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IMTS 2022
THE GEAR PAVILION AND MORE

WORKHOLDING

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The American Gear Manufacturers Association

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A Publication of
The American Gear Manufacturers Association

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Vol. 39. No. 6 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.

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Vol. 39. No. 6

departments

THE GEAR INDUSTRY'S INFORMATION SOURCE

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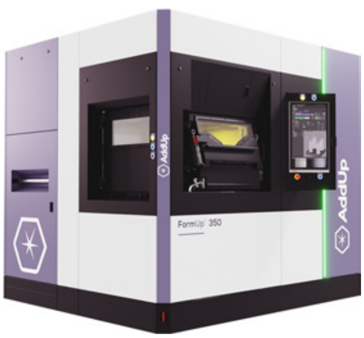
GT Revolutions

Big Daishowa Highlights Four Workholding Tips

Big Daishowa specializes in modular workholding that provides flexibility, efficiency, and functionality. UNILOCK zero-point workholding provides value through versatile solutions that are simple to integrate into existing machinery and setups. In this article, the company examines four tips for choosing the right workholding device:

geartechnology.com/blogs/4-revolutions/post/30003-big-daishowa-highlights-four-workholding-tips



AddUp Launches Process Monitoring Software

AddUp, a joint venture created by Michelin and Fives, is a global metal additive manufacturing OEM and service provider of powder bed fusion (PBF) and directed energy deposition (DED) technologies. They have launched a suite of new process monitoring software to bolster the capabilities of the FormUp 350 PBF machine: *AddUp Dashboards*, *Recoat Monitoring*, and *Meltpool Monitoring*. This new software suite for its metal 3D printing technology optimizes part quality for prototyping and end-use industrial applications:

geartechnology.com/blogs/4-revolutions/post/29966-imts-preview-addup-launches-process-monitoring-software

IMTS Coverage

Both the July and August issues of Gear Technology feature comprehensive articles covering IMTS including a preview of additive manufacturing, booth highlights, metal cutting robots and more. Check out additional IMTS information online here:

geartechnology.com/articles/29977-preview-of-3d-printing-at-imts-2022

geartechnology.com/articles/29976-imts-2022-booth-previews

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What Will *You* Find at IMTS?

Publisher & Editor-in-Chief
Randy Stott

I'm presuming that you'll be attending IMTS at McCormick Place, Chicago, September 11–17. I mean, why wouldn't you? If you're reading this magazine, then you're somehow involved in the world of gear manufacturing, and whether you're a design engineer sitting at a computer every day, a machinist working on the shop floor or an inspector working in a quality control lab, you need to understand how gears are made to do your job well.

And there's no place better suited to build and grow that understanding than at IMTS, where you can see all the latest technology from the leading manufacturers.

In the Gear Pavilion, you'll find the most recent gear manufacturing technology from the likes of Gleason, Helios, Klingelnberg, Liebherr, Nidec Machine Tools, Star Cutter and more—including new gear machines debuting at this show. You'll also find Booth #237314, home to *Gear Technology*, *Power Transmission Engineering* and the rest of the American Gear Manufacturers Association family. We hope you'll stop by to see us. Renew your subscription. Talk to us about how we can help you improve your marketing efforts by reaching out to our audience by print, email, online and through social media. Ask about the benefits to your company of becoming an AGMA member, or if you're already a member, chat with us about ways you can make the most of your membership.

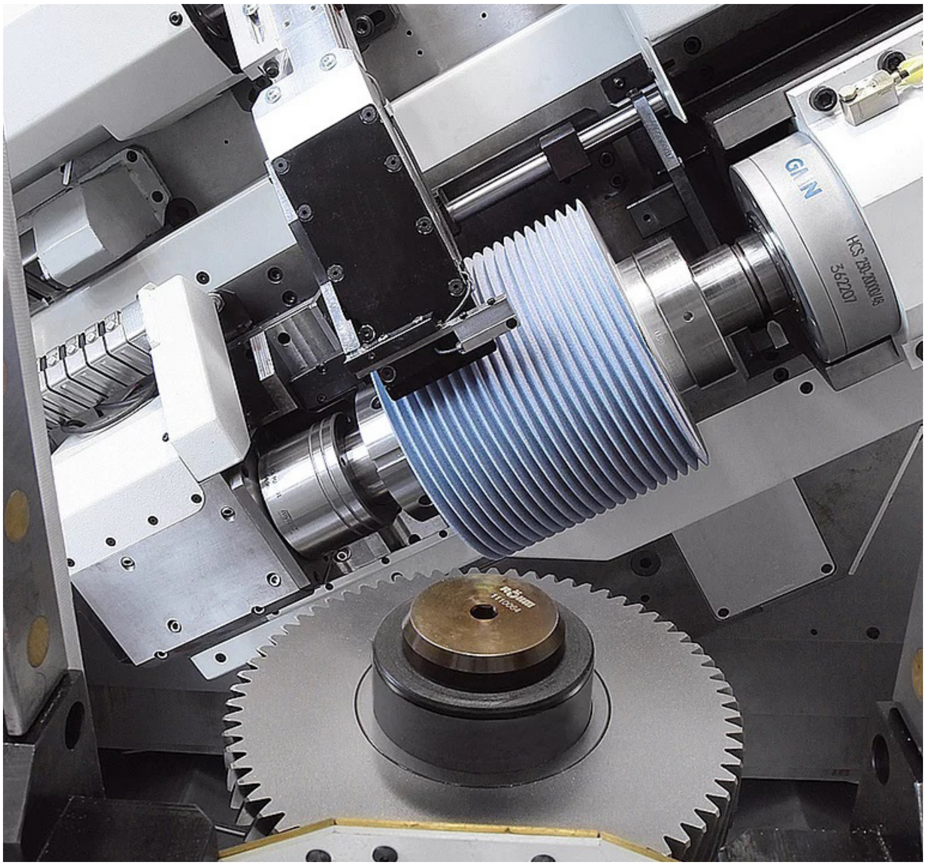
Beyond the gear pavilion, there's lots more to the show, including cutting tools, workholding, inspection technology and machine tools for turning, grinding, milling and 5-axis cutting and much more.

You can learn more about what some of these exhibitors will have on display by reading our booth previews article, beginning on p. 20, along with our Showstoppers special advertising section (p. 32), our IMTS Workholding preview (p. 34) and even this issue's edition of Addendum (p. 72).

In any case, we hope to see you there. We're looking forward to a great show.

EMAG

OFFERS GRINDING SOLUTIONS FOR E-MOBILITY AND DATA-OPTIMIZED PRODUCTION



Whether electric drive, hybrid motor or conventional drive—production planners face the great challenge of developing a wide range of manufacturing solutions for the future. On the one hand, they need new production solutions for a wide variety of components, on the other hand, costs must be reduced and production processes optimized. EMAG recently showcased its grinding solutions for electromobility and more during Grinding Hub 2022.

The future belongs to data-optimized production, EMAG is convinced of this. Optimizing cycle times and unit costs is important, but EMAG goes one step further and focuses on overall plant efficiency (OEE) and its optimization based on production data. To make it as easy as possible for EMAG customers to enter the world of data-optimized production, machines can now be delivered IoT-Ready. This makes it possible to integrate the machines directly and without major effort into existing IoT networks. An EDNA IoT Core (an IPC) is then installed in the control cabinet of the machines, which is already fully installed and networked with the machine control. In addition, the machines can be equipped with the EDNA Neuron 3DG sensors (acceleration sensors), which enables regular automatic monitoring of machine health. With the right software offer from EMAG, data-optimized production can be started directly.

Grinding solutions from EMAG Weiss

CNC technology Weiss has made a name for itself in recent years as a successful developer of cylindrical grinding machines. Founded in 1993, the company has acquired its know-how through the maintenance and modernization of Karsten's cylindrical grinding machines. Since 2002, CNC-Technik Weiss has had its own range of cylindrical grinding machines, ranging from classic conventional cylindrical grinding machines to high-tech CNC cylindrical grinding machines. Weiss displayed two of these machines at GrindingHub: a W 11 CNC and a W 11 EVO. The W 11 CNC is a grinding machine equipped with a modern, fast, grinding-oriented control. It can be used to automate many operations. The W 11 EVO is a further development of the well-known K11 series from Karstens. It is a new, contemporary version of the conventional grinding machine with many extras that make production life easier: hydraulic-free, axle drives with servo motor and ball screw, modern HMI with touchscreen, automatic parallel dressing and free-driving and much more. Both machines offer the highest precision in external round machining with a grinding length of up to 2,000 mm and a maximum grinding diameter of 360 mm.

Combination machining with the VLC 350 GT

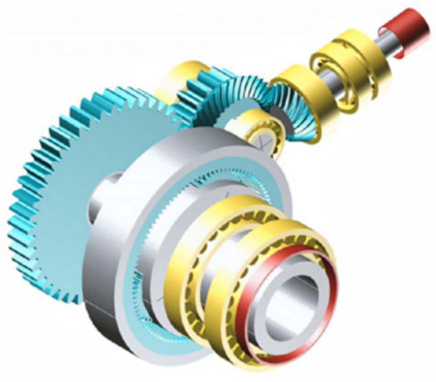
EMAG also presented a VLC 350 GT for the first time at GrindingHub. The abbreviation "GT" stands for the words "Grinding" and "Turning." The combination of grinding and turning (plus other processes) with EMAG pick-up automation enables countless manufacturing solutions. The machine is designed for components up to 350 mm in diameter and offers the option of integrating a grinding spindle with NC swivel axis. On it, for example, there is a cylindrical abrasive with which internal holes can be ground. It is fundamentally important that the combination of (hard) turning and grinding ensures fast processes and high machining quality.

After turning, only a residual thickness of a few mikrons remains. The grinding process with corundum or CBN grinding wheels is therefore significantly shorter. In addition, the grinding wheel specification—in view of the small thickness—can be designed more specifically for the final quality. An integrated touch probe checks the diameter and length of the component after the process. A linear motor in the x-axis also ensures short chip-to-chip times because it brings the components into the machining position particularly quickly.

In addition to these exhibits, EMAG offered new products from EMAG SU (rolling and profile grinding of gears) and dedicated a complete area to the topic of brake discs.

www.emag.com

KISSsoft
EXAMINES BEVEL GEAR STRENGTH RATING



Strength rating of bevel gears according to standards such as ISO, AGMA, etc. is executed based on virtual cylindrical gears, only modified by a few specific bevel gear factors. The rating methods of these standards also include the calculation of permissible stresses and finally result in safety factors.

The contact analysis for bevel gears allows a calculation of the stresses. It considers the individual flank modifications such as crowning, twist, etc., including the corresponding displacements. A limitation of the contact analysis is the missing determination of permissible stresses and thus the lack of safety factors and lifetime calculation.

Combining both methods, the accuracy in the rating of bevel gears increases significantly. Considering the E, P, G and Alpha displacements due to the bending of the shafts, the largest possible contact pattern is modeled in the software *GEMS*, strictly avoiding any edge contact. Based on the stress numbers from the contact analysis, the relevant parameters of the rating standard are derived, and the bevel gear pair is assessed for various failure modes such as root bending, pitting, scuffing and flank fracture.

Are you interested in further information about bevel gear calculation? Then join KISSsoft for “Innovations in Bevel Gear Technology,” from August 31 until September 1, 2022, in Aachen, Germany. Dipl.-Ing. Jürg Langhart will hold a presentation on “Bevel gear strength and life rating—the appropriate combination of rating standards with tooth contact analysis.”

kisssoft.com

Mitutoyo

INTRODUCES QUICK VISION PRO SERIES

Mitutoyo America Corporation has release the Quick Vision Pro Series, the latest generation of Mitutoyo Vision Measurement Systems. Quick Vision Pro Series machines are packed with high-performance technologies that greatly improves 3D noncontact measurement and productivity. This highly advanced noncontact measuring system delivers even more speed, efficiency, and versatility to the Mitutoyo Vision Measurement line.

The new QV Pro Series features newly developed StrobeSnap vision measuring function that speeds up run time by approximately 35 to 45 percent regardless of measurement position or continuity while achieving higher throughput and high-precision measurements.

Autofocus on the QV Pro Series is about 39 percent faster than previous models, which were already fastest in their class, without loss of accuracy.

An optional Stream function realizes very high throughput using nonstop measurements that synchronizes the main XY unit drive and strobe lighting. Stream takes images intermittently without stopping the stage and performs batch measurements at the same time, greatly improving measurement speeds.

Optional tracking autofocus (TAF) utilizes a laser tracker that will keep the part in focus while moving the joystick, eliminating the need to keep manually focusing on the part if it is not flat. When a part program is running, TAF keeps the part in focus, so the program does not have to stop for autofocus and stops potential errors from occurring if the part is out of focus. TAF cuts speed measurement times by approximately 30 percent, further improving throughput while maintaining high accuracy.

All the QV Pro Series machines can be retrofit with Stream capability, RGB (Red, Green, Blue) illumination systems, and side-mounted touch probe kits.

mitutoyo.com

Big Daishowa

UNVEILS EWA AUTOMATIC BORING HEAD

The Big Kaiser EWA Automatic Fine Boring System from Big Daishowa performs closed-loop boring operations without a human operator. This breakthrough eliminates the need to stop the spindle to manually adjust the boring tool, which results in considerable time savings. Also, eliminating human interaction reduces cost, improves accuracy, and minimizes scrap. The adjustment range of this fine boring head allows for the handling of multiple bore sizes with the same tool and ensures a repeatable boring process.

The EWA fine boring head is available in two sizes, one with a boring range of Ø2.677"–5.276" (Ø68-134 mm) and the other with a range of Ø.394"–2.126" (Ø10-54 mm). EWA kits are also available for each of these head sizes. These can include inserts, insert holders, a controller, antenna, and protective case.

The EWA can be used on machines with BT/BBT30-40-50, CV/BCV(SK)40-50, BIG CAPTO 5-6-8 and HSK-A63-80-100-125 spindles. The Automatic Fine Boring System can be integrated in three primary configurations: fully integrated, PC control, or tablet control.

A fully integrated system has the EWA control software running directly on the machine tool control via an app or technology cycle, requiring no external control device. The fully integrated system

can only be integrated on new machine tools.

For legacy machines, a PC interface between the machine tool and the EWA can provide a fully automated, closed-loop control cycle. Commands are sent from the machine tool to the EWA, automatically adjusting the tool in synchronization with the machining process.

The PC acts as a synchronization interface between the machine tool and the EWA. It stops the machining cycle after the touch probe makes a measurement, reads the result, and sends the corresponding adjustment value to the EWA. After the EWA has been adjusted, the PC notifies the machine tool to continue the process.

The EWA can also be operated as a standalone tool, controlled manually with the Big Kaiser app on a tablet or smartphone. This enables the option to measure bores using an in-machine probe or manually, and to make fast adjustments in the app. Adjustments also can be done semiautomatically, where the head will move to pre-entered diameter values after a stoppage.

bigdaishowa.com

Exact Metrology

EXHIBITS AT COORDINATE METROLOGY SOCIETY CONFERENCE

Exact Metrology recently exhibited at the Coordinate Metrology Society Conference (CMSC) with their sister division, OASIS Alignment Services: A Division of In-Place Machining Company.

Held between July 25th and July 29th at the Renaissance Orlando SeaWorld,

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IMTS 2022

Visit us at

IMTS

September 12 - 17
Chicago, USA
North Hall, Booth 236914

this practical, user-driven metrology conference provided attendees with the opportunity to try the latest innovative coordinate metrology equipment and educate themselves in metrology principles.

Face-to-face interaction was available with over 400 master end users of metrology solutions, including developers, decision makers, and equipment vendors and service providers. The CMSC includes numerous technical presentations from industry experts, hands-on workshops providing training opportunities on metrology hardware and software solutions.

According to Dean Solberg, vice president of metrology at Exact Metrology, "Our focus for this show was to share who we are now as the two precision measurement companies that currently make up the Measurement Services Group of In-Place Machining Company. Metrology services include 3D scanning, dimensional inspection, long range scanning (Geospatial), reverse engineering, industrial CT scanning, precision machine alignment and training on Polyworks and Geomagic."

exactmetrology.com

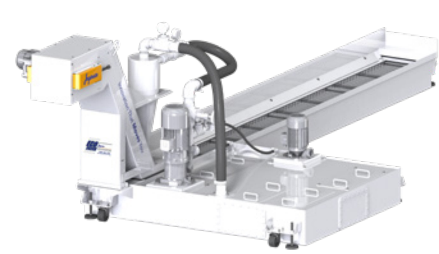
Jorgensen

LAUNCHES THREE NEW SYSTEMS TO OPTIMIZE THE MACHINING PROCESS

Jorgensen Conveyor and Filtration Solutions announces the introduction of three new systems that will reduce labor and improve performance throughout the entire machining process.

The new PermaClean filtration system eliminates sludge build up by adding optional agitation to the coolant collection tank. Eductor nozzles keep coolant in motion, suspending chip particulates and preventing them from settling. Collection tanks equipped with PermaClean combined with cyclonic filtration are virtually maintenance free and significantly reduce the labor required for frequent tank cleaning.

PermaClean incorporates into Jorgensen's multistep filtration system that includes the EcoFilter conveyor and filter cell, additional filtration options



and fine filtration for high-pressure applications. It also adapts as an option to improve the performance of any Jorgensen filtration system on the market.

To further reduce coolant tank maintenance, Jorgensen now offers Will-fill, a revolutionary new metalworking fluid optimizer. Will-fill combines automatic volume measurement and metalworking fluid analysis with faultless filling, permanent conditioning, and timely reporting to provide worry-free coolant care.

The addition of PermaClean and Will-fill to Jorgensen's FlexFiltration portfolio uniquely positions the company to deliver complete, maintenance-free conveyor and filtration solutions—allowing users to return their focus to machining.

FlexForce is Jorgensen's new high-pressure coolant system that dramatically outperforms ordinary flood systems. Available in 500 and 1,000-psi options, FlexForce breaks through the heat-generated vapor barrier created at the cutting tool and workpiece that can cause surface deformities and damage tooling. FlexForce penetrates this barrier and gets coolant directly to the cutting zone, improving lubrication and heat dissipation, speeds and feeds and chip control. Plus, FlexForce increases coolant and tool life and provides improved surface finishes.

Jorgensen will feature PermaClean, FlexForce and Will-fill at IMTS 2022, along with the company's recently released modular FlexFiltration line, chip processing systems, conveyors and the new Auger Assist Conveyor that handles higher chip volumes and decreases labor required for chip hopper management on machines with a cone/auger discharge system.

jorgensenconveyors.com

Dillon

CLAW JAWS PROVIDE MAXIMUM GRIP WITH FLEXIBILITY

Dillon Manufacturing's Claw Jaws have an optimized contour which provides a secure grip on the workpiece, and the jaws weight, center of gravity and cutting forces combine to minimize jaw clamping force loss. Designed to bite into the workpiece, they provide increased holding power during turning operations. Manufactured from 8620 steel for durability and long service life, an extensive product range is ideal for I.D., O.D., and bar clamping applications. The Dillon Claw Jaw system is available for most chuck brands. Optional rest buttons allow setting up different clamping depths. Competitive pricing with fast delivery, coupled with enhanced productivity and long service life combine to reduce tooling costs. Dillon Claw Jaws are ideal for turning applications in any industry. Dillon Manufacturing, Inc. manufactures a complete line of standard and custom workholding solutions including

chuck jaws, chucks, soft jaws, hard jaws, collet pad jaw systems, chuck lubrication, and more. All products are made in the United States and Dillon is ISO 9001:2015 registered.

Dillonmfg.com

Schunk

PGL-PLUS-P GRIPPER OFFERS INCREASED SAFETY AND PERFORMANCE

With the new PGL-plus-P, Schunk is introducing a flexible and robust gripper that provides certified safe gripping force maintenance.

The pneumatic universal gripper in five sizes offers a unique performance package of stroke, force and connectivity, making it perfectly suited for handling tasks where flexibility is required. Thanks to its large jaw stroke of 10 to 25 mm per finger, users can handle a wide range of parts with just one gripper. This saves investment costs and is particularly interesting for small batch sizes and high part variance, such as in machine loading and assembly. The new gripper has a gripping force of 220 N in size 10 to 1,300 N in size 25. In addition to its flat design and its proven and robust multi-tooth guidance, it also scores with its sealing as standard according to IP 64, which means that it can also do its job without further ado in dirty environments. In combination with an integrated air purge connection, the protection class can be increased to IP 67. Thanks to the H1-compliant lubrication as standard, the gripper can also be used in medical and pharmaceutical applications or in the food industry.

With the PGL-plus-P, Schunk is providing safety as well as a wider range of applications. To this end, Schunk is offering the pneumatic gripper with GripGuard certified safe gripping force maintenance. This reduces the risk of operators injuring themselves during part removal, for example, to a minimum, as uncontrolled jaw movements in the event of a sudden drop in pressure are eliminated from the outset. Also, no workpieces are lost in the event of a failure or an emergency stop. At least 80 percent of the nominal gripping force is reliably maintained in the event of pressure loss. This saves time and costs when it comes to the CE declaration of conformity according to the Machinery Directive and the risk analysis of the entire system. In addition to the new GripGuard technology, the PGL-plus-P is also available on request with conventional gripping force maintenance via compression springs.

Another highlight is the already integrated IOL sensor system. It also increases the performance of the gripper and simplifies acquisition, commissioning and repair by eliminating the need for external sensors. It can be used to monitor the finger position over the entire range of stroke. It can also distinguish workpieces with high precision. An important feature for handling a more extensive range of parts. Users can switch between IO-Link and SIO modes. With the "Gripping Point Mode" and "Gripping Range Mode", Schunk also offers two sensor profiles for the conceivably easy programming of workpiece positions or areas. The program for the PGL-plus-P is versatile and combinable. This means that the gripper can be individually adapted to almost any application—for example, with conventional sensors instead of the new IOL sensor system, as a precision variant, or as a high-temperature variant for use at up to 130°C.

schunk.com

Guill

OFFERS INTERNAL SPLINE TOOL FOR AEROSPACE APPLICATIONS

Guill Tool, a growing supplier of components to the global aerospace industry, has announced the production of a new internal spline tool made of anodized carbon steel.

Dimensions on this product are 2.750" outer diameter x 6.000" overall length, or (69.85 mm outer diameter x 152.4 mm overall length). This Guill internal spline tool was splined by the EDM department and completed milling on a Bridgeport milling machine.

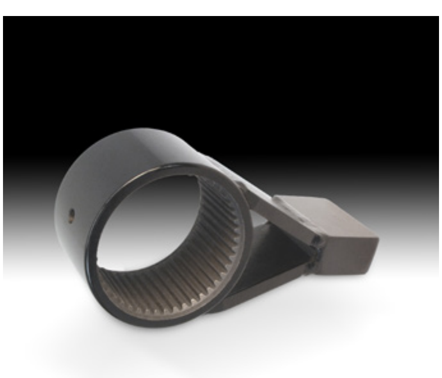
Guill now offers its substantial machine shop capabilities as an independent service to customers in aerospace manufacturing. Products are made to customer specification.

For over 55 years, Guill Tool has offered high-quality, precision machined components for the defense and commercial industries. The company manufactures flanges, valves, fittings and various critical components for aircraft, weapons, and nuclear submarines.

Guill offers its full capability of CAD/CAM design, plus EDM and 5-axis machining centers to the aerospace industry. Owing to its many years in the government and defense sectors, Guill also provides industry-standard cybersecurity and NDA confidentiality to its customers.

