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The Star NXT linear CNC tool and cutter grinding machine sharpens both straight and spiral gash hob designs up to 8” OD x 10” OAL. With a small footprint and maximized grind zone, the NXT also sharpens disk, shank and helical type shaper cutters, Scudding® cutters, and a wide range of round tools, making it a versatile tool room machine.

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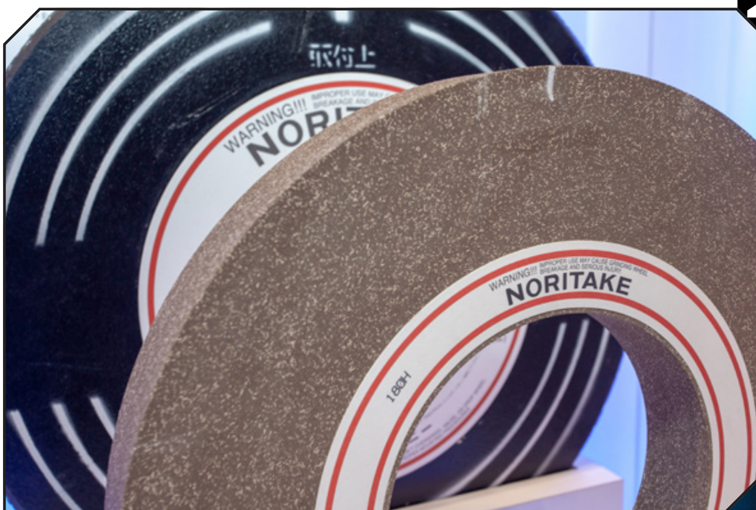

features

technical

Vol. 37, No. 3 GEAR TECHNOLOGY, The Journal of Gear Manufacturing (ISSN 0743-6858) is published monthly, except in February, April, October and December by The American Gear Manufacturers Association, 1840 Jarvis Avenue, Elk Grove Village, IL 60007, (847) 437-6604. Cover price $7.00 U.S. Periodical postage paid at Arlington Heights, IL, and at additional mailing office (USPS No. 749-290). The American Gear Manufacturers Association makes every effort to ensure that the processes described in GEAR TECHNOLOGY conform to sound engineering practice. Neither the authors nor the publisher can be held responsible for injuries sustained while following the procedures described. Postmaster: Send address changes to GEAR TECHNOLOGY, The Journal of Gear Manufacturing, 1840 Jarvis Avenue, Elk Grove Village, IL, 60007.

Canadian Agreement No. 40038760.

gear TECHNOLOGY®
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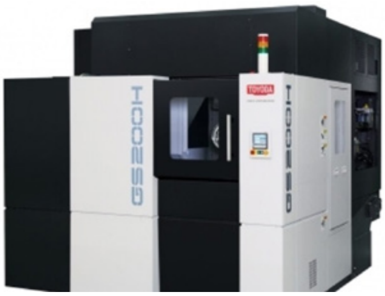
DVS SynchroForm V

DVS offers this modular machine for geared drive components. Learn more here:

www.geartechnology.com/videos/DVS-SynchroForm-V-/

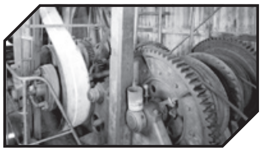


JTEKT Toyoda GS200H Gear Skiving Center

Perform five separate machining operations in a single machine. Toyoda's gear skiving series offers improved productivity and flexible machining through high-speed cutting and integrated gear part processes. Learn more here:

www.geartechnology.com/videos/JTEKT-Toyoda-GS200H-Gear-Skiving-Center-/

Gear Talk with Chuck Schultz



Check out the latest entries from our resident gear blogger on topics ranging from COVID-19 to the importance of quality in gear manufacturing. Catch-up with the latest news here:

www.geartechnology.com/blog/

Gear Matters Blog

Hainbuch's Michael Larson discussed the need for flexibility, adaptability and capability in manufacturing during and after the COVID-19 pandemic in a recent AGMA Gear Matters Blog. Learn more here:

www.agma.org/resources/gears-matter-blog/lets-make-something-out-of-this/

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AGMA MEDIA
1840 JARVIS AVENUE
ELK GROVE VILLAGE, IL 60007
(847) 437-6604
FAX: (847) 437-6618

EDITORIAL

Publisher & Editor-in-Chief
Randy Stott, Vice President Media
stott@agma.org

Senior Editor
Jack McGuinn
mcguinn@agma.org

Senior Editor
Matthew Jaster
jaster@agma.org

Technical Editors
William (Bill) Bradley, Robert Errichello, John Lange, Joseph Mihelick, Charles D. Schultz, P.E., Robert E. Smith, Mike Tennutti, Frank Uherek

DESIGN

Art Director
David Ropinski
ropinski@agma.org

ADVERTISING

Associate Publisher & Advertising Sales Manager
Dave Friedman
friedman@agma.org

Materials Coordinator
Dorothy Fiandaca
fiandaca@agma.org

China Sales Agent
Eric Wu, Eastco Industry Co., Ltd.
Tel: (86)(21) 52305107
Fax: (86)(21) 52305106
Cell: (86) 13817160576
eric.wu@eastcotec.com

CIRCULATION

Circulation Manager
Carol Tratar
tratar@agma.org

MANAGEMENT

President
Matthew E. Croson
croson@agma.org

ACCOUNTING

Accounting
Luann Harrold
harrold@agma.org

FOUNDER

Michael Goldstein founded Gear Technology in 1984 and served as Publisher and Editor-in-Chief from 1984 through 2019. Thanks to his efforts, the Michael Goldstein Gear Technology Library, the largest collection of gear knowledge available anywhere, will remain a free and open resource for the gear industry. More than 36 years' worth of technical articles can be found online at *www.geartechnology.com*. Michael continues working with the magazine in a consulting role and can be reached via e-mail at *michael@geartechnology.com*.


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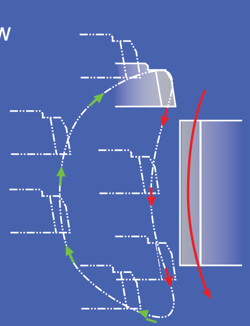


Staying Connected

Publisher & Editor-in-Chief
Randy Stott

With much of America still under stay-at-home orders, it's very difficult for many of us to stay connected. In our personal lives, we're celebrating birthdays with a drive-by and a wave, we're attending religious service on our laptops and talking with loved ones via video chat. If you're allowed to go to work, you're expected to wear a mask and keep your distance. And if you're working from home, your only connection to co-workers, employers, suppliers and vendors is via virtual meetings and conference calls.

As "The Gear Industry's Information Source," we're here to help. We're here to help you stay connected to the gear industry, no matter your situation.

Our online buyers guides are a great example. With supply chains disrupted and more people than ever using the internet to source goods and services, now is the perfect time to remember this great resource. If you're a supplier to the gear industry, you should make sure you're listed in the buyers guide and that your company appears in the appropriate categories. If you need to make any changes, you can just e-mail me (*stott@agma.org*), and I'll help you get everything squared away. If your company isn't listed, but should be, just go to *www.geartechnology.com/getlisted.php* and fill out the form. Gear industry buyers are visiting every day and looking for you.

Of course, many of you are suppliers or buyers of gears, gear drive, couplings or other mechanical power transmission components, which can be found in the buyers guide at *powertransmission.com*. If your company isn't listed but should be, visit *www.powertransmission.com/getlisted.php* to join the community. And if you're looking for suppliers of power transmission components, please use the buyers guide. Contact the suppliers there to get more information about how they can help you.

No matter what, we're looking for your feedback. Tell us how we can improve the buyers guides. Are there important categories missing? Are there features and functions you'd like to see? Whether you are a supplier listed in the guides or a user looking for new vendors, we value your input. Especially in these times, our goal is to make those resources as useful to you as they can be.

Another great way to stay connected is by making sure your subscriptions are up to date. We need your renewals every year in order to stay in compliance with U.S. postal regulations and to ensure that we are reaching the right audience with our unique content. Also, when you subscribe, you can opt to have your magazine delivered in print, via e-mail/online or both. If you happen to be working from home, you can also have your magazine delivered there instead of the office. Now is a great time to choose the option that works best for you. Visit *www.geartechnology.com/subsribe.htm* to update your information. We sincerely appreciate it when you do!

Also, when you're renewing your magazine subscription, you have the option to also subscribe to our regular e-mail communications. Our e-mail newsletter brings you unique gear-related content as well as updates on the latest industry news. Our product alerts deliver timely information about product technology related to gear manufacturing from the many suppliers in our industry who continue to innovate.

Finally, those of you who are buyers of mechanical components, whether they are gears, bearings, electric motors, gear drives or other power transmission devices, you should seriously consider adding *Power Transmission Engineering* to your reading list. Just like *Gear Technology*, *Power Transmission Engineering* is free to qualified readers. It's written for design engineers, maintenance engineers and anyone else who designs, buys or specifies mechanical power transmission components. Sign up at *www.powertransmission.com/subscribe.htm*

Hopefully, the COVID-19 pandemic will ease up soon, and we will all be able to get back to the lives we're used to. In the meantime, please know that the team at AGMA Media is here to help in any way we can. We'll do everything we can to help you stay connected and to get the information you need to stay successful in these trying times.

Randy Stott

EMAG Lasertec

DEVELOPS HOLISTIC APPROACH TO COMMERCIAL VEHICLES

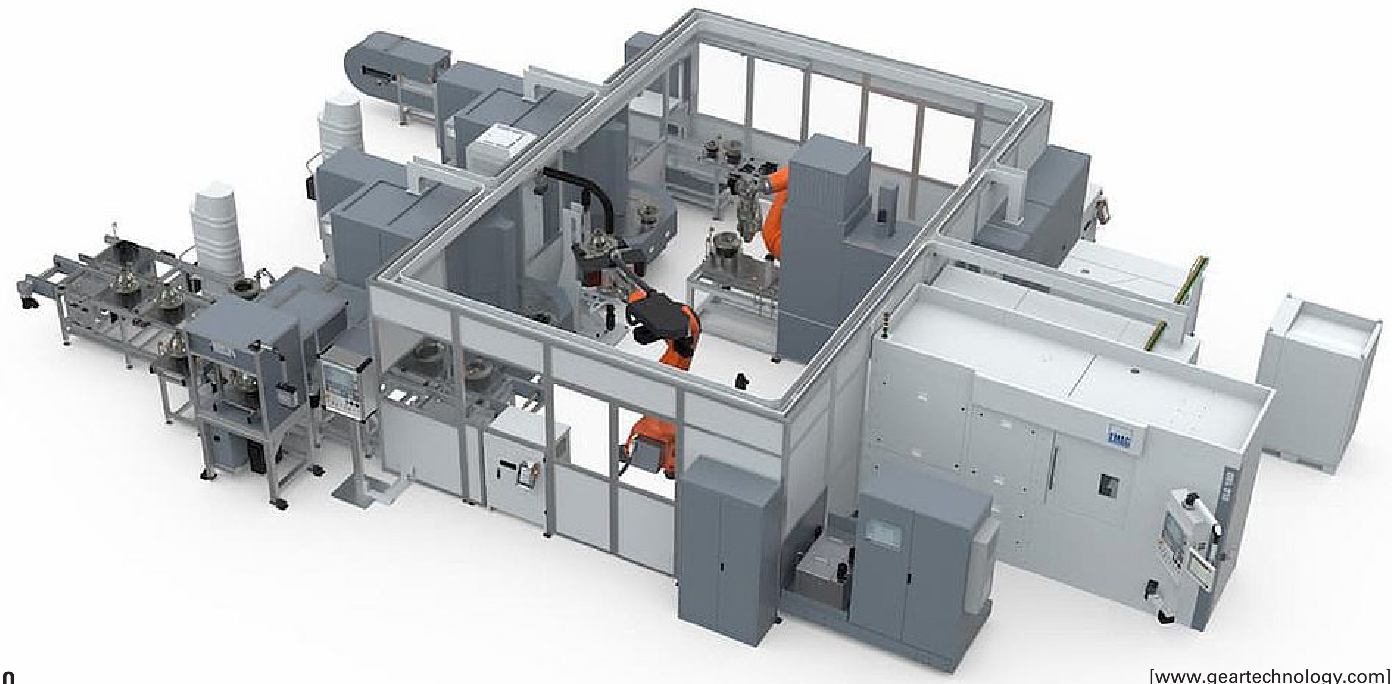
When the catch phrase "lightweight design" is used for the automobile production, it typically refers to passenger cars, rarely commercial vehicles. However, there is an enormous amount of potential for weight reduction and cost savings when considering the large, heavy parts needed for the drivetrain in trucks. Recently, a supplier in North America demonstrated the possibilities and benefits that a complete laser welding production system from EMAG LaserTec can provide. The commercial vehicle specialist currently uses an EMAG production system that welds three different parts together to manufacture a large truck differential—eliminating approximately 40 costly screwed connections. What type of processes take place in this production line?

A Shell Commercial Vehicle Study predicts that the number of commercial vehicles on the road will continue to rise, very quickly, until 2040. The study claims that the number of new registrations in Germany each year will increase from the current 290,000, all the way up to 344,000, and that the rolling stock of vehicles will reach nearly 3.5 million in 2040 (currently 2.9 million). We will also continue to see the same push for energy efficiency in an effort to achieve climate goals, as well as political pressure on manufacturers to develop vehicles that are more economical. Based on this, a system that will allow manufacturers to achieve a lightweight design in the commercial vehicle sector will be a game changer. Many truck manufacturers have naturally been focusing on well-established light weighting systems from the passenger vehicle sector, that have allowed for massive cost savings with enormous decreases in weight—and that's precisely where laser welding comes into play.

For years, laser welding has been essential in the development of drive train workpieces for passenger vehicles. Welded joints now replace screwed connections in many places. Even if a workpiece cannot be made lighter, it can be produced more cost-effectively by eliminating expensive screwed connections. For instance, some modern double-clutch transmissions have no less than 16 laser weld seams—on the various transmission wheels, the double clutch and the differential. With that in mind, it is not surprising that a North American supplier to commercial vehicle manufacturers called EMAG LaserTec. The experts, headquartered in Heubach, Germany, specialize in the development of complete laser welding systems.

"The customer knew us, since they already use a variety EMAG machines in other application areas. Their goal is to produce a considerably lighter and more cost-effective large-sized truck differential. This is an ideal task for us, even though we are implementing it for the first time in the truck sector," explains Dr. Andreas Mootz, managing director of EMAG LaserTec. "Having a high level of expertise as a system provider was an absolutely crucial factor for the customer. We develop complete process chains revolving around laser welding, which in principle simplifies planning at the customer end and simultaneously guarantees safe and effective processes."

A perfectly timed sequence becomes apparent for truck differentials, it consists of three individual parts before



production starts: two housing parts and the ring gear. These each weigh up to 130 kilos (287 lbs) and have a diameter of up to 600 millimeters (24 in). The detailed sequence is as follows:

After being fed by two separate loading stations, the two housing parts and the ring gear run through an EMAG laser cleaning system—a new in-house development that already looks and feels like a standard machine. The process is extremely fast and removes all residues, such as coolants or preservatives, using a focused laser beam.

Robots then remove the parts from the laser cleaning machines. The ring gear is first preheated with induction heating and is then transported to the joining station (preheating is performed using a low-frequency generator by EMAG eldec). The two halves of the housing are directly fed into the joining station and press-fitted together with the ring gear. The process is performed under force/path monitoring.

The subassembly is now ready for welding—a robot loads it into the EMAG ELC 600. After axial clamping, the housing is closed, and the ring gear is joined with the housing using two welds.

An EMAG ultrasonic testing system automatically checks the quality of the welded joint —a key step in the process that is just as important to specialists as is the machining of the workpiece.

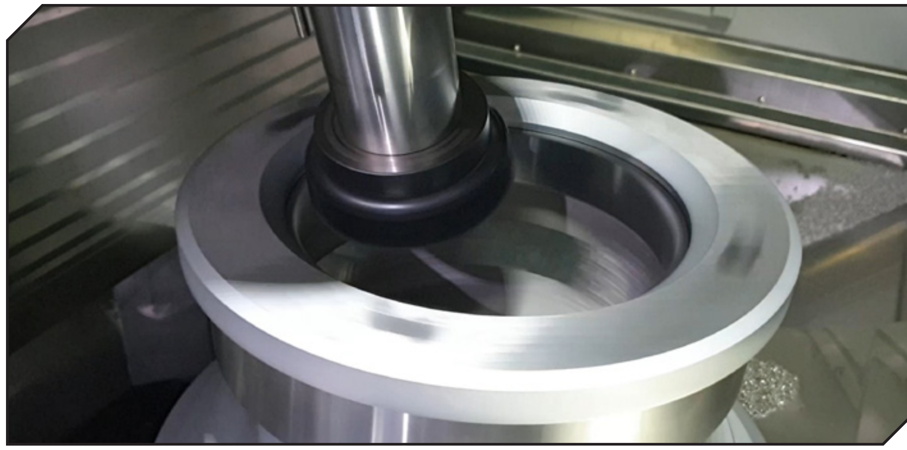
Within 12 months, the development of this process was completed! The specialists at EMAG LaserTec had to overcome a number of process-related challenges during this time—after all, the weld seams are cast steel/case-hardened steel connections with great depth, which are welded with an 8 kW (11 hp) solid-state laser and with welding additives. Aside from that, the dimensions of the manufacturing system are impressive: The whole system consists of two laser cleaning stations, a heating station, a joining station, the ELC 600, and the ultrasonic testing station, which are interlinked with complex feeding technology and two industrial robots.

"This development project perfectly illustrates how we work," says Mootz about the holistic laser production system. "We always start out with the workpiece and its constituents to develop the matching process with optimal timing and control. This results in customized solutions that stand for productivity and process reliability."

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

Helios

ANNOUNCES NEO POWER SKIVING MACHINE



Helios Gear Products announces a new line of machine tools from YG Tech that serves gear manufacturers seeking a power skiving solution. This line, called "NEO Power Skiving" or "NEOPS," is the latest affordable innovation brought to the North American market by Helios. "Gear manufacturers for powertrain systems will welcome this new competitor in the marketplace for its affordable price, high technology, productivity, quick delivery, and domestic support," said Adam Gimpert, president of Helios.

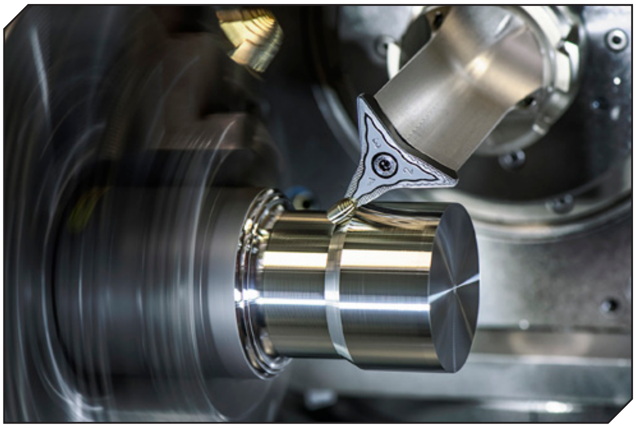
Internal or external spur or helical gears are candidates for power skiving — in particular, those that may traditionally require shaping due to clearance requirements. Compared to shaping, power skiving offers a gear tooth generating operation that is a fraction of the time. Consequently, NEO Power Skiving allows manufacturing gears with a game-changing level of productivity and profitability. This is achieved with a continuous process where the cutting tool is constantly producing small cuts, whereas traditional shaping has unavoidable idle backstrokes that reduce productivity.

The NEO Power Skiving line includes the model 200 and model 400 with capacities for parts up to 420 mm (16.535") diameter and a pitch rating of 4 module (6.35 DP). The machines use high quality components such as direct-drive torque motors for the work and cutter spindles, FANUC 0i MF CNC, and precision linear scales. Key optional features include automatic tool changer, deburring, cutting tool resharpening, and automatic loading/unloading. The NEOPS 200 and NEOPS 400 offer manufacturers a leading combination of technology and productivity at an affordable price with domestic support.

For more information:
Helios Gear Products
Phone: (847) 931-4121
www.heliosgearproducts.com

Ceratizit

OFFERS SINGLE POINT TURNING SOLUTION



High Dynamic Turning (HDT) from Ceratizit combined with the company's dynamic FreeTurn tooling allows customers to carry out all traditional turning operations such as roughing, finishing, contour turning, face turning and longitudinal turning with just one tool. HDT with FreeTurn represents a completely new method of turning.

For 100 years, new cutting materials, new chip breakers and a few new tooling systems have been invented to optimize turning. However, the actual basic turning process has remained essentially unchanged. Even today, a contour is created with an indexable insert at a fixed angle to the workpiece. This method has not changed, even with the addition of controllable axes in modern turning-milling centers, machines which are intended to serve one purpose, namely, to manufacture a component as completely as possible within a single machine work envelope.

Ceratizit has taken advantage of the features on these turning-milling centers and developed the High Dynamic Turning (HDT) System. The simple idea behind HDT: the tool approach and point of contact in the machine can be varied as opposed to conventional turning with a fixed tool.

Instead of the classic, static position of the insert in the holder, the milling spindle is now used to produce the corresponding approach angle to the workpiece. The use of the spindle drive, in conjunction with the slim, axial tool design of the FreeTurn tools by Ceratizit, creates a degree of freedom of 360° without the risk of collision, thus providing unprecedented flexibility. Due to the rotation around its own tool axis, the change can be done without interrupting the cutting process.

Additionally, the angle of approach is freely variable at any time and can even be changed while cutting. This not only enables flexible machining of almost every workpiece contour, but also optimum chip breaking, higher feed rates and an increase in tool life. Depending on the machine capabilities, the technology can be used functionally in all areas of turning operations. The approach of the milling spindle on the Y/Z axis on turning-milling centers is widespread.

For more information:
Ceratizit USA, Inc.
Phone: (800) 783-2280
www.ceratizit.com

Mahr

ADDS DEPTH GAGES TO WIRELESS LINE OFFERINGS

Mahr Inc. has announced an expanded line of digital depth gages. The pocket-sized 30 EWRi is easy to take along for fast depth measurements and the new universal depth gage 30 EWR-U/40 EWRi-U includes interchangeable anvils.

The 30 EWRi is a compact depth gage with a 0.06 inch (1.5 mm) contact and 1 inch (25 mm) gaging range with integrated wireless data transmission. It is ideal for mobile use in manufacturing and inspection at the point of manufacture.

"Taking measurements on the shop floor and transmitting them wirelessly speeds up the quality assurance process," said George Schuetz, director of precision gages at Mahr Inc. "It also adds portability, flexibility and a measure of safety by eliminating troublesome cables. This speeds setup and provides more efficient data processing, especially for quality control in production or incoming goods inspection."

Mahr's new 30 EWR-U universal depth gage includes MarConnect output for wired USB RS-232 or Digimatic while the 30 EWRi-U with integrated wireless data transmission brings new application versatility to depth gage measurements. Both gages incorporate interchangeable anvils to multiply the measurement capabilities of the gage. The gage also comes with a 30 Ud twin hook anvil standard for measuring basic widths and distances.

Five anvil choices are also optionally available to increase the gages' measurement capabilities. Now, measuring depths and recesses with various configurations of ball or chisel style anvils becomes a lot easier and cost effective rather than trying to find a costly special alternative. Both the 30 EWR-U and 40 EWRi-U come in measuring ranges of 0–12 inches (300 mm) or 0–20 inches (500 mm) and each has resolution of 0.0005 inches (0.01 mm).

All MarCal depth gage products offer IP67 resistance to dust, coolants and lubricants, and are easy to use with high contrast digital display, locking screw, zero reset function, and reference system for retaining zero immediate measurement readout. Built to provide years of quality service, the units include steel measuring surfaces; hardened steel slide and beam construction; raised and lapped guideways for the protection of the scale; and even include dirt wipers integrated in the slide.

Integrated wireless data transmission simplifies the recording and documenting process, especially in the networked factory of Industry 4.0. With the touch of a button on the instrument, keyboard, timer, remote control, or foot switch, acquired data is sent from the gage to an i-Stick radio receiver plugged into the USB port of the computer.

MarCom 5.2 software enables fast and easy setup of measuring stations with wireless (or wired) data transfer to the PC. The *MarCom* cell control is highly flexible. Measured values from connected devices can be automatically transferred into separate Excel columns, tables, or files ensuring the reliability of measurement data documentation. At the same time, the *MarCom* software ensures that readings can be passed on through an integrated virtual interface box to an SPC/CAQ software such as *Q-DAS* or *Babtec.*

For more information:
Mahr Inc.
Phone: (401) 784-3100
www.mahr.com

Mitutoyo America

INTRODUCES PROCESSOR PACKAGE WITH PH-3515 PROFILE PROJECTOR

Mitutoyo America Corporation recently announced the release of the new M2 2D Processor as part of a new package with the PH-3515 Profile Projector. The M2 2D processor updates the PH-3515 Profile Projector with a new touch screen tablet and easier 2D processing for measuring dimensions.

