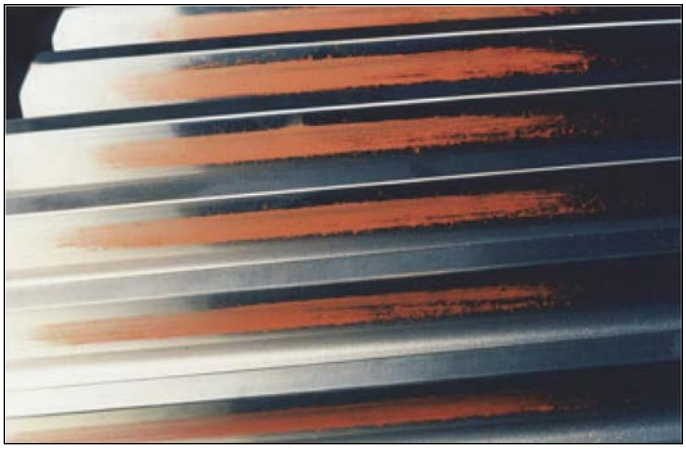

Figure 4 No-load contact pattern transferred to an unpainted gear.

Check shaft seals. Look for oil leaks at the shaft seals. If there are signs of oil leakage, the seals are probably allowing ingression of dust and water. If the gearbox has labyrinth seals, it should have external seals such as V-rings to prevent contaminant ingression.

Inspect structural interfaces. Figure 1 shows cracked paint at an interface, which indicates there was movement. The 45° direction of the cracks suggests the component on the right moved downward relative to the component on the left.

Examine through inspection ports. Examine the inspection port cover and determine whether all bolts are tight and the cover is properly sealed, or if there is oil leakage. Only qualified personnel should be allowed to open inspection ports; in some cases it is necessary to secure the ports with padlocks to enforce security.

Clean the inspection port cover and the surrounding area. Remove the cover, being careful not to contaminate the gearbox interior. Count the bolts and store them in a separate container so there is no chance they will fall into the gearbox. Observe the condition of the gears, shafts and bearings.

If the gears or bearings are damaged but still functional, management may decide to continue operation and monitor damage progression. In this case, the gear system should be continuously monitored. You should also make certain there are no risks to human life.

For critical applications, examine the gears with magnetic particle inspection to ensure there aren't any cracks that prevent safe, continued operation. If there are no cracks, you should periodically perform a visual inspection and measure temperature, sound and vibration.

Collect samples of the lubricant for analysis, examine the oil filter for wear debris and contaminants, and inspect magnetic plugs for wear debris.

The best place to take an oil sample from a gearbox is as close to the gearset as possible. Using a minimess (*Ed.'s note: Hydrotechnik's patented ball sealing threaded test point and plug-in coupling*) sample port with tube extension will allow you to mount the sample port in the drain and manipulate the tube so that it terminates exactly where you want it.

The rule of thumb for installing sample port tube extensions is to keep the end of the tube at least two inches away from any static or dynamic surface.

Figure 5 Different sector of unpainted gear revealed.

Figure 6 Documentation of no-load contact patterns.

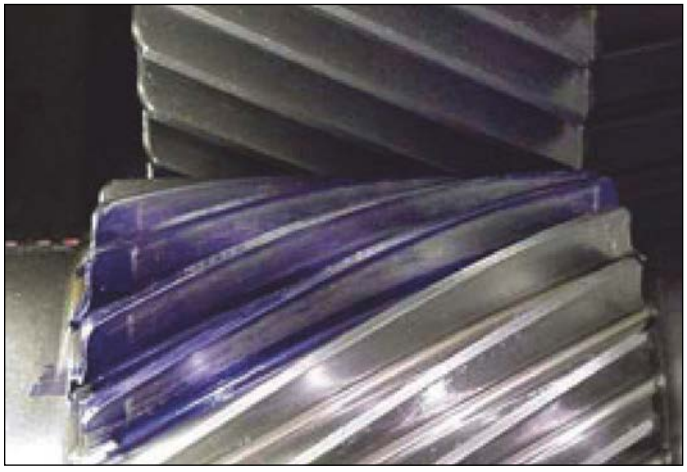

Figure 7 Pattern recorded at 50 percent load.

You will need to flush the entire combination of tube extension, minimess sample port, sample port adapter and sample tube before you take your sample for analysis. Flush at least 10 times the volume of all the components prior to taking the sample for analysis. This typically works out to three or four ounces of fluid for a sample port with a tube extension of 12 inches.

To prevent further damage to the gears and bearings from wear debris, replace the filter element and then drain, flush and refill the reservoir with new lubricant. Continue to monitor lubricant properties during operation and repeat the maintenance if necessary.

If cracks are found or the damage is severe enough to warrant removal of the gearbox, measure shaft coupling endplay and alignment before removing the gearbox. Note the condition and loosening torque of fasteners, including coupling and mounting bolts. To check for possible twist in the gear housing, install a dial indicator at each corner of the gearbox and then measure movement of the mounting feet as bolts are loosened. If there's no twist, each indicator will record the same vertical movement. If there is twist, calculate the twist from relative movements.

If no obvious damage is detected, document the condition of gears and bearings with photographs, sketches and written descriptions. Also, record gear tooth contact patterns for future reference (see Recording Gear Tooth Contact Patterns section).

Equipment to Use for a Gearbox Inspection Toothbrush for contact patterns

- PT-650 tooth marking grease for no-load contact patterns
- DYKEM layout lacquer for loaded contact patterns
- 6-inch, medium-mill bastard file for recording graphite contact tapes
- Drafting pencil with 2H lead for recording graphite contact tapes
- Utility knife with scissors for recording contact tapes
- Scotch No. 845 book tape for recording contact tapes
- 0.03 mm and 0.04 mm shims
- Felt-tip paint marker
- Earplugs
- Sweatband
- Tool belt
- Metric/inch tape measure
- Tweezers
- Spatula
- Telescoping magnet
- Leatherman "super tool"
- High-intensity LED flashlight
- Fiber-optic attachment for LED flashlight
- 6-inch metric/inch scale
- 3.5-inch magnifier
- 2-by-3.5-inch telescoping mirror
- 30× Panasonic light scope microscope
- Torque wrench
- Dial indicators with magnetic bases
- Inspection forms
- Lubricant sampling equipment
- Baggies and tags for specimens
- Micrometers
- Borescope
- DSLR camera with close-up flash
- Sound meter
- Vibration probe

- Digital thermometer
- Infrared thermometer or infrared imaging camera

Measure gear backlash and shaft endplay. Measure gear backlash by mounting a dial indicator so it is similar to a pinion tooth profile; block the gear to prevent its rotation and rock the pinion through the backlash.

To measure shaft endplay, mount a dial indicator at the end of a shaft and move the shaft in the axial direction. In most cases, this requires a fixture with a ball bearing on the central shaft that allows pushing and pulling the shaft while it is rotated to seat the bearing rollers.

Gear mesh alignment. Gears have maximum load capacity when the gear shafts are perfectly aligned and the transmitted load is uniformly distributed across the entire active face width. Unfortunately, many factors, such as design issues, manufacturing accuracy, deflections, thermal distortion and external effects may combine to cause misalignment of the gear mesh. The result is that the gears are misaligned and the load distribution is not uniform.

Gear tooth contact patterns. It is important to inspect gear tooth contact patterns because they can disclose gear mesh misalignment. The inspection should be done during commissioning of the gearbox to catch misalignment before it causes damage. Inspections should be regularly repeated to determine any changes in contact patterns caused by problems such as bearing failure.

What to look for. Watch for heavy contact at the edges of the contact area — especially at each end of the pinion and gear

Figure 8 Pattern recorded at 100 percent load.

face, at the tips of the teeth, and along the roots of the teeth at the start of active profile (SAP). Determine if there are wear steps at the tooth ends, tips or the SAP. The pinion is often wider than the gear, and if there is misalignment, a wear step is likely to be at either end of the pinion. Severe misalignment usually causes macropitting.

Recording gear tooth contact patterns. If there's evidence of gear misalignment, such as macropitting concentrated at the ends of the teeth but no broken teeth or other failures that would prohibit rotating the gears, record the gear tooth contact patterns. The way gear teeth touch indicates how they are aligned. Tooth contact patterns can be recorded under loaded or unloaded conditions. No-load patterns aren't as reliable as loaded patterns for detecting misalignment because the marking compound is relatively thick. In addition, no-load tests don't include misalignment caused by load, speed or temperature. Therefore, if possible, follow any no-load tests with loaded tests.

Recording no-load contact patterns. For no-load tests, thoroughly clean and paint the teeth of one gear with a soft marking compound and then roll the teeth through the mesh so compound transfers to the unpainted gear. Turn the pinion by hand while applying a light load to the gear shaft by hand or a brake. Use clear tape to lift transferred patterns from the gear and mount the tape on white paper to form a permanent record.

The compound PT-650 tooth marking grease from Products/Techniques Inc. works best. Scotch No. 845 book tape (two inches wide) is preferred for lifting contact patterns.

Figure 6 shows contact tapes that indicate a contact pattern wandering from centered in some sectors of the gear to biased, toward the left end of the face width in other sectors. This type of misalignment is caused by run-out of the gear; it can only be corrected by replacing the gear with a more accurate one.

Recording loaded contact patterns. For loaded tests, thoroughly clean the teeth with a solvent and acetone. Paint several teeth on one or both gears with a thin coat of machinist's layout lacquer (DYKEM). Run the gears under load for sufficient time to wear off the lacquer and establish the contact pattern. Photograph the patterns to obtain a permanent record.

If possible, record loaded contact patterns under several loads, such as 25, 50, 75 and 100 percent of full load. Inspect the patterns after running about one hour at each load to monitor how the patterns change with load. Ideally, the patterns shouldn't vary with load. Optimum contact patterns cover nearly 100 percent of the active face of the gear teeth under full load, except at extremes along tooth tips, roots and ends, where contact should be lighter as evidenced by traces of lacquer.

Think of on-site gearbox inspections as preventative maintenance. Problems caught early and corrected can prevent catastrophic, costly and dangerous failures down the road.

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Recording Micropitting

A permanent record of micropitting can be obtained by rubbing fine graphite into micropitted areas and lifting the graphite pattern with transparent tape. The procedure is as follows:

1. Clean the tooth by rubbing with a clean, lint-free cloth soaked in fast-drying solvent.
2. Place a clean lint-free cloth on a flat surface and rub a drafting pencil on a file or sandpaper to coat the cloth with graphite.
3. Rub the entire tooth surface with the cloth so graphite covers micropitted areas, top-land and edges of the tooth.
4. Rub the entire tooth surface with a clean lint-free cloth to remove loose graphite.
5. Place a length of transparent tape over the entire tooth. Allow the tape to fold over the edges and top-land to define the boundaries of the tooth. Scotch No. 845 book tape works best.
6. Rub the back of the tape with a clean cloth to ensure intimate contact with the tooth surface.
7. Starting at one end, carefully peel the tape from the tooth.
8. Place one end of the tape (with adhesive side down) on white paper and carefully spread the tape across the paper. Micropitted areas will appear as dark gray, machining marks as lighter gray, and polished areas will look white.
9. Annotate the record to fully describe tooth location and orientation.

For more information:

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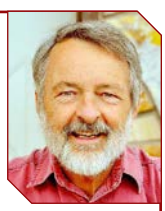

Robert Errichello is a longtime AGMA member. He has served on a number of its various committees and is the instructor of the Gear Failure Analysis seminar, easily one of AGMA's most popular and attended classes. The author of numerous gear-relevant technical papers and books, Bob also serves as a Gear Technology technical editor, and is owner-operator of GEARTECH, a gear industry consultancy.

Jane Muller is a mechanical engineer with GEARTECH since 1986 and a consultant to the gear industry for the past 27 years. She has presented numerous seminars on design, analysis, lubrication, and failure analysis of gears to professional societies and the gear and lubrication industries. Muller is a graduate of the San Francisco State University and holds a BS degree in mechanical engineering, and also studied fine arts at Wilkes College in Pennsylvania. Jane has published several articles on design, analysis, and application of gears.

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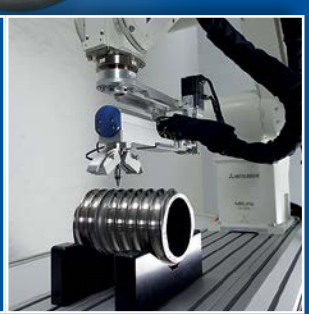

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Lubrication Specification and Methodology

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

I need to specify a method of lubrication and the type of lubricant for a speed reducer with three-stage helical gear, but the peripheral speed on the reference circle is too low. We have for 1st stage the Stribeck rolling pressure ks = 34.76 N/mm² and the speed v = 0.80 m/s²; for the 2nd stage ks = 49.4 N/mm² and v = 0.39 m/s²; and finally for 3rd stage the values are ks = 37.6 N/mm² and v = 0.27 m/s².

Could you help me with the type and method of lubrication? Thank you.

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Response provided by Robert Errichello, GEARTECH owner/operator
(geartech@mt.net)

Because of the low speed, the application warrants a rigorous analysis of the elastohydrodynamic lubrication (EHL) according to the method given in AGMA 923-A03 (Ref. 1). This method explains how to calculate the specific oil film thickness, which is the ratio of the minimum EHL oil film thickness to the composite surface roughness of the gear teeth. With the specific oil film thickness known, you can predict the probability of wear-related distress.

In lieu of an EHL analysis, ANSI/AGMA 9005-E02, Annex B, gives guidelines for lubricant viscosity based on operating oil sump temperature, pitch line velocity, and lubricant viscosity index. For example: Assume your ambient temperature is 25°C and the temperature of the oil in the oil sump is 65°C under the highest operating load. ANSI/AGMA 9005-E02 (Ref. 2) would recommend an ISO VG 680 lubricant for a mineral oil. Unfortunately, the guidelines are limited to a pitch line velocity greater than 1 m/s, and your lowest velocity is 0.27 m/s. Therefore, the viscosity should probably be increased to ISO VG 1000. If your operating temperature is greater than 65°C, the oil viscosity should be increased further.

High oil viscosity may lead to problems with oil circulation. Therefore, you need to consider cold starts, circulation of the lubricant to all gears and bearings, pumping losses, and filterability. You may need to use synthetic oil with a low pour point, or use sump heaters to preheat the oil for cold starts.

(**Robert Errichello** *is a longtime AGMA member. He has served on a number of its various committees and is the instructor of the Gear Failure Analysis seminar, easily one of AGMA's most popular and attended classes. The author of numerous gear-relevant technical papers and books, Bob also serves as a* Gear Technology *technical editor, and is owner-operator of GEARTECH, a gear industry consultancy.*)

References

- AGMA 923-A03: Effect of Lubrication on Gear Surface Distress.
- ANSI/AGMA 9005-E02: Industrial Gear Lubrication.