Guill has the following registrations and certifications: A.S9100:2016—Aerospace Manufacturing, ISO9001:2015 registered, JCP Certified—Government Contracting, ITAR Registered and NIST SP800-171—Compliant Cyber-Security.

guill.com/aerospace



Machine Tool Builders

ADDS HIGH-SPEED CHAMFER DEBURRING MACHINE FOR PRECISION GEAR PRODUCTION

Machine Tool Builders Inc. (MTB) has added a high-speed, high-precision Chamfering and Deburring Machine to its family of new gear production machines.

The RGC 350 Chamfer Deburring Machine, built by TEC for Gears (TfG), Furtwangen, Germany, utilizes a high-performance Radial Gear Chamfering (RGC) process to produce a defined, reproducible chamfer on workpieces with diameters and lengths up to 350 mm. The process allows for precise chamfering of external cylindrical gear teeth, and can be applied to workpieces with interfering contours, such as those with multiple gears, shaft attachments and bearing seats.

With the RGC 350, the chamfering process is carried out continuously, in a dry environment utilizing high cutting speeds to deliver very short cycle times. Despite its compact size, the RGC 350 offers a particularly large work area to maximize capacity and simplify load/unload, whether done manually or through integration of automation for continuous machining.

"The RGC 350 is the perfect solution to complement to our array of vertical and horizontal hobbing machines, allowing us to meet our customers' needs for producing burr-free gears with precise chamfers in advance of hard finishing operations downstream," says MTB Director of Sales and Marketing KC Warren.

In addition to offering TfG chamfering deburring, MTB offers a broad range of new gear manufacturing machinery from leading builders around the world, including HAMAI horizontal hobbing machines, SMG vertical hobbing machines, BURRI generating and profile grinding machines and Donner + Pfister gear inspection systems.

machinetoolbuilders.com

Röhm

INTRODUCES DURO-M LATHE CHUCK

The variable machining of turned parts has never been easier. This is made possible with Duro-M, the new geared scroll chuck, innovative lens geometry and optimized power transmission by Röhm. The company supplies its new lathe chuck generation across the whole range with two, three, four or six jaws. This way, even particularly thin-walled workpieces can be clamped and machined perfectly.

"The Duro-M is our new series of lathe chucks for the clamping of turned parts on turning and milling machines, rotary tables and dividing attachments with conventional clamps. We have the right Duro-M solution for every application, so that all metal workers can truly benefit from the many advantages of our new geometry," said Jörg Bauriedl, product manager for the manual lathe chuck division at Röhm.

The new Duro-M series has a noticeable lens recess, which provides users with a whole host of benefits. Thanks to this significant recess, the lathe chuck becomes lighter. With its reduced weight,

the Duro-M goes easier on the bearings of the turning machine spindle compared to other lathe chucks, and at the same time it enables acceleration with less demand for energy.

There is an added benefit with regard to the workspace, so that the machining tools are better accessible, and for example drilling or milling operations on the turned parts near the clamping position can be much more flexible than before.

"As the milling cutters do not need to be unclamped as far, the risk of oscillations is reduced. Machining is safer and more precise – this enables higher cutting speeds," said Bauriedl.

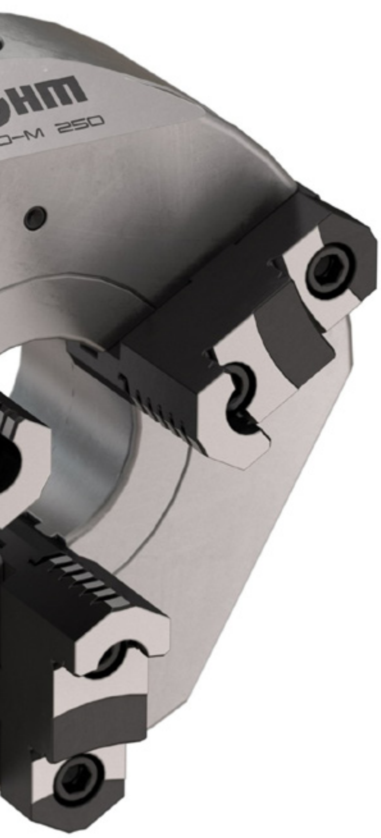
The new Duro-M series impresses with an excellent power transmission, so that the maximum clamping force can be achieved with low expenditure of energy. For particularly quick and precise alignment of the Duro-M series' lathe chucks with the machine spindle, they are equipped with a control edge. This enables the user to optimize concentricity using the dial gauge already during setup, saving time during commissioning of the machine.

Naturally, thespiral ring from Röhm is also used for the Duro-M. It is drop-forged and highly hardened and tempered. On the outside of the chuck body, the Duro-M lathe chucks have a drip edge, where the cooling water can drain off in a defined way. Another advantage for users: The steel carrier of the Duro-M is a one-piece design, which makes it very rigid and prevents chip accumulation.

The Duro-M lathe chucks have a minimal interference contour and have a high true-running accuracy already in the standard version. "We can meet specific customer requests here as required, and individually adapt the clamping assemblies such as chuck body, spiral ring and jaws to each other once again," said Bauriedl.

The new Duro-M series is particularly versatile with regard to connections and can be mounted cylindrically (from the front and rear) as well as via short tapers (from the front, via camlock or bayonet), each meeting all ISO and DIN standards. The Duro-M lathe chucks are optionally also available with double jaw guide. The Duro-M is supplied complete with either a set of inside and outside jaws or reversible jaws in addition to the base jaws. The jaws are finish ground to fit the chuck at the factory.

roehm.biz/en



IMTS 2022 Booth Previews

The gear pavilion and beyond at McCormick Place, Chicago, September 11–17

Matthew Jaster, Senior Editor

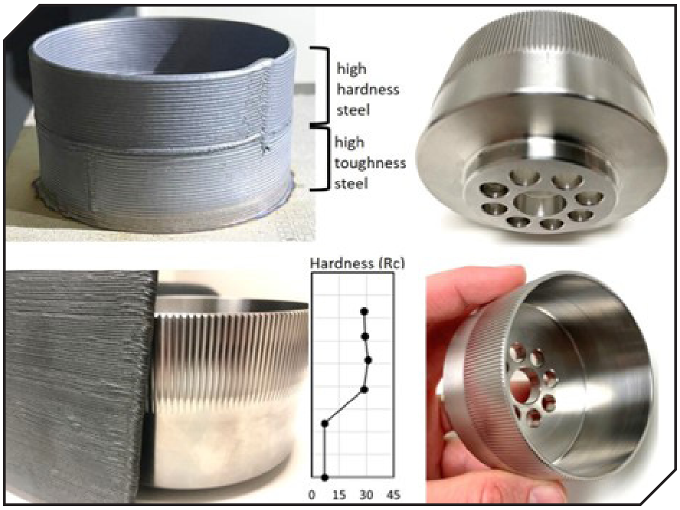
Amorphology—#237118 (North Building)

Amorphology Inc. has partnered with Additive Technologies (AddiTec). Together, Amorphology and AddiTec are developing the additive manufacturing of multimetal and functionally graded gear components for robotics.

Building on their previous collaboration of 3D printing large-scale strain wave gear flexsplines using directed energy deposition (DED), the partnership between Amorphology and AddiTec has now turned to the development of multimetal and functionally-graded gear components, combining two different steels together within a single part. Similarly, you can use other alloys such as titanium.

The three-inch diameter flexspline demonstrator is part of a zero-backlash strain wave gearbox used in robotic arms and precision-motion mechanisms. The thin-walled flexspline has competing requirements of wear resistance in the teeth and a fatigue-resistant body that motivates the use of two different materials during 3D printing. The steel in the toothed region is a precipitation hardening martensitic stainless steel typically used in high-strength applications with an average hardness of 35 Rc. In contrast, the steel below the toothed region is known for high toughness with a lower average hardness. By combining the two steels strategically in a gear, it becomes possible to tailor the mechanical properties to take advantage of the benefits of each alloy.

Through its exclusive licensing agreement, Amorphology is developing its intellectual property around multimetal 3D printing, specifically functionally graded metals, which allows for the strategic transition between more than one metal during 3D printing to produce multifunctional parts that are free from cracks and unwanted phases. The core technology, developed over a decade ago at JPL, focuses on the design of multimetal transitions to achieve predictable mechanical or physical properties in the printed part. Unlike conventional claddings or overlays, functional grading aims to achieve the best possible properties at the interface between dissimilar metals or composites in a 3D printed part, which is useful for preventing failures such as those caused by thermal mismatch or fatigue cracks. Tailoring the interface between different metals during printing can be achieved through diffusion at the interface by allowing the disparate metals to mix or by adding one or more intermediate compositions at the transition. The prototype developed in the current partnership was produced through wire-fed DED by printing the base of the gear from high-toughness steel and then sharply transitioning to the high hardness steel at the vertical location where the teeth begin, using the melt pool to diffuse the layers. The materials could have also been transitioned by mixing powders of the two materials in the powder-blown configuration of the DED printer.



"Functional grading with multiple materials allows us to develop gear components for robotics that cannot be fabricated with conventional metallurgy. The ability to tailor the properties of a gear via alloy composition gives us an entirely new design freedom when developing precision mechanisms," said Dr. Glenn Garrett, Amorphology CTO. "Whether it's improving the wear resistance of gear teeth while maintaining toughness in the rest of the part or using high-value steel in combination with low-cost steel to save cost, additive manufacturing is allowing us to innovate in the way that we approach gears for robotics. We can tailor properties for machinability, cost, hardness, strength, corrosion resistance, even density. For large gears where it makes sense to use additive manufacturing to save machining costs, this could be a real advantage."

"Meltio's dual-wire DED technology provides an ability to change from one material to another material automatically during the fabrication of metal components. This results in gradual change in properties and functions which can be tailored for enhanced performance," said Dr. Yash Bandari, business development manager at AddiTec.

The multimetal flexspline demonstrator from Amorphology and Additec is designed so that the high-performance high-hardness steel resides in the gear teeth and the rest of the cup is made from highly machinable tough steel. The as-printed hardness of the gear teeth through DED was measured to be around 30 Rc while the base of the cup measured at around 7 Rc (87 Rb). A further increase of the gear teeth hardness is possible through subsequent heat treatment. Future work will focus on different combinations of steels, and the development of localized heat-treating strategies to optimize the properties of each metal in the bimetallic gear. Amorphology is actively developing other applications for functionally graded metals in applications such as thrusters, rockets, robotics, and gears, and is seeking partners for further development and licensing.

amorphology.com

ANCA—#237406 (North Building)

The ANCA Integrated Manufacturing System (AIMS) optimizes cutting tool production through streamlined manufacturing, automation, and connectivity. With ANCA and AIMS, customers can achieve continuous, unattended production that dramatically reduces non-productive machine time, with smart automation that connects sequential tool production processes and offers connectivity across the whole factory.

This is Industry 4.0—factory-wide integration. The technology considers a factory as a single machine, rather than separating it into many different process elements. This concept brings together one ecosystem and builds it to be as efficient as possible. AIMS, being a modular solution, can be deployed in stages, allowing for easy, gradual, and smooth transition from traditional to automated and integrated manufacturing.

A fully operational manufacturing cell will be displayed at IMTS, demonstrating a fully automatic process of tool manufacturing, from blanks to ground tools. Included will be ANCA's latest premium machine MX7 ULTRA capable of

manufacturing high quality cutting tools, along with an AutoSet job preparation station, AutoLine for pallet and tool transfer as well as AutoFetch—a robot responsible for material transfer between processes—pallet and individual tools between job preparation, grinding and tool measurement on Zoller measuring machine.

Jan Irzyk, AIMS product manager said: "AIMS can be configured in many ways but at IMTS visitors can see an unattended manufacturing workflow of two varieties of endmills on one MX7 machine. An important part of this workflow is closed loop measurement and compensation process using Zoller

Genius as a measurement station. Depending on an individual customer's requirements, our system can automatically transfer a tool from the ground batch, clean it, measure required geometries and transfer the results to the respective grinder where grinding parameters compensation is taking place to achieve required dimensional tolerance of the batch."

CPX In-Process OD Measurement System

The CPX in-process OD measurement system is a quality control system that monitors and controls the OD of ground blanks within a batch production.

Batch grinding on a CPX with high material removal rates and to tight tolerances is a basic function of the machine, the OD measurement system takes it further by utilizing the Statistical Process Control (SPC) feature that comes standard with the OD measurement software. SPC is user defined, the tolerances along with the Cp and CpK values are constantly monitored, controlled, and reported to the user.

The OD measurement system is permanently mounted inside the machine and only called upon when required, based on the set tolerances and the frequency of measurement, an accurate in-process measurement and compensation is applied to maintain the blank OD to the nominal diameter.

The system is flexible with the ability to handle multiple diameters in one setup, making it perfect for complex blank geometries/shapes and longer batch runs.

GCX LINEAR

Driven by the automotive industry's electrification and the general rise of e-mobility, the demand for skiving cutters has seen 30 percent year on year growth. The GCX Linear provides a complete solution for customers to tap into this rapidly developing market, including the ability to produce skiving cutters, shaper cutters and regrinding of hobs. It offers advanced stand-alone software to design and optimize the tool, neatly interfaced with the gear tool package inside ANCA's *ToolRoom* software.

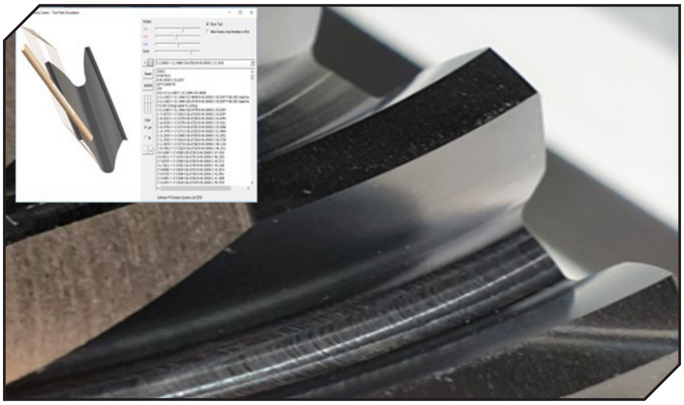
The machine is designed for accuracy with features including all axes with LinX linear motors and an enhanced headstock. GCX Linear boasts a series of technologies: AEMS dressing, MTC on grinding spindle and dresser spindle, integrated gear tool measurement and direct compensation—setting the new standard for producing skiving tools that achieve the highest DIN AA quality class.

ANCA has developed a world-first integrated gear tool measurement system, which enables all the grinding-measuring-compensation to be done in the machine. This is the only practical closed-loop solution in the market and will be on display at IMTS as part of the skiving cutter production process on GCX Linear.

anca.com

Dontyne Gears/Dontyne Systems—#237227 (North Building)

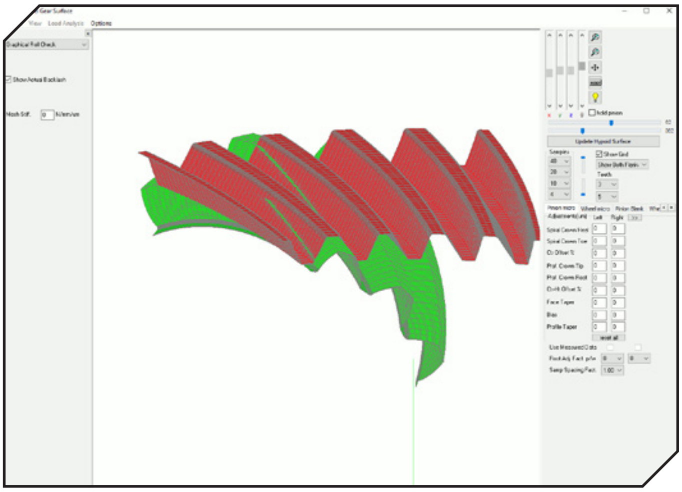
Dontyne Gears is looking forward to IMTS to promote the company's range of gear design services developed during COVID restrictions. Dontyne Gears continues to work with companies to complete design projects including CAD models and drawings if required. They recently purchased an Okuma Genos 5-axis to add to the Osaka Siemitsu high accuracy gear inspection center already in house for prototyping. As well as cylindrical gears it is possible to produce straight, spiral, and hypoid bevels. The work is facilitated by using *Gear Production Suite* (*GPS*) from Dontyne Systems to generate tool forms, G-code, and inspection protocols which can be used by the machines.



Dontyne has designed and constructed a test rig to bench test cylindrical gear system. This is specialized to the higher ratio ranges typically found in EV applications, but they've worked on custom models for some clients to test their own applications. The test rigs are now offered as a product line of Dontyne. Offering a more complete development service with at least a basic test validation from one source keeps costs and lead times down encouraging companies to enter a development program with lower risk levels.

It has been possible to complete R&D projects including production not available onsite by collaborating with companies with specialist knowledge in forging, grinding, and sintering. Dontyne has worked on the design of bevels with increased bending strength and reduced production times by making dies on 5-axis machines, grinding of non-involute gear forms, and improved performance characteristics using powder metal gears.

Dontyne has entered into a sales agreement with Renishaw Inc. to offer their own inspection solution using their Equator device called Dontyne Integrated Gear Gauging Solution (DIGGS). The hardware works with Dontyne software and support services to remove bottle necks caused by dependence



on measurements in temperature-controlled environments. Measuring cycles have been reduced to less than 30 seconds in some cases while maintaining a realistic level of accuracy for production. A simulation added to the *GPS* software can establish inspection type, time, and check for interference of the probe at the design stage prior to production. This is only for cylindrical gears at this point, but a bevel gear option is in development. Dontyne will be demonstrating this during IMTS.

Dontyne Systems will promote the latest developments of *GPS* at IMTS. In recent years, the company has concentrated strongly on linking gear design to tool design and manufacture. An important part has been to produce complex gear forms at low cost on flexible multi-axis machines. As wells as cylindrical gears, it is possible to produce straight and spiral bevels using standard end mill tools. The software has been adopted by many companies in the UK and beyond for low volume production and for R&D. A hypoid design option has been added for the current *GPS 5.7* release. Interfacing to the Equator and Sprint devices from Renishaw has enhanced the ability to create a closed loop control system at low cost compared to dedicated gear machines.

Dontyne has also improved the hob/grind simulation for *GPS 5.7* already in wider spread use worldwide, to manufacture Beveloid gear forms compatible with grinding machines such as those produce by Reishauer AG. The hob/grind functionality in *GPS* has been integrated to the Romax Technology system model software to confirm correct gear generation and define stable and safe production tolerances at the design stage. An interface exists from system model software of both Romax and Ricardo to *GPS* this to enable user to quickly and accurately export data to tool makers using Dontyne's software whether in house or outsourced. The manufacturer can quickly check and take corrective action if required. The correction can be updated in the client while still in the design stage. There are significant savings to be made in avoiding mistakes during production.

There has been significant improvement to the skiving and honing simulations. This has included validation of gear tooth profile calculated by skiving simulation in *GPS* with software used internally by Kashifuji, Japan. Good correlation was seen in various cutting conditions including expected profile changes due to tool sharpening. The *GPS* project files can be utilized by tool makers using the *Dontyne Machine Centre* module reducing production times and the risk of inaccurate data transfer. Dathan Gauge and Tool, UK has been able to produce skiving tools more quickly and accurately by adopting the software while also improving communication with their clients.

dontynesystems.com
dontynegears.com

Helios Gear Products—#236906 (North Building)

Helios Gear Products will debut two state-of-the-art gear manufacturing solutions at the International Manufacturing Technology Show in Chicago, September 12–17, 2022.

After a soft launch of the Hera series gear hobbing machines during the 2020 COVID-19 pandemic, the company is delighted to officially debut the leading Hera 90 and Hera 350

to the North American market at IMTS. The Hera CNC gear hobbing machines support micro- to coarse-pitch gear manufacturing applications with world-leading technical features such as complete Fanuc CNC and direct-drive torque motors, x-axis linear scales, easy-to-use (and train) dialog programming, and versatile unified automation systems. With globally competitive pricing, proven domestic support from the expert Helios team, and a unique combination of technical capabilities in a small footprint, the Hera machines offer both job shops and end-product gear manufacturers world-class hobbing solutions.

"Manufacturers have found the Helios Hera CNC hobbing machines to be extremely cost-effective, high-quality platforms for 21st century gear production," said David Harroun, Vice-President of Helios Gear Products. With several transformative installations across the United States, the Helios team is excited to demonstrate the capabilities of the Hera gear hobbing machines to the North American public for the first time at IMTS. Jeff Kamps, Helios customer and president at Wisconsin Gear & Machine, says, "We've cut our cycle times down from four hours to a half hour. It's really been beneficial for Wisconsin Gear. With the shortage of people, it's really made a big difference; we can still get a large volume of work done in a timely manner."

Heliosgearproducts.com

Index Corporation—#339119 (South Building)

Index has announced that IMTS 2022 will host the North American debut of the company's next generations of its G220 turn mill center, MS32-6 CNC multispindle and TNL12 sliding headstock lathe. The company will also be presenting information on the latest additions to its iX4.0 Industry 4.0 platform, as well as providing space for the demonstration of a metal 3D printer by its subsidiary One Click Metal. Index will be located in Booth 339119 in the South Building.

The new G220 incorporates and refines the design principles introduced via the larger G320, G420 and G520 machines. With twin spindles, dual tool turrets, a 5-axis milling spindle and high-capacity tool magazine, the machine can easily produce a wide variety of parts in a single setup.

The design concept of Index's G Series machines begins with a rigid, vibration damping machine bed in a mineral cast block design. Each machine in the series combines optimal stability and damping properties with high dynamics and generously dimensioned linear guides in the x and z axes.

The G220's milling spindle offers a hydrodynamically mounted y/b-axis arranged above the axis of rotation. Each of the machine's turrets provides movement along the x, y and z axes and each of the turrets' stations can be equipped with live tooling. Additionally, the G220's large workspace and internal layout enables simultaneous machining with the milling spindle and both turrets. Combined, these features allow incredible flexibility to cut varied part features and geometries with extremely high efficiency.

The new MS32-6 CNC multispindle features a modular design that achieves flexibility and fast, user-friendly setups, bringing the benefits of multispindle production to a much broader range of applications.

Accommodating up to 32 mm bar stock, the MS32-6 easily handles a wide variety of complex parts, as the machine is equipped with two v-shaped cross slides at each spindle position. Each cross slide offers x and z axes as standard, and c and y axes, together with live tools, can also be implemented to allow for a broad range of machining processes, including off-center drilling, threading, contouring, hobbing and polygonal turning. Each of the machines' slides can also be alternatively configured with a single NC axis for grooving or drilling.

Each cross slide in the MS32-6 now incorporates Index's patented W-serration locating system that provides µm-accurate alignment of the tool holder. Coupled with the company's newly developed quick clamping device, tools can be set up off of the machine and then quickly installed, reducing tool change times by 50 percent. Additionally, the machine incorporates the same W-serration system on its live units for drilling, milling and polygonal turning. By presetting tooling for these operations off of the machine, setup times can be reduced by up to 92 percent.

Furthermore, the MS32-6 allows users to apply twin turrets with rigid tools in up to five spindle positions. These hydraulically controlled units can alternate between tools in less than half a second. This enables the efficient use of separate tools for roughing and finishing in the same position. The twin turrets can also be used to reduce tool changes by incorporating

duplicate tools, an option that is especially attractive when working with difficult-to-machine materials.

Comprehensively redesigned from its previous iteration, the new TNL12 sliding headstock lathe offers an exceptional value proposition to manufacturers of small parts, especially those serving the medical industry.