M2 2D Processor Features:

- Easy-to-use high-tech touch screen M2 geometric measurement display
- Graphics-based "part view" constructions: generate distances and tangent lines from within the graphical part view
- Geometric Tolerancing: measure features, set nominals, apply tolerances and view deviation results with only a few quick clicks
- Report Flexibility: Customize report data and format, including header, footer and graphics
- M2 Geometric 2D Measurement Software
- Optional Edge Detection

PH-3515 Profile Projector Features:

- ø14" screen horizontal projector
- Horizontal projector is equipped with accurate linear glass scales
- Profile and Fiber Optic Surface Illumination
- 10" × 6" Travel T Slot table for accessories
- Digital built-in angle counter

For more information:
Mitutoyo America Corporation
Phone: (630) 820-9666
www.mitutoyo.com

CAS DataLoggers

INTRODUCE MONITORING SOLUTIONS FOR HEAT TREATERS

CAS DataLoggers provided the temperature data logging solution for a factory with multiple lines of (fixed) heat treating ovens. The factory's existing procedures required employees to periodically read temperatures from controller displays and record all these temperatures on a piece of paper. However, this manual method proved to be inaccurate and time-consuming, so the customer wanted to eliminate these recording/transposing errors and extra labor. Since the goal was to increase data precision and quantity and provide high-accuracy reporting to their own customers, data collection needed to be simple and unobtrusive. Management decided that it needed a compact yet rugged solution offering a large number of inputs along with convenient data downloading capability.

The factory installed 2 dataTaker DT85 Intelligent Data Loggers to automate their data recording process. The data logger inputs consisted of a combination of new thermocouple sensors and repeated signals (4–20 mA, 0–5 VDC) from the existing controllers/display units. In case the temperature monitoring scope suddenly needed to expand, the dataTaker inputs could be increased up to 300 channels or 900 single-ended inputs using dataTaker channel expansion modules.

Each stand-alone DT85 data logger could connect to a wide range of sensors and data measurement devices using its 16–48 universal analog sensor channels. The systems' rugged construction withstood the factory's extreme heat ensuring years of durability and dependable operation. Current temperature readings of the heat treating ovens were shown on each logger's built-in display, and each data logger could store up to 10 million data points allowing independent control of schedule size and mode so that users could log only as long as necessary. All curing data was now recorded to non-volatile memory without any human intervention needed.

Additionally, whenever power interruptions occurred, the dataTakers generated a record of the temperatures, allowing engineers to determine exactly how much of the heat treating cycle had been completed. This reduced scrap product, lowered the building's wasted energy and helped increase product quality. The dataTakers also archived data on alarm event, sending data an Ethernet network without needing polling or specific host software.

Temperature data was also available via the network and the DT85's built-in web server for ad hoc monitoring of the oven temperatures throughout the plant. The free software provided for configuration, setup, and displayed temperature measurements in real-time, allowing the factory's quality engineer to remotely access the logger's web server from home for effective remote monitoring.

Ethernet connection to LAN was present at each data logger so that the temperature data could be automatically pushed via FTP to a local server for historical archive. The DT85's sophisticated communications array also included RS232/485 as well as support for Modbus for connection with SCADA systems. Calculations and diagnostic information were easily accessible in the browser style interface, and users also viewed the data as mimics, charts, and tables.

The factory's heat treatment monitoring needs were fully met by the intelligent dataTaker DT85 data loggers, which entirely replaced the previous reliance on fault-prone manual measurements and freed up time for more important tasks. The data loggers automatically monitored the oven temperatures with precise accuracy while also handling data transmission and enabling remote access. Users relied on the intuitive dataTaker software to view the real-time temperature data in any network-accessible location using the loggers' many advanced logging and communications features. Additionally, the dataTakers kept on taking measurements even during occasional power interruptions, allowing operators to effectively track the heat treating cycle and save on energy costs.

For more information:
CAS DataLoggers
Phone: (800) 956-4437
www.dataloggerinc.com

Seco/Warwick

VECTOR FURNACE ACCOMMODATES WIDE RANGE OF THERMAL PROCESSES

Vector from Seco/Warwick is a single chamber HPGQ model loaded with capabilities, and highly flexible to accommodate a wide range of thermal processes including hardening, tempering, annealing, solution heat treating, brazing and sintering applications. It is characterized by high speed cycles, low consumption of energy and low process gas emissions, and is available with curved graphite elements or an all-metal hot zone.

"Our Vector offers customers real value which they can use to improve performance of in-house heat treatment departments or custom heat treat service providers alike. Four Vector furnaces sold in just two months is confirmation that we have both a product and a support team that are attractive to our customers," said Piotr Zawistowski at Seco/Vacuum Technologies.

In addition to Vector, Seco/Vacuum offers several other thermal technologies, from single chamber configurations to multi-chamber systems with gas or oil quench, to single-piece flow inline heat treating and quenching systems. Multiple specialized vacuum heat treat technologies can create opportunities for OEMs and commercial heat treaters to improve throughput, quality and performance.

For more information:
Seco/Warwick
Phone: (814) 332-8400
www.secowarwick.com

Kyocera Corporation

DEVELOPS NEW GENERATION OF HIGH-PERFORMANCE MILLING CUTTERS

Kyocera Corporation announced its new MEV series of efficient, multi-functional milling cutters for metal machining applications. The new product series, which includes six inserts and 25 holders, are now available worldwide.

A milling cutter typically has cutting edges on its outer holder body and bottom and is used to cut grooves and forms out of the surface of a metal workpiece. The process requires continuous improvement in cutting precision and efficiency to support the growing range of materials and applications demanded within many industries, including automotive and aerospace manufacturing.

While a conventional milling cutter can deliver high rigidity and high-precision machining through increased web thickness, this often results in higher cutting forces that decreased efficiency. Alternatively, if efficiency is prioritized instead, the tool can become prone to vibration shock, which diminishes cutting accuracy. To overcome this longstanding challenge, Kyocera developed a unique "vertical triangle" insert design that delivers both high rigidity and lower cutting forces.

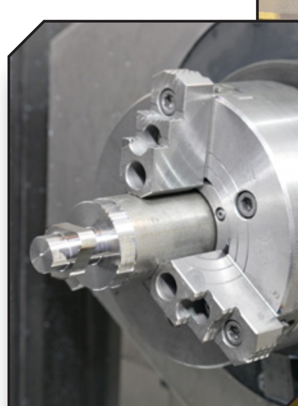
In addition, Kyocera achieved longer product life and greater versatility by adjusting the angle of the cutting edges, increasing the rigidity of the holder body, and optimizing the insert shape to improve chip control.

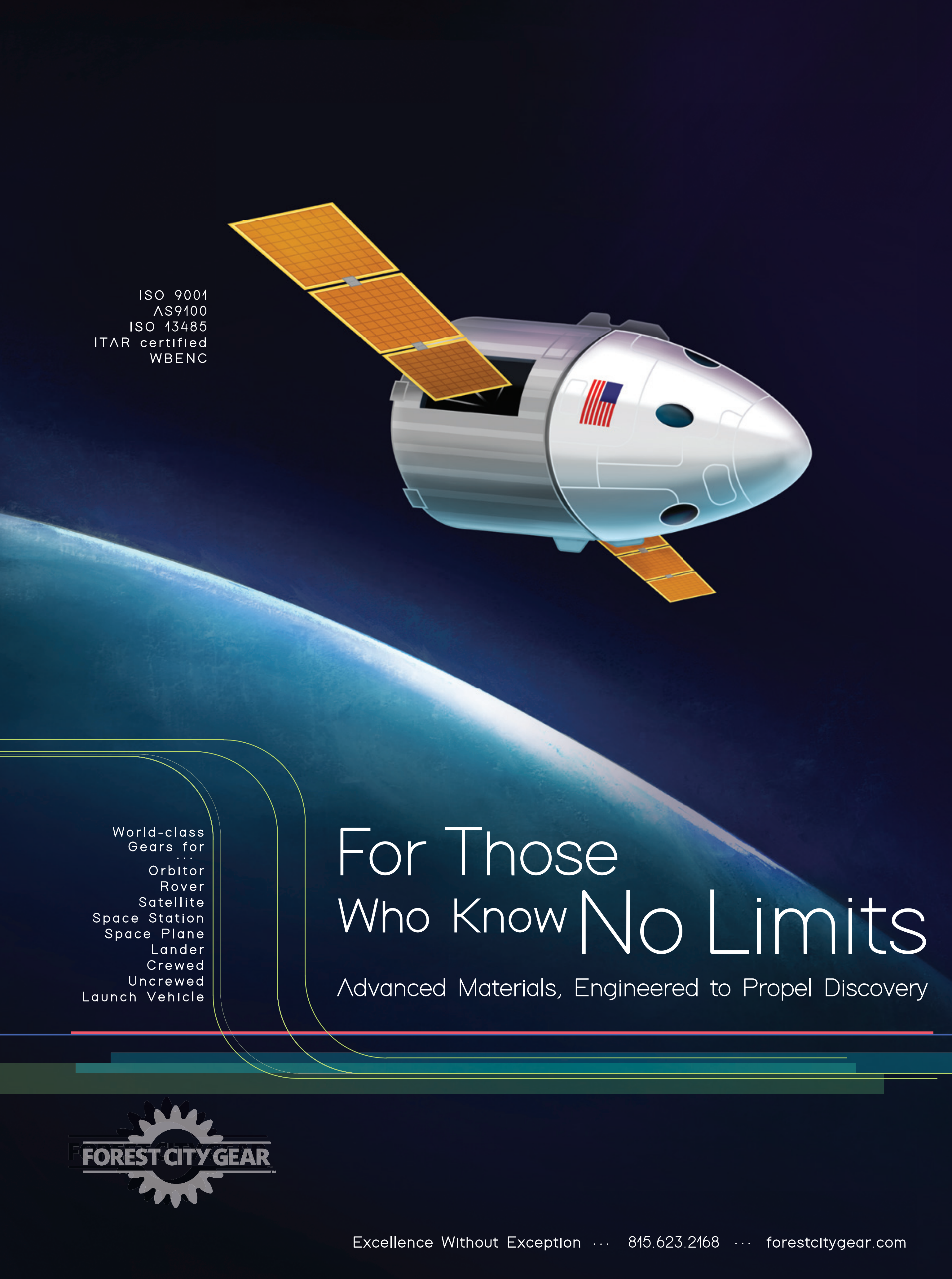
The web thickness of the MEV Series holder body has been increased to approximately 120 percent compared to conventional milling cutters by changing the insert orientation to a tangential mounting style for the first time among Kyocera's indexable end mills. In addition, the use of a triangular-shaped insert with low cutting resistance ensures both higher rigidity and lower cutting forces for greater machining precision and efficiency.

The innovative design features larger cutting edges for increased strength. In addition, all three usable cutting edges feature Kyocera's proprietary MEGACOAT NANO coating technology (CVD coating will also be available) with wear and adhesion resistance for increased tool life. Increasing holder rigidity and creating wider area of contact with the inserts leads to high durability.

By optimizing the design of the chipbreakers, the MEV maintains exceptional chip evacuation. The MEV can also achieve stable machining in more difficult applications where chip recutting and high cutting force can be challenges such as slotting and ramping at a depth of cut (DOC) up to 6 mm.

For more information:
Kyocera Corporation
Phone: (800) 823-7284
global.kyocera.com

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Inside Look at the Hard Finishing Cell

Gleason Combines Threaded Wheel Grinding with GRSL Gear Inspection

Dr. Antoine Türich, Gleason Corporation

At the 2019 MPT show in Detroit, Michigan, Gleason unveiled for the first time its new Hard Finishing Cell (HFC) with integrated, 100% inspection of all gears in process. The new manufacturing system was among the most noteworthy of the new technologies introduced and heralded the beginning of a new era in the manufacture and inspection of high-quality gears. For the first time, the HFC combines the latest Threaded Wheel Grinding with GRSL gear inspection with laser scanning in a single system to finally solve the problem of random gear inspection in conventional gear production.

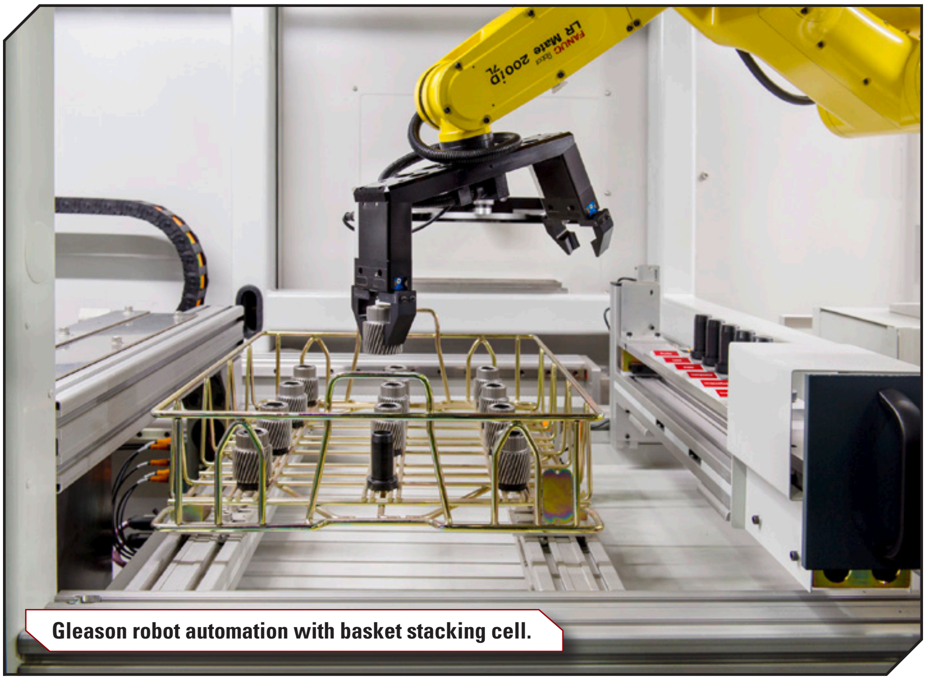
Today: 95% of Gears Go Untested

In conventional gear manufacturing, quality control is carried out only randomly. This is due, among other things, to the significantly longer measuring times required in comparison to the actual production time and the limited measuring capacity available. In hard fine machining, for example, it is not unusual in continuous generating grinding to measure only one or two components per dressing cycle. Depending on the dressing cycle, this corresponds to only about 5% of the components produced. In order to guarantee an almost 100% reliability, statistics are instead used to validate most of the gears produced. Typical measuring characteristics can be represented and statistically evaluated on a Gaussian bell curve. By deliberately narrowing down the tolerances on the measured components, it is possible to guarantee compliance with the required drawing tolerances with a sufficiently high probability (typically > 99.99%). This method is commonly used for machine and process capability studies and is recognized worldwide. The machine or process capability values cmk & cpk frequently taken as a basis are usually above 1.67. Statistically, the reject rate is only 0.57 components per 1 million manufactured components, but this means that only about 50% of the intended drawing tolerances are available as manufacturing tolerances. In today's world, that's not good enough. The constantly increasing power density of gears and the growing importance of noise behavior are leading to increasingly tight tolerances. Clearly, the heavy reliance on statistics poses a significant problem for a growing number of gear manufacturers.

But up until now, much of the focus on production floor inspection has been concentrated on achieving objectives such as establishing a 'closed loop'

Hard Finishing Cell (HFC) consisting of a Gleason Genesis 260GX, Gleason 70ARC robot automation and a Gleason GRSL Gear Rolling System with Laser Scanning.

connection of inspection to production machine, and putting the measuring machine on the shop floor in close proximity to the production machine, e.g. by using shop hardened measuring machines. Gleason's new GRSL roller testing device with integrated optical measuring technology, however, takes a completely different approach: reducing measuring time so that it can realistically be done within the actual production time. This provides the possibility of 100% inspection of all manufactured components. There is no need for additional narrowing of tolerances and the 100% inspection of all manufactured components can be accomplished in-process.



Gleason robot automation with basket stacking cell.

Many Technologies, One Closed-Loop System

The HFC thus offers significant added value. It's a fully automated system with robot loading that integrates modules for auxiliary processes in order to meet specific customer requirements easily and flexibly. The concept presented for the first-time last year demonstrated a complete process sequence including gear grinding, washing, laser marking, measuring and part handling in a stackable basket system. The HFC can nevertheless be configured for any desired process, with a single system replacing many machines.

HFC's 100% inspection capability results from the new GRSL roller inspection unit which is fully integrated into the system. The component to be tested is loaded by the robot onto the two-flank rolling test device. During the gear inspection, a laser scanner is used to measure all gear characteristics. Thus, all relevant information for profile, pitch, and runout and, if desired, lead measurement is available. This is done for each tooth and not, as is usually the case, only on four teeth distributed over the circumference.

The deviations determined in the

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> Dr. Antoine Türich, Gleason Corporation

process — provided they are within the tolerance — are fed back directly into the production machine by means of a closed correction loop. Both fully automatic correction and real-time adjustment of the corresponding parameters can be achieved. Compare that to the conventional measurement process in the Quality Lab, where 45 to 60 minutes may well pass between removing the component from the machine and providing the measurement result. With HFC's in-process inspection and Closed Loop, the desired correction ensuring optimum quality during the ongoing production process is much faster.

Components whose characteristics lie outside the tolerances are automatically rejected. It is also possible to create extensive trend analyses of individual features and perform further gear noise analysis.

4.0 Inside

In addition to the many analysis options that the system provides for optimizing workpiece quality, the Hard Finishing Cell is also equipped with the latest 4.0 functions. The Gleason Fingerprint Machine Analysis for predictive maintenance allows the user to keep planned machine availability at peak levels. Gleason's "gTools" tool management system reduces operator errors and tool wear and optimizes the use of tools. Of course, the HFC is equipped with the latest Gleason accessories, including the Quik-Flex Plus modular fixture, which allows changeovers in minutes, and Gleason dressing tools.

In Summary

HFC with its many new technology features shows what a global team with a common vision can achieve. HFC is indeed a highly desirable solution for many industries and applications where consistent high quality is important, such as the production of high precision eDrive gears with minimal noise characteristics. A single system for the fast and high-quality production with 100% gear inspection, long the dream of many customers, is now a reality.

GRSL — double flank roll testing with integrated laser scanner, fully integrated for in-process, high volume 100% inspection of gears in a Closed Loop. Also available as a stand-alone machine.

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Gleason Corporation
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Dr. Antoine Türich is director product management — hard finishing solutions at Gleason.

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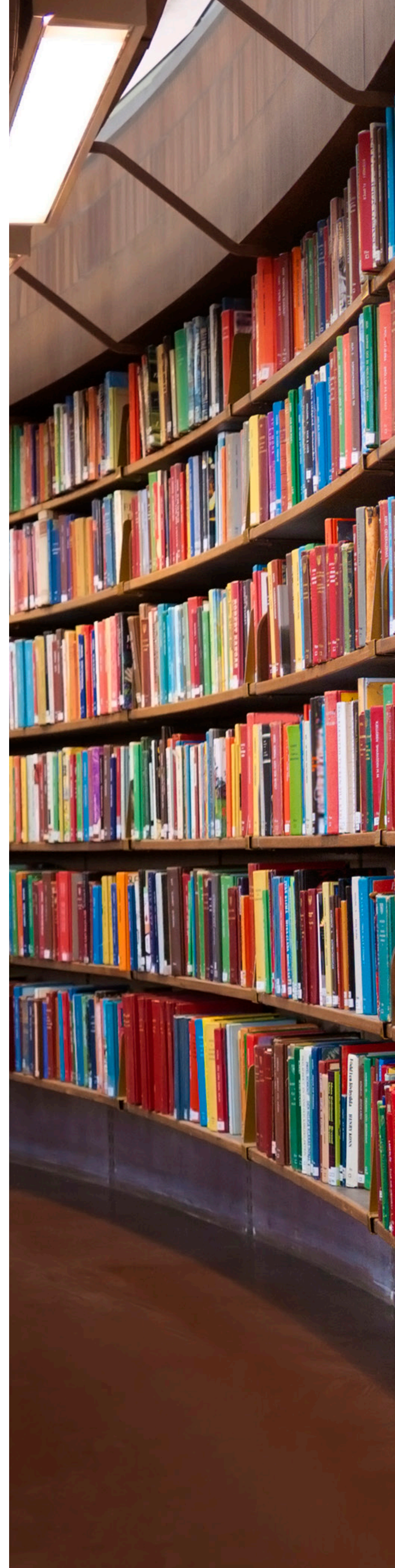

The All-in-One Application Advantage

A Look at Complex, High-Performance Five-Axis Machining Solutions

Matthew Jaster, Senior Editor

With new manufacturing challenges in every industry from aerospace to automotive, construction to mining and energy, more gear manufacturers are entertaining the idea of adding complex, five-axis machines into their shop floor equipment.

Diverse part production, multiple setups, and productivity gains are just a few of the advantages to five-axis machining. Many shop visits in recent years start or end at a five-axis machine with the operator bragging about how the unit is either the workhorse or the best machine tool found in the factory. Here's some recent highlights from five-axis machine tools:

Methods Machine Tools

INTRODUCES FIVE-AXIS BRIDGE-TYPE MACHINING CENTER

Methods Machine Tools, Inc. has introduced the all-new Methods MB 450U Simultaneous five-axis Bridge-Type Machining Center, loaded with features and capabilities for efficiently manufacturing complex parts with a high degree of quality, reliability and accuracy.

Due to the FANUC 31i-MB5 control, this machine is able to perform full five-axis precision machining of challenging parts, significantly reducing the need for multiple setups. Thanks to the control that is available exclusively to Methods, due to its partnership with FANUC, Methods Machining Centers are the only machines from Taiwan that can offer five-axis simultaneous.

"In addition to having a unique, powerful FANUC control, the MB 450U machining center is packaged with comprehensive, high end functionality for exceptional performance," said Nicholas St Cyr, machining centers product manager. "We are pleased to offer customers a five-axis machining solution that is fully loaded with robust features and provides high value for the cost. Also, we offer our customers tremendous depth of support through Methods industry leading application engineers, technical service and parts support."

The FANUC 31i-MB5 Simultaneous five-axis control has a 15" color display and includes a range of powerful standard features including a 2 GB data server, Manual Guide I, AICC II 600 Block Look Ahead, 1 MB of NC memory and 0.4 ms Block Processing Time. The FANUC control offers collision detection with a 3D interference check and a Fast Package III with tool center point control.

Methods MB 450U features a 15,000 rpm Big Plus, 40-Taper Spindle with air-oil lubrication and a spindle chiller for longevity. A 15 hp hollow shaft spindle motor with 1,000 psi (70 bar) coolant-thru spindle prep and couple is also standard. The new MB 450U five-axis Bridge-Type Machining Center includes a large capacity, dual swing arm-type 48-tool automatic tool changer. Travel is 15.7" (400 mm) on the X-axis and 13.8" (350 mm) on the Y and Z-axes. The B-axis has -50°~+110° tilting capability and the rotary C-axis has a 360° rotation angle.

Offering high machining stability, the MB 450U has a robust bridge-type construction with thermal compensation including 1.771" (45 mm) linear roller guide ways in the X/Y-axes and 1.377" (35 mm) in the Z-Axis and weighs 13,250 lbs. (6,000 kg). Heidenhain linear scales in the X/Y/Z axes and Heidenhain rotary scales in the B & C axes offer high precision part production. Kinematic calibration features a spindle probe with a table center point calibration ball and kinematic software. A laser tool measurement system detects tool wear, damage and breakage, reducing non-productive time and enabling automated operation.

For more information:
Methods Machine Tools
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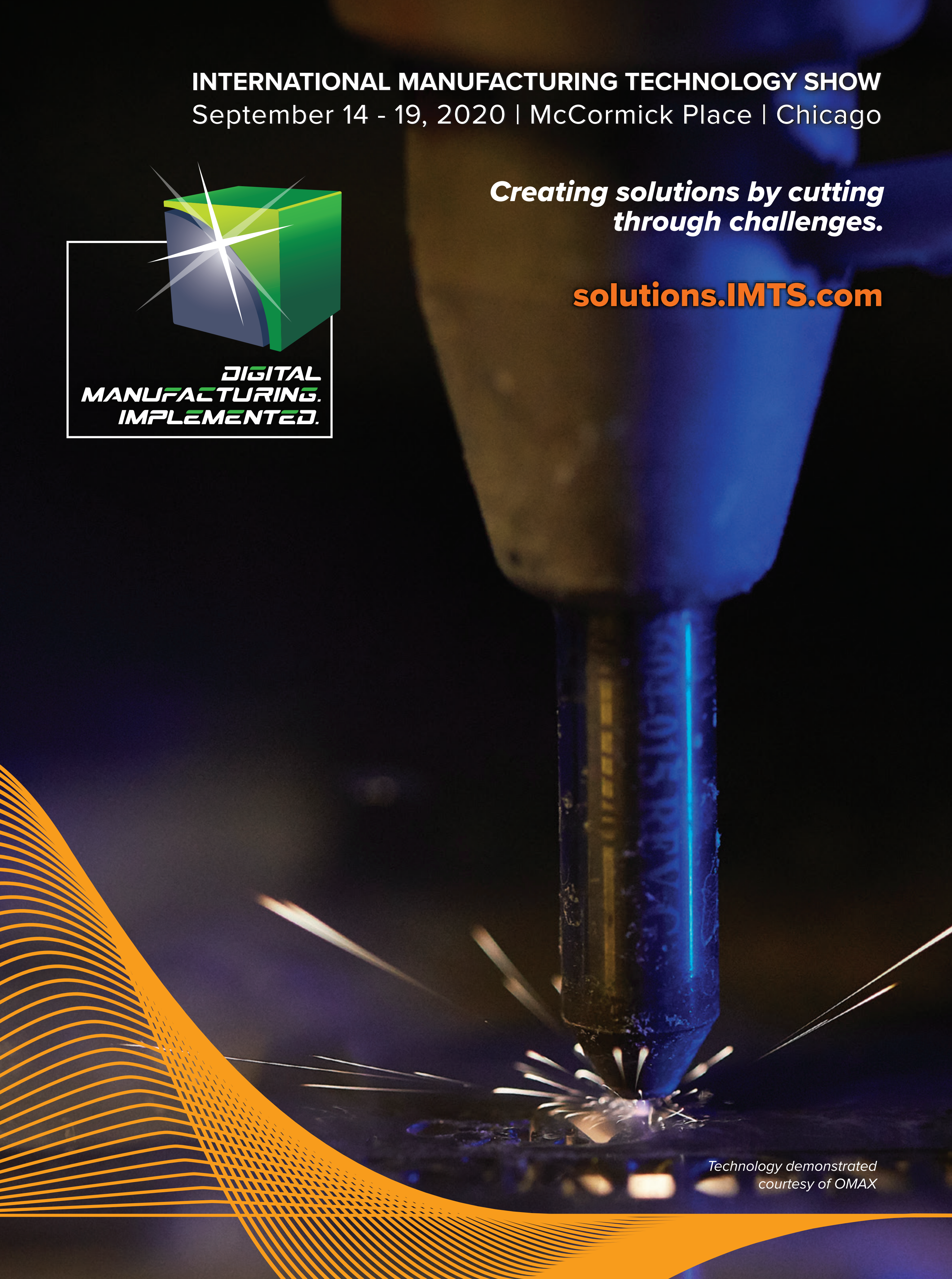
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Doosan

OFFERS DIVERSE LINEUP OF FIVE-AXIS TECHNOLOGY

Producing complex parts for industries such as aerospace, automotive, medical, firearms, and others allows Doosan the opportunity to offer manufacturers a single-setup machine tool solution instead of cobbling together a machine line to slightly boost productivity. Here are some of the recent highlights to Doosan's five-axis machine tool lineup:

DVF 5000

The DVF Series is fully loaded to handle diverse 5-sided or simultaneous five-axis applications to meet a variety of customer needs.

