gear TECHNOLOGY®

JAN/FEB 2022

STATE OF THE GEAR INDUSTRY

SURVEY RESULTS
THE FUTURE OF GEAR MANUFACTURING
SURVIVING THE LABOR SHORTAGE

www.geartechnology.com

Gear Technology is published by **The American Gear Manufacturers Association**

A New Dimension in Productivity

Star SU and GMTA have aligned on Profilator Scudding® technology to radically improve on traditional gear production technology

GMTA and Star SU combine the vast experience in gear cutting tool technology for new tool development and tool service center support from Star SU together with Profilator's Scudding® technology for special gear and spline applications.

With Scudding, quality meets speed in a new dimension of productivity, FIVE TIMES faster than conventional gear cutting processes. The surface of the workpiece is formed through several small enveloping cuts providing a surface finish and quality level far superior to traditional gear cutting technology. Scudding is a continuous cutting process that produces external and internal gears/splines as well as spur and helical gearing, with no idle strokes as you have in the shaping process. Ring gears, sliding sleeves and annulus gearing, whether internal helical shapes or internal spur, blind spline, plus synchronizer parts with block tooth features, and synchronizer hubs are among the many applications for this revolutionary technology from Profilator / GMTA.

SAMPUTENSILI

Phone: 847-649-1450
5200 Prairie Stone Pkwy. | Ste. 100 | Hoffman Estates | IL 60192

FFG

GMTA
German Machine Tools of America

Profilator

Scudding® machines and tools
www.star-su.com

gear TECHNOLOGY®

contents

JAN/FEB 2022

A Publication of
The American Gear Manufacturers Association

24

features

technical

Stay Connected

Join the Gear Technology Facebook group at
www.facebook.com/help/312721188838183

Follow us on Twitter
twitter.com/Gear_Technology

Connect with us on LinkedIn
www.linkedin.com/groups/3893880/

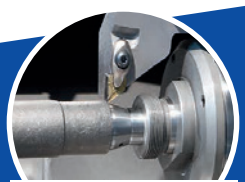
Subscribe Online
www.geartechnology.com/subscribe.htm

Vol. 39. No. 1 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.

WMZ
WERKZEUGMASCHINEN

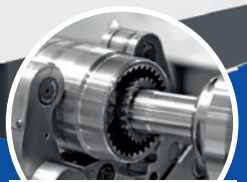
DVS TECHNOLOGY AMERICA

WMZ – Power Skiving with Total Shaft Machining


TURNING


MILLING


HOBBING


SKIVING


MEASURING

WMZ V300e

The MACHINE for multiple shaft machining

- **Complete machining of shafts include SKIVING**
- **Multi-technology: 16-fold tool magazine, universal machining head with turret ensure shortest cycle times**
- **Designed as center drive machine for large quantities and highest concentricity**
- **Automation flexibly: manual loading, portal or robot**

Curious to learn more?
CONTACT US:

DVS Technology America Inc.
734-656-2080
sales.america@dvs-technology.com

www.wmz-gmbh.de www.dvs-technology.com

DVS TECHNOLOGY GROUP

gear TECHNOLOGY® Vol. 39. No. 1

departments

By the Numbers

Greg Schulte

It's 2022! AGMA's 106th year. Numbers are interesting things; here are a few pertinent ones for AGMA.

AGMA has **429** members.

Of that total, **326** are companies that manufacture gears, gearboxes and related components.

In 2022, **90** members are global — with operations completely outside of the United States. WE are part of a thriving global gear community.

AGMA promulgates **65** standards and **40** information sheets for the industry.

AGMA also publishes **37** ABMA standards for the bearings industry.

AGMA has **23** technical committees with more than **350** individuals from AGMA member companies guiding the standards development process. And we need more! We would love to get your people involved.

AGMA has **21** live education classes, with **11** instructors.

In 2021, whether online or in person, AGMA trained **347** engineers.

AGMA created a robust online webinar series to provide members with important information regarding trade, tariffs, emerging technology and marketing insights. More than **400** industry professionals participated in these webinars and AGMA will continue to offer top-quality content in 2022.

AGMA published **four** gear market reports, **one** Operating Ratio Report and the ongoing Monthly Market Trend Report for those that participated in 2021. We will continue to offer these products in 2022 and the gear market reports are now included in your membership!

AGMA has **four** emerging technology committees, with **85** members guiding the efforts to stay ahead of technology innovations that could disrupt the gear industry.

In 2021, these committees published an Electric Vehicle white paper from a gearing perspective.

In 2021, AGMA brought together an additional **221** leaders for learning and networking — the Annual Meeting was online, the SRN and FTM were face to face.

In 2021, MPT Expo brought together **1,000** industry professionals for a small, focused tradeshow. The first since the pandemic started.

In 2021, *Gear Technology* was read 8×, by **13,000** industry professionals. An additional **17,000** read Power Transmission Engineering 8×.

So many positive numbers, even with COVID-19, its Delta and Omicron variants — and even during a global supply chain crisis that I am sure everyone reading this column is experiencing in some way.

But what does it all mean?

These numbers mean one thing: AGMA delivers value — and this value is delivered with members leading the way on our committees and leadership positions.

As a Board of Directors, we identified four major strategic objectives, and new ways of delivering value.

1. AGMA identified business connections as a strategic objective, and we deliver with publications, events and opportunities to connect online or in person.
2. AGMA identified education as a strategic objective, and we deliver classes and training.
3. AGMA identified emerging technology as a strategic objective, and we deliver speakers, white papers and opportunities to tour facilities.
4. AGMA identified standards as a strategic objective, and we continue to deliver as a leading Standards Development Organization (SDO) at the national and global level.

Now the question is, what's next? What does the next 10 years look like?

That is a challenging question, but one the Executive Committee is going to ask when we get together in February.

Some thoughts we are sure to touch on in 2022:

- How will AGMA convene the industry over the next 10 years?
- What will our events like MPT Expo, FTM, Annual Meeting and SRN look like?
- How does the digital world intersect with AGMA by 2030 in terms of education, training, sharing of technical data?
- Who will the leaders of tomorrow be, and how do we prepare them to guide an organization steeped in valuable history and experience, into a future where the past may not be a value?

We do not know the answers to any of these questions yet. And we may not know them in 2022 either!

- But the show committee is already talking about MPT Expo 2023 and beyond….
- The education committee is already talking about how its platform may need to adjust to a post COVID reality….
- The emerging technology committee is developing two white papers in 2022…
- The standards committees will continue to gather technical leaders together and to continue our focus on publishing relevant standards that define performance.
- The market intelligence committee is already securing new data analysis companies to provide insights to our members….

The one thing I know is that PEOPLE will be driving our future — working together collaboratively, debating and having dialogue about the right steps to move us forward, together.

I encourage you to get involved, be an active part of your industry and join us as we figure out our future, before it figures it out for us.

If you are reading this and looking for how to get involved, drop Matt Croson an email at *croson@agma.org* (or scan the QR code). We will connect you immediately, and get the ball rolling.

Greg Schulte
Chairman of the Board, AGMA, and President, Bonfiglioli USA

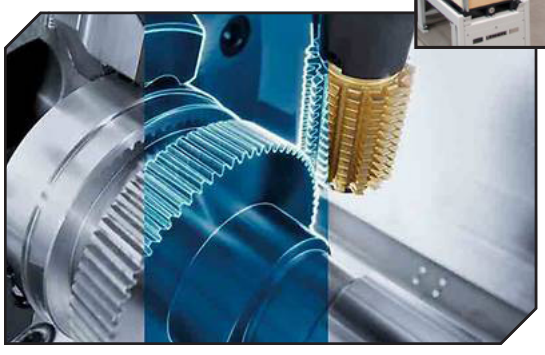
THE GEAR INDUSTRY'S INFORMATION SOURCE

www.geartechnology.com

Liebherr Pallet Handling

The modular design concept of the pallet handling system PHS 10000 Pro enables unlimited flexibility in the realization of customer requirements. Machine tools from all manufacturers can be integrated into the system.

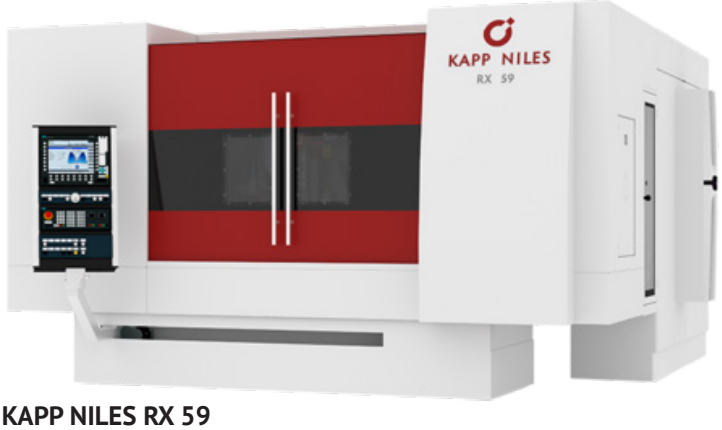
www.geartechnology.com/videos/Liebherr-Pallet-Handling-Systems-/



DMG MORI Gear Hobbing

DMG MORI offers gear profile modifications that are easy to handle. Learn more here:

www.geartechnology.com/videos/DMG-Gear-Hobbing/



KAPP NILES RX 59

The machines of the RX series are used for pre-finish and finish grinding of pre-profiled steel and cast-iron screw rotors. Learn more here:

www.geartechnology.com/videos/Kapp-Niles-RX-59/

Event Spotlight: Gear Dynamics and Gear Noise Short Course 2022

The purpose of this unique short course is to provide a better understanding of the mechanisms of gear noise generation, methods by which gear noise is measured and predicted, and techniques employed in gear noise and vibration reduction.

www.geartechnology.com/news/11621/Gear_Dynamics_and_Gear_Noise_Short_Course_2022/

gear TECHNOLOGY®

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
Matthew Jaster
jaster@agma.org

Senior Editor
Aaron Fagan
fagan@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

CIRCULATION
Circulation Manager
Carol Tratar
tratar@agma.org

ACCOUNTING
Accounting
Luann Harrold
harrold@agma.org

MANAGEMENT
President
Matthew E. Croson
croson@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*.

iptex22
7TH INTERNATIONAL POWER TRANSMISSION EXPO

Grindex INTERNATIONAL 2022
5TH INTERNATIONAL EXPO ON GRINDING AND FINISHING PROCESS

21-23, April 2022
Auto Cluster Exhibition Center, Pimpri-Chichwad, Pune, India

TWO MEGA EVENTS, ONE PLATFORM

Explore the Great collaboration between
Gear and Grinding Technology

BOOK YOUR STALL SPACE NOW!

Event Highlights:

- Network with leading brands from the Gears, Power Transmission & Grinding Technology
- Meet face-to-face with end users, potential buyers and industry leaders
- Explore new business tie-up and joint ventures
- Attend technical seminars on Modern Technology trends for Gears, Heat Treatment and Grinding
- Witness state-of-the-art products, technologies and services from India & International players

Join the league of leaders in Gear & Grinding Industry.

SUPPORTED BY
American Gear Manufacturers Association

ORGANISED BY
virgo COMMUNICATIONS AND EXHIBITIONS (P) LTD

Contact: Mr.Vashdev S G, M: +91 97406 11121 Email: dev@virgo-comm.com www.virgo-comm.com

The Gear Industry's Case of Long Covid

Publisher & Editor-in-Chief
Randy Stott

> **"Some people with COVID-19 have lingering symptoms for weeks or months after they begin to recover. You might know this as 'long COVID.'"**
>
> —WebMD

Does the gear industry have a case of long COVID? It would seem so, based on the results of our annual State of the Gear Industry Survey. At least, it seems clear from the results that many of the worries keeping gear manufacturers up at night do stem from the pandemic. While many of the immediate effects of the pandemic — such as shutdowns and severe disruptions — seem to be a thing of the past, there's a lingering economic malaise that's more persistent.

According to the survey (see p. 24), our readers are still fighting supply chain issues and inflation, which many would argue are a direct result of the pandemic and our collective response to it.

"Supply chain issues are creating very difficult situations with regard to being able to deliver in a timely manner," said one respondent. "Constantly changing replies from vendors make it increasingly difficult to give the customer a commitment that you can stand by."

Another complained about "government regulations, inflation, transportation costs, material shortages and skyrocketing material costs."

Unfortunately, COVID strikes hardest among those with underlying conditions. And the gear industry has a few of those, too. For example, the struggle to find and retain skilled labor has been an ongoing challenge for at least a decade. We've been talking about it for years — and then COVID came along and made it worse.

"It's difficult to man all machines with laborers not able to show up," one respondent said. "There's little interest in new people taking open jobs."

Many companies have struggled with these problems, and many continue to do so. But most have pulled through and seem to be looking forward to the next economic upturn. The world is tired of the whole COVID thing. Even though COVID is far from over, we're over it and ready to move on. In that sense, the pandemic has been like any other economic downturn. Eventually it fades away, and the good times return. There's a sense that the gear industry is ready for that to start happening. In some places, it looks like it already has begun.

By the numbers, the gear industry is in a better place than it was a year ago, if only marginally. Our respondents are more optimistic than they were last year, but less optimistic than they've been in the past. In general, sales and production are trending upward, and it's clear that the industry is in the process of bounding back from the downturn.

But there's another underlying condition threatening the gear industry, and unfortunately, it's one that won't go away with COVID. I'm talking about the threat of disruptive technologies. In particular, our survey results reveal that the electrification of automobiles is the No. 1 concern on the minds of many gear manufacturers. Internal combustion engines are being replaced by electric motors. This change is happening faster than most anticipated, and it represents an existential threat to those who rely heavily on the automotive industry.

"The landscape of gearing is changing," said one respondent, indicating concern that the demand for gears will be lower as a result. However, the same respondent also hinted that opportunities will remain for those who are willing and able to change with the times. "The amount of gears may be fewer, but all will be hard finished and the quality critical to the success. Noise issues take front and center with EV, and printed gears will become a factor as powdered metal did 20 years ago."

We hope you'll spend a few minutes with the survey results. And whether you're glad to see signs of an economic rebound or worried about the lingering effects of the pandemic or the uncertainty about the future of gearing, you can rest assured that *Gear Technology* will continue to bring you the best and most current information available in order to make the best choices for your business in 2022 and beyond.

ZE26C

High speed gear grinding

The Nidec ZE26C
Gear Grinder
Fast and Reliable

Bias control grinding
Available option

Reliable
Stable production

Super fast
Part exchange available

Surface Finish
Improved with polishing

ZE16C also available for parts up to 160mm OD

Nidec

Nidec Machine Tool America

Higher Technology at High Speed with Precision
The ZE26C from Nidec Machine Tools features high speed stock divide and part exchange for improved cycle times. You can depend on the Nidec team to provide **LEGENDARY RELIABILITY** at high speed.

Available NOW for immediate delivery. Call to arrange a grinding test.

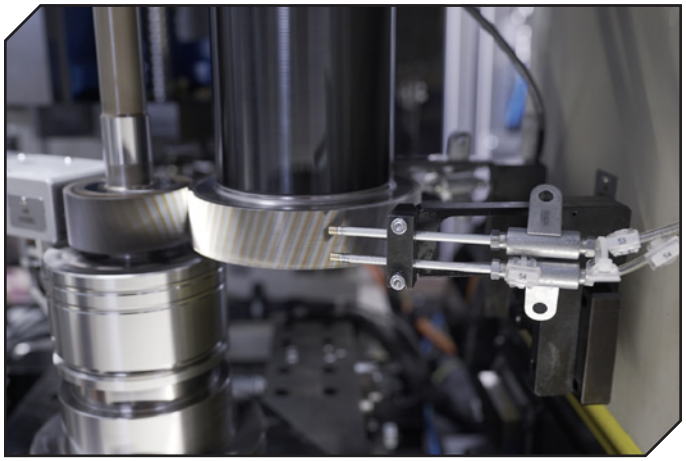
Visit **www.nidec-machinetoolamerica.com** or contact sales at **248-669-6136**.

LEGENDARY RELIABILITY

Marposs

ANNOUNCES NVH GEAR TESTER

Marposs has announced its NVH Gear Tester for identifying potential gear defects at the component level prior to gearbox assembly. The NVH gear tester, which works on the Single Flank testing principle of one master gear meshing with the component under inspection, is able to detect macro-geometry (nicks, runout, etc.) and micro-geometry (gear mesh excitation, ghost orders) defects that cause gear whine and noise phenomena.



With electrification of the automotive industry, many hybrid (HEV) and full electric-vehicle (EV) drivetrains are facing a variety of challenges, such as increased NVH requirements in high-speed e-drives. And, although the number of gear wheels is significantly reduced in EVs due to the use of one or two speed reducers instead of the classic manual, automatic or twin-clutch gearboxes, these gear wheels are loaded with torque and rpm not previously found in high-volume production.

With HEVs and EVs, the noise from an internal combustion engine is intermittent or non-existent, so that transmission makes the most dominant vehicle noise. Noise, therefore, becomes not only a mechanical issue for the performance of the transmission, but also a comfort issue for the driver.

Basically, the concept of NVH testing is to stress the gears by applying rotation speeds and torque values similar (or even higher) to those that are applied in the real working conditions. The ability to test gears at operating conditions almost comparable to the final e-drive is a main benefit of the NVH Gear Tester.

The output parameter is the angular acceleration of the part (or master), evaluated instantaneously and in the long run with the use of encoders (TE inspection) and torsional accelerometer inspection. The stiff granite structure of the NVH gear tester makes it impervious to external interferences and a highly configurable software package makes this system as good as correlating data with the end-of-line test rig.

The NVH gear tester has a max rotating speed of 3,000 rpm, driving torque of 0–30 Nm, and can accommodate a max gear tooth height of 70 mm and shaft length of 280 mm. It can be designed to work with either manual or automatic loading.

www.marposs.com

Solar Atmospheres of California

ADDS SMALL FURNACE CAPACITY

To support R&D and additive manufacturing projects, Solar Atmospheres of California (SCA) has added some much-needed small vacuum furnace capacity to their expansive equipment offerings. The new vacuum furnace was procured from SCA's furnace manufacturing sister facility, Solar Manufacturing (SAMI) located in Sellersville, Penn., and was specifically designed to process a variety of materials between 600°F–2,400°F (±10°F) in both vacuum and/or partial pressure environments. Precise cooling capability up to 2-Bar in argon, nitrogen or helium is available with a maximum operating temperature up to 2,650°F. The furnace is also equipped with the SAMI's state-of-the-art SolarVac Polaris Control System for optimum performance and precise cycle control.

SCA President Derek Dennis states, "We are pleased to add this needed piece of vacuum furnace equipment to service our valuable customers. The additive manufacturing industry continues to grow, and this new furnace will allow SCA to respond to small builds and R&D projects quickly and precisely. SCA has plans to add additional equipment in the future to ensure that we have the capacity available to handle the rebounding industry post-COVID."

www.solaratm.com

Mahr

INTRODUCES MAR4D PLQ SERIES

Mahr recently introduced its new Mar4D PLQ product series. The cylinder coordinate measuring machines (CMMs) with multi-sensor technology are optimized for use in production and in the measuring room. Complex workpieces require a highly efficient measuring machine: It should solve various measuring tasks as quickly as possible, close to production and reproducibly in one system. This is exactly what the cylinder coordinate measuring machines of the new Mar4D line do. Equipped with up to four CNC axes, optical and optional tactile sensors, as well as sophisticated monitoring systems, they reliably and precisely record 3D measured values.Depending on the machine variant and equipment, the Mar4D PLQ can inspect rotationally symmetrical workpieces up to a diameter of 200 mm, a length of 1,000 mm and a weight of 50 kg.

www.mahr.com

Kennametal

INTRODUCES FIX8 FOR HEAVY-DUTY TURNING

Kennametal has released the FIX8 heavy-duty turning system, delivering maximum metal removal rates in steel, stainless steel and cast iron. With eight cutting edges per insert, the system increases productivity of any heavy-duty turning operation, providing the lowest cost per edge while reducing cutting forces up to 15 percent.

"FIX8 is designed to cover a wide range of applications, including turning and facing, smooth surfaces, interrupted, and heavily interrupted cuts. From medium depth-of-cut to roughing in steels, cast iron and challenging materials like stainless steel, FIX8 handles it all. Even extreme feed rates of up to 1.4 mm (0.055") and depths of cut up to 12 mm (0.472") are possible with FIX8," says Matthew Fuerst, product manager, Kennametal.

The tangential design of the FIX8 insert features a rigid clamping system that pulls the insert securely into the pocket seat, offering suitable stability that enables the insert to withstand large cutting forces and vibrations for optimal performance. The insert is also supported by a replaceable carbide shim, protecting the pocket against deformation and damage.

The FIX8 tool holder features precision 3D coolant technology, supplying sufficient coolant precisely where needed. Three coolant nozzles are directed to the rake face, controlling temperature, chip evacuation, and supporting chip formation. Coolant exit holes in two different locations are directed toward the flank of the insert, controlling the heat in the cutting zone and prolonging tool life.

www.kennametal.com

Kapp Niles

OFFERS KNG 350 FLEX

The KNG 350 Flex HS is based on a compact, setup-optimized machine concept and is intended for use in small to large-scale series production of externally geared workpieces with a diameter of up to 350 mm. The integrated loading device ensures shortest nonproductive periods and can accommodate both bore parts and shaft workpieces. The new functional and ergonomic machine design, paired with the KN grind inerface, supports the user during setup and optimization of grinding projects. High-performance technology options mean that maximum precision and surface qualities can be achieved. The KNG 350 series is characterized by flexibility in processing options, loading options, automated and manual, as well as application-oriented software functions.

www.kapp-niles.com

Southern Gear

ADDS PRECISION MEASUREMENT RESOURCES

Southern Gear is meeting customer requirements for the precise measurement of increasingly complex cylindrical and bevel gears with two advanced new Keyence Image Dimension Measurement Systems, capable of measuring up to 300 dimensions on as many as 100 parts in just seconds.

Dimensional measurement with conventional instruments and measurement tools is typically a slow, tedious process requiring the setup and adjustment of multiple complex fixtures — a process that's heavily dependent on highly trained operators to achieve accurate and consistent results. With the new Keyence IM-8000 systems, setup and operation is greatly simplified and

highly automated. For example, there is no time-consuming part positioning work or datum setup required. The simple "place-and-press" operation ensures consistent measurement of hundreds of dimensions on multiple parts with just the push of a button and regardless of operator skill.

"These new systems seem tailor-made for the complex precision parts we're producing today for customers across the widest spectrum of applications," says Southern Gear President Karen Malin. "We're working to speed throughput in every facet of our operation; these new systems are taking significant time and effort out of these increasingly important operations."

The addition of the Keyence systems is part of a multi-million dollar, company-wide investment in new technologies, methodologies and processes that, over the last several years, has, according to Malin, added much needed capacity to Southern Gear's vertically-integrated shop floor.

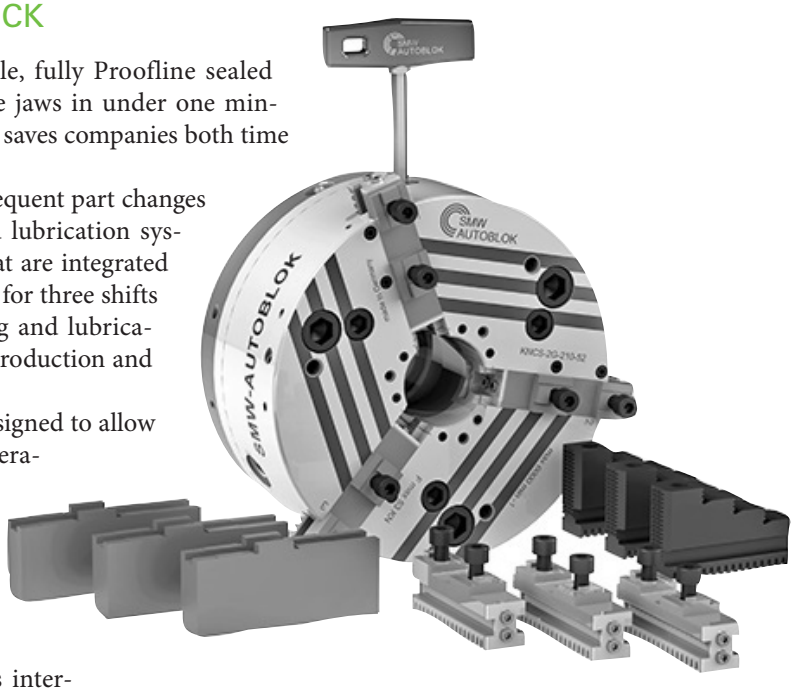
www.southerngear.com

SMW Autoblok

INTRODUCES KNCS-2G POWER CHUCK

SMW Autoblok has recently introduced the flexible, fully Proofline sealed KNCS-2G power chuck that allows users to change jaws in under one minute—reducing downtime during changeovers which saves companies both time and money.