Standards Summary

AGMA 925—A03: Description

This document provides currently available information pertaining to oil lubrication of industrial gears for power transmission applications. It is intended to serve as a general guideline and source of information about gear oils, their properties, and their tribological behavior in gear contacts. Equations provided allow the calculation of specific film thickness and instantaneous contact (flash) temperature for gears in service, and to help assess the potential risk of surface distress (scuffing, micropitting and macropitting, and scoring) involved with a given lubricant choice.

ANSI/AGMA 9005–E02: Description

This standard provides the end user, original equipment builder, gear manufacturer and lubricant supplier with guidelines for minimum performance characteristics for lubricants suitable for use with enclosed and open gearing which is installed in general industrial power transmission applications. It provides recommendations for selecting lubricants based on current theory and practice in the industry, and attempts to align with current ISO standards. It is not intended to supplant specific instructions from the gear manufacturer. Replaces ANSI/AGMA 9005-D94.

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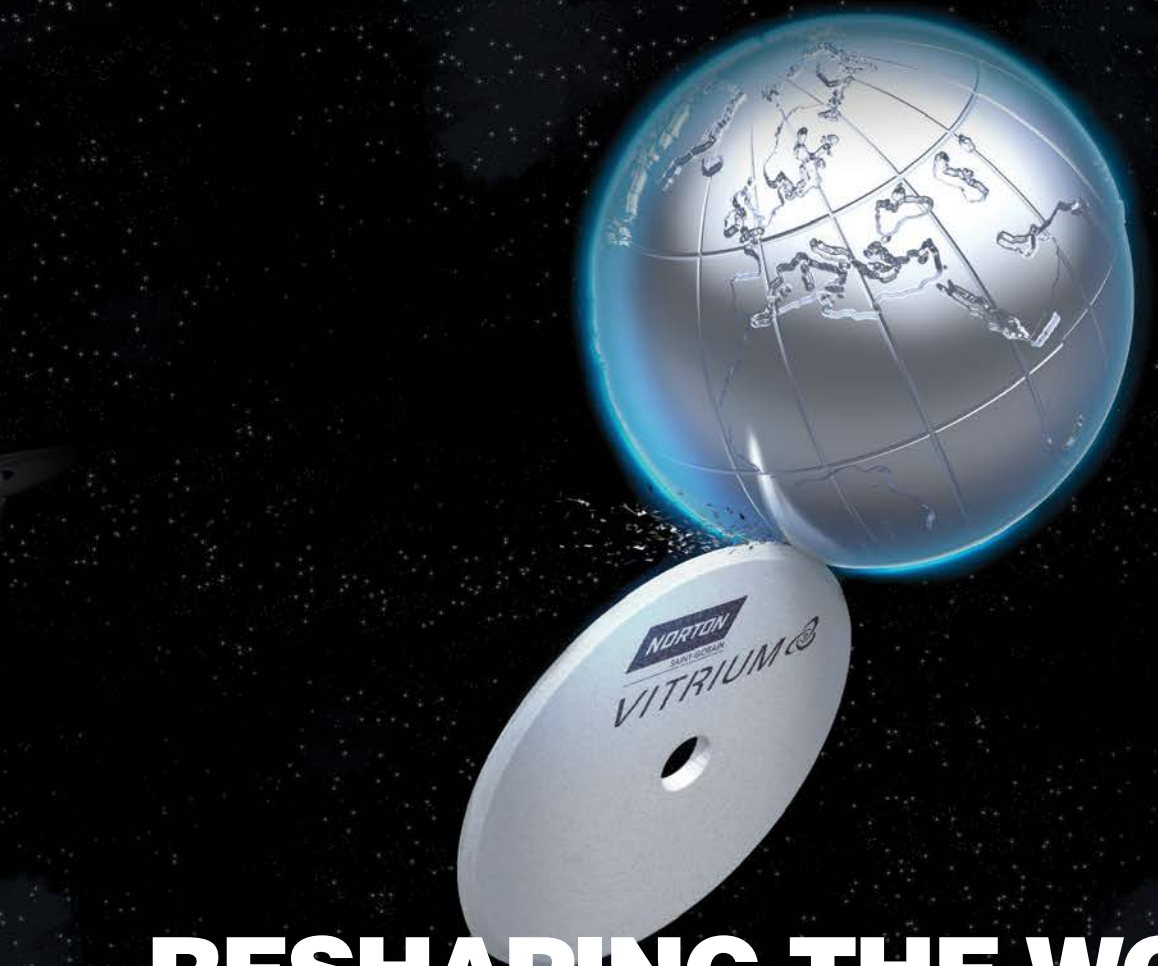

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New-Formula Acetylene Cool for Heat Treatment

Daniel H. Herring and Robert V. Peters Jr.

Acetylene with DMF solvent enables benefits of low-pressure vacuum carburizing

The vacuum carburizing process continues to evolve, constantly offering new and improved process innovations (Refs. 1 and 2). Chemical acetylene with DMF solvent is one of these technological breakthroughs, and an especially important one for gear heat treatment.

Low-pressure carburizing (LPC) has proven itself the technology of choice for precision-carburizing of high-performance gearing (Refs. 3 and 4). In recent years acetylene and acetylene-based mixtures have become the preferred choice in the industry (Ref. 5). What users are discovering is that the type of acetylene being used has an enormous impact on productivity and quality.

Technical Advantages

Acetylene helps shorten carburizing cycle times and improves uniformity of case depth. This is due in part to its higher carbon flux value (Table 1) and an ability to penetrate blind holes, with 12:1 (Ref. 6) through 20:1 (Ref. 7) length-over-depth ratios now possible. An example: when using acetylene for low-pressure vacuum carburizing, the case depth in the root of gear teeth approaches 90 percent of that in the active flank, making it an extremely attractive hydrocarbon choice.

Carbon flux—that is, the transfer of carbon to the steel surface from the source supplying the carbon—depends on the actual load surface area and carbon yield (Table 2), or carbon availability from the carburizing gas that is used. The carbon yield is the amount of carbon transferred into the parts, relative to the amount of carbon supplied to the treatment chamber by injecting the carburizing gas. For acetylene, the carbon yield has been found to be in the range of 65 percent or greater (Refs. 2 and 7). This has been independently verified in a number of field installations (Refs. 1 and 8); no other hydrocarbon gas approaches this value. The amount of transferred hydrocarbon is a function of several factors, including:

- Length of the pulse
- Temperature
- Gas volume (i.e., flow) into the vessel
- Pulse parameters (constant vs. variable flow)
- Surface area of the load

Gas purity has also been found to increase carbon yield (Ref. 8), with more carbon being available at the part surface per-cubic-meter (cubic foot) of gas injected.

The LPC Story

The history of vacuum carburizing (Table 3/OR SIDEBAR) is a fascinating one. The process was invented in late 1968 and subsequently patented (U. S. Patent No. 3,796,615, U. S. Patent RE 29,881) by Herbert W. Westeren, director of research and development for C. I. Hayes, Inc., Cranston, RI. The process

Table 1 (Ref. 9)—Carbon flux values in LPC

Hydrocarbon Species	Dissociation Products	Average Carbon Flux (g/m^2-h)
Acetylene C_2H_2	$2C + H_2$	150
Cyclohexane C_6H_{12}	$C_xH_y + C + H_2$	[a]
Ethylene C_2H_4	$CH_4 + C$	120
Methane CH_4	$CH_4 + C$	<5
Propane C_3H_8	$C_xH_y + C + H_2$	130

Notes: a) Not reported.

Table 2 (Ref. 8)—Decomposition characteristics of hydrocarbon gases used in LPC

Gas Species	Decomposition Characteristic [a]	Effectiveness [b] (%)
Acetylene	Catalytic	65 – 85
Methane	Thermal	5 – 20
Propane	Thermal	5 - 20

Notes

a) Thermal decomposition limits the carbon available to workload and creates a higher percentage of unwanted by-products.

b) Effectiveness in this context is another term for carbon yield.

Table 3 (Ref. 10)—Significant developments in the history of vacuum carburizing

Year	Activity
1968/1969	Vacuum carburizing technology invented and introduced to industry (oil quench vacuum furnaces); methane was the original hydrocarbon choice at 13 mbar (10 torr); equipment limitations slowed commercial development.
1972	The first true production vacuum carburizing furnaces were introduced; process limitations using methane were fully understood; propane was introduced as the hydrocarbon gas of choice at 200–400 mbar (150–300 torr); soot and tar formation required increased maintenance.
1977	Experiments and patenting of acetylene-based carburizing (former Soviet Union); technology remained virtually unknown outside the Soviet Union.
1979/1980	Commercial development slows dramatically as problems with propane are difficult to overcome.
1980–1995	Various attempts at making the vacuum carburizing process more tolerant, including operation at lower operating pressures; development of high-pressure gas quenching technology; chemical acetylene with DMF solvent introduced to the non-heat treat industry by Praxair.
1994–1996	Introduction and patenting of acetylene-based, low-pressure carburizing (Japan) under 10 mbar (7.5 torr).
1999–2000	Commercialization resumes in earnest using acetylene; propane- based systems are slowly being phased out; introduction of modular vacuum carburizing technology by ALD Vacuum Technologies GmbH.
2006	Chemical acetylene with DMF solvent first introduced to heat treat industry and first used commercially at ALD.
2007–Present	Rapid growth and acceptance of vacuum carburizing technology; equipment and process synergy; growth of modular technology.

was commercialized in early 1969. However, full acceptance of the process involved nearly three decades of work and countless contributions from all over the world. The development effort involved such areas as:

- Improvements in the design and construction of vacuum furnaces
- Development of low-pressure carburizing methods
- Process optimization—especially the selection of hydrocarbon gas
- Development of optimized gas-injection methods and flow/pressure controls
- Creation of empirical databases and design of process simulators
- Development of high-pressure gas quenching technology and optimization of oil quenching techniques
- Availability of low-cost carburizing alloys specifically designed to take advantage of vacuum carburizing and gas quenching, including high- temperature capability
- Innovations in fixture materials, including the use of carbon/carbon fiber composite materials

The Process Explained

LPC is a recipe-controlled, boost/diffuse process. By contrast, atmospheric gas carburizing is controlled via carbon potential. In vacuum carburizing, the process-related parameters such as temperature, carburizing gas-flow, time and pressure are adjusted and controlled to achieve the desired case profile in the parts.

Recipe development by means of simulation programs (Fig. 1) allows the user to determine a sequence of carburizing and diffusion steps in which carbon profile as a function of depth can be predicted. Typical input parameters of the software include:

- Material
- Carburizing temperature
- Targeted carburizing depth
- Targeted surface carbon content
- Surface carbon content limit
- Load surface area

Input back into the simulation allows cycle refinements to take place.

Why acetylene? Acetylene is a catalytically decomposable hydrocarbon, which essentially means that it will break down into its elemental constituents (Eq. 1, Fig. 2) in the presence of a hot metal surface in a vacuum furnace operating at low pressure—typically at or below 10 mbar (7.5 Torr). Other hydrocarbons (e.g., methane, propane) are thermally decomposable, which means that they will break down immediately upon entry into the hot zone of the vacuum furnace, negating the ability of the carbon to react with the surface of the steel and creating unwanted hydrocarbon byproducts (Table 4).

$$C_2H_2 \rightarrow 2C + H_2 \quad (1)$$

The complete chemical reaction (Fig. 3) is actually more complex than that shown in Equation 1, and consists of nine separate reactions. A detailed explanation of acetylene pyrolysis can be found in the literature (Refs. 13–16).

Types of acetylene. Acetylene can be supplied as welding- or industrial-grade (transported in

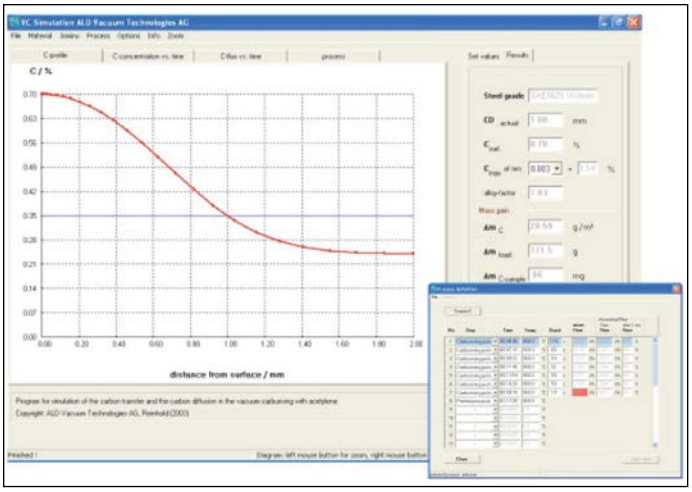

Figure 1 LPC simulation program (all photographs courtesy of ALD Vacuum Technologies GmbH).

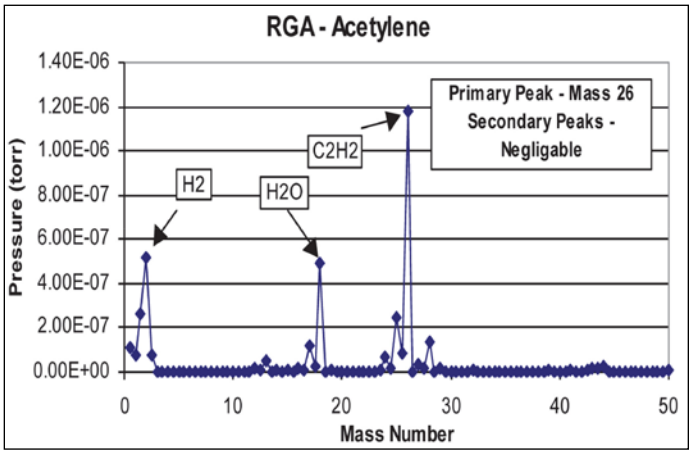

Figure 2 (Ref. 11)—Acetylene decomposition: RGA analysis.

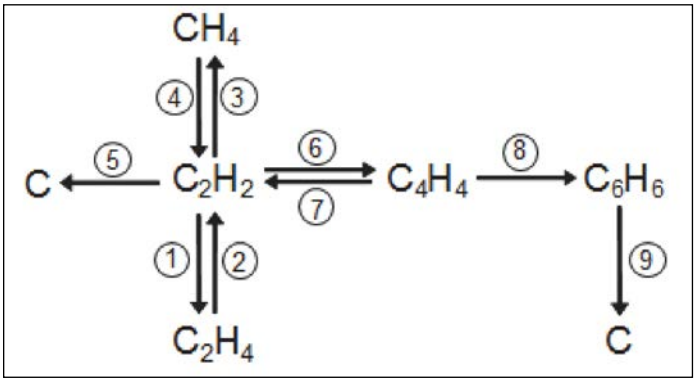

Figure 3 (Ref. 13)—Dissociation reactions during acetylene pyrolysis.