The machine table is now an integrated cantilever style full five-axis table allowing you to tackle your parts from angles you couldn't on the DNM. We are presently offering a machine with a table diameter of 19.7" (DVF 5000); other table diameters slated for a Q3 launch will include 26" (DVF 6500) and 31.5" (DVF 8000). With this range of table diameters, you will be able to choose the size you need for your type of work. The DVF 5000 features a built-in 25/29.5hp (continual/short-term) 18,000 r/min spindle, allowing for high speed metal removal. It also comes standard with a 60-tool magazine, with options of up to 120 tools, to tackle your complex parts without having to re-tool your machine each time.

Another advantage of the DVF 5000 is the optional Automatic Work Changer which gives you lights-out capability. It can be ordered in numerous pallet configurations: 4/6/8/10/16, etc.

Here's what Paul Anderson, applications engineer at Doosan had to say about the DVF 5000:

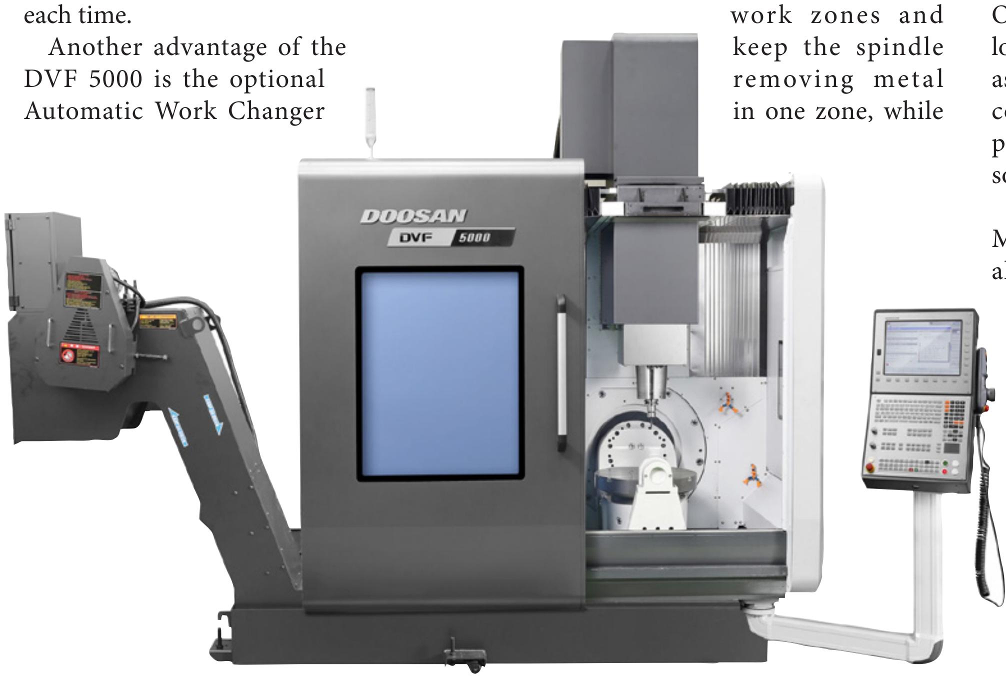
"Over the last 10 years, we've made plenty of machine tool advancements. Quantity, quality, getting our name out there. But the DVF is easily our biggest game changer right now. Where we used to concentrate on lathes, VMCs, our segue into five-axis has been really positive."

Anderson has worked in machining for 41 years, 38 with CNCs. He's programmed and run more projects than he can count.

"Our first five-axis machines were very good, but with the DVF 5000, we now have a more customer style machine that can go head-to-head with the other name brand manufacturers," Anderson added.

VCF 850LSR

The VCF 850LSR is a large, multi-purpose, vertical machining center that is equipped with a 18,000 r/min CAT40 B-axis swiveling spindle head that has X-axis travel of 118". With this machine, you have two choices in the type of C-axis available: a mounted ø19.7" rotary table, or a built-in ø31.5" rotary table. With a 138"-long table, plus a standard center dividing partition (which can be easily removed for extra-long work pieces), you can create multiple work zones and keep the spindle removing metal in one zone, while the other is being loaded. For example, you can have an area equipped with the C-axis table for five-axis work, and another area of the table dedicated to 3- or 4-axis work — maximizing the uptime potential. If flexibility is what you need in a five-axis machine, this would be a great choice.



DHF 8000

It's not only verticals and 40 tapers that offer Doosan five-axis technology. Built from the NHP high performance horizontal machining center series is the DHF 8000, a 50-taper nodding spindle five-axis machine. In addition to the full B-axis (360,000 positions) in the 800 mm pallet, the A-axis in the spindle has a tilting range of +60 to −100 degrees, allowing five-axis accessibility. Dual ballscrews in the Y- and Z-axis in an already robust base give it even more rigidity, with a geared 6,000 r/min spindle, users can tackle hard metal aerospace parts. Linear and rotary scales on all axes are standard.

Mazak

ENHANCES FIVE-AXIS CAPABILITIES

From the start of its multitasking machine development process, Mazak strived for completing parts in one setup: A solid raw piece of material enters the machine, and a completed component exits. But to reach DONE IN ONE — part production, many technological advancements had to occur, such as the development of integral motors, controllers/computers with increased processing power and CAD/CAM software.

Higher power controllers, like Mazak's MAZATROL Smooth CNCs, allow manufacturers to maintain data points across milling and turning operations within the same workpiece setup on a multitasking machine. This ensures repeatability and eliminates the risk of human error when moving workpieces from one single-process machine to the next. Further CNC advancements ensured that machines could control a greater number of machining axes and simplify part-programming requirements.

Unfortunately, traditional belt drives tended to hinder the performance and positioning accuracy of additional spindles on multitasking machines — until the development of integral motor technology. Electric motors that fully encase the machine spindle, integral motors initially delivered speeds up to 5,000 rpm and positioning accuracies within 1 degree. In addition to improving the spindle's ability to stop and position accurately, integral spindle motors introduced the ability to perform complex contours with C-axis turning spindles. For milling spindles, the technology introduced B-axis control to the spindle along with higher rpm and horsepower.

Following the introduction of integral spindle motors, Mazak experimented with the use of worm wheels for further performance improvements, but the design had backlash issues. Instead, Mazak developed a highly capable roller cam design and is currently exploring the use of direct drive technology for milling spindle headstocks on Mazak Multi-Tasking machines. For its vertical Multi-Tasking machine platform, roller cam technology paved the way for Mazak's tilt/rotary tables and full, simultaneous five-axis machining.

But it was the introduction of lower turrets and second spindles that allowed for DONE IN ONE and simultaneous part processing, meaning the machine's upper turret is working on a part in the machine's main spindle while the lower turret works on another part in the second spindle. This configuration resulted in significantly shorter part cycle times and higher machining accuracy along with increased capacity, flexibility and productivity — all with one machine. Here are some five-axis highlights for gear machining:

The INTEGREX i-200ST AG HYBRID machine is equipped with the AUTO GEAR (AG) package, the machine efficiently processes mid-size complex components with the added versatility of twin spindles, milling spindle (S) and a lower turret (T) as well as a full range of SMOOTH TECHNOLOGY solutions specifically aimed at the DONE IN ONE production of gears.

Mazak's AG package gives manufacturers the ability to perform complete part processing for a wide variety of gear types. The machine can produce datum features, chamfers, edges and other part features in a single set up, reducing the need for redundant workholding and work-in-progress (WIP) inventory.

The SMOOTH Gear Cutting software package includes SMOOTH Gear Skiving, SMOOTH Gear Hobbing and SMOOTH Gear Milling for the production of both external and internal spur, helical and spline-type gears. This assures complete geometric freedom without added complexity — operators can use Mazak's powerful HMI solution to easily create programs on the control. The AG package pairs well with the highly productive INTEGREX i-200ST platform, which features two turning spindles that provide equally high levels of performance thanks to 5,000-rpm speeds and C-axis turning control. Both spindles have a bore capacity measuring 3" (76 mm) in diameter.

With even faster, higher torque spindles, the INTEGREX i-630V/6 machine processes large, highly complex parts in the shortest cycle times possible. When paired with the new TOOLTECH tool system, the machine provides efficient tool storage as well as easy loading and unloading of large size, heavy tools.

A spindle cartridge design gives the INTEGREX i-630V/6 higher horsepower and increased speed as well as ease of maintenance. The rigid CAT 50, 10,000 rpm milling spindle tilts in the B-axis –30/+120 degrees for complex contour machining.

The machine's turning spindle/C-axis features a direct-drive motor and a new bearing design along with glass scales. All of which further boosts rigidity, stiffness and accuracy. The robust turning spindle with C-axis control delivers 50 hp and 550 rpm.

For C-axis contouring versatility at either turning spindle, the INTEGREX i-200ST AG uses a vertically mounted milling spindle that provides 30 hp (22 kW), 12,000 rpm and a rotating B-axis range of +120° and -120° for 240 degrees of motion.

Able to accommodate workpieces up to 41.3" (1,049 mm) in diameter and 39.3" (998 mm) high, the machine comes with a two-pallet changer that accepts square 24.8" (630 mm) × 24.8" (630 mm) pallets or round 31.5" (800 mm)-diameter pallets. The pallet changer moves pallets in and onto the machine's table within 11 seconds.

DMG

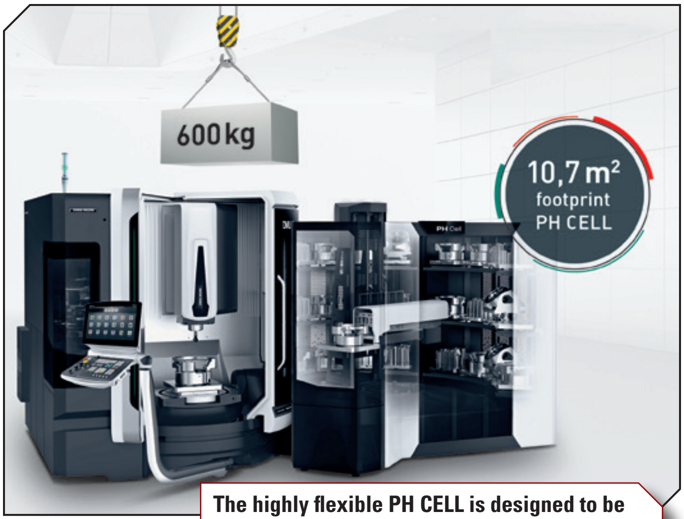
MORI OFFERS INNOVATIVE AUTOMATION PLATFORM FOR FIVE-AXIS MACHINING

The extensive DMG MORI automation portfolio offers innovative and versatile solutions for an autonomous and cost-efficient production for both milling and turning applications. The latest highlight is the new PH CELL for five-axis machining centers and vertical machines. Modular in design the pallet handling system has space for 40 differently sized pallets with dimensions up to maximum 500 × 500 mm.

With a footprint of 10.7 m², the PH CELL is a space-saving automation solution, which enables very autonomous manufacturing even in tight production areas. The pallet system is based on a modular design and offers a high degree of flexibility. The basic version with one shelving module can process up to twelve 500 × 500 mm pallets, sixteen 400 × 400 mm pallets or up to twenty 320 × 320 mm pallets — distributed over three or four shelves. The system can also be expanded with a second shelving module providing up to 40 pallet storage spaces. The second shelving module can also be subsequently integrated. The height of the shelves can be easily adjusted. Every shelf can hold up 600 kg. The transfer weight is maximal 300 kg. In addition to the normal setup station, the modular design also includes a version that can be rotated in 90° steps for improved ergonomics during set-up parallel to production.

The concept behind the flexible PH CELL is that numerous machining centers can be connected, and thus optimally supports DMG MORI's automation strategy. Initially available on the DMU 65 monoBLOCK, it will successively be available on the DMU 50 3rd Generation and the DMU eVo series from May 2020. This will be followed from July with the duoBLOCK models, the CMX U universal machines and the DMC V and CMX V vertical machining center models. It is possible to connect the PH CELL to the machines retrospectively. The prerequisite for this is that an automation interface is available on the machine.

The Robo2Go Vision is an innovative solution that offers a flexible automation layout with free access to the machine and an intelligent safety concept for human-machine collaboration. The Robo2Go Vision, a further development of the flexible robot automation, enables direct loading of Euro pallets and thanks to the new 3D-camera achieves robust recognition without the need of any specific workpiece deposits. With the aid of the dialog-guided control via CELOS and the 3D-camera the teach-in of the Robo2Go Vision takes less than ten minutes. DMG MORI will also be presenting the Robo2Go 2nd Generation on an NZX 2000 with MAPPS control for the first time.



The highly flexible PH CELL is designed to be module and offers optimal accessibility.

For more information:

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Us.dmgmori.com

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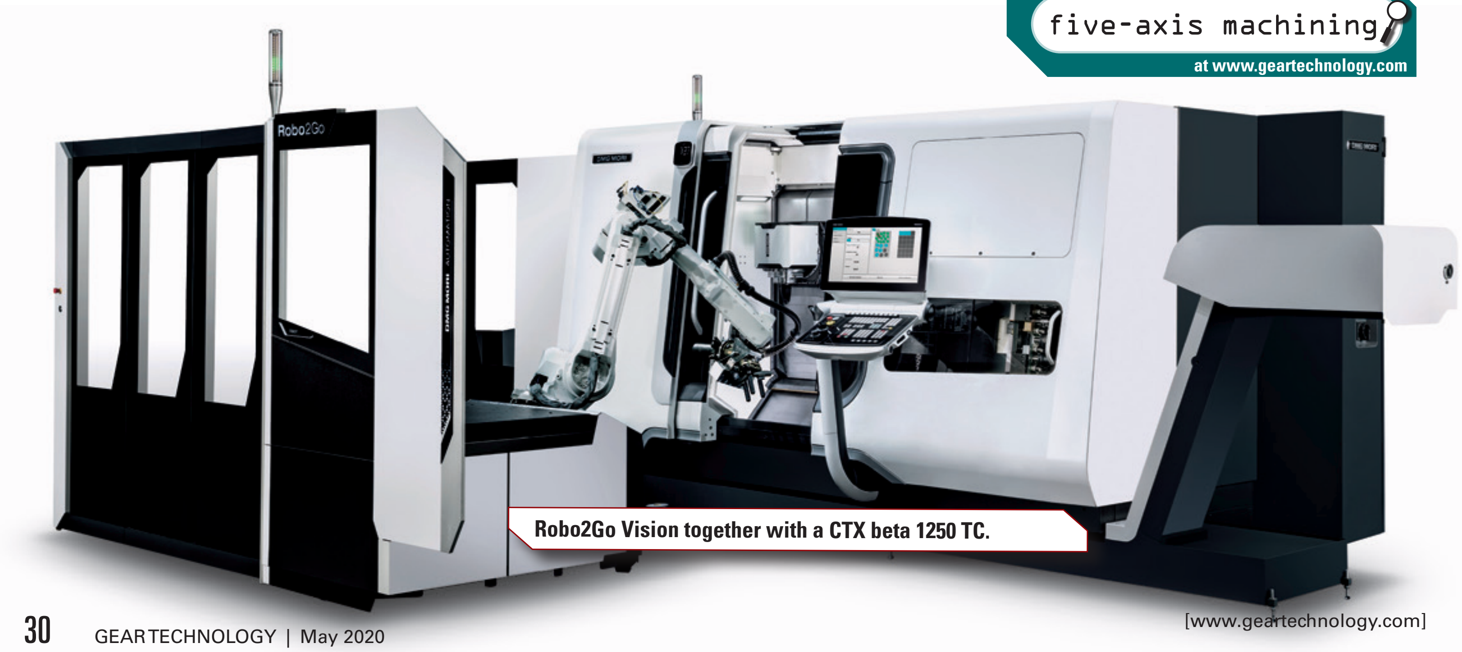

Robo2Go Vision together with a CTX beta 1250 TC.


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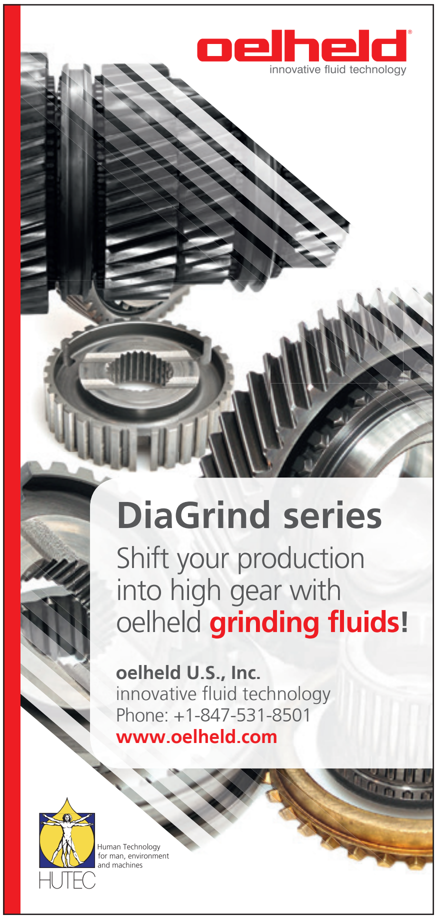
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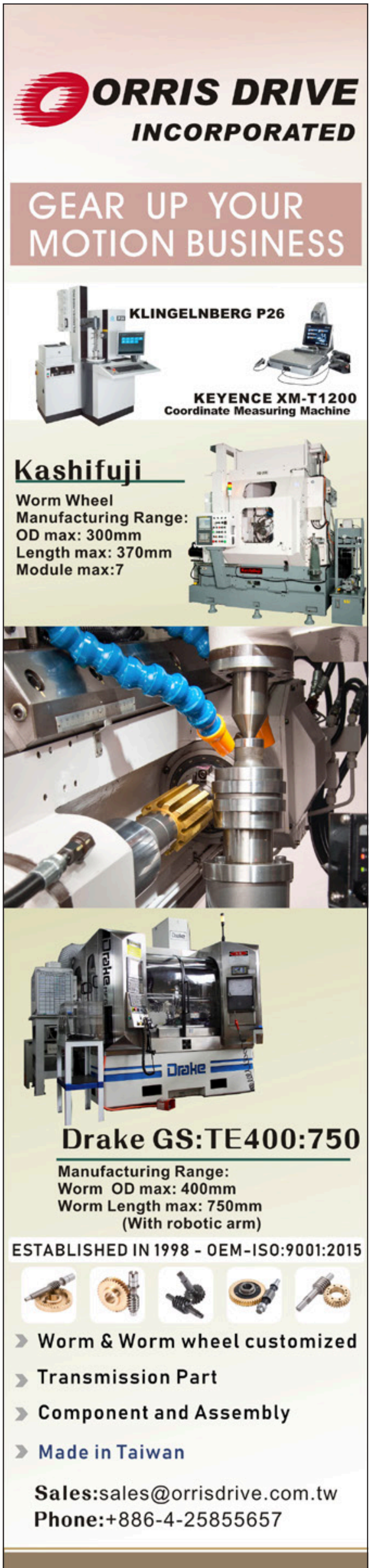
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New Guideline for Determining the Reliability of Planetary/Spur Gear Units

Dr.-Ing. Dirk Strasser and Technical Officer Dirk Stemmjack
of the VDMA Power Transmission Association

In the wind power industry, the reliability of powertrain components plays a major role.

Especially in multi-megawatt offshore applications, an unplanned replacement of drivetrain components can lead to extremely high costs.

Hence, the expectation of wind farm operators is to forecast the system reliability. Under the leadership of the VDMA (Mechanical Engineering Industry Association), the standardization paper 23904 "Reliability Assessment for Wind Turbines" was published in October 2019.

Up to now, wind gearboxes have been designed according to IEC 61400-4. This specifies minimum safety requirements for all relevant load-carrying components in the gear unit, which must be fulfilled for the various operating and extreme loads (Ref. 3). For example, the gear teeth are designed in accordance with ISO 6336-3 and ISO 6336-2, with minimum safety factors for the tooth root and flank load carrying capacity, and also the scuffing and micro-pitting load carrying capacity, in accordance with ISO/TS 6336-20 or ISO/TS 6336-21 and ISO/TS 6336-22. The shafts are designed according to DIN 743, bolted connections according to VDI 2230, and structural components are designed according to the FKM guidelines "Dimensioning of Machine Components Made of Steel and Cast Iron" and "Fracture Mechanics" (Ref. 4), specifying the boundary conditions for the calculation. What all calculation methods have in common is that they are based on a safety concept, i.e. — the permissible load is evaluated with the load that occurs in the form of a safety factor. Standardization paper 23904 provides a method for calculating the system reliability of gearboxes in wind turbines (Fig. 1). The method is essentially based on the principles of statistical determination of failure probability according to Bertsche (Ref. 5).

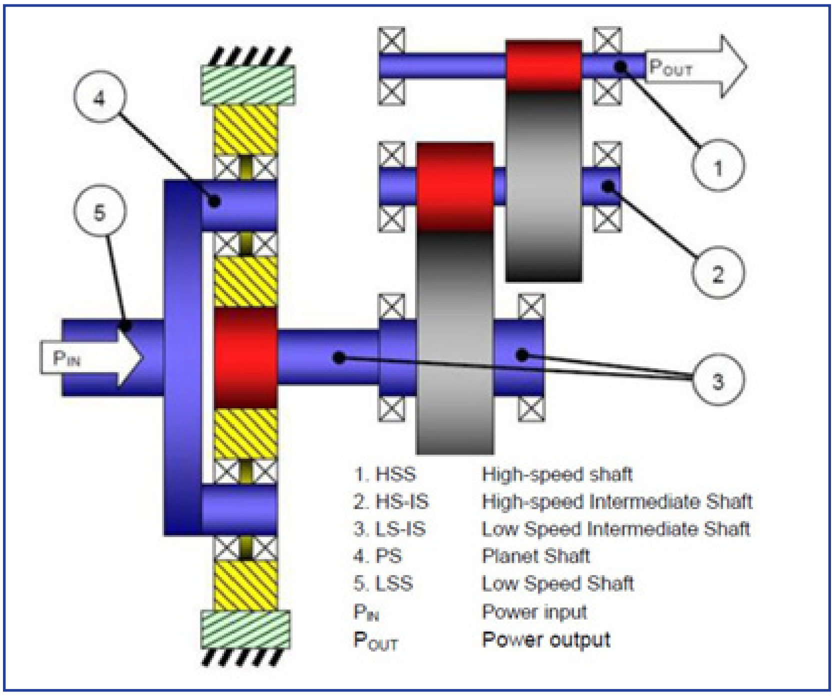

Figure 2 Determination of the functional elements (Ref. 1).

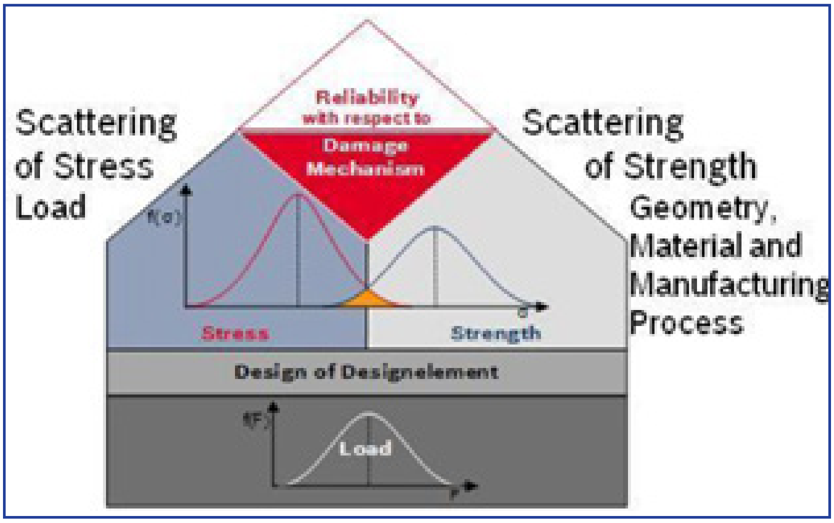

Figure 1 System reliability.