Ideal for lathe and mill-turn applications where frequent part changes are prevalent, the KNCS-2G features an optimized lubrication system with additional channels and grease pockets that are integrated into the jaw guideways to allow the chuck to operate for three shifts before additional lubrication is needed. The sealing and lubrication system makes the KNCS-2G suitable for mass production and ensures constant clamp force and extended life.



The chamfered guideways of the KNCS-2G are designed to allow for quick-change of jaws, making it flexible for operations needing multiple jaw changes and setups. The fully Proofline sealed chuck body and base jaws also provide additional protection against chips, lubricants and other debris.

The chuck body and internal parts are case hardened for increased chuck life and highest rigidity, precision and durability. The KNCS-2G is interchangeable with the standard KNCS-N chucks and existing master jaws can still be used without sealing. Sizes are available in 170–630 mm.

www.smwautoblok.com

WFL Millturn

OFFERS HEAVYWEIGHT MACHINING BENEFITS

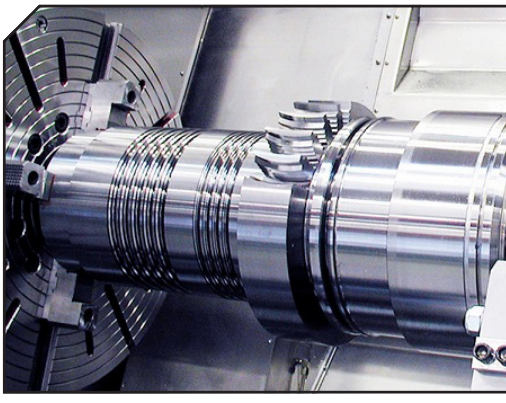
Higher, faster, further — as the saying goes, but now there's "longer, wider, heavier." Industrial requirements are constantly being pushed upwards. All of which means that WFL is entering exciting territory: heavyweight machining. The machining of large and very heavy components is often an extremely laborious undertaking that involves significant costs. Maximum process reliability and, above all, time savings in a component's throughput time are the name of the game.

Combining all machining and measuring operations into a single Millturn complete machining center from WFL massively increases the efficiency of manufacturing. The unique Millturn machine concept and turning-boring-milling unit with gearbox offers precise chipping performance.

Gas and steam turbines or components for wind turbines, rollers, crankshafts and transmission parts in machine construction — can now be machined by WFL. A Millturn can even easily handle high-strength steel or HRSA (heat resistant super alloy) material.

A Millturn eliminates the need for tedious changeover processes. Warpage-free and secure clamping is critical for premium quality standards. Large masses have a tendency to deform or change simply as a result of their net weight. The sag of a turbine shaft weighing 60 tonnes is so great that this needs to be taken into account when clamping the workpiece.

This variable can be compensated with the correct design of the clamping device and clamping method. FEM calculation (finite element method) can be used to precisely determine how the workpiece can be correctly clamped and supported. In this case, WFL uses a rolling or hydrostatic steady rest depending on the characteristics of the workpiece. This ensures optimal machining quality and production. The accessibility to the machine with folding grate elements and



tread plates also ensures the best possible ergonomics.

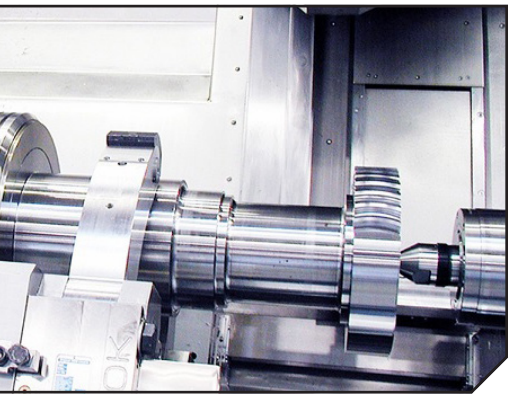
What's more, the enclosed working area enables machining under high coolant pressures. The UHPC pump (Ultra High Pressure Coolant) can be used to reach up to 200 bar. This ensures an optimum tool life even with high machining parameters.

Flexible measurement technologies support the user and once again clearly highlight the benefits of measuring components with large dimensions. WFL measuring cycles are carefully considered down to the last detail. For example, special calibration methods using the measuring probe and temperature compensation — which is particularly important when working with large diameters — allow the expansion of the material to be taken into account. The WFL measurement methods can even be used to produce a workpiece with maximum precision in adverse production conditions (e.g., external influences such as temperature).

It is also possible to precisely measure the position of the workpiece in the working area. This is necessary to precisely manufacture extremely narrow shape and position tolerances, for example, fir tree profile slots or locating holes.

The CrashGuard Studio programming software also supports an effortless review of the machining program. This makes it possible to minimize production errors ahead of time.

www.wfl.at



Doosan Robotics

THRIVES IN COLLABORATIVE ROBOT MARKET

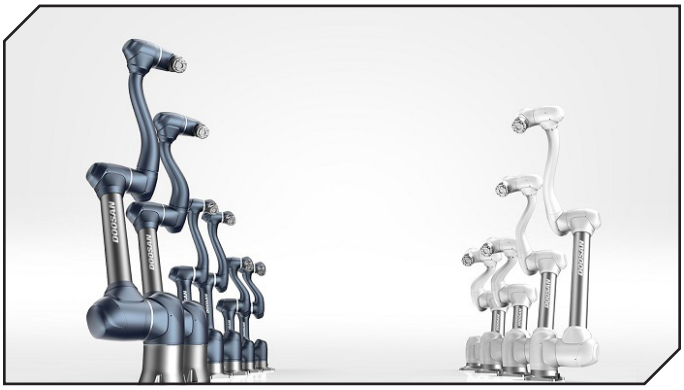
Doosan Robotics has manufactured cobots using proprietary technology in South Korea since 2018.

The company's global performance now accounts for 70 percent of its total sales, with demand continuing to increase from markets including North America and Western Europe. The company plans to establish subsidiaries in these regions to further accelerate growth.

The company also announced it has successfully raised an investment worth $33.7 million from Praxis Capital Partners and Korea Investment Partners. Funds will be used to expand global sales base and strengthen R&D to attract additional partnerships both global and domestic. The company also plans to pursue an initial public offering (IPO) with the ambition to increase cobot production in the manufacturing and service fields.

"We're looking forward to expediting the growth of our business with the recent funds raised," said William (Junghoon) Ryu, CEO at Doosan Robotics. "We will further enhance the competitiveness of new products and software that are mounted with our proprietary technology and strive to attain the position as number one market share holder in the global cobot market," he added.

www.doosanrobotics.com/en/



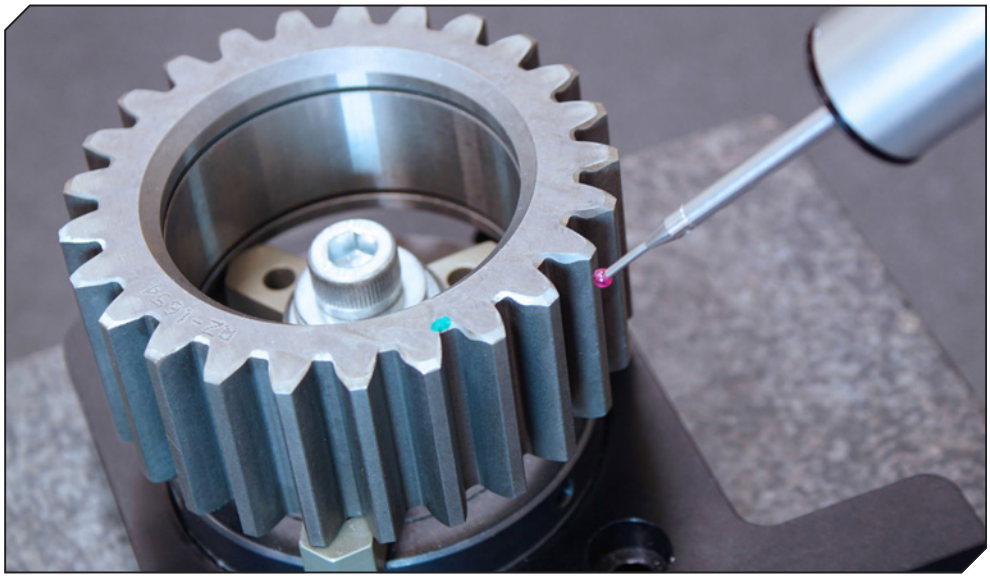
LK Metrology

SOFTWARE UPDATE INSPECTS GEARS AUTOMATICALLY

Coordinate measuring machine (CMM) manufacturer LK Metrology has introduced a third release of its *CAMIO 2021* programming and measurement software featuring numerous improvements. The most significant is the inclusion of a module that automates the inspection of spur and helical involute gears.

CAMIO GEARS makes it possible to begin measuring the specific geometry of gears quickly by using the core capabilities of *CAMIO* software to generate straightforward inspection programs, advanced gear reports and automated probe calibration routines.

For each gear type, the software has a unique set of definitions, evaluation algorithms and reporting graphics conveniently packaged in one add-on module, making it easy for users to bring a new capability to their existing CMM. The module supports alignment of the gear axis during measurement using any of the three CMM axes and traditional touch trigger probes or advanced scanning probes.



Several other improvements have been incorporated into *CAMIO 2021 R3*. Smart 3-2-1 datum alignment is new functionality that intelligently selects the datum axis and origin constraints, as well as the most suitable datum features using best-practice techniques. Should the user change the alignment properties manually, the selections automatically update.

Explorer Tree Datum Definition allows datum features to be defined more efficiently directly from the feature explorer, with the option of specifying the datum label. Report Table Feature Order provides new options for controlling the order in which features are reported in graphical tables, either alphabetically, by program output or in a user-defined order.

Teach-path coordinates and directions may now be defined using the CAD model. The GD&T (geometric dimensioning and tolerancing) reporting algorithm has been further enhanced to be independent of the standard used. Finally, there is new capability for retrieving points from a feature measured using a tactile probe, complementing existing functionality for retrieving data from a point cloud.

For CAD users, exchange file versions are compatible with the latest release of Spatial's InterOp, as was the case in the previous iteration of *CAMIO 2021*. The interoperability software is an industry leader in CAD data translation that enables users to import, interact with, share and export 3D data easily across CMM platforms and manufacturing sites.

CAMIO 2021 R3 encourages novice as well as experienced users to drive the inspection process graphically from the CAD model, either online or offline, although teach-and-learn using the CMM handbox is available. An advanced user interface makes part alignment, feature inspection and dimensional tolerancing fast and intuitive.

The virtual CMM programming environment means that accurate axis movement and probe motion sequences may be simulated for collision detection and cycle time estimations. Help Files now use a version of HTML5 help that supports modern internet browsers, such as Microsoft Edge and Google Chrome, and link to locally installed help pages.

CAMIO 2021 supports *Metrology Gate*, Industry 4.0 software that enables production teams to view and analyze quality data and monitor all CMM activity remotely from any internet-connected device. The web-based portal provides 24/7 access to information from any enabled metrology device for automatically retrieving inspection results and a summary of errors, a record of program changes, uptime of the CMMs and OEE (overall equipment effectiveness).

Historical logs assist troubleshooting and warn when routine maintenance is due, not only of the inspection machines but also of the machine tools or other equipment on which the components are being made. The software provides a modular solution for various levels of CMM automation to raise productivity, cost effectiveness and product quality.

www.lkmetrology.com

A World of Smart Processing & Digital Advancements

What will gear manufacturing look like in the next five years?

Matthew Jaster, Senior Editor

It's that time of year again! Pandemic fears, supply chain issues, economic growth sprinkled in with some economic uncertainty. Every year, we take an in-depth look at the State of the Gear Industry and every year provides an interesting and colorful array of challenges, surprises and new innovations. *Gear Technology* spoke with Prasad Kizhakel, Chief Sales Officer at the Klingelnberg Group, Udo Stolz, Vice President of Sales and Marketing, Gleason Corporation, and Shane Hollingsworth, Vice President Sales at Kapp Technologies to assess what the next five years in gear manufacturing may look like from the machine tool providers:

What will be the focus in gear manufacturing in the next five years?

Stolz: Quality and cost per piece are going to drive future gear manufacturing strategies.

As we see a strong shift towards sustainability including e-mobility and renewable energies like wind power, requirements for high quality, silent gears will increase. Since manufacturing solutions alone will not be able to support meeting all requirements, integrated design, manufacturing and inspection solutions in a closed loop are key to future success. As the boundaries and especially cost per piece for specific manufacturing processes are already set during the design phase, it will be mandatory to provide gear and transmission designers with some substantial manufacturing know-how. Inspection results and advanced waviness solutions will provide feedback to design and manufacturing experts, to understand whether specific gear designs can meet the targeted noise requirements. If that is done in a smart and efficient way, gear manufacturing will step up to a completely new level of accuracy and efficiency. At Gleason, we are convinced that such smart processing is indeed the future of gear manufacturing and that closed-loop — "design-manufacture-inspect" — solutions in combination with highly accurate, productive and reliable machining systems will

support this development.

Kizhakel: The elephant in the room is gears for e-mobility. I believe there will be two areas of focus over the next five years. Demand for higher power density and compactness in this sector will challenge technology providers like Klingelnberg to focus on manufacturing solutions that ensure superior NVH characteristics, geometrical accuracy, service life and cost per piece. Another thrust area would be quality assurance solutions that are precise, reliable and highly productive. If I have to pick an area amongst others which would be different in five years, it would be the reliance of gear industry on big data and the use of artificial intelligence to find patterns and solutions by analyzing them.

Hollingsworth: This question has a lot of influence on the industry that is being served, such as the shift from traditional transmissions to EV technology. The quantity of gears are reduced, but the quality requirements are much more stringent. The continued discussion of replacing the workforce that is retiring is another factor. What areas will be different than they are today? We will see continued growth in education programs to address the workforce requirements. The developments for smarter/adaptive machine tools with more connectivity whether that is remote support, process monitoring, maintenance planning or production/quality control. The effects of COVID have accelerated this requirement and the surface is only being scratched.

What emerging technologies will be most important in gear manufacturing moving forward?

Kizhakel: There are gears in many critical fields of application and they demand different end solutions, some of which may have an overlapping thread. For example, the gears in e-mobility, wind power or industrial applications have unique end requirements, however they all would benefit from emerging technologies in the field of cleaner steel, vacuum carburizing or production technologies that combine multiple processes. Another example of exciting emerging technology is digital products and cloud solutions where better hardware, an empowered software eco system and data analytics could provide seamless user experiences. Specifically for transmission gears themselves, we foresee our technologies such as quiet surface shifting, polish grinding, closed-loop manufacturing, hybrid metrology and the recently introduced e-mobility specific noise finder under the name R 300 leading the charge.

Hollingsworth: The *adaption* of Industry 4.0 and the *adoption* from the customer base can be provide a significant shift on how we look at manufacturing today as compared to the future.

Stolz: Even though we do not see major shifts in general gear manufacturing technologies, we are driving continuous improvement regarding precision and productivity of all existing processes. Quality, advanced surface roughness requirements and increased productivity will be the focus of gear manufacturers. Especially hard fine finishing technologies including power skiving will play a significant role in achieving ambitious quality goals. There is no "one solution fits all." Choosing the most efficient manufacturing technology for a specific part, including machine, tooling, and optimum processing will be the key for success in coming years. While manufacturing systems continuously improve, Gleason is indeed making a quantum leap with its new metrology systems, extreme accuracies, in-process inspection, and advanced analytics for up to 100% quality and noise control in daily production life. With digital manufacturing we move one step further, striving to create digital twins representing accurate predictive dynamic models of gearing/drivetrain solutions and the related manufacturing processes, making sure that waste is avoided, taking a direct route to optimum results.

How has the global pandemic altered the way you do business today (and in the future)?

Hollingsworth: From the sales perspective, the use of virtual meetings has become more accepted, and we will see some percentage of in-person visits continue to be virtual. In other ways, it has highlighted the importance of in-person relationships and the value we as individuals recognize. We do anticipate the logistics impacts from the pandemic that customers will review their supply chains as well as

inventory planning. As we see the supply chain stretch out again, it will force the industry to look further into the future for required technology.

Stolz: The continuous restrictions have made meetings in person more difficult and have altered the way we communicate. Video conferencing and live video demonstrations have helped a lot. Flexibility and speed in adapting to these changes have also created opportunities: right after the start of the pandemic Gleason began to offer Gear Trainer Webinar series in multiple languages. This free service has reached more than 10,000 participants from over 30 countries. In many cases, the possibility of bringing experts from around the world together without the need of travelling thousands of miles has increased the efficiency of customers as well as of our own work force. At Gleason, we are convinced that we experience a true paradigm change, and our communication behavior will result in a "new normal" after the end of the pandemic. Actually, the pandemic has only sped up the process of digitalization and growth of online communication we have witnessed for the past years before COVID hit the global economies. Webinar streams, online training classes, virtual shows and live remote machine demonstrations have become part of daily business and will complement in-person interactions going forward.

Kizhakel: The global pandemic forced a universal paradigm shift, which quickly and profoundly impacted the way business is done today. This short-term impact will also influence the way we plan to do business in the future too. There are three areas, which stand out, where things would not be the same anymore. First is the *Connect & Communication* with our customers and suppliers, this important pillar of our business has taken a digital dominance. Second is the *Sales & Customer Support* channels, where the focus will be entirely on the strength of the last mile. Third is the adherence to hybrid work culture which ensure well-being of our employees. At the end, the global pandemic simply presented itself to be a coincidence that reinforced convictions that we already had and definitely accelerated certain processes that otherwise would have taken longer to implement.

Do you believe the next generation of skilled workers will be properly prepared to handle the challenges ahead in manufacturing?

Kizhakel: I wouldn't dare to prejudge the next generation, essentially because every generation so far has proved to be smarter and better equipped to deal with the challenges of their times than the previous ones. That said, we should look at this very valid question from a completely different perspective. Leaving aside the impact of the COVID pandemic, if we look at the World Bank statistics over the last two decades, the percentage contribution of the service sector to the GDP among leading western economies and say, east Asia-Pacific is roughly in the range of 70% and 56.3% respectively. Some of these western economies like Germany, Italy, USA, Sweden, etc. still have an impressive value adding to the manufacturing sector as well. Therefore, I visualize a situation where, in certain influential market regions, we will experience a shortage of manpower for the manufacturing sector, even before we get busy about the skill sets of workers in the next generation. Companies like Klingelnberg, can choose to look at this as either twin challenges or twin opportunities. In fact, we choose the latter.

We will continue to develop our machines and the related ecosystem with high degrees of digital compatibility yet lowest degree of complexity to the user. Across our product lines, intuitive software solutions and adoption of artificial intelligence will provide enhanced support to workers so that the learning curve is shortened. Experiences so far have shown us that our integrated closed-loop solutions for gear manufacturing and "done in one" approach to quality assurance are precisely addressing the needs of the industry. We must continue in this direction to bring more value addition and support to the industry and workers of tomorrow.

Stolz: This question has been regularly discussed for many years. So far, manufacturing companies have been able to find adequate solutions to cope with skilled labor shortages. For gear manufacturing companies it will be

very important to educate gear experts in-house and recruit skilled labor on a global level. Gleason offers a variety of training classes and free webinars aimed to help customers to improve their gear technology know-how including gear design, manufacturing, and inspection challenges. At the same time Gleason continues to expand its educational programs internally, offering employee trainee programs starting at high school and college level in many of its global operations.

Hollingsworth: At the moment, there is a clear short fall and not enough reactiveness from "institutions," The current trajectory would suggest that companies will need to look internally at developing their own programs. The need to hire sooner for succession planning is clear. We are hiring for the future knowing the development time will be extended. We are also looking at opportunities to expand/utilize existing global apprenticeship where we would bring potential new employees for a period time to our facility.

What improvements need to be made to become more sustainable in gear manufacturing?

Stolz: In many parts of the industry, gear manufacturing has already achieved a comparably high level of sustainable processing, but there is room for improvement. Cleaner, more efficient technologies and qualified local support are of essence for the efficient use of limited resources. Gear providers must be able to guide their customers directly towards the most suitable design, manufacturing, and inspection alternative, to achieve the required quality without trial and error, resulting in minimum scrap and optimum efficiency. Qualified local service must support customers to benefit from maximum equipment uptime. As labor force limitations are becoming an issue in many parts of the world, automation will play an even more important role in future installations.

Hollingsworth: Technology is ever evolving and at a much faster pace than we have historically seen, Mechanically, we see machine tools outliving the controls. New developments from controls providers, drives, and software continue to rapidly develop and taking advantage and investing in these new technologies including the perishable items will drive efficiency on a cost per part basis. This could be in labor reduction, cycle time, reducing setup, quality control or a new cutting/grinding tool.

Kizhakel: I believe this is a work in progress and that the industry has been forever striving for improvements in all these fields. Significant gains in efficiency can be gained by combing more and more operations on a single asset thereby eliminating inefficient handling, set up and qualifying operations. We can better exploit the innovations in tool technologies, by building robust and energy efficient machines that accommodate higher cutting/grinding speeds and/or bigger tools. On a strategic level, the point may be examining "cleaner" needs to be defined in terms of reduced carbon footprint in gear manufacturing than the very cleanliness of the gear itself.

One wish that is perhaps beyond our sphere of influence is the need for industry friendly regulatory environment for data acquisition and transfer. This would accelerate the universal adoption of digital technologies that can further drive gains in efficiency and productivity.

Check out *Gear Technology's* annual "State of the Gear Industry Survey" to learn more on page 24.

www.gleason.com
www.kapp-niles.com
www.klingelnberg.com

For Related Articles Search
state of the gear industry
at www.geartechnology.com

2022 State of the Gear Industry

Reader Survey Results

Gear Technology's annual State-of-the-Gear-Industry survey polls gear manufacturers about the latest trends and opinions relating to the overall health of the gear industry. As in years past, the survey was conducted anonymously, with invitations sent by e-mail to gear industry companies—primarily in North America, but also including some respondents from around the world. Nearly 200 individuals responded to the survey.

All of the responses included in these results come from individuals who work at locations where gears, splines, sprockets, worms and similar components are manufactured. They work at gear manufacturing job shops as well as captive shops at OEMs.

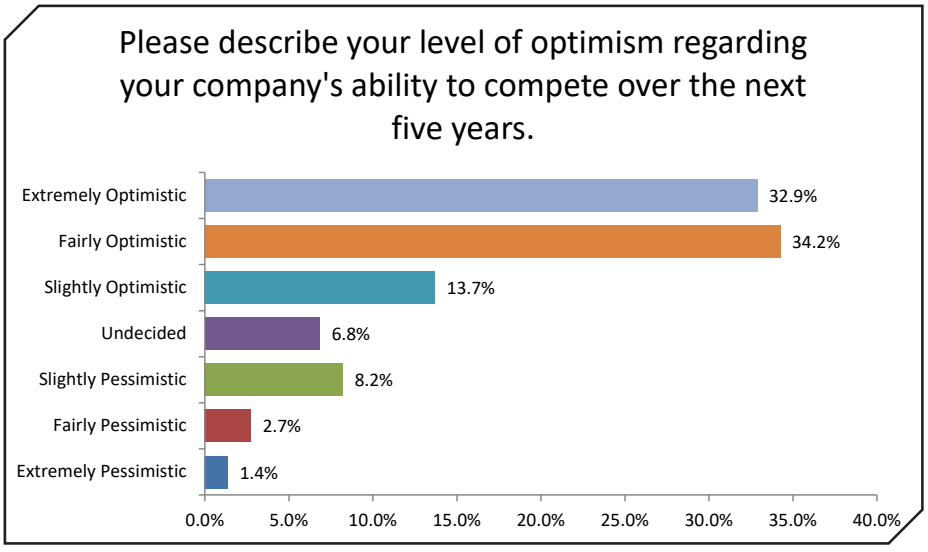
A full breakdown of the respondent demographics can be found at the end of this article.