Table 4 (Ref. 12)—Gas reactivity

Gas Species	Undesirable Byproducts (%)	Undesirable Byproducts (species)
Industrial Acetylene (with acetone solvent)	5	Sulfides (500 ppm), phosphine/arsine (500 ppm) and ammonia (50 ppm).
Chemical Acetylene (with DMF solvent)	0.5+	Ethylene
Methane	5	
Natural Gas [a]	15	
Propane	10	Heavy hydrocarbons [b]

Notes:
a) Unsuitable for lpc (due to oxygen content and contaminants in the gas).
b) Includes propylene, iso-butane, butane, methane, pentane, n-pentene, and others.

Table 5 (Ref. 1)—Hydrocarbon choices for LPC	
Family	**Combinations**
Acetylene & Acetylene Mixtures	100% Acetylene (C_2H_2) [a]
	Acetylene + Nitrogen [b]
	Acetylene + Hydrogen [c]
	Acetylene + Ethylene (C_2H_4) + Hydrogen [d]
	Acetylene + Cyclohexane
Cyclohexane & Cyclohexane Mixtures	100% Cyclohexane (C_6H_{12}) [e]
	Cyclohexane + Acetylene
Methane & Methane Mixtures	100% Methane (CH_4) [f]
	Methane + Propane [g]
Propane & Propane Mixtures	100% Propane (C_3H_8)
	Propane + Methane [f]
	Propane + Hydrogen
	Propane + Butane (C_4H_{10})

Notes:
a) Chemical acetylene with DMF solvent preferred
b) Typical dilutions up to 50 percent
c) Typical dilution 7:1 (U.S. Patent 7,514,035, Solar Atmospheres Inc.)
d) Typical ratios of acetylene to ethylene to hydrogen are 3:2:1 or 2:2:1 (U.S. Patent 7,550,049, Seco/Warwick Corp.)
e) Cyclohexane (U.S. Patent 7,267,793, Surface Combustion, Inc.)
f) Temperatures above 955°C (1,750°F) recommended unless plasma-assisted
Typical dilution: 40/60 to 60/40 (methane/propane)

Table 6 (Ref. 5)—Solubility comparison		
Property	**Acetone**	**DMF**
Boiling Point (°C)	56.5	152
Acetylene Solubility [a]	425	400

Notes: a) g/L of solution at 21°C and 17 atmospheres

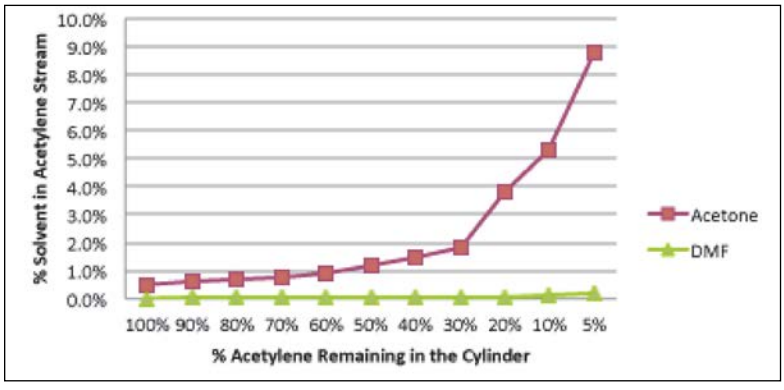

Figure 4 (Ref. 17)—Solvent carry-through in the acetylene stream.

Table 7 (Ref.17)—Percentage of solvent carry-through		
Cylinder Capacity (%)	**Acetone**	**DMF**
100	0.5%	0.010%
90	0.6%	0.012%
80	0.7%	0.015%
70	0.8%	0.018%
60	0.9%	0.020%
50	1.2%	0.027%
40	1.5%	0.035%
30	1.8%	0.049%
20	3.8%	0.072%
10	5.3%	0.132%
5	8.8%	0.207%

acetone), and chemical-grade (transported in dimethylformamide or DMF). Industrial-grade is produced by the reaction of calcium carbide and water (Eq. 2). Byproducts include sulfides, phosphine, arsine and ammonia—all of which are unwanted contaminants in vacuum carburizing.

By contrast, chemical acetylene is the result of hydrocarbon (typically, natural gas) cracking (Eq. 3), the major byproduct of which is ethylene, which is also used as a hydrocarbon source in vacuum carburizing.

$$CaC_2 + 2H_2O = C_2H_2 + Ca(OH)_2 \quad (2)$$

$$2CH_4 \rightarrow C_2H_2 + 3H_2 \quad (3)$$

Why chemical acetylene with DMF solvent? As early as 1999, industrial-grade acetylene in acetone and various acetylene gas mixtures (Table 5) was replacing older types of hydrocarbon gases throughout the heat treat industry. Acetylene dramatically reduced the amount of carbon build-up in the furnaces, simplifying maintenance and improving uptime productivity.

While good news for the industry, it came at somewhat of a cost premium; i.e., only 70–75 percent of industrial-grade acetylene gas could be used from each bottle to avoid introducing acetone into the process. But with the introduction of chemical acetylene with DMF solvent, as much as 95 percent of the gas could be used from each bottle. As a result, the heat treater no longer has to purchase more acetylene bottles to perform the very same process. The more bottles on- site, the more storage space needed, as well as increased handling and safety concerns (e.g., more piping and hookups). In addition, there is an ambient temperature limitation for industrial-grade acetylene bottles—they must be stored above 4°C (39°F). In summary, chemical acetylene offers higher gas purity, which, in turn, offers even more control of the carburizing process while using less gas and requiring less equipment maintenance.

The role of stabilizing solvents. Due to acetylene's triple bond between carbon atoms, it is fundamentally unstable and will decompose if compressed. Under pressure, an explosive exothermic gas reaction will occur if the gas pressure exceeds 100 kPa (15 psi). This makes transport of the gas under pressure dangerous, unless a stabilizing transport solvent is used. Acetone (C_3H_6O) and dimethylformamide (C_3H_7NO)—or DMF—are the transport solvents of choice.

But acetone, while a proven transport solvent, has the disadvantage of high volatility, as it tends to vaporize and leave with the acetylene gas when acetylene is withdrawn from the cylinder. This is problematic for vacuum carburizing. By contrast, DMF has a boiling point about 100°C (212°F) higher than acetone, with similar solubility. Thus DMF is less likely to volatilize (Table 6) and be carried by the gas stream into the vacuum furnace.

DMF also provides higher gas yield (Fig. 4, Table 7), as it is 40 times more stable than acetone. While acetone introduces oxygen into the process—and with it the potential for intergranular oxidation/intergranular attack (IGO/IGA)—DMF is more stable over a wider range of temperatures (-18°C to 0°C), making it far less likely to be introduced into the gas stream.

Case Study: ALD Thermal Treatment

ALD Thermal Treatment, in Port Huron, MI has been using chemical acetylene with DMF solvent since 2006. Increased yield from individual cylinders (over 20 percent more gas) was an important consideration, as was the storage and usage of acetylene in northern climates. Flow restrictions occur with industrial-grade acetylene below 4°C (40°F). By contrast, chemical acetylene has no flow-related issues—even at -18°C (-30°F). Another requirement was purchasing in bulk as opposed to simply buying individual cylinders. Chemical acetylene can be purchased in trailer quantities (Fig. 5), with up to 200 bottles linked together as a single unit. This became an increasingly important consideration as the organization grew from an initial installation of four carburizing chambers to the present-day 40-plus chambers. Another consideration is the purchase of a trailer for dedicated use, which can be refilled by the gas supplier. In this way, cross-contamination from other users is avoided.

Figure 5 A typical trailer set-up: chemical acetylene with DMF solvent.

A small set of bottles is still required off the trailer to continue operation while the trailer is being changed out. These bottles are re-charged with the acetylene from the trailer, unlike industrial-grade acetylene, which cannot be recharged in this manner. Finally, from a process and process control standpoint, it was soon discovered that less gas was required and a volume reduction of approximately 40 percent was realized.

Here's what ALD Thermal Treatment found regarding *industrial-grade acetylene* in individual cylinders:

- The percent of acetylene in each cylinder (solvent, volume) varies
- The number of times a bottle has been recharged affects gas purity and acetylene yield
- The number of contaminants in each cylinder varies over time
- Flow rate limitation exists, as each cylinder must flow separately into the acetylene system
- Temperature of each bottle affects both flow rate and volume of solvent drawn into the gas stream
- Purity (as delivered) varies between 95 and 98 percent
- Only 70–75 percent of a bottle can be used; if bottles are not changed promptly, you will pull contaminates from the bottom of the bottle into the vacuum furnace
- The customer pays for a fully charged bottle, even if they don't use the volume in each bottle
- The pressure in each acetylene cylinder is roughly 16.9 bar (245 PSI); the maximum withdrawal pressure is 1.03 bar (15 PSI), with a flow rate equivalent to one-seventh of cylinder capacity; each bottle must be independent in the piping system and cannot run in series
- Depending on volumes required, changing out each bottle could be an issue (time/safety)

Here's what ALD Thermal Treatment found regarding *chemical acetylene*:

- Chemical acetylene with DMF solvent is a precisely packaged gas and is ready to use (no solvent variations bottle to bottle)
- Purity is 99.5 percent or better
- The required volume of chemical acetylene is lower than acetone-based acetylene to process the equivalent product
- Weather/outdoor temperature (in upstate Michigan) is not an issue
- Chemical acetylene bottles can be assembled in series or in parallel, while staying under the maximum allowable delivery pressure of 1.03 bar (15 PSI) for piping running inside an industrial building
- Chemical acetylene comes in cluster packs or on a trailer system with bottles connected to a manifold; when it is time to change out the trailer, back-up bottles on the ground are used while the trailer is being removed and a new trailer installed; the backup bottle on the ground can then be re-charged with the DMF acetylene from the new trailer
- When the used trailer is returned, a credit is issued for the volume(s) of unused gas left in the bottles
- Back-up bottles on the ground can be re-charged repeatedly without concern of introducing contaminates
- One-line-hook-up and very easy change-out of the cluster pack or trailer, with no changing of individual bottles

Figure 6 Load of input sun gears ready for processing.

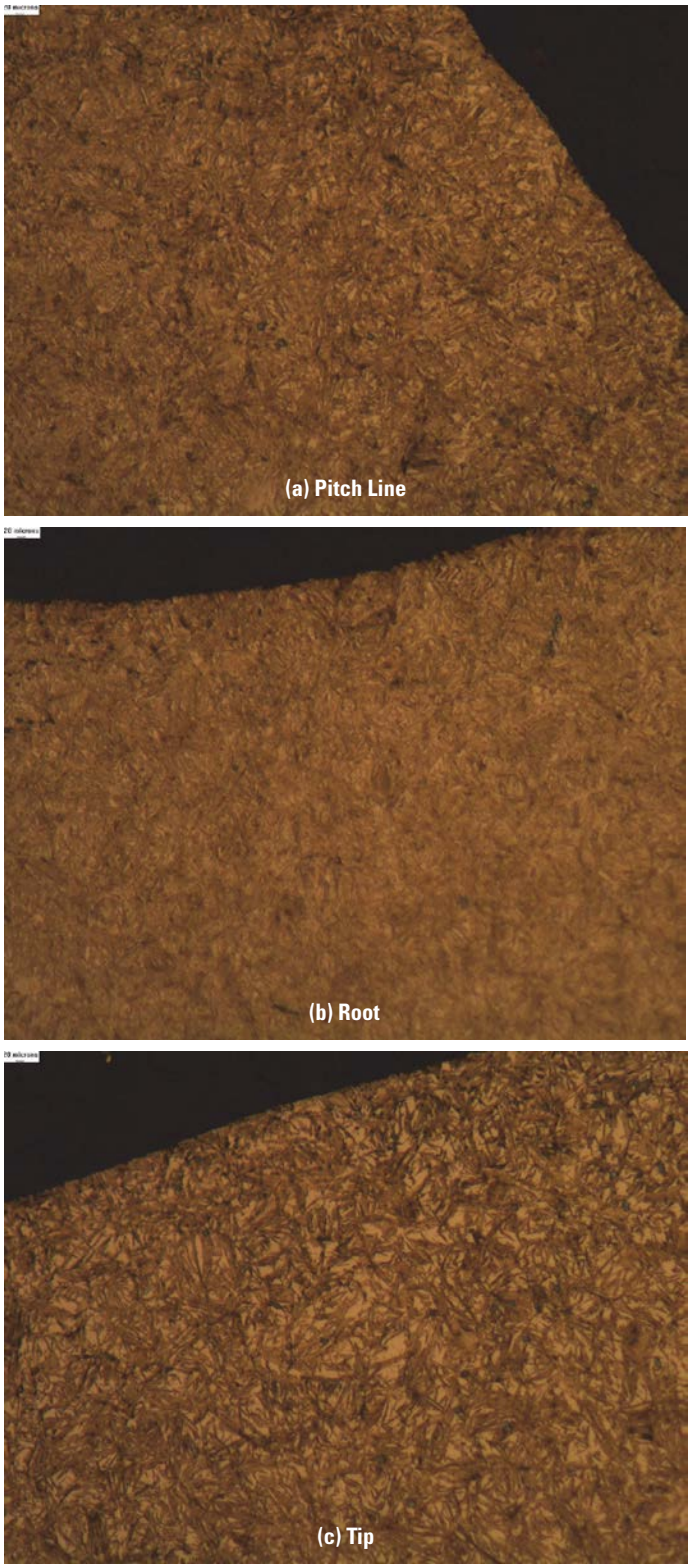

Figure 7 Sun gear microstructures at 500×.

- Maintaining flow rate is not an issue, given that the acetylene is in gaseous form; there is no concern over changing concentrations, volume or flow rates

Application example. Production loads of input sun gears (Fig. 6) of SAE 5120M material are low-pressure vacuum carburized with DMF acetylene to achieve a total case depth of 0.3–0.5 mm (0.012"–0.020") at the pitch line, while achieving a surface hardness of 58–62 HRC. Bainite, excessive amounts of retained austenite and excessive carbide formation are to be avoided in the root, active flank and tip (Fig. 7).

Lessons Learned

- Chemical acetylene with DMF solvent provides extended equipment uptime productivity with dramatically simplified downtime, increased safety and simplicity of operation while producing superior metallurgical results. The bottom line is that the consistency of gear quality is positively impacted.
- While there are many choices for hydrocarbon, gases with low-pressure carburizing, and although very special circumstances may necessitate an alternative choice, chemical acetylene and acetylene mixtures are now clearly become viable choices, and are the hydrocarbon of choice.