Like its predecessor, the new TNL12 features four tool carriers that can be applied to a workpiece simultaneously, albeit with significant changes to the machine's kinematics.

Index will also be demonstrating the expanded capabilities of iX4.0, the company's Industry 4.0/IoT platform. A wide variety of new apps have been added to the platform, giving manufacturers the tools needed to easily monitor, gather, and analyze data on machine performance. Each Index machine includes 12 months of access to iX4.0.

Lastly, Index's booth will also feature a metal 3D printer from One Click Metal. A subsidiary of Index, One Click Metal is an additive manufacturing solutions provider dedicated to the vision of making the technology user friendly and accessible to all manufacturers.

www.index-usa.com

Kapp Niles—#237024 (North Building)

Kapp Niles will highlight a variety of machine tool technologies at IMTS 2022 for areas like mobility, automation, energy, and more.

KNG 12P Master

The machines in the master series are perfect for high-precision machining of external and internal gears as well as special profiles.

The machine concept stands for maximum workpiece quality. High thermal stability and rigidity are achieved through an optimized design and matching components. The inherently rigid machine base enables easy installation without anchoring in the hall floor. The dressing and grinding spindles are equipped with state-of-the-art direct drives.

The new functional and ergonomic machine design paired with an innovative user-friendly interface supports the user during set-up and optimization of grinding projects. High-performance technology options and application-specific alignment and measuring devices mean that maximum quality can be achieved even with batch size 1.

KNM 5X

The KNM 5X analytical measuring machine is designed for high-precision measurements of gears, gear tools and rotationally symmetric workpieces up to a diameter of 650 mm.

All guides as well as the base plate made of granite are extremely stable in the long-term and have identically low expansion coefficients. With the temperature sensors in all axes and for the workpieces, temperature fluctuations are additionally compensated. As a result, the KNM 5X remains measurable even in thermally demanding environments. Air bearings with emergency operation properties ensure perfect and wear-free guides without short-term errors. Air spring elements underneath the base plates safely shield jolts and vibrations; separate bases are not required.

Non-ferrous linear and torque motors of the rotary tables ensure ultimate position precisions and path accuracy. Despite the compact design, spacious travel ranges ensure a tangential generating motion towards the base circle for any profile. Based on the requirements, different scanning touch probe systems can be used. The control cabinet can be arranged freely.

Digital Solutions

With tool data management, outside the machine exchangeable, intelligent components with all geometric and process-relevant data can be handled and clearly displayed. All tool data are stored centrally in one place and retrieved from there.

Individual storage systems can be fully displayed within a freely configurable storage structure. Components that do not originate from Kapp Niles can also be handled in the storage system. The warehouse management system can reduce set-up times when assembling the components, which represents a further building block in the overall process chain regarding optimizing the grinding process through digitalization.

The KN extender (computer set-up for workshops that equips workbenches with digital functionalities) maps the customers' operation, labelling and management of all components outside the machine. In addition to the identification of components by RFID, optical recognition of the components is also possible. The system is designed so that components without RFID or QR code/DMC can also be managed.

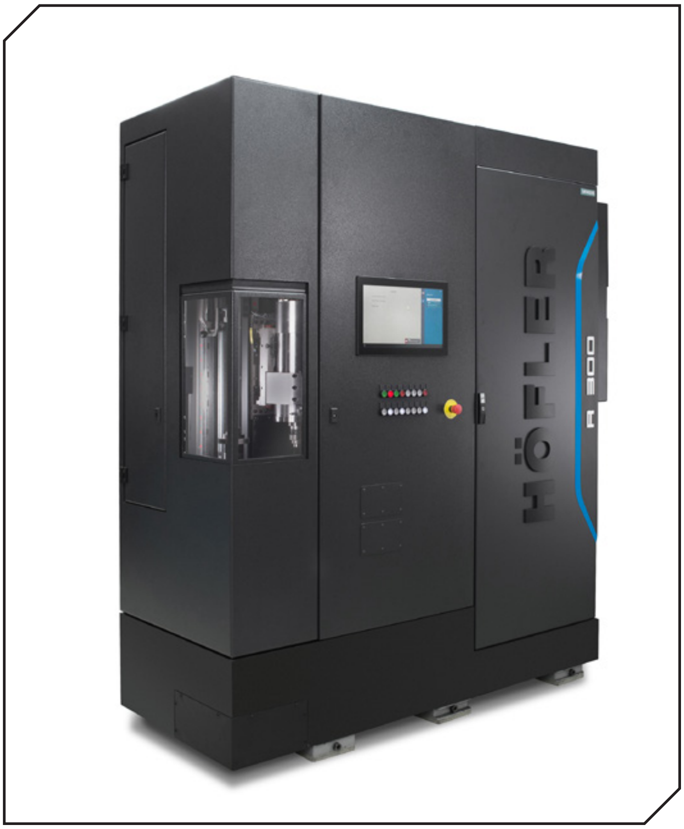
kapp-niles.com

Klingelnberg—#236935 (North Building)

R 300—The Gear Noise Finder

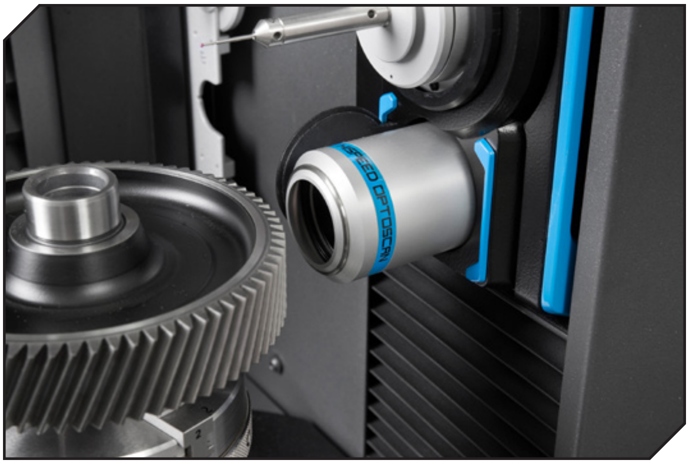
The Höfler Cylindrical Gear Roll Testing Machine R 300 is the latest machine development in the area of cylindrical gear technology. Due to the increasing quality requirements in large-scale transmission manufacturing, some transmission and vehicle manufacturers now require a certificate of quality for 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 is building on roll testing technology, a familiar method from the bevel gear industry that is now moving into the world of cylindrical gears. 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. The many quality control requirements for gears can only be met with a flexible test machine.

Depending on the configuration, the R 300 provides the



option of using all five roll testing methods. These include the single flank test, structure-borne noise and angular acceleration test, double-flank and helix roll test. Thus, the R 300 can be used at every point in the production process chain for cylindrical gears—from monitoring the soft cutting to checking the hardening distortions, to evaluating the noise behavior of the installation-ready gear.

In terms of axis traversing paths, the R 300 covers the same component spectrum as the tried-and-tested Höfler Generating Gear Grinding Machine Speed Viper. Wheel components can be tested up to an outside diameter of 300 mm. In conjunction with the optional counter support, shafts up to 800 mm long in extreme cases can be analyzed to determine their running performance and noise behavior. Yet the machine's footprint is a compact 2 m^2—saving costs on expensive production floorspace.



Reducing Measurement Times in Serial Measurement with a Hybrid Solution

Klingelnberg Hybrid Metrology is a smart combination of tactile and optical measuring technology. An optical sensor system developed specifically for gear measurement, as well as the rapid changeover between the 3D NANOSCAN tactile sensing system and the HISPEED OPTOSCAN optical sensor, enable flexible, fast, and highly precise measured value acquisition under all conditions.

With the current version of this option, pitch, tooth thickness, and gear concentricity can be measured optically on cylindrical gears, making it possible to increase the number of measurements for shop floor quality control per shift and machine by 20 percent on average. The appeal of this option grows with the number of teeth on the gear to be inspected. Approximately two minutes of quality control time can be saved per gear when it comes to gears of interest to the automotive industry. For gears used in electromobility, which frequently have a large number of teeth, this measuring time savings is even greater. And optical pitch measurement, like tactile pitch measurement, is performed in accordance with VDI/VDE 2613 Group I.

The measurement and analysis are performed using Klingelnberg's well-known cylindrical gear software. With the latest version of the software, hybrid use of tactile and optical precision measuring centers as part of a networked system is made easy. Because the optical measuring system used by Klingelnberg is highly accurate on nearly every metallic surface, approximately 90 percent of cylindrical gears in a typical portfolio are suitable for optical measurement. All Klingelnberg precision measuring centers in the P 26 to P 100 series can be optionally equipped or retrofitted with an optical solution.

klingelnberg.com

Liebherr Gear Technology—#236914 (North Building)

LGG 180/280 generating and profile grinding machine

The Liebherr LGG 180/280 stands out with its compact design, impressive accessibility, and ease of setup. Different grinding heads can be used on the machine for every specific application. Also, an internal grinding arm can be adapted very quickly and easily—and even retrofitted. This means that both external and internal gears can be machined very economically and efficiently on this machine.

The GH240CB grinding head can accommodate large grinding worms with a width of up to 200 mm, considerably increasing productivity and economic efficiency. In addition, large multiple sector grinding worms can be used, which are ideal for generating grinding, finishing grinding and polishing grinding. Collision-critical gears can be ground with very small grinding worms, thanks to the extremely rigid spindle bearing and the counter bearing. The integrated centrifugal unit removes chips and coolant from the ground workpiece, eliminating any undesired oil loss in the machine.

Digitalization solutions: Customized digitalization solutions for your requirements

With a combination of data profiles, protocols and the *LHWebPlatform*, Liebherr provides an infrastructure for the acquisition, transmission, storage, processing, provision, and display of machine, operating and production data. In the basic app *LHMachineInfo*, users can see the live status of their machine tools briefly and observe changes in real time. The *LHSignalInfo* app visualizes the recorded signals, considering all measuring points and their exact time stamp. Liebherr has expanded the range of functions of *LHWebPlatform* to include a further tool: The *LHReportInfo* app visualizes and analyzes the performance of the machine and generates reports and evaluations from the machine data—a decisive step toward more productivity.

WGT 280 and WGT 400 gear inspection devices

The four-axis measuring instruments of the WGT series have high-precision mechanics and electronics, which are controlled by smart and user-friendly software. They meet all accuracy requirements regarding gear measurement and comply with VDI guideline VDI/VDE 2613, group 1. In addition to the gear inspection machine options available as standard, customer-specific solutions are also available, such as adjusting the travel range on the z-axis, longer tailstocks to accommodate long shafts, and rotary tables adapted to the payload. An automatic sensor changing system ensures uninterrupted measurement of the workpieces and offers the highest levels of convenience for the user. The extensive software features make the machines suitable for measuring all types of gears, such as spur gears, bevel gears, worms, worm gears, shafts, gear cutting tools, and other rotation-ally symmetrical parts.

Training for gear hobbing and generating grinding

Are you looking for high-quality, individual training courses and workshops on the topics of gear hobbing and generating grinding? Would you like to specifically improve or refresh your gearing knowledge in an effective way? Liebherr Academy offers a new and modern Machine Training Center (MTC) including a gear hobbing and generating gear grinding machine for practice purposes. Sign up here: *go.liebherr.com/axd8mh*

Pallet handling systems as a productivity booster

Liebherr pallet handling systems open the door to increased productivity, even for small batches.

Pallet handling systems handle workpieces on uniform transport pallets. This makes them the ideal automation system for one-off and small batch manufacturing, facilitating unmanned shifts through to "lights-out manufacturing" and enabling unit costs to be reduced by up to 40 percent and machine running times increased to up to 90 percent. The application and combination possibilities are diverse

The rotary loading system provides compact automation for one or two machining centers. The modular PHS Allround can be expanded in one-meter increments and links up to four machines. This means that the front ends of the system can also be used, and attractive options such as front access for machine access without downtimes, or the double loader for even more productivity, are available. The PHS Pro has no upper limit and can automate any number of machines, also with integrated material management.

Bin picking solutions with *LHRobotics.Vision*: From the technology package to the turnkey robot cell

Liebherr supplies automation systems for automated raw parts input and finished parts removal in production facilities and possesses extensive system and software competence for position and object recognition with 2D and 3D camera systems.

With the *LHRobotics.Vision* technology package, Liebherr is making this industrial application expertise available to a broad range of users of robot integrations, to withdraw unsorted components from deep bins with process reliability. As a manufacturer of bin picking robot cells, Liebherr knows the challenges of the application and, with the aid of artificial intelligence has simplified the software so much that it can be intuitively used by anyone.

The technology packages consist of a 3D image recognition system and the *LHRobotics.Vision* software for object identification and selection, collision-free withdrawal of parts, and robot path planning up to the depositing point.

A special feature is the optional simulation tool *LHRobotics. Vision Sim*. This enables the user to test and optimize the processes in a completely virtual manner, without expensive hardware investment.

liebherr.com

Mahr—#135810 (East Building)

Mahr Inc., recently introduced a new generation of electronic digital comparators, the Millimess 2000 W(i) and 2001 W(i). The new digital comparators combine practical and reliable operation with maximum precision. Using a unique inductive measuring system, measurements are more precise than ever with added probe linearization—whether it's a static or dynamic measurement task.

The principle of inductive length measuring probes allow for extreme sensitivity of the measuring system thus providing resolution of 0.1 um/5u". Colored LED signals visually indicate an additional clear measured value classification (good, reject, rework or warning limit) according to stored tolerance and warning limit values.

Durable and reliable

With practical touch control panels, the new digital comparators offer maximum measuring reliability even in harsh workshop environments. A light tap on the touchscreen is sufficient to safely operate the digital comparators with most commercially available gloves. This eliminates the possibility of measurement errors by accidental adjustment or deformation of the comparator. The full-surface glass display also offers protection against liquids and dirt, which cannot penetrate the sealed housing.

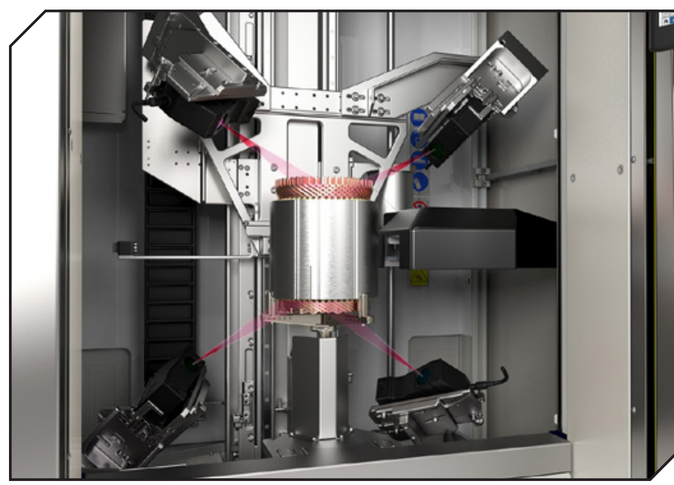
Convenient handling

The new bidirectional data connection system allows measurement data to be transmitted via integrated wireless or a data cable. In addition, Mahr digital indicators can be programmed and controlled remotely with the free *MarCom Professional* software. This offers a unique, convenient, and fast input of measurement parameters. With the integrated rechargeable battery, the digital comparators can be used completely autonomously for up to one month.

mahr.com

Marposs—#135621 (East Building)

Marposs will be demonstrating OptoCloud EDU (Electric Drive Unit), its latest generation of 3D precision inspection solutions designed for the electrical vehicle industry. Using multiple laser heads in tandem with contact sensors for measurement and vision inspection, OptoCloud EDU reconstructs the 3D model of complex and articulated workpieces in less



than a minute to ensure accuracy of the produced component. For example, it can validate 240 electrical contacts of a motor stator in only 30 seconds, which is 100 times faster than a traditional contact system.

The laser heads are integrated over a moving axis designed to position the lasers for the 3D acquisition.

To generate a point cloud of the workpiece, the part is quickly rotated 360° while the different laser heads each acquire spatial data that is then combined into a single 3D reconstruction and graphical representation made possible through the software. The system then executes the requested measurement and vision inspection tasks. Line operators can easily review images and navigate to the desired level of detail to identify any anomalies.

In addition to quality control capability, the multiple laser heads create a point cloud with such a high level of spatial resolution that the details provide a reliable dataset that can also be used for design reviews and final project validation.

Part handling is fast and easy with the OptoCloud EDU. Its design features a z-axis that allows the laser heads to automatically move out of the handling area, leaving a large space for workpiece handling and removing risk of sensor damage due to handling error. Marposs OptoCloud EDU can handle components up to 300 mm x 300 mm (12" x 12") and weights of 60 kg (132 lbs.). The system measures 1,200 mm x 1,304 mm x 2,304 mm (47" wide x 51" deep x 91" tall).

marposs.com

Nidec Machine Tool—#237036 (North Building)

Supply chain issues are driving more companies to bring manufacturing back in-house. Parallel to this trend in automotive manufacturing is the rise of electric vehicles and increasing automation. Nidec Machine Tool (Wixom, Mich.), responding to the needs of the industry, is debuting the new The GE15HS gear hobbing machine from Nidec. Emphasizing high speed, precision and efficiency, the new machine produces gears for electric and hybrid cars, as well as for robotic and automation applications.

The GE15HS model is designed for gears with a maximum diameter of 150 mm, widely used in automobiles and motorcycles. The high-speed, high-torque direct-drive motor for the main cutting spindle provides a maximum spindle speed of 6,000 min^{-1}—three times faster than previous models. The high efficiency spindle holding the workpiece uses a special table that provides high rigidity and high-speed rotation to handle the necessary thrust load for high efficiency machining. Cutting gears with Nidec super-hard cutting tools yields a surface roughness of less than Ra=0.4; on par with gear grinding.

Scott Knoy, Nidec Machine Tool America vice president of sales says, "The GE15HS provides process efficiency, eliminating the finishing process of shaving prior to heat treatment, thereby improving productivity, and reducing processing cost." A larger machine, the GE25HS, is also available.

Used in combination with Nidec Machine Tool's new materials and coatings for cutting tools, the GE15HS model provides stable mass production with a maximum cutting speed of 1,500 m/min.

More than 2,800 Nidec GE Series hobbing machines have been delivered and installed since the product launch in 2004.

The Nidec booth will also feature the ZI20A-G Generating Internal Gear Grinder. Hard finishing of internal ring gears in mass production is the final frontier for automotive and truck transmission applications. For quiet, smoothly meshing internal ring gears, the ZI20A-G utilizes patented technology for threaded wheel grinding. This breakthrough process delivers fast and very cost-effective production of internal ring gears for planetary gear sets.

nidec-machinetoolamerica.com

Star Cutter Company—#237013 (North Building)

Star Cutter Company will be displaying its newest generation automated NXT 5-axis tool grinder in Booth #237013 at IMTS 2022 featuring detailed graphics that enable visitors to take a self-guided tour of the machine, which will be shadow grinding during the show. The display system will feature the 28 kW spindle option and four-station wheel change capability. It will be equipped with a robot loader and flat blade/insert clamping fixture for live demonstration of automated production. Videos to showcase tooling for form cutters, boring bars and medical hip rasps will also be on display.

The NXT is versatile tool grinder that offers a small footprint with a large grind zone, providing the ability to run both small and large diameter wheels. Featuring a modular design, it can be easily configured to meet specific customer grinding and resharpening applications while maintaining a competitive price point.

The NXT wheel pack and coolant manifold is configurable per application with up to five stations, offering the flexibility to handle everything from high mix/low volume production through low mix/high volume applications. It also has two

spindle options—a 28 kW, 20,000 rpm Auto HSK for general manufacturing or a 15 kW, 24,000 rpm Auto HSK for manufacturing, regrinding, and high rpm applications. In addition to the automation solution, other options for process enhancement include a clearance-optimized flip-up, air-actuated tailstock and other various workholding solutions.

With the NXT, preventative maintenance is improved through real-time tracking of temperatures, spindle hours and bearing travel distances. Key to the system's functionality is the control software, featuring the latest Flexium Tools with *NUMROTO 4.3.0*, as well as an *ESPRIT CAD/CAM* for free-form grinding with 3D simulation and special capability for medical components.

The NXT 5-axis Tool Grinder has a 6.5' W by 7.5' L footprint with a 30.2" x 19.9" x 25.6" (LWH) grinding zone and ability to run tools up to 10" (250 mm) in diameter. It offers FANUC robotic automation with 0.196"–1.250" (5–32 mm) gripper assembly.

starcutter.com

United Grinding—#236802 (North Building)

At IMTS 2022, United Grinding North America will be featuring the STUDER S131r cylindrical ID-radius grinding machine for I.D. grinding operations where maximum precision is paramount.

The STUDER S131r excels in general grinding applications and the production of complex workpieces made from extremely hard materials, along with hydraulic components such as axial pump pistons, guide plates and housings from hardened steel, cast iron and copper. The machine also handles single-clamping production of complex workpieces with tapers between 20˚ and 90˚.

The machine's fully automatic, completely sealed, simultaneously swiveling direct-drive b-axis offers superior thermal stability, mechanical rigidity and interpolation from -60˚ to +91˚, while the workhead c-axis enables form and thread grinding. High-precision axis drives with linear motors add speed and accuracy, and a -50˚ to +280˚ swiveling spindle turret with up to four grinding spindles enhances grinding flexibility. Temperature-stabilized components maintain precision while a Granitan S103 mineral casting machine bed provides thorough vibration damping.

With a swing diameter of 300 mm (11.81") above the table, 350 mm (13.78") x-axis/cross slide travel and 400 mm (15.75") z-axis/longitudinal slide travel, the S131r can machine external diameters up to 160 mm (6.3") with an external grinding wheel 250 mm (9.84") in diameter. The S131r accommodates parts up to 300 mm (11.81") long and up to 100 kg (220 lbs.), including clamping devices.

StuderSIM software enables operators to machine complex parts, often in a single clamping. *StuderSIM* derives workpiece geometry from a drawing, completely defining and generating all the data required for grinding cycles. Furthermore, operators can simulate grinding to easily check and visualize the processes on a PC or on the machine itself.

The S131r also features high-precision axis drives with linear motors, a Granitan machine bed for high levels of damping, thermal stability, and guidance accuracy, and the StuderGuide guideway and linear drive system for high wear resistance and long working life.

grinding.com

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Innovative Workholding Solutions for Gearing Technology at IMTS 2022

Clamping systems save time and stabilize manufacturability

Aaron Fagan, Senior Editor

Gleason hydraulic workholding system.

Gleason gear pitch-line fixture.

Workholding solutions increase throughput which generates uptime because they greatly reduce setup and changeover times. Operators can change workpieces in a highly repeatable manner which significantly increases the quality of the finished part. The primary function of streamlining production is to develop a workholding solution that optimizes the machining of multiple parts at once while maintaining tight tolerances. Below you will find a cross-section of companies that will be showcasing their approach to workholding systems at IMTS from Sept. 12–17 at McCormick Place in Chicago.

Gleason Corporation—#236909 (North Building)

Gleason Hydraulic Workholding Systems

Gleason Hydraulic Workholding Systems are an attractive alternative to traditional mechanical systems, offering benefits for many bore and shank clamping applications. With different expansion zones hydraulic workholding systems easily accommodate to multiple gear stacking and different bore diameters. They deliver a powerful and consistent clamping force with uniform expansion over the complete chucking length, making them an ideal solution for clamping thin-walled parts. Gleason Hydraulic Workholding Systems work in a completely enclosed system, impervious to contamination limiting maintenance downtime when compared to exposed mechanical systems. Depending on the application Gleason Hydraulic Workholding Systems deliver accuracy and repeatability of up to of 1.3 microns (0.00005") TIR or even better. Gleason Hydraulic Workholding Systems are available for standard machining, gear manufacturing like hobbing or skiving, and tool sharpening work.