Summary

This year's survey was conducted in mid-January 2022, toward the end of the COVID Omicron surge in the United States. And although the pandemic is still on a lot of people's mind, it didn't seem to weight quite as heavily in this year's result—at least not directly. The disease has had a long-lasting effect on the workforce, supply chain and overall economy, and these things continue to weigh heavily on our industry, just as they do most other industries, manufacturing or not.

Apart from pandemic and its lasting effects, the trend that has the gear industry most concerned is the continued focus on electrification of the auto industry. It's a technological disruption that has nearly all gear manufacturers in that sector worried about their future.

Historically, our industry has been fairly optimistic as a bunch, at least according to our annual survey numbers. In typical years, 85% or more of our respondents have been optimistic about their companies' ability to compete. But then COVID hit. In January of 2020, only 75% of respondents indicated some level of optimism. Last year, that number was 76.5%. This year, it's 80.8%. So while there's some sense that maybe we're going to get through this COVID thing, there's still more negative sentiment than normal.



What Are the Most Important Trends Affecting the Gear Industry in 2022?

"Gear surface quality in regards to NVH due to increased demand for high RPMs of EVs."

"Electric cars on the rise."

"In particular for the automobile industry, I am observing a big change to electric vehicles, opening new opportunities and risk for current suppliers."

"The trend of building in USA. Stop being dependent on imports!"

"Price and availability of metal. Tremendous labor shortage."

"On-shoring. Labor shortages. Increasing health care costs."

"Electric driven automobiles!"

"Governmental influence on the overall market."

"Raw material cost increases."

"COVID absences."

"Automation of production and inspection due to the lack of skilled operators and technicians."

"Development of next gen workforce."

"Supply chain and steel constraints. Difficulty to get the right steel grade in a timely manner. U.S. forging houses have very long lead times."

"Supply chain issues are creating very difficult situations with regard

to being able to deliver in a timely manner. Constantly changing replies from vendors make it increasingly difficult to give the customer a commitment that you can stand by."

"Electro mobility, advanced agriculture applications, wind mill generator gearboxes."

"Long-term view and targets shared by customers to gear suppliers are essential to create a true partnership. Tomorrow's winners are companies that are able to provide to their gear suppliers a long-term vision and targets to enable suppliers get ready for the next challenges. We may lose alone, but we win only together!"

"Trend to production with skiving cutters."

"Renewable energy. Wind turbines pitch and yaw drives. Electric vehicle drives. Highly efficient drives."

"Sustainability - retrofit older machines; EV gearboxes - requirements and solutions; ICEs - improve fuel consumption."

"Globally local support of big players more important to international customers."

"High RPM with low NVH."

"Agri market in Russia and construction market worldwide look strong and it will stay in 2022."

"Supply chain to meet increase in product demand."

"Discounted price demand from customer with increase in commodity prices calls for value analysis and value engineering."

"Electrification."

"High speed gears."

"Supply high quality product with reasonable delivery time."

"Challenge of creating the next generation of technical skilled workers. Continued supply chain issues and inflation."

"Wind energy, renewable energies."

"Paying more attention to planetary gears with control."

"Epidemic, politics and industrial development in various countries."

"The adaptation of direct drive technology in all sectors of transmission industry may become a challenging time in the near future and more so in automobile sector."

"Optimization in product selection and design, process selection. Good finishing teeth surfaces, vacuum heat-treatment."

"Electric drives ."

"Lack of workers with gear knowledge on the workforce."

"Higher complexity and finishing grades required by e-mobity applications."

"Will we have a recession after this inflation."

"The move to electrification of the automotive industry. What will transfer to direct motor technology?"

"Cost and availability of materials."

"Worker shortages."

"Manufacturing sector is highly affected during COVID times. Gear manufacturing is one of them. Potential is good but skilled labor is in shortage. Raw materials are issue. Many related factories are under lockdown or closed."

"Automotive electrification, superfinishing of gears, gear polishing."

"Inflation on materials and services. Skilled labor shortage."

"Digitalization."

"More power densitiy on gears."

"High efficient gears/less standards."

"Skilled labor in gear machining. Next generation interest in metal manufacturing. Trades need to be part of high school learning in order for USA maintain the skill labor edge."

"Downturn in military helicopter sales, slow recovery of commercial airlines and production issues at major airframers."

"problems with the raw material production."

"Vehicle electrification."

"Market changes due to the pandemic."

"Supply delays."

"Gears for e-mobility."

"Imports from China and Taiwan. The rates of the gearboxes imported are unbelievable, and we cannot compete."

"Electric mobility."

"Transition from ICE to EV."

"Existing players needs to be involved in diversification of their product portfolio, i.e. to explore EV related opportunities."

"Improvements in gear design..."

Electric vehicles and fuel cell vehicles' penetration and growth are a disruptive element in gear industry."

"High operating costs making it more difficult to compete. Raw material and utilities such as gas and electric. Problems finding employees."

"Electrification."

"The geared drives all along the industry were affected through this pandemic, many enterprises stopped extension projects on their production plants and made just the necessary maintenance works. Nevertheless, now with vaccines developed and people coming back entirely to work in the first quarter of the year, investments will arise and the gear industry might have a lift up. It's optimistic."

"Electrification."

"(Electric Vehicle) EV."

"Special plastic gears and sintered worm gears."

"Electrification."

"Being able to get both labor and materials will affect us this year. The COVID virus and variations have

> "Raw material lead times and pricing make it hard to supply customers as well as increasing labor shortages AND hourly wages compared to even fast food facilities."

"Supply issues."

"Material lead time and availability."

"Material pricing."

"Qualified labor market and their interest to work."

"Skilled labor difficulties."

"E-mobility mainly."

"Cost increases on materials."

"Government regulations, inflation, transportation costs, material shortages, skyrocketing material costs."

"Lack of qualified workers."

"Not enough emphasis on gear train architecture."

"EV market ."

"Transmissions for electric vehicle."

"Automotive sector is swiftly switching to electric."

"Space industries are booming."

"How will EV penetration affect auto gears? How will chip shortages affect trucking gears?"

"Lack of qualified employees both at our own facility and those of suppliers. Lack of management understanding what equipment new employees are willing to learn to operate."

"Precision (quality), size and quantity of gears demanded by electric vehicles versus the actual combustion vehicles demand."

"Measuring gear vibration when assembled into gearboxes as an indicator of defect (mainly gear noise)."

hindered getting labor, and current supply chain issues around the world make getting components and raw material more difficult this year."

"Getting employees and rising costs."

"Price increases in shipping and shipping delays."

"Material increases."

"Continuing microchip shortages."

"Material shortages, price increases."

"Quality of workmanship."

"Quality of material."

"Huge labor shortage."

"Lack of contact with customer on face to face basis, to highlight capacities and capabilities."

"The future of automotive drivetrains. Rate of change and mix of IC, Hybrid and BEV. Drives will change, but supply of energy and transmission is not being addressed."

"Availability of local steel and forging capacity as more companies are localizing gears in order to meet the USMCA targets."

"Hard gear finishing with skive hobbing, scudding."

"Disconnect from buyer and manufacturing. High tooling costs, low production numbers."

"Supply/procurement shortages. How long will the industry take to return to predictable and consistent supply?"

"Shortage of raw materials on international market."

"Materials, gear shaping, increase strength of gear."

"Supply chain issues are hampering capacity. Business is moving elsewhere due to this."

"1) Hiring quality employees and retention. 2) Investment on next generation equipment. 3). Supply chain issues and government inflation will affect the ability to stay competitive globally."

"Tighter tolerances with same expected turnaround times and inspection reports."

"Orders."

"Employees."

"Raw material lead times and pricing make it hard to supply customers as well as increasing labor shortages AND hourly wages compared to even fast food facilities."

"Health of auto industry and material availability. Supply chain."

"E-Mobility with great impact on the manufacturing industry."

"New methods like power-skiving are being implemented on multi-tasking machines, enabling complete machining and fulfilling very high precision demands."

"The impact of the electric vehicle on the powertrain gear box and transfer case."

"Ability to find qualified machinists and the supply chain issues continue to hit our bottom line severely."

"Training of engineers with respect to design and manufacture in smaller companies."

"Gears sold to the energy sector, fertilization producers and plastics industries are in a state of uncertainty as politicians influence the maintenance and development of these industries subject to scrutiny orchestrated by climate change."

"The pandemic."

> "The adaptation of direct drive technology in all sectors of transmission industry may become a challenging time in the near future and more so in automobile sector."

"Electric vehicles."

"Digitization of the daily life, making gears omnipresent for transmitting power from a click to an actuator."

"Finding people."

"Increased costs/inflation."

"Offshore competition, increasing costs due to inflation, coupled with the current labor shortage will be an issue facing the gear industry and the U.S. in general."

"Supply chain - tied to on-time deliveries."

"Prices for raw materials affect final products' prices."

"Hiring new qualified employees and retaining the existing ones—affecting productivity."

"Attracting younger generation into manufacturing to replace those who retire, and avoid a huge intellectual/knowledge and production gap."

"Factory automation—affecting manufacturing process, especially when it is hard to find workers."

"Offering packages instead of individual products."

"Defense industry cyber security requirements. The aerospace industry is still in hibernation. Price of raw materials keeps increasing."

"3D gear printing, gear design customization for a particular application."

"Electric vehicles, additive manufacturing, laser inspection."

"The landscape of gearing is changing. The amount of gears may be fewer, but all will be hard finished and the quality critical to the success. Noise issues take front and center with EV, and printed gears will become a factor as powdered metal did 20 years ago."

"Employees."

"Effect of electric vehicles on industry."

"Whether the supply chain is stable."

"1. Moving towards more precision gears; 2. Increased gear grinding requirement; 3. Increased traceability requirement; 4. Increase in gear export from India; 5. Visibility of shop floor CMMs."

"Pandemic's impact on labor force."

42%

of Gear Industry companies saw an increase in employment levels in 2021 (versus 44% who saw a decrease in 2020).

59%

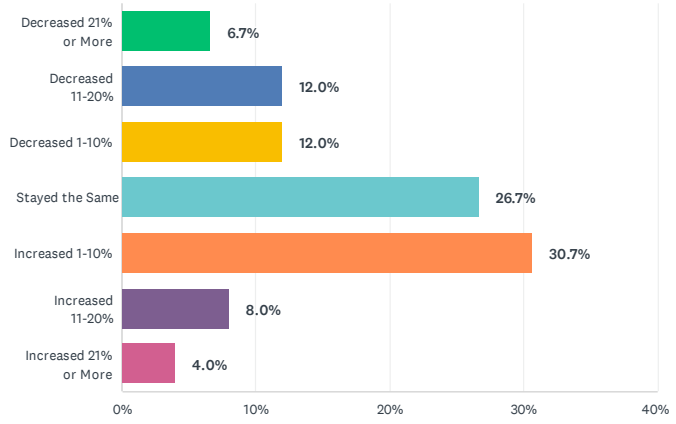
expect unemployment levels to increase in 2022 (versus 42% who expected it last year).

Production levels increased at

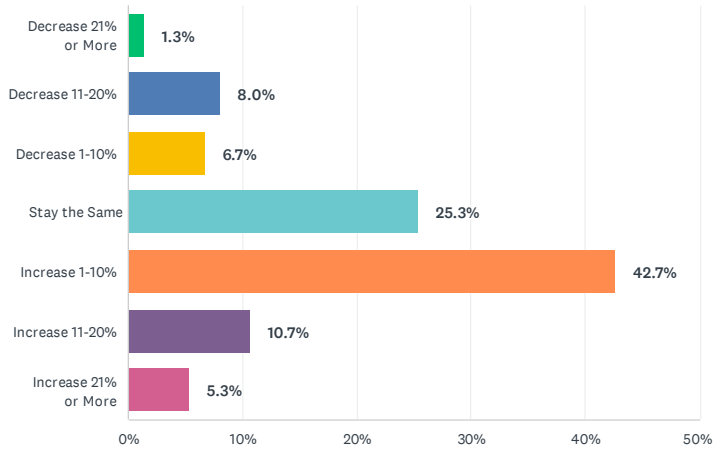
63%

of respondents' locations (versus a 59% decrease last year)

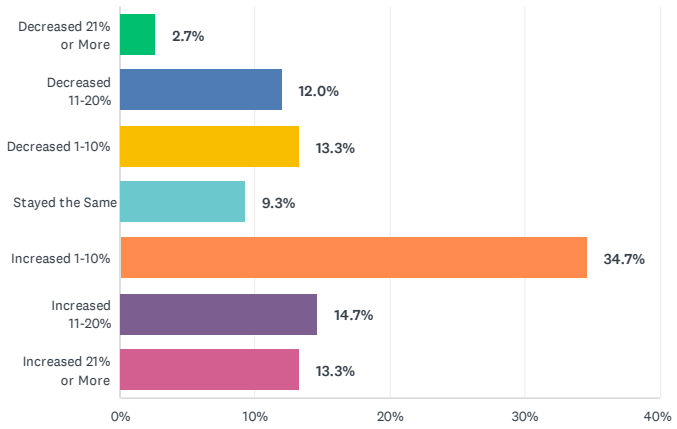
How has your location's LEVEL OF EMPLOYMENT changed over THE PAST 12 MONTHS?



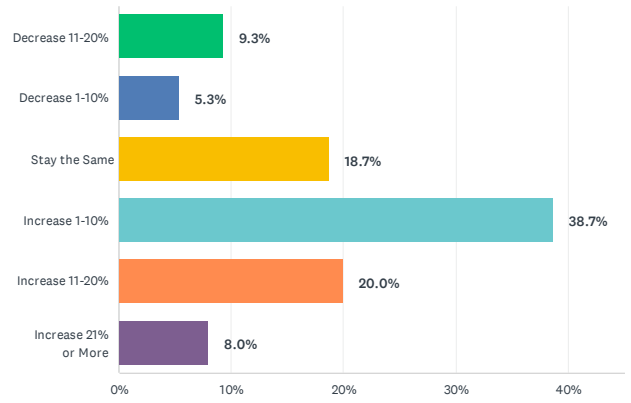
How do you anticipate your location's level of employment will change in the NEXT 12 MONTHS?



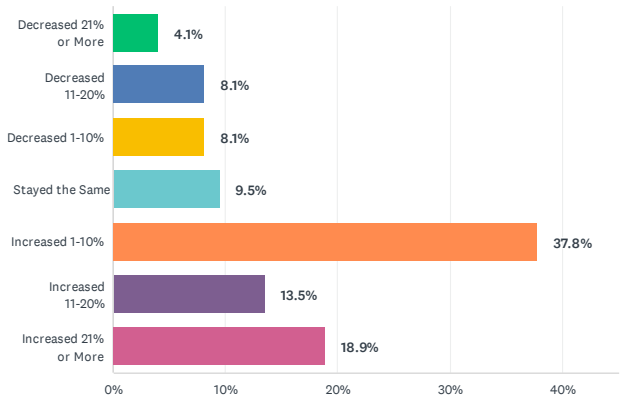
How has total PRODUCTION OUTPUT (unit volume) changed over the LAST 12 MONTHS?



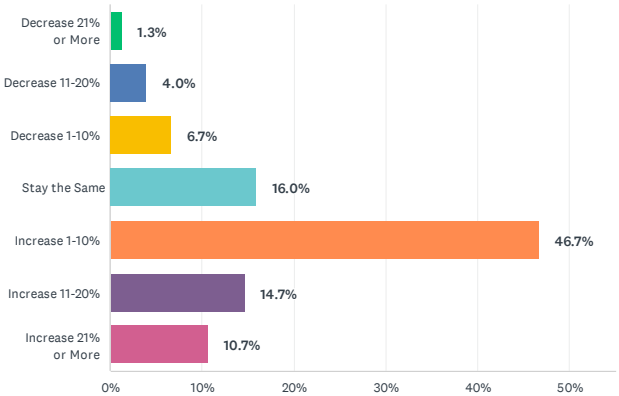
How much do you expect production output (unit volume) to change over the NEXT 12 MONTHS?



How has total SALES VOLUME changed over the LAST 12 MONTHS?



How much do you expect SALES volume to change over the NEXT 12 MONTHS?



67%

expect production levels to increase in 2022 (versus 57% who expected it last year).

Sales increased for

70%

of respondents (versus 62% last year).

72%

expect sales to increase in 2022 (versus 66% who expected it last year)

Capital spending increased at

52%

of respondents' locations (versus 54% who indicated a decrease last year)

57%

expect to see an increase in capital spending in 2022 (versus 44% who expected it last year)

How has the COVID Pandemic affected your business?

"Dramatically. Huge reduction in demand for civil aircraft parts."

"Extremelly hard. Several projects were stopped."

"Caused many delays and now is just the excuse for anything that costs more or is delayed."

"Absences. It is difficult to recover from absences in today's environment."

"The first year was very tough due to automotive pause. 2021 ended up being a record year for us once automotive came back to life."

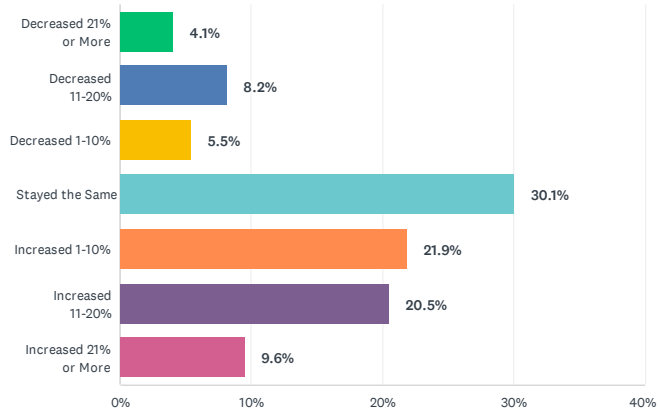
"Restricted access to end users did require different sales approach to maintain and grow order intake."

"Impacts on workforce availability due to illness and supply chain has made it difficult to provide reliable lead times."

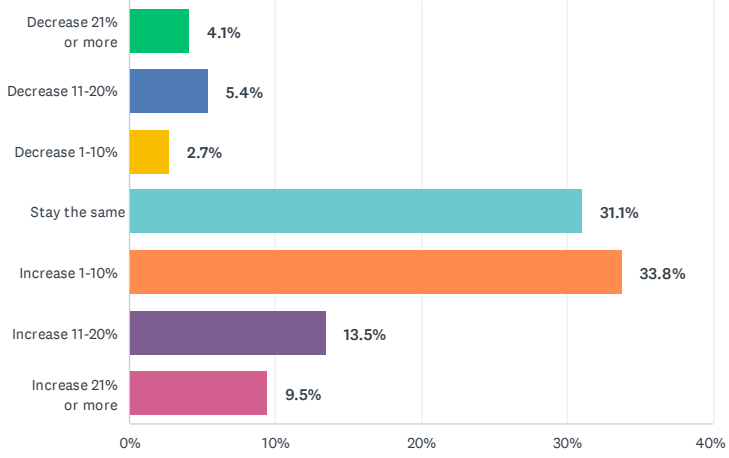
"Being an essential business we have been able to stay open the entire length of the pandemic and business has actually increased due to the product line."

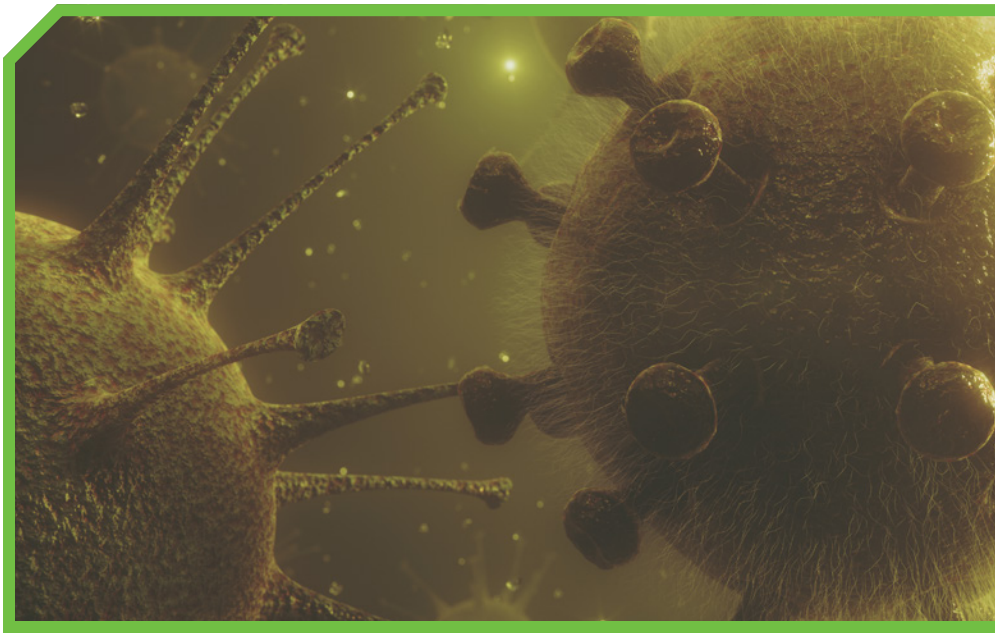
"Meetings with customers and supplier are more difficult."

How did your location's CAPITAL SPENDING in 2021 compare with 2020?



How do you anticipate your location's capital spending will change over the next 12 months?





"Presence of associates at work has become hardly predictable; Suppliers share same problem, so, deliveries of raw material/half finished blanks have been delayed throughout the year."

"Slump late 2020, early 2021. Steep rise later in 2021."

"2020 dipped from previous but 2021 bounced well back."

"Delay in shipment from supply chain; difficult to hire workers to increase our production to respond to the increased orders."

"Decreased production capacity."

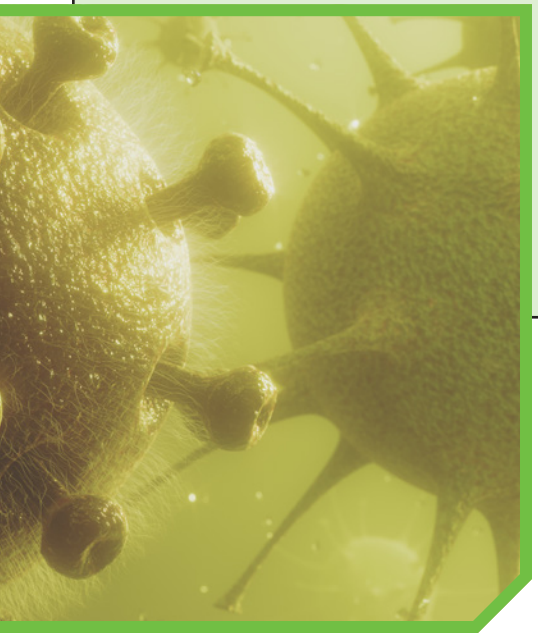
"Difficult in travels, no raw material availability."

"20% revenue loss."

"Growth is positive. But getting raw material at competitive price became hurdle."

"Fed and State dysfunctionality on safety and protocols are simply astounding. Some level of uncertainty is expected. The lack of clear direction and significant uncertainty, constant state of turmoil was massively disruptive to efficiency."

"Difficult to man all machines with laborers not able to show up. Little interest in new people taking open jobs."



"Very little impact."

"Not very seriously."

"Hasn't."

"It has made it more difficult to predict employee engagement. Having whole departments out due to COVID."

"Lost one employee completely. Have had to shut down departments within the organization due to Covid related illnesses."

"Sales are stagnant. We are still comparing ourselves to 2019."

"Decrease in demand from commercial airline customers, attendance challenges."

"Lots of volatility in the business."

Decreased sales compared to 2019; 2020's sales of gearboxes were 80% compared to 2019."

"Hard to find employees, everything cost more."

"Not at all."

"2020 was worst period. However 2021 we surpassed previous best."

"Minimally."

"Laid off night shift."

"Bad shutdowns."

"Increased our customers' demand for our product."

"Continues to limit face to face interaction."

"Projects have been delayed."

"Somewhat positively from the revenue standpoint. It kept us very busy from keeping employees healthy and safe to making our customers happy. Many unprecedented situations and questions had to be resolved and addressed, as well as going thru a long period of adaptation."

"Hard to find people and many want to work from home."

"Having employees quarantine for a positive test even though no symptoms are present has significantly affected our production efficiency."