Author and lecturer **Daniel H. Herring** — "The Heat Treat Doctor"— has penned over 500 published papers and four books; the most recent is Vacuum Heat Treatment. Herring completed his undergraduate work at the University of Illinois in 1971, moving on to gain a post-graduate degree in 1974 at Chicago's Illinois Institute of Technology (IIT). An active member of the engineering, materials and metallurgical community, Herring's credentials include a research associate professorship at the Illinois Institute of Technology/Thermal Processing Technology Center, and consulting technical editor and monthly columnist for Industrial Heating magazine. Prior to forming The Herring Group(specializing/consulting in for solving heat treating problems in industry and heat treat and metallurgical offering services) in 1995, Herring spent over 25 working for several furnace equipment manufacturers, where he held key positions in metallurgy, engineering, international marketing, sales, research and development, and new product and business development. He is an active member of a number of technical societies, which include ASM International, APMI International, SAE International, SME and AGMA, and is a member of the American Gas Association (AGA) "Hall of Flame."

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References

1. Herring, Daniel H., *Vacuum Heat Treatment*, BNP Custom Media Group, 2012.
2. Heuer, Volker. *Low-Pressure Carburizing (LPC)*, ASM Handbook (in preparation).
3. *Gear Materials, Properties and Manufacture*, Joseph R. Davis (Ed.), ASM International, 2005.
4. Herring, Daniel H., David J. Breuer and Gerald D. Lindell. "Selecting the Best Method for the Heat Treatment of Gears," *AGMA Technical Conference Proceedings*, 2002.
5. Esper, Bob. "Acetylene: The Right Carbon Source for Low-Pressure Carburizing," *Industrial Heating*, 2009.
6. Kubato, Ken. US Patent No. 5,702,540, Dec 1997 (JH Corporation).
7. Unpublished research. ALD Vacuum Technologies, GmbH.
8. Sugiyama, M. and H. Iwata. "Evaluation of Acetylene Vacuum Carburizing," *50th Japanese Heat Treat Conference*, May 2000.
9. Edenhofer, B. "Acetylene Low-pressure Carburizing: a Novel and Superior Carburizing Technology," *Heat Treatment of Metals*, December 1999.
10. Herring, Daniel H. "The History of Vacuum Carburizing," White Paper, The Herring Group, Inc., Elmhurst, IL, 2013.
11. Jones, William R. "Low Torr Range Vacuum Carburizing in an Experimental Vacuum Furnace," *IIT/TPTC Vacuum Carburizing Symposium*, November 2004.
12. Internal Study. ALD Thermal Treatment, Port Huron, MI.
13. Buchholz D., et al. "Modellierung des Pyrolyseverhaltens von Ethin unter den Bedingungen des Niederdruckaufkohlens von Stahl," *HTM* 62, 2007, 1, pp. 5-12.
14. Buchholz, D. et al. "Simulation der Pyrolyse und der Oberflächenreaktionen von Ethin beim Niederdruckaufkohlen von Stahl," *HTM* 63, 2008, 2, pp. 75-83.
15. Gräfen, W. "Pyrolyse und Aufkohlungsverhalten von C_2H_2 Bei der Vakuumaufkohlung von Stahl," PhD Dissertation, Universität Karlsruhe 2007.
16. Gräfen, W. and K. Seehafer. "*Einsatzhärten in Theorie und Praxis*," Fachtagung Härterei, 2009, Münchener Werkstofftechnik–Seminar, pp. 19-20, March 2009.
17. Technical Acetylene Datasheets. Praxair.
18. Sugiyama, M. "Vacuum Carburizing with Acetylene," *Advanced Materials & Processes*, April 1999.
19. Osterman, Virginia. "Development Experience on Low-Torr Range Vacuum Carburizing," *Industrial Heating;* September 2005ASM Handbook, Volume 4: *Heat Treating*, ASM International, 1991, pp. 348–351.
20. Herring, D. H. "A Case for Acetylene-Based Low-Pressure Carburizing of Gears," *Thermal Processing /Gear Solutions*, Fall/Winter 2012.
21. Heuer, V., K. Loeser, G. Schmitt and K. Ritter. "Integration of Case Hardening Into the Manufacturing Line: One-Piece-Flow," AGMA Technical Paper 11FTM23, 2011.
22. Kula, Piotr, Maciej Korecki, Robert Pietraski, Emila Stanczyk-Wolowic, Konard Dybowski, Lukasz Kolodziejczyk, Radomir Atraskiewicz and Michal Krasowski. "FineCarb: The Flexible System for Low-Pressure Carburizing," *17th IFHTSE Congress*, Kobe, Japan 2008.

Light-Weight Design for Planetary Gear Transmissions

Bernd-Robert Höhn, Karsten Stahl and Philipp Gwinner

There is a great need for future powertrains in automotive and industrial applications to improve upon their efficiency and power density while reducing their dynamic vibration and noise initiation. It is accepted that planetary gear transmissions have several advantages in comparison to conventional transmissions, such as a high power density due to the power division using several planet gears (Ref. 1). This paper presents planetary gear transmissions, designed according to ISO 6336 (Ref. 3), optimized in terms of efficiency, weight and volume, and calculated using low-loss involute gears (Ref. 4) as well as the maximum feasible number of planets.

Introduction

As mentioned, planetary gear transmissions generally feature various advantages in relation to conventional gear transmissions, such as higher efficiency, higher feasible gear ratios, compactness and lower weight. Present research concentrates on planetary gear transmission designs with a low volume, low power losses and, therefore, high efficiency values. Most of the present applications are characterized by basic planetary gear trains as an integral part of the synthesis process to achieve different transmission types, such as negative-ratio and positive-ratio drives. The power density of planetary gear transmissions is dependent on the adjusted number of planets linking two central gears. The input power of a central gear is then distributed to several planet gears, resulting in lower load and lower tooth forces for each gearing. Depending on the alignment of each gear wheel, or, rather, the chosen planetary gear transmission structure, different efficiency, volume and weight values can be achieved. Especially in combination with the desired transmission gear ratio, it is not obvious which gear train type ought to be chosen in order to provide an optimal transmission in terms of efficiency, volume and weight.

Outline

The objective of this paper is to calculate and compare the volume, weight and efficiency of three basic planetary gear transmissions with one degree of freedom (Fig. 1), applying three different gear ratios (5, 25 and 125). Due to the fact that this study focuses on reducing volume and weight, the lowest feasible number of gear teeth and as many planets as possible will be applied to each concept in order to reach a preferably high power density. In order to comply with the demand of high efficiency values, special low-loss gears will be designed that feature low load-dependent power losses due to low sliding in the loaded gear meshes. The gears of each concept and each gear ratio are designed according to ISO 6336 (Ref. 3), with optimized tool parameters to produce characteristically low-loss gears. The volume of each concept is calculated assuming the gear wheels, as well as the two-sided carrier shafts, to be solid cylinders. For the sake of simplicity, detailed shaft geometries, as well as the weight and additional power losses of bearings and other machine elements, are not considered here.

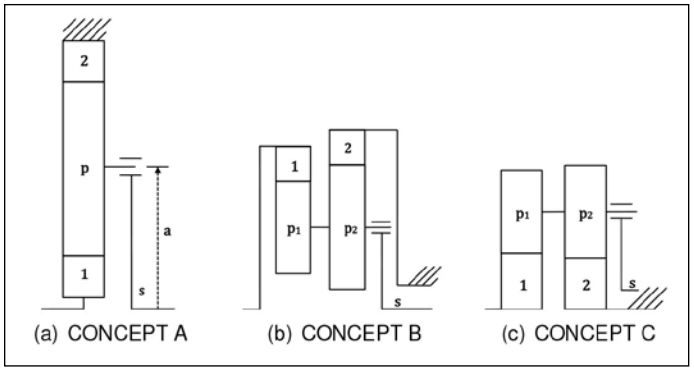


Figure 1 Planetary gear transmission concepts.

Kinematic Equivalence of Planetary Gear Transmissions

Mueller's book (Ref. 1) provides basic information and rules for planetary gear trains, such as for fundamental positive-ratio and negative-ratio drives with a fixed carrier, as well as for coupled or complex-compound planetary gear transmissions. According to Mueller, two fundamental planetary gear trains are kinematically equivalent if one gear ratio of a transmission is equal to one gear ratio of another transmission. In that case, all other gear ratios are equal too. Thus this rule reveals that multiple planetary gear train types can come into consideration if they feature the same desired gear ratio between the input and output shaft.

For the predefined gear ratios, one negative-ratio drive and two structurally different positive-ratio drives will be designed and compared (Fig. 1). The calculation of the gear ratios for each concept (Table 1) shows the kinematic equivalence, since all of the concepts have the same gear ratios. One can easily recognize that each fundamental planetary gear train always features four positive and two negative ratios. Furthermore, the corresponding input and output shafts, as well as the required basic gear ratio i_{12}, can be derived for all transmission concepts of this study. For instance, Central Gear 1 is used as the input shaft, and the carrier as the output shaft for Concept A; the input and output shafts of Concepts B and C are the carrier shafts and Shaft 1, respectively.

Table 1 Gear ratios of the given transmission concepts

Gear Ratio	Concept A	Concept B	Concept C
i_{12}	–4	0.8	0.8
i_{21}	–0.25	1.25	1.25
i_{1s}	**5**	0.2	0.2
i_{s1}	0.2	**5**	**5**
i_{2s}	1.25	–0.25	–0.25
i_{s2}	0.8	–4	–4

Design of Light-Weight Planetary Gear Transmissions

In order to ensure valid comparison of the different transmission concepts, several default parameters must be pre-defined for the design process of the gears. Each input shaft is applied with a pre-set torque of 300 N-m and a speed of 1,500 rpm. A fixed number of teeth are applied at that gear of each transmission concept with the minimum carrying load—a minimum of 17—according to Mueller (Ref. 1). Further geometric constraints must be met to properly assemble the planetary gear transmission. These geometric constraints mainly refer to the number of gear teeth applied in compliance with Looman's assembly rules for planetary gear transmissions (Ref. 5). To achieve compact transmission designs, the number of teeth generally has to be as low as possible, since the number of teeth z is proportional to the reference diameter d of each gear:

$$d = z \cdot m_n \tag{1}$$

For further considerations, geometric relations will only be set up as a function of the number of teeth, which is valid as long as the normal module m_n is constant for each gear of a transmission concept. In this case the number of teeth is proportional to the corresponding reference diameter, and diameters of different gears can be compared on the basis of their number of teeth. After determining the number of gear wheel teeth in each concept, the minimum normal module at the gearing, including the gear with the minimum number of teeth, is calculated according to ISO 6336 (Ref. 3), assuming the ratio between tooth width b and reference diameter d to be 1:0. Further requirements to ensure proper comparison of the three concepts refer to the factors (application factor K_A, dynamic factor K_V, transverse load factor $K_{H\alpha}$ face load factor $K_{H\beta}$, which are each set to 1:0. The mesh load factor kg is chosen according to AGMA 6123-B06 (Ref. 6) for the ISO quality of 6 and according to the number of planet gears applied to the transmission concept.

Determining the number of teeth. Assembling planetary gear transmissions is more complex than conventional spur gear transmissions; additional geometric constraints fundamentally result from integrating several planets between at least two central gears (sun and/or ring gears). Thus the number of teeth is determined in such a way that, on the one hand, all geometric constraints are satisfied, and on the other hand, the other requirements concerning low weight and volume, as well as high efficiency, are optimally met. The following procedure is used to determine the minimum feasible number of teeth:

1. Select the number of teeth on each gear wheel so that the gear ratio deviation between the input and the output shaft is lower than ± 10%
2. Apply as many planets as possible to each concept without causing a collision of adjacent planet gears
3. Select the number of teeth on each gear wheel so that all gears can be assembled according to Looman's assembly rules (Ref. 5)
4. Apply the minimum number of teeth — 17 — at the gear wheel with the lowest theoretical (loss-free) load
5. The center distance of each gear pair of one concept (sun/planet gear or ring/planet gear) must be equal

Using a small number of teeth while also complying with further assembly rules will create a gear set with a number of teeth that meet the desired transmission gear ratio, with only a certain deviation. When even higher gear ratios are desired, this deviation tends to result in higher particular values. The center distance for Concept A has to be equal for both gear pairs (sun gear/planet gear and planet gear/ring gear) because one gear is used in both gear pairs—the planet gear. For Concepts B and C the center distances of both gear pairs must be equal, thus enabling both planet gears to be connected to one stepped planet gear shaft (assuming the same normal module for both gear pairs). Nominal differences in the center distances of each gear, according to the calculated number of teeth, can be offset by applying appropriate addendum modifications × to the gears (assuming the same normal module for both gears).

***Concept A*:** For Concept A, the shaft with the minimum acting torque is Input Shaft 1, so z_{min} is applied to the sun gear. The number of teeth on ring gear z_2 can be derived directly from the basic gear ratio i_{12}:

$$i_{12} = \frac{z_2}{z_1} \rightarrow z_2 = i_{12} z_1 \tag{2}$$

The number of teeth on the planet gear can be derived from the geometric constraint that the center distances of each gear pair must be equal. This constraint, reduced by the normal module and using a negative number of teeth for the ring gear, reads as follows:

$$0 = z_1 + 2 = z_p + z_2$$
$$z_p = -\frac{z_2 + z_1}{2} \tag{3}$$

In the next step the maximum number of planet gears must be determined in order to minimize the acting load in each gear mesh (power division). Figure 2a shows the geometric limit case where adjacent planet gears are in contact with each other, assuming the tip diameter of the planet gears to be the number-of-teeth-plus-two, which equates to the reference-diameter-plus-two-times the normal module:

$$\cos\alpha = \frac{z_p + 2}{z_1 + z_p} \tag{4}$$
$$with\ \alpha = 90 - \frac{\beta}{2} = 90 - \frac{360}{2 \cdot n_{max}}$$

Rearranging this equation yields the maximum number of planet gears n_{max} for the given number of teeth, $n_{max} =$:

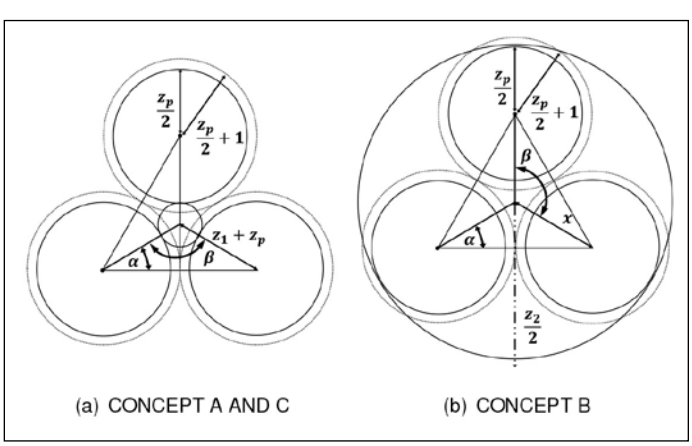


Figure 2 Assembly of planets.