Theoretical calculation approaches are not available for all failure mechanisms occurring in real operation. The present method is limited to failure mechanisms for which a fatigue life can be described according to the recognized rules of technology. It is therefore possible to investigate parameters influencing reliability and to compare gear designs. An absolute forecast of the system reliability is not yet possible. For this purpose, calculation approaches for the failure mechanisms that have not been calculable thus far, or associated statistical distributions must be determined in the future.

The method first identifies the functional ealements that are relevant for the determination of system reliability (Fig. 2). Typically, these are the

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power transmitting components and supporting structures.

In the next step, the so-called system elements are determined based on failure mode effect analysis (FMEA); the system elements describe the failure mechanisms of the functional elements. For example, a gear wheel can fail due to a tooth root bending fatigue or pitting damage (Fig. 3).

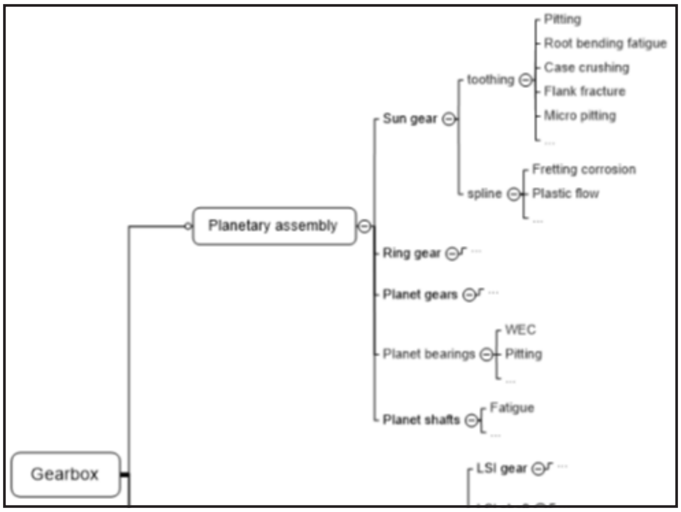

Figure 3 System elements.

The system elements are then classified, whereby system elements are classified as reliability relevant (A1, A2, B) and neutral (C) for the system under consideration (Fig. 4). A1 represents those elements for which calculation methods are available (e.g. — ISO 6336), while A2 refers to elements for which calculation methods are not available. Elements of category B are characterized by non-deterministic error distributions (e.g. — scuffing or smearing). Experience and experiments should therefore be used to predict the reliability of these elements. Category C elements are irrelevant to the reliability of the system and are therefore not considered in the calculations. The A1, and partly A2, system elements are considered in the present reliability calculation. The classification corresponds to the current state of the art and will be adjusted if a recognized calculation approach becomes available for an A2 element.

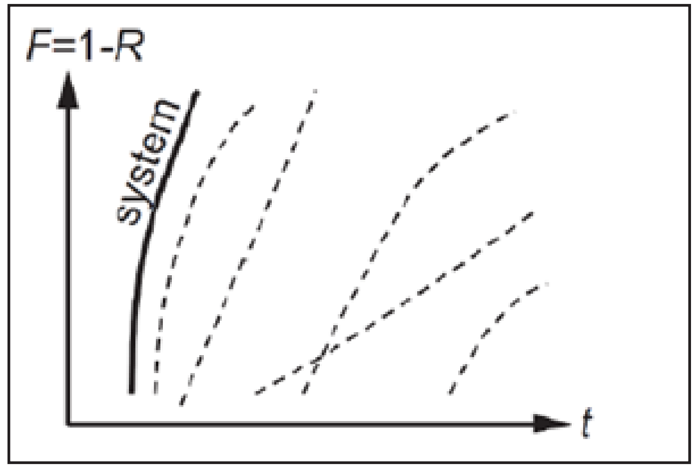

Figure 5 Calculation of the system reliability (Ref. 6).

The system reliability is determined by multiplying the reliability of the system elements. This assumes that the failure modes are independent of each other and that a failure leads to the failure of the functional element (Boolean condition) (Fig. 5).

$$R_s(t) = R_{C1}(t) \cdot R_{C2}(t) \cdot \ldots \cdot R_{Cn}(t) = \prod_{i=1}^{n} R_{Ci}(t)$$

The method provides calculation approaches for the A1

Life calculation	A1 recognized codes available	A2 recognized codes not available	B recognized codes not available	C irrelevant
Load Profile	Deterministic	Deterministic	Stochastic	Stochastic
Typical Weibull shape	$\beta > 1$	$\beta > 1$	$0{,}8 \le \beta \le 1{,}2$	$0 \le \beta \le 1$
Gears	• Pitting • Root bending fatigue	• Flank fracture • Rim fracture	• False brinelling • Hard-end contact • Scuffing • Tip fracture • Abrasive wear • Micropitting	• Case crushing • Overload fracture • Plastic deformation
Rolling bearings	• Rolling contact fatigue (pitting)	• Cage fracture • Rim fracture • Ring fracture • Subsurface initiated fatigue (WEC)	• Fretting corrosion • Smearing • False brinelling • Abrasive wear • Thermal runaway • Thermal fracture • Surface initiated fatigue (Micropitting) • Ring creeping	• Moisture corrosion • Excessive voltage • Current leakage • Plastic deformation by handling • Plastic deformation by debris • Plastic deformation
Shafts	• Fatigue		• Overload fracture • Loosening (axial)	

Figure 4 Classification of the system elements.

system elements.

The reliability of a component R is calculated using a 3-parametric Weibull distribution. These are the shape parameter β, the characteristic lifetime η for the failure probability $F(\eta)=63.2\%$ and the location parameter γ, which is often interpreted as failure-free time in fatigue analysis. The reliability $R(t)=1-F(t)$ is the complement of the failure probability. If the component lifetime B_x is specified for another failure probability $F(B_x)=$ x%, the lifetime B_{10} is calculated as follows:

$$B_{10}=\frac{B_X}{\frac{\gamma}{B_{10}}+\left(1-\frac{\gamma}{B_{10}}\right)\cdot\sqrt[\beta]{\frac{\ln(1-x)}{\ln(1-0{,}1)}}}$$

$$\eta=\frac{B_X-\gamma}{\sqrt[\beta]{-\ln(1-x)}}$$

$$R(t_d)=\begin{cases}1 & \text{If } t_d\leq\gamma\\ e^{-\left(\frac{t_d-\gamma}{\eta}\right)^{\beta}} & \text{If } t_d>\gamma\end{cases}$$

Recommendations for the form parameters and f_{tb} are given in the present paper.

The method provides in addition an extended calculation approach for the error modes tooth root breakage and pitting of involute gears. Based on ISO 6336-6 (Ref. 2), the damage sum for a certain load spectrum is determined and compared with the underlying Wöhler curve. Iteratively, the spectrum is expanded over time and the corresponding failure probability is calculated for each calculation step. By this, the failure probability of the system element over the operating time is obtained (Fig. 6).

The essential content of the method has been transferred to IEC 61400-4. The publication of Edition 2 will contain a chapter dealing with the determination of gearbox reliability, and there will be a reference to the VDMA paper. The IEC 61400-4 Edition 2 will be available as of 2021.

For more information.

Questions or comments regarding this paper? Contact Dirk Strasser at *dirk.strasser@zf.com*.

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Dr.-Ing. Dirk Strasser is Senior Expert in Gearbox & Innovation R&D at ZF Wind Power, Belgium.

Dirk Stemmjack is Technical Advisor of VDMA trade association and Power Transmission Engineering and Committee Manager of ISO/TC 14 and ISO/TC 60/SC 2.

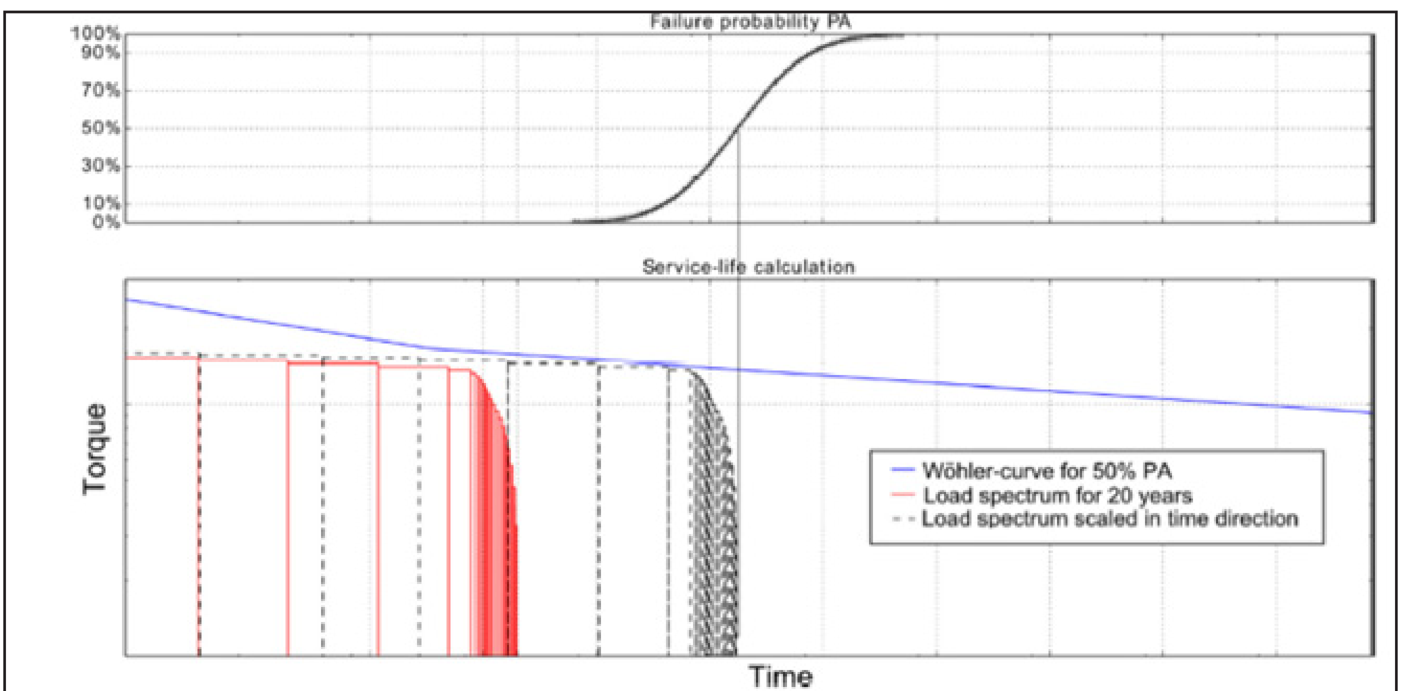

Figure 6 **Iterative determination of the probability of failure based on the accumulation of damage according to ISO 6336-6.**

Optimal Polymer Gear Design: Metal-to-Plastic Conversion

Dr. Alex Kapelevich

Introduction

Nowadays, the progress in polymer materials and injection molding processing has enabled a drastic expansion of plastic gear applications. They are used not only for lightly loaded motion transmissions, but also in moderately loaded power drives in automotive, agriculture, medical, robotics, and many other industries. According to (Ref. 1), "plastic gears may be considered for powertrain applications, like auxiliary drives of vehicle drivetrains, industrial gear units and even the main transmissions of light vehicles." This basically means replacing the currently used metal gears with plastic ones. This metal-to-plastic conversion takes advantage of the benefits of plastic gears—such as low production cost, reduced weight and inertia, low noise and vibration, zero corrosion and electric current conductivity—and the advantages of the injection molding process in producing complicated multifunctional parts. However, exact replication of a metal gear design typically does not work, mainly because of the low strength, wear resistance, thermal resistance, and thermal conductivity of polymers compared to metals. These downsides can be compensated for by the optimal design of plastic gears.

Direct Gear Design Method

Traditional gear design is based on rack generation, imitating the hobbing process of machined metal gears (Fig. 1). The main advantage of traditional gear design is the ability to use the same hob cutter for machining gears with different numbers of teeth and addendum modifications (X-shifts), significantly reducing tooling inventory. Traditional gear design is also well-supported by standards and the availability of standard gear cutters. At the same time, this gear design method has limited options to optimize gear tooth geometry for achieving maximum performance for a particular application. After selecting the basic (or generating) rack parameters—which in most cases are standard—there are only addendum modifications (X-shifts) that can be considered as optimization parameters.

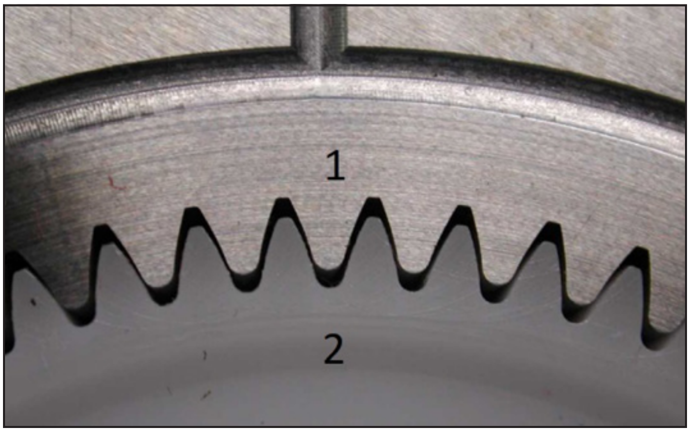

Figure 2 Plastic gear injection molding; 1 – tooling cavity, 2 – gear.

Mass-produced plastic gears are formed by the cost-effective injection molding fabrication technology. A gear molding tool is very different than a hob cutter used for machining metal gears. Its cavity has the same profile as the gear, but adjusted for shrinkage and warpage during polymer cooling and crystallization (Fig. 2). Unlike a hob cutter, it is dedicated to producing one particular gear. Nevertheless, plastic gears are designed the same way as machined metal gears, with all the limitations of the standard traditional gear design, based on rack generation, though without the benefit of using one tool for gears with different numbers of teeth. It is not necessary to use this gear design technique for plastic gears.

The alternative *Direct Gear Design* (Ref. 2) defines and optimizes tooth geometry based on gear mesh characteristics without the limitations of specific gear tooling or machining technology. This gear design method utilizes mathematical modeling, finite element analysis (FEA), and CAD software, allowing us to optimize gear tooth geometry for maximum performance in custom gear drives. It is applicable for gears with symmetric and asymmetric teeth, which makes it the preferable design method for plastic gears.

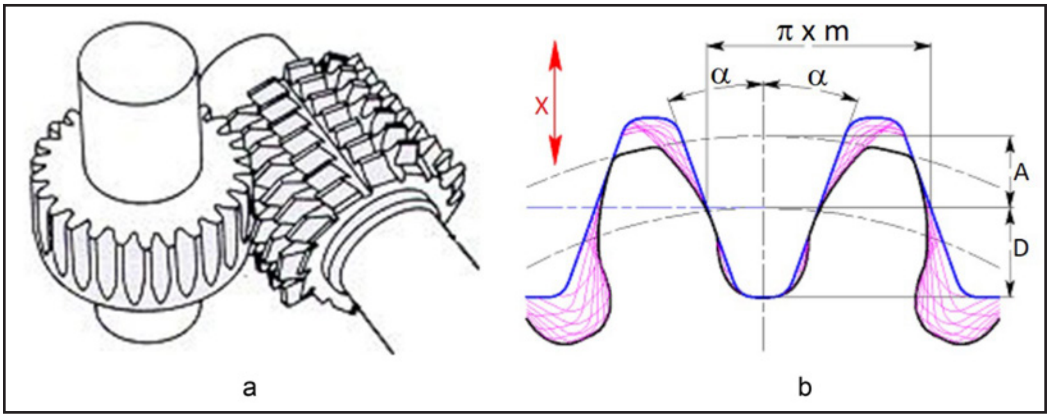

Figure 1 a – metal gear hobbing; b – definition of the gear profile by rack generation; m – module; α – rack profile (pressure) angle; A – gear tooth addendum; D – gear tooth dedendum; X – addendum modification or X-shift.

This method describes a symmetric gear tooth (Fig. 3) as formed by two involute flanks (1) of the base circle diameter d_b, an arc distance between them represented by the tooth thickness S at the reference diameter d, the tooth tip diameter d_a and the root fillet (2).

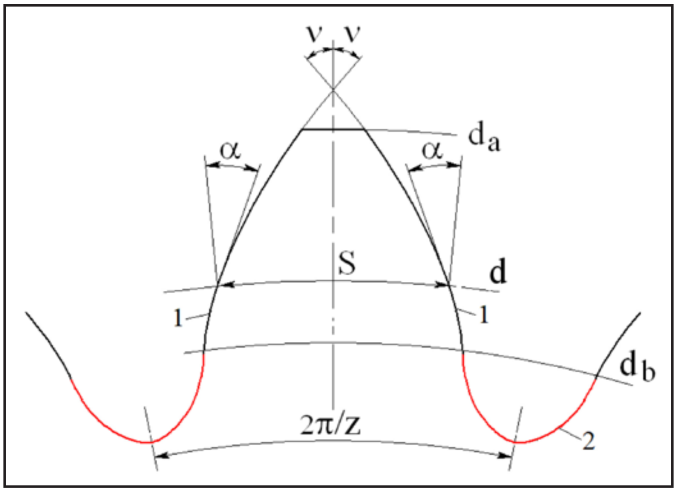

Figure 3 Gear tooth profile construction.

1 – involute tooth flanks
2 – root fillet
d – reference circle diameter
d_b – base circle diameter
d_a – tooth tip circle diameter
S – circular tooth thickness at the reference diameter d
ν – involute intersection profile angle
z – number of teeth

Two gears with equal base circle pitch p_b can be engaged in a gear mesh (Fig. 4).

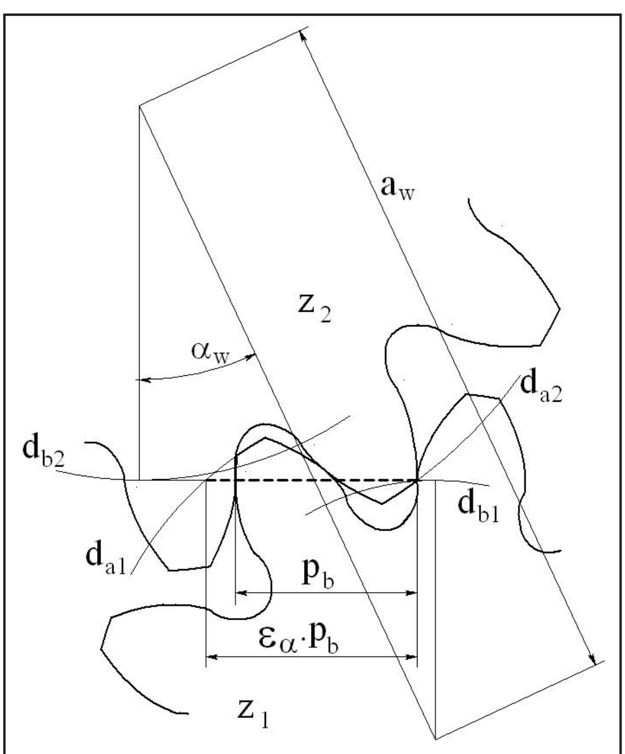

Figure 4 Gear mesh.

a_w – center distance
p_b – base circle pitch
α_w – operating pressure angle
ε_α – contact ratio

The nominal pressure angle α_w and contact ratio ε_α, are defined by the following equations (Ref. 2):

$$\alpha_w = arcinv\left(\frac{inv\nu_1 + u\,inv\nu_2 - \frac{\pi}{z_1}}{1+u}\right) \tag{1}$$

$$\varepsilon_\alpha = \frac{z_1}{2\pi}\left[\tan\alpha_{a1} + u\tan\alpha_{a2} - (1+u)\tan\alpha_w\right] \tag{2}$$

Where

$z_{1,2}$ – numbers of teeth of the pinion and gear;

u – gear ratio, $u = \frac{z_2}{z_1}$,

$\alpha_{a1,2}$ – involute profile angles at the tooth tip diameters,

$$\alpha_{a1,2} = \arccos\frac{d_{b1,2}}{d_{a1,2}}$$

Tooth flank optimization. In *Direct Gear Design*, practically every parameter of the gear tooth and mesh is a subject for optimization. It allows us to simultaneously increase the nominal (or designed) pressure angle and the contact ratio, which are defined by tooth geometric parameters in Equations 1 and 2. The operating or effective contact ratio can be defined as the ratio of the tooth engagement angle to the angular pitch. The tooth engagement angle is the gear rotation angle from the start of tooth engagement with the mating gear tooth to the end of the engagement. For a spur gear pair, the effective contact ratio is:

$$\varepsilon_{\alpha e} = \frac{\varphi_1}{360/z_1} = \frac{\varphi_2}{360/z_2} \tag{3}$$

where:

φ_1 and φ_2 – pinion and gear engagement angles (Fig. 5)
$360/z_1$ and $360/z_2$ – pinion and gear angular pitches

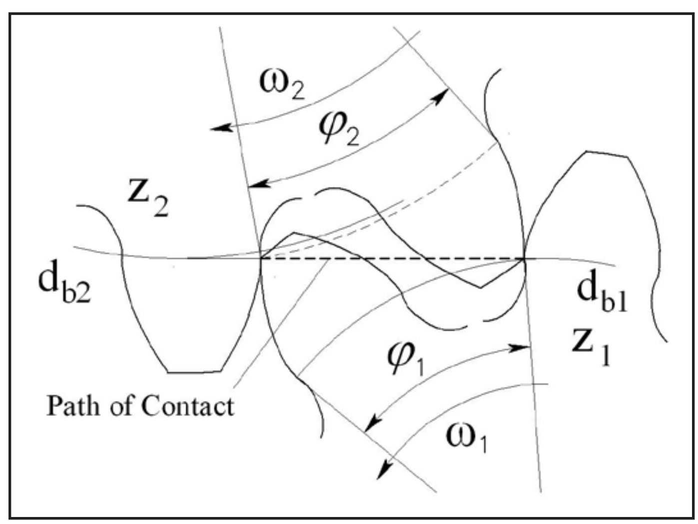

Figure 5 Pinion and gear engagement angles.

The effective contact ratio is affected by manufacturing tolerances and operating conditions, including deflections under the operating load, temperature, etc. of the gears and other gearbox components. In this article, only bending and contact tooth deflections are considered for the definition of the effective contact ratio. Each angular position of the driven gear relative to the driving gear is iteratively defined by equalizing the sum of the tooth contact load moments of each gear to its applied

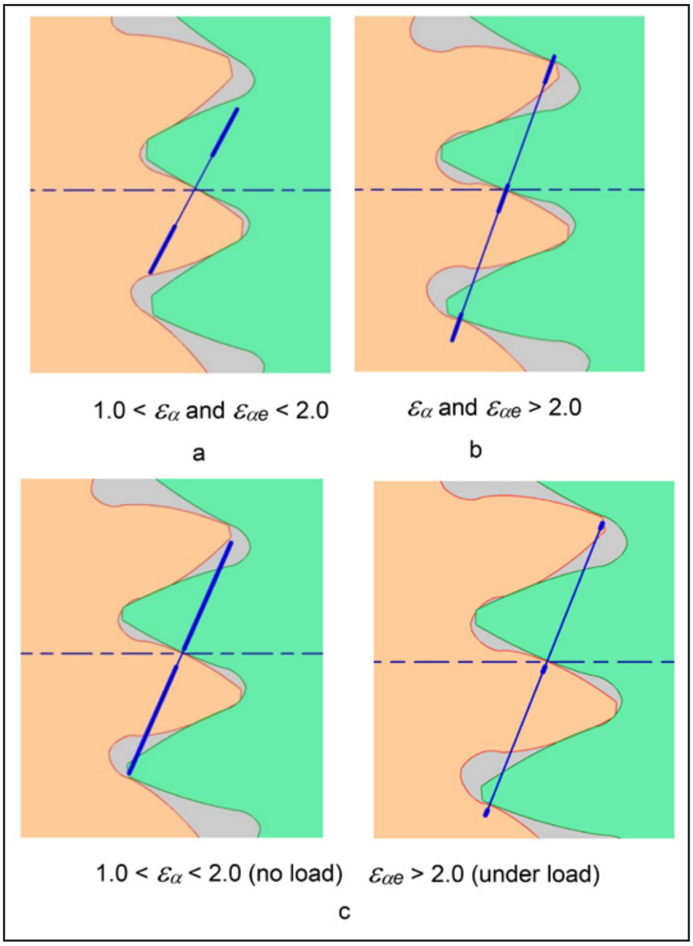

Figure 6 Gears with medium (a), high (b), and transitional (c) contact ratios.

torque. The corresponding tooth contact loads are also iteratively defined to conform to tooth bending and contact deflections, where the tooth bending deflection in each contact point is determined based on the FEA-calculated flexibility and the tooth contact deflection is calculated by the Hertz equation. Under the operating load the effective contact ratio $\varepsilon_{\alpha e}$ is greater than the nominal contact ratio ε_α — mostly because of bending tooth deflections.

Conventional spur gears have medium nominal and effective contact ratios $1.0 < \varepsilon_\alpha$ and $\varepsilon_{\alpha e} < 2.0$ (Fig. 6a). High contact ratio (HCR) spur gears have both nominal and effective contact ratios ε_α and $\varepsilon_{\alpha e} > 2.0$, sharing the transmitted load between at least two tooth pairs and significantly reducing tooth flank and root stresses (Fig. 6b).