"Significant reduction in revenue."

"High absentee rates, lateness in receiving product due to shipping delays."

"Covid tossed in the proverbial Monkey Wrench. Between remote employees and absences, it takes a lot longer to do some simple things."

"The flow of people and goods got worse."

"Very minor effect."

"Increased challenges in managing an already thin workforce."

"Had a staffing issue when 5 of 10 employees had covid at the same time."

"The pandemic has completely transformed how we approach sales: meetings are nearly all remote and live, and travel expenses have plummeted."

"Initially took a hit, has since recovered."

How are you handling and navigating supply chain issues heading into 2022?

"Minimal issues with supply chain."

"Not handling."

"Fortunately, in our company the impact of lack of supplies has not been significant."

"Looking for other vendors to fill the gap."

"Adding more suppliers.."

"Day to day..."

"These issues are handled by our Corporate division. For components without contracts, cost increases are passed through."

"So far, we have not had supply chain issues. We are purchasing ahead of orders on some longer lead time parts."

"Pre-order and more planning."

"Steel substitutes and finding new suppliers."

"Probably the biggest issue ahead along with hiring skilled labor. Looking for alternatives to the current vendor base. Increasing stocking orders to allow for the extended lead times and to minimize the constant price increases."

"Anticipating the order of new material."

"Providing longer and more stable planning; periodical meetings to assess suppliers are providing us adequate capacity."

"Taking early action. Seeking alternative suppliers. Higher Stock levels."

"Freight costs and delivery times are channeled directly to customers and quotes."

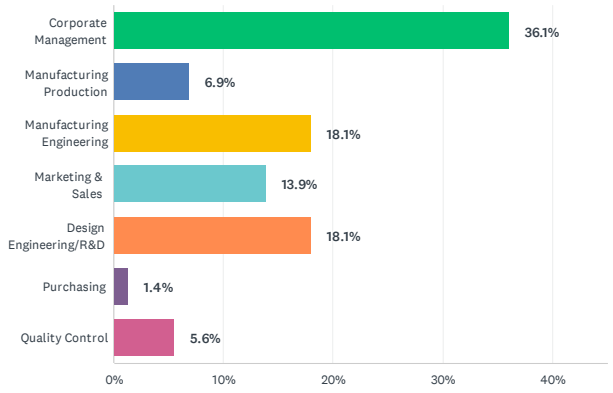
"Try to find other suppliers who have available capacity for the new business."

"Trying to find alternative suppliers and work with higher stocks."

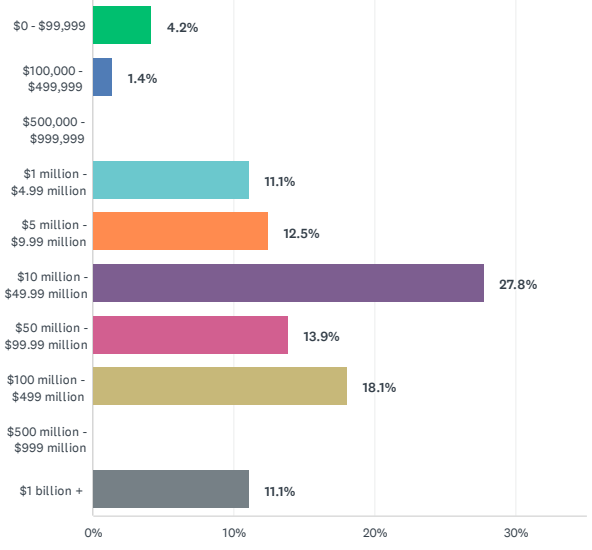
"Monitoring closely, developing alternate sources, but the prices of raw material are not stable."

DEMOGRAPHICS

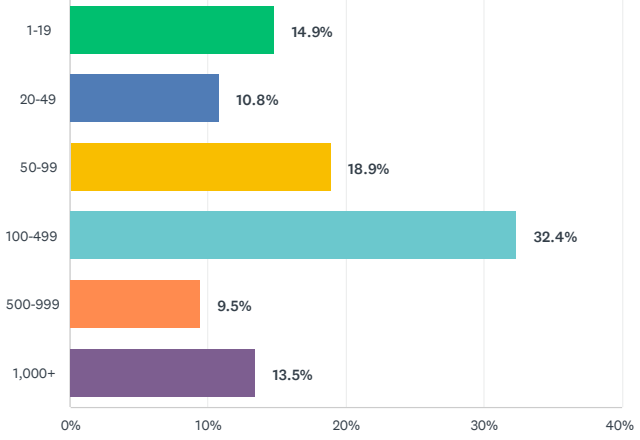
Which category best describes your job title/function?



What is the approximate annual revenue for your company? (If this location is owned by another company, please use figures from the corporate parent)

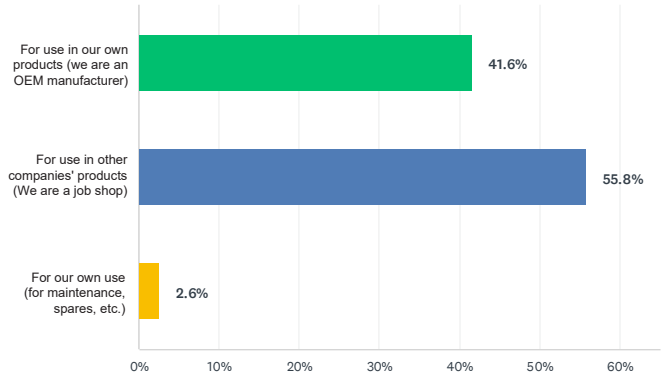


How many employees work at your location?

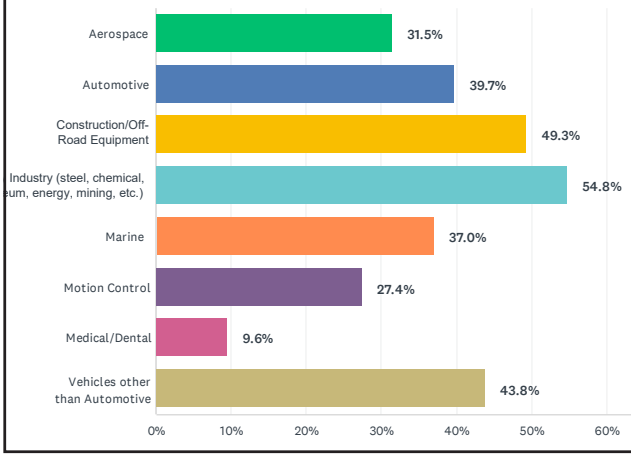


DEMOGRAPHICS

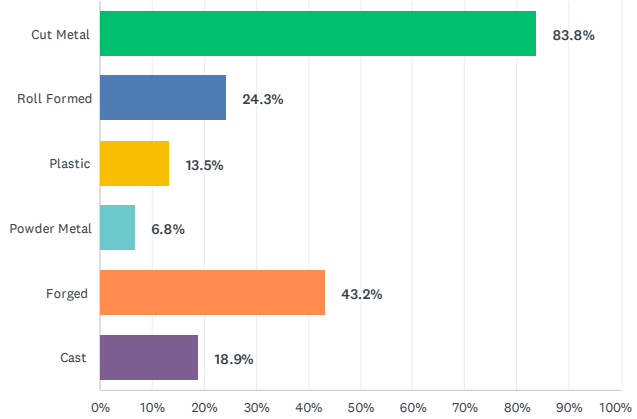
Gears (including splines, sprockets, worms and similar components) are manufactured at this location:



The gears (including sprockets, splines, worms and similar components) made at this facility are used for (check all that apply):



The gears manufactured at this location are (Check all that apply):



"With difficulties. Need to extended supply network."

"We continue to significantly adjust schedules and take down weeks because of lack of material and supplies."

"Doing the best we can, planning where we can."

"Badly."

"It is our No. 1 concern."

"Quoting longer lead times. Increasing prices to cover additional costs."

"Increasing inventory while seeking alternative sourcing."

"Apprehensively."

"Lead time extensions."

"You have to work more closely with customers as to deliveries."

"Purchasing excess inventory to hedge for shortages."

"Paying considerably more if materials are even available."

"Looking ahead for materials required. Allowing more time for outside services."

"Suffering with the inflation of prices but no lack of supplies. Our customers are being more impacted than we are."

"The beginning of 2022, material availability has been slow in stock and delivery. Steel suppliers have consolidated their inventory to specific key cities. Large steel orders and small are slow to fill."

"Pessimistic ."

"Management cannot formulate a plan as our suppliers are affected randomly and are struggling to keep up."

"Order early."

"Preparing the stock for the critical pieces (bearings, some raw materials) and increasing the future contracts."

"Long-term call orders."

"We try to keep at least two suppliers."

"Larger stock built."

"Some parts shortage affected the total output."

"Buy early and more than usual."

"Lost production due to shortage."

"Using multiple suppliers."

"Work with what I have in hand, telling our clients our situation before accepting the job."

"Long-term agreements, larger stock."

"Delivery time increased."

"Poorer selection."

"Buying ahead, more shopping for price."

"Our customer schedules are getting affected due to this."

"Buying in advance on projected requirements."

"Buying extra and ahead of normal."

"Minimal negative impact."

"Just dealing with upset customers for the long shipping delays!"

"Poorly."

"We're not."

"Ordering parts as early as we can and sometimes we search ebay and Amazon for short order supplies."

"Very well."

"Dual sourcing as much as possible as well as bringing on new suppliers. Carrying more inventory."

"Additional pre-planning, anticipating requirements."

"Not a big problem."

"No real supply chain issues."

"With some delays that affect production, but were able to find intermittent solutions."

"So far not so bad except for price increases."

"By forcing our forwarders to look outside the box for savings/lead time improvements. Also adjusting budgets for the increase in costs."

"Careful prediction of needs for forward ordering to adjust for logistics issues."

"Preordering raw materials where deliveries may be critical."

"Like everyone else, trying to be patient while leveraging any and all connections."

"Doing what we can to stay ahead of any issues. Finding backup suppliers."

"Increase inventory."

"Increase the frequency of contact with suppliers."

"Stocking heavily on items where we are confident there will be turnover."

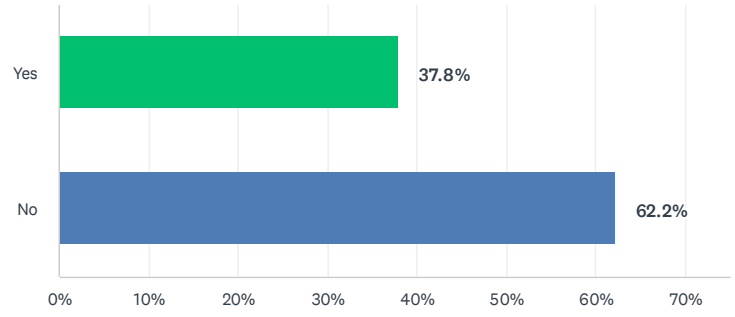
"Spending more and waiting longer."

"Supply chain is slow in delivery."

"All quotes have been updated with extended deliveries. New vendors have been found for competitive shipping solutions."

"Stretching commitment times."

Is your company currently a member of the American Gear Manufacturers Association (AGMA)?



For Related Articles Search
state of the gear industry
at www.geartechnology.com

FEELING SOCIAL?

Interact with your Gear Industry peers at ***www.geartechnology.com***.

- *Gear Technology* blog
- *Ask the Expert*
- Follow us on Twitter
- Join the *Gear Technology* group on LinkedIn (3,156 members and growing!)

Follow us on Twitter
twitter.com/#!/Gear_Technology

Connect with us on LinkedIn
www.linkedin.com/groups/Gear-Technology-Magazine-3893880

Subscribe Online
www.geartechnology.com/subscribe.htm

Our Librarian Will Never Shush You

at the GT LIBRARY

That's because the MICHAEL GOLDSTEIN GEAR TECHNOLOGY LIBRARY is all online and you can visit it anytime. Just go to *www.geartechnology.com* and use the search box for access to 36 years of technical content focused on gears.

- **Every issue since 1984**
- **More than 2,000 technical articles**
- **More than 6,000 archived news items**
- **Addendum, Publisher's Page, Back to Basics and more**

And the best news of all? You don't even need a library card. That's because the GT LIBRARY is open to everyone. Knowledge is free. All you have to do is go and get it.

www.geartechnology.com

Surviving the Labor Shortage

Joe Arvin

On a personal level, one of the challenges that I have faced during the past months of the pandemic has been my inability to visit with customers. This is something that I truly enjoy. While phone calls, Zoom meetings, and emails have been a necessary alternative, nothing beats face-to-face interactions and the discussions that result.

Thankfully, as these barriers have started to be lifted, I am once again having the opportunity to meet with people in person. As usual, one of my first questions is, "What problems are you having?" I am happy to report that I have heard many stories of strong business activity and even record backlogs. On the flip side, I have also heard many reports of a serious problem stemming from increased business volumes. One of the major problems is the shortage of workers.

The worker shortage is something that we are all fully aware of. In fact, I find it amazing to see help-wanted signs absolutely everywhere. This is a problem that exists not only in the United States, but in other countries as well. The reasons for this problem are myriad, but the million dollar question on everyone's mind is, "How long will it last?"

A few weeks ago, I had the opportunity to attend a presentation at the open house of Fusion OEM. Located in Burr Ridge, Illinois, they are an award-winning, CNC systems integrator for collaborative robots, focused on automating machine tending solutions for CNC turning and milling machines to increase productivity. During the presentation, the speaker provided some fairly compelling data about the global labor shortage and the sobering forecast that the labor shortage in manufacturing will not be ending anywhere in the near future.

Given the extensive nature of this serious problem, I wanted to share some information that manufacturers may find useful in navigating through this challenge.

Looking Beyond the Conventional Recruiting Methods

In the past, there have been a number of traditional methods used by companies for recruiting employees. These include:

- Job listings on your company website
- Signage on your property
- Print, radio, and online advertisements
- Social media
- Staffing agencies
- Online recruiting portals such as Indeed, ZipRecruiter, Monster, and others
- Job fairs

While these methods still have a place in a well-rounded recruiting strategy, many organizations are finding that these existing efforts are not meeting their needs during the current labor shortage. What is a manufacturing company to do?

As with other problems in manufacturing, the key to improvement is to use innovation. I would like to suggest that this current problem will require some innovative thinking and techniques by company leaders. Here are just a few ideas.

Finder's Fees and Signing Bonuses

In any tight market with increased competition, one way to stand out is by the use of incentives. For example, consider offering current employees a finder's fee for people they send in to apply for a job. If these people are hired, and stay for a minimum of three months, you would then pay the referring employee a fee of $500 to $1,000.

One company I spoke with relies heavily on word-of-mouth referrals by their employees. While these recruits are not likely to be highly skilled, it may be a good way to connect with someone who possesses aptitude and a good work ethic. Remember that the days of trained people showing up at your door are basically gone. I believe that most manufacturers now realize they will have to provide this training, but they want to invest that time and expense into someone with the "right stuff."

The same approach applies to providing incentives to the people you recruit. Consider offering initial signing bonuses as well as additional bonuses periodically after their on-board date.

People in Your Community

As you interact in your community, such as when you are getting your oil changed, having new tires installed, shopping at a store, or eating at a restaurant, keep an eye out for people who are hard workers and appear to be interested in doing a good job. As appropriate, try to start a conversation about job opportunities that you may have. Give them your business card and ask them to contact you for more information.

Those of us in the power transmission industry are aware of the well-paying jobs and solid career opportunities that exist. But this does not mean other people in our community know about this as well.

Plant Closings

Even though many companies are doing well these days, there are others that will need to close their doors for one reason or another. When you hear about the closing or the regional relocation of a manufacturing company, you need to take immediate action. Be sure to contact their Human Resources department or someone else you may know from the company. Ask if they would give you the contact information of employees who might be looking for a job. Then, be sure to personally contact every single one to schedule an interview.

Ex-Military Personnel

If the opportunity presents itself, consider hiring veterans that are transitioning out of the service to the private sector. These people will generally have very desirable traits as potential employees.

Specialized Job Postings

Both the American Gear Manufacturers Association (AGMA) and the Society of Manufacturing Engineers (SME) have online job listings from their member organizations. While these are similar to conventional job listings, they are, however, very specialized to the manufacturing industry. Seriously consider taking advantage of these focused channels.

Be a Place People Want to Work

Acquiring good people does not end with someone starting their first day of work. You must retain people you like for the long run. For this reason, it is important that you provide a place where people will initially want to work and then want to remain working.

A few weeks ago, I had a conversation with Jared Lyford, the Director of Manufacturing Operations at Forest City Gear, in Roscoe, Illinois. I have known this excellent organization run by Fred and Wendy Young for many years. During our discussion on the topic of retaining workers, Lyford had comments that I thought were very important for others to consider.

> **"Work environment is a key component for us. We interview and record the responses of all new hires to understand the influential factors in why they selected our company as a place of employment. Many of them say that the clean, organized, and efficient manufacturing floor is a large contributor. It is our opinion that when the employee's environment is conducive to high performance, high-performing individuals will arise from that.**
>
> **Culture is another important component of our workforce retention. We have fostered a collaborative team environment where assisting and training is celebrated. That attitude is hard for new employees to overlook.**
>
> **Combine the above attributes with competitive wages and a rich benefits package and you have the ingredients for a winning recipe when it comes to employee retention." (Jared Lyford)**

Get Into Gears

In your recruitment efforts, as potential employees learn about you and your industry, it is important to have printed material available to support your communication efforts with them. The good news here is that the AGMA Foundation has produced a package of materials for this purpose and they are available to use free of charge. This campaign, which is entitled Get Into Gears, includes all the selling points of why a person should consider a career path in the gear industry. The digital tool kit can be downloaded from their website at *agmafoundation.org/getintogears*.

Technical Schools and Programs

While many new employees will not be skilled in the ways of metal-working manufacturing, there is a good way to connect with individuals who are. I would suggest that you visit your local technical college to see the job training going on there. If this fits your needs, you might consider offering some of these students with part-time work. There are two major reasons for doing this. One, this way they will know if they like shop floor manufacturing work, and you can see if you like them. The second reason is that most good-to-average students already have a job by the time they graduate. So it is important to connect with them before another company does. Academia realizes the importance of today's manufacturing sector, and there are a lot more high schools now offering machine shop courses. Check them out for students who are not going to college. While realizing that a machine operator must be eighteen years old, there are many other jobs in your plant that will give you the opportunity to try them out.

One organization that is taking advantage of this type of program is the aforementioned Forest City Gear. Lyford explained how this is working for them.

"We utilize the local chapter of the National Tooling and Machining Association (NTMA) which is the Rock River Valley Tooling and Machining Association (RRVTMA). They provide an apprentice tract that will yield a credential of Precision Machinist Journeyman in either CNC Turning/Milling or Gear Manufacturing. We manage the on-the-job portion with hour tracking through various departments working to fill the 8,000 hours to take place throughout the entire production process. At the conclusion of the program, the apprentice will receive their Journeyman status and also a certificate from the Department of Labor documenting the achievement of their Journeyman status." (Jared Lyford)

Training is critical to a productive workforce, and I have addressed this topic many times. While technical school-based training programs are an excellent resource, it is important to realize that trained people are not going to be routinely coming to your door. You will need to develop and train your new people.

This point was highlighted in a recent conversation I had with Nick Patel, CEO of Rave Gears in Seguin, Texas, as he too reported his difficulties in finding skilled people. He also spoke about the challenge he had found in those that did have skills but how they would often have "baggage" that presented a red flag. This combination is leaving them with few other options than to provide training in-house.

He also mentioned a couple of other good points. He is very interested in finding young people who have good computer and math skills. As part of the interview process, it is important for your technical people, such as shop floor managers, to talk with the applicant. This will allow them to be assessed for their level of sincerity, their interest in working with their hands, their mechanical aptitude, and their problem-solving abilities. In addition, he explained his goal of finding people with good character who will fit in well with his organization.

Finally, I believe that a critical attribute is work ethic. I am afraid that if the work ethic is not there, your training efforts will be wasted. In other words, do your best to pick the right person, because the wrong person will come with a lot of problems down the line.

While this article is not necessarily about training, I did want to share some of my experiences with new hires that you might want to consider. During my time at Arrow Gear Company, we did not just hand off the trainee to an experienced operator and hope for the best. During the probationary period their attendance was monitored. There were written reviews by their supervisor at 15-, 30-, and 60-day intervals. The trainee was moved every 30 days into areas which were in need of help. This gave both the trainee and us the opportunity to see what type of work best fit their abilities. This training path was also supplemented with classroom and video-based training programs. These topics included shop math, blueprint reading, safety, and material handling, just to name a few. Later, more advanced and broader training was provided, such as why it is important to hold certain tolerances much closer than the final blueprint specified, and why every operation is essential to produce a quality end-product to the customer.

Automation

Referencing back to the presentation I attended at Fusion OEM, the robotic integrator, one of the points they mentioned in view of the labor shortage was the importance of integrating robotic technology.

I would encourage you to take the time to study your operation and look for ways to streamline manual operations that can be improved with robotics. Robotic integrators can assist you in this process. This area provides a great deal of opportunity for productivity improvements.

In Conclusion

So, these are a few ideas to consider as you wrestle with the labor shortage now facing the manufacturing world. The bottom line is this. As with other challenges faced by manufacturers, it will be highly valuable to approach the labor shortage problem from the perspective of innovative thinking and methods.

Finally, if I can ever be of assistance, even if it is a phone conversation to pick my brain for ideas, please reach out to me at *ArvinGlobal@Gmail.com*.

Joe Arvin is a veteran of the gear manufacturing industry. After 40 years at Arrow Gear Company, Joe Arvin is now President of Arvin Global Solutions (AGS). AGS offers a full range of consulting services to the manufacturing industry. His website is *www.ArvinGlobalSolutions.com* and he can be reached by email at *ArvinGlobal@Gmail.com.*

For Related Articles Search
labor
at www.geartechnology.com

Hungry for More?

Everything you need to be a world-class gear manufacturer — the suppliers, the technical information and the market intelligence — can be found online

gear TECHNOLOGY

- The Michael Goldstein Gear Technology Library includes a complete archive of back issues and articles, 1984-today
- Directory of suppliers of machine tools, services and tooling
- Product and Industry News updated daily
- Exclusive online content in our e-mail newsletters
- Calendar of upcoming events
- Comprehensive search feature helps you find what you're looking for — fast!

FREE Knowledge Served Daily

www.geartechnology.com

Effect of the ISO 6336-3:2019 Standard Update on the Specified Load Carrying Capacity Against Tooth Root Breakage of Involute Gears

Stefan Sendlbeck, Maximilian Fromberger, Michael Otto, and Karsten Stahl
Gear Research Center (FZG), Technical University of Munich

Nomenclature

C_a Tip relief, µm;
d_a Tip diameter, mm;
d_f Root diameter, mm;
d_{Na} Active tip diameter, mm;
F_{bt} (Nominal) Transverse load in the plane of action (base tangent plane), N;
f_ε Load distribution influence factor;
h^* Tool addendum factor;
h_{Fe} Bending moment lever arm for tooth root stress relevant to load application at the outer point of single pair tooth contact, mm;
h^* Tool dedendum factor;
K_A Application factor;
m_n Normal module, mm;
N_L Number of load cycles;
q_t Material allowance for finish machining, mm;
S_F Safety factor against tooth root breakage;
s_{Fn} Tooth root chord at the critical section, mm;
x^* Profile shift factor;
Y_F Form factor;
Y_β Helix angle factor;
z_0 Number of teeth of the tool;
α_{Fen} Load direction angle, relevant to direction of application of load at the outer point of single pair tooth contact of virtual spur gears, °;
α_n Normal pressure angle, °;
α_{n0} Tool normal pressure angle, °;
α_{pr0} Tool protuberance angle, °;
β_b Base helix angle, °;
ε_α Transverse contact ratio;
$\varepsilon_{\alpha n}$ Virtual contact ratio of the virtual spur gear;
ε_β Overlap ratio;
θ_{oil} Oil temperature, °C;
ρ^* Tool tip radius factor;
ρ_{a0} Tool tip radius, mm;
ρ_F Tooth root radius at the critical section, mm;
1 Index for pinion;
2 Index for gear wheel;
a Center distance, mm;
b Face width, mm;
d Reference cylinder diameter, mm;
LOA Line of action;
n Rotational speed, $min^{-1;}$
pr_0 Protuberance of the tool, mm;
r Relative change of the safety factor against tooth root breakage (2006/2019);
T Torque, Nm;
u Teeth ratio;
z Number of teeth;
β Reference helix angle, °.