(5)

$$n_{max}=\frac{360}{2\cdot\left(90-\arccos\frac{z_p+2}{z_1+z}\right)}$$

which has to be rounded down to the next integer value. In the last step, the assembling rule according to Looman (Ref. 5) has to be satisfied so that the planet gears can be mounted. Depending on the numbers of teeth—as well as the transmission structure—the following equation must be true:

(6)

$$f=integer\ value=\frac{|z_1|+|z_2|}{n}$$

for basic negative-ratio drives with the applied number of planet gears *n*. If this equation is not fulfilled, the corresponding gears cannot be assembled. Thus the number of teeth on the planet and ring gears must be increased until Equations 3 and 6 are satisfied.

***Concept B*:** As with Concept A, several geometric constraints must be fulfilled in order to assemble this type of planetary gear train. The basic gear ratio of Concept B is given by:

(7)

$$i_{12}=\frac{z_{p1}}{z_1}\cdot\frac{z_2}{z_{p2}}$$

Unlike Concept A, it is not as easy to calculate suitable numbers of teeth for Concept B. Fundamentally, four unknown parameters must be determined. One unknown variable can be defined by the minimum number of teeth for planet gear p_1, which is loaded with the minimum (loss-free) torque for this concept. The next essential equation must be met in order to comply with the equal center distances of gear pairs p_1:1 and p_2:2 so that both planet gears have the same axis of rotation:

(8)

$$z_{p1}+z_1=z_{p2}+z_2$$

The maximum applicable number of planets for this concept can be determined according to the geometric limit case (Fig. 2b). The avoidance of a collision of adjacent planets has to be proved for the gear pair with sun 2 and planet gear p_2. As both gear pairs feature planets, which could theoretically touch each other, a collision analysis must be conducted for both gearings. Nonetheless, it is sufficient to check only the gear pair with the planet gear that has the higher number of teeth and, therefore, the higher tip diameter. Thus if the planets of gear pair *p*2:2 do not collide, then the planets of gear pair *p*1:1 will not collide either, due to their lower number of teeth. The following equation must be true for the geometric limit case:

(9)

$$\cos\alpha=\frac{z_{p2}+2}{2\cdot x}$$

$$x=\frac{z_{p2}+2}{2\cdot\cos\alpha}$$

$$-z_2=\frac{z_{p2}+2}{\cos\alpha}+z_{p2}$$

If a collision does not occur at the planet gears *p*2, then no collision can occur at adjacent planet gears *p*1, due to their smaller diameter. In conclusion, three equations can be set up for three unknown numbers of teeth. Transforming Equations 7, 8 and 9 yields a quadratic equation for the number of teeth on planet gear *p*2:

(10)

$$y_1\cdot z_{p2}^2+y_2\cdot z_{p2}+y_3=0$$

with the following coefficients:

(11)

$$y_1=\frac{-1}{\cos\alpha}$$

$$y_2=\frac{\cos\alpha\cdot i_{12}+z_{p1}-2\cdot i_{12}}{i_{12}\cdot\cos\alpha}+z_{p2}$$

$$y_3=\frac{2\cdot z_{p2}}{i_{12}\cdot\cos\alpha}$$

Solving the quadratic equation yields the number of teeth on planet gear *p*2:

(12)

$$z_{p2}=\frac{-y_2\pm\sqrt{y_2^2-4\cdot y_1\cdot y_3}}{2\cdot y_1}$$

Only the solution resulting in a positive number of teeth can be used for external gears by definition such as the planet gear *p*2. The missing numbers of teeth can then be derived from Equations 7 and 8. According to Looman (Ref. 5), the assembling rule for Concept B reads:

(13)

$$f=\frac{|z_2|\cdot z_{p1}-z_{p2}\,|z_1|}{n\cdot T}=integer\ value$$

with the greatest common divisor of z_{p1} and z_{p2}. If Equation 13 is not satisfied for the calculated number of teeth, then the number of teeth for central gears 1 and 2 must be increased as long as Equations 8 and 13 are fulfilled.

***Concept C*:** For Concept C, no additional equations need be set up in order to determine the number of teeth; all of the necessary equations can be derived from the geometric constraints of Concepts A and B. The minimum number of teeth is likewise applied to the gear wheel with the lowest (loss-free) load—planet gear *p*1. The equation for the basic gear ratio of Concept C can be determined as in Equation 7, and the center distance constraint of Concept B (Eq. 8) must be true for Concept C as well. As with Concept B, the critical transmission gear pair for a potential planet collision is gearing *p*2:2. Because the structure of Concept C is similar to that of Concept A in terms of a potential planet collision (only the ring gear doesn't exist, but is needed neither for Concepts A nor C to detect a planet collision), the same appropriate Equation 6 of Concept A can be used, substituting z_p with z_{p2}, accordingly. The resulting quadratic equation for the number of teeth on planet gear *p*2 can be solved analogously to Equation 10 with the following coefficients:

(14)

$$y_1=1$$

$$y_2=\frac{z_{p1}\cdot\cos\alpha-z_{p1}}{i_{12}}+2-z_{p1}\cdot\cos\alpha$$

$$y_3=-\frac{z_{p1}\cdot 2}{i_{12}}$$

Solving the quadratic equation for Concept C yields the number of teeth for planet gear *p*2; only solutions resulting in a positive number of teeth for the external planet gear *p*2 are permissible, per definition. The missing number of teeth for central gears 1 and 2 is derived from Equations 7 and 8; Looman's

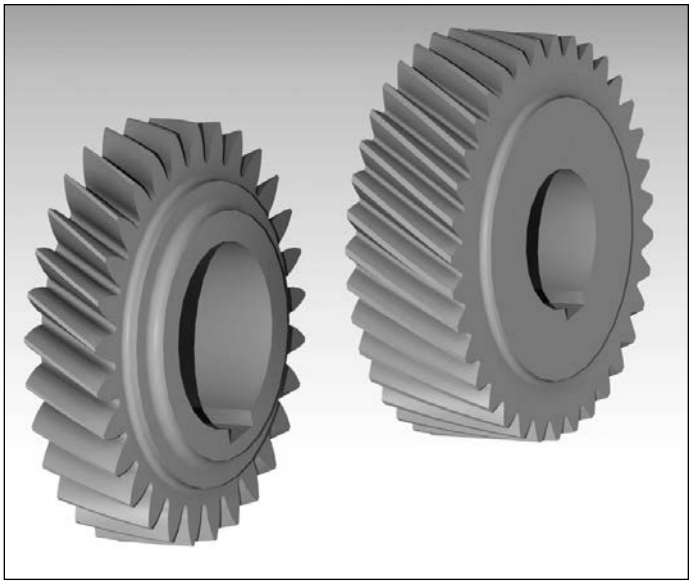


Figure 3 Conventional and low-loss external gear (m_n=2; z=35).

assembling rule for Concept C is equal to that of Concept B (Eq. 13), and must be true for the determined numbers of teeth. If this equation is not satisfied, the numbers of teeth for central gears 1 and 2 must be increased until Equations 8 and 13 are fulfilled.

Low-loss gears for external and internal gears with highest efficiency. Low-loss gears in transmissions are typically used whenever high efficiency values are necessary. Power losses in the meshing of a gear pair are mainly caused by load-dependent power losses that depend on the acting load, coefficient-of-friction and sliding velocities in the meshing of the gearing. In terms of efficiency, calculation of the average power losses in the meshing is accurate enough to determine the load-dependent power losses, or, rather, the efficiency of a gear pair. According to Niemann (Ref. 7) the load-dependent power loss P_{loss} reads:

$$P_{loss} = \mu_m \cdot H_V \cdot P_{in} \tag{15}$$

with the mean coefficient-of-friction μ_m and the tooth loss factor H_V, according to Ohlendorf (Ref. 8):

$$H_V = \frac{\pi \cdot (i+1)}{z_{p1} \cdot i \cos\beta_b} \left(1 - \varepsilon_\alpha + \varepsilon_1^2 + \varepsilon_1^2\right) \tag{16}$$

In order to obtain efficient gears with minimal load-dependent power losses, it is obvious that the tooth loss factor, as well as the mean coefficient-of-friction, must be reduced. Wimmer (Ref. 4) highlights several parameters that have a significant, positive influence on these two factors, such as a low transverse contact ratio ε_α, a low normal module m_n, a high pressure angle α_n and a high number of teeth on pinion z_1. Figure 3 shows a conventional and a low-loss external gear. One can notice that the low-loss gear wheel features a higher tooth depth in comparison to the conventional gear wheel, due to a reduced transverse contact ratio ε_α. Moreover, the face width of the low-loss gear wheel must be increased to obtain the same load-carrying capacity (in particular, surface durability and tooth-bending stress are affected). Regarding the geometry of a characteristic low-loss gear set, ideally for the gearing p:2 of Concept A, with a gear ratio of 5, one can determine that the pitch point of the gearing is roughly in the middle of the tooth depth. For low

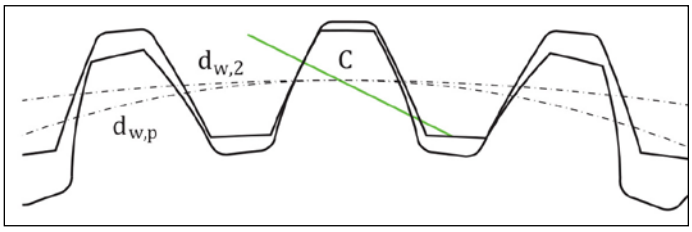


Figure 4 Low-loss gearing for Concept A with (green) transverse path of contact (i=5; H_V=0.038).

tooth-load factors, the addendum contact ratio of the pinion and wheel ε_1 and ε_2 should preferably have the same value.

For this study several parameters are predetermined and cannot be changed within the optimization process to improve efficiency. The following parameters, which are part of the optimization and have an impact on the tooth-loss factor and mean coefficient-of-friction, as well as on the gearing volume, are the center distance a; the addendum modification of pinion and wheel $x_{1,2}$; the tooth width b and the normal module m_n.

Calculation of the load-carrying capacity. In addition to an optimized gear pair for high efficiency values, calculation of the load-carrying capacity of each gear pair must be proved in terms of surface durability (pitting) and tooth-bending strength. The fatigue-durable design of the gear wheels is created using well-established values for the safety factors against pitting ($S_{H,min}$ = 1.3), and against tooth breakage ($S_{F,min}$ = 1.7). Further default values are used for all gear pairs to ensure proper comparison, such as the normal pressure angle α_n = 20°, the helix angle β = 0° and a pre-defined lubricant (ISO–VG–220). In addition to optimizing the tooth flank to obtain low power losses, each transmission stage is optimized in terms of a minimum gear wheel volume so that the normal module and tooth width are as low as possible. Within one transmission stage the normal module and tooth width are determined by the weakest gearing in terms of the load-carrying capacity. The load factors are assumed to have a default value of 1.0. The mesh load factor K_γ that accounts for the uneven distribution of load among meshes for planetary gear transmission must be applied to all gears. The corresponding value of the mesh load factor is given in AGMA 6123–B06 (Ref. 6), according to the number of applied planets and assuming ISO quality six.

Determining efficiency, volume and weight. After calculating the load-carrying capacity of each gear pair for one transmission

Table 2 Design parameters at a glance

Parameter	Default Value	Unit
z_{min}	17	-
T_{in}	300	Nm
n_{in}	1500	rpm
Δi_{max}	±10	%
$S_{F,min}$	1.7	-
$S_{H,min}$	1.3	-
K_A, K_v, $K_{H\alpha}$, $K_{H\beta}$	1.0	-
K_γ	acc. to [6]	-
ε_α	1.1	-
α_n	20°	-
β	0°	-
b/d @ gear with z_{min}	1	-

concept, all of the geometric parameters that affect efficiency and volume are determined, after which the efficiency of each gear pair with pinion × and wheel *y* can be calculated according to:

$$\eta_{xy} = 1 - (H_{V,xy} \cdot \mu_{m,xy}) \quad (17)$$

In the next step, the single efficiency values of each gear pair can be combined into the basic train efficiency for Concepts A, B and C $\eta_{12,A,B,C}$ that represents the corresponding transmission efficiency between central shafts 1 and 2 with a fixed carrier shaft:

$$\eta_{12,A} = \eta_{1,p1} \cdot \eta_{p1,2} \quad (18)$$

$$\eta_{12,B(C)} = \eta_{1,p1} \cdot \eta_{p2,2} \quad (19)$$

By converting the basic train efficiency, the overall transmission efficiency for each concept can be achieved according to Mueller (Ref. 1), equivalent to the efficiency between input and output shafts. For Concept A the corresponding efficiency is calculated between input shaft 1 (sun gear) and carrier shaft *s*:

$$\eta_A = \eta_{1s} = \frac{i_{12,A} \cdot \eta_{12,A} - 1}{i_{12,A} - 1} \quad (20)$$

For Concepts B and C, the overall efficiency between the input shaft *s* (carrier shaft) and shaft 1 can be calculated with:

$$\eta_{B(C)} = \eta_{s1} = \frac{i_{12,B(C)} - 1}{i_{12,B(C)} \cdot \eta_{12,B(C)} - 1} \quad (21)$$

For the sake of simplicity, only the gear wheels and both sides of the carrier plate are considered in calculating the weight of each concept. The weight of further transmission components such as bearings, shafts and other machine elements will not be considered. The weight of an external gear (sun or planet gear) is approximated with the volume of a solid cylinder having the same reference diameter and face width as the corresponding gear. With the density of steel ρ_{steel}, the weight for an external gear × then reads:

$$m_x = V_x \cdot \rho_{steel} = \frac{d_x^2}{4} \pi \cdot b_x \cdot \rho_{steel} \quad (22)$$

For an internal gear *y* (ring gears), an equivalent hollow cylinder is assumed for the volume, with the reference diameter of the internal gear as the inner diameter and the reference diameter plus six times the normal module as the outer diameter:

$$m_y = V_y \cdot \rho_{steel} = \frac{(d_y + 6 \cdot m_n)^2 - d_y^2}{4} \pi \cdot b_y \cdot \rho_{steel} \quad (23)$$

The weight of both carrier plates can be estimated using two times the weight of a solid cylinder with the center distance of the gearing as radius and a width 0.2 times the maximum **occurrent** face width b_{max}:

$$m_y = V_y \cdot \rho_{steel} = 2 \cdot a^2 \cdot \pi \cdot 0.2 \cdot b_{max} \cdot \rho_{steel} \quad (24)$$