Gleason Gear Pitch Line Fixtures

Gleason Pitch Line Fixtures are a great way to improve final accuracy between gear datums and gear pitch. Undesirable runout results from the heat treatment of gear and other manufacturing processes which may cause distortions. Pitch line fixtures can be used in applications such as hard turning, grinding and inspection. Depending on the application Gleason offers Pitch Line Fixtures with gear member accuracy of up to 5 microns (0.0002") relative to the bearing journals or bores.

Gleason Quick-Flex Plus modular quick-change workholding system.

Hainbuch Maxxos T211 mandrel.

Gleason also offers hydraulic quick-change solutions for part-to-part quick changeovers.

Quik-Flex Plus—Modular Quick-Change Workholding

Now accommodating a changeover for different workpieces can be done with a new module that's installed and removed in just seconds, with only a single tool, and by even a novice. Quik-Flex Plus is so simple and effective that even non-operator contestants in Gleason's tradeshow demonstration challenges have routinely removed and installed Quik-Flex in under 10 seconds. For gear manufacturers running small and medium batch lots throughout the day, this can mean a savings of an hour or more in spindle time. The ease of changeover when utilizing Quik-Flex Plus can greatly support less skilled machine operators and toolmakers, which are becoming harder to find.

gleason.com

Hainbuch America—#431636 (West Building)

The Hainbuch Maxxos T211 is a mandrel with hexagonal geometry for added process reliability and maximum cutting performance.

Hainbuch Maxxos T211 is a mandrel with a hexagonal pyramid shape instead of a round taper, designed with stringent manufacturing requirements and process reliability in mind. Hainbuch has acted in response to demand from specific areas that have been growing year by year. Users are requesting mandrels that deliver higher performance as well as process reliability. The result is called Maxxos. The segmented clamping bushing with hexagon inside shape fits perfectly onto the clamping pyramid and enables maximum cutting performance. The lubrication, combined with its tightness ensures a very constant production flow and as a result, achieves maximum reliability. Customers who value process reliability and maximum torque transmission will be delighted with the Maxxos T211.

Thanks to the hexagonal pyramid clamp, maximum torque transmission can be achieved. Up to 155 percent more transmissible torque and up to 57 percent higher bending stiffness compared to the classic Mando T211 mandrel. This makes it possible to achieve higher process parameters and consequently improve the yield of finished parts. Greater process reliability is facilitated by the spacious layout between the clamping bushing and the clamping pyramid. Even during the clamping process, this design prevents virtually any dirt from getting onto the surfaces. This significantly cuts down the frequency of maintenance times for cleaning and lubrication. Overall, the mandrel has a clamping diameter range of 18 to 100 mm. The clamping areas of each size are designed to overlap. This has the advantage that users can choose from up to three mandrel sizes depending on the clamping diameter. The larger the mandrel is, the greater its stability and rigidity. Smaller mandrels may be able to handle more of the customers' smaller workpieces. The aligned, segmented clamping bushings have a minimum concentricity of 0.01 mm and can even be supplied in a high-precision version.

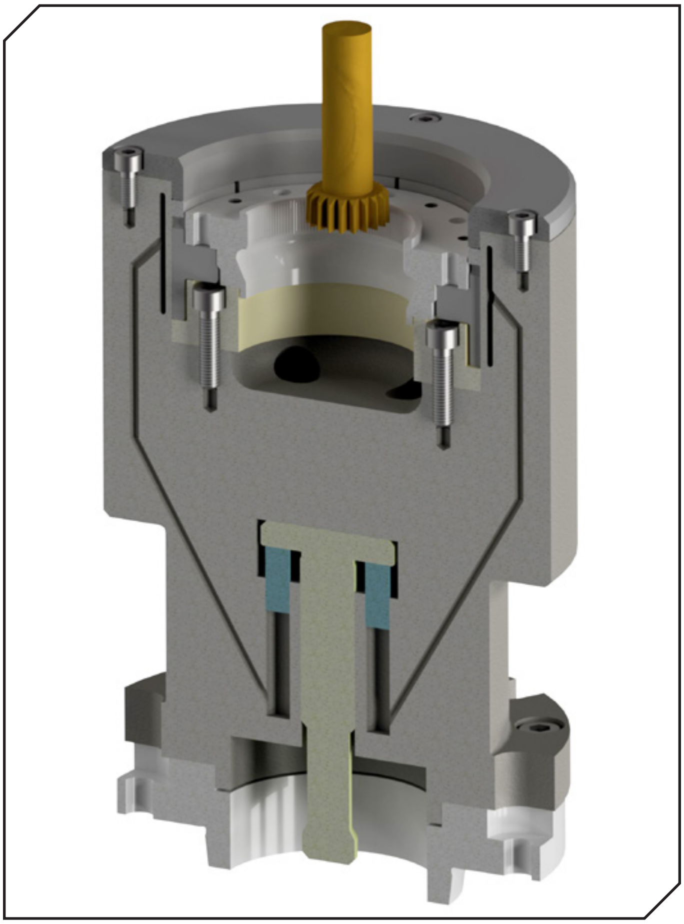
Key advantages:

- I.D. clamping mandrel for clamping diameters of 18 to 100 mm
- Ideal for stringent manufacturing demands and process reliability
- Unique rigidity due to spacious layout of the clamping segments
- High transmissible torque and holding forces
- Contamination resistant due to hexagonal pyramid shape
- Concentricity < 0.01 mm also available in high precision version

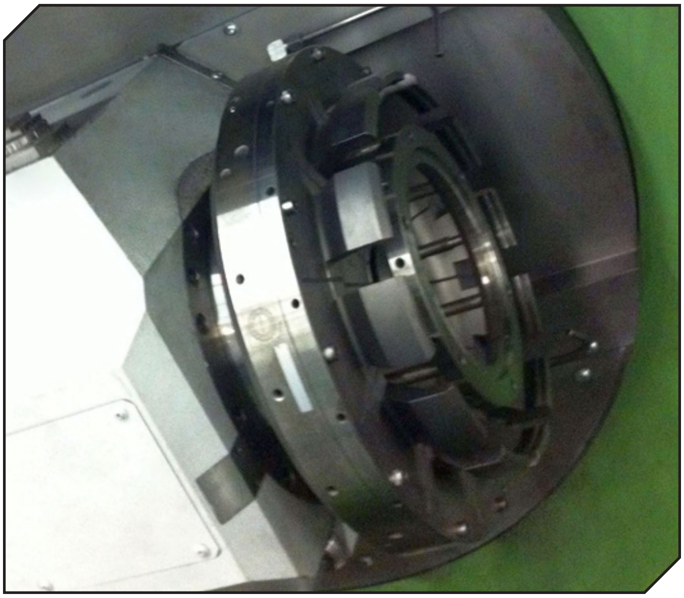
hainbuchamerica.com

Euro-Tech Corporation—#432272 (West Building)

Skiving has been around for a long time, but recent advances in technology have improved the speed and effectiveness of this gear-making process making it a more viable manufacturing option for gear producers. It has long been recognized that skiving would be a much more productive process than shaping for cutting many internal gears. Mytec Hydraclamp clamping tools are robust and rigid enough to minimize vibrations caused by the high spindle rpms and significant cutting forces generated by the new gear-skiving process.



Mytec Hydraclamp clamping tool for gear skiving.



Ringspann clamping fixture for gear skiving.

Today's demands also include clamping very thin parts for the robotic gearboxes (flex spline gearbox). Mytec Hydraclamp clamping tools are designed to clamp components the entire length of the clamping area. If the component is irregularly shaped, we clamp around it to achieve the highest accuracy. View the graphic as an example of a clamping situation with such a component used in the robotic gearbox. Note the external shape is irregular and the clamping area is very short. We designed a hydraulic chuck in combination with a changeable backstop and slotted collet. This gives the customer options to clamp different diameters and components with one hydraulic chuck. This hydraulic chuck is used to machine the spline in the "Gear Shaping" process on a Liebherr machine.

Mytec Hydraclamp continues to work closely with different machine producers to develop the perfect clamping solutions providing the highest runout accuracy, successive repeatability, and high clamping force applications. Euro-Tech Corporation is the exclusive North American distributor of the Mytec Hydraclamp product line.

eurotechcorp.com

Ringspann—#431968 (West Building)

Precision clamping fixtures for the complete machining of thin-walled lightweight components and high-precision internal clamping systems for use in gearing technology—just one reason why Ringspann has recently consolidated its position as an OEM supplier for machine tool manufacturers. Now the German company is surprising the industry with another innovation: high-performance diaphragm and taper sleeve clamping systems that are specially tailored to the requirements of the currently very popular power skiving process to produce high-precision external and internal gears.

As an alternative to gear hobbing, gear shaping, and broaching, skiving is enjoying renewed interest in the domain of gearing technology. Increasing quality and productivity demands in gear manufacturing are reviving the interest of machine tool manufacturers and e-drive producers in the manufacturing principle developed more than 100 years ago. Why? The process not only meets high standards of precision and accuracy but is also proving to be an extremely economical method for the cutting soft and hard machining of internal and external gears in the face of growing demands for batch size flexibility in series production. In addition, innovative leaps in control technology, high-performance machining and machine statics are fueling the entry of skiving into the production processes of gear manufacturers and gear suppliers. While other gearing processes must be used on special machines, power skiving can be used within the scope of complete machining in modern 5-axis centers. Accuracy losses due to multiple clamping can be reduced, as well as machining and set-up times.

Deformation-free Clamping

However, the many advantages of skiving can only be fully realized in the practice of gearing technology if suitable clamping systems are used on the machines. This is because gear skiving is characterized by a precisely positioned skew between the driven workpiece and tool axes (axis intersection angle) and the synchronization of both speeds. The adjustment of the tool with a defined axial feed and the speed coupling of the workpiece and tool results in a relative movement with which the free space between the teeth is peeled into the material. In order for this to take place disturbance-free and with very short machining times (up to 50 percent faster than with gear hobbing), the clamping systems used here must be balanced for high speeds and guarantee problem-free chip removal. The diaphragm and taper sleeve clamping systems from Ringspann, which have been further developed for skiving, are precisely tailored to these requirements. They are particularly predestined for the internal gear cutting of thin-walled workpieces that must not deform under circumstances during machining—for example, weight-optimized toothed rings for planetary gears. In this application, for example, they replace conventional jaw chucks.

Open for Safe Chip Removal

"Both versions of Ringspann's skiving clamping systems are based on fundamental functional principles that have proven themselves in gearing technology over a number of years," says Joe Thompson, North American product manager of Workholding Solutions. Typical of their design is a relatively open construction, which enables rapid chip removal. Characteristic of the diaphragm clamping systems are a short overall length and a very uniform application of the clamping forces on the workpiece. They also offer the possibility of clamping on the shortest clamping surfaces. The key features of the taper sleeve clamping systems, on the other hand, are the large clamping depth and an impressive degree of rigidity. In both cases, the frictional connection is made via workpiece encompassing clamping elements, which can be quickly and easily exchanged during changeover. Ringspann supplies both versions ready for use, balanced and, if required, with air system control.

Added Benefit in the Process

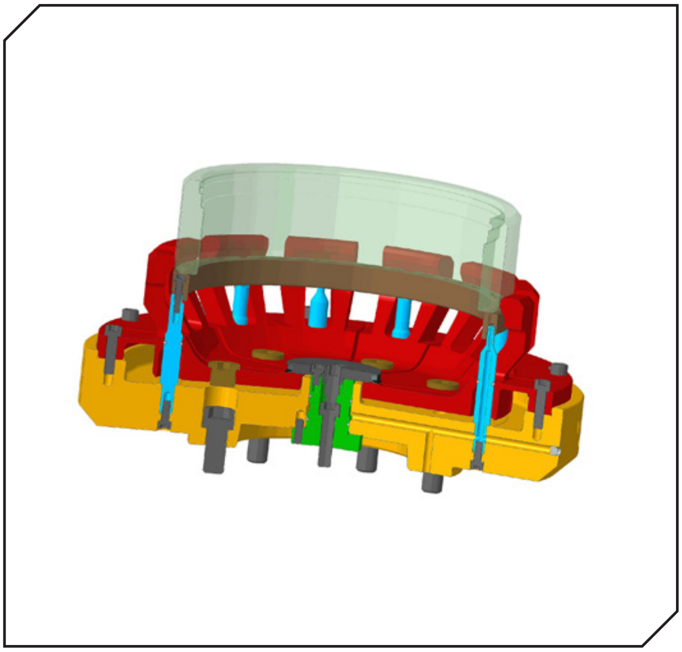
The e-mobility boom in particular is causing a significant rise in demand for planetary gears. This is currently leading to growing interest in internal gears that can be manufactured very efficiently via skiving. The use of Ringspann's diaphragm and taper sleeve clamping systems can help both gear suppliers and gear manufacturers to fully exploit the productivity and flexibility benefits of this process. Machine tool manufacturers, on the other hand, who offer skiving as part of complete multiaxis machining, can offer their customers Ringspann clamping systems as an added benefit within the scope of process integration.

Ringspann's skiving clamping systems at a glance

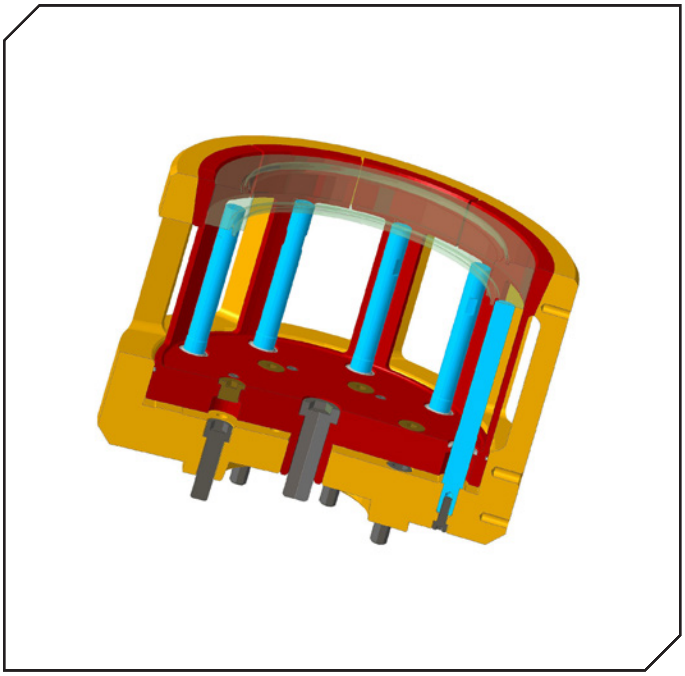
Diaphragm clamping system for internal gears:
- Lightweight construction
- Power or manual operation
- Clamping with draw-down effect
- Air system control in contact bolt or backstop ring
- Open design optimizes chip removal

Taper sleeve clamping system for internal gears:
- Power operation
- Clamping with draw-down effect
- Air system control in contact bolt or bearing ring
- Open design optimizes chip removals

ringspanncorp.com



Ringspann diaphragm clamping system.



Ringspann sleeve clamping system.

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Next Level IIoT

Cost-Effective Solutions to Bring Your Factory Floor into the Future

Matthew Jaster, Senior Editor

Training and employee development can seem daunting to manufacturers still playing catch-up post-COVID and trying to move product out the door. Management wants to implement new IIoT and smart manufacturing strategies to increase manufacturing productivity, but a lack of time, money and available resources can complicate these goals.

"You can collect all this data, but what are you really doing with it? How can this data help you better understand your processes? Companies are going to be looking for information like this. How can robotics and automation help? What can artificial intelligence do for me?" said Jeff Burnstein, president of the Association for Advancing Automation (A3). "Smart manufacturing/IIoT solutions are certainly of interest to small or medium-sized companies moving forward."

In 2022, manufacturers are looking for shortcuts to develop cost-effective IIoT solutions. Companies like Siemens, CC-Link, KUKA, and Yasakawa are supplying robotics, automation, controls and data collection in order to improve areas like shipping, material handling, machining cells, lights-out manufacturing and applications like hobbing, grinding and skiving.

Siemens Integrates Automation/ Robotics with Digital-Native CNC

With Sinumerik One, the first digital native CNC for machine tools, Siemens works with software to create the machine controller and the associated digital twin from one engineering system seamlessly. The latest iteration of the CNC system was on display recently at Automate 2022 where machine tool builders and CNC users were able to see the product, production, and performance benefits on the show floor.

"Sinumerik One can be used for a variety of machining applications including milling, grinding and gear hobbing," said Russell Rumschlag, senior applications engineer at Siemens Industry, Inc. "Here at the Automate Show, we're displaying its capabilities as a robot control."

In the factory of the future, robots and machine tools will work closely together on workpiece handling, set-up, rework, and parallel machining. *Sinumerik Run MyRobot* makes it easier to integrate one or more robots into Sinumerik-controlled machine tools. For high-end and premium controls, this includes complete system integration of the robot kinematics into the CNC system—including drives, motion control, safety technology, maintenance, and commissioning functions—up to PC-supported simulation and optimization with digital twin. But *Run MyRobot* also offers the option of integrating robots into mid-range CNC systems.

"There are different packages available for *Run MyRobot*, including a handling package, a machining package, or we simply take our motors and drives and connect them to a robotic arm," Rumschlag said. "Since it's a CNC-based control system and not a robot-based system, you can take advantage of the tool management, for example. There's a significant difference between the processing power of a CNC versus the power of a robotic control."

According to Rumschlag, *Run MyRobot* allows a machine operator to seamlessly utilize a robot in a manufacturing cell without additional training or certification. "If the operator is familiar with G-Code, he or she can run these programs. It offers a much more versatile robotic work envelope versus a standard machine tool," he added. "This is particularly useful for 3D-printing/additive manufacturing applications."

Using *Create MyVirtual Machine*, machine tool builders can virtually map their entire development processes—significantly reducing the product development phase and time-to-market for new machines. The virtual preparation of machine commissioning can also reduce the duration of actual commissioning considerably. Machine users can also benefit from a "digital first" strategy for their central processes during production when they use Run MyVirtual Machine.

Programming, production planning and process optimization can be simulated instead of performing them directly at the machine and non-productive times are eliminated. Even training can be conducted using the digital twin instead of training on the actual machine, Rumschlag said.

At its core, mechatronics brings together software and hardware solutions to create a more intuitive and user-friendly experience. Sinumerik One perfectly fits into the Totally Integrated Automation (TIA) Portal and makes a highly efficient engineering framework available for machine tool builders. With additional integrated features, the control system supports safety standards, cybersecurity protocols and other engineering concepts.

new.siemens.com/global/en/products/automation/systems/cnc-sinumerik/automation-systems/sinumerik-one.html

Time Sensitive Networking with CC-Link

The convergence of real-time control streams used in automotive and industrial applications involves a set of standards known as Time Sensitive Networking (TSN).

Siemens My Virtual Machine for Machine Builders **allows users the opportunity to deploy a "digital first" strategy.**

"When it comes to discussions around connected industries, several buzzwords are generally included, making it seem like an endless number of high-tech devices are required to make factories smart. However, at the core of most digital transformation journeys lies an open high-speed industrial network architecture. In effect, future-oriented operations need a suitable data flow to connect various parts and players within an enterprise to generate data-driven, actionable insights and offer advanced control," said Mariana Alvarado, marketing specialist at CC-Link Partner Association.

CC-Link is an open-technology fieldbus network supplying absolute deterministic behavior and cost effectiveness, flexibility, and ease of use. Using CC-Link IE TSN technology for Ethernet bandwidth has made it possible to build flexible IIoT systems.

"Having every single asset communicating with the enterprise is the goal, at least in theory. However, in practice this may not seem feasible, because of the time and cost involved as well as company specific cybersecurity protocol," Alvarado said. "In most cases, it is advisable to 'start small', focusing on enhancing the connectivity of a machine or process that can deliver a quick return on investment (ROI)."

An example could be supplying remote access to a machine on the shop floor, enabling operators to check or control different elements. For example, cameras and other internal sensors, not just the controller, can be installed and connected to receive notifications in case of anomalies as well as interact with assets to maximize uptime, productivity, and efficiency. Once this project is successfully completed, then it is possible to move on to the next area, identifying where more value could be added to a process.

This approach is therefore ideal for small to medium enterprises, as it offers a sustainable pathway to drive continuous improvement and competitiveness in a fast-paced marketplace. When implementing a stepwise strategy, it is fundamental to select suitable solutions that support it by offering the level of flexibility and scalability required. More precisely, specifying a network technology for future machines that can support interoperability and interconnectivity on small and large scale is key.

"TSN is highly recommended when embarking on a digital transformation journey and modernizing the architecture of your machines. By doing so, companies can make sure they will be able to support both information technology (IT) and operational technology (OT) communications on the same network while delivering reliable, unmatched performance in data sharing. This means that they will be able to smoothly integrate any asset they want at any stage of their digitalization," Alvarado said.

This solution is a future-oriented platform for industrial communications that can help companies create Connected Factories. As an open technology, it offers maximum compatibility and interoperability, so that devices, machines, or lines can be connected to each other, regardless of their vendor. This capability further optimizes flexibility and costs for small to medium businesses.

By specifying CC-Link IE TSN to futureproof operations, companies can make sure they are using the most suitable backbone to support any application related to the connected industries, such as remote control, IIoT, and digital twins.

"In effect, they can benefit from a considerable leap forward in realizing smart operations where data-driven insights are used to improve productivity, efficiency, flexibility, and responsiveness. Even more, businesses can do this in a stepwise approach making targeted investments in terms of cost, time and resources while considerably enhancing their competitiveness," Alvarado added.

cc-link.org

Robotic Simulation in Minutes with KUKA

KUKA's advanced automation planning software, *KUKA.Sim* allows manufacturers to accurately plan their automation solutions before the system has even been put into operation. Robot motion sequences are programmed offline, depicted in real time, analyzed, and perfected to ensure that processes and work cell layouts can be implemented as planned.

KUKA.Sim creates a digital twin and identical image of the proposed production process that becomes the basis for virtual commissioning of production lines. The offline commissioning capability saves time, improves planning reliability and verification, and increases sales. KUKA's simulation of a robot system with *KUKA.Sim* is conducted in just a few minutes without deep programming knowledge.

KUKA.Sim is based on a modular software architecture—with an efficient, flexible and durable toolbox principle. The basic package can be expanded with three add-ons: for powerful modeling of an individual component library, for virtual commissioning and for simulation of welding applications. This means customers only pay for the functional expansions they need. If their requirements change, users can easily add further add-ons in the future. The modular system stands out for its flexibility and durability.

VR hardware can offer a virtual demonstration of your system concepts and machining cells. These simulation results can be viewed on a mobile device—smartphone or tablet—through an app.

Additionally, KUKA has been actively promoting its intelligent machines and IIoT strategies at recent trade shows.

KUKA recognized the potential of networked and open automation systems back in the 1990s. Engineers believe that no robot today has any future unless it is capable of being

KUKA insists that robots must be integrated into complex production systems on standardized technologies.

integrated into complex, networked production systems based on standardized mainstream technologies.

Intelligent robots—in a variety of forms and configurations—are leading this evolution. They will not only be tethered within cells as we knew them in the past, but provided with new intelligence, apps that are simple to integrate and give them new capabilities at a click, or cloud-based functions that turn them into active players in the flexible, autonomously operating smart factory.