Considering that the flexural modulus of gear polymers is dozens of times lower compared to gear steels, the goal of plastic gear flank optimization is to achieve a high pressure angle (≥25°) and an effective contact ratio under the operating load slightly greater than 2.0 (in a range of $\varepsilon_{\alpha e} = 2.05–2.10$) while having a medium nominal contact ratio $1.0 < \varepsilon_\alpha < 2.0$. Such transitional contact ratio gears perform as HCR gears under the operating load (Fig. 6c).

Tooth root optimization. The tooth root fillet is designed after completing the definition of the involute flank parameters. The optimized root fillet profile provides an even distribution for the maximum bending stress along a large portion of the fillet and minimizes bending stress concentration. The initial fillet profile traces the trajectory of the mating gear tooth tip in a zero-backlash mesh (Fig. 7). This prevents interference with the mating gear tooth tip.

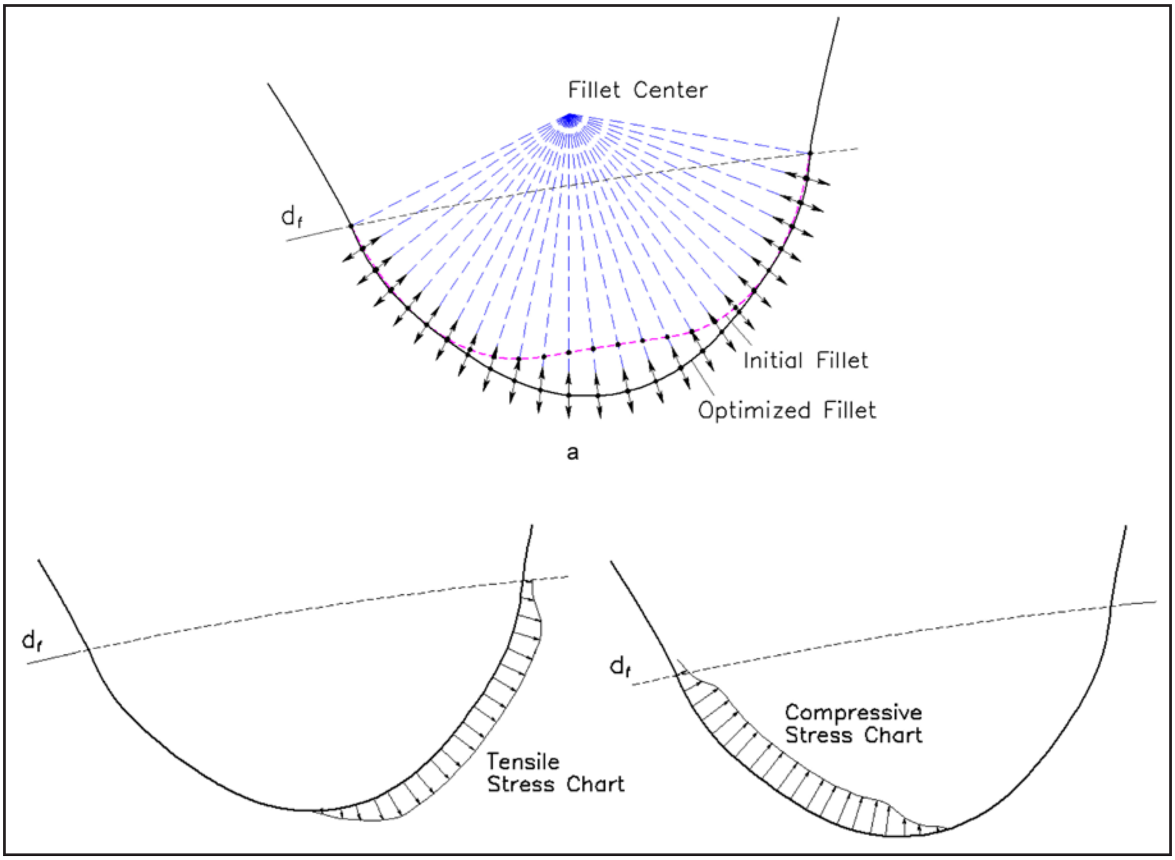

Figure 7 Root fillet profile optimization (a), tensile (b) and compressive (b) stress charts.

Fillet profile optimization utilizes the following calculation processes:

- Definition of a set of mathematical functions that are used to describe the optimized fillet profile. This set may contain trigonometric, polynomial, hyperbolic, exponential, and other functions and their combinations. The parameters in these functions are defined during the optimization process.
- Two-dimensional finite element analysis (FEA) that achieves satisfactory optimization results within a reasonable time period.
- Random search method that defines the next step in the multi-parametric iteration process of the fillet profile optimization.

Detailed description of the tooth root optimization is in (Ref. 2).

Gear Polymers

The selection of gear polymers is driven mostly by the required gear drive load capacity, life, and operating conditions (temperature and humidity, for example). Other considerations may include the cost of the gear drive, weight, noise and vibration, prohibition of external lubrication, etc.

The main polymer gear materials are acetals (POM) and nylons, polyesters, and polycarbonates. They can be used with operating temperatures up to 150°C. For elevated temperatures (<170°C) suitable gear polymers are polyphthalamide (PPA), nylon 46, and similar, high-temperature (<200°C) plastic materials including polyetherimide (PEI), polyetheretherketone (PEEK), and liquid crystal polymers (LCPs).

Some drawbacks of gear plastics properties can be mitigated by additives to the polymer composition. Additives for higher flexural strength include glass, carbon, and aramid (Kevlar) fibers. Tooth flank wear resistance of non-lubricated plastic gears can be increased by anti-wear and anti-friction additives: silicone, polytetrafluoroethylene (PTFE), graphite powders, molybdenum disulfide (MoS2), etc.

It is typically recommended to use dissimilar polymers for mating gears to avoid squeaking noise.

Table 1 Metal-to-plastic symmetric tooth gear conversion

		Metal Gear Pair		Plastic Gear Pair	
Design Method		Traditional (Standard 20° Pressure Angle Tool)		Direct Gear Design	
Gear		Driving	Driven	Driving	Driven
Number of Teeth		32	56	24	42
Normal Module, mm		1.500		2.000	
Pressure Angle		20°		26°	
Generating Rack Coefficients	Addendum	1.0		N/A	
Generating Rack Coefficients	Dedendum	1.25		N/A	
Generating Rack Coefficients	Tip Radius	0.3		N/A	
Generating Rack Coefficients	Radial Clearance	0.25		N/A	
X-shift Coefficient		0.0	0.0	N/A	N/A
Tooth Tip Thickness Coefficient		0.73	0.76	0.25	0.25
Pitch Diameter (PD), mm		48.000	84.000	48.000	84.000
Base Diameter, mm		45.105	78.934	43.142	75.499
Tooth Tip Diameter, mm		50.924	72.427	53.195	88.163
Root Diameter, mm		44.162	86.925	43.468	78.344
Root Fillet		Trochoidal	Trochoidal	Optimized	Optimized
Tooth Thickness at PD, mm		2.330	2.330	3.487	2.740
Normal Backlash, mm		0.050		0.050	
Center Distance, mm		66.000		66.000	
Face Width, mm		13.0	12.0	13.0	12.0
Nominal Contact Ratio		1.66		1.65	
Mesh Efficiency, %		98.7		98.3	
Operating Temperature, °C		80		80	
Maximum Driving Torque, Nm		10.0	-	10.0	-
Gear Material		Steel AIS1-1144, annealed		Victrex HPG 140 GRA [5]	
Flexural Modulus, MPa		200,000		3,500	
Poisson Ratio		0.29		0.4	
Effective Contact Ratio		1.76		2.08	
Yield Tensile Strength, MPa		345		70	
Root Stress (FEA), MPa		56.6	61.6	27.8	27.8
Root Safety Factor		6.1:1	5.6:1	2.5:1	2.5:1
Compressive Strength, MPa		794		100	
Contact Stress (Hertz), MPa		504		54.4	
Flank Safety Factor		1.6:1		1.8:1	

Metal-to-Plastic Conversion

An example of the metal-to-plastic symmetric tooth gear conversion is presented in the Table 1. In this case, a moderately loaded standard gear pair made out of the annealed steel AISI 1144 is supposed to be replaced with a plastic gear pair made of Victrex HPG 140 GRA. Previously, Victrex PEEK polymers were used for metal gear replacement in an internal combustion engine mass balance system (Refs. 3–4).

Overlays of the metal and symmetric plastic gear tooth profiles are shown (Fig. 8).

Despite the fact that the yield tensile strength and also the compressive strength of AISI-1144 steel is significantly greater than that of the Victrex HPG140 GRA polymer, the plastic gear's tooth size increase and flank and root optimization result in acceptable root bending stress and flank contact stress safety factors.

For uni-directionally loaded gear drives undergoing

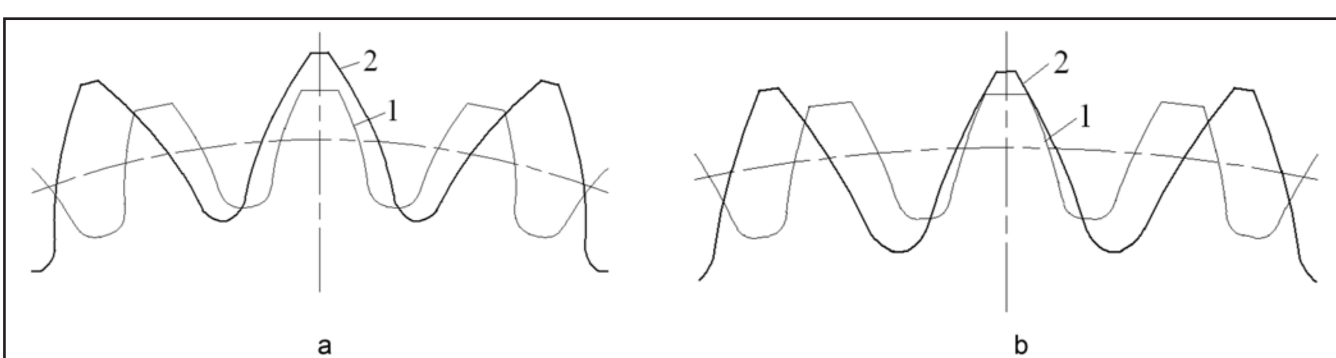

Figure 8 Metal (1) and plastic (2) gear tooth profile comparison; a – pinion teeth, b – gear teeth.

metal-to-plastic gear conversion, asymmetric tooth plastic gears can be considered. They allow for an additional performance enhancement by improving the load capacity of the primary drive tooth flanks at the expense of the opposite coast tooth flanks, which are unloaded or lightly loaded during a relatively short work period (Ref. 6).

Direct Gear Design describes an asymmetric gear tooth construction similarly to a symmetric one, but in this case, it is formed by the involute drive and coast flanks unwound from two different base circle diameters d_{bd} and d_{bc} (Fig. 9).

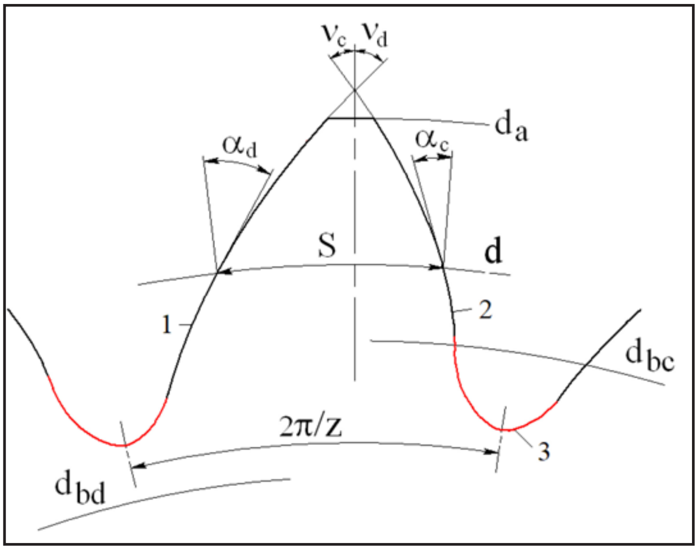

Figure 9 Asymmetric gear tooth profile construction.

1 – drive tooth flank
2 – coast tooth flank
3 – root fillet
d_{bd} – drive flank base circle diameter
d_{bc} – coast flank base circle diameter
ν_d – drive flank intersection profile angle
ν_c – coast flank intersection profile angle

Table 2 presents a metal-to-plastic symmetric tooth gear conversion similar to the one shown in Table 1 with additional columns for the asymmetric plastic gear's data.

Overlays of the metal and asymmetric plastic gear tooth profiles are shown (Fig. 10).

Using optimized asymmetric tooth plastic gears for uni-directionally loaded gear drives can additionally reduce the contact stress and increase drive tooth flank durability.

Conclusion

The goal of using the optimal plastic gear design for metal-to-plastic conversion is to utilize the benefits of polymer materials and injection molding technology, and simultaneously to compensate for relatively low load capacity.

Design guidelines for optimal plastic gear design include:

Increasing tooth size (larger module or coarser diametral pitch) to reduce root bending stress and reducing numbers of teeth to keep the required gear ratio and center distance. This also reduces tolerance sensitivity—especially for fine pitch gears.

Optimizing tooth flanks to achieve an effective (under load) contact ratio ≥ 2.0 and at the same time higher operating pressure angle, which is possible considering the low flexural module of polymers compared to steels. This allows for the distribution of the transmitted load between at least two tooth pairs, significantly reducing tooth flank and root stresses and increasing tooth flank wear resistance.

Optimizing the root fillet profile for root bending stress reduction.

Applying an asymmetric tooth profile for uni-directionally loaded gear drives.

Acknowledgement. The author would like to acknowledge that this research was accomplished with the support of Victrex plc.

For more information.

Questions or comments regarding this paper? Contact Alex Kapelevich at *ak@akgears.com*.

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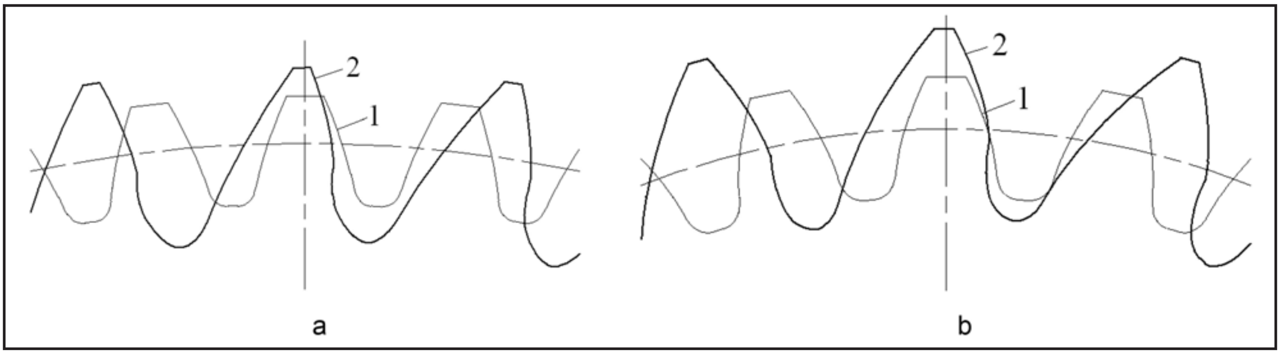


Figure 10 Metal (1) and asymmetric plastic (2) gear tooth profile comparison; a – pinion teeth, b – gear teeth.

Table 2 Metal-to-plastic symmetric tooth gear conversion with asymmetric plastic gear data

		Metal Gear Pair		Plastic Gear Pair		Plastic Gear Pair	
Design Method		Traditional Gear Design (20° Pressure Angle Rack)		Direct Gear Design (Symmetric Teeth)		Direct Gear Design (Asymmetric Teeth)	
Gear		Driving	Driven	Driving	Driven	Driving	Driven
Number of Teeth		32	56	24	42	24	42
Normal Module, mm		1.500		2.000		2.000	
Pressure Angle		20°		26°		32°/10°*	
Generating Rack Coefficients	Addendum	1.0		N/A		N/A	
	Dedendum	1.25		N/A		N/A	
	Tip Radius	0.3		N/A		N/A	
	Radial Clearance	0.25		N/A		N/A	
X-shift Coefficient		0.0	0.0	N/A	N/A	N/A	N/A
Tooth Tip Thickness Coefficient		0.73	0.76	0.25	0.25	0.25	0.25
Pitch Diameter (PD), mm		48.000	84.000	48.000	84.000	48.000	84.000
Base Diameter, mm		45.105	78.934	43.142	75.499	40.706/ 47.271*	71.236/ 82.724*
Tooth Tip Diameter, mm		50.924	72.427	53.195	88.163	53.655	88.681
Root Diameter, mm		44.162	86.925	43.468	78.344	42.936	77.871
Root Fillet		Trochoidal	Trochoidal	Optimized	Optimized	Optimized	Optimized
Tooth Thickness at PD, mm		2.330	2.330	3.487	2.740	3.490	2.742
Normal Backlash, mm		0.050		0.050		0.050	
Center Distance, mm		66.000		66.000		66.000	
Face Width, mm		13.0	12.0	13.0	12.0	13.0	12.0
Nominal Contact Ratio		1.66		1.65		1.66**	
Mesh Efficiency, %		98.7		98.3		98.3	
Operating Temperature, °C		80		80		80	
Maximum Driving Torque, Nm		10.0	-	10.0	-	10.0	-
Gear Material		Steel AIS1-1144		Victrex HPG 140 GRA		Victrex HPG 140 GRA	
Flexural Modulus, MPa		200,000		3,500		3,500	
Poisson Ratio		0.29		0.4		0.4	
Effective Contact Ratio		1.76		2.08		2.10**	
Yield Tensile Strength, MPa		345		70		70	
Root Stress (FEA), MPa		56.6	61.6	27.8	27.8	31.7	29.6
Root Safety Factor		6.1:1	5.6:1	2.5:1	2.5:1	2.2:1	2.4:1
Compressive Strength, MPa		794		100		100	
Contact Stress (Hertz), MPa		504		54.4		51.1	
Flank Safety Factor		1.6:1		1.8:1		2.0:1	

* drive/coast flank
** drive flank

Dr. Alex Kapelevich has a Master Degree in Mechanical Engineering at Moscow Aviation Institute and a Ph.D. in Mechanical Engineering at Moscow State Technical University, Moscow. He operates the consulting firm AKGears, LLC, a developer of trademarked Direct Gear Design methodology and software. He has 30 years of experience in custom gear drive development. His areas of expertise are gear transmission architecture, planetary systems, gear tooth profile optimization, gears with asymmetric teeth, and gear drive performance maximization. Alex is author of the book titled Direct Gear Design and many technical

Prototyping on Bevel Gear Cutting and Grinding Machines

Dr. Hermann J. Stadtfeld

Why Prototyping with End-mills on Bevel Gear Machines?

Manufacturing of spiral bevel and hypoid gears can be conducted in several ways. The following methods are commonly known:

A. ***Face hobbing*** with a circular face cutter, which rotates while the work rotates in the opposite direction (continuous indexing).

B. ***Face hobbing*** with tapered hob (peripheral cutter), which rotates while the work rotates as well (continuous indexing).

C. ***Planning method*** with one or two tools which move linearly, while the work either is performing a roll rotation or a combination of roll rotations and an additional rotation for a spiral-shaped flank line (single indexing).

D. ***Face milling***, with circular face cutter, which rotates while the generating gear is not rotating, the work only performs a roll, but no indexing motion (single indexing).

E. ***Universal 5-axis milling*** with pencil-shaped end mill or disk-shaped cutter (single slot manufacturing).

Methods A through E are well known and have been performed for more than 50 years. Method E became available with the possibility to enter complex free form surfaces into the control of 5-axis universal milling machines. While the manufacturing time is between 10 and 100 times that of the processes A through D and the accuracy might generally be lower than that of the dedicated machines used to perform methods A through D. The advantage of 5-axis bevel gear machining is the flexibility. No special cutting tool is required and the bevel gear size is only limited by the size of the 5-axis machines available (Refs. 1–2).

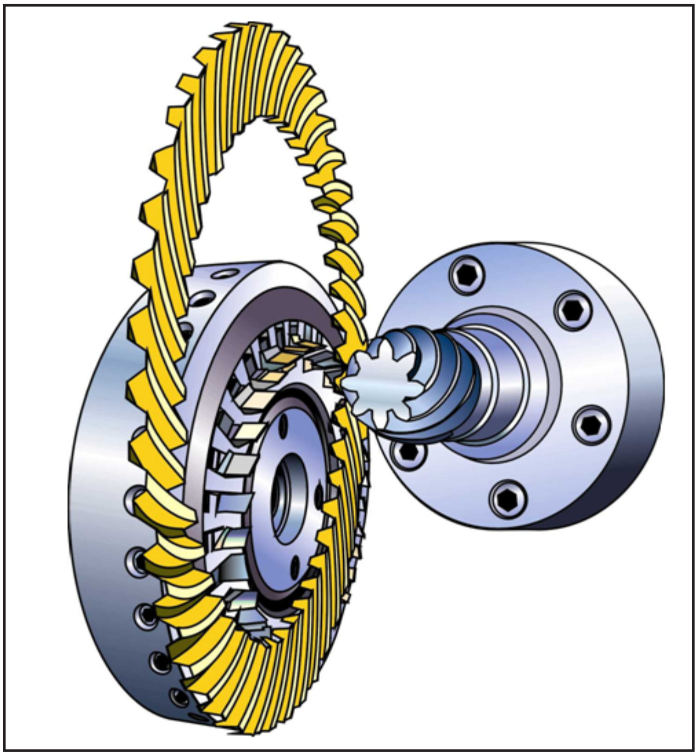


Figure 1 **Face cutter representing one tooth of a generating gear.**

Five-axes machining uses a spherical or cylindrical shaped mill to shape the flank surfaces. The data post processing uses flank surface points and in some cases normal vectors to calculate the machining paths. The machining paths have to be close enough to achieve enveloping paths which approximate the target surface precise enough. The orientation of the enveloping paths (flats) is only linked to the machining strategy, in order to minimize the machining time and the deviation from the target flank surface. It has to be considered in manufacturing of bevel gears with machining centers that a generated bevel gear tooth consists of up to 7 different areas:

Flank surface — first flank
Flank surface — second flank
Root fillet radius — below first flank
Root fillet radius — below second flank
Slot bottom — between both root fillet radii
Undercut section — below first flank and above root fillet
Undercut section — below second flank and above root fillet

The true profile and lead generation according to the gearing law only works within the flank surface and in the root fillet area from the flank transition down towards the root bottom, ending in the area of the 30° tangent point. Depending on the severity and character of the undercut it is not possible to generate this area precisely with correct normal vectors. Also the slot bottom, connecting the fillet region from the 30° tangent through the deepest bottom land to the opposite side root radius at the 30° tangent cannot be generated using the common surface generating algorithm for bevel and hypoid gears.

In the case of face hobbed gears with extended toe or heel ends, it becomes also equally difficult or impossible to generate the extension of the flank surface, which in many cases does not consist of a true flank surface according to the gearing law. One typical example is slotted nose pieces, which represent flank surface extension far behind the heel of the pinion to be clamped in front of the nose piece. However, those problem areas are formed with a face cutter head, which represents one tooth of the generating gear exactly the same way as the generating gear in Figure 1 will form them, i.e. — as undercut section, as root bottom area or as enveloping form cuts beyond the theoretical face width. If the undercut, root bottom area etc. are formed by the generating gear, then it is assured that rolling without disturbances between pinion and gear can occur. Undercut, for example, is not an "evil" caused by the manufacturing process; rather, it is a geometrical necessity in order to assure correct rolling

The following is another chapter from Dr. Hermann J. Stadtfeld's new book, Practical Gear Technology, part of an ongoing series of installments excerpted from the book. Designed for easy understanding and supported with helpful illustrations and graphic material, the e-book can be accessed for free at *Gleason.com.*

without interferences (Ref. 3).

The solution for the problem areas is not a substitution of those sections with plane, cylindrical or parabolic surface elements because of the risk of either weakening the teeth or causing rolling disturbances.

Universal Method Derived from Face Cutting Process

The face milling method defines flank surfaces dependent on basic settings which define the relative location between a face cutter head, a generating gear axis and a work axis — as well as a kinematic relationship between those three components. A spread blade face milling cutter envelopes an outside cone and an inside cone which form a circular channel. Cup-shaped grinding wheels are dimensioned to duplicate the cutting channel for one particular gear design (stock allowance taken into account).

A typical cutting or grinding channel is shown (Fig. 2). Particularly for large spiral bevel gear sets, it is common to use pressure angles of 20° for concave and convex flanks. In such a case, outside and inside silhouettes of the cutting channel are cones which have angles of +20° and −20° relative to the axis of rotation. A tapered milling tool with a cone angle of 20°, and a tip diameter with the value of the point width compared to the face mill cutter head, would fit into the cutting channel.

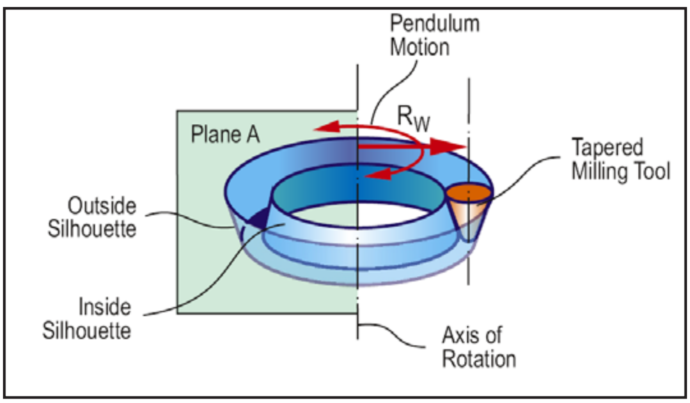


Figure 2 A typical cutting or grinding channel.