The volume of each transmission concept is likewise approximated, using the sum of the volumes for each transmission stage. The volume of Concept A can be calculated using the volume of a solid cylinder with the diameter of the ring gear plus six times the normal module plus the volume of two-sided carrier plate:

$$V_A = \left(\frac{(d_2 + 6 \cdot m_n)^2}{4} \cdot b_2 + 2 \cdot a^2 \cdot 0.2 \cdot b_{max} \right) \cdot \pi \quad (25)$$

The volume of Concept B can be calculated using the sum of the volumes of both ring gear cylinders and the volume of the two-sided carrier plate, where the cylinder width of one carrier plate is equal to the maximum **occurent** face width:

$$V_B = \left(\frac{(d_1 + 6m_n)^2}{4} \cdot b_2 + \frac{(d_2 + 6m_n)^2}{4} \cdot b_2 + 2a^2 \cdot 0.2 \cdot b_{max} \right) \cdot \pi \quad (26)$$

The volume of Concept C is determined using the volume of the cylinders with a diameter two times the center distance plus the tip diameter for each transmission stage:

$$V_B = \left(\left(a + \frac{d_{a,p1}}{2} \right)^2 \cdot b_1 + \left(a + \frac{d_{a,p2}}{2} \right)^2 \cdot b_2 + 2a^2 \cdot 0.2 \cdot b_{max} \right) \cdot \pi \quad (27)$$

For reasons of comparability, all calculated volumes and weights are normalized using the weight and volume of Concept A with a gear ratio of five. The normalized volume and weight of a concept then reads:

$$V^* = \frac{V}{V_{concept\ A,\ i=5}} \quad (28)$$

$$M^* = \frac{m}{m_{concept\ A,\ i=5}}$$

Design results for Concept A. Before the calculation of the load-carrying capacity can be conducted, the number of teeth on each gear wheel must be determined. Because the sun gear of this concept features the minimum carrying load, the minimum number of teeth is applied to this gear wheel. The number of teeth on the ring gear can then be determined in accordance with Equation 2, which yields –68. The number of teeth for the planet gear is 25, using the respective rounded-down results from Equation 3. In the next step the maximum number of planets must be determined with Equation 5, which yields a maximum of four planets. In the final step, Looman's assembly rule has to be checked in order to freeze the number of teeth for each gear in this concept. The result of Equation 6 is not an integer value for this configuration; therefore it is not possible to mount four planets with the given number of teeth. In that case the number of teeth on the planet and ring gear must be increased until Equations 3 and 6 are satisfied. The resulting numbers of teeth are 17 for the sun gear, 27 for the planet gear and –71 for the ring gear. The transmission ratio for Concept A, then, is 5.18 so that the gear ratio deviation of 3.5% is within

Table 3 Design results—Concept A

$i_{nominal}$	5		25		125		Unit
$z_i : z_p : z_2$ n_{max}	17 : 27 : –71 4						- -
Gearing	1:*p*	*p*:2	1:*p*	*p*:2	1:*p*	*p*:2	
μ	0.069	0.052	0.085	0.064	0.107	0.08	-
H_v	0.158	0.04	0.152	0.038	0.159	0.042	-
η	0.989	0.998	0.987	0.998	0.983	0.997	-
i_{act} (Δi)	5.18 (3.5%)		26.8 (7.2%)		138.71 (11%)		-
m_n	2.15		3.75		6.5		mm
η	0.990		0.977		0.961		-
M^*	1		6.3		33.9		-
V^*	1		6.3		33.7		-

the permitted range. The results of the design are summarized in Table 3.

Due to the limited practicable basic gear ratio in transmission Concept A, higher transmission ratios are not realized by varying the numbers of teeth, but by connecting two equal transmission stages of Concept A (Fig. 5a), each characterized by a nominal transmission ratio of five. Therefore the carrier shaft of the first stage is connected to the input shaft (sun gear) of the second stage. The resulting overall nominal gear ratio is then $5^2 = 25$, and likewise, $5^3 = 125$ for Concept A, with a nominal transmission gear ratio of 125 (Fig. 5b). The weight and volume for Concept A with the gear ratio of 25 is calculated by adding the weight and volume values of each transmission stage (as with Concept A with a gear ratio of 125).

Design results for Concept B. Solving Equation 12 with the desired basic gear ratio of $i_{12,B} = 0.8$ and the corresponding value for $\cos\alpha$ according to Equation 9, which is dependent on the number of applied planet gears, yields the number of teeth on planet gear p_2. Likewise, Equations 7 and 8 provide the number of teeth on the two ring gears. The resulting numbers of teeth are mainly dependent on the desired number of planets. Especially for Concept B, which features no sun gear, two versions are conceivable, in principle. These differ in terms of the applied number of planets—one with only three planets (Concept B3) and one with five planets (Concept B5). Concept B3 has lower numbers of teeth for the ring gears as well as a lower mesh load factor K_γ, but features a higher normal module and tooth width due to the fact that only three planet meshes are transferring the power to the ring gears, in comparison to the five meshes in Concept B5. The design, according to AGMA 6123, shows which of the concepts achieves the optimum weight, volume and efficiency; results of the design are summarized in Tables 4 and 5. It must be mentioned that for both versions of Concept B, and all desired gear ratios, it is not possible to apply the theoretical number of teeth resulting from Equation 12 because Looman's assembly rule (Eq. 13) is not fulfilled. The number of teeth must be increased for both ring gears until Equations 13 and 8 are satisfied, as well as complying with the maximum pre-set gear ratio deviation. In particular, it is even not possible for both versions of Concept B with a gear ratio of 125 to satisfy Equation 8, where the numbers of teeth and the gear ratio deviation remain small; either the gear ratio deviation or the number of teeth on the ring gears is too high. Not satisfying Equation 8 results in a different center distance between gear pairs 1:p_1 and 2:p_2. In order to find a buildable transmission, a compromise between a preferably small number of teeth (to keep dimensions low) and a small gear ratio deviation must be found, where the deviation of the center distances for both gearings has to be as small as possible. The deviation of the center distances (Eq. 8) can then be compensated by applying appropriate addendum modifications for the pinion and wheel of a gearing. However, the tooth-load factor then reaches higher values because the transverse load factor cannot be reduced to the desired value of 1.1. Consequently, low-loss gearing (Fig. 4) cannot be achieved due to the constraint of equal normal modules for each gearing.

Design results for Concept C. As with Concept B, Equation 14 provides the number of teeth for Concept C. Because Looman's assembly rule (Eq. 13) is not satisfied, the number of teeth in

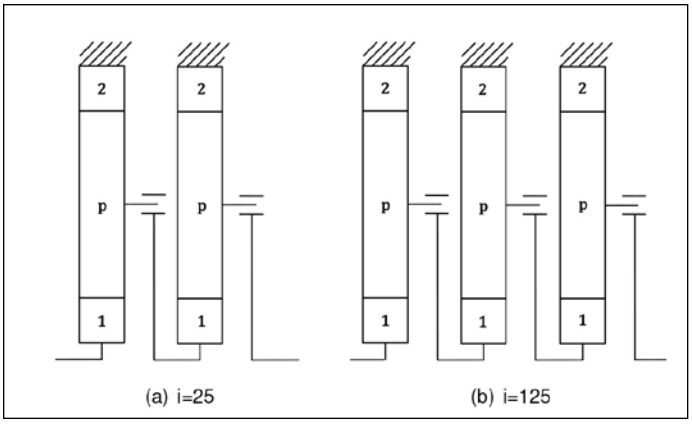


Figure 5 Concept A with gear ratio 25 and 125.

Table 4 Design results—Concept B3

$i_{nominal}$	5		25		125		Unit
n_{max}	3						-
$z_1 : z_{p1}$	–50 : 17		–50 : 17		–40 : 17		-
$z_2 : z_{p2}$	–57 : 24		–51 : 18		–42 : 18		
Gearing	1 : $p1$	$p2$: 2	1 : $p1$	$p2$: 2	1 : $p1$	$p2$: 2	
μ	0.054	0.047	0.048	0.047	0.44	0.05	-
H_v	0.062	0.04	0.066	0.062	0.057	0.062	-
η	0.997	0.998	0.997	0.997	0.998	0.997	-
i_{act} (Δi)	5.19 (3.9%)		27.3 (9.1%)		120.0 (4.0%)		-
m_n	2.2		3.7		6.6		mm
η	0.980		0.862		0.60		
M^*	0.76		3.59		17.46		-
V^*	0.96		4.95		18.41		-

Table 5 Design results–Concept B5

$i_{nominal}$	5		25		125		Unit
n_{max}	5						-
$z_1 : z_{p1}$	–62 : 17		–57 : 17		–61 : 17		-
$z_2 : z_{p2}$	–68 : 23		–58 : 18		–64 : 18		-
Gearing	1 : $p1$	$p2$: 2	1 : $p1$	$p2$: 2	1 : $p1$	$p2$: 2	
μ	0.053	0.048	0.044	0.044	0.44	0.049	-
H_v	0.069	0.05	0.067	0.062	0.074	0.083	-
η	0.996	0.998	0.997	0.997	0.997	0.996	-
i_{actual} (Δi)	5.28 (5.6%)		25.7 (2.6%)		109.8 (12.1%)		-
m_n	2		3.5		5.2		mm
η	0.975		0.877		0.557		
M^*	0.75		4.10		15.71		
V^*	0.96		5.06		20.37		

Table 6 Design results—Concept C							
$i_{nominal}$	5		25		125		Unit
n_{max}	5						-
$z_1 : z_{p1}$	23 : 17		52 : 17		39 : 17		-
$z_2 : z_{p2}$	21 : 19		53 : 18		41 : 18		-
Gearing	1 : *p*1	*p*2 : 2	1 : *p*1	*p*2 : 2	1 : *p*1	*p*2 : 2	
μ	0.059	0.059	0.047	0.049	0.045	0.05	
H_v	0.163	0.159	0.124	0.126	0.145	0.162	
η	0.990	0.990	0.994	0.994	0.994	0.992	-
i_{actual} (Δi)	5.46 (9.3%)		26.74 (7.0%)		140.4 (12.3%)		-
m_n	3.5		4.0		7.5		mm
η	0.922		0.765		0.330		
*M**	3.2		13.3		67.6		
*V**	3.7		15.6		78.9		

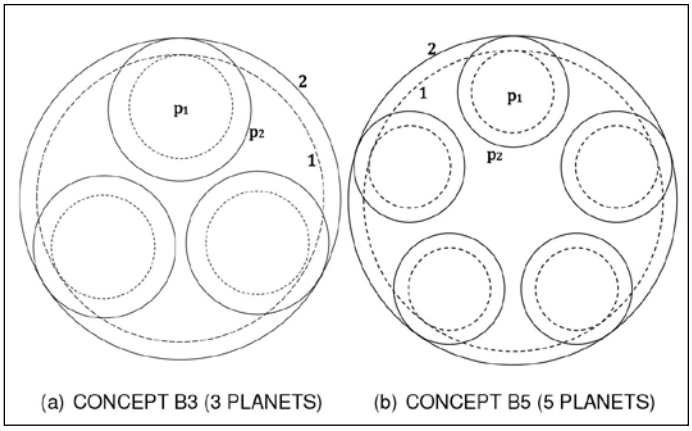


Figure 6 Concept B.

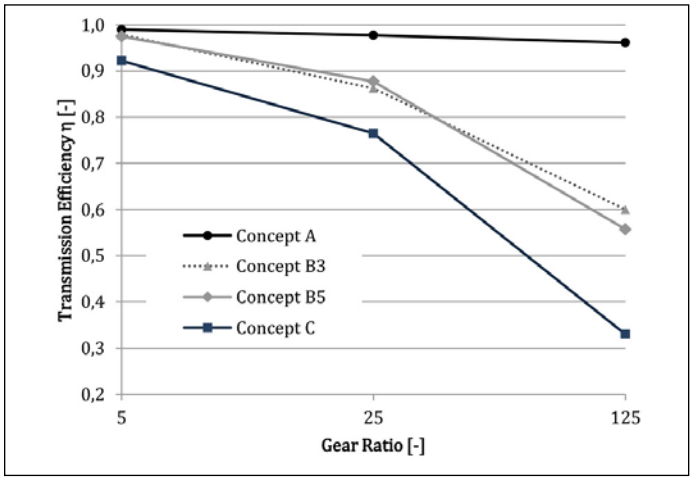


Figure 7 Efficiency of conventional and low-loss external gear.

sun gears 1 and 2 must be increased. Likewise, it is not possible to find admissible numbers of teeth for gear ratios 25 and 125 that satisfy both the assembling rule (Eq. 13) and the center distance constraint (Eq. 8), where the gear ratio deviation is within the permissible range. Therefore, appropriate addendum modifications of the pinion and wheel have to be applied to achieve the same center distances for both gearings.

Comparison of the Transmission Concepts

In terms of efficiency, Concept A takes advantage of the consistently higher epicylic transmission efficiency η_{1s} in comparison to the basic transmission efficiency η_{12} (Ref. 1). Even for the concepts with higher gear ratios, Concept A features obviously the best efficiency values for all examined transmission concepts. Concepts B and C are characterized by a high meshing power ($P_{mesh} = T \cdot (n - n_s)$) in relation to their input power, which results in high power losses. Comparing Concepts B and C shows that Concept C features lower efficiency values for all gear ratios. The deviation is primarily the result of different tooth-load factors H_V for each gear pair. Generally, internal gears feature lower load-dependent power losses due to lower sliding velocities in the loaded gear mesh; so Concept B, with two internal gear pairs, achieves higher efficiency values for every gear ratio. Furthermore, the applied addendum modifications to Concept C could not be varied in any way that would be the optimum to achieve low tooth-load factors, but had to be chosen in order to reach the same center distances for both gear pairs.

Generally, the results for weight and volume show proportional behavior over the gear ratio. All of the concepts feature approximately the same weight for gear ratio 5. Concept B3 is even lighter than Concept A—although three planets are applied to Concept B3 in comparison to four planets applied to Concept A—and the tooth widths for the gears of Concept B3 are higher. This is due to the lower center distance, which has a quadratic influence on volume and weight. For higher gear ratios, Concept A considerably exceeds the weight of Concept B due to the increasing number of transmission components by connecting two/three basic transmission stages. Concept C yields by a significant margin the highest volume and weight for gear ratios 25 and 125, caused by the highest normal module and center distance of all concepts.