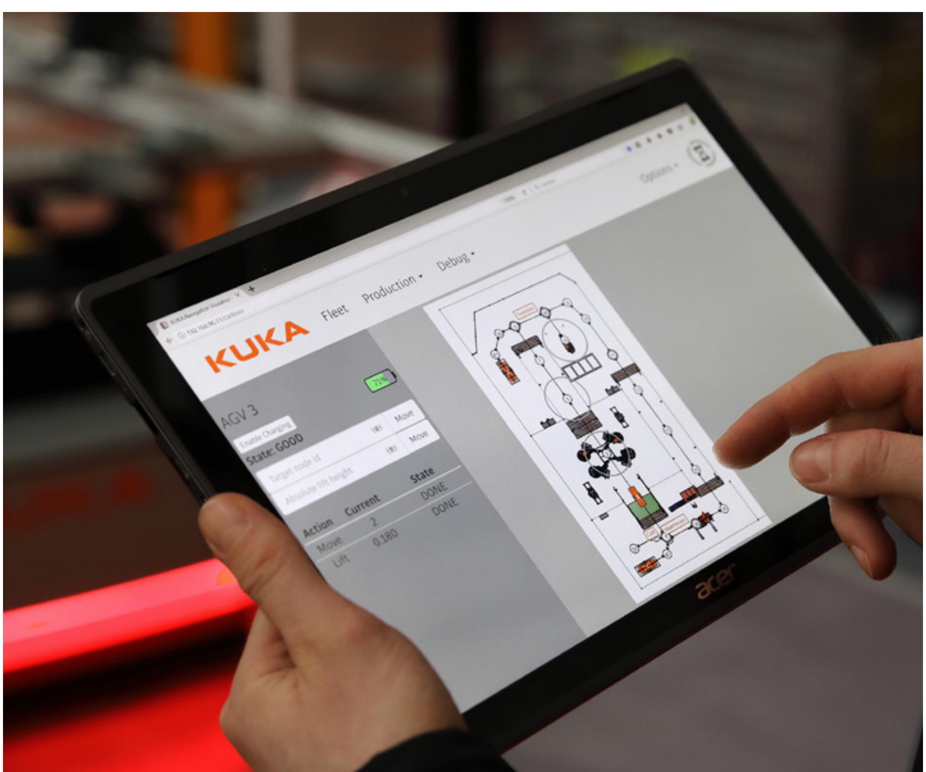
Machines must accomplish three things: they must carry out their task as efficiently as possible, be able to adapt to new framework conditions, and be capable of sharing this knowledge with processes and systems in an intelligent way.

kuka.com

Upgrading Robotic and Automation Performance with Yasakawa

Featuring multiple improvements and optimization, Yaskawa's *Smart Pendant v2.1* software extends capability for quick robotic implementation of basic assembly, injection molding, inspection, machine tending, material handling, and pick and place tasks.

Enabling previously unsupported functions, *Smart Pendant v2.1* provides a built-in classic interface view. Ideal for more experienced robot operators, this option enables the end user to reset minor and major



Programming a robotic system today can be conducted in minutes without prior programming knowledge thanks to IIoT solutions.

alarms or to edit concurrent I/O with reduced programming downtime.

Expanding on the performance improvements and extension app capabilities introduced previously, *Smart Pendant v2.1* improves configuration and programming of third-party devices, including Yaskawa's *Smart Packager* software development kit (SDK). This desktop tool enables third parties to combine multiple components into a single convenient file. Each file, known as a Yaskawa installation package (YIP), enables easier robot setup by automating processes typically outlined in a manual.

Various advances, such as YRC1000 controller software updates, multi-touch jogging, 3D viewer optimizations, basic concurrent job support, improved HC-series configuration and other INFORM usability improvements are also included.

Smart Pendant is available for use with select Yaskawa Motoman YRC-controlled robots. *Soft Pendant* software—a digital version of the YRC1000 pendant that can run on a Windows operating system—is also included.

Expanding *Smart Pendant* capability for handling tasks, the easy-to-use *Smart Pattern* extension enables quick development of jobs for repetitive handling tasks. Ideal for common tasks like stacking, unstacking, case packing, machine loading and unloading, this intuitive interface supplies guided prompts for single part, grid (2D array), 3D grid (3D array) and stack patterns.

Prompts are supplied to create two types of jobs. Pattern jobs define a specific pattern and robot movement for managing each part in the pattern. Supervisor jobs define which patterns should be used to pick and place parts, as well as the overall flow of the system, including basic I/O signals.

Easily customizable, job editing is available to accommodate specific system requirements. A wide variety of grippers and end-of-arm tooling can be used.

Compatible with the YRC1000 and YRC1000micro controllers, *Smart Pattern* is available as a complimentary download for use with HC-series and GP-series robots.

Classic view of *Smart Pendant* from Yaskawa (above).

***Smart Pattern* from Yaskawa enables the quick development of jobs for repetitive handling tasks.**

This technology can increase production and efficiency for shops in areas like arc welding, assembly, machine tending, machining, material removal, packaging, part transfer and more.

motoman.com

Just Scratching the Surface

As IIoT solutions increase in the industrial sector, manufacturers—through the cloud, A.I., augmented reality and other technologies—will have easier access to machine data in real-time. This can lead to more automated processes as well as an overall improvement in productivity. As these systems and suppliers continue to share data—a facility where products, systems, machines, and management harness advanced analytics can accelerate innovation. This is the common thread throughout IIoT implementation. These development tools and training will become more readily available to allow management to find faster, more efficient manufacturing solutions in the future.

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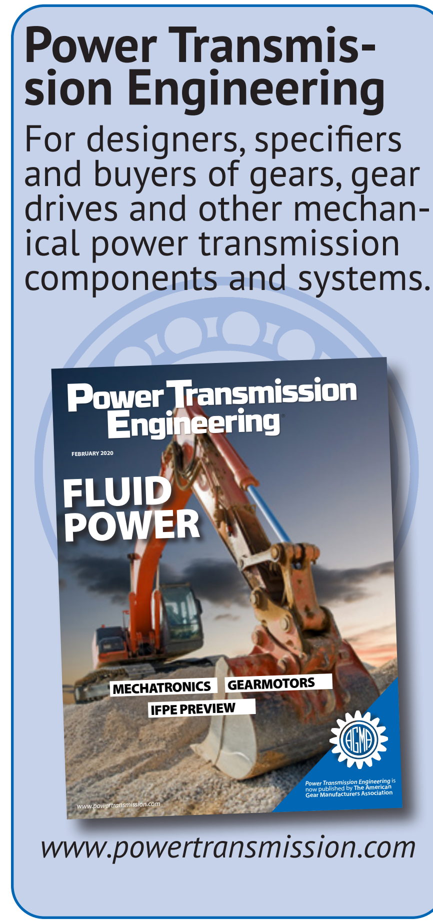
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First Gear: The Roots of the Fall Technical Meeting

Phillip Olson, Director, AGMA Technical Services

How did you first learn about gearing? If you're like most people I've talked to, your initial exposure was likely a chapter or two in a survey college course.

Now that you're in the gear industry, how do you stay up to date with the latest gear research? Reading *Gear Technology*, of course, is a good answer to this question, but you may further answer that you hunt down the rare gear paper presented in journals and conferences that cover a much broader scope of engineering topics than just gearing alone.

The premise of the AGMA, since its founding in 1916, has been to serve the gear industry. The tradition of informing the industry of the latest technology goes all the way back to when the first AGMA technical papers were presented at the inaugural AGMA Annual Meeting in 1917. The very notions of standards themselves were the topic of the day back then, with papers such as "Job Gearing—To What Extent Can It Be Standardized," presented by Frank Burgess of Boston Gear. It is fascinating to look at the history of gear standards and see how often the cutting-edge research of the day, presented at AGMA meetings, made its way into the standard industry practice of the future.

"The tradition of informing the industry of the latest technology goes all the way back to when the first AGMA technical papers were presented at the inaugural AGMA Annual Meeting in 1917."

AGMA meetings have attracted, and continue to attract, gear luminaries, such as Earle Buckingham with his first AGMA publication, "Wear on Gear Teeth," presented at the 10th AGMA Annual Meeting in 1926. Even to this day, his books *Manual of Gear Design* and *Analytical Mechanics of Gears* are mainstays on the gear engineer's desk. Darle Dudley, author of another famous gear textbook, *Dudley's Gear Handbook,* was also a frequent AGMA presenter, with his first paper "Cutting and Hobbing Worms and Gears" presented at the 26th Semi-Annual Meeting in 1943. And as a testament to the international appeal of AGMA, three out of the four authors of the widely used German gear textbook, *Maschinenelemente 1*, have presented papers for AGMA.

Over the years, the AGMA event that had attracted the most technical-minded folks was the AGMA Semi-Annual Meeting. To better signify the scope of the meeting, it was renamed the AGMA Fall Technical Meeting (FTM) in 1979—a name and tradition that has continued to this day. In 1986, the FTM launched the first AGMA Gear Expo with 22 exhibitors. The tradeshow quickly grew to be the premier event to physically see the latest products in power transmission manufacturing, and now boasts on average 150 exhibitors at the renamed, biannual, Motion + Power Technology Expo trade show.

Today, the FTM continues to be the best venue to get all the latest information on gear research in one place. You can self-select as a technology leader and carry on the tradition by joining us from Monday, October 17th to Wednesday, October 19th in Chicago for the 2022 FTM. Registration and lineup of the 26 planned presentations are available on the AGMA website.

We hope to see you in October!

agma.org/events/fall-technical-meeting-ftm

Nomenclature of Micropitting

Robert Errichello

Introduction

To understand a complicated subject, one needs to have a consistent and coherent system of nomenclature. It is the key to understanding the morphology and mechanism of micropitting. Unfortunately, it is typical for researchers to invent ambiguous terms for phenomena that are not well understood. It seems that the less we know about a failure mode, the more names we ascribe to it. This shortcoming is especially true for the complex phenomenon of micropitting.

Nomenclature

Tallian (Ref. 1) coined the phrase "surface distress," which he later (Ref. 2) explained included micropitting. Tallian (Ref. 1) stated that the first sign of surface distress is a "burnished" appearance that is characterized by a "high gloss" of the metal and partial or total obliteration of the original finishing marks. He went on to say, "It is now believed that this appearance arises from plastic deformation of the asperities" and continued: "In a more advanced stage of this failure, small pits form on the burnished surface, which are at times aligned along ridges of the original asperities."

In a later document (Ref. 2), Tallian introduced the term "glazing" when he stated that: "surface distress is attributed to asperity interactions causing plastic deformation (glazing) with subsequent microcracking and micropitting."

In his Failure Atlas (Ref. 3), Tallian defined the early plastic flow stage of surface distress as glazing, and the later stage as micropitting. He describes a glazed surface as showing smoothing of asperity ridges into almost featureless flat areas (with valleys still discernible), possibly with some incidental wear marks or dents. In contrast, he states that under SEM magnification, microcracks opening to the surface may be visible in the glazed areas and describes a micropitted surface as appearing "frosted" to the unaided eye, possibly with barely visible black spots representing the micropits.

Incubation

Tallian's early stage of surface distress is now confirmed to be the incubation stage for micropitting. In addition to Hertzian stress due to normal loading, sliding between gear teeth causes tractional forces that subject asperities to shear stresses. The first 10^4 to 10^6 cycles of stress occurring during run-in are an incubation period (Refs. 1, 12, 13) during which damage consists primarily of plastic deformation at asperities (Refs. 1–14). Spikes, Olver, and Macpherson (Ref. 12) give an excellent dissertation on the mechanism of the plastic deformation that occurs during the incubation period. Macroscopically, surfaces appear glazed or glossy (Ref. 12). Microscopically, surface asperities appear plastically deformed and original-machining marks might be partially or totally obliterated. Cyclic Hertzian and shear stresses accumulate plastic deformation on asperities and at shallow depths below asperities. The length of the incubation period depends on the relative hardness of the specimen and the mating components. Plastic flow produces tensile residual stresses (Refs. 10, 15) that increase the cyclic range of stresses that asperities are subjected to. With sufficient cycles, fatigue cracks initiate.

Nucleation and Growth

After incubation, micropits rapidly nucleate, grow, and coalesce. Microscopy shows a continuously cracked surface. Periodic inspection of gear tooth profiles with a gear inspection machine discloses a steady rate of surface deterioration. The process of plastic deformation, followed by initiation, growth, and coalescence of cracks may be continuous (Refs. 11, 16, 17). Damage may be extensive after only 10^6 cycles (Refs. 4, 12, 16, 18, 19).

Micropitting begins when a fatigue crack grows from the gear tooth surface at an angle to the surface. A micropit forms when a branch crack connects the subsurface main crack with the surface and separates a small piece of material. The resulting micropit may be only 10 μm deep and not resolved by the unaided eye. Subsurface crack networks are usually much more extensive than would be implied from surface features.

The main crack undermines the surface by growing deeper and spreading in a fan shape. Micropits enlarge as the back edges of the micropits crack and small pieces of surface material are dislodged. Some particles are trapped in micropits, and others fall out of craters and entrain

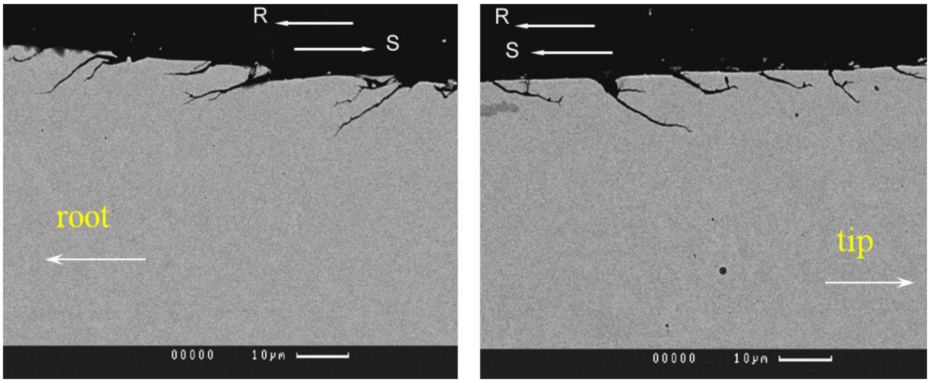

Figure 1 The image shows two polished metallurgical specimens cut transversely through gear tooth micropitting. The left shows the dedendum, and the right shows the addendum of the tooth of a driven gear. The vectors R and S indicate the rolling and sliding directions. Micropitting cracks start at the gear tooth surface and grow at a shallow angle (typically 10–30 degrees, but sometimes as steep as 45 degrees) to the surface. Image courtesy of Newcastle University.

in the lubricant. Because debris from micropitting can be as small as 1 μm, it is unlikely filters will remove much (Ref. 11). The particles act as polishing agents and polishing wear is often found on gear teeth with micropitting, in areas between micropits, and in areas without micropitting.

Ground gear teeth with longitudinal scratches often have micropits along the edges of scratches (Refs. 11, 20). On the driver, micropits nucleate at the lower edges of addendum scratches, and at the upper edges of dedendum scratches (Ref. 20). Fan-shaped growth patterns cause adjacent micropits to coalesce and form continuously cracked edges that follow along grind scratches.

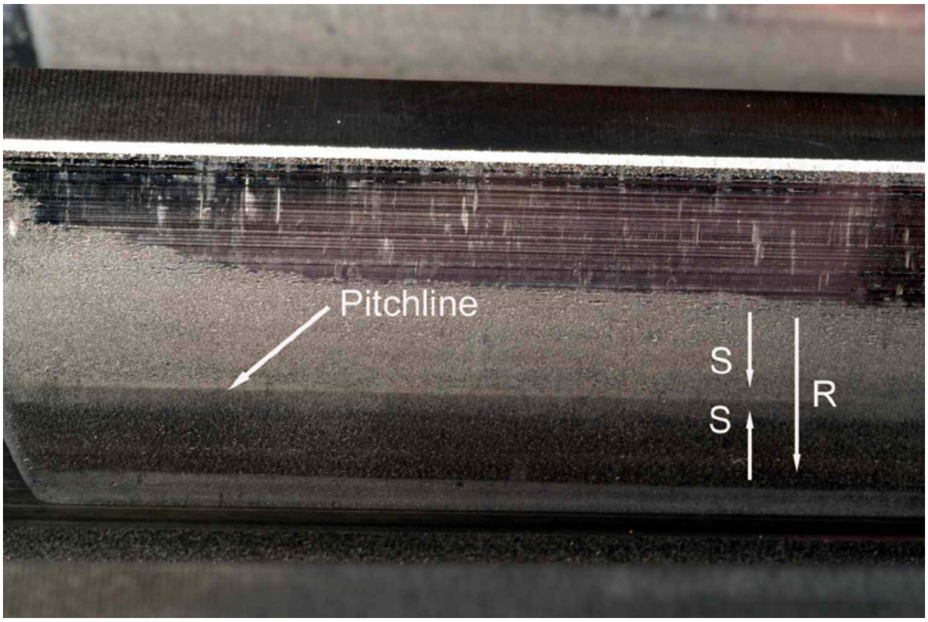

Figure 2 The image shows a driven wind turbine pinion with micropitting. The pitchline is readily discernible because the floors of the micropit craters are oppositely directed in the addenda and dedenda, which resulted in light reflection directed into the camera lens in the addenda, and directed away from the camera lens in the dedenda. This resulted in the addenda appearing light and the dedenda appearing dark.

Morphology

To the unaided eye, micropitted gear teeth appear dull, etched, or stained with patches of gray. Micropitting is difficult to see under diffuse fluorescent lighting and is best observed with intense directional lighting. A flashlight with a concentrated beam held in the proper direction effectively illuminates micropitting. With intense lighting, micropitting may sparkle or appear speckled.

Scanning electron microscopy (SEM) shows the floor of a micropit crater slopes gently downward from its origin at the tooth surface. The floor has a rough surface typical of that caused by ductile fatigue crack propagation. A featheredge forms at the back of the crater due to the plastic flow of material over the crater rim. The featheredge appears white in SEM when it becomes charged with electrons. Material surrounding a micropit generally appears smooth and featureless unless abraded.

Metallurgical sections cut transversely through micropits show cracks start at or near the gear tooth surface and grow at a shallow angle (typically 10–30°, but sometimes as steep as 45°) to the surface, as shown in Figure 1 (Ref. 21). Like macropitting, micropitting cracks grow opposite the direction of sliding at the gear tooth surface (Refs. 10, 19–23). Because slide directions reverse as the pitchline is crossed, micropitting cracks grow in opposite directions above and below the pitchline. If micropitting grows across the pitchline, it makes the pitchline readily discernible because opposite inclinations of the bases of micropit craters scatter light in opposite directions above and below the pitchline (Refs. 11, 12, 24), as shown in Figure 2. When metallurgical sections are polished and lightly etched with nital, dark etching alterations (DEA) may be found at shallow depths below surface asperities (Refs. 20, 25, 26). DEA locate areas of microscale plastic deformation.

Nonpreferred Names for Micropitting

The micropitting phenomenon has been studied since early 1960 resulting in a vast literature. As is typical of many research subjects, micropitting has a long list of terms used to describe the failure mode. However, by general consensus, the preferred name is micropitting because it aptly describes both the appearance and mechanism. Therefore, to reduce confusion, and to improve communication, the following nonpreferred names are discouraged.

- Asperity microcracking
- Asperity microspalling
- Asperity-scale distress
- Asperity-scale fatigue
- Delamination wear
- Fatigue scoring
- Fatigue wear
- Flecking
- Frosting
- Glazing
- Gray discoloration
- Gray mottle
- Gray staining
- Gray stippiness
- Microcracking
- Microspalling
- Peeling
- Superficial cracking
- Superficial pitting
- Superficial spalling
- Surface distress
- Surface fatigue
- Surface-initiated fatigue
- Surface-origin spalling

Conclusions

Micropitting begins with an incubation period during which damage consists primarily of plastic deformation at asperities. Macroscopically, surfaces appear glazed or glossy. Microscopically, asperity ridges appear as almost featureless flat areas possibly with roughness valleys still discernible. The preferred nomenclature for the damage that occurs during the incubation period is glazing.

After incubation, micropits rapidly nucleate, grow, and coalesce. Macroscopically, a micropitted surface appears dull, etched, or stained with patches of gray. Microscopically, a dense field of micropits of various sizes can be seen. The preferred nomenclature for the damage that occurs during the micropitting period is micropitting.

The root cause of micropitting is plastic deformation that occurs during the incubation period.

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Robert Errichello heads his own gear consulting firm, GEARTECH, and is founder of GEARTECH Software, Inc. He has over 57 years of industrial experience. He has been a consultant to the gear industry for the past 44 years and to over 50 wind turbine manufacturers, purchasers, operators, and researchers. A graduate of the University of California at Berkeley, Errichello holds BS and MS degrees in mechanical engineering and a Master of Engineering degree in structural dynamics. He is a member of several AGMA Committees, including the AGMA Gear Rating Committee, AGMA/AWEA Wind Turbine Committee, ASM International, ASME Power Transmission and Gearing Committee, STLE, NREL GRC, and the Montana Society of Engineers. He is technical editor for GEAR TECHNOLOGY and STLE Tribology Transactions. Errichello is recipient of the AGMA TDEC Award, the AGMA E.P. Connell Award, the AGMA Lifetime Achievement Award, the STLE Wilbur Deutch Memorial Award, the 2015 STLE Edmond E. Bisson Award, and the AWEA Technical Achievement Award.

Gear Skiving—A Step Changing Manufacturing Process Applicable to Multifunctional 5-Axis Machine Tools

Bethany Cousins, Chao Sun, Dr. David Curtis, Michael Farmery, Steven Staley, and Ben Cook

The gear skiving cutting process is a machining method applicable to producing both internal and external gear teeth. The process is known to have significant productivity advantages over shaping, and when compared to hobbing, the tool demands less clearance and therefore has the advantage of being able to machine in close proximity of shoulders. Despite only becoming an area of prevalent interest within the gear industry in recent years, the gear skiving method for gear cutting was first patented in 1910 (Ref. 1). The process demands a high degree of synchronization accuracy between the workpiece spindle and the tool spindle, as the two mesh together, similarly to a pair of gears at increasing depths to create the gear form. As stated by Weppelmann, "Machines and cutting spindles simply weren't robust and rigid enough to minimize vibrations caused by the high spindle rpms and significant cutting forces generated by the skiving process" (Ref. 2). However, as machine tools and their capabilities have improved, bespoke gear skiving machine tools have been manufactured. The AMRC has been keen to pursue the capabilities and performance of generic multifunctional machine tools such as those that are already in use on many factory floors, when faced with the gear skiving cutting cycle. The main benefits of performing the gear skiving process on a multifunctional machine tool include smaller manufacturing cells, reduced capital expenditure, and the potential for an increase in dimensional accuracy of components, as the gear form can be generated in the same setup as the majority of other turned/milled features. Sandvik Coromant AB state that "Advances in machining centers have paved the way to a more productive process for producing internal gears—gear skiving. This faster process offers improved quality at lower cost and is four to ten times more productive than, for example, shaping. It also gives better flexibility and quality than broaching. Consequently, machine tool manufacturers are now developing machining centers and software solutions capable of dealing with the specific requirements of the process" (Ref. 3). The medium-long term aim is to use the gear skiving process to both rough and finish gears. Whilst in the short term, it is more feasible to assess gear skiving as a roughing process only, where the gears would undergo a secondary finishing operation such as grinding after case hardening.