If the milling tool has an edge radius and a straight or curved profile and additional features, then the cross sectional view of the milling tool can exactly duplicate the cross section of the cutting channel. Such a milling tool can be positioned in the cutting spindle of a free form bevel gear cutting machine. If the cutting machine axis would perform the regular cycle of movements as it is applied to generate a bevel gear in the conventional face cutter head process, then the pencil shaped milling tool would not form the correct tooth geometry.

However, the milling tool would in this case be located in the center of the face milling cutter. To duplicate the flank surface forming action (cutting and generating), two additions to the standard setup and cutting cycle are necessary to accommodate the pencil milling tool. First, the milling tool is required to be moved from the face mill cutter center to an offset location ("*a*" in Fig. 4). The offset vector is identical to the average cutter point radius vector and can be located in the center of the tooth face width (point *a* in Figure 4). Second, the milling tool has to follow a circular arc in the plane of the face milling cutter. Figure 4 shows the case where the face milling cutter rotational

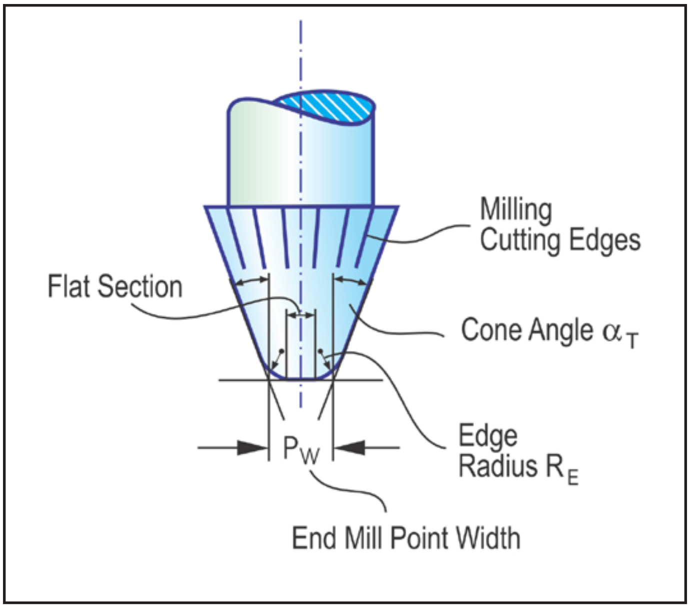


Figure 3 Conical milling tool.

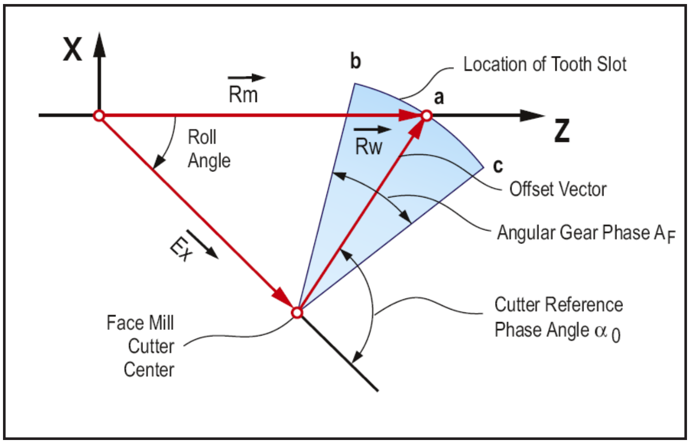


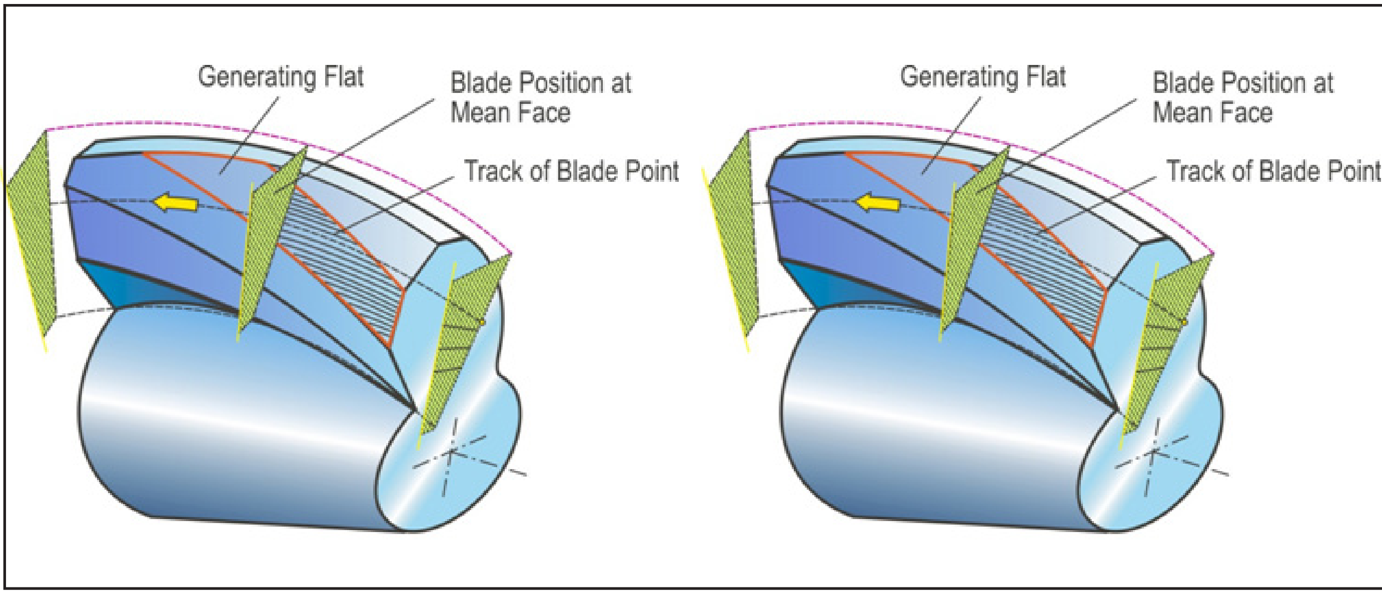
Figure 4 Pencil milling tool moved to offset location.

plane is identical to the plane *X-Z*.

The conventional cutting machine setup positions the cutter center at the position of the tip of the vector *Ex* (Fig. 4) in order to use a tapered milling cutter, the center of the cutter spindle has to be positioned along the path of the arc b-a-c (Fig. 4) and also move between the positions b-a-c (and reverse), while the cutting machine is in one roll position. In the next roll position the movement along b-a-c has to repeat. It is also possible to use a continuous slow roll motion, while the machine axes perform a fast pendulum motion of the tool center between b-a-c.

The cycle described can utilize a standard free-form cutting machine with a standard cutting cycle. The only change vs. the conventional part program is the additional term shown in the formulas below:

Milling Cutter Location	Conventional Face Cutter Center	Additional Term
b:	$\vec{E_x}$	$+ R_w \times \begin{Bmatrix} \sin\left(-q_0+\alpha_0+\frac{A_F}{2}\right) \\ 0 \\ \cos\left(-q_0+\alpha_0+\frac{A_F}{2}\right) \end{Bmatrix}$
a:	$\vec{E_x}$	$+ R_w \times \begin{Bmatrix} \sin\left(-q_0+\alpha_0\right) \\ 0 \\ \cos\left(-q_0+\alpha_0\right) \end{Bmatrix}$



$$\text{c:} \qquad \vec{E}_x \qquad + R_w \times \begin{Bmatrix} \sin\left(-q_0+\alpha_0-\frac{A_F}{2}\right) \\ 0 \\ \cos\left(-q_0+\alpha_0-\frac{A_F}{2}\right) \end{Bmatrix}$$

In order to generate the profile of a tooth, the generating gear has to rotate. This rotation is equal to a rotation of the vector *Ex* (Fig. 4) about the axis *Y* (perpendicular to the drawing plane).

The introduced new process is called "*UNIMILL*." The infrastructure and accuracy level of the free-form bevel gear machine are a desirable platform for bevel gear cutting with the *UNIMIL*L process.

One advantage of the *UNIMILL* method is the fact that it produces identical bevel gear geometries as produced with face milling cutters. Even the generating flats have the same characteristics and angular orientation between the presented method and the face cutter method. Figure 5 (left) shows a three- dimensional representation of the conical milling tool as it simulates the face cutter in one instantaneous roll position. Since the face cutter would produce in this roll position one generating-flat-per flank (indicated on the outside silhouette in Figure 5), the tapered milling tool will produce the identical flat. As the rolling motion progresses, further flats will be produced. Figure 5 (right) shows how the generating flat sections of the tool silhouette relate to the real generating flats on a flank surface.

The generating flat orientation of the 5-axis methods E are different to the face milling or face hobbing cutting method, which will introduce in many cases different roll conditions. A surface structure which is identical to the original face cutter process is a significant advantage of the *UNIMILL* process. A second advantage of the *UNIMILL* method is the fact that standard cycles can be applied (super-imposed by said pendulum motion), e.g. — for soft cutting, which leads to manufacturing times of 5 to 50 times that of the processes A and D, which is in most cases only 50% of the manufacturing time of a 5-axis machine using an end mill according to process E. At the same time, the gear accuracy of the *UNIMILL* method is comparable to the process A and D due to the use of a gear machine tool concept.

A third advantage of the *UNIMILL* method is the unlimited compatibility of the cutting and grinding with face cutters. All existing design and optimization computer programs can be used. Also the nominal data calculations and correction matrixes which are well established and proven in correction software tools such as *G-AGE* can be applied without limitation. An additional advantage of *UNIMILL* is the fact that undercut conditions and root fillet geometry are identical to the original geometry, generated by the face cutter process. As mentioned earlier, the elimination of undercut in an existing design is not an option because of the roll disturbances this will cause.

Even the case of unequal inside and outside blade angles of the analogue face cutter process, a tapered milling cutter with half the included blade angles $(\alpha_{IB}+\alpha_{OB})/2$ as cone angle can be used if the milling tool will be inclined by $\kappa_{mill\text{-}tool}=-(\alpha_{IB}+\alpha_{OB})/2$.

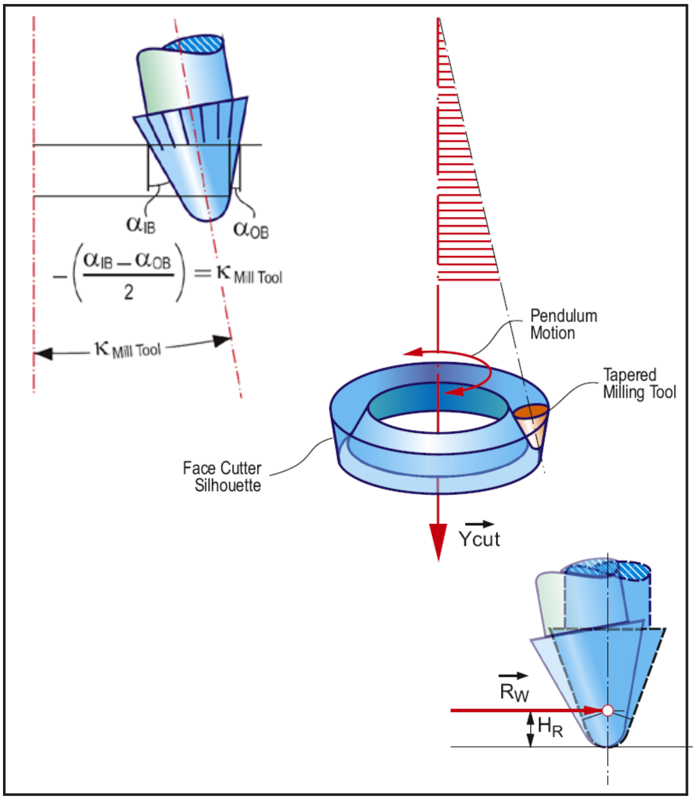


Figure 6 Inclination of tapered milling tool.

The calculation of the position of a tapered milling tool in the general case can be calculated, based on the geometric relationships (Figs. 6 and 7) as follows:

Input:
¤ Cutter tilt = Wx
¤ Cutter swivel = Wy
¤ Mean cutter radius = Rw
¤ Cutter phase angle reference value = α_o
¤ Cutter phase angle = α_x
¤ Roll position = q
¤ Blade reference height = H_R
¤ Sliding base position = X_B
¤ Additional milling tool inclination = κ_{Mill_Tool}
¤ Radial Setting = S
¤ Cutter Radius vector at reference position = $Rw\ (\alpha_0)$

After performing the transformations from conventional basic settings to the settings of a tapered mill cutting tool the following steps can be applied in order to prepare all data for the *UMIMILL* process:

- Chose a number of roll positions that split q_{start} and q_{end}; e.g. — in 50 increments:

→ $q_1, q_2, q_3 \ldots q_{51}$

where: $q_1 = q_{\text{start}}$; $q_2 = q_{\text{start}} + \Delta q$; $q_3 = q_{\text{start}} + 2\Delta q$; $q_{51} = q_{\text{start}} + 50\Delta q$

$\Delta q \Rightarrow \Delta q = (q_{\text{end}} - q_{\text{start}})/50$

- Apply for each roll position the formulas for the tool position; e.g. — for 200 increments:

→ $\alpha_1, \alpha_2, \alpha_3 \ldots \alpha_{201}$

where: $\alpha_1 = \alpha_0 - A_F/2$; $\alpha_2 = \alpha_1 + \Delta\alpha$; $\alpha_3 = \alpha_1 + 2\Delta\alpha$; $\alpha_{201} = \alpha_1 + 200\Delta\alpha$

$\Delta\alpha = A_F/200$

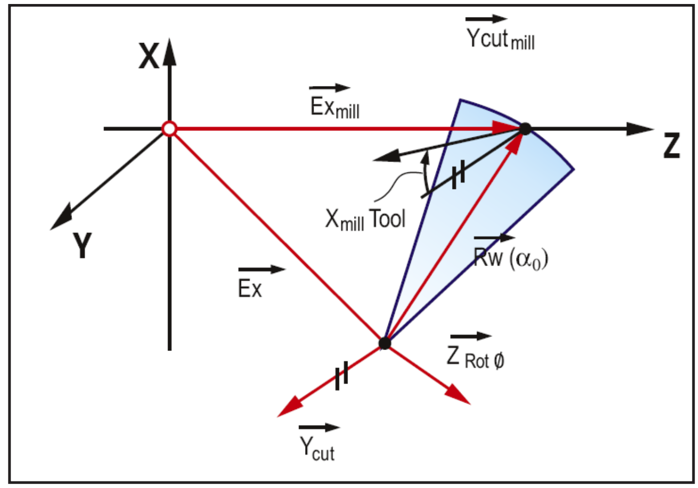


Figure 7 Triangular vector for generating bevel gears with tilted end-mill.

Processing for Generation and Swing Motion

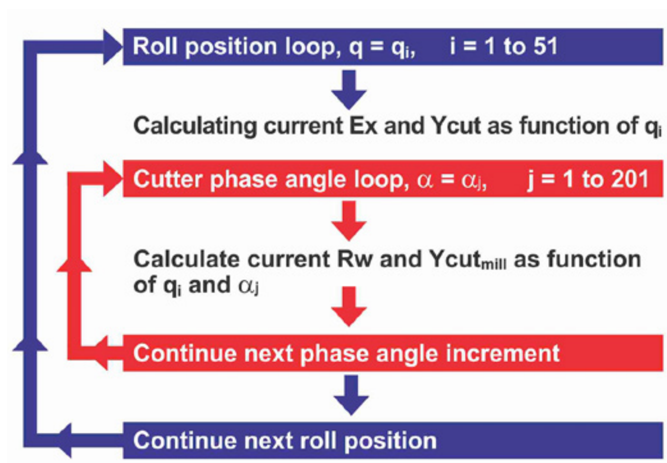
The described method was shown and explained for the single indexing process. It can also be applied to the continuous indexing process. The cutter rotation ω is in a timed relationship to the work rotation, superimposed to the roll motion on the work (in a continuous mode) or applied in discrete roll positions, similar to the previous explanations, where either roll and cutter rotation angle (equal tapered mill position) have been observed in discrete increments:

$$\omega_{work} = \Omega_{Cradle}/RA + \omega\ Z_{Tool}/Z_{Work}$$

or

$$\delta_{work,i,j} = \delta_{work,start} + q_i/RA + \alpha_j Z_{tool}/Z_{work}$$

where
RA… Ratio of Roll



However, the discrete observation and processing of the roll positions lead to a looped data and position processing:

In both cases, continuous or single index machining, the last presented formulas are valid and can be applied. Those formulas can be applied in case of an asymmetrical cutting channel (Fig. 6) as well as for a symmetrical cutting channel (Fig. 2). The symmetrical cutting channel only presents a special case of the more general asymmetrical cutting channel ($\kappa_{mill\_tool} = 0$).

There are a multitude of possibilities to derive the formulas in order to position and move the tapered milling tool. However, trigonometric calculations would in their solution show intrinsic function depending on roll, tool rotation, and work rotation angles as well as linear constants. The derivations shown here use the basic machine settings, which relate to the generating gear. The resulting vectors Ex_{mill} and $Ycut_{mill}$ can be converted to basic settings:

$$S_i = \sqrt{Ex_x^{\,2} + Ex_z^{\,2}}$$
$$q_i = \arctan(Ex_x / Ex_z)$$
$$X_{B,i} = Ex_y$$
$$Wx,_i = \arccos\,(Ycut_{mill,y})$$
$$Wy,_i = \arctan\,(Ycut_{mill,x}\;/\;Ycut_{mill,z}) - q_i$$

Additional basic settings, such as:

X_P

E_M

γ_M

R_A

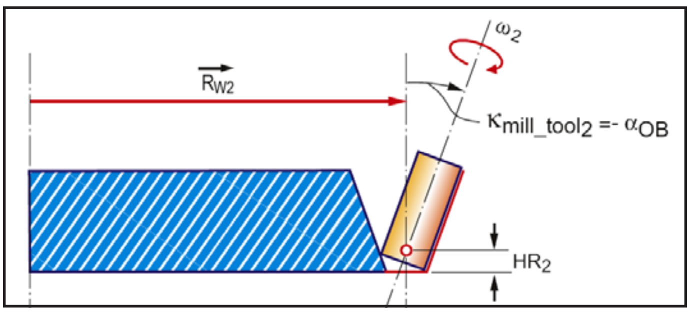


Figure 8 Cylindrical tool, machining outside profile only.

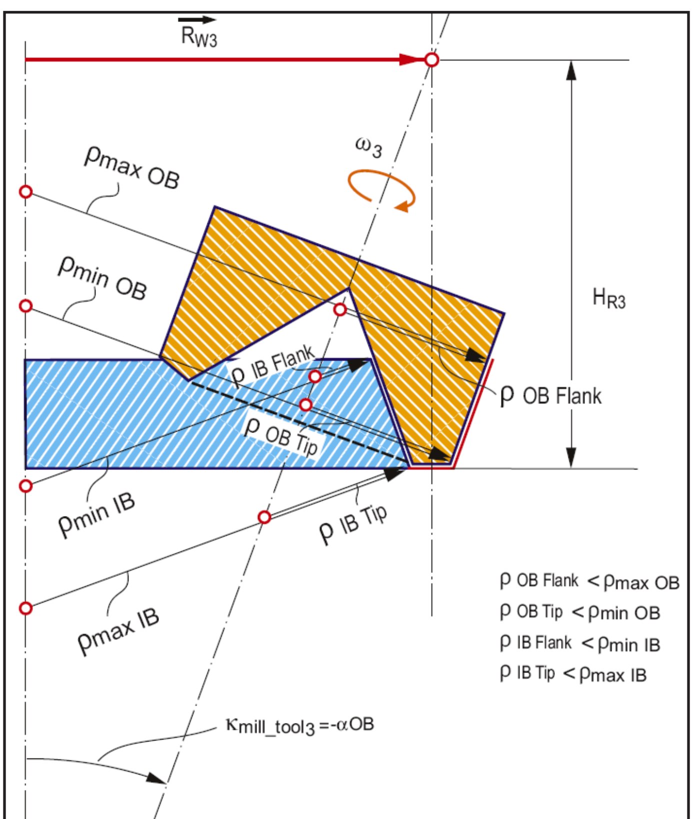


Figure 9 Cylindrical tool with conical inside profile.

do not change during the conversion from conventional tool to tapered mill. The basic settings, as shown above, can be converted into a 6-axes Phoenix coordinate system.

Expanding to a Variety of Highly Efficient Tools

The *UNIMILL* machining method can be expanded to use a milling tool which is, for example, cylindrical and only machines one flank surface at a time, such as the outside flank (Fig. 8). The tool inclination angle in this case is $-\alpha_{OB}$. The maximal diameter of such a tool is limited (Fig. 8). A diameter larger than shown in Figure 8 causes mutilation of the opposite flank (inside flank). It is possible with such a cylindrical tool to machine the opposite flank in a second set of machining passes, if the sign of the tool inclination angle is changed ($+\alpha_{OB}$). For correct definition it should be stated, that the vector R_{W2} points to the centerline of the reference profile. Its preferred location is in the center of the face width; in the case of asymmetric pressure angles, it is located radially in order to split the point width of the reference profile in two equal parts. The point width is the width of the bottom of the reference channel, in an axial plane in the case of face milling cutters and in the offset plane in the case of face hobbing cutters. The milling tool can be located using different references which has no effect on the functionality of the presented method.

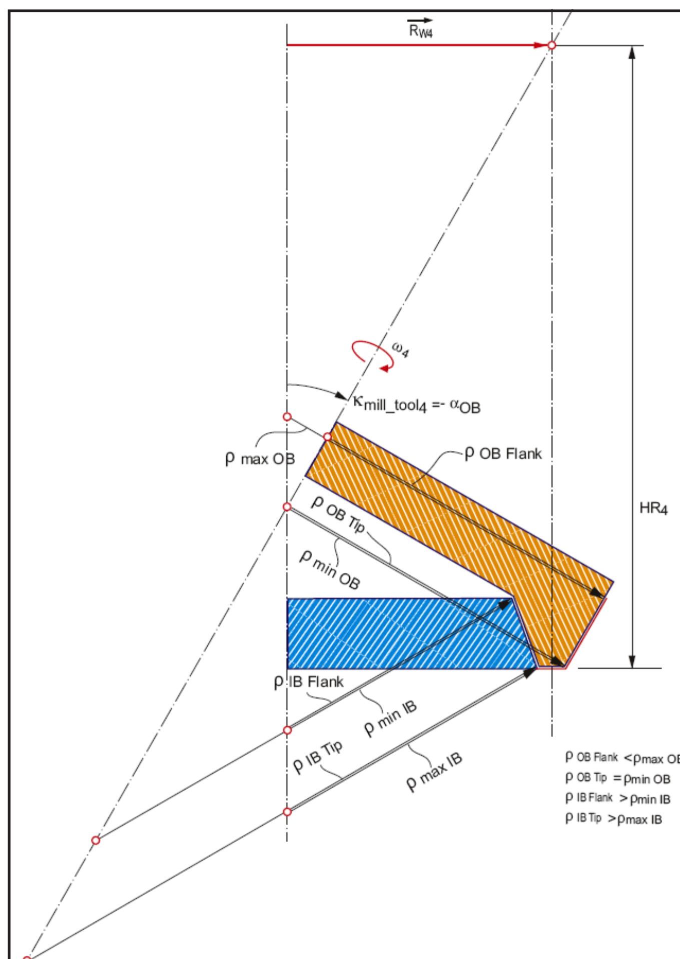


Figure 10 Cylindrical tool with conical inside profile and larger diameter in order to avoid mutilation.

If the tool diameter is increased to a certain extent, it becomes possible to machine the second flank (*IB*) simultaneously to the first (*OB*-flank (Fig. 9).

However, in order to machine a flank without mutilation, the requirement regarding the curvature radius is as follows:

$\rho_{OB\ Tip} \leq \rho_{minOB}$ (given in Fig. 9)

$\rho_{OB\ Flank} \leq \rho_{maxOB}$ (given in Fig. 9)

$\rho_{IB\ Tip} \geq \rho_{maxIB}$ (not given in Figure 9)

$\rho_{IB\ Flank} \geq \rho_{minIB}$ (not given in Figure 9)

The diameter of the cutting tool (Fig. 9) has to be increased until the axis of rotation crosses the origin of ρ_{minOB} (intersection with original cutting tool axis). In such a case, $\rho_{IB\ Tip} = \rho_{maxIB}$ and $\rho_{IB\ Flank} > \rho_{minIB}$ applies (Fig. 10). κ_{mill_tool} (Fig. 10) is still $-\alpha_{OB}$

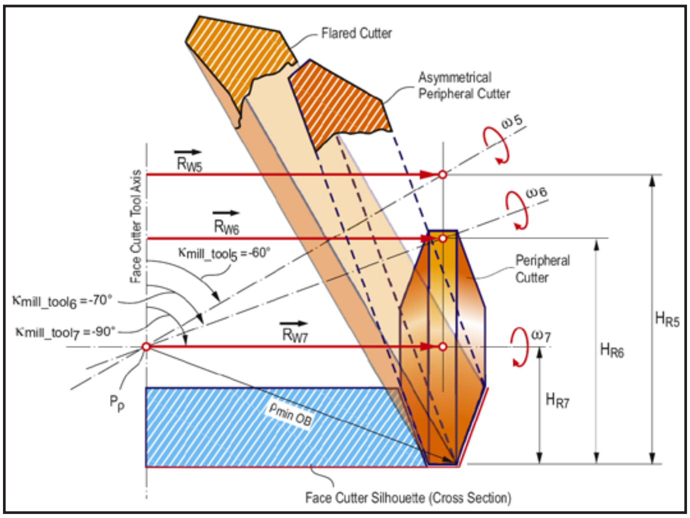


Figure 11 Variety of tools by increasing tool inclination angle, leading to a pure peripheral cutting tool.