Introduction

The ISO 6336 series of standards contains a verified specification for calculating the strength of involute gears. Updates issued in November 2019 contain more detailed calculation methods based on the latest research findings.

Of particular interest here is Part 3 (Ref. 1), which focuses on the tooth bending strength of spur and helical gears and provides a safety factor against tooth root breakage. Following the update of the previous 2006 version (Ref. 2), the revised standard from 2019 (Ref. 1) can yield a higher or lower safety factor depending on the specific gear design. Consequently, to enable an optimal gear design, the gear engineer needs to be aware of the effects of the changes in the standard on the overall result of the calculation.

Therefore, we summarize the current structure of the ISO 6336 standard in this paper and present a detailed review of the key changes introduced in ISO 6336-3:2019 (Ref. 1). We outline the overall effects of the changes in the form of a calculation-based study of different variants with regard to contact ratio and tooth root geometry and compare the results to the ISO 6336-3:2006 (Ref. 2) version.

Overview of the Current ISO 6336 Structure

The current ISO 6336 series of standards consists of multiple parts that are grouped in international standards, technical specifications and technical reports.

International standards (ISO 6336):

- Part 1: Basic principles, introduction and general influence factors (Ref. 3)
- Part 2: Calculation of surface durability (pitting) (Ref. 4)
- Part 3: Calculation of tooth bending strength (Ref. 1)
- Part 5: Strength and quality of materials (Ref. 5)
- Part 6: Calculation of service life under variable load (Ref. 6)

Technical specifications (ISO/TS 6336):

- Part 4: Calculation of tooth flank fracture load capacity (Ref. 7)
- Part 20: Calculation of scuffing load capacity (also applicable to bevel and hypoid gears) — Flash temperature method (Ref. 8)
- Part 21: Calculation of scuffing load capacity (also applicable to bevel and hypoid gears) — Integral temperature method (Ref. 9)
- Part 22: Calculation of micropitting load capacity (Ref. 10)

Additional technical reports (ISO/TR 6336) (Refs. 11–12) containing calculation examples for Part 1, 2, 3, 5 and of micropitting load capacity.

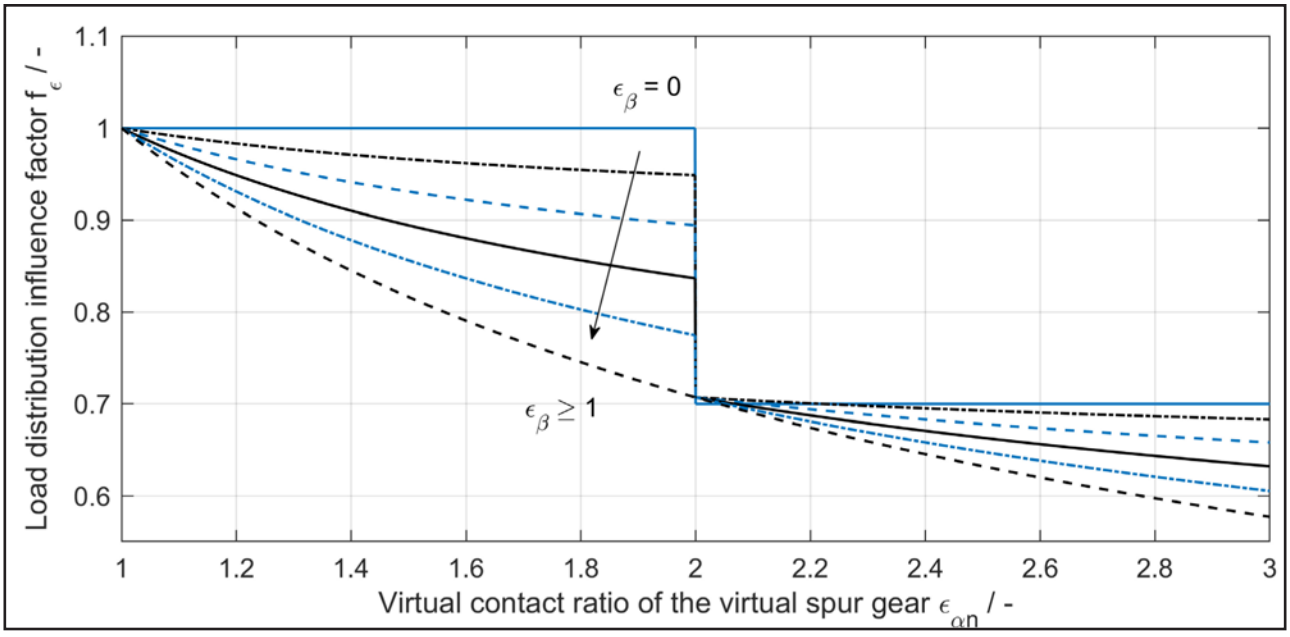


Figure 1 Load distribution influence factor according to ISO 6336-3:2019 (Ref. 1).

ISO 6336-3:2019 Standard Updates

The revised ISO 6336-3:2019 (Ref. 1) standard contains fundamental changes (i.e., a new load distribution influence factor that accounts for the effects of high overlap ratios and a more precise consideration of the helix angle on the stresses). The determination of the tooth root geometry of internal gears by means of a shaper cutter has also been added to the standard.

Load Distribution Influence

Load distribution influences affect the tooth root stresses of gears, they are crucial for calculating the bending strength of the gears, and are therefore an ongoing field of research (Refs. 13–15). Gears and especially helical gears with high contact ratios proved to normally have a higher bending strength than predicted with previous ISO 6336-3:2006 (Ref. 2) calculations (Refs. 16–17).

According to the ISO 6336-3 specification, the location for determining the nominal tooth root stress is in the tooth root area at the 30°/60° tangent to the center line for external/internal gears, respectively (see Fig. 2). The calculation variables derived at this critical section are the bending moment lever arm h_{Fe}, the tooth root chord s_{Fn}, and the tooth root radius ρ_F. Based on this, the form factor Y_F accounts for influences of the tooth shape on the tooth root stresses with a load applied at the outer point of the single pair tooth contact.

In the current ISO 6336-3:2019 (Ref. 1) standard, the new load distribution influence factor f_ε extends the previous calculation of the form factor Y_F from ISO 6336-3:2006 (Ref. 2) (see Eq. 1). It accounts for stress-reducing effects by applying a more favorable load distribution over several pairs of teeth for deep teeth at high contact ratios (Refs. 16,18). The load distribution influence factor is $f_\varepsilon \leq 1$.

$$Y_F = \frac{\frac{6h_{Fe}}{m_n}\cos\alpha_{Fen}}{\left(\frac{s_{Fn}}{m_n}\right)^2\cos\alpha_n} \cdot f_\varepsilon \quad (1)$$

where

Y_F is the form factor
h_{Fe} is the bending moment lever arm for tooth root stress relevant to load application at the outer point of single pair tooth contact, mm;
m_n is the normal module, mm;
s_{Fn} is the tooth root chord at the critical section, mm;
α_{Fen} is the load direction angle, relevant to the direction of application of load at the outer point of single pair tooth contact of virtual spur gears, °;
α_n is the normal pressure angle, °;
f_ε is the load distribution influence factor.

For a load distribution influence factor of $f_\varepsilon = 1$, there is no change in the ISO 6336-3:2019 (Ref. 1) calculation compared to the previous version, ISO 6336-3:2006 (Ref. 2). However, when the load distribution influence factor is $f_\varepsilon < 1$, the different versions vary, resulting in a reduced form factor Y_F in ISO 6336-3:2019 (Ref. 1), which, in turn, causes a smaller calculated tooth root stress.

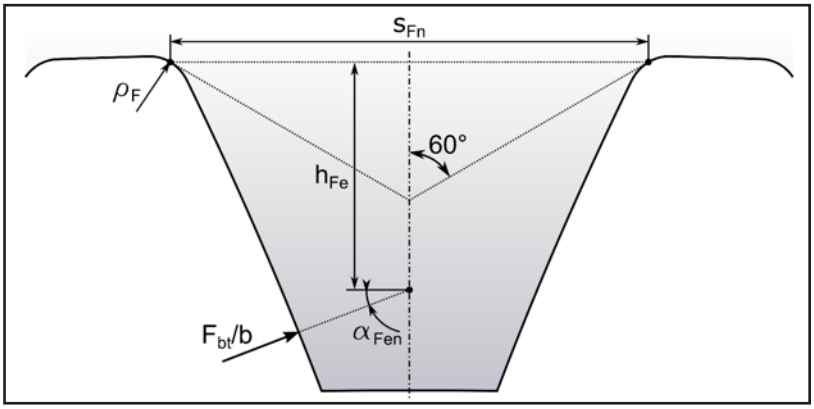


Figure 2 Geometrical variables at the critical section for internal gears according to ISO 6336-3:2019 (Ref. 1).

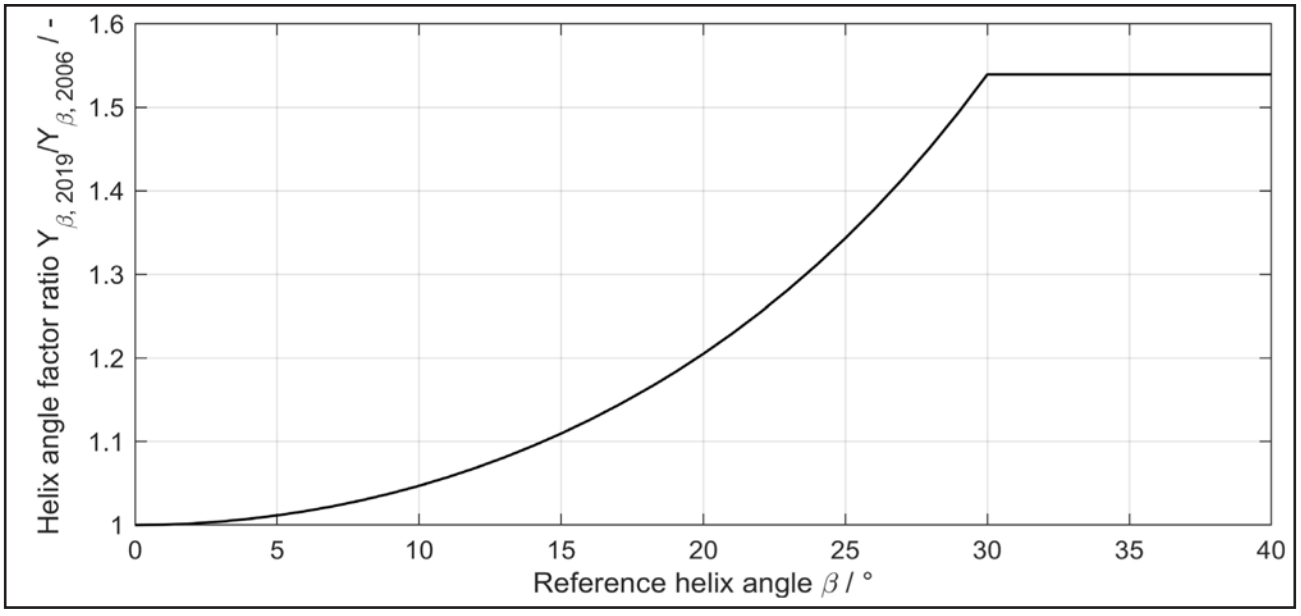


Figure 3 Helix angle factor ratio of ISO 6336-3:2019 (Ref. 1) and ISO 6336-3:2006 (Ref. 2).

In detail, the load distribution influence factor f_ε depends on the contact ratio of the spur gear ε_α or the virtual contact ratio of the virtual spur gear $\varepsilon_{\alpha n}$ and the overlap ratio ε_β (see Eqs. 2–7). An overview is given in Figure 1.

For spur gears with a transverse contact ratio of $\varepsilon_\alpha \geq 2$ the new load distribution influence factor produces a smaller form factor and, in turn, a lower calculated stress in the tooth root according to Equation 2 and Equation 3.

$$f_\varepsilon = 1.0 \quad \text{for } \varepsilon_\beta = 0, \varepsilon_\alpha < 2 \tag{2}$$

$$f_\varepsilon = 0.7 \quad \text{for } \varepsilon_\beta = 0, \varepsilon_\alpha \geq 2 \tag{3}$$

where
f_ε is the load distribution influence factor;
ε_α is the transverse contact ratio;
ε_β is the overlap ratio.

For helical gears, an equivalent virtual spur gear forms the basis of the calculation. The virtual contact ratio $\varepsilon_{\alpha n}$ results from the transverse contact ratio ε_α of the helical gear and its base helix angle β_b according to Equation 4.

$$\varepsilon_{\alpha n} = \frac{\varepsilon_\alpha}{\cos^2 \beta_b} \tag{4}$$

where
$\varepsilon_{\alpha n}$ is the virtual contact ratio of the virtual spur gear;
ε_α is the transverse contact ratio;
β_b is the base helix angle, °.

The new load distribution influence factor for helical gears according to Equations 5–7 tends to lower both the form factor and the calculated tooth root stress as the virtual transverse contact ratio $\varepsilon_{\alpha n}$ and overlap ratio ε_β increase.

$$f_\varepsilon = \varepsilon_{\alpha n}^{-0.5} \quad \text{for } \varepsilon_\beta \geq 1 \tag{5}$$

$$f_\varepsilon = \left(1 - \varepsilon_\beta + \frac{\varepsilon_\beta}{\varepsilon_{\alpha n}}\right)^{0.5} \quad \text{for } 0 < \varepsilon_\beta < 1, \varepsilon_{\alpha n} < 2 \tag{6}$$

$$f_\varepsilon = \left(\frac{1 - \varepsilon_\beta}{2} + \frac{\varepsilon_\beta}{\varepsilon_{\alpha n}}\right)^{0.5} \quad \text{for } 0 < \varepsilon_\beta < 1, \varepsilon_{\alpha n} \geq 2 \tag{7}$$

where
f_ε is the load distribution influence factor;
$\varepsilon_{\alpha n}$ is the virtual contact ratio of the virtual spur gear;
ε_β is the overlap ratio.

Determining the Tooth Root Geometry

Bending moment lever arm h_{Fe}, tooth root chord s_{Fn}, and tooth root radius ρ_F are the variables at the critical section that are key to calculating the form factor Y_F with Equation 1, and they account for the influence of the tooth and, in particular, the root shape on the maximum calculated nominal tooth root stress from ISO 6336-3. The necessary geometrical properties are illustrated in Figure 2, with the load applied at the outer point of the single pair tooth contact (face width specific transverse load in the plane of action F_{bt}/b, load direction angle α_{Fen}).

For external gears, no fundamental changes apply, and ISO 6336-3:2019 (Ref. 1) follows ISO 6336-3:2006 (Ref. 2) in quantizing the geometrical variables relevant to the tooth root stress calculation illustrated in Figure 2. The geometrical variables are determined according to the manufacturing principle of using toothed rack-like tools, such as gear hobs.

For internal gears, ISO 6336-3:2019 (Ref. 1) presents a modified method of calculating the following three geometrical variables at the critical section: bending moment lever arm h_{Fe}, tooth root chord s_{Fn}, and tooth root radius ρ_F. Theoretical and experimental research have shown that determining the tooth root geometry of internal gears based on the tool roll-off of a shaper cutter yields a more precise basis for tooth root stress and bending strength calculation (Refs. 19–21).

The previous version of ISO 6336-3:2006 (Ref. 2) uses a simplified calculation method to determine the form factor variables. This calculation is based on the principle that internal gearing is manufactured using a virtual toothed rack-like tool. The method thus follows the calculation of external gears with a toothed rack-like tool.

In ISO 6336-3:2019 (Ref. 1), however, the principle used for internal gearing calculation is that gears are made with a shaper cutter and its associated roll-off, in accordance with VDI 2737:2016 (Ref. 21) guideline. The shape of the tool corresponds to a pinion conjugate to the internal teeth of the ring gear. As with external gears produced with a toothed rack-like tool, the contour of the tooth root is defined by the relative path of the

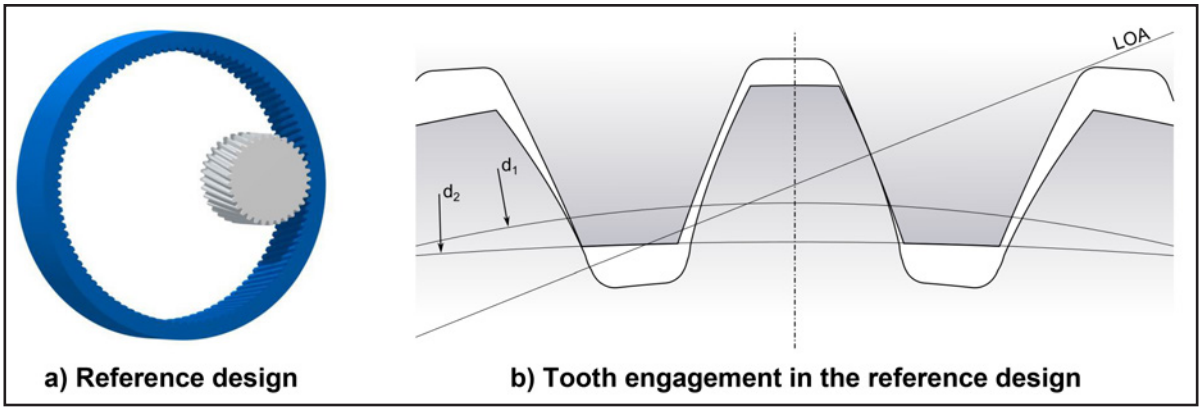


Figure 4 Reference design and tooth engagement in the external-internal gear stage.

tool boundary and therefore allows the geometrical variables of the form factor of internal gears to be determined directly, based on the tool contour.

Influence of the Helix Angle

The helix angle factor Y_β is part of the ISO 6336-3 calculation for adjusting the calculated tooth root stress of the virtual spur gear to the actual tooth root stress of the helical gear; the influence of the helix angle is thus accounted for.

In ISO 6336-3:2006 (Ref. 2), the helix angle factor is determined by Equation 8. If β would exceed 30°, β remains constant at $\beta = 30°$ when calculating the helix angle factor.

$$Y_\beta = 1 - \varepsilon_\beta \frac{\beta}{120°} \tag{8}$$

where
Y_β is the helix angle factor;
β is the reference helix angle, °;
ε_β is the overlap ratio.

Many experiments for determining the tooth root strength are done with spur gears. Additional research findings based on helical gear experiments and advanced calculations show that slightly modifying the helix angle factor depending on the helix angle would better represent the helix angle influence and therefore would lead to a more accurate stress calculation (Refs. 16–17).

Following the update in accordance with the research findings, Equation 9 applies to ISO 6336-3:2019 (Ref. 1). If β would exceed 30°, β remains constant at $\beta = 30°$ when calculating the helix angle factor.

$$Y_\beta = \left(1 - \varepsilon_\beta \frac{\beta}{120°}\right) \frac{1}{\cos^3 \beta} \tag{9}$$

where
Y_β is the helix angle factor;
β is the reference helix angle, °;
ε_β is the overlap ratio.

Taking into account Equations 8 and 9, Equation 10 represents the effective change resulting from ISO 6336-3:2019 (Ref. 1) compared to ISO 6336-3:2006 (Ref. 2) owing to the helix angle factor ratio of $Y_{\beta,2019}/Y_{\beta,2006}$. It is additionally illustrated in Figure 3.

$$Y_{\beta,2019}/Y_{\beta,2006} = \frac{1}{\cos^3 \beta} \tag{10}$$

where
Y_β is the helix angle factor;
β is the reference helix angle, °.

Calculation Study

To investigate the overall effects of these changes, we varied the contact ratio by using gears with different transverse contact ratios and different overlap ratios as a basis for computing the specifications of the standard. By simultaneously varying the transmission ratio and the tool tip radius, we investigated the effect of different internal-gear tooth-root geometries on the calculation.

To enable the calculation study of variants, first, a reference gear design was defined that is as close as possible to one used in everyday practice. We then varied selected gear geometry parameters while keeping the face load and the load influence factors constant. This enabled us to keep general load influences separate from solely geometric changes and to investigate the effects of the changes between the ISO 6336-3:2006 (Ref. 2) and the ISO 6336-3:2019 (Ref. 1) standards selectively.

The reference gear design used is a helical external-internal gear stage with a case-hardened pinion and a hardened and tempered wheel (see Fig. 4 and Tables 1–4). The tip diameter and

Table 1 Reference design – fundamental data

	Pinion	Ring gear
Number of teeth z	33	–103
Tip diameter d_a	107.50 mm	–313.74 mm
Root diameter d_f	96.09 mm	–324.63 mm
Center distance a	–107.78 mm	
Normal module m_n	3.00 mm	
Normal pressure angle α_n	20.00°	
Face width b	80.00 mm	
Profile shift factor x^*	0.40	–0.80
Transverse contact ratio ε_α	1.23	
Overlap ratio ε_β	1.47	
Reference helix angle β	10.00°	
Material	18CrNiMo7-6 case-hardened	42CrMo4 hardened and tempered

Table 2 Reference design – tool data (roughing)

	Pinion	Ring Gear
Tool	Gear hob	–
Tool normal module m_n	3.00 mm	–
Tool normal pressure angle α_{n0}	20.00°	–
Tool addendum factor h^*_{aP0}	1.30	–
Tool dedendum factor h^*_{fP0}	1.80	–
Tool tip radius factor ρ^*_{a0}	0.20	–
Protuberance of the tool ρ_{r0}	0.30 mm	–
Tool protuberance angle α_{pr0}	10.00 mm	–
Material allowance for finish machining q_t	0.28 mm	–

Table 3 Reference design – tool data (finishing

	Pinion	Ring gear
Tool	Grinding disc	Shaper cutter
Tool normal module m_n	3.00 mm	
Tool normal pressure angle α_{n0}	20.00°	
Tool addendum factor h^*_{aP0}	1.10	1.00
Tool dedendum factor h^*_{fP0}	1.80	1.77
Tool tip radius factor ρ^*_{a0}	0.20	
Number of teeth of the tool z_0	—	29

Table 4 Reference design – additional data

	Pinion	Ring gear
Gear tooth quality ISO 1328:2013	5	
Torque T	2000 Nm	6242 Nm
Rotational speed n	$3000\frac{1}{\text{min}}$	$961\frac{1}{\text{min}}$
Number of load cycles N_L	171.7 Mio	55.0 Mio
Lubricant	FVA-3A	
Oil temperature θ_{oil}	60°	
Lead correction	–	
Tip relief C_a	18µm	
Application factor K_A	1.0	

Table 5 Variation range (contact ratio) based on reference design

Variation	
Torque T and face width b	T/b (const.) → ε_β = 0.07 ... 2.21
Active tip diameter d_{Na} and tool addendum factor h^*_{aP0}	c* (const.) → ε_α = 1.30 ... 2.10

not the tool dedendum defines the gear tips to ensure that the tool dedendum does not influence the results of the calculation study in the following.

For each variant of the calculation study, we determined the safety factor against tooth root breakage according to the calculation specification in the standard. This allowed us to compare the relative change r between the two ISO 6336-3 versions as a percentage, using Equation 11 with the safety factor of ISO 6336-3:2006 (Ref. 2) as a reference value.

$$r = S_{F,ISO6336:2006\rightarrow ISO6336:2019} = \frac{\Delta S_F}{S_F} + \frac{S_{F,ISO6336:2019} - S_{F,ISO6336:2006}}{S_{F,ISO6336:2006}} \quad (11)$$

where

r is the relative change of the safety factor against tooth root breakage (2006/2019)

S_F is the safety factor against tooth root breakage

Variation in Contact Ratio

In the following, the new load distribution influence factor f_ε in combination with the modified helix angle factor Y_β as described in Load Distribution Influence (p.45) and Influence of the Helix Angle (p.47) are investigated by varying the contact ratio.

Variation in Contact Ratio — Method

Starting from the reference design, we simultaneously varied both the transverse contact ratio ε_α and the overlap ratio ε_β in accordance with Table 5.

Varying the overlap ratio is possible by changing the helix angle β or the face width b, with a non-zero helix angle assumed. Because the specific face load needs to remain as constant as possible to achieve comparable results, we varied the face width b and the torque T so as to keep T/b constant and thus change the overlap ratio. This is possible because the reference helix angle of the reference design is $\beta > 0$. The advantage is that the variation does not cause the gear and root shape to change.