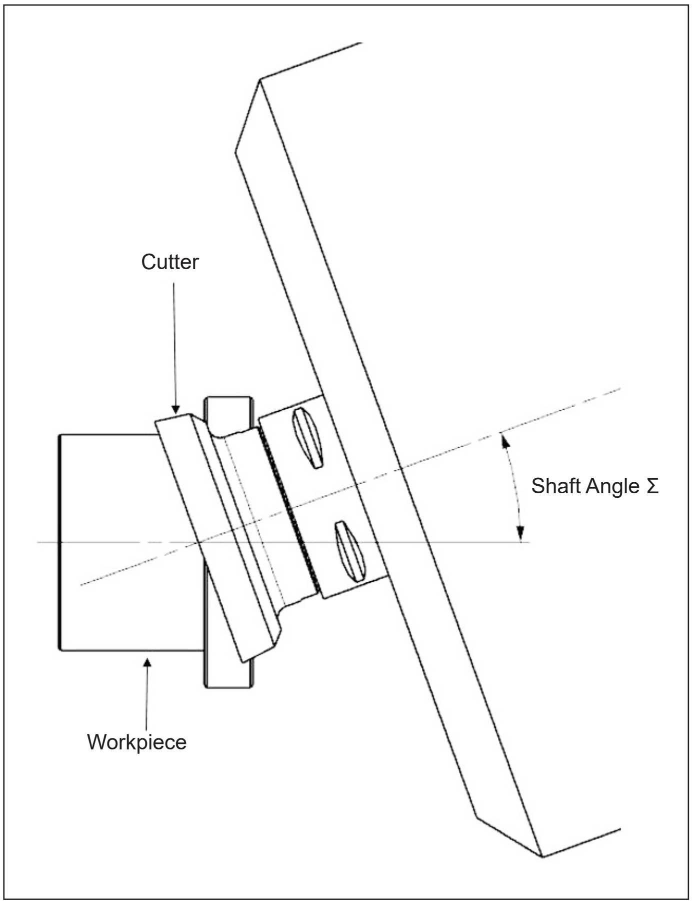

Figure 1 Gear skiving kinematics.

The gear skiving cutting process operates using a pinion-like cutting tool (similar to a shaping cutter), held at a cross-axis shaft angle, rotating in synchrony and meshing with the workpiece gear. The cutter traverses the face width of the gear, with ever-increasing radial depths over numerous passes, each achieving a small depth of cut until the workpiece gear's root diameter is reached. A small scoop of material is removed from each of the tooth gaps with each revolution, with V-shaped chips generated. The process has attributes in common with hobbing, shaping, turning, and milling, but in essence, is an entirely distinct process for which new machining techniques must be developed and optimized.

The method involves a geometry-specific tool with numerous teeth, which rotates at high spindle speed whilst traversing

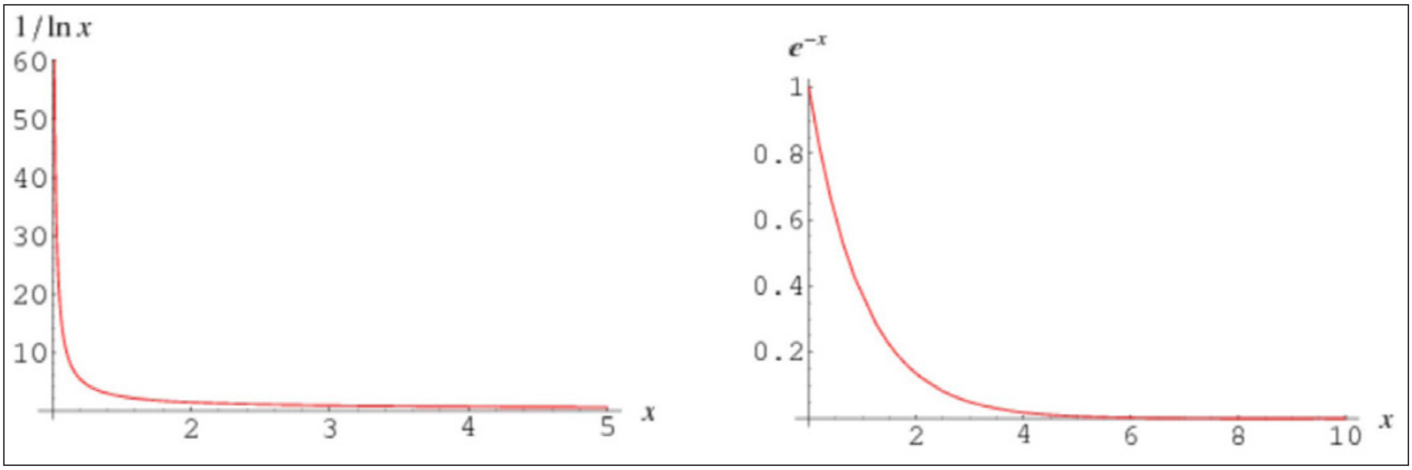

Figure 1 Comparison of logarithmic decay (left) and exponential decay (right).

around the gear diameter (Fig. 1). The teeth mesh with the gear shape as both the tool and workpiece rotate. A cutting action is generated through an angle of inclination, or "shaft angle" of the tool relative to the workpiece, as depicted in Figure 1 for an external gear workpiece. The cutting speed achieved is directly proportional to this angle of inclination, where a higher shaft angle requires less rotational speed of both the tool and workpiece spindles, up to a maximum possible inclination of 45 degrees (Ref. 7).

Parameters used in this process are not commonly understood and are restricted to a few experienced engineers, and these engineers still rely on iterative processes to define optimum parameters. Iterative processes result in high costs due to extensive time and use of materials.

Within literature, there are limited publications specifically on cutting parameter calculation, some of which are in contradiction. Many methods are discussed in theory but are not proven in trials. It is suggested the parameters required for gear skiving include tool rpm, workpiece rpm, linear federate, and depth of cut plan. The tool and workpiece rpms are related to surface speed, and this will vary depending upon material. Surface speed (Vc) or rpm has multiple variants of calculation dependent upon academic resource. The AMRC has previous experience implementing the following formulae for rpm calculation, hence these were taken forward:

$$n_1 = 1{,}000\ v_c \cos\beta\ /\ \pi\ D_{tmaj} \sin\Sigma \quad (1)$$

$$n_2 = n_1(z_t/z_g) \quad (2)$$

where

β = Helix angle (radians)
z_g = Number of teeth on part
z_t = Number of teeth on tool
D_{tmaj} =Major diameter of tool (mm)
Σ =Cross angle of tool (radians)
n_1 = rpm of tool
n_2 = rpm of part
v_c = Surface speed (m/min)

Bylund (Ref. 7) discusses that a logarithmic decay in depth of cut would be the most appropriate method to use. When assessing a logarithmic decay, it can be seen that the initial gradient of the decay is very steep, essentially taking an initial cut of extreme depth followed by many cuts of very little depth. An exponential decay would allow for a gradual transition from deep cuts to shallow cuts and is therefore more suited to a machining process. The logarithmic and exponential decrease curves are compared in Figure 2.

The AMRC previously created and tested a spreadsheet calculator that would give an exponential decrease for a given gear depth but would use maximum and minimum depths of cut to suit machining processes and also set boundaries for the exponential decay to remain within. Machining processes generally begin with deep roughing cuts to remove large volumes of material, but these are limited to a maximum depth due to the cutting force required at greater depths. The inverse applies to the final tool paths, as a minimum limit is required in order to reach the material shear force; these are the limits in which the exponential decrease must occur between in order to reach the required total gear depth. This work highlighted the requirement to further control the force through each cutting pass.

The overarching focus was to specialize in developing gear machining methods using multifunctional 5-axis machine tools in partnership and collaboration with partner companies. This was done to develop and quantify the capabilities and publicize this for the benefit of the industry and to show gear skiving as a viable option for gear manufacturers.

To achieve this, the objective was to develop and optimize a toolkit to establish capable gear skiving parameters for a range of gear and spline geometries over the course of three case studies. Previously, the AMRC developed a capability to demonstrate the gear skiving process with high performance on a few geometries, whilst supporting the development of a force prediction software model for gear skiving. The objective of more recent work was to continue and further this work into an internally developed toolkit to better understand the process, the impact of parameters, the transferability onto a range of geometries, and the limitations of the operating envelope.

The first case study's initial focus was to undertake repeatability trials to robustly demonstrate and quantify the performance capability of the baseline process through manufacturing batches of a particular geometry (a spur gear of 4.75-inch diameter and DP 6.5, which had teeth roughed and finished in

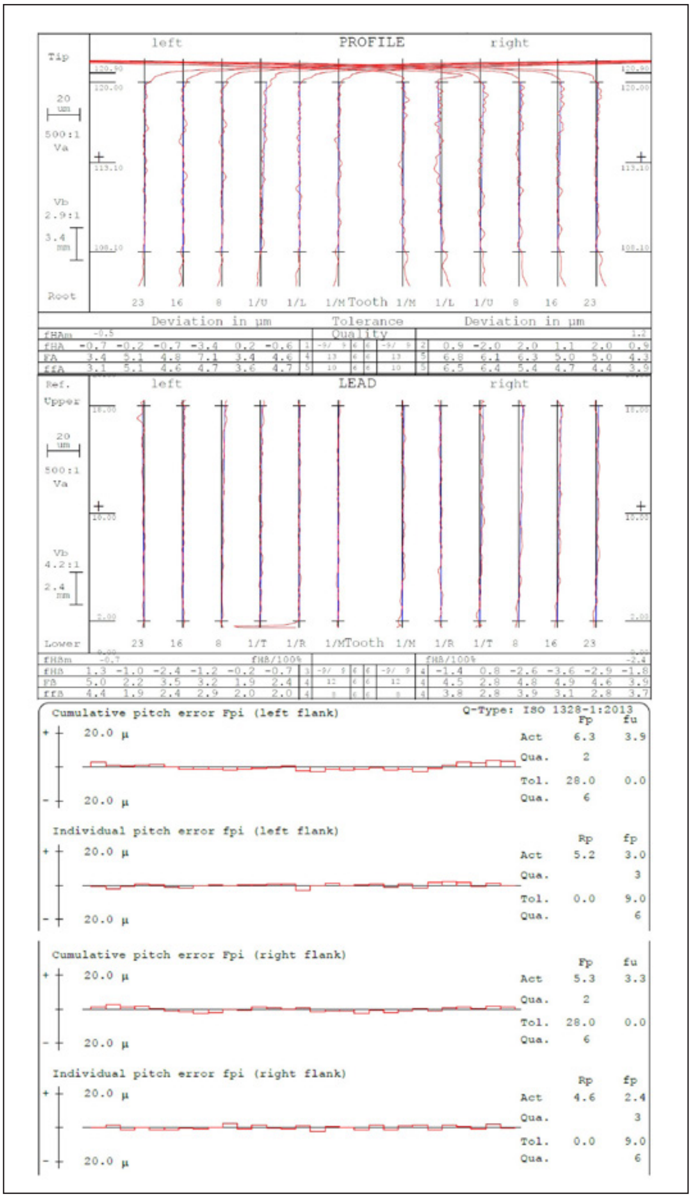

Figure 3 Extract from the metric inspection report showing achievement of (AGMA 2015-A01 class A5 (AGMA 2000-A88 class Q12).

6 minutes 20 seconds) with varying force parameters to understand the influential variables affecting this and assessing tool life. The AMRC had previously demonstrated capability for gear skiving with high productivity and to an AGMA 2015-A01 class A5 (AGMA 2000-A88 class Q12) for this baseline gear geometry, during previous parameter optimization trials. The profile, lead, and spacing inspection results are shown (measured in metric assessed against the ISO 1328-1:2013 standard) in Figure 3.

Following this initial work, a second case study aimed to develop and test the transferability of the internally developed toolkit to predict cutting forces and establish cutting parameters for new geometries, including splines, helical gears, and comparably large ring gears. The aim was to expedite the process development and baseline performance onto different geometries. Quality, vibration, cycle time, and tool life were monitored throughout the trials.

This final case study facilitated the design of a planetary gearbox, which aimed to be representative of a number of industry sectors to allow future technology development and demonstration.

Research methodology

The first case study consisted of two initial repeatability experimental trials performed utilizing two sets of cutting parameters: experiment 1.1 with a varying force approach and experiment 1.2 with a force normalized approach, in order to qualify the preferred approach and thus validate the force modeling strategy, as well as to quantify currently achievable tool life and thus production-viability of the process.

Case study 2, a second round of trials, was performed on a newly designed artifact, which intended to incorporate a number of geometries judged most pertinent for further study. These geometries were selected to represent the automotive and aerospace industries and included helical gears and internal splines.

An extensive machining trial was undertaken to determine the feasibility to read across the previously established parameter set to alternate geometries.

Over the course of these trials, different methods for machining chatter alleviation during the gear skiving process, including

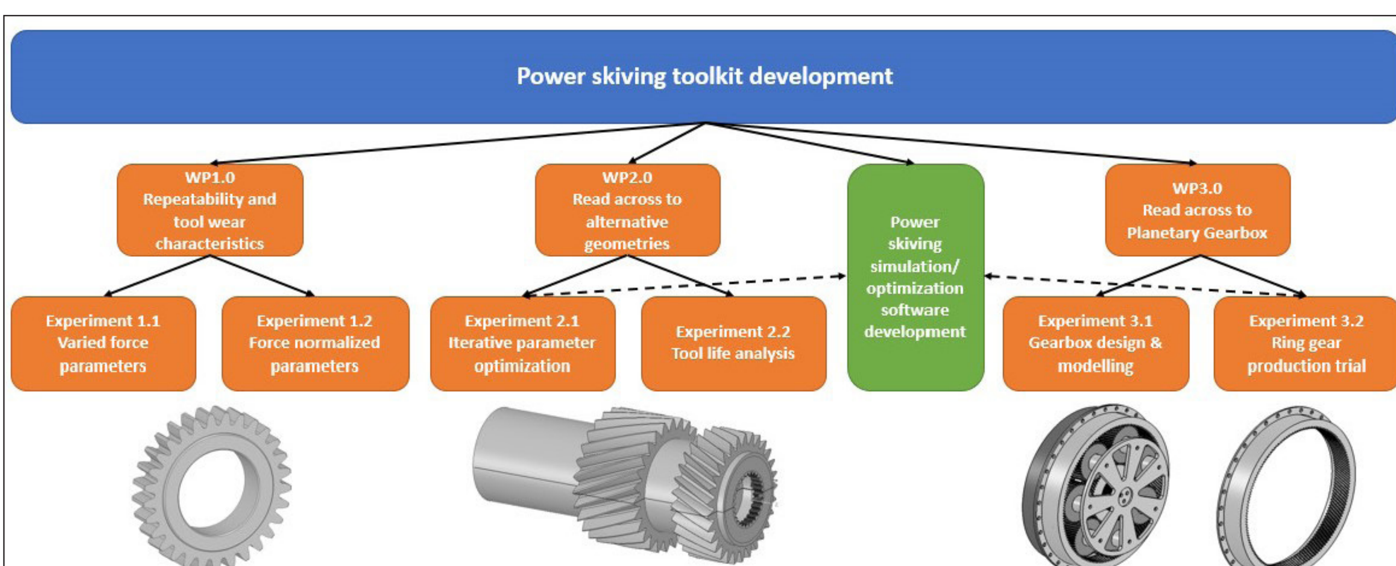

Figure 4 Work breakdown structure with component models.

Gear Data		
Quality Grade Assessment	ANSI/AGMA ISO 1328-1-B14	
Number of Teeth	29	
Helix Angle	0°	
Normal Module	3.9 mm	0.154"
Pressure Angle	20°	
Tip Diameter	120.90 mm	4.760"
Root Diameter	102.18 mm	4.023"
Reference Diameter	113.100 mm	4.453"
Base Diameter	106.2792 mm	4.184"

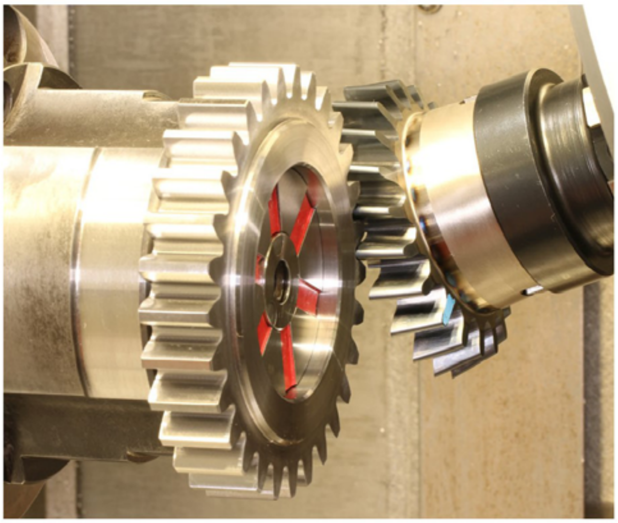

Figure 5 Pulsator gear table (left) and geometry with gear skiving tool (right).

spindle speed and feed rate optimization, were attempted based on dynamic data and analysis of the process.

With optimized parameters obtained for the new geometries, a tool life study was undertaken.

Case study 3, a final work stream, included the design of a planetary gearbox that would be representative of aerospace-geared turbofan applications but also suitable to showcase gear manufacturing technologies applicable to numerous industries, such as automotive and wind. To follow on from the previous work streams and transfer the findings to a larger internal geometry, a helical ring gear of this large gearbox was selected for further study of the application of gear skiving, utilizing the AMRC's developed analysis techniques.

Figure 4 Work breakdown structure with component models.

In parallel to the machining trials, process monitoring, and optimization work was undertaken. Moreover, a new gear skiving force software simulation was developed to predict cutting force/torque to output optimized depths of cut specific to the gear geometry. The developed simulation model differed from previous work significantly; the new model exploited a geometric repeatability assumption, which allowed for use of a single, 1D radial dexel map to record the part geometry and to predict tool workpiece engagement. This assumption greatly reduced the complexity required for simulation of gear skiving forces and was adapted for force prediction and process planning for both external and internal spur and helical gears.

In this project, different methods for chatter alleviation during the gear skiving process, including spindle speed and feed rate optimization, have been tried.

Equipment

Case study 1

A test spur gear geometry (known as the "Pulsator") from Newcastle University's Design Unit (Ref. 6) was utilized as the first of three workpieces for the most recent experiments. This same workpiece geometry has been adopted by the AMRC as their baseline for proof of concept on machines, tooling, and novel processes. The gear geometry and its key attributes are detailed in Figure 5, which approximate to 4.5-inch reference diameter.

Case study 1 was completed on an Okuma MULTUS U3000, kinematically pictured in Figure 6. The OSPP300 controlled machine had a maximum turning spindle speed of 5,000 rpm, maximum milling spindle speed of 12,000 rpm, and could turn diameters up to 25.6". The AMRC machine was stocked with Hangsterfers emulsion coolant, maintained at a concentration of 8–10 percent. The gear skiving activity was always performed with the tool loaded in the 'A Turret' (milling spindle) of the machine, and the workpiece in the main spindle.

Inspection was undertaken using a Hexagon Leitz PMM-C, which is a precision CMM with gear inspection capability. Its accuracy specification, MPE-e, was 0.023622 + L / 800 thou, where L is the measurement length, the machine has three degrees of freedom (X, Y, Z), and it was maintained to a strict temperature range of 19.5-20.5°C.

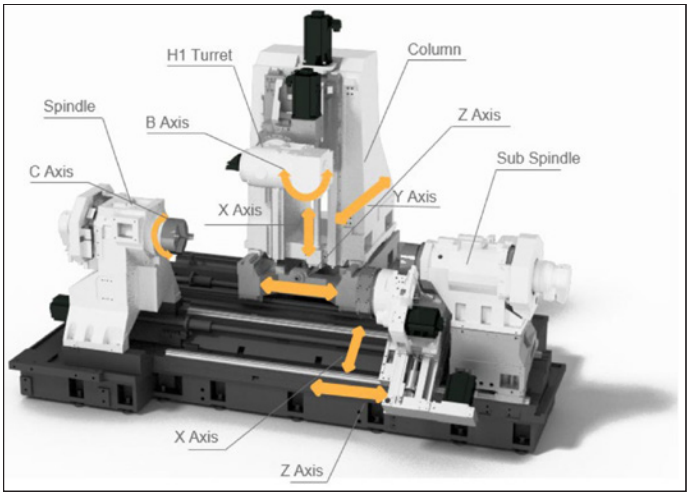

Figure 6 Okuma MULTUS U3000, kinematic diagram.

All gear skiving tooling is specific to each gear form. The AMRC acquired their tooling for the Pulsator from Sandvik Coromant AB mounted using a Sandvik Coromant AB 392.41005C6332060 HSK 63A holder.

Case study 2

The second geometry used for the trials was a hybrid workpiece made up of three gear forms, known as Gear Shaft B (Ref. 4). The workpiece shown in Figure 7 was designed by the AMRC specifically, with the aim of expanding the range of gear geometries and gear types the AMRC had experience in gear skiving, and to assess the transferability of all previous findings to alternate geometries. The Gear Shaft B component consisted of two external helical gears and an internal spline on a cylindrical datum shaft; the key attributes of these gears and the spline are listed in Table 1. The test components were manufactured in EN36B steel with a through hardness of approximately 25 HRC.

Case study 2 was also completed on an Okuma MULTUS U3000 described in Case study 1 and kinematically pictured in Figure 6. The inspection was similarly undertaken on the same machine (Hexagon Leitz PMM-C) detailed and described in Case study 1.

The AMRC acquired their tooling for Gear Shaft B component from two suppliers: Horn Cutting Tools Ltd manufactured by Paul Horn GmbH and Dathan Tool & Gauge Co. Ltd. Three separate tool holders were used during the trials. For Gear C, a Sandvik Coromant AB 392.41005C6332060 HSK 63A holder was used, whilst Gear B utilized the longer length of an Erickson HSK63ASMC32100M HSK 63A holder to allow access to gear skive in the center of the shaft. Due to the small size of the cutter used to produce Spline A, a Horn Cutting Tools MLtdX60.0063.0150HSK 63A holder was used.

Table 1 Gear Shaft B key attributes

Geometry	Spline A	Gear B		Gear C	
Quality Grade Assessment	ANSI B92.1-1970	ANSI/AGMA ISO 1328-1-B 14			
Number of Teeth	28	26		29	
Helix Angle	0	22°		14°	
Spline Pitch/ Normal Module	20/40	2.935 mm	0.116"	2.76 mm	0.109"
Pitch Diameter/ Reference Diameter	1.4"	82.303 mm	3.240"	82.49 mm	3.248"

Figure 7 Gear Shaft B component geometry (Spline A internal, Gear B bottom external, Gear C top external).

Case study 3

The third geometry used in the most recent trials was designed internally to develop key technologies from across the AMRC Machining Group teams, demonstrated via a representation of a geared turbofan engine assembly, visualized in Figure 8. Each key component team collaboratively designed aerospace engine components that would showcase new technologies and would also be assembled into a display piece.

The gearbox design was chosen to be representative of aerospace geared turbofan applications but also be suitable to showcase gear manufacturing technologies applicable to numerous industries, such as automotive and wind.