(Fig. 8). Different angles of κ_{mill_tool} can be realized, if the axis of rotation intersects with the original tool axis in point P_ρ. P_ρ is determined as the origin of ρ_{minOB}. $\rho_{IB} > \rho_{maxIB}$ and is always given in such a case. Figure 11 shows machining tool geometries based on $\kappa_{mill\_tool} = -60°$, $-70°$ and $-90°$. $\kappa_{mill\_tool} = -90°$ is an interesting special case of a peripheral tool.

In every case in Figure 11 (vector designations 5, 6, and 7) the vector ρ_{minOB} was constructed first. It has an intersection with the face cutter tool axis in point P_ρ. The chosen milling tool inclination angle κ_{mill_tool} leads in Figure 11 to a tool axis, which crosses the face cutter tool axis in point $P\rho$. This leads to the smallest possible milling tool diameter which fulfills the requirements:

$\rho_{OB\ Tip} \leq \rho_{minOB}$ (in Fig. 11 $\rho_{OB\ Tip} = \rho_{minOB}$)

$\rho_{OB\ Flank} \leq \rho_{maxOB}$ (given in Fig. 11)

$\rho_{IB\ Tip} \geq \rho_{maxIB}$ (given in Fig. 11)

$\rho_{IB\ Flank} \geq \rho_{minIB}$ (given in Fig. 11)

Tools and Examples

If *UNIMILL* is utilized as a prototyping method, the use of disk cutters is most productive, but the use of tapered end mills requires the lowest tool investment (Fig. 12-right side and middle). Multi-start fly cutters, which are similar to bevel gear chamfer cutters, present certain restrictions regarding blade point width and edge radius due to the use of standard inserts (Fig. 12-left side). Flared disc cutters which use stick blades (PentacSlimLine) are also available (Ref. 4). The advantage of tapered end mills is that most gear manufacturers can find nearby local tool shops which can manufacture a new milling tool from carbide material, including coating, in less than two weeks. The basic dimensions of a tapered end mill are point width, edge radius and the included angle of the taper.

Figure 12 Variety of *UNIMILL* tools.

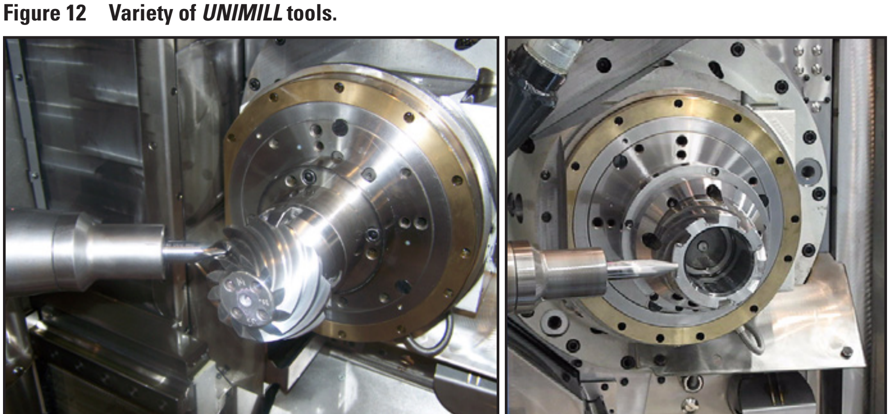


Figure 13 Milling of a face hobbed hypoid pinion (left) and a slotted nose piece (right).

The cutting scenario of a face hobbed hypoid pinion is shown (Fig. 13-left). The end mill moves from heel to toe while it is milling one generating flat at the convex pinion flank. After the end mill exits the slot at the toe, the machine axes set over to the concave side in order to machine the corresponding drive side generating flat.

The movement along the face width is called "swing motion." Changing the swing motion between start and end roll position is possible in three sections, depending on the different chip load in the different areas. After a part is finished, a coordinate measurement is conducted and in the case of significant deviations between nominal and actual flank, *G-AGE* corrections are calculated and sent via network to the Phoenix machine control. Similar to the procedure in conventional bevel gear manufacturing, the corrections are applied in a menu to the basic settings and the *UNIMILL* software converts the basic settings to a part program with axes motion commands.

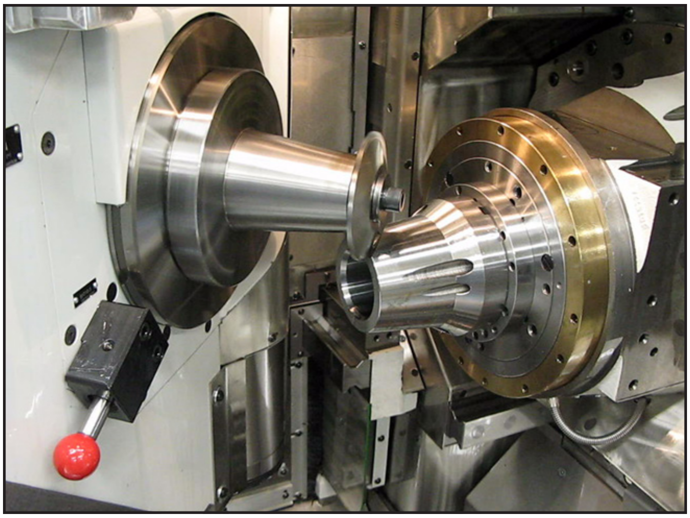


Figure 14 Milling of slotted nose piece with HSS disk cutter.

In Figure 14 the scenario of a nose piece milling with a disk-shaped HSS cutter is shown. In the case of nose pieces, disk cutters are very efficient. The slots are normally very wide and the ot fillet radius can be standardized because root bending strength is not a criterion for those parts.

Today, all the *UNIMILL* software is implemented in the machine control. The control computer receives a download file which includes basic settings with gear blank data, very similar to regular bevel gear machining. The operator screen allows the entering of speeds and feeds, as well as the number of generating flats and over travel amounts, etc. In order to utilize existing experiences in bevel gear manufacturing, the basic settings are calculated by the machine control and displayed to the operator. The basic settings can be changed not only with *G-AGE* corrections, but also by adding or subtracting delta values. The "Master Summary" feature allows return from the developed summary to the original summary at any time.

Figure 15 Different gear types machined with the *UNIMILL* process.

A variety of different parts manufactured with *UNIMILL* is shown (Fig. 15). In addition to spiral bevel and hypoid gears, milling of straight bevel gears has also been developed. The photo (Fig. 15-right) shows a large spiral bevel gearset which was soft cut with *UNIMILL* and then hard skived after heat treatment. The *UNIMILL* process has shown to be suitable for a hard skiving process, which replaces either grinding or skiving with a dedicated face cutter. Just like in soft cutting, the *UNIMILL* hard skiving process also applies to small quantities — as, for example, prototypes — in order to minimize the cost of required equipment and tooling.

Practical Experience with Straight Bevel Gears

In the case of straight bevel gears, in addition to prototype manufacturing, the possibility of machining parts with a front bearing hub is an attractive application for *UNIMILL*. These parts have been manufactured in the past with two-tool generators, which only delivers medium quality in a rather slow process. Often, the material of solid parts with an integrated front hub was difficult to machine because of a high strength requirement. The possibility to use coated carbide tools in *UNIMILL* gives manufacturers an incentive to replace their aged two-tool

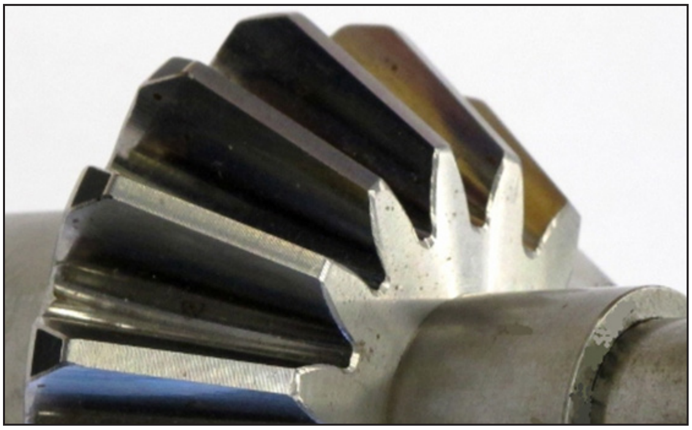


Figure 16 Straight bevel gear with front hub.

generators with modern CNC equipment — allowing for a state of the art closed loop manufacturing. The straight bevel gear (Fig. 16) requires a manufacturing time of 2 hours, with a tool life of 4 parts. The tools can be re-sharpened up to 10 times until they have to be replaced.

Experience in the cutting of straight bevel gears with *UNIMILL* has been gained over the past few years. A variety of tool holder and coated carbide cutting tools were applied. In some cases the manufacturer of these gears like to use pre-slotted parts in order to reduce the amount of chip removal and subsequently reduce the *UNIMILL* cutting time. The software was also expanded for stock division capability, vector feed and a Coniflex quick cycle.

Basic Milling Tool Data

The basic information is retrieved from the Dimension Sheet and from the Blade Profile Grinding Summary of the particular job. Figure 17 shows a section of the Dimension Sheet with the convex and concave pressure angles (highlighted yellow). Both added together (in the present case 20° + 20°) results in the included pressure angle (here equals to 40°). The end-mill cone angle has to be less than half of the included pressure angle. In the present case, a cone angle of 15° is optimal.

G L E A S O N CORPORATION R&D - BEVEL GEAR TECHNOLOGY
HYPOID & SPIRAL BEVEL GEAR DIMENSIONS

	PINION	GEAR
NUMBER OF TEETH.	25	25
PART NUMBER.		
FACE MODULE.		4.233
NORMAL MODULE AT CENTER.		3.606
FACE WIDTH	22.17	22.17
PINION OFFSET.	0.00	
PRESSURE ANGLE - PIN CONCAVE. .	20.00	
PRESSURE ANGLE - PIN CONVEX. . . .	20.00	
LIMIT PRESSURE ANGLE	0.00	
SHAFT ANGLE.	90.00	

Figure 17 Section of Dimension Sheet.

The axial height of the end-mill can be retrieved form the Blade Profile Grinding Summary in Figure 18, item 16 "Axial Grind Depth."

BPG/300 CG BLADE PROFILE GRINDING SUMMARY V. 2.4
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1. SUMMARY: GLEASON CONIFLEX 9" RUNOFF JOB

P I N I O N BLADE SPECIFICATIONS - CONIFLEX (R) Plus

3. CUTTER DIAMETER.	8.999 " = 228.573mm
4. NO. OF BLADES PER SIDE	24
5. CUTTER NUMBER.	132
6. HAND OF CUTTER - BLADE GRINDING	RIGHT
7. TYPE OF BLADES	PENTAC 2-FACE
8. SMALLEST POINT WIDTH AT TOE. . . .	2.14 mm
9. TOP WIDTH IN PCT OF PT WIDTH. . . .	85.671
10. CALC. SOFTWARE	UNICAL-CONIBLD

BLADE DATA	ALL BLADES => OUTSIDE
01. BLADE PRESSURE ANGLE	17.17deg
02. BLADE CLEARANCE ANGLE	11.17deg
03. BLADE DEDENDUM	4.28 mm
04. RADIUS OF CURVATURE - P.A.	0.00 mm
05. RADIUS OF CURVATURE - CLEAR . . .	0.00 mm
06. EDGE RADIUS PRESS. ANG. SIDE . . .	0.51 mm
07. EDGE RADIUS CLEARANCE SIDE. . . .	0.51 mm
08. BLADE DISTANCE.	6.60 mm
09. BLADE TOP WIDTH.	1.84 mm
10. TOPREM DEPTH.	0.00 mm
11. TOPREM ANGLE.	0.00deg
14. RELIEF ANGLE P.A. SIDE	8.00deg
15. RELIEF ANGLE CLEAR SIDE.	6.00deg
16. AXIAL GRIND DEPTH.	12.04 mm
17. TOP RELIEF ANGLE	16.00deg

Figure 18 Blade profile grinding summary.

For the correct dimensioning of the edge radius R_E it is advisable to calculate first the maximum possible edge radius for the given dimensions. In addition to the cone angle α_T, the end-mill point width P_W is required. The end-mill point width should match the Blade Top Width (item 09, Fig. 18). A larger P_W can be used within limits, however P_W cannot be larger than the smallest point width of the gear slot (item 8 in top section in Fig. 18). The formula in Figure 19 is used to calculate the largest possible edge radius for the end-mill R_E. In the present case, using $P_W = 1.84$ mm, the largest possible edge radius is $R_E = 0.65 * P_W = 1.2$ mm. After R_E is calculated, it has to be compared to the Edge Radius Pressure Angle Side (item 06 in Fig. 18). If the result of R_E is smaller than item 06 in Figure 18, then the calculated number of R_E must be used for the end-mill.

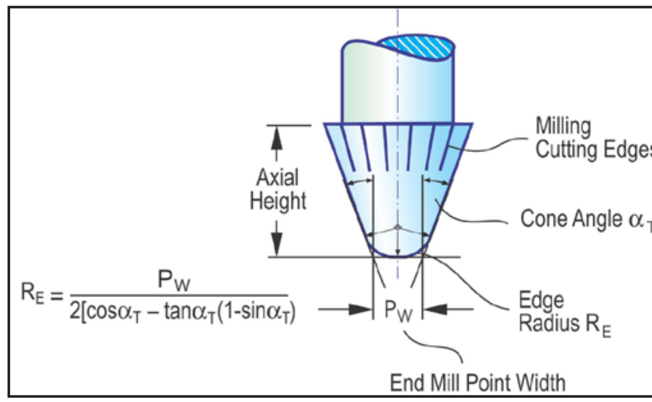

Figure 19 Fully rounded end-mill tip.

In the present case, the summary item 06 (Fig. 18) is 0.51 mm, which is smaller than the calculated maximum possible radius for R_E. In this case, $R_E = 0.51$ is the correct edge radius for the end-mill. The end-mill design, according to the graphic (Fig. 20), will have a flat spot at the tip, connecting the two edge radii in the cross-sectional drawing (which will not form a fully rounded end-mill tip).

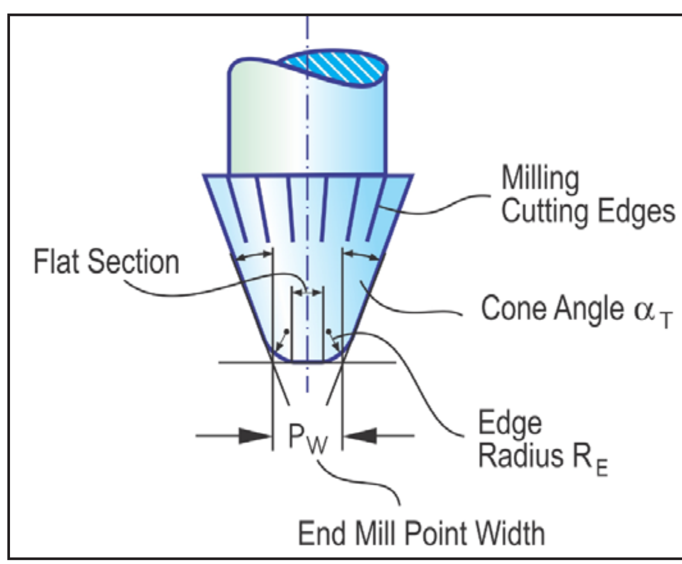

Figure 20 Conical end-mill with edge radius smaller than the fully rounded radius.

Measurement of the stock division probe reference height is shown (Fig. 21-left). The probe is placed in the milling tool holder and an electronic height measurement caliper on a granite plate or any other precisely flat surface is used to determine the overall height (Stock Division Probe Reference Height) of the assembly. The same procedure (Fig. 21-right) is applied to determine the cutter reference height. Both reference heights are entered into the machine summary. For the initial stock division teaching, the probe is inserted into the tool holder on the machine instead of the tool.

The next step is performed manually by jogging the probe along a predetermined feed vector while the unclamped work is rotated back and forth until the probe sphere begins to contact both flanks (Fig. 22). Now the part is clamped and the automatic stock divider teaching is done by simply running the teaching routine via menu. To begin the milling, the probe is now exchanged with the milling tool.

Coniflex cutting with *UNIMILL* uses basic settings from a datafile. Because the original Coniflex process is not a completing, but a single side cutting method, it is recommended to use the standard *UNIMILL* cycle if the parts are not pre-slotted. The standard cycle mills the generating flat in one roll position on the lower flank (from heel to toe) and then a surface flat in the same roll position on the upper flank in the return swing, as schematically explained (Fig. 23-left). This cycle, which constantly alternates between lower and upper flank, avoids double flank contact of the fast rotating tool, which assures a smooth milling action.

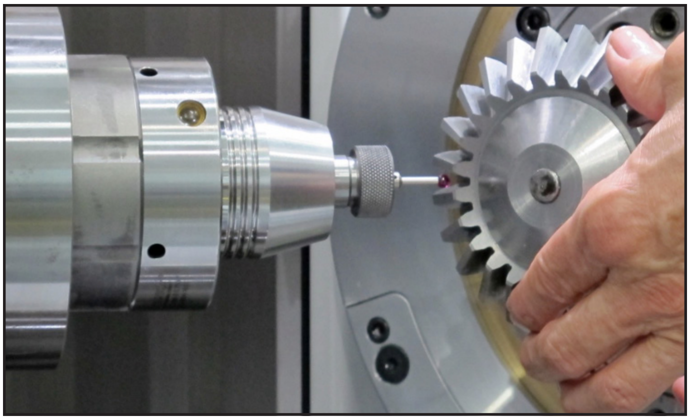

Figure 22 Manual stock division of pre-slotted part.

If straight bevel gears are pre-slotted, the slotting can be done on a two-tool generator or on planers with an indexing head. For the case of pre-slotted parts, the "Optimized Roll Mode" is recommended. In the optimized roll mode the tool swings from heel to toe in one roll position (cutting the lower flank), and then returns from toe to heel in the next roll position, still milling the lower flank as indicated in the right side graphic (Fig. 23). The heel to toe swing is, for example, conventional cutting while the return swing is climb cutting. After finishing the complete lower flank, the milling tool changes to the upper flank and repeats the same cycle. With the described optimized cycle the constant change between lower and upper flank is avoided — which saves about 15% cycle time. The pre-slotting allows faster milling with a lower number of roll positions — which saves 25% of the original cutting time. Both cycle time reduction elements together will reduce the cycle time for cutting pre-slotted parts down to about 60% of the original cycle time of cutting un-slotted parts.

An interesting observation is the fact that the optimized roll mode mills consecutive surface flats alternating between conventional and climb

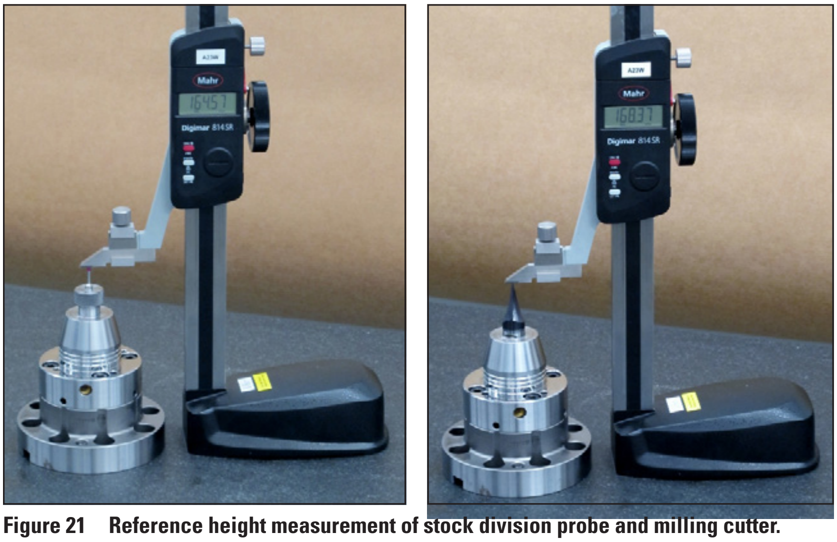

Figure 21 Reference height measurement of stock division probe and milling cutter.

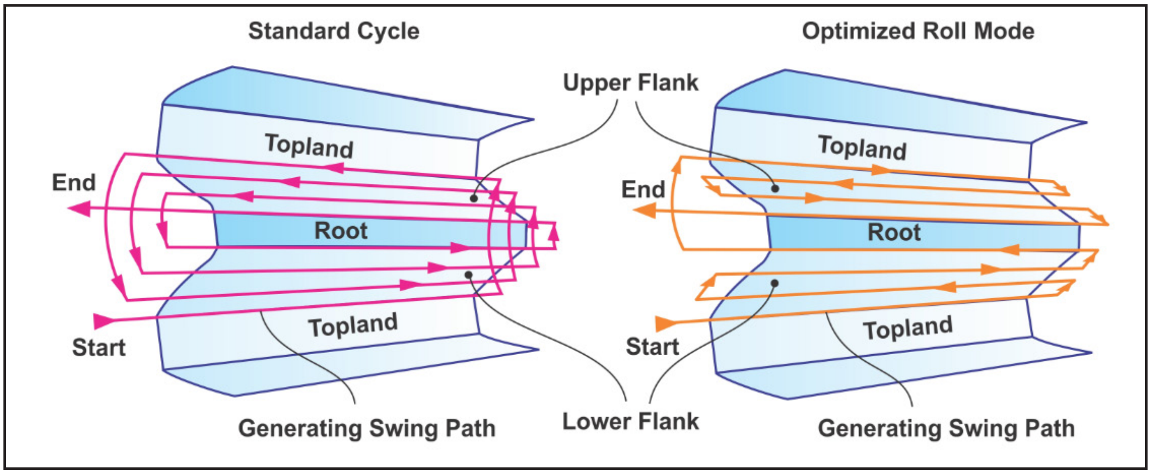

Figure 23 Standard and optimized roll mode for straight bevel gears.

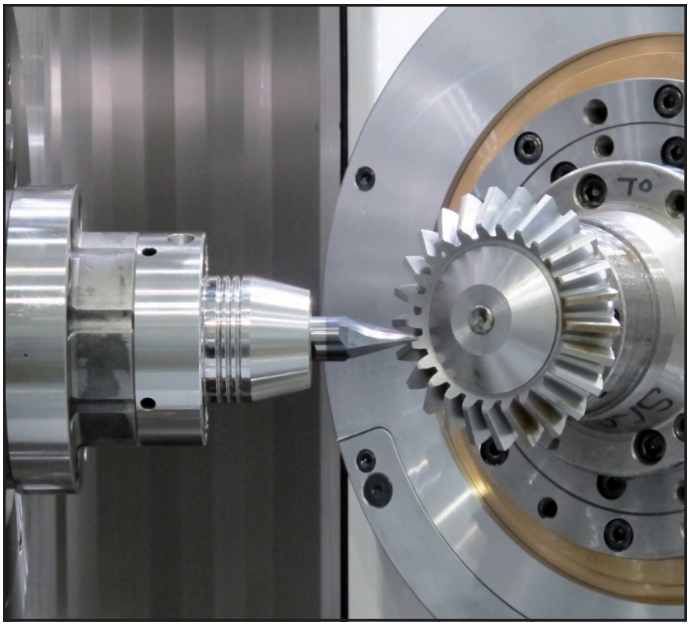

Figure 24 ***UNIMILL*** **straight bevel gear milling.**

cutting, which results in a very good average surface finish and two completely equal flank surface structures. In the standard cycle, which alternates after each swing between upper and lower flank, the lower flank is milled in conventional cutting, while the upper flank is milled in climb cutting. This leads to slightly different surface textures between the two flanks.

In order to allow for easy contact pattern development via roll tester, the *UNIMILL MMC* software was expanded to accept and process standard proportional changes. In addition, independent depth and slot width changes can be entered into the *UNIMILL* summary.

After setup and summary entry the outer swing position on toe and heel can be tested for sufficient clearance in the start and end roll positions. If the clearance values appear too small or too large, corrections of the input items for swing over-travel as well as roll positions can be independently entered into the *UNIMILL* summary.

Before starting the cutting cycle, a hold back value can be entered for cutting of a first slot with some stock allowance. If cutting surface finish, over-travel on toe and heel and correct flank form have been verified the hold back can be cleared via soft key.

The cutting engagement of a tapered *UNIMILL* end-mill in the end-roll position of the lower flank is shown (Fig. 24). The surface speed of 250m/min is calculated in the middle of the whole depth of the tooth which is at the blade dedendum point of the end-mill. The end-mill material is AlconaPro-coated tungsten carbide with a 10% cobalt contents.

Summary

UNIMILL is a milling method for the manufacture of prototype bevel gears using end-mills or disk cutters. The *UNIMILL* software requires basic settings in form of SPA files as an input. Additional input items like speeds and feeds, number of generating flats, over travel amounts, etc. are entered into the process parameter input screen directly on the Phoenix cutting machine. If high RPMs are required, like in case of tapered end mills, it is possible to use Phoenix grinding machines or cutting machines with high-speed spindles.