Conclusion

The appropriate transmission Concepts A, B or C for a specified application depend on the desired transmission gear ratio. For a desired gear ratio of five, transmission Concepts A and B feature similar values for weight and volume. For gear ratios $i = 25$ and $i = 125$, two or three basic transmissions of Concept A (Figs. 5a and 5b) must be applied, whereas Concepts B and C do not change the basic structure for all gear ratios (Figs. 1b and 1c). Concept A provides the highest efficiency value and a very narrow design. If a gearbox with a low diameter is required, Concept B achieves the best weight and volume values, while the number of applied planets has a minor influence. A higher number of applied planet gears results in a higher mesh load factor, according to AGMA 6123–B06, as well as an increasing difficulty in assembling the planets according to Looman with

low numbers of teeth. Thus the number of teeth for the central gears is increased in order to compensate for the advantage of a better power division for higher numbers of applied planets. Only for high gear qualities where the mesh load factor drops significantly could Concept B, with its high number of planets and a reduced center distance, also be used for gear ratios higher than five. Concept C is characterized by the highest normal modules and center distances, and it features the lowest efficiency due to very high tooth-load factors. This is why using Concept C is not recommended for high gear ratios. As already mentioned, it is increasingly difficult for high gear ratios and a high number of planets to comply with all of the geometric constraints, such as ensuring the assembling of the planets according to Looman, not exceeding a given maximum gear ratio deviation, and ensuring the same center distances of each gear pair. The center distance constraint is increasingly difficult to satisfy for the given requirements and low number of teeth. Therefore a difference in the center distances of two gear pairs is offset by applying addendum modifications for transmission concepts with high gear ratios. In that case the addendum modifications cannot be applied in the best way to reduce the tooth-load factors, or, in other words, to increase efficiency. One possibility in order to achieve equal center distances would be to use different normal modules for each transmission stage. The addendum modifications can then be chosen so that the tooth-load factor of each gear pair reaches a minimum.

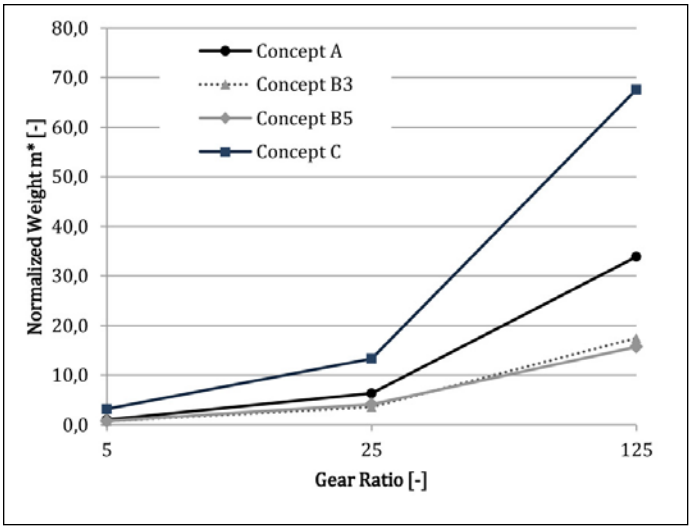


Figure 8 Weight of conventional and low-loss external gear.

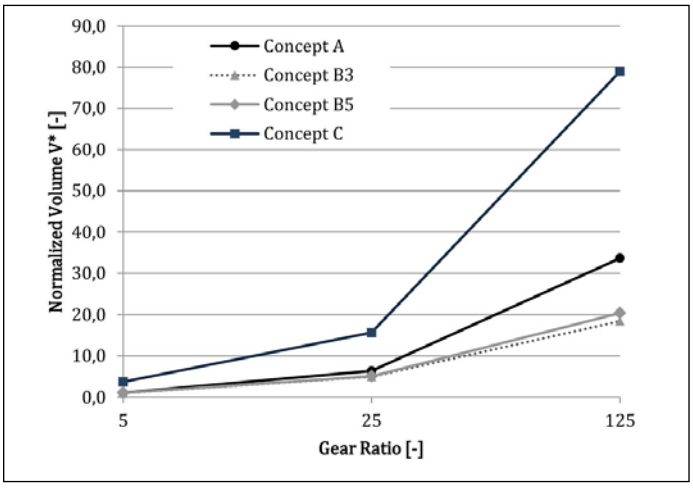


Figure 9 Volume of conventional and low-loss external gear.

References

1. Müller, H. W. "Die Umlaufgetriebe," Vol. 2, Springer, 1998.
2. Mulzer, F. "Systematik hoch übersetzender Koaxialer Getriebe," Ph.D. Thesis, Technische Universität München, 2009.
3. ISO 6336. Calculation of Load Capacity of Spur and Helical Gears, ISO 2006.
4. Wimmer, A. J. "Lastverluste von Stirnradverzahnungen," Ph.D. Thesis, Technische Universität München, 2006.
5. Looman, J. Die Zahnradgetriebe, Springer, 1996.
6. AGMA 6123–B06. Calculation of Load Capacity of Spur and Helical Gears, ISO 2006.
7. Niemann, G. and H. Winter. "Maschinenelemente Band 2: Getriebe Allgemein, Zahnradgetriebe-Grundlagen, Stirnradgetriebe," Springer 2003.
8. Ohlendorf, H. "Verlustleistung und Erwämung von Stirnrädern," Ph.D. Thesis, Technische Hochschule München, 1958.

Bernd-Robert Höhn studied mechanical engineering at the Technical University Darmstadt (1965-1970) and served as an assistant lecturer (1970-1973) at the Institute for Machine Elements and Gears at the Technical University Darmstadt prior to becoming an assistant professor at the university (1973-1979); in 1978, he received his PhD (Dr. Ing.) in mechanical engineering. In early April, 1979 Höhn worked as a technical designer in the department for gear development of the Audi, and by 1982 was head of the department for gear research and design for the automaker. In 1986 Audi named Höhn department head for both gear research and testing of automotive transmissions, until his departure in 1989 to become head of both the Institute of Machine Elements at the Technical University and of the Gear Research Centre (FZG). Höhn has served since 2004 as vice president for VDI for research and development and since 1996 has led the working group 6 and 15 for ISO TC 60—calculation of gears.

Prof. Dr.-Ing. K. Stahl studied mechanical engineering at the Technische Universitaet Muenchen before serving as research associate at the Gear Research Centre (FZG) at the Technical University Munich 1994 until 2000. In 2001 he received his PhD in mechanical engineering and that year started as gear development engineer at the BMW group in Dingolfing, subsequently being named head of "Prototyping, Gear Technology & Methods" in 2003. From 2006–2009 he changed to the BMW/MINI plant in Oxford, UK, first as group leader, and in 2007 as department leader for Validation Driving Dynamics and Powetrain. In 2009 Stahl returned to Munich, responsible for predevelopment and innovation management within BMW Driving Dynamics and Powertrain. Stahl was then named head in 2011 of the Institute for Machine Elements and the Gear Research Centre (FZG) at the Technische Universitaet Muenchen.

Philipp Gwinner, 26, completed in 2011 his studies in mechanical engineering at the Technische Universitaet Muenchen, with a special focus on automotive and drive engineering. Since 2011, he has worked as a research associate at the Institute for Machine Elements (FZG), Technische Universitaet Muenchen.

Mazak

CONVERTS PLANT TO MTCONNECT PROTOCOL

As a first in the machine tool OEM industry, Mazak Corporation is converting its Florence, Kentucky, manufacturing plant over to the MTConnect open communications protocol. The transformation will allow Mazak to monitor its manufacturing equipment and gather valuable data that will be used to further improve manufacturing operations. These improvements, in turn, will ensure that Mazak customers are provided the advanced technology they need as quickly as possible to keep pace with today's increased manufacturing production demands.

In implementing the protocol into the Kentucky operations, Mazak continues its MTConnect leadership and demonstrates its commitment to the protocol as a powerful tool for all manufacturers to improve productivity, machine utilization and efficiency. Mazak has been an ardent supporter of MTConnect since its inception, offering all its machines with MTConnect compatibility. Currently, over 100 Mazak customers are at various stages of MTConnect integration within their own facilities involving approximately 300 machines within a wide range of model types.

"We continue to take a leadership position in propagating the MTConnect open protocol," said Brian Papke, president of Mazak Corporation. "MTConnect's value to our customers is in the ability for them to establish extensive and open channels of communication for plug-and-play interconnectivity between devices. MTConnect allows software to be universally applied between different types of machine models so that information is readily available for improving machine tool utilization. Using this capability, Mazak is taking another positive step in further increasing the productivity of our North American operations and ensuring the strong competitiveness of our Kentucky manufacturing."

With MTConnect, Mazak will initially monitor overall equipment efficiency. The company will also use MTConnect for several custom applications unique to its manufacturing operations. These applications include monitoring machine tool spindle sensors for valuable maintenance data, as well as tracking part cycle times to benefit the company's scheduling department. But most significant, MTConnect working with third-party software will make it possible for Mazak to incorporate the use of mobile apps as methods for monitoring its manufacturing in real time.

With these apps, Mazak managers and other key personnel will have access to live real-time data from equipment monitoring dashboards via mobile devices. Additionally, text and/or email alerts and notifications can be received instantaneously when certain manufacturing or equipment issues or conditions arise.

According to Neil Desrosiers, Mazak's developer of digital solutions, the full improvement potential resulting from MTConnect at the Kentucky plant will be achieved when the measurement data is collected and full potential machine tool utilization is realized in the factory. This data will then be made available for review to those attending Mazak's Discover 2013 event beginning October 8. By that time, most machines in the Kentucky factory will be able to be monitored via iPhones. "We want to demonstrate to our customers that they, too, can improve their productivity through MTConnect machine monitoring capability. Because when it comes to machine tool performance, you have to measure it before you can improve it," said Desrosiers.

Star SU

APPOINTS VICE PRESIDENT OF SALES

Star SU has appointed **Thomas Bell** as vice president of sales for its Cutting Tool division. Bell earned a Bachelor of Science in Marketing from Ferris State University and an MBA from Lake Forest Graduate School. He has extensive experience in sales, marketing and product management within the metalworking and steel industry. Bell was formerly the director of sales for Schmiedewerke Groditz's USA sales office. Groditz, located in Germany, is a large open-die forging company. Prior to his Groditz experience, he spent 19 years with specialty steelmaker Bohler Uddeholm, where he served as vice president of Cold Work Application & International Account Management. During his tenure, he gained experience in all facets of tool and die applications as well as concentration on specifier selling strategies, field sales management and distribution channel management. Bell has held various trade association committee positions within Precision Metalworking Association as well as membership to APMI, SME and MSCI.

GKI

ANNOUNCES MARKETING AGREEMENT WITH ESCOFIER

GKI Incorporated, Crystal Lake IL, and Escofier, Chalon-sur-Saône France, have announced a marketing agreement for Escofier's products in the U.S. Escofier specializes in cold rolling technology, including: gear burnishing, thread rolling, spline rolling, knurling and cold forming of finned tubes. The company's proprietary systems are used by companies like BMW, Ford, Hyundai, Mercedes Benz, Bosch and many others. GKI has specialized in metalworking products & services in the U.S. for 42 years, and is recognized for providing exceptional service to its customers throughout North America. With this partnership, GKI will provide support, service and spare parts for Escofier's customer base in the U.S. Escofier will be exhibiting their tooling and equipment at the EMO international manufacturing show in Hannover Germany, September 16–21 2013, Hall 9.

Seco Tools

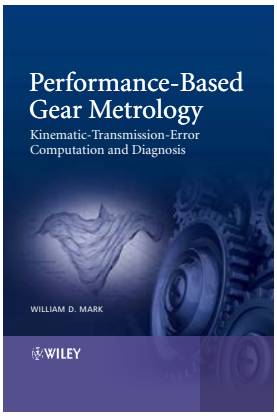
INKS SPONSORSHIP DEAL WITH ANDRETTI AUTOSPORT

Seco Tools recently signed on as a technical and supplier sponsor of the Izod IndyCar Series championship racing team Andretti Autosport. The team led by racing legend Michael Andretti also competes in the Firestone Indy Lights, Pro Mazda Championship and Cooper Tires USF2000 Championship. Seco is the latest to join an elite group of technical sponsors that includes leading machine tool company DMG/Mori Seiki USA. "We are excited to be affiliated with the legendary Andretti name that has grown and transcended the sport of auto racing over the past 50 years," said Kurt Nordlund, president of Seco Tools in North America. "Our partnership with Andretti Autosport is a natural fit as both of us uphold a winning tradition of performance excellence, and speed, precision and reliability are all key to success in our respective industries."

In addition to its new partnership with Andretti, Seco also works with vehicle-based organizations around the world that rely on the company's advanced cutting tool solutions to overcome tough machining challenges. Whether it involves helping a shop reduce costs on a cylinder head application or developing new ways to cut engine materials, Seco's advanced technologies, tools, strategies and component solutions help drive success within the automotive industry.

William Mark

RELEASES BOOK ON GEAR METROLOGY



Performance-Based Gear Metrology: Kinematic-Transmission-Error Computation and Diagnosis, written by William Mark, Ph.D., is a mathematically rigorous explanation of how manufacturing deviations and damage on the working surfaces of gear teeth cause transmission-error contributions to vibration excitations

Some gear-tooth working-surface manufacturing deviations of significant amplitude cause negligible vibration excitation and noise, yet others of minuscule amplitude are a source of significant vibration excitation and noise. Presently available computer-numerically-controlled dedicated gear metrology equipment can measure such error patterns on a gear in a few hours in sufficient detail to enable accurate computation and diagnosis of the resultant transmission-error vibration excitation. How to efficiently measure such working-surface deviations, compute from these measurements the resultant transmission-error vibration excitation, and diagnose the manufacturing source of the deviations, is the subject of this book.

Use of the technology in this book will allow quality spot checks to be made on gears being manufactured in a production run, to avoid undesirable vibration or noise excitation by the manufactured gears. Furthermore, those working in academia and industry needing a full mathematical understanding of the relationships between tooth working-surface deviations and the vibration excitations caused by these deviations will find the book indispensable for applications pertaining to both gear-quality and gear-health monitoring.

Key features:

- Provides a very efficient method for measuring parallel-axis helical or spur gears in sufficient detail to enable accurate computation of transmission-error contributions from working-surface deviations, and algorithms required to carry out these computations, including examples.
- Provides algorithms for computing the working-surface deviations causing any user-identified tone, such as 'ghost tones,' or 'sidebands' of the tooth-meshing harmonics, enabling diagnosis of their manufacturing causes, including examples.
- Provides explanations of all harmonics observed in gear-caused vibration and noise spectra.
- Enables generation of three-dimensional displays and detailed numerical descriptions of all measured and computed working-surface deviations, including examples.

The book is currently available from Amazon.

Mark is senior scientist applied research laboratory and professor emeritus of acoustics at The Pennsylvania State University.

GMTA

ANNOUNCES RENOVATIONS AND PERSONNEL CHANGES

German Machine Tools of America (GMTA) represents various top-quality German metalworking machine builders, including Profilator, Pittler, Praewema and WMZ. These machines are sold to the North American market by GMTA primarily for gear and spline production, as well as other power transmission applications. The company's target markets include automotive, off-highway, OCTG and other heavy equipment manufacturing. Machines are provided for gear honing, gear grinding, Scudding, polygon milling, turning, gear tooth pointing and multiple machining operations.