To influence the transverse contact ratio, we changed the active tip diameter d_{Na} in conjunction with the tool addendum factor h^*_{aP0}. Although this allows us to keep the relative tip clearance c^* constant, it results in the tooth root geometries changing within the range of the variation (Fig. 5). It should be noted that another option is a single change in the active tip diameter, which results in gear meshes with different tip clearances and a constant tooth root geometry. But the shapes tend to be highly impractical in everyday applications. It is for this reason that we chose the above approach.

A two-dimensional mesh of 40 linearly distributed calculation points in the transverse contact ratio direction and the overlap ratio direction is the basis for all plots in the following. Each contour plot therefore contains 1,600 calculations of standard comparisons.

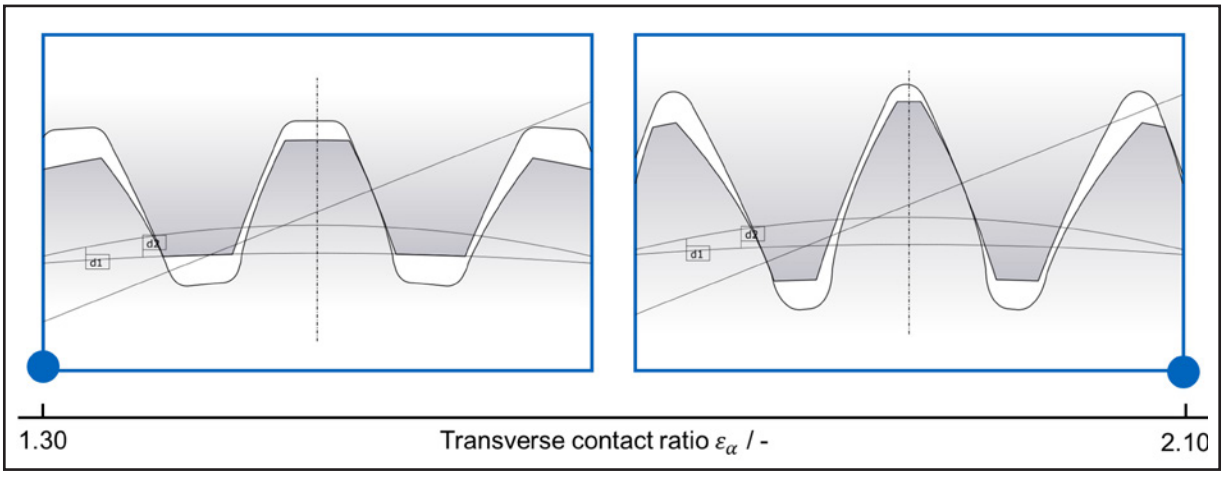


Figure 5 Gear variation with respect to transverse contact ratio.

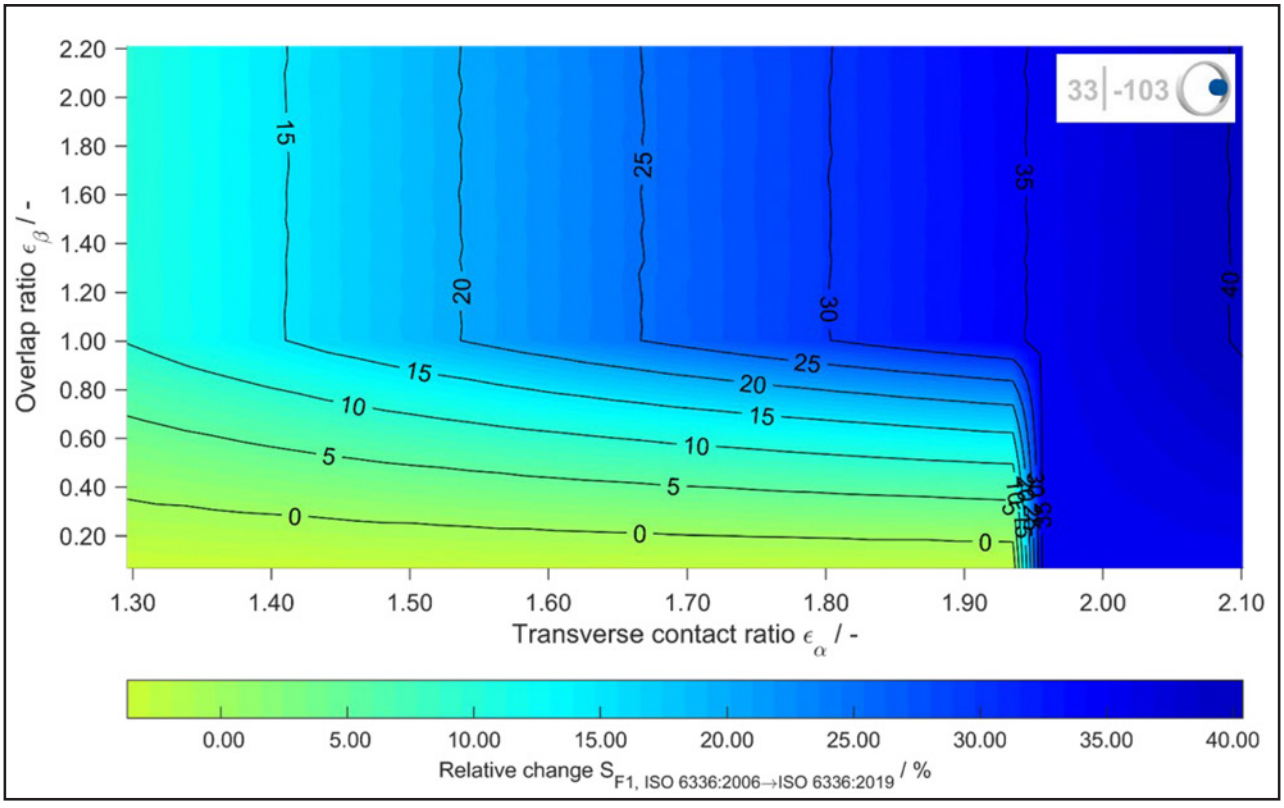


Figure 6 Relative change in the safety factor against tooth root breakage S_{F1} for the pinion, 40 × 40 calculation points.

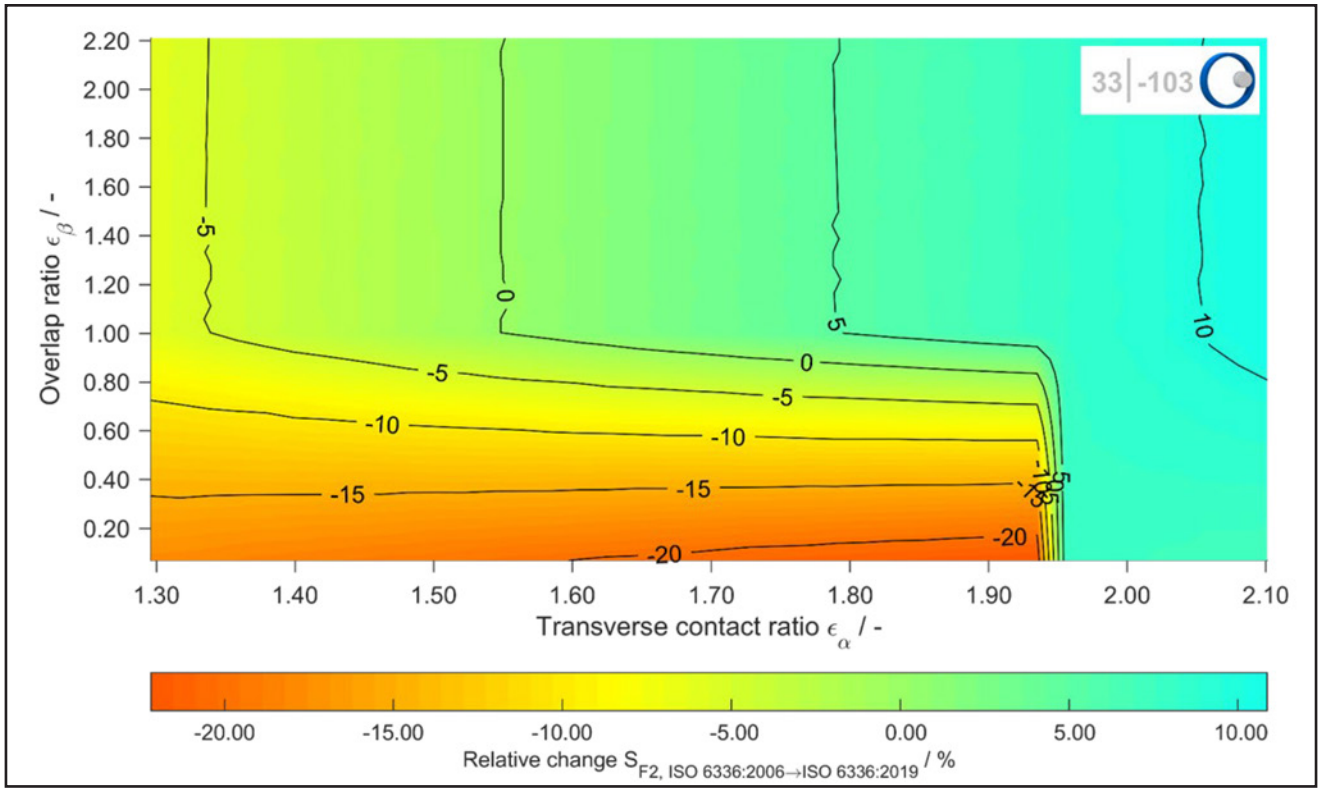


Figure 7 Relative change in the safety factor against tooth root breakage S_{F2} for the wheel, 40 × 40 calculation points.

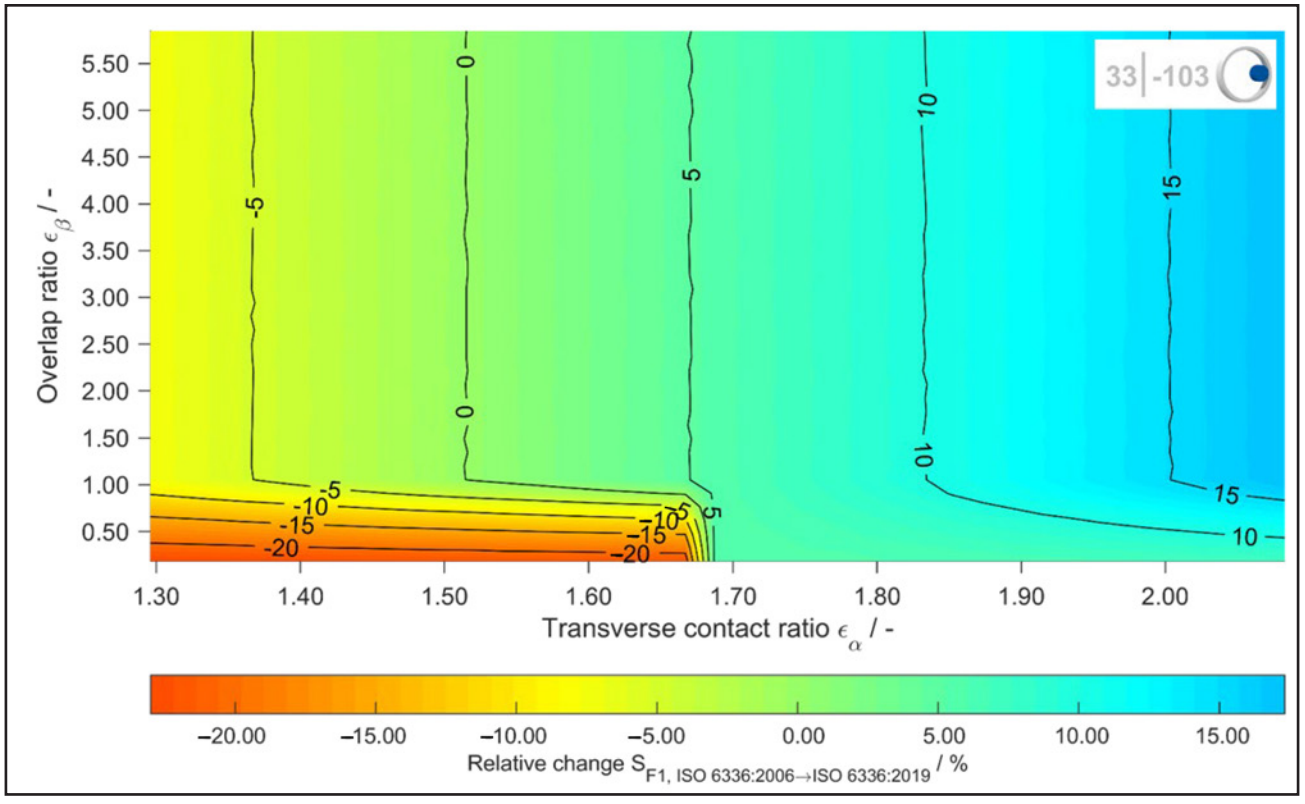


Figure 8 Relative change in the safety factor against tooth root breakage S_{F1} for the pinion, reference helix angle $\beta = 25°$, 40 × 40 calculation points.

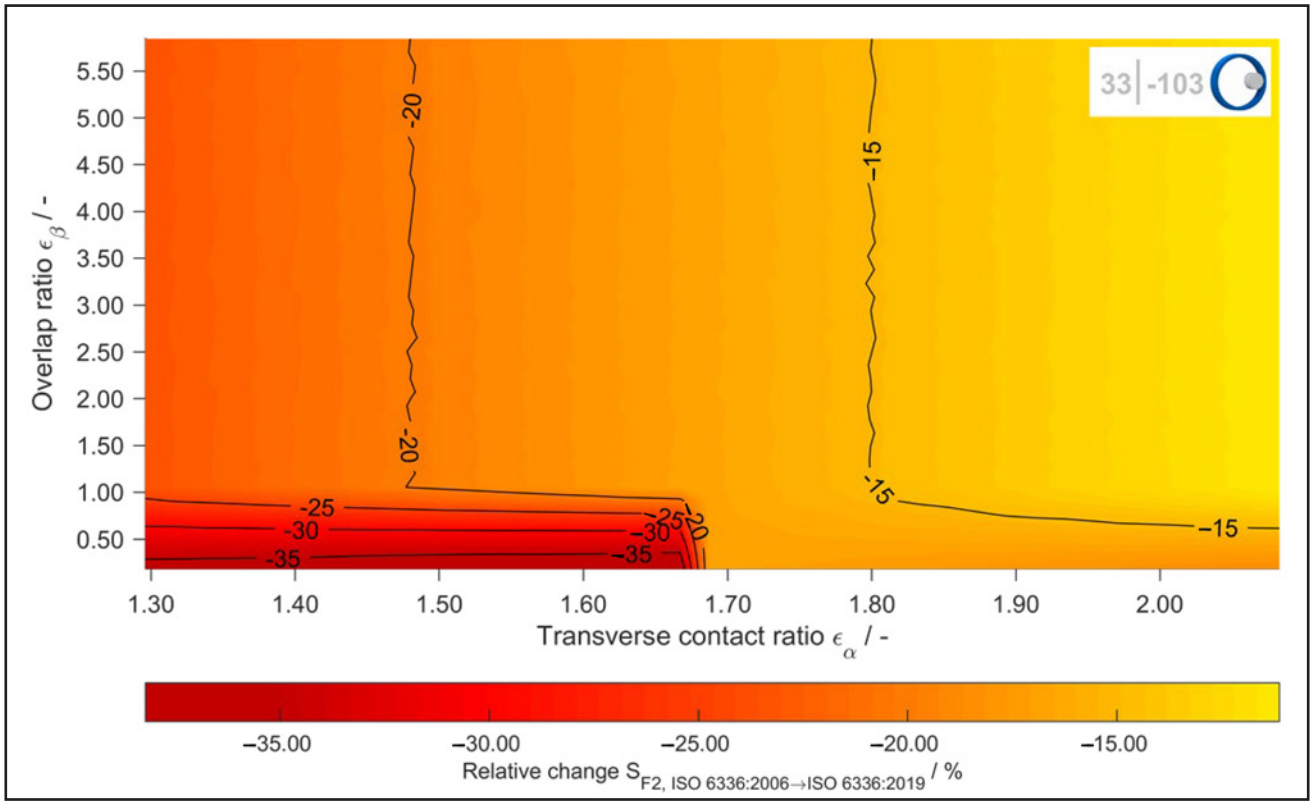


Figure 9 Relative change in the safety factor against tooth root breakage S_{F2} for the wheel, reference helix angle $\beta = 25°$, 40 × 40 calculation points.

Variation in Contact Ratio — Results

Figure 6 provides the results of the variation calculation of the external gear pinion in external-internal gear pairs according to the procedure described in Variation in Contact Ratio — Method (p.48). The load distribution influence factor f_ε added in the updated standard from 2019 generally leads to an increase in the safety factor against tooth root breakage compared to the 2006 version. The helix angle factor Y_β has only marginal influence on the results. As shown in Figure 3, it reduces the relative change by less than 5%, independently of the contact ratio.

For overlap ratios of $\varepsilon_\beta \geq 1$, the safety factor increases almost linearly as the transverse contact ratio increases. The relative change ranges from approximately +10% at a transverse contact ratio of $\varepsilon_\alpha \approx 1.3$ to approximately +40% at a transverse contact ratio of $\varepsilon_\alpha \approx 2.1$.

At a low overlap ratio of $\varepsilon_\beta \approx 0$, the data in the diagram displays a distinct step at a transverse contact ratio of $\varepsilon_\alpha \approx 1.95$. According to the determination of the load distribution influence factor f_ε a step should occur for spur gears when the virtual contact ratio of the virtual spur gear $\varepsilon_{\alpha n} = 2.0$. This is valid when applying the relation between helical gears and virtual spur gears described by Equation 4. In the overlap ratio range of $0 < \varepsilon_\beta < 1$, the relative change in the safety factor increases continuously from low to high.

The results for the internal gear wheel are shown in Figure 7. As with the external gear pinion shown in Figure 6, the characteristic influence of the load distribution influence factor is present, but the relative change in the safety factor against tooth root breakage is smaller. While the load distribution influence factor tends to lead to a higher safety factor, changes are additionally caused by the modified calculation of the tooth root geometry for internal gears according to Determining the Tooth Root Geometry (p.46). As a result, the relative change in the safety factor varies from approximately –20% to +10%, depending on the transverse contact ratio and the overlap ratio.

The calculation study also covers variations in the helix angle. While the reference design has a reference helix angle of $\beta = 10°$ and the changes in the helix angle factor are thus of relatively low impact, the results shown in Figure 8 and Figure 9 are based on a reference helix angle of $\beta = 25°$ for pinion and wheel, respectively. To enable comparability of the results, we also changed the normal module m_n, the normal pressure angle α_n and the profile shift factors beside the helix angle with respect to the reference design such that the gear teeth in the transverse plane corresponded as closely as possible within the variation range.

In areas of low transverse contact ratios ε_α, and especially with additionally low overlap ratios ε_β, the calculation according to the new ISO 6336-3:2019 (Ref. 1) results in a lower safety factor against tooth root breakage than the previous version. It increases with higher transverse contact ratios. Due to the higher reference helix angle compared to the reference design, the step in the relative change in the safety factor against tooth root breakage at low overlap ratios shifts to a lower transverse contact ratio of $\varepsilon_\alpha \approx 1.68$. This is the effect of a high helix angle and the associated relation between the transverse contact ratio of helical gears and its virtual spur gear (Eq. 4).

The generally lower values of the relative change in the safety factors against tooth root breakage compared with previous investigations shown in Figure 6 and Figure 7 are a result of the change in the helix angle factor Y_β. The load distribution influence factor f_ε tends to have a stress-reducing effect, which leads to an increase in the safety factor. However, with increasing helix angle, the modified calculation of the helix angle factor shows a greater and greater impact in accordance with the relations illustrated in Figure 3. This generally causes an increase in calculated stresses and, consequently, a reduced safety factor against tooth root breakage. Thus, the helix angle factor counteracts the effects of the load distribution influence factor, especially at high helix angles.

Variation in Tooth Root Geometry

Due to the new specification for calculating geometric gear properties, the tooth root geometry and its impact on the safety factor against tooth root breakage presented in Determining the Tooth Root Geometry (p.48) are also investigated. The focus is on internal gears and their tooth root, since it is these that are affected by the revised standard, as the root geometry is now additionally determined using a shaper cutter tool.

Variation in Tooth Root Geometry — Method

To investigate the influences of the changes such that the tooth root geometry is determined in ISO 6336-3:2019 (Ref. 6), we examined several tooth root geometries of internal-external gears. Starting from the reference design, we simultaneously varied the teeth ratio $|u|$, thus the transmission ratio, and the tooth root fillet by adapting the tip radius of the tool ρ_{a0} (see Table 6).

Table 6 Variation range (tooth root geometry) based on reference design

Variation	
Number of teeth of the wheel z_2	$z_1 = 33$ (*const.*); $z_2 = -115$ ... -60
Tool tip radius factor ρ^*_{a0}	$\rho^*_{a0} = 0.10$ ... 0.38

The teeth ratio $|u|$ is varied by changing the number of teeth of the wheel z_2 within a wide range while keeping the number of teeth of the pinion z_1 constant (Fig. 10).

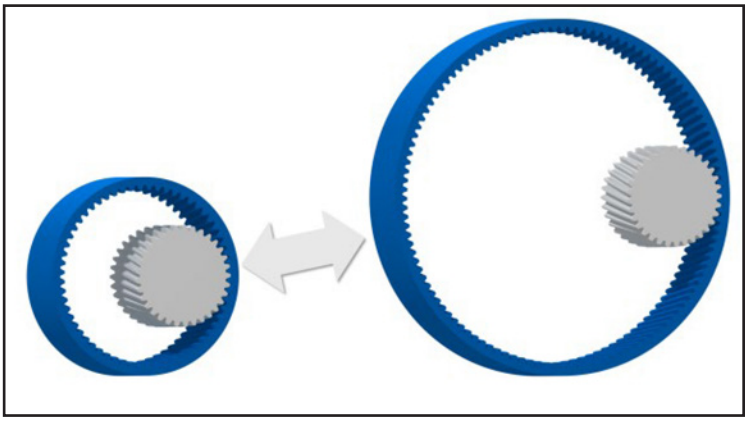


Figure 10 Variation in tooth root geometry and transmission ratio/teeth ratio.

To ensure comparability of the results, the transverse contact ratio ε_α and overlap ratio ε_β should be kept constant throughout this variation. The overlap ratio depends on the helix angle

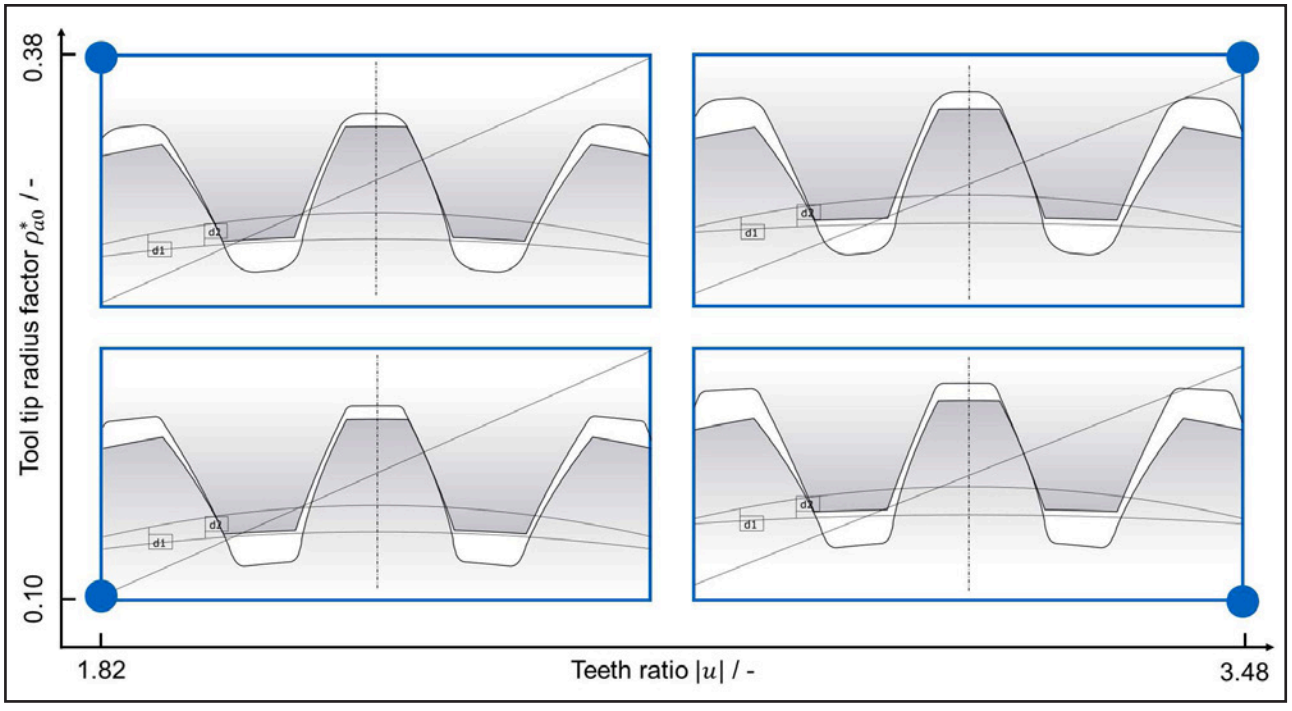


Figure 11 Gear variation with respect to teeth ratio and tool tip radius factor.