The gearbox consisted of two helical ring gears, a double-helical sun gear, and seven double-helical planet gears with carrier. An unusually large number of planet gears was chosen in order to showcase a number of manufacturing routes (e.g., generative milling, form milling, broaching, gear skiving, hobbing, grind from solid), materials (e.g. steels, stainless, PEEK, bronze), and design attributes (e.g. varying helical gap, microgeometry, lightweighting features) in a single showcase assembly. This enables discussion of their relative merits and emphasizes the flexibility of the AMRC's offering whilst showcasing the majority

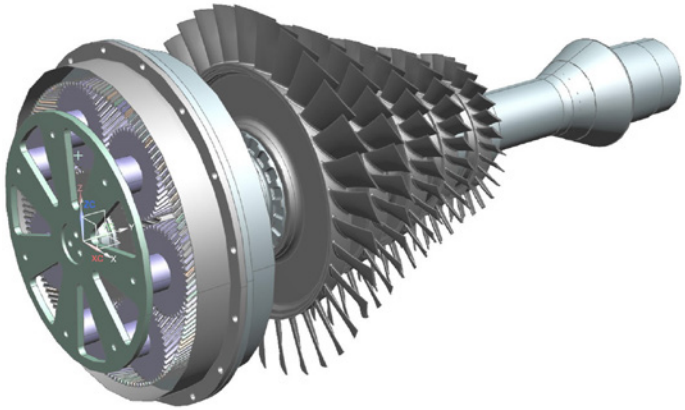

Figure 8 Aero-engine demonstrator.

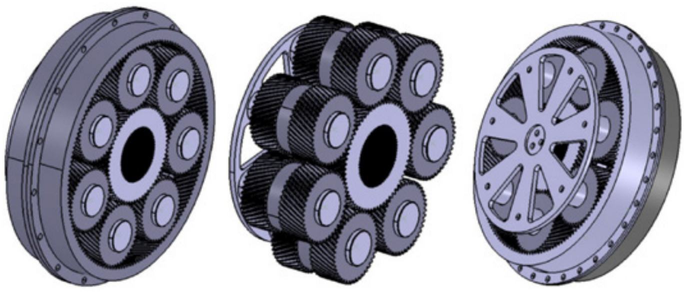

Figure 9 Planetary gearbox designed.

of our technologies in a single place. The components were designed with oversized wall thicknesses to maximize flexibility in the light weighting approaches planned to be showcased in future trials.

Figure 9 shows a CAD model of the full gearbox.

The design features large ring gears to allow demonstration of gear skiving in its element, where the productivity will offer a step change to the legacy manufacturing route, on a component type key to future 11 21FTM15 propulsion and renewables. The ring gear with its overall size and thin wall thickness is potentially the most challenging gear to produce, requiring detailed analysis and development, but with the potential for the most impact on productivity improvement.

This report includes details of the gear skiving development of the right-hand ring gear pictured in Figure 10. The key attributes of this gear are listed in Table 2. The test components were manufactured in forged BS-S132 steel in a soft condition of approximately 42 HRC (Ref. 9). This is a common aerospace nitriding steel with a tensile strength of "1320-1470 MPa" (Ref. 8). This material was recommended as industrially relevant to ring gear applications by industry experts via the British Gear Association's Special Interest Group for Modern Manufacturing.

Case study 3's ring gear trials were completed on a second machine, an Okuma MU8000V-L, kinematically pictured in Figure 11. This is a 5-axis vertical mill turn trunnion platform with gear skiving capability. The OSP-P300 controlled machine had a maximum turning spindle speed of 800 rpm, maximum milling spindle speed of 10,000 rpm, and table size of 800 mm diameter with a load capacity of 700 kg. The gear skiving activity was always performed with the tool loaded in the milling spindle of the machine, and a prepared blank fixture to the machine bed.

Inspection was again undertaken using a Hexagon Leitz PMM-C detailed in described in Section 1.1.1. The ring gear utilized a Dathan Tool & Gauge Co Ltd gear skiving tool mounted on a Sandvik Coromant AB 392 41005C10040100M tool arbor with HSK100 spindle interface.

Parameter selection

Case study 1

The initial experimental trials assessed the performance of two parameter sets through the production of a number of repeats with a single tool per set of repeats. The parameter sets were trialed on a geometry the AMRC had previously gained high confidence in gear skiving, the Pulsator. Experiment 1.1 used a parameter set derived from the AMRC's previous work considering the capability of gear skiving and its application to industry. Experiment 1.2 used a parameter set derived by the AMRC from previous work exploring the dynamics of gear skiving through modeling and simulation to provide a tool to further assess the process.

Case study 2

The subsequent experimental trials in case study 2 aimed to transfer all the accumulated prior knowledge from the previous work at the AMRC to alternative gear geometries to broaden gear skiving knowledge and provide a greater understanding of how the gear skiving process performs for geometries that are

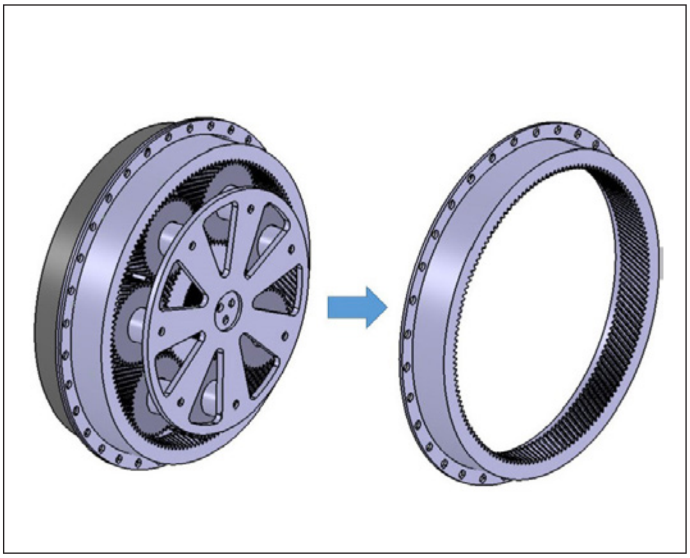

Figure 10 Planetary gearbox and right-hand ring gear component geometry.

Table 2 Ring gear key attributes

Feature	Size (metric)	Size (imperial)
Quality Grade Assessment	ANSI/AGMA ISO 1328-1-B14	
Number of Teeth	152	
Module	2.5 mm	0.098"
Helix Angle/Hand	28°/Right hand	
Tip Diameter (Minor Diameter)	424.199 mm	16.701"
Root Diameter (Major Diameter)	435.949 mm	17.163"
Flange Outer Diameter	525.000 mm	20.669"

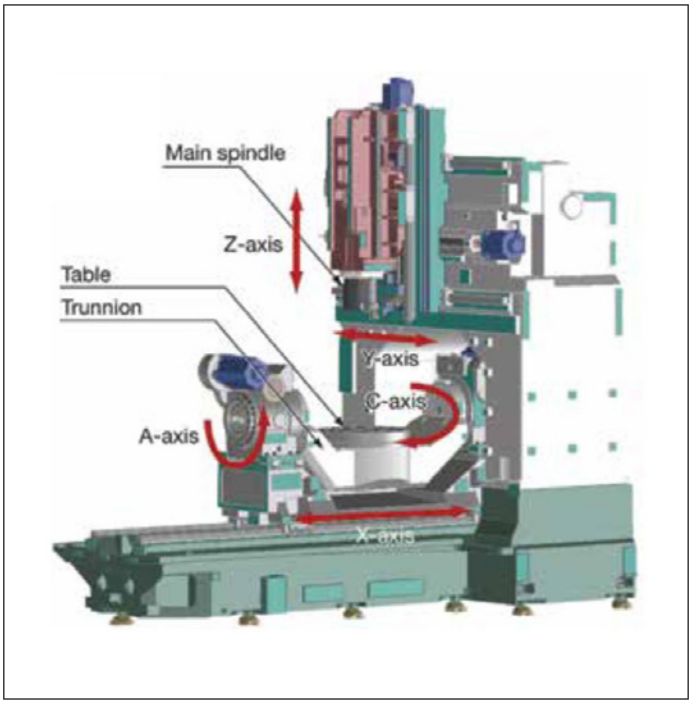

Figure 11 Okuma MU8000V-L, kinematic diagram.

likely to be applicable to the wider gear industry. This included a single test piece with two different external helical gears and an internal spline. The first 26 test pieces were produced in an iterative manner, with CMM inspection and data analysis between each test piece to reflect on performance and make the relevant parameter changes to improve the quality and understanding of the subsequent gears.

A following 19 test pieces were produced over a five-day period, without any changes to parameters, to further assess the limit of tool wear.

Case study 3

A similar iterative approach was utilized during Experiment 3.2, trials on the Ring Gear geometry. Parameters were selected based on the performance of the two previous case studies but limited to produce static cutting forces ranging from 500 N–1,000 N. Figure 12 plots the trialed tool spindle speeds along the graph produced from the dynamic tap testing process that was performed at the start of machining. A speed that intersects the graph at an area of high magnitude would have undesirable performance, as the machining frequency

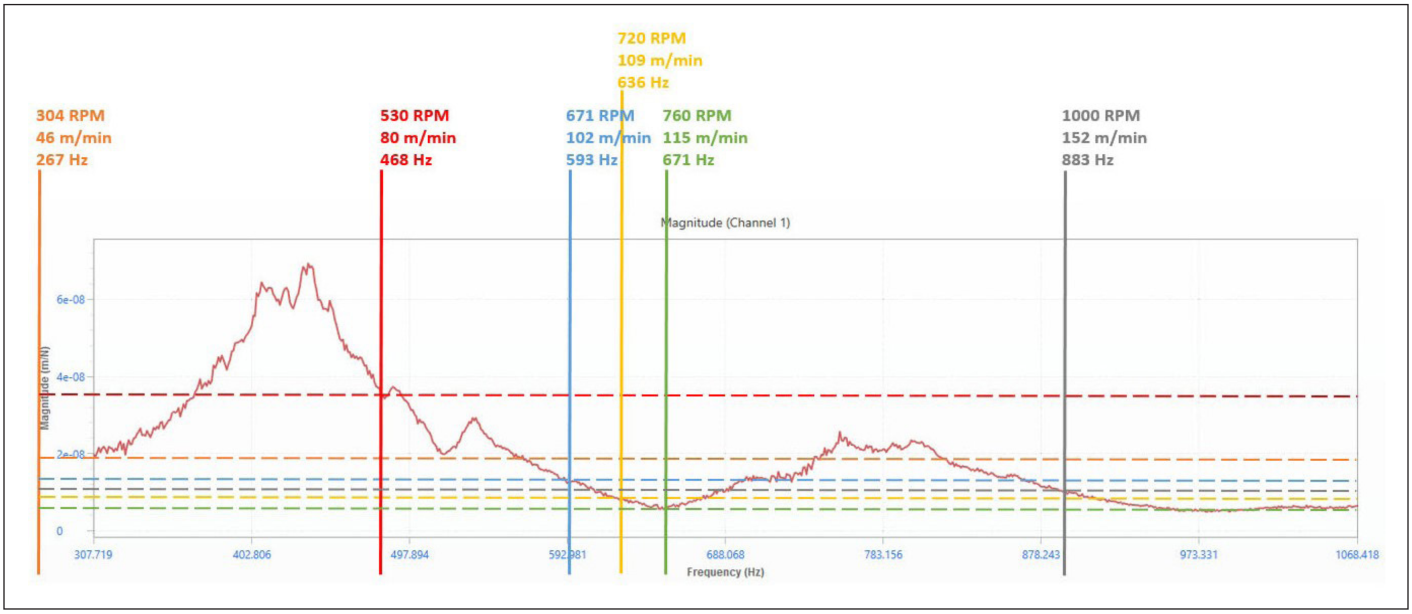

Figure 12 **Tool spindle speed—frequency magnitude analysis.**

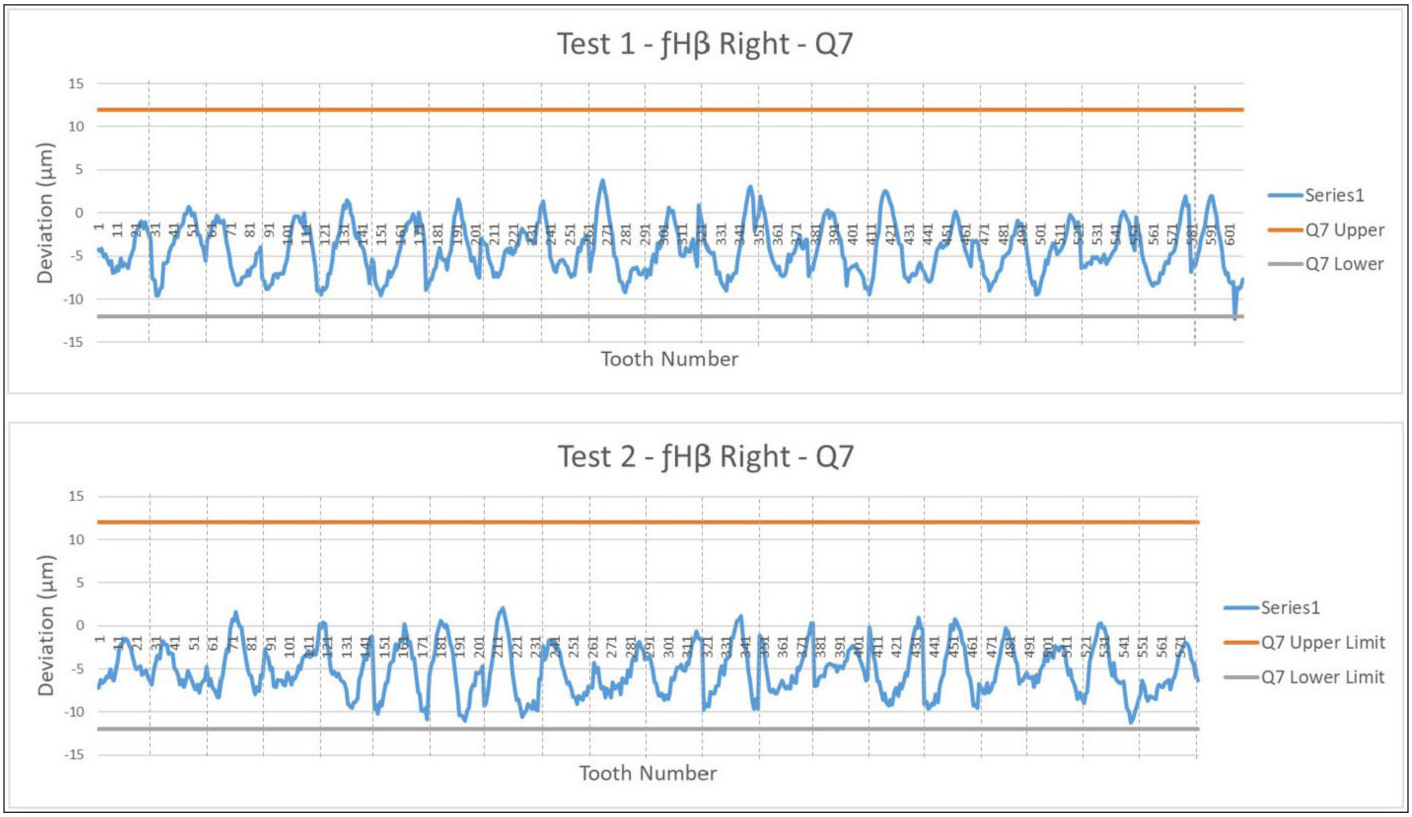

Figure 13 **Experiment 1.1 (top) and 2 (bottom) fHβ Right profile results.**

would match the natural frequency of the tool assembly or workpiece setup.

A new gear skiving force simulation capability was developed to predict cutting force and torque during gear skiving operations. The new model exploited a geometric repeatability assumption, which allowed for use of a single, 1D radial dexel map to record the part geometry and to predict tool-workpiece engagement. This assumption greatly reduced the complexity required for the simulation of gear skiving forces and was adapted for force prediction and process planning for external spur and helical gears.

The force prediction model was implemented during the Gear Shaft B and Ring Gear experimental trials to provide a series of depths of cut for both external helical gears, which was specifically designed to control the forces at the specific depth for each pass specific to the individual gear geometry.

Load data recorded from the machine during the cutting process was used for comparison against the theoretical forces predicted by the model to refine the output and improve the accuracy of the depths of cut to reduce the level of vibration and improve the quality of gear produced.

Results and observations

Case study 1

During Experiment 1.1, with varying force parameters, all components conformed repeatedly to an AGMA 2015-A01 Class A7 (AGMA 2000-A88 class Q10), whereas Experiment 1.2, with force normalized parameters, only conformed to Class A7 on 45 percent of the components tested. The remaining components were a range of Class A8–Class A11 at worst, despite consistent cutting parameters. The range of performance in Experiment 1.2 was not accredited to tool quality, due to the lack of consistent errors within the inspection report. Due to the pattern of results not showing a constant degradation in quality as part number increased, the range of results was also not attributed to tool wear.

To further analyze any pattern in the results from component to component, the inspected profile and lead features of each tooth across the batch were plotted sequentially for all profile and lead features for both Experiment 1.1 and 1.2. Figure 13 shows the metric plots of the right flank line angle error (fHβ) profile results for both experiments. As the gear skiving cutting process contacts several teeth at any one time, the first tooth cannot be accurately determined. For the purpose of the below graphs, a tooth was selected at random with all further teeth counted in a clockwise direction (viewed from the datum B end).

The metric plots in Figure 13 show a pattern representative of the majority of the profile and lead inspection results. When plotted in sequence the teeth showed an emerging wave pattern with some—but little—noise. This pattern appeared to be consistent throughout the full experimental batches indicating a potential behavioral pattern within the machine tool that was not affected by a component change or machine restart—the components within the batch are separated by hashed vertical lines in Figure 13.

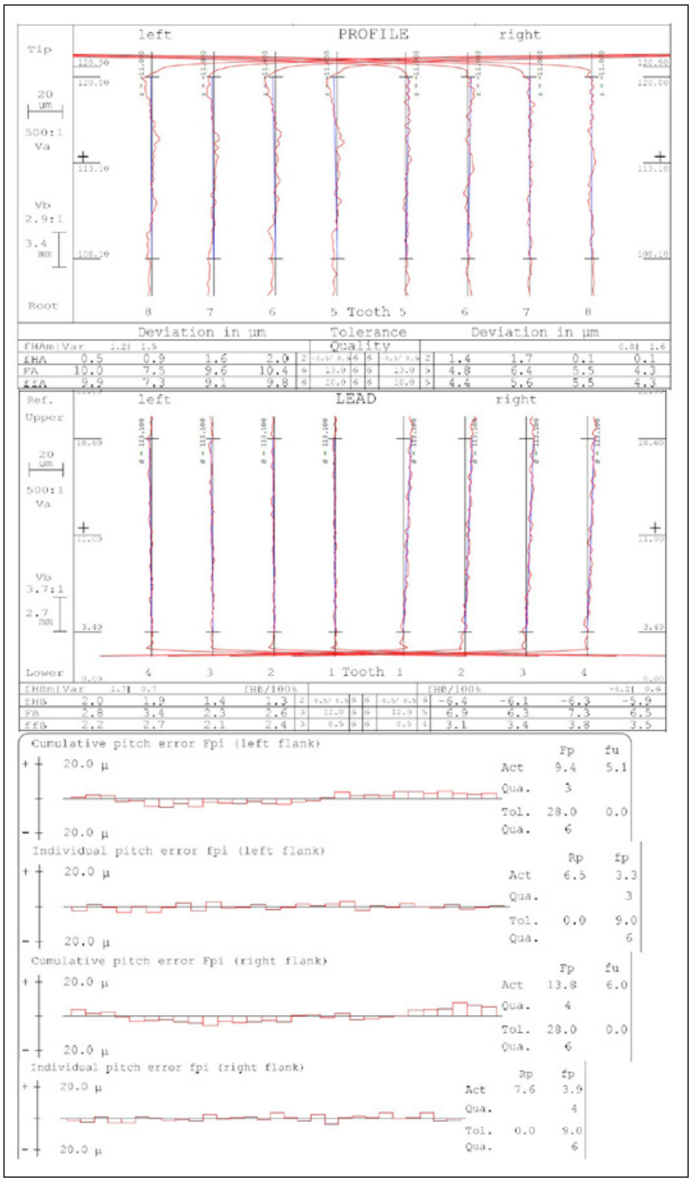

Figure 14 **Extract of inspection data for Experiment 1.1, Component 19.**

Figure 14 shows the best quality gear out of the two batches of components. Experiment 1.1, Component 19 conformed to an AGMA 2015-A01 class A6 (AGMA 2000-A88 class Q12).

Table 3 shows the Cp data, which assesses the repeatability of the results through the amount of scatter alone, regardless of any skew in the data. The Cp, rather than the Cpk (with skew), was chosen for the process capability assessment due to intentional offsets that were made for the trial. For example, to improve the quality of the tooth profile, the root diameter was intentionally offset towards the top tolerance. Therefore, despite highly repeatable results, the process capability score for root diameter was low at 0.359 (1 σ) due to the off-centered results. When the skew is removed from the equation, the root diameter shows a favorable process capability score of 4.559 (6 σ), as seen in Table 3.

Table 3 Process capability (Cp) scores for both sets of Pulsator geometry trials			
Inspected Feature		Experiment 1.1	Experiment 1.2
Profile error	Profile angle error fHα right	1.897	1.830
	Total profile error fα right	2.202	2.035
	Profile form error ffα right	1.876	1.663
	Profile angle error fHα left	1.915	1.703
	Total profile error fα left	1.847	0.974
	Profile form error ffα left	1.442	0.789
Lead error	Flank line angle error fHβ right	1.009	1.032
	Flank line trace error fβ right	1.232	1.260
	Flank line form error ffβ right	1.676	1.737
	Flank line angle error fHβ left	1.015	1.007
	Flank line trace error fβ left	1.337	0.705
	Flank line form error ffβ left	2.376	0.589
Pitch error	Cumulative fp right	1.926	1.977
	Individual fp right	1.131	1.844
	Cumulative fu right	1.496	3.261
	Cumulative fp left	4.004	2.056
	Individual fp left	1.131	1.264
	Cumulative fu left	1.496	3.261
Runout deviation fr		1.535	1.472
Dimension over balls—mean		17.096	15.991
Root diameter		4.559	4.179

Table 4 Maximum and mean force comparison of the 15th and 20th Pulsator test piece.				
Pass Number	15	20	15	20
	Maximum Force (%)		Mean Force (%)	
1	8	9	3.022	2.979
2	12	12	4.222	4.200
3	12	12	4.268	4.195
4	13	12	4.378	4.324
5	13	13	4.695	4.545
6	14	13	4.811	4.737
7	14	13	4.954	4.816
8	14	14	5.103	4.994
9	15	14	5.204	5.076
10	15	14	5.340	5.212
11	15	14	5.439	5.271
12	15	15	5.534	5.422
13	16	15	5.778	5.600
14	16	15	5.902	5.724
15	16	15	5.886	5.691
16	5	5	1.865	1.802
Average overall passes	13.3	12.8	4.775	4.669

Tool life

The life of the tooling used during both sets of parameter trials on the Pulsator geometry was monitored and assessed under a microscope every fifth gear. The trials saw 21 components produced using the varied force parameters in Experiment 1.1 and 20 components produced using the force normalized parameters in 1.2. This result is comparable to and supports the AMRC's previously published tool life of 22 gears for the same gear geometry (Ref. 5). Due to increasing wear levels throughout the trial, the teeth chipped at some point after the tool was inspected on the microscope after production of the fifteenth test piece. However, there is no data to suggest at which point before the final microscope inspection at 21 and 20 test pieces the teeth became chipped. Up to the point of tool fracture, no consequence of tool wear was reflected in the gear metrology reports. Table 4 compares the milling spindle load data recorded from the machine for the fifteenth and twentieth test pieces produced in Experiment 1.2, as no data was recorded during the production of test pieces 16–19. The table compares the maximum and average loads on a pass-by-pass and overall basis. This shows that no increase in load was recorded after the tool became chipped. In the majority of cases, the earlier test piece showed a reduced load compared to the latter.