In contrast to general multi-axes machining which utilizes surface coordinates and normal vectors, *UNIMILL* does not depend on certain grid specifications and definitions about undercut and root fillet (which are difficult to obtain). *UNIMILL* tools follow the path of a face cutter head silhouette, while the face cutter is performing a generating (or form cutting) motion. The result is a faster process with surface finish characteristics very similar to the traditional cutting process. *UNIMILL* is available on all PhoenixII cutting and grinding machines, as well as on all later models.

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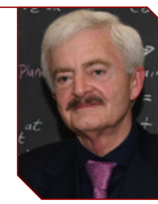

Dr. Hermann J. Stadtfeld is the Vice President of Bevel Gear Technology and R&D at the Gleason Corporation and Professor of the Technical University of Ilmenau, Germany. As one of the world's most respected experts in bevel gear technology, he has published more than 300 technical papers and 10 books in this field. Likewise, he has filed international patent applications for more than 60 inventions based upon new gearing systems and gear manufacturing methods, as well as cutting tools and gear manufacturing machines. Under his leadership the world of bevel gear cutting has converted to environmentally friendly, dry machining of gears with significantly increased power density due to non-linear machine motions and new processes. Those developments also lower noise emission level and reduce energy consumption.

For 35 years, Dr. Stadtfeld has had a remarkable career within the field of bevel gear technology. Having received his Ph.D. with summa cum laude in 1987 at the Technical University in Aachen, Germany, he became the Head of Development & Engineering at Oerlikon-Bührle in Switzerland. He held a professor position at the Rochester Institute of Technology in Rochester, New York From 1992 to 1994. In 2000 as Vice President R&D he received in the name of The Gleason Works two Automotive Pace Awards — one for his high-speed dry cutting development and one for the successful development and implementation of the Universal Motion Concept (UMC). The UMC brought the conventional bevel gear geometry and its physical properties to a new level. In 2015, the Rochester Intellectual property Law Association elected Dr. Stadtfeld the "Distinguished Inventor of the Year." Between 2015–2016 CNN featured him as "Tech Hero" on a Website dedicated to technical innovators for his accomplishments regarding environmentally friendly gear manufacturing and technical advancements in gear efficiency.

Stadtfeld continues, along with his senior management position at Gleason Corporation, to mentor and advise graduate level Gleason employees, and he supervises Gleason-sponsored Master Thesis programs as professor of the Technical University of Ilmenau — thus helping to shape and ensure the future of gear technology.

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Gleason

EXPANDS ACCREDITED CALIBRATION SERVICES

Gleason Metrology Systems' Gear Calibration Lab now features an enhanced quality system and ISO/IEC 17025:2017 accreditation, lower measure measurement uncertainties, and more comprehensive A2LA accredited calibration services with the addition of the latest Gleason 300GMSL Gear Measuring System and GAMA 3.2 analytics software.

The 300GMSL gear measurement system is now commissioned to provided accredited calibration of new parameters and ranges including diameters of plain cylinders and rings, dimension over/under balls, and tooth thickness, on gears and splines diameters up to 300 mm.

Additionally, the lab provides length measuring capabilities, reduced length measurement uncertainties for diameter, dimension over/under pins as well as calibrate sphere roundness for precision spheres including diameter and roundness up to 25 mm diameter spheres.

With the addition of these new services, expedited calibrations can now be provided in less than seven days on request. Services include the supply of new master storage cases and a wealth of non-accredited contract services for gears, splines, and spiral bevels up to 400 mm diameter.

Gleason Metrology Systems can also provide A2LA Accredited on-site calibration of analytical gear and spline measurements regarding gear involute and helix. (*www.gleason.com*)

Klingelnberg

NOMINATED A SECOND TIME FOR BEST OF INDUSTRY AWARD

Initiated by the trade magazine *mm Maschinenmarkt*, the highly visible "Best of Industry" platform showcases the year's outstanding industry products and recognizes the "best of the best" of these with the "Best of Industry Award," now in its fifth year. In 2018, Klingelnberg received the coveted trophy in the "Industry 4.0" category for its cyberphysical gear production system. This year, Klingelnberg is a contender in the "Measuring and Testing Technology" category with its G Variant Precision Measuring Center for measuring multidimensional and complex components. On April 6, the industry magazine opened an online poll for readers to choose their favorites from among the nominees.

Top accolades were achieved for the "Best of Industry Award" again in 2020, by way of a month-long vetting process for innovative solutions that had won an industry award, had been shortlisted or had attracted the most interest for their novel qualities from *maschinenmarkt.de* readers between January 1 and December 31, 2019. Klingelnberg won the reader-interest nomination by earning the most clicks for its reporting on the complete measurement of complex components. "We are extremely proud to have been nominated a second time for the Best of Industry Award," said a delighted Martin Boelter, COO of the Klingelnberg Group. "This reaffirms that we get to the heart of innovation."

Whether turning blanks, ground workpieces or rolling bearings – Klingelnberg G Variant Precision Measuring Centers are specifically designed for use in the production process of axially

symmetrical components. With these machines, Klingelnberg follows the approach of executing various measurement processes in one stage as a complete measurement (done in one). A Klingelnberg Precision Measuring Center is capable of fast measurement of dimensions, shape, contour and surface roughness in one automated cycle. This reduces the investment costs and helps to reduce the process costs.

Furthermore, Klingelnberg Precision Measuring Centers also ensure the required measuring accuracy if they are used directly in production. As a result, not only does this save on air-conditioning costs, but the measuring center can also be directly integrated into the production process. This eliminates the need to set up several different machines, saving valuable production space. With its G Variant Precision Measuring Center, Klingelnberg is therefore making a significant contribution to reducing quality costs.

Readers of the industry magazine and an independent jury of experts can now choose the winners of the "Best of Industry Awards" from among the nominees. The final result is based on a 50 percent weighting of the jury portion and a 50 percent weighting of the online reader survey.

"We are hoping once again for active participation on the part of the readers and will of course be very pleased if as many of them as possible choose to cast their vote for us," said Dr. Christof Gorgels, head of the precision measuring center business division. The online survey is expected to remain open at the website below until beginning of June 2020.

The winners of the "Best of Industry Awards" will be honored on June 25, 2020. (*www.klingelnberg.com*)

SMW Autoblok

WELCOMES THOMAS AS TECHNICAL OPERATIONS SENIOR MANAGER

SMW Autoblok recently announced that **Shaun Thomas** has rejoined their Wheeling, Illinois, company as technical operations senior manager. Thomas brings over 15 years of experience and technical knowledge in engineering and workholding in addition to leadership and development to his new senior role with SMW Autoblok.

As technical operations senior manager, Thomas leads the continued development and execution of the company's technical workholding and project management including implementing Continuous Improvement Processes. Focusing on engineering, quality and custom solutions, Shaun leads our production and engineering team to ensure that SMW Autoblok's products meet and exceed customer requirements for quality and timeliness.

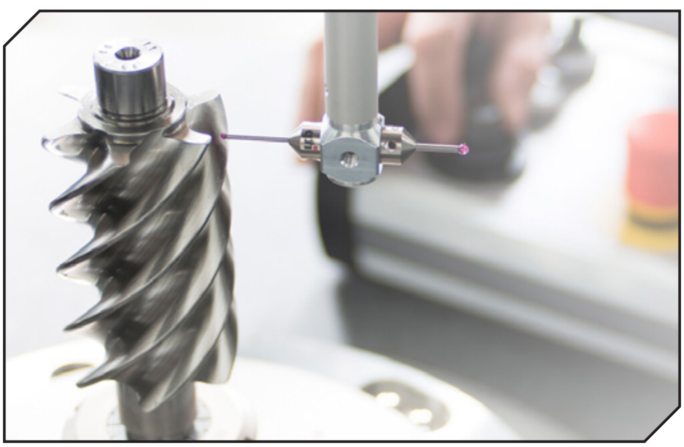
"Shaun is an asset to our growing engineering and technical team, and we are happy to have him back at our company," said Ron Shibovich, president – operations division. "His many years of experience and expertise in engineering, workholding, PDM and ERP will serve us well."

Prior to his role with SMW Autoblok, Thomas worked as senior manager, engineering manufacturing for Kitagawa Northtech. He also previously worked for over a decade at SMW Autoblok as engineering supervisor where he managed and mentored a four-person engineering team and oversaw quality control operations. He holds an M.B.A. from Capella University and a B.A. in Industrial Technology from Northern Illinois University. Thomas currently resides in Arlington Heights, Illinois, in the neighborhood where he was born and raised with his wife and two young sons. (*www.smwautoblok.com*)

Kapp Niles

ACQUIRES METROTEK GMBH SOFTWARE RIGHTS FOR SPECIFIC MACHINES

Kapp Niles Metrology GmbH has acquired rights use Metrotek's software.The employees at the Karlsruhe location were successfully integrated into the Kapp Niles Metrology team. Evaluation software is the central element of a gear measuring machine in addition to the high-precision mechanics and control technology. Kapp Niles stationary machines can be used to measure gears, gear cutting tools and rotationally symmetrical components from 6 up to 6,000 mm in diameter. (*www.kapp-niles.com*)



KISSsoft

OFFERS SOFTWARE TO STUDENTS

Nowadays, engineering studies should include the use of modern relevant software. For mechanical engineering students, these are mainly CADs and calculation programs.

It is a matter of concern to us to present KISSsoft to future engineers during their studies. A software cannot replace learning the calculation methods "by hand", however, such a program can multiply the learning effect of a lecture, when it is properly used.

Universities can apply for a university license to make KISSsoft available for students. The university licenses are subject to separate commercial and licensing conditions.

Students will then receive a license key and access to the software from the responsible faculty of the school. The distribution and administration of the licenses is regulated in a university contract and is the responsibility of the school itself. University licenses and conditions can be requested from KISSsoft.

PS: Are you currently working from home and would like to deepen your know-how? Then take part in KISSsoft's free web demo on April 8. It will cover the innovations in ISO 6336, the most important standard for strength calculation of cylindrical gears. KISSsoft experts will explain the theoretical background and show you the effects of the changes using examples from wind power, EV gearboxes etc. (*www.kisssoft.com*)

AFC-Holcroft

NAMES MANAGING DIRECTOR FOR EUROPEAN OPERATIONS

AFC-Holcroft, headquartered in Wixom, Michigan, USA, has named **Marek Kedzierzynski** their new managing director of European operations. Kedzierzynski secedes the outgoing managing director for Europe, Marc Ruetsch, who plans to retire mid-year. Kedzierzynski will report to Tracy Dougherty, vice president of sales for AFC-Holcroft.

Along with a master of engineering degree (M.Eng) received from University of Zielona Gora in Poland, Kedzierzynski is currently pursuing a Ph.D. from West Pomeranian University of Technology in Szczecin, Poland. Kedzierzynski has focused on engineering and heat treating exclusively throughout his career, beginning with his start as a design engineer while still in college, while working his way thru several technical roles with major furnace equipment suppliers, and eventually moving into sales and related activities. Upward momentum and increasing responsibilities led to high level roles including director of furnace sales and commercial director/member of the board, before joining AFC-Holcroft in 2019. In addition, Kedzierzynski owned and operated his own heat treat consulting business while pursuing his university studies. He is fluent in Polish, English and Russian languages.

Kedzierzynski, says, "It is an honor to take the reins of AFC-Holcroft's European operations from my distinguished colleague Marc Ruetsch. I am grateful to have this opportunity to join AFC-Holcroft in this role, and be able to use my education, technical know-how and sales experience on a daily basis." He added, "I am honored to be selected to be a part of the AFC-Holcroft team." (*www.afc-holcroft.com*)

Weiler Abrasives

APPOINTS DIRECTOR OF NATIONAL ACCOUNTS

Weiler Abrasives has announced the promotion of **John Hobbs** to director, national accounts.

Since joining Weiler Abrasives in March 2013, Hobbs has held multiple sales positions of increasing responsibility, including district sales manager, business development manager and national accounts manager.

"John is a natural fit for his new role. He's exceptionally driven and is always focused on elevating our customers' experiences with Weiler Abrasives," says Jason Conner, vice president, sales for U.S. and Canada. "He's proven he can lead efforts with our national accounts team and our distributor partners — while delivering results, and bringing positive energy and excellence along the way."

In his new role, Hobbs will be responsible for managing a team of national account managers who are responsible for delivering the Weiler Abrasives' Value Package to the company's largest national account business partners serving the U.S. and Canada. The Weiler Abrasives' Value Package defines how the company partners with its distributors to help them achieve their business goals and how together they can bring valued-added solutions to customers across the globe. (*weilerabrasives.com*)

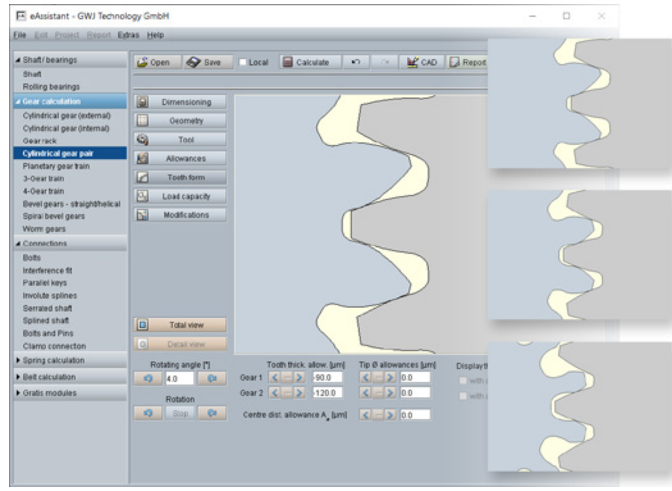
GWJ Technology

SUPPORTS VIRTUAL TEACHING

With its web-based software *eAssistant*, GWJ Technology ideally supports the digitization in teaching and education.

It has always be important to GWJ to support and promote teaching and learning. Therefore, GWJ provides the web-based software *eAssistant* free of charge to universities and other educational institutions for training purposes as well as to students for private use. This gives students the opportunity to work from home without any problems. Now that the universities has moved from face-to-face classes to online teaching, the web-based application can help ensure continuous learning during the current situation.

With the *eAssistant*, the software application for the calculation, design and optimization of machine elements such as shafts, bearings, shaft-hub connections, bolted joints or gears, users learn practical skills they can apply immediately and deepen. Integrated functions like redo/undo or the automatic recalculation after entering values help to explain certain contexts in a way that can be easily understood. A recalculation



occurs after every data input. Any changes that are made to the user interface take effect immediately.

This is possible not only for number values, but also for the representation of the tooth form. The effect of the profile shift on the gear tooth form can be quickly understood. (*www.gwj.de*)

MC Machinery

ANNOUNCES PARTNERSHIP WITH KM INDUSTRIAL MACHINERY

MC Machinery Systems recently announced that Km Industrial Machinery, Inc. is the new Michigan dealer for its EDM/Machining Division.

A third-generation family-run business, Km Industrial Machinery Vice President Pat Byers said that "as ambassadors of technology at our core, EDM fluid runs through our veins."

In fact, Pat's father Walt was a research engineer directly involved in revolutionizing the entire EDM process in the 1950s.

"We are thrilled to have Km Industrial Machinery join our team," said Alan Hallman, national sales manager of MC Machinery's EDM/Machining Division. "They have tremendous experience and depth of knowledge in EDM and milling, along with outstanding customer service and a beautiful new facility." (*www.mcmachinery.com*)

MPIF

OPENS REGISTRATION FOR BASIC PM SHORT COURSE

The powder metallurgy (PM) industry's leading short course returns to State College, Pennsylvania, this August to bring together new PM employees and those seeking to enhance their depth of knowledge and advance their careers in the industry. Held at Penn Stater Conference Center Hotel, State College, Pennsylvania, this intensive three-day course will run from August 10–12, 2020.

This year's programming will focus on:

- History, current practice, and the future of the PM industry;
- Why PM is a leading method for producing metal parts;

- The many applications that use PM parts;
- The fine points in designing for PM;
- How metal powders are produced;
- Designs for compacting tools;
- How sintering develops functional properties;
- Various secondary operations;
- The Metal Powder Industries Federation material and test standards;
- Metal injection molding;
- And the latest high-tech PM technologies, including metal additive manufacturing (3D printing).

POWDER METALLURGY BASIC SHORT COURSE

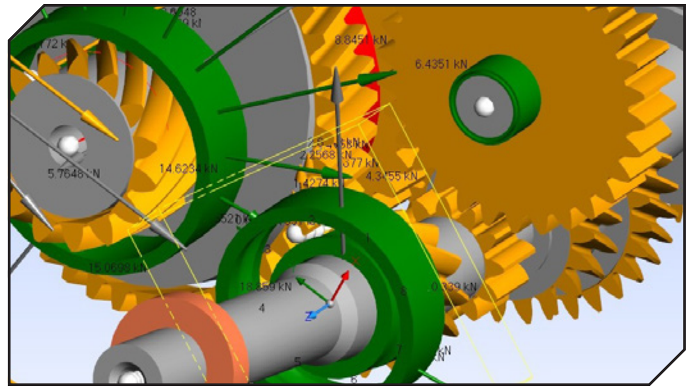
Attendees also receive hundreds of dollars in publications, including current MPIF standards.

"The Basic PM Short Course is nearing its 60-year mark of serving the PM industry," states Bill Edwards, director of technical and member services, Metal Powder Industries Federation. "It provides concentrated knowledge from numerous industry experts over three days and is an invaluable tool to showcase PM technology to anyone who would like to enhance their knowledge." (*mpif.org*)

SKF and SMT

COLLABORATE ON SOFTWARE FOR TRANSMISSION SYSTEMS

By combining SKF and SMT's technical analysis and optimization capabilities, engineers can now have a seamless experience when designing transmission systems. The SMT MASTA software helps engineers to accurately and rapidly design and predict performance characteristics. It also helps them to identify potential failure modes and undertake full-system (including time-domain MBD) simulations for any gearbox layout. The combined software allows bearings to be assessed within the context of full system level models. It also includes SKF bearing data for thousands of the company's bearings, alongside ISO 281 and ISO 16281 results. SKF rating life safety factors and reliability are displayed for individual load cases as well as combined for duty cycles and design states. These results are fully integrated into SMT's MASTA software. They are also available in RUNNA, MASTA's batch running capabilities, SMT's innovative Custom Reporting Framework, MASTA's Parametric Study Tool and MASTA's extensive scripting functionality. The combination of SKF and SMT in this way means that engineers now have, at their fingertips, everything needed to design highly reliable rotating equipment. Paul Langlois, software engineering director, at SMT, says: "This latest addition to our ongoing collaboration with SKF adds great value for our mutual customers. This will allow them to assess their bearings within the context of full system level models in MASTA, while benefiting from the proprietary life calculations of SKF." Hedzer Tillema, product line manager engineering tools, at SKF, says: "This joint development is of high importance for SKF. It helps our customers to design reliable rotating



equipment through key bearing knowledge and shows that 'seamless engineering' is becoming a reality for more and more machine design engineers." (*www.skf.com*, *www.smartmt.com*)

Blaser

EXAMINES COOLANT OPTIONS DURING EXTENDED PRODUCTION STOPS

The machines may not be running, but you need to monitor and maintain your metalworking fluid anyway. A production stop, triggered by a virus or anything else, may also be a good opportunity to clean your machines and fill them with new coolant.

Chemistry and microbiology continue to be active in your water-miscible metalworking fluid even when the machines are not running. The fluid doesn't circulate anymore and there's no supply with fresh emulsion. All this can lead to severe problems such as bad smell, corrosion of machine parts and splitting of the emulsion. You therefore need to decide whether you maintain your coolant during the production stop or whether it's a good opportunity to dispose your old coolant, clean your machines and get them ready for future production.

Two options–maintain or dispose

Water-miscible metalworking fluids cannot be left on their own. They need to be monitored and maintained regularly to ensure the stability of the emulsion. Cutting and grinding oils

do not need any specific precautions. However, the production stop may be a good opportunity to clean the machines and change to a new oil. (*www.blaser.com/production-stops*)

Solar Manufacturing

JOINS FORCES WITH METALPRO RESOURCES

Solar Manufacturing is pleased to announce that MetalPro Resources will assume the role of sales representative for the states of Ohio, Indiana and Kentucky. MetalPro Resources consists of three extraordinarily qualified individuals in the field of thermal processing and metallurgy. Jim Senne, Steve Maus and Bill Andreski bring a combination of over 100 years of heat treating knowledge and experience. With offices located in the Cincinnati, Indianapolis and Cleveland areas, MetalPro Resources offers many valuable services to their customer base.

Pictured left to right: Steve Maus, Jim Senne, Bill Andreski.

In making this announcement, Adam Jones, Midwestern regional sales manager remarked, "I am excited to have the opportunity to work with Jim, Steve and Bill. They are all great contributors to the heat treating market and the value that this will provide for our customers is immeasurable."

Maus of MetalPro Resources commented, "We have relationships with the people of Solar going back decades, and the time was finally right for us to join forces. Our region is rich in vacuum furnace applications and opportunities and we're moving forward with the best possible partner in Solar Manufacturing." (*solarmfg.com*)

Mobile Industrial Robots

ADDS FIVE CERTIFIED SYSTEM INTEGRATORS TO GLOBAL NETWORK

Mobile Industrial Robots (MiR) recently announced the signing of five certified system integrators (CSI) in both North and South America. US-based JMP Solutions, Iris Custom Solutions, Flex-Line Automation, Advanced Handling Systems, as well as Nordika Brazil in Sao Paulo, Brazil, all have specific MiR robot, software and application expertise to support end users with large and complex implementations.

"In today's uncertain business environment, companies – whether deemed essential or not – need to improve efficiencies and get their products to customers as quickly as possible," said Ed Mullen, vice president of sales, Americas, Mobile Industrial Robots. "They need strong technology partners who can ensure fast and effective integration to help them optimize the efficiency and productivity of their internal logistics. These five CSIs know our AMRs, they know the applications in which they can be used most effectively, and they know how to implement even complex systems with multiple AMRS while providing the highest degree of customer service."

MiR's global network of CSIs ensure proper installation and service of MIR's fleet of user-friendly, powerful and robust AMRs for heavy and light internal transport. The MiR100, MiR200, MiR250, MiR500 and MiR1000 are designed to optimize logistics throughout the entire production chain, from the warehouse to the delivery of goods. MiR AMRs are already installed in more than 60 countries at companies such as Toyota, Ford Motors, Raytheon, ABB and CABKA North America. (*www.mobile-industrial-robots.com*)

ad index

Parenting in the Pandemic

Jack McGuinn, Senior Editor

Several months into the coronavirus, uncertainty is still an everyday experience. Given the wealth of sometimes confusing and contradictory information we are spoon fed by Washington, we are left to our own devices to decipher announcements, e.g. — Do I wear a mask or not wear a mask? Do I still need to practice social distancing (a classic oxymoron: what is sociable about keeping distances between each other)? And so on.

But one thing we can be absolutely sure of: there's a whole lot of what we'll call parenting in place going on around the world. Whether you are parenting your children — or parenting your parents — for many people that must be very stressful. Familiarity breeds contempt, as the saying goes, but 24/7 familial hunkering sends contempt to a whole other universe. Dealing with the pandemic means most working people (who are lucky to be working) who used to have their youngsters tended to by grandparents, babysitters and pre-school providers are now filling that role themselves. Meanwhile, we are all hoping for the best possible outcome. But hope is not a plan.

So of course what parents need are some quality time distractions for the kids. Ideally, your charges aren't watching TV or playing video games all day and night. Wait — scratch that — many kids of all ages would be perfectly satisfied watching TV or playing video games all day and night.

So the key is finding some other bright, shiny object to distract them from all that screen time.

Look no further than Amazon — for if you buy it, they will build it (hopefully). What we're talking about buying are assembly-required, gear-intensive models of construction equipment, cars, robots, etc. Indeed, there's a model for all ages. They are made of various materials, including plastic, metal and wood. We should probably stipulate here that some of these may have appeared in earlier Addendums. But given the heightened need for such worthwhile distractions, a second showing seems in order. And consider: when this is all behind us, you'll have a quality souvenir from a time that scared the bejesus out of us. So go to Amazon and pick the model (or models) that will grab the kids' — and adults', why not? — attention for hours on end. It's a pro-active move that will aid you and your family during the pandemic.

Here are just a couple of suggestions. Check Amazon for current price and delivery options:

Learning Resources Gears! Gears! Gears! Motorized Wacky Wigglers Gears Building Set, 130 Pieces

Kids develop creativity, imagination and fine motor skills by building glowing creatures

Supports STEM by introducing children to sorting, grouping, counting, designing, constructing, and putting physics into play with spinning gear movement

This 130-piece motorized set includes colorful gears, springs, chomping teeth, flashing lights, whiskers and glow-in-the-dark eyeballs for endless creative combinations

Requires 3 AA batteries, not included. Ideal for ages 5+.

ROBOTIME 3-D Puzzle Engineering STEM learning mechanical wooden laser-cut model gears kit for adults & teens

This is a perfectly designed DIY kit that requires your hands-on work to complete. The whole set is extremely well designed, with very tight tolerances and good machining. The interlocking mechanisms are pretty ingenious. Details are already cut and ready to assemble. The wood is beautiful and smooth. With Laser Cutting Technology, the pieces are easy to remove from the sheet of plywood, the laser cutting is precise and clean (no residue smoke burns). The pieces go together smoothly and with step-by-step visual instructions.

Game Changer

With Gleason's new Hard Finishing Cell (HFC), fast, automated production of 100%-certified precision gears is a reality. HFC connects GX Series Threaded Wheel Grinding and the new GRSL Gear Rolling System with Laser Scanning in a Closed Loop; gear checking, analysis and correction are done in-process, in real time.

www.gleason.com/HFC

Total Gear Solutions **Gleason**