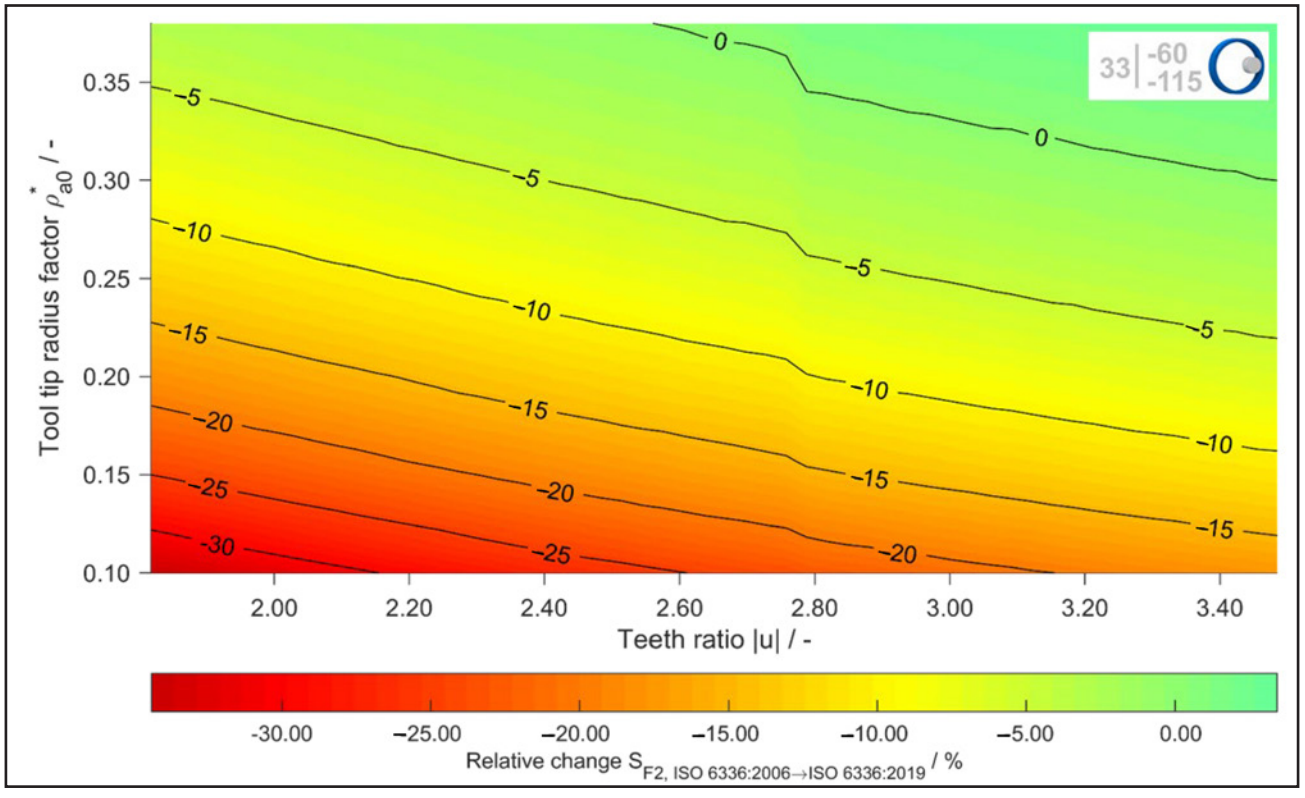


Figure 12 Relative change in the safety factor against tooth root breakage S_{F2} for the wheel, 56 × 40 calculation points.

and the face width of the gear. Because both parameters are constant while the tooth root geometry is varied, the overlap ratio does not change. However, the transverse contact ratio can change as a result of the changing transmission ratio. With the same module and tools, the center distance a increases as the number of teeth of the wheel increases. As a result, both the reference diameter and tip diameter also increase. As the tip diameter $d_{Na} = d_a$ is predefined and is not a tool-dependent variable, changing the tip diameter within a certain range allows the transverse contact ratio to be influenced for each variant of the internal gear. We therefore conduct one-dimensional optimization by varying the tip diameter to keep the transverse contact ratio constant independently of the number of teeth of the wheel and, in turn, independently of the transmission ratio.

Additionally, the curvature of the tooth root fillet ranges from minimal to fully rounded. In this case, the variation is based on the tool tip radius factor ρ^*.

The boundary gear mesh geometries in the transverse section of the calculation study, used to investigate the tooth root influence, are shown in Figure 11.

A two-dimensional mesh of 40 linearly distributed calculation points in the tool tip radius factor direction and 56 in the teeth ratio direction is the basis for the plot in the following. The contour plot therefore contains 2,240 calculations of standard comparisons.

Variation in Tooth Root Geometry — Results

Figure 12 provides the results of the calculation study in terms of tooth root geometry influences as described in Variation in Tooth Root Geometry — Method (p.51) for the internal gear.

There are only small deviations in the safety factor against tooth root breakage between ISO 6336-3:2019 (Ref. 1) and the 2006 version; these are in the range of high teeth ratios with a large tool tip radius. As the teeth ratio and the tooth root fillet curvature become smaller, the relative change in the safety factor decreases. Thus, ISO 6336-3:2019 (Ref. 1) shows lower safety values against tooth root breakage than the previous version for a range of gear geometries. It is worth mentioning that the results presented in Figure 12 include an almost constant offset of +7.81%, due to the impact of the updated helix angle factor Y_β and the newly added load distribution influence factor f_ε.

The results shown in Figure 12 are based on the updated method of calculating the geometrical properties of the bending moment lever arm h_{Fe}, the tooth root chord s_{Fn}, and the tooth root radius ρ_F at the critical section. The calculated bending moment lever arm according to ISO 6336-3:2019 (Ref. 1) is approximately –8.5% to –12.0% lower than in the previous version and almost independent of the tooth root fillet curvature. The updated standard did not result in any appreciable change to the tooth root chord. The relative change is within a range of -2.0% to 0.0%. However, the tooth root radius at the critical section changed gradually from high teeth ratios and tool tip radii, with relative changes from approximately –20.0% to –70.0% towards lower values.

The updated standard did not result in any changes to the calculation of the tooth root geometry for external gears and so there is no change to the resulting safety against tooth root breakage.

Discussion

We chose the reference design and the variants derived from such as to cover a wide range of influences on the calculation given in the new standard; however, the calculation study does not cover every possible gear geometry and constellation. Nonetheless, the results of the calculation study give a broad insight into the updated standard and enables the engineer to assess its overall effects. To improve the comparability of the results, we limited the variation to a few key parameters, even if varying several parameters at a time would have helped remain within a practical range of gears. This compromise makes it easier to isolate the individual changes in the standard and shows their effect on the calculation in the standard as a whole. The inclusion of the root geometry calculation for internal gears in particular enables the engineer to comprehend the direct effects of the updated standard on the safety factor against tooth root breakage.

Conclusion

This paper provides a compact overview of the main changes in the updated calculation in ISO 6336 Part 3 from 2019 and its effects on the analysis of the tooth-bending strength of involute gears.

The most important changes include a new load distribution influence factor that accounts for the effects of high overlap ratios. An updated version of the helix angle factor refines the influence of the helix angle on the stresses. Additionally, the manufacturing principle of a shaper cutter is now the basis for determining the tooth root geometry for internal gears and has an effect on the relevant geometrical calculation variables, namely the tooth root curvature, the tooth root chord and the associated bending moment lever arm.

By varying both the transverse contact ratio and the overlap ratio in a calculation-based study, we demonstrated the stress-reducing effects of the new load distribution influence factor and the influence of the helix angle on the safety against tooth root breakage with respect to the contact ratio. In addition, by simultaneously varying the transmission ratio and the tool tip radius, we reveal the effect on the updated calculation of internal gears with different tooth root geometries.

All in all, the findings of this research allow a detailed insight into which updates enhance the ISO 6336 standard and how they affect and allow more accurate load carrying capacity calculations.

Acknowledgment. The findings presented are part of the research project "FVA-Nr. 814 I – Heft 1371 – Normstudie Stirnradtragfähigkeit. Forschungsvereinigung Antriebstechnik e.V., Frankfurt/Main (2020)". We therefore thank the Forschungsvereinigung Antriebstechnik e.V. (FVA) and partners for funding and valuable support. Moreover, the calculation based on the current ISO 6336:2019 series is user-friendly available in the *FVA-Workbench* for further use and investigation.

References

1. ISO 6336-3:2019-11. 2019,"Calculation of load capacity of spur and helical gears - Part 3: Calculation of tooth bending strength," 6336-3.
2. ISO 6336-3:2006-09. 2006,"Calculation of load capacity of spur and helical gears - Part 3: Calculation of tooth bending strength," 6336-3.
3. ISO 6336-1:2019-11. 2019,"Calculation of load capacity of spur and helical gears - Part 1: Basic principles, introduction and general influence factors," 6336-1.
4. ISO 6336-2:2019-11. 2019,"Calculation of load capacity of spur and helical gears - Part 2: Calculation of surface durability (pitting)," 6336-2.
5. ISO 6336-5:2016-08. 2016,"Calculation of load capacity of spur and helical gears - Part 5: Strength and quality of materials," 6336-5.
6. ISO 6336-6:2019-11. 2019,"Calculation of load capacity of spur and helical gears - Part 6: Calculation of service life under variable load," 6336-6.
7. ISO/TS 6336-4:2019-01. 2019,"Calculation of load capacity of spur and helical gears. Calculation of tooth flank fracture load capacity," 6336-4.
8. ISO/TS 6336-20:2017-11. 2017,"Calculation of load capacity of spur and helical gears. Calculation of scuffing load capacity (also applicable to bevel and hypoid gears). Flash temperature method," 6336-20.
9. ISO/TS 6336-21:2017-11. 2017,"Calculation of load capacity of spur and helical gears. Calculation of scuffing load capacity (also applicable to bevel and hypoid gears). Integral temperature method," 6336-21.
10. ISO/TS 6336-22:2018-08. 2018,"Calculation of load capacity of spur and helical gears. Calculation of micropitting load capacity," 6336-22.
11. ISO/TR 6336-30:2017-11. 2017,"Calculation of load capacity of spur and helical gears - Part 30: Calculation examples for the application of ISO 6336 parts 1,2,3,5," 6336-30.
12. ISO/TR 6336-31:2018-09. 2018,"Calculation of load capacity of spur and helical gears - Part 31: Calculation examples of micropitting load capacity," 6336-31.
13. Paucker, T., M. Otto and K. Stahl. 2019,"Determining the load distribution by measuring the tooth root stresses," *Forsch Ingenieurwes,* 83(3), pp. 621–626.
14. Paucker T., M. Otto and K. Stahl. 2019,"A precise prediction of the tooth root stresses for involute external gears with any fillet geometry under consideration of the exact meshing condition," *Proceedings of the Institution of Mechanical Engineers, Part C: Journal of Mechanical Engineering Science,* 233(21-22), pp. 7318–7327.
15. Hotait, M., and A. Kahraman. 2008,"Experiments on Root Stresses of Helical Gears with Lead Crown and Misalignments," *Journal of Mechanical Design, Transactions of the ASME*, 130 (7).
16. Otto M., 2009,"Lastverteilung und Zahnradtragfähigkeit von schrägverzahnten Stirnrädern [Load Distribution and Carrying Capacity of Helical Gears]," Ph.D. Thesis, Gear Research Centre (FZG), *Technical University of Munich*, Munich.
17. Höhn B.-R., P. Oster and M. Otto. 2010, Tooth bending strength of Helical Gears, *International Conference on Gears*.
18. Schinagl, S. 2002,"Zahnfußtragfähigkeit schrägverzahnter Stirnräder unter Berücksichtigung der Lastverteilung [Tooth Root Load carrying Capacity of Helical Gears considering Load Distribution]," Ph.D. Thesis, *Gear Research Centre* (FZG), *Technical University of Munich*, Munich.
19. Slansky, R. 2015,"Experimentelle und theoretische Untersuchungen zur Fußtragfähigkeit der Innenschrägverzahnung [Experimental and Theoretical Investigations on the Root Load carrying Capacity of Internal Helical Gears]," Ph.D. Thesis, *Technical University of Dresden*, Dresden.
20. Linke, H. 2010. *Stirnradverzahnung: Berechnung - Werkstoffe - Fertigung [Spur Gearing - Calculation - Materials - Manufacturing]*, 2nd ed., Hanser, München.
21. VDI 2737:2016-12. 2016,"Calculation of the load capacity of the tooth root in internal toothings with the influence of the gear rim," 2737.

Stefan Sendlbeck, M.Sc. is currently a Research Associate at the Institute of Machine Elements, the Gear Research Center (FZG) at the Technical University of Munich in Germany. He started his scientific career with a bachelor's and a master's degree in mechanical engineering from the Technical University of Munich including a study abroad at the University of Waterloo in Canada. He joined FZG as a researcher in 2018. Since then, he focused on gear design and calculation methods, gear condition monitoring and prognostics, and the use of machine learning methods in gear technology.

Dipl.-Ing. Maximilian Fromberger is with the calculation and software development department of RENK, a Germany-based company manufacturing transmissions for the industrial, energy and marine sectors, among others. Before that, he was research associate at the Gear Research Center (FZG) of the Technical University Munich. FZG's research focuses on experimental and analytical investigations of endurance, tribology, NVH, materials and fatigue life analysis on gears, transmission components and drive systems. FZG is also developing software that many German gear-related companies rely on. Some of these software products solve mechanical problems; others implement standardized (DIN / ISO) calculation rules. Fromberger was software team leader at FZG. His personal research activities aimed at gear condition monitoring.

Dr.-Ing. Michael Otto joined the Gear Research Center (FZG) at the Technical University Munich in 2000 as a research assistant and gained his position as head of department in 2006. He holds a Ph.D. in mechanical engineering, topics of his research activities were load distribution and tooth root carrying capacity. Current research activities include gear geometry, tooth contact analysis and gearbox related NVH. Another main topic is deformation and stress analysis of supporting shafts and bearings in the gearbox. He drives the development of various scientific programs that are available for companies that are member of FVA (German Research Association for Gears and Transmissions). He is head of the research group 'Calculation and Verification of Transmission Systems' at FZG, Prof. K. Stahl, TU Munich.

Prof. Dr.-Ing. Karsten Stahl is full professor at the Institute for Machine Elements and director of Gear Research Center (FZG) at the Technical University Munich. FZG research focuses on experimental and analytical investigations of endurance, tribology, NVH, materials and fatigue life analysis on gears, transmission components and drive systems. Prof. Stahl is board member of several scientific associations, convener of DIN and ISO working groups, editor of several scientific journals, author of several hundred publications, and president of the International Conference on Gears.

EVERYBODY HATES TELEMARKETERS.

Renew your subscription TODAY, and we won't bother you for at least a year!

www.geartechnology.com/subscribe

THANK YOU!

gear TECHNOLOGY

Klingelnberg

HONORS 23 EMPLOYEES FOR LONG-TERM SERVICE

In 2021, the Klingelnberg Group continued its longstanding tradition of celebrating work anniversaries by honoring 830 total years of employee service to the company, and along with it, their experience, knowledge, loyalty, and trust. This year's honorees included three employees with 50 years of service, twelve employees with 40 years of service, and eight employees with 25 years of service.

Left to right: Christel Thiel, Christian Neuber, Werner and Karin Hager.

"Even though celebrations are still difficult due to the current situation, we can't miss the opportunity to express our heartfelt thanks to our employees celebrating their service anniversaries. We are especially proud that we have three employees celebrating 50 years of service to the company," noted Christoph Küster, CFO of the Klingelnberg Group. "Without our exceptional team, we would not be what we are today — a leading manufacturer in gear technology."

The honorees with 50 years of service include Christian Neuber (warehouse manager), Werner Hager (production), and Christel Thiel (order center).

Christian Neuber with a long family tradition at Klingelnberg

Neuber is a veritable institution at the company, having begun his training as a machinist in 1971. For a long time, he worked as a machinist in single-part production before becoming a foreman in the lapping and testing machines in the early 1990s. Today he heads the warehouse department. "After 50 years of working here, the company has become like a home to me. I have always greatly appreciated the family atmosphere I enjoy with my colleagues. Work colleagues have become friends. Even with a workforce of 750 employees, I know everyone, from the owner to the crane operator," said Neuber in describing his time at Klingelnberg. "In these 50 years, things have never gotten boring. Due to the variety of tasks I have been involved with over the many years, I have hardly noticed how quickly the time has gone by. And during this time, entire warehouses have been renovated and built from the ground up."

Christian Neuber has a family story of his own at Klingelnberg. His father before him was employed as a pattern maker at Klingelnberg, his brother was an electrician at the company, and his mother worked in the factory canteen. "Because I grew up in a company-owned housing settlement, rather than having a specific type of training in mind, I really just wanted to know what it was that Klingelnberg was looking for," continued Neuber. And now the next generation is working for Klingelnberg: his son and daughter-in-law are also employed by the machine manufacturing firm. "They might also end up staying here for 50 years — for me, that's the type of family-oriented company that Klingelnberg is," said Neuber.

Werner and Karin Hager together celebrate 90 years of service to Klingelnberg

Werner Hager and his wife Karin Hager have been with the company for a grand total of 90 years combined. Karin Hager has been employed at Klingelnberg since 1981 and today works as a commercial clerk in the Standards department. "For us, working together in the same company had many advantages," says Karin Hager. "We were able to drive to work together, so we only needed one car. Vacation days were also easier to plan. Over the many years, we always felt at home at Klingelnberg. When I first started working in the central warehouse, I was reserving material from stock using index cards that were located in a special paternoster filing system. So, I was there during the beginnings of digitization, but I quickly became accustomed to working with computers."

Her husband Werner Hager began his career at Klingelnberg 10 years earlier. After training as a toolmaker, he worked as a boring mill operator and trained as a technician in the 1980s. Since 1988, Werner Hager has been working in NC programming. "In my 50 years with the company, things have continually evolved," Werner Hager remarked. "During my training period in the early 1970s, there were almost exclusively conventional machines. In 1978, I had the opportunity to work on the first CNC-controlled boring mill. At that time, data transfer was still done by means of a mechanical punch tape reader, and tools had to be inserted by hand.

Today, by contrast, we use only automatic tool changers in mechanical engineering, resulting in less downtime. My work in NC programming has also changed continuously. In the beginning, the programs were written on a small CRT monitor with only one image window and a keyboard without a PC mouse, and only 2D drawings were available. Various sequences were still sketched by hand. Today, with the introduction of special software, programs are created with graphically interactive programming. In addition, 3D solid models give us the necessary data for workpiece and tool geometry. They also serve as optical aids for identifying the often complicated geometry."

Christel Thiel looks back on a varied career at Klingelnberg

Thiel began her training as an office clerk in 1971 and, during her many years of service with the company, she has worked in

the purchasing, sales and production departments. She has been working as a commercial clerk in the order center since 2002.

"After my training, I was very happy that I found a position in such a great company. By working in the different departments, I always had a lot of variety in my professional life. I particularly appreciate the fact that Klingelnberg has always been a reliable employer—even in difficult times. Whenever I speak of Klingelnberg, I always refer to it as *our place*." Thiel is now entering her well-deserved retirement and looks back with positive feelings. "My time at Klingelnberg was well spent."

www. klingelnberg.com

Tyrolit

ANNOUNCES MANAGEMENT CHANGES

Dr. Christoph Swarovski already declared a year ago that he would be stepping down from the executive board in the first quarter of 2022 after 20 years in the company's management. However, he will continue to support the company as a member of the advisory board: "I would like to thank all employees and partners for the successful years in which Tyrolit has developed into one of the world's most successful market providers. I look forward to remaining associated with Tyrolit as an active member of the advisory board."

Left to right: Thomas Friess and Christoph Swarovski.

Thomas Friess will take over the position of Chairman of the Executive Board on January 1, 2022. The international orientation, continuity at all locations and the development of future industries will remain the focus of the family-owned company.

Friess comes from Germany and has lived in Austria for 18 years. The married family man holds a degree in business administration and has held numerous management positions at internationally active companies in Germany, the USA and Austria over the past 23 years. Mathias Margreiter, Chairman of the Tyrolit Advisory Board: "Tyrolit has a stable foundation for consistent and sustainable growth. In Thomas Friess we have

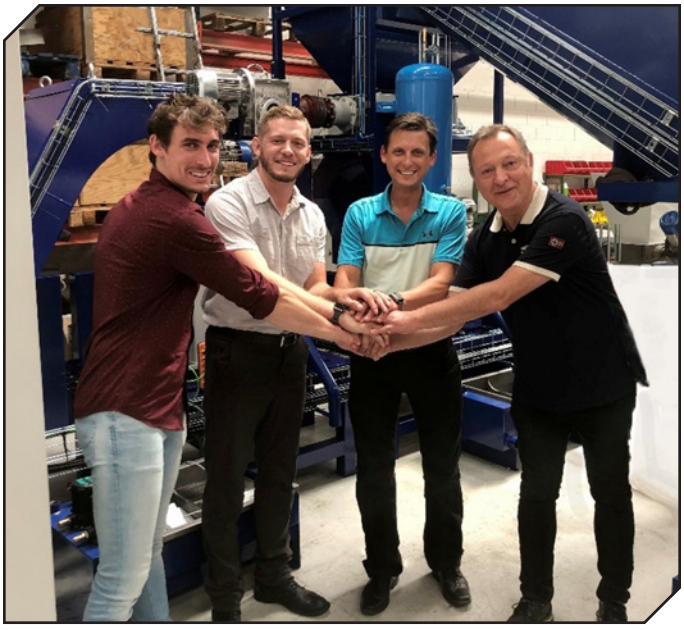
found a highly experienced and qualified person to continue the path successfully taken under Christoph Swarovski."

Since 2019, Friess has been a mainstay in the corporate development of the international abrasives manufacturer and is very familiar with the strategic orientation of the group of companies, the organization and the values it lives by. "I am looking forward to this responsible task. Innovative spirit, vision and partnership in practice remain central virtues at Tyrolit," confirms Friess. The new CEO's particular focus is on advancing digitalization and the development of future industries such as medical technology, electrical engineering and environmental technology. "With the help of innovative Tyrolit technologies, we will ensure the necessary precision within these future industries in the future and also make a valuable contribution to reducing the CO2 footprint," adds Friess, aware of the company's successful orientation.

In addition to Christoph Swarovski, Andreas Buchbauer is also retiring from the Tyrolit management board. A new executive board has been appointed for the group of companies around Friess: Peter Dollinger will in hold the position of CFO, Arno Pichler (Metal Industries) and Andreas Sauerwein (Construction) will represent their respective divisions on the board. All three people have already been active in the company for years in the executive board or in management positions.

"Thomas Friess and his team will find a profitable, very healthy Tyrolit Group with an excellent international position. The owner families and the new operational management are clearly committed to the group's locations and employees. The main plant in Schwaz will remain the heart and brain of Tyrolit," Margreiter said.

www.tyrolit.com



Jorgensen

PARTNERS WITH CHIP PROCESSING SUPPLIER S.F.H.