The renovation of the GMTA facility in Ann Arbor, Michigan is now complete with plans in the works for future expansion of the campus. Additional floorspace, showroom capacity and training facilities, plus more personnel, are planned, according to company VP Scott Knoy. In that regard, two personnel announcements were made by GMTA company President Walter Friedrich on August 1. **Doug VanDeven** is now GMTA parts manager and **Shawn Wilkin** is now GMTA service manager. As Friedrich remarked, "These two positions are essential parts of our business, as they reflect our company's image to our customers."

Sandvik Coromant

APPOINTS VP MARKETING AND COMMUNICATION

Björn Roodzant has been appointed vice president marketing and communication at Sandvik Coromant. He takes over from Jessica Alm, who recently became executive vice president and head of group communications at the Sandvik Group. Roodzant most recently served as senior manager of Global Web, Mobility and E-marketing at Sandvik Coromant. Prior to that, he was director of communications, Sandvik Coromant U.S., based in Fair Lawn, New Jersey, where he drove U.S. marketing operations, including communications, public relations and online marketing.

September 16–21—EMO Hannover 2013. Hannover, Germany. Under the motto "Intelligence in Production," EMO will be showing what modern-day production technology looks like and who is offering it. "Everyone wants to be there. That's why once again the EMO Hannover is well set to continue its success story," says Carl Martin Welcker, general commissioner of EMO Hannover 2013. At the beginning of the year, more than 1,600 companies from 34 different countries had already registered: they will be occupying around 145,000 m^2 of net exhibition space. Thus the current registration status is significantly higher than the comparable figure for the preceding event. The flourishing demand among vendors of production technology evidences the high perceived importance of EMO Hannover as one of the sector's international highlights and as a superlative platform for innovations. "Meet the world at EMO" is one of the most important arguments for participating. It's not only German manufacturers who have registered for large-size stands. Asian companies are particularly prominent in showing the flag, with firms from Japan, China, Taiwan and Korea keen to play a bigger role on the global market. They have once again upsized their areas compared to the preceding event's equivalent period, a trend that's been observable for some years now. In all, Asia currently accounts for a good fifth of the EMO's exhibitors. For more information, visit *www.emo-hannover.de*.

September 17–19—Gear Expo 2013. Indiana Convention Center, Indianapolis, Indiana. Gear Expo is a biennial event designed exclusively for the gear industry. For three days, gear buyers and manufacturers network and build relationships that benefit their respective companies. Attendees see firsthand the latest technology on the market and discuss trends in the industry with experts. Exhibitors have the opportunity to meet face-to-face with attendees and other exhibitors and will display more than 750,000 pounds of machinery on the show floor. Thousands of professionals from around the United States, international manufacturing hubs, and emerging markets conduct profitable business transactions and collaborate on the innovations that make their operations more streamlined. The ASM Heat Treating Society Conference and Exposition is co-located with Gear Expo 2013. For more information, visit *www.gearexpo.com*.

October 15–17—School for Gear Manufacturing Technology. Anaheim, California. Hosted by Gear Manufacturing Inc. (GMI), this three-day seminar is designed to give the student a deeper understanding of the relationships between the geometry of the gear and the manufacturing and inspection processes leading to a practical, logical approach to trouble shooting. In this regional course we address the problems associated with gear generation (hob and shape) and gear finishing (grind and shave), for cylindrical gears, in respect to the machine tool and the associated tooling and cutters. Analysis of inspection results from traditional manual and digital inspection processes are covered in depth. New for 2013 is an introduction to the new AGMA standards, which relate directly to the international ISO standards. For more information, visit *www.gearconsultinggroup.com*.

October 15–17—Westec 2013. Los Angeles Convetion Center, Los Angeles. Westec returns to California amidst an encouraging environment that has seen a measurable increase in exports, production, overall employment growth, and recent legislation designed to enhance the state's manufacturing sector. While California has long been the nation's leading industrial state, recent economic gains have been powered by new technologies, many of which will be on display during the show. Produced by SME, Westec has built a reputation as a technological showcase for the manufacturing industry for nearly 50 years. Generations of manufacturers have used the event as a forum to find cutting-edge equipment, explore advanced technologies, and learn innovative new production methods to help grow their businesses. Many of the industry's top equipment manufacturers unveil technological breakthroughs at Westec—from software to cutting tools, 3-D printers to multitasking machines. Several manufacturers, such as Boeing, BYD and Ecologic Brands, all opened or announced increased manufacturing programs or facilities within the state of California recently. "We are greatly encouraged by recent developments in California, which has seen an uptick in manufacturing and production." said Christine Longroy, Westec event manager. "The economic climate is one of the reasons why we decided to move Westec up from March 2014 to October 2013." For more information, visit *www.westeconline.com*.

October 16–18—Kapp-Niles Rocky Mountain Gear Finishing School. Boulder, Colorado. The Sixth Annual Kapp-Niles Rocky Mountain Gear Finishing School (RMGFS) is designed to benefit gear manufacturing engineers, machine operators and production managers, as well as gear designers. The opening presentation, Gear Basics, provides a solid foundation, including a section on gear nomenclature for relative newcomers. The RMGFS provides both classroom-style and shop floor lessons, each focusing on advances in profile and generating gear grinding. In the multi-layered program, sessions are interconnected and lead each step to the next. Participants study the principles and mechanics behind different gear finishing processes, apply them through practical sessions on a Kapp-Niles machine, and hold group workshops for discussions. For more information, visit *www.kapp-usa.com*.

October 28–31—Power Transmission and Control 2013. Shanghai New International Expo Centre, Shanghai, China. Organized by Deutsche Messe, PTC Asia is the continent's leading trade fair for electrical and mechanical power transmission, fluid power, compressed air technology, machine parts, bearings, linear motion systems, internal combustion engines and gas turbines. Sponsors include Bosch Rexroth, Emerson, DMG, Parker, Siemens, EMAG, SKF, Lenze, Tsubaki, ABB, NSK, SEW Eurodrive, Gates and others. An important part of PTC ASIA is the gathering of companies from industries including gears, chain transmission, belt transmission, couplings, brakes, electrical power transmission, fasteners, springs and powder metallurgy. It is held in combination with CEMAT Asia 2013, the international exhibition for material handling, automation technology, transport systems and logistics. For more information, visit *www.ptc-asia.com/EN/*.

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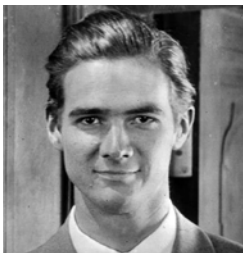
A MECHANICALLY MARVELOUS SEA SAGA:

Plumbing the Depths of Cold War Paranoia

Jack McGuinn, Senior Editor

In the summer of 1974, long before Argo, there was "AZORIAN"—the code name for a CIA gambit to recover cargo entombed in a sunken Soviet submarine—the K-129—from the bottom of the Pacific Ocean. The challenge: exhume—intact—a 2,000-ton submarine and its suspicious cargo from 17,000 feet of water.



Undated photo of a young Howard Hughes—entrepreneur, inventor, movie producer—whose Jimmy Stewart-like appearance here belies the truly bizarre enigma he would later become.

The Soviet sub had met its end (no one claims to know how, and the Russians weren't talking) in 1968, all hands lost, some 1,560 nautical miles northwest of Hawaii. After a Soviet-led, unsuccessful search for the K-129, the U.S. undertook one of its own and, by the use of gathered sophisticated acoustic data, located the vessel.

What made this noteworthy was that the U-boat was armed with nuclear missiles. Nuclear arms-capable submarines posed a new threat to the U.S. and its allies in that missiles launched from a submarine cannot be detected on radar until they are already underway to their target. For the bold caper to succeed, however, a cover story, a distraction—or a McGuffin, as Hitchcock enjoyed putting it—was needed; more on that follows.

> "No one had ever tried to design an at-sea docking system for such massive bodies. To have gotten it right on the first try, without the benefit of today's CAD/CAM capabilities, is simply incredible."
>
> **David H. Sharp,** author of The CIA's Greatest Covert Operation and CIA head of systems recovery on the Hughes Glomar Explorer

The custom-designed, one-off vessel was the *Hughes Glomar Explorer.* The ship's "owner" was none other than storied aviator and inventor Howard Robard Hughes, Jr. Hughes was recruited for the "job" by the CIA, and one can only wonder at the reaction from the bizarrely private and legendary paranoid. In truth, however, Hughes had little to do with building the *Glomar Explorer;* it was only the Hughes *brand* that was needed—as a front. Project Azorian proved to be "one of the most complex, expensive, and secretive intelligence operations of the Cold War—at a cost of ($3.7 billion in 2013 dollars)," but none of it came out of Hughes' pocket.

Designated by ASME in 2006 as "a historical mechanical engineering landmark," the ship had an array of mechanical and electromechanical systems with heavy-duty applications requiring robust gear boxes; gear drives; linear motion rack-and-pinion systems; and precision teleprint (planetary, sun, open) gears.

One standout was the *Glomar's* advanced rack-and-pinion jacking system: its impressive motors and gear boxes provided the massive lifting force needed for bringing the sub to the surface. Other marvels cited by ASME: a "claw" (think old-timey arcade game) designed to grab and hold the submarine with mechanically articulated fingers that used surface-supplied sea water as a hydraulic fluid; a motion-compensated, gimbaled (bearings, bearings) work platform system for enhanced roll, pitch and heave motion control.

And that cover story that was used by the CIA to explain the presence of the U.S. ship in international waters? People paid to know these things (oceanographers) say that areas of the Pacific sea floor are paved with manganese nodules. Seizing upon this serendipitous cover afforded them, the G then approached Hughes about using a deep-ocean mining project (the nodules) of his as a front for the clandestine project. Hughes was all-in.

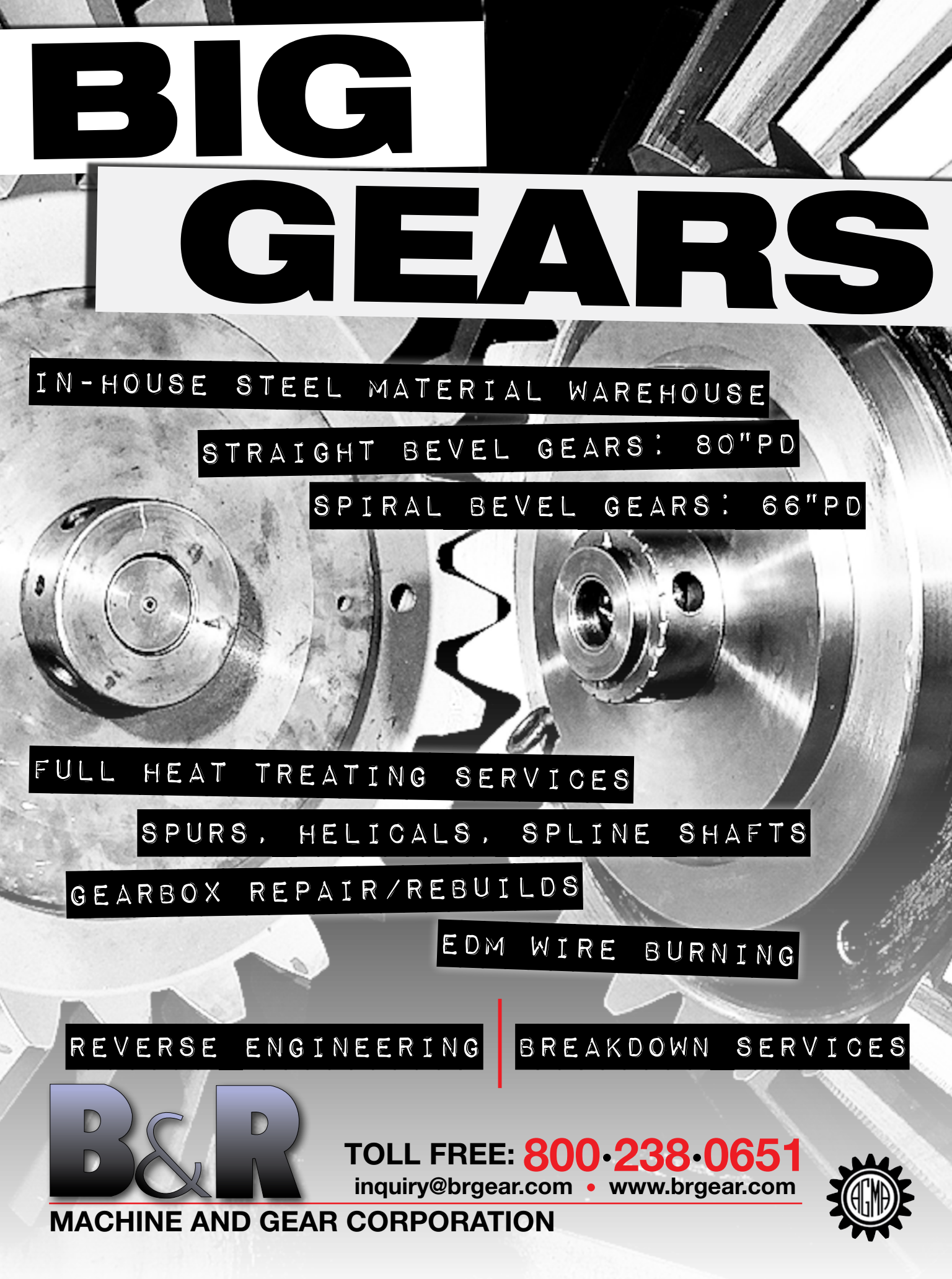
But now, the bad news: After a number of attempts, the ship's "custom claw" managed to sustain a firm grip on the submarine, but at about 9,000 feet roughly two-thirds of the (forward) hull broke away when a number of the claw's teeth failed. The broken hull of the submarine returned to the bottom, and with it most of the intelligence that the CIA was expecting to recover. The *Explorer* did ultimately retrieve the section of the hull—along with the bodies of six Soviet submariners.

Spook watchers have speculated over the last 30+ years as to the intelligence that Project Azorian sought so dearly—and expensively. The gambit's cost overruns have been estimated at about $500 million—*in 1974 dollars.* The CIA would not so much as reveal the mission's name until 2010.

A second mission to recover the K-129's broken hull was scheduled, but the mission was scrapped as the U.S. government was attempting at the time to improve relations with the Soviets. In 1976, Hughes died—intro irony here—on an airplane while en route to Methodist Hospital in Houston. The *Glomar Explorer* was eventually "decommissioned" and in 1997 was leased out for deep-water drilling. She was stripped of her high-tech mechanical systems, her "marvel" status along with them.

(Sources: *cia.gov; hnsa.org; navsource.org;* historylearningsite.co.uk; *gwu.edu; asme.org*)

BIG GEARS



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