To strengthen its breadth of product offerings and provide manufacturers a one-stop-shop for all metal chip processing needs, Jorgensen Conveyor and Filtration Solutions has solidified a strategic alliance with chip processing equipment manufacturer S.F.H. based in Saint-Étienne, France. The new business partnership will benefit both companies and provide Jorgensen the exclusive rights to sell S.F.H. products in North America.

Jorgensen will initially focus on offering a wide variety of S.F.H. chip processing products including chip shredders, briquetters and centrifuges. In addition, Jorgensen will offer complete, integrated chip processing solutions. In the future, the two companies plan to introduce several additional products to the North American market.

According to Karl Kleppek, Director of Sales and Marketing at Jorgensen Conveyor and Filtration Solutions, "S.F.H. produces extremely robust chip processing products and systems, and Jorgensen is confident they will be a great partner and perfect fit for our customers in the machine tool industry. This new partnership will enable us to sell individual chip processing equipment and complete turnkey systems alike." Kleppek adds, "our new relationship with S.F.H. coupled with our wide range of conveyor and filtration solutions position Jorgensen as a complete coolant circuit and chip processing solutions provider."

With over 40 years of experience, S.F.H. specializes in three key areas of chip management: hydraulic fluid pump systems, equipment for separation of solids and liquids and waste recycling. "As S.F.H. enters the North American market, we welcome Jorgensen's leadership as our strategic partner in this step toward long-term growth," said Bruno Fillardet, President of S.F.H. "We're eager to build on our professional relationship."

www.jorgensenconveyors.com

Sandvik Coromant

TO ACQUIRE ICAM

Sandvik has signed an agreement to acquire Canada-based ICAM Technologies Corporation, a provider of innovative solutions that translate CAM data into optimized coding for guiding CNC machining operations. With a global reach, ICAM sells to some of the world's most renowned companies in the aerospace and defense, general engineering and automotive industries. The company will be reported in Sandvik Coromant, a division within Sandvik Manufacturing and Machining Solutions.

"I am really happy to welcome ICAM to Sandvik Coromant and I look forward to us working together and strengthening our offer to our customers. ICAM's ability to deliver code reliability across all major CAD/CAM systems is well-aligned with our goal to serve all our customers in the best way possible, with a CAD/CAM-neutral portfolio" says Helen Blomqvist, President Sandvik Coromant.

ICAM's software combines post-processing, machine simulation, and tool-path optimization into solutions that save programming and part machining time, streamlining customer workflows as the user can go from their CAM system

to verified and optimized coding (G-code) in just one step. ICAM's offering is complimentary with the verification and optimization technology of CGTech, a global leader in software for numerical control (NC/CNC) simulation, verification and optimization, also owned by Sandvik and reporting into Sandvik Coromant.

"For more than 30 years, CGTech has been a leader in simulating CNC machining, while ICAM has been a leading processing provider. ICAM and CGTech synergies will give customers a competitive advantage by reducing machining time and dependency on programming experience. Like CGTech, ICAM is a technology leader with entrepreneurial spirit, and we have known and respected each other for years. We look forward to working with everyone on the ICAM team." says Margaret Schmitt, president of CGTech.

"I and the rest of the ICAM team are really excited about the future. For many decades ICAM and CGTech have seen the world of CAM systems, computers, operating systems, machine tools and their controls evolve exponentially. And only through hard work, focus and dedication, both companies not only kept pace with all this change but have distinguished ourselves in our respective disciplines. ICAM and CGTech continue to share the same prestigious customer base who use our products as part of the most dependable and accurate Virtual Part Manufacturing Process in all metal removal industries worldwide. On top of all this, we come from the same business culture, we have similar roots and equally have a rare tremendous depth-of-knowledge in a very complex world guaranteeing that this new relationship holds huge potential and promise for developing even greater innovations for our customers for years to come" says John Nassr, owner of ICAM.

ICAM was founded in 1971 in Montreal, Canada, and currently has 27 employees. In 2020, the company had revenues of approximately SEK 30 million and an EBITA margin of approximately 25%. The transaction is expected to close during the fourth quarter of 2021 and is subject to customary closing conditions.

www.sandvik.coromant.com

GearOffice

CONSULTING ANNOUNCES PRODUCT AND SERVICE EXPANSION

GearOffice Consulting Services announces an expansion of its products & services and the launch of a new GearOffice website. In addition to the GearOffice computer program for gear hobbing analysis, the new services include gear design, gear processing, gear inspection and process debugging, SPC for gear manufacturing, and training.

The GearOffice principal engineer, **Yefim Kotlyar**, has over 40 years of experience in the art of gearing. His expertise includes developments of various gear cutting & grinding technologies, development of gear inspection and evaluation technologies, development and implementation of SPC for gear manufacturing processes and design and validation of gears and gearing systems. He is the author and one of the owners of GearOffice computer program. Yefim Kotlyar has served on a number of AGMA technical committees and he has authored many articles on gearing subjects.

The GearOffice computer program was designed to performs various hobbing and gear geometry calculations and maintain Gear/Hob/Machine/Hobbing Project records. The program keeps gears, machines, and hobs as independent objects. It can combine a gear, a machine, and a hob into a hobbing project, to determine (or select) cutting parameters, and calculate the results: cycle time, chip thickness, approach and overrun distances, hob setting angle, feed scallop depth, depth of enveloping cuts, force, torque, as well as tooth thickness/DOP/span. It also determines tolerances based on AGMA/DIN/ISO class and vice versa. Finally, it calculates many important gear geometry characteristics i.e. roll and polar angles, roll length, pressure angle, tooth/space thickness and more for normal, transverse, and axial planes at any gear diameter.

www.gearoffice.com

Walter Surface Technologies

ACQUIRES ALLEGRO INDUSTRIES

In its quest to become a global leader for safety and productivity, Walter Surface Technologies is pleased to announce the acquisition of Allegro Industries, a USA-based leading

manufacturer of high-quality safety equipment, respirators, air sources and ventilation equipment.

Through this acquisition, Walter is expanding its safety and PPE product offering to industrial users complementing its high-end metalworking products.

"We are very excited to welcome Allegro to the Walter family. Walter is always looking to provide solutions that answer the needs and challenges facing industrial end-users. Now, with this acquisition, Allegro brings the product and manufacturing expertise that will allow us to continue our mission to help our customers work better all while keeping them safe," said Marc-André Aubé, CEO of Walter. "This transaction is an unequalled opportunity to build up our activities in the North American

market as we continue to evaluate other growth strategies, namely through accretive acquisitions," he added.

Tom Johnston, president and founder of Allegro Industries welcomes the new relationship: "We are proud to see Allegro adding its solutions to Walter's renowned offering. The fit is right, and we look forward to Allegro's potential within the Walter group of companies." He adds, "We are very excited to be a part of the Walter team."

Following this transaction, Allegro will continue to operate under its own brand. The transaction is effective immediately, and activities for both customers and suppliers remain unchanged.

www.walter.com

Forest City Gear's Wendy Young

NAMED BUSINESS CATALYST OF THE YEAR

Forest City Gear is proud to congratulate **Wendy Young**, President and CEO, for being named the 2021 Individual Business Catalyst of the Year by the Rockford Chamber of Commerce.

Young began her career at Forest City Gear in 1983 as a delivery driver, machine operator and expediter. Young has been part of Forest City Gear's leadership team for over 20 years, during which time she has helped drive significant growth and expansion. Young currently serves as president (since 2002) and CEO (since 2015).

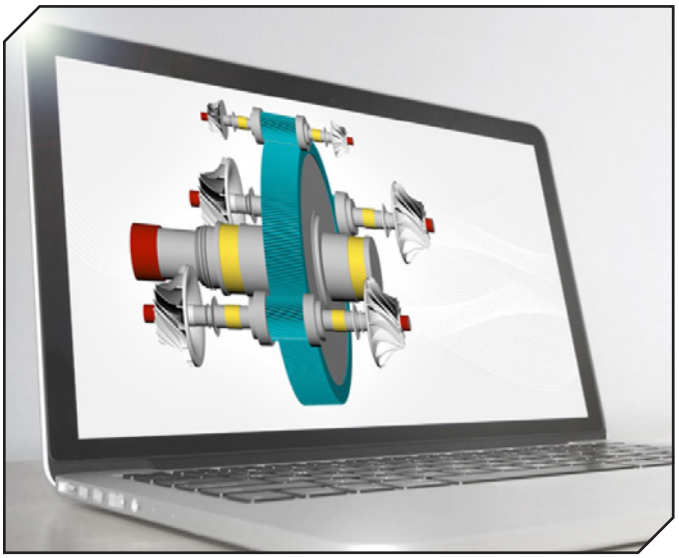
According to the Rockford Chamber of Commerce, Young's nominator had this to say, "Wendy's energy and dedication to her family, business, and community are second to none. Wendy is in constant pursuit to help those in need and less fortunate. Over the years I have personally observed Wendy's business acumen at work as she has led a world class, precision Gear Manufacturing Company through many difficult periods. Wendy often is found mentoring and assisting associates through hardships they were experiencing that was totally unrelated to work and business. Wendy's spirit, drive and compassion for excellence has been instilled in her family and is felt and noticed by those who know her."

www.forestcitygear.com

KISSsoft

ANNOUNCES TRAINING SCHEDULE THROUGH SUMMER 2022

The KISSsoft training program 2022 in English offers introductory training courses, advanced training courses and special training courses on selected topics. This year, KISSsoft will again be offering live streams, which will allow attendees flexibility and planning security, as well as the opportunity to interactively ask questions and participate in discussions in a virtual setting.



March 1–2
Shaft and Bearing Calculation (Basis)

March 22–24
KISSsys - Modeling Gearboxes (Basis)

March 29–30
KISSsys - System Calculations (Advanced)

March 31
KISSsys - Model Customization (Special)

May 9–12
Fine Pitch Gears in Plastic and Sintered Material (Special)

June 21–23 / June 28–30
Cylindrical Gear Design, Analysis and Optimization (Advanced)

www.kisssoft.com/en/products/training/upcoming-seminars

March 5–12—IEEE Aerospace Conference 2022

Big Sky, Montana. The International IEEE Aerospace Conference, with AIAA and PHM Society as technical cosponsors, is organized to promote interdisciplinary understanding of aerospace systems, their underlying science and technology, and their applications to government and commercial endeavors. The annual, week-long conference is set in a stimulating and thought-provoking environment. The 2022 conference will be the 43rd in the series. Plenary sessions feature internationally prominent researchers working on frontiers of science and engineering that may significantly impact the world we live in. Registrants are briefed on cutting edge technologies emerging from and intersecting with their disciplines. Each year, a large number of presentations are given by professionals distinguished in their fields and by high-ranking members of the government and military.

www. aeroconf.org.

March 21–24—Gear Dynamics and Gear Noise Short Course 2022

Columbus, Ohio. The purpose of this unique short course is to provide a better understanding of the mechanisms of gear noise generation, methods by which gear noise is measured and predicted, and techniques employed in gear noise and vibration reduction. Over the past 40+ years about 2,450 engineers and technicians from over 380 companies have attended the Gear Noise Short Course. The course is of particular interest to engineers and technicians involved in the analysis, manufacture, design specification, or utilization of simple and complex gear systems. Industries that find this course helpful include the automotive, transportation, wind-energy, process machinery, aircraft, appliance, general manufacturing, and all gear manufacturers. The course material is covered in such a way that the fundamentals of gearing, gear dynamics, noise analysis and measurements are covered first. This makes the course appropriate to the gear designer with minimal knowledge of noise and vibration analysis as well as to the noise specialist with little knowledge of gears.

www. nvhgear.org.

March 22–24—Gearbox CSI

Concordville, PA. A good understanding of individual failure modes and the failure scenarios that led to the actual system failure is an essential skill to designing gear/bearing systems that will operate properly for their full design life. In this course, instructors will define and explain the nature of many gear and bearing failures and discuss and describe various actual failure scenarios. In addition, a detailed primer on bearing technology prefaces the failure scenario discussions. Attendees will gain a better understanding of various types of gears and bearings.

www. agma.org/education/advanced-courses/2022-gearbox-csi/.

April 4–8—AGMA Basic Training for Gear Manufacturing - Spring

Chicago, IL. Learn the fundamentals of gear manufacturing in this hands-on course. Gain an understanding of gearing and nomenclature, principles of inspection, gear manufacturing methods, and hobbing and shaping. Utilizing manual machines, develop a deeper breadth of perspective and understanding of the process and physics of making a gear as well as the ability to apply this knowledge in working with CNC equipment commonly in use.

www. agma.org/education/advanced-courses/2022-basic-training-for-gear-manufacturing-spring/

May 18–19—CTI Symposium USA 2022

Novi, Michigan. The CTI Symposium USA will update attendees on latest technical developments and applications on automotive transmissions for conventional and alternative drives. Exchange experiences, discuss technologies and strategies with automotive experts from USA, Asia and Europe. The conference and exhibition provides expert-led plenary and technology sessions as well as expert discussions and product showcases representing the full range from complete drivetrain systems to components and engineering services.

drivetrain-symposium.world/us/.

May 30–June 2—Hannover Messe 2022

Hannover, Germany. Hannover Messe 2022 focuses on industrial transformation, which is driven by two megatrends: digitalization of industry and a reduction of C02 emissons.Digitization covers topics such as networking, data analytics, the Internet of Things, platforms, artificial intelligence and IT security. Companies that want to remain globally competitive must take advantage of digitalization to develop, manufacture and sell products faster and more efficiently. In Hanover, companies from the electrical engineering, mechanical and plant engineering, software and IT sectors will be demonstrating how the automation and digitalization of entire production and business processes can succeed.

www.hannovermesse.de

gear TECHNOLOGY

FREE SUBSCRIPTION

18GTPAGE

RESPONSE REQUIRED

☐ **YES** I want to receive/continue to receive ***Gear Technology***

☐ **NO** Thanks anyway, but I don't need the world's best publication on gear engineering and manufacturing.

Name _____ Job Title _____
(please print)

Signature _____ Date _____
(required)

How would you like to receive *Gear Technology*?

☐ PRINT version (Verify mailing info below)
☐ DIGITAL Version (E-mail required)
☐ BOTH Print AND Digital (E-mail required)

E-mail _____*

***Your PRIVACY is important to us. You get to CHOOSE how we use your personal information. The next e-mail we send you will have clear instructions.**

How are you involved with GEARS?

☐ My company MAKES GEARS (20)
☐ My company BUYS GEARS (22)
☐ I DESIGN gears (23)
☐ I am a SUPPLIER to the GEAR INDUSTRY (24)
☐ OTHER (Please describe) _____

What is your company's principal product or service? _____

_____

MAILING INFORMATION

NAME:
JOB TITLE:
COMPANY:
ADDRESS:
☐ Check if this is a home address

CITY:
STATE/Province:
ZIP/Postal Code:
PHONE:
FAX:

Put your business card here to make it easier!

Mail to:
1840 Jarvis Ave., Elk Grove Village, IL 60007 USA

or

FAX to 1-847-437-6618
SCAN to: subscribe@geartechnology.com

Gears that Transport Bearings for Entertainment

Joseph L. Hazelton, Contributing Editor

Ron Walters started building his wooden machine as a pastime after his foot surgery. Months later, the retired mechanical engineer had an entertaining device that featured 16 gears and could move ball bearings at a rate of 7,200 per hour.

The device, called a marble machine, holds 75 ball bearings, weighs 30 lbs., stands 30" tall, has a base 19" square, and includes two ring gears, each 14.5" in diameter.

All 16 gears move the ball bearings the 30" from the bottom of the machine to the top. Moreover, the two largest gears actually *carry* the bearings. They are identical ring gears, and they carry bearings in holes carved in their rims.

Starting at the machine's base, each bearing rolls into a hole in the rim of the lower ring gear. The gear rotates clockwise, carrying its bearings upward. The bearings stay in their holes because the ring gear has a backing. The backing is circular and stationary, but with a hole at its top. So, as the lower ring gear rotates, each of its holes reaches the backing's hole. When a gear hole lines up with the backing's hole, a bearing transfers from the lower ring gear to the upper one.

Rotating counterclockwise, the upper ring gear has an identical backing with an identical hole at its top, which is also the top of the machine. So, when a gear hole lines up with the backing's hole, a bearing rolls out of its hole and through the other hole.

Now at the top of the machine, a bearing starts its way back down by first rolling into a vortex funnel that looks like a flower pot. The funnel has three holes: one in the bottom of the funnel, two in the wall of the funnel. The two in the circular wall are diametrically opposite each other. If a bearing goes through the bottom hole, it rolls down a spiral track. At the bottom of this path, the bearing rings two old, brass telephone bells.

Marble Machine Back & Side

Marble Machine Front & Side

Built with 16 gears, this entertaining device is called a marble machine because it usually transports glass marbles. Ron Walters, though, prefers to use 5/8" ball bearings. Unlike glass marbles, the ball bearings don't chip despite constantly knocking against each other.

If a bearing goes through one of the holes in the wall, it rolls back and forth, back and forth down a zigzag track. If it goes through the other hole in the wall, it rolls to a flip-flop mechanism that directs the bearing to one or the other of two paths. One path leads to the machine's xylophone, six bars of rosewood. "Apparently, they use rosewood in real xylophones," Walters said.

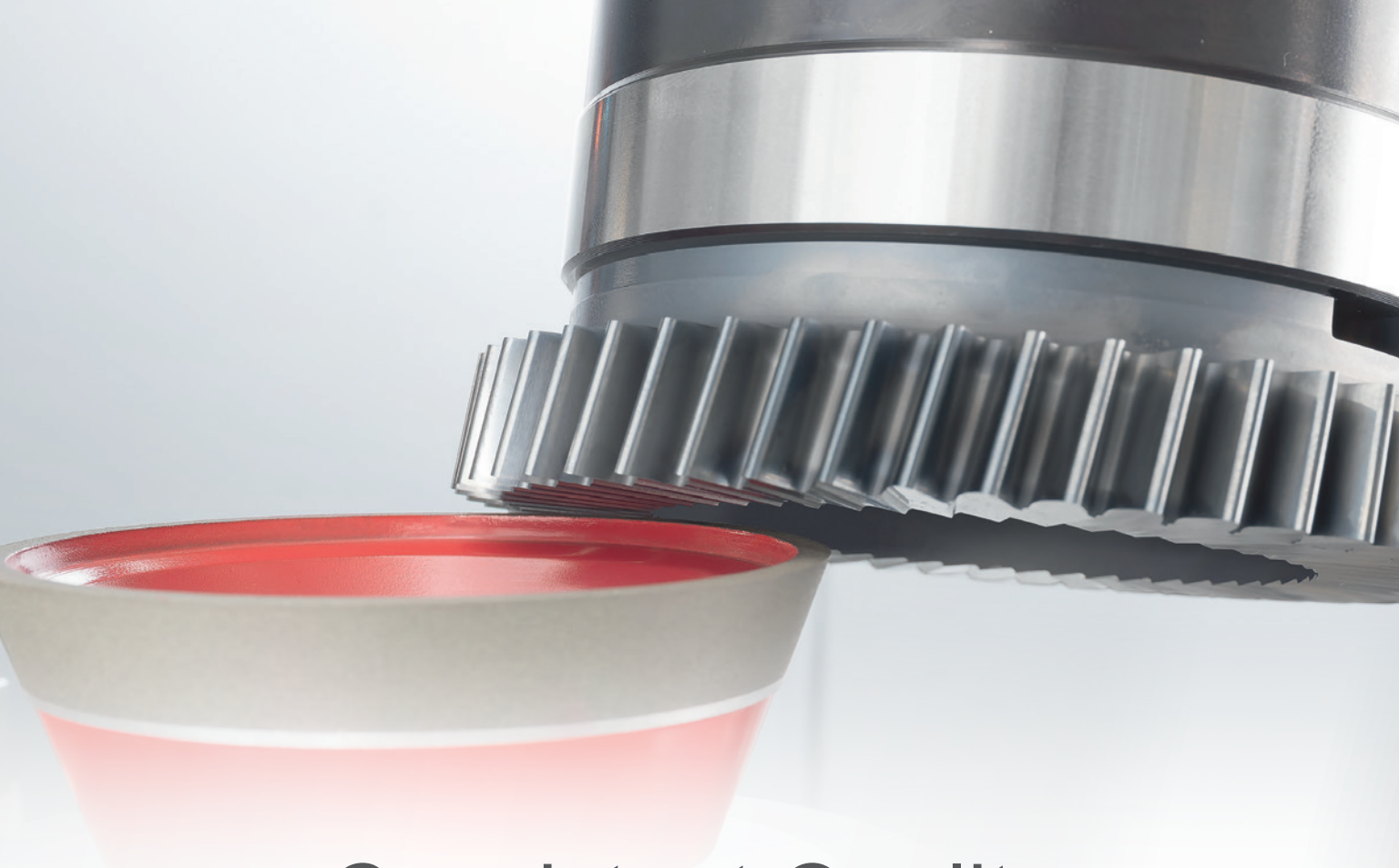
The other path leads to a divide-by-three mechanism. This mechanism works like an automatic trapdoor. When three bearings are on the free end of the mechanism, their weight causes the end to drop like a trapdoor opening in a floor. The bearings then roll down a track and fall into a dump-o-matic. This wooden cup can hold up to 12 bearings. Once 12 accumulate, their weight causes the cup to tip over, dumping the bearings onto the machine's base.

In total, a bearing can take one of four paths: the spiral path, the zigzag track, the xylophone path, or the dump-o-matic. Which path the bearing takes is up to chance. However, Walters observed the machine and figured out there were tendencies. Almost 10 percent of the bearings reach the bottom of the funnel and roll down the spiral path. About 50 percent take the zigzag track, and about 40 percent roll to the flip-flop mechanism.

At the end of each path, a bearing reaches the machine's base. The base is sloped so the bearings roll back to the front of the machine, where they start a trip to the top all over again.

All of this motion can be seen in three videos on Walters's YouTube channel, Ronald Walters. The main video is at youtube.com/watch?v=QzIG9stFXSI.

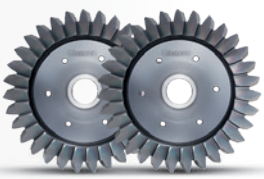
Also, all of this motion is possible because the two ring gears rotate at the same speed, cleanly transferring their bearings. The identical speeds result from two identical timing gears. These gears are connected to the machine's two driving pinions: a pinion of the lower ring gear and a pinion of the upper ring gear. The two pinions are powered by a 110-volt shaded-pole gearmotor.



Consistent Quality with Reduced Cost

Resharpening of cutters for both soft cutting and hard finishing can now be fully automated on Gleason 300PS and 600PS vertical Power Skiving machines. Tool cost-per-piece is greatly reduced, and consistently high quality ensured.

gleason.com/ps



Total Gear Solutions Gleason

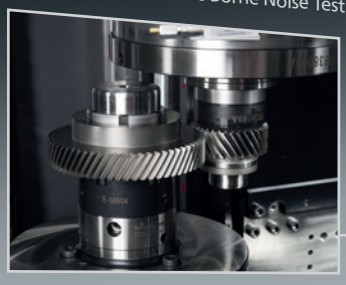
R 300 THE GEAR NOISE FINDER

MAXIMUM PRODUCTIVITY FOR QUIET GEARS

HIGH-PRECISION TESTING FOR ALL FIVE ROLL TESTING METHODS

KLINGELNBERG

Gear Noise Check by Single-Flank, Torsional Acceleration & Structure Borne Noise Test



Heat Treatment Distortion Check by Helix Test

Subject to changes

Due to the increasing quality requirements in large-scale transmission manufacturing, some transmission and vehicle manufacturers now require a certificate of quality for all gears installed in the powertrain. A further driver of ever-higher inspection levels is e-mobility, which places much higher demands on the noise behavior of a transmission due to the elimination of the combustion engine. To meet this challenge, Klingelnberg has developed the Höfler Cylindrical Gear Roll Testing Machine R 300. Designed for all five roll testing methods, this compact machine is the ideal solution for anyone who wants to combine inspection cycles and reduce disassembly costs while benefiting from a user-friendly design.

BEVEL GEAR TECHNOLOGY | CYLINDRICAL GEAR TECHNOLOGY | PRECISION MEASURING CENTERS | DRIVE TECHNOLOGY

WWW.KLINGELNBERG.COM