Case study 2

With regards to case study 2, trials focusing on the two helical gear forms and the internal spline of Gear Shaft B; Table 5 summarizes the class of gear achieved by both gears and the spline on all ten test pieces inspected using the Hexagon Leitz PMM-C from the 26 parameter optimization test pieces. Spline A could be seen to repeatedly achieve at least a Class 6 ANSI B92.1-1970 standard with a desirable Class 4 achieved on an early test piece. Gears B and C were both assessed against the AGMA 2015-A01 standard, with Gear B repeatedly conforming to a Class A12 standard, but at best, achieving a Class A8 on 40 percent of the test pieces. Gear C conformed to an improved Class A11 standard but only achieved a Class A8 on 30 percent of the inspected batch. The large range of results was anticipated due to the high number of parameter changes within the first 26 test pieces for both Gear B and C, creating the inconsistency.

Table 5 Gear Shaft B class/quality achievement summary			
Quality grade assessment	ANSI B92.1-1970	AGMA 2015-A01	
Test Piece	Spline A	Gear B	Gear C
WP2.1-5	5	10	8
WP2.1-6	4	12	9
WP2.1-12	5	10	8
WP2.1-15	6	9	9
WP2.1-19	5	12	10
WP2.1-20	6	8	9
WP2.1-21	5	8	8
WP2.1-22	5	8	9
WP2.1-23	6	8	11
WP2.1-26	5	11	11

When evaluating the profile (PVar) and lead (LVar) data of the ten splines inspected on the Hexagon Leitz PMM-C, seven full splines conformed to a Class 5 standard when assessed against ANSI B92.1 standard, with one of these conforming to a Class 4. Breaking the splines into individual flanks, 99.375 percent flanks conformed to a Class 5 with respect to profile (PVar) and 98.889 percent a class 5 with respect to lead (LVar). When assessed against a Class 4 95.625 percent flanks conformed to a Class 4 PVar and 78.75 percent a class 4 LVar. These results show a high level of repeatability which enhanced the confidence of the gear skiving process to produce splines with excellent productivity. The program run for Spline A took 1 minute 36 seconds in total including tool change, with only 58 seconds in cut, to repeatedly gear skive to the above standards. Figure 15 shows the profile section of the inspection report of an example spline conforming to a Class 4.

The objective of the project for dynamic analysis was to develop a simulation toolkit to simulate gear skiving mechanistic process requirements and to provide insight for feasible parameter selection for a range of gear and spline geometries. The AMRC applied process monitoring, optimization, and the development of a cutting depth optimization software for gear skiving, through consideration of the process optimization aspects of this project through practical data capture, analysis, processing, and interpretation of data. This data included audio recording during the cutting process, the endured spindle forces, and the static impact testing results.

Tool life

After the iterative parameter development of Gear Shaft B trials, a short tool life assessment with consistent parameters was performed. Of the nineteen additional test pieces produced in the tool life trial, only two were evaluated by the Hexagon Leitz PMM-C, due to budget and time constraints. The mid-batch test piece—WP2.2-10—and the final test piece—WP2.2-20—were selected to give the best overview of overall batch performance. Table 6 summarizes the performance of these two test pieces.

Based on the two inspected test pieces, the repeatability of the process was in question. As the tool began to wear throughout the trial, it was anticipated that the performance would decrease as the trial progressed. As Table 6 shows, the quality of Gear B was improved on the final test piece when compared to the mid-batch test piece; the assumption from this is that there was a lack of consistency between all nineteen tool life test pieces, which were produced as direct repeats, without any parameter alterations.

Images of the tool were taken prior to and on completion of the trials. Comparison of these images showed the tools used to produce the two external helical gears appear to have worn, however, the visible wear was minimal. The tool used to produce the internal spline had no visible signs of wear under the microscope. The tool wear progression of the three gear skiving tools used for Gear Shaft B has been compared before the trials, after 26 gears/splines and after 46 on completion of the experimental trials—Spline A in Figure 16, Figure 17, Figure 18, Gear B in Figure 19, Figure 20, Figure 21 and Gear C in Figure 22, Figure 23, Figure 24.

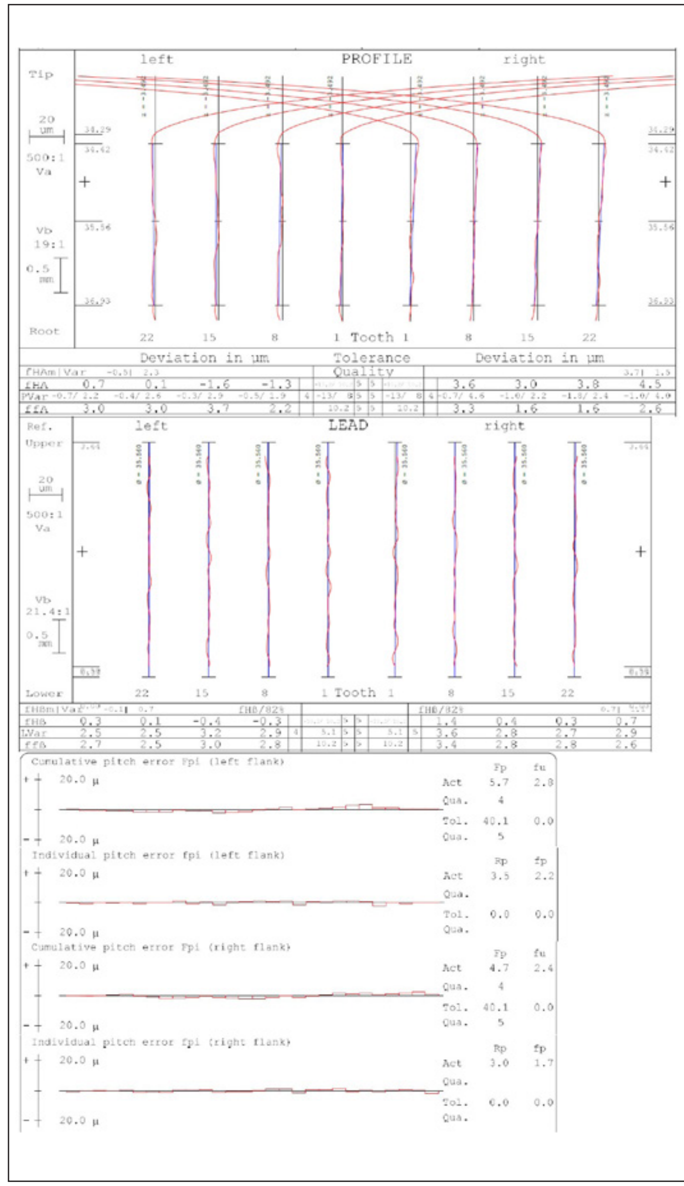

Figure 15 Extract of the inspection report for WP2.1-6.

Table 6 Gear Shaft B class/quality comparison for tool life

Quality grade assessment	ANSI B92.1-1970		AGMA 2015-A01			
Test Piece	**Spline A**		**Gear B**		**Gear C**	
Gear feature	**Profile**	**Lead**	**Profile**	**Lead**	**Profile**	**Lead**
WP2.2-10	4	5	12	10	8	8
WP2.2-20	5	4	9	9	9	9

Analysis of the tool images along with the gear inspection reports implies that all three tools could continue to skive gears to the same standard as was achieved during the tool life trial. The tools had therefore shown the manufacturability of at least 46 components, removing 149.84 in^3 of material between regrinds, despite the varied parameters (some of which were sub-optimal) used during this trial.

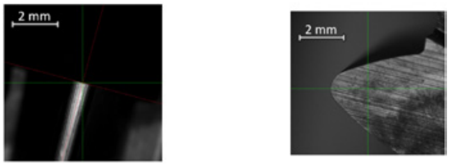

Figure 16 **WP2 Gear Shaft B, Spline A 0 Gears produced Tooth 1—Tip (left) Face (right).**

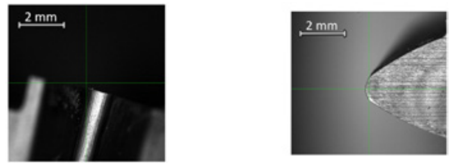

Figure 17 **WP2 Gear Shaft B, Spline A 26 Gears produced (Material removed: 0.9594 in^3) Tooth 1—Tip (left) Face (right).**

Figure 18 **WP2 Gear Shaft B, Spline A 46 Gears produced (Material removed: 1.6974 in^3) Tooth 1—Tip (left) Face (right).**

Figure 19 **WP2 Gear Shaft B, Gear B 0 Gears produced Tooth 1—Tip (left) Face (right).**

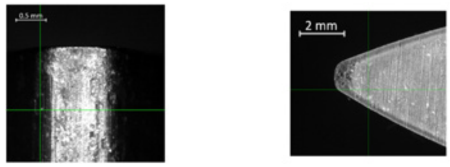

Figure 20 **WP2 Gear Shaft B, Gear B 26 Gears produced (Material removed: 84.69 in^3) Tooth 1—Tip (left) Face (right).**

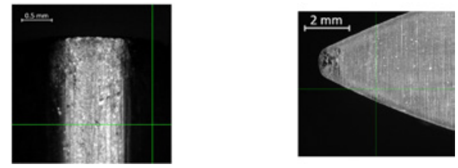

Figure 21 **WP2 Gear Shaft B, Gear B 46 Gears produced (Material removed: 149.84 in^3) Tooth 1—Tip (left) Face (right).**

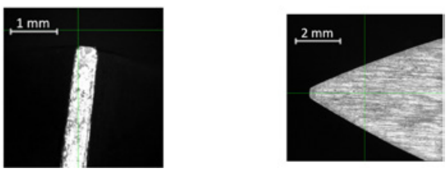

Figure 22 **WP2 Gear Shaft B, Gear C 0 Gears produced Tooth 1—Tip (left) Face (right).**

Figure 23 **WP2 Gear Shaft B, Gear C 26 Gears produced (Material removed: 58.13 in^3) Tooth 1—Tip (left) Face (right).**

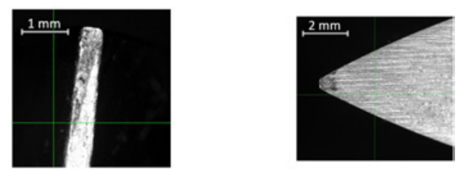

Figure 24 **WP2 Gear Shaft B, Gear C 46 Gears produced (Material removed: 102.85 in^3) Tooth 1—Tip (left) Face (right).**

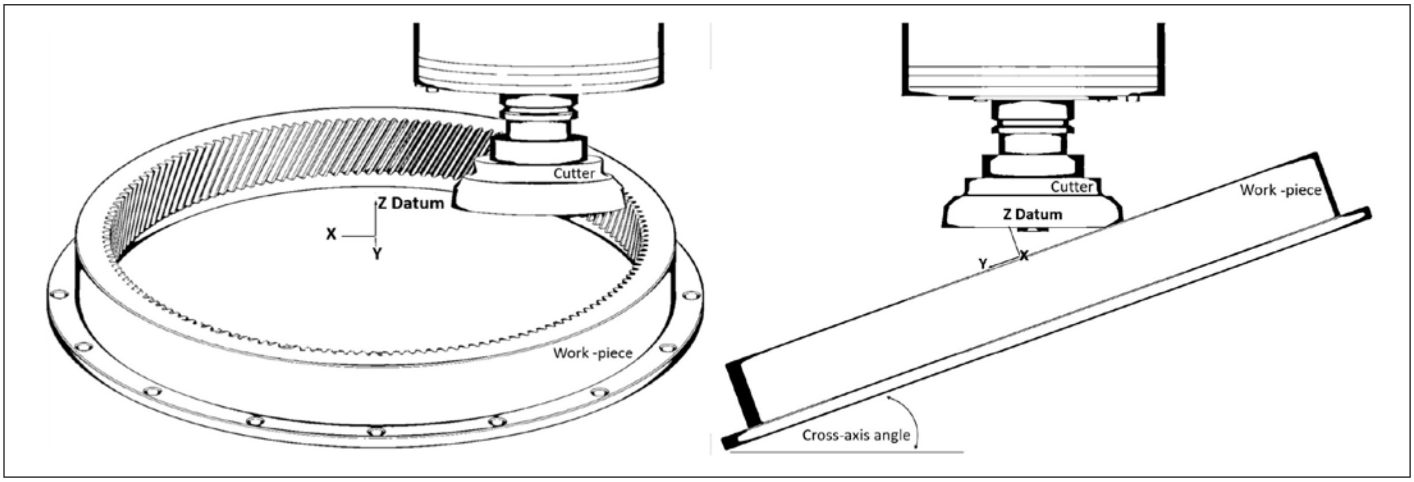

Figure 25 **Proven gear skiving strategy in the XZ (left) and YZ (right) planes.**

Case study 3

In the initial stages of Experiment 3.2 trials gear skiving the right-hand ring gear, the methodology and setup to use were defined as illustrated in Figure 25.

Six gears were produced to full depth, trialing depths of cut and parameters generated by the mechanistic force model to a force limitations of 1,000 N on the first gear produced and 500 N on the final gear. Between these gears, a range of parameters (spindle speeds, feed rates, depth of cut) and methods, including spring passes and multiples of finishing cuts, were tried to improve an inconsistent/wavy surface texture that was produced on the flanks when gear skiving. The surface texture was improved through these trials but was not eliminated. The final surface and an extract of the lead inspection report are shown in Figure 26.

The final Ring Gear produced achieved a Class 10 ANSI B92.1-1970 for profile, 11 for lead, and cumulative pitch with a runout of Class 9. Analysis of the lead shows that the slope deviation is conforming to the targeted Class 7. The form deviation values, however, were more representative of a class 10 gear in the majority of cases but achieved a Class 11 overall. A deeper analysis of the profile results showed more consistency with the majority of results, equating to Class 10.

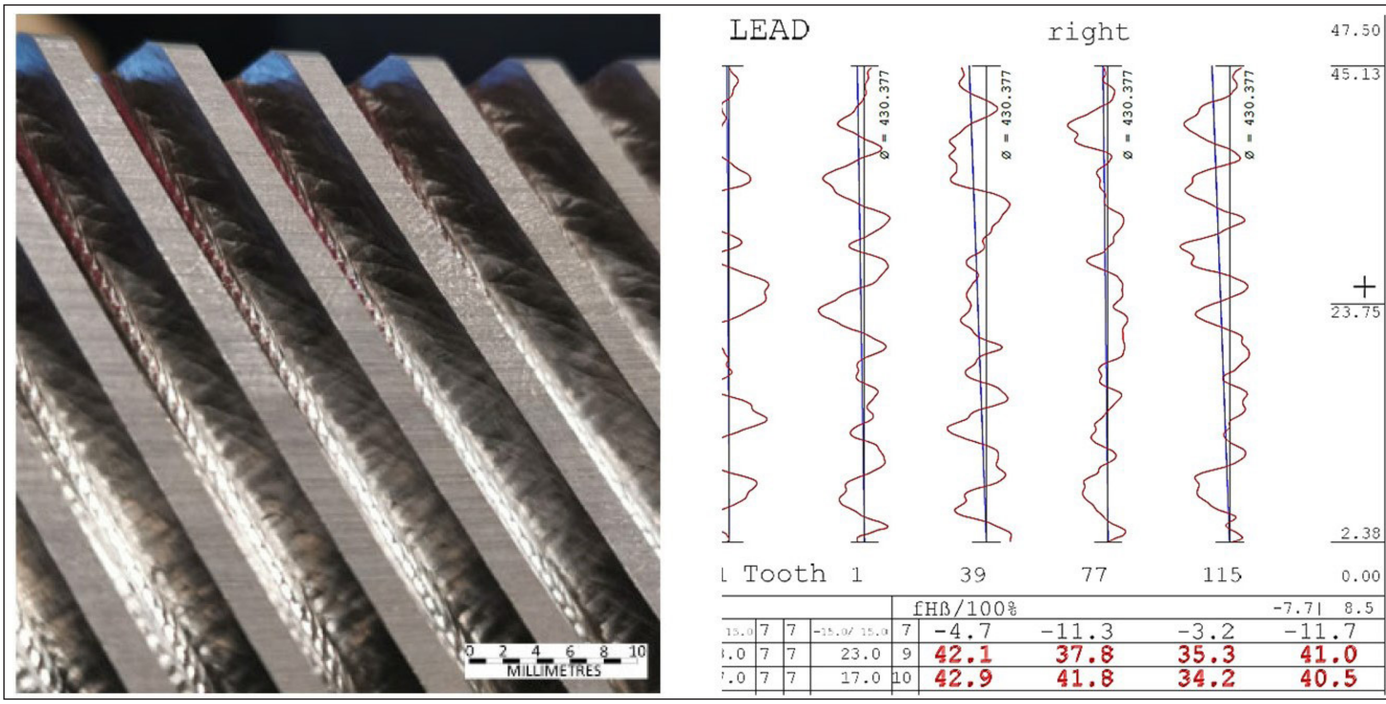

Figure 26 Final surface finish (left) and extract of lead inspection (right).

Tool life

Throughout the duration of the ring gear trials, a range of parameters was trialed in an attempt to refine the cutting process. Some of these were sub-optimal, hence the gear skiving tool was observed to be worn after the production of six test pieces. Figure 27 and Figure 28 compare a tooth of the gear skiving tool before use and after the six test pieces.

Due to the size of the ring gear compared to the Pulsator and Gear Shaft B, the tool life was not anticipated to meet the same number of gears per tool, as the material removal per gear was substantially increased. The ring gear has over five times the number of teeth of the other three gears discussed. When the volume removed was compared, the ring gear results exceed the life of the Pulsator, 62.11 in^3 to 40.45 in^3 (912 teeth to 609) respectively. But the tool did not achieve the same results as the two used to produce the gears in Gear Shaft B, where 149.84 in^3 and 102.85 in^3 were removed (1,196 and 1,334 teeth) with minimal wear observed.

However, the tool life of the Ring Gear was expected to improve under optimized production parameters.

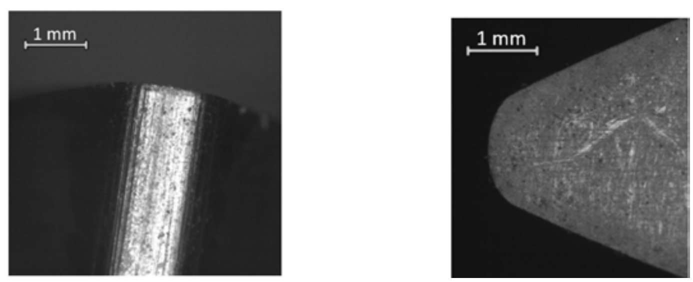

Figure 27 WP3 Ring Gear, 0 Gears produced Tooth 1—Tip (left) Face (right).

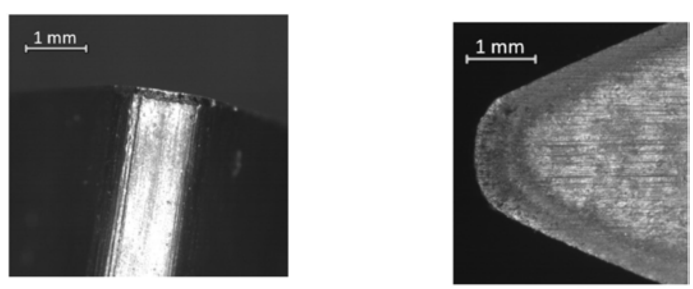

Figure 28 WP3 Ring Gear, 6 Gears produced (Material removed: 62.11 in^3) Tooth 1—Tip (left) Face (right).

Conclusion

AMRC is specializing in developing gear machining methods using multifunctional 5-axis machine tools in partnership and collaboration with partner companies. This project has demonstrated a viable machining method, applicable to multifunctional machine tools, in gear skiving. This modern gear-cutting process is gradually being adopted by industry, but its application to date has been considered a secretive black art. The focus is to develop and quantify the capabilities and publicize this for the benefit of the industry.

In machining batches of the initial Pulsator test geometry during Experiment 1.1, with varying force parameters, all components conformed repeatedly to an AGMA 2015-A01 Class A7 (AGMA 2000-A88 class Q10).

Experiment 1.2 complemented previous tool life assessments on the same geometry completed at the AMRC by achieving a tool life of 20 and 21 gears.

Further test geometries were trialed, including helical gears and internal splines. An AMRC software model was developed to predict cutting forces and establish cutting parameters for new geometries in order to expedite the process development. A range of cutting parameter strategies was employed to establish an optimal approach for enhanced quality and reduced vibration. Cutting tool life was established as in excess of 45 components for this range of geometries.

The final work stream discussed successfully developed skills to devise a design of a planetary gearbox representative of a number of industry sectors, which will allow for future technology development and demonstration, which can be directly relevant to a number of industries. Process capability and an understanding of how to rough ring gears via the novel gear skiving method on a multifunctional machine tool were achieved through the development of previous experience and refinement of the mechanistic force model to assist in parameter selection.

This development and validation allowed the achievement of a Class 11 ANSI B92.1-1970 gear in approximately 35 minutes, including a final spring pass. Some earlier gears were produced in less than 20 minutes but to reduced quality. A closer look at tool design for performance improved the understanding of how the mechanics of tool design affects capability, highlighting an area of opportunity for future research and collaboration with tooling suppliers. Further to this, the project built on previously established stakeholder relationships through collaborative investigation, feedback, and discussion at the design, manufacture, and analysis stages of the project, which proved great value in the AMRC's wide network of internal teams and external partners.

Gear skiving offers great opportunities for production with step-changing productivity, particularly for internal gears, whilst offering high-quality finishing capabilities and being applicable on a 5-axis machine tool with its inherent flexibility and multifunctionality. The development and application of the toolkit proved beneficial and showed to be applicable to a range of gears with great potential for time saving.

Future vision

Through this project, AMRC has gained an understanding of how to translate the excellent performance obtained for a baseline gear geometry to a range of further geometries, yet there remains a great deal to learn about the process in order to develop its performance. Areas of opportunity include:

- Further development of the mechanistic force model would be advantageous. A design of experiments (DOE) approach would allow for a number of variables to be investigated and subsequently, feed into the model to improve performance and understanding.
- A continued investigation with the aim of removing the inconsistencies in the surface of the flanks would prove beneficial to all future gear skiving work on the Okuma MU8000V-L.
- From a dynamics point of view, an enhancement would be anticipated by using an artificial intelligence (AI) method. For example, the vibration could be monitored, and process parameters were then optimized during the machining process through reinforcement learning methods.

The planetary gearbox assembly is now designed, and so the planet gears, planet carrier, and sun gear, as well as the ring gears, are now available as baseline geometries, without IP restriction, to develop and showcase numerous manufacturing technologies.

AMRC and our partners are actively pursuing routes to furthering the research on gear skiving in these areas and would welcome engagement from AGMA members and others in opportunities to collaborate.

Acknowledgements

The authors would like to thank the High-Value Manufacturing Catapult and Innovate UK for funding the research detailed in this paper to allow the AMRC to develop and understand the capability of the gear skiving process.

Thanks to the three tooling suppliers; Dathan Tool & Gauge Co. Ltd., Horn Cutting Tools Ltd. and Sandvik Coromant AB for their continued development, interest, and support in the area. The machine supplier NCMT has assisted with data collection, analysis, and development through much of the AMRC's gear skiving development work on the OKUMA platforms for years, which reaches beyond the remit of this paper.

Also, thanks to Dontyne Systems Ltd. for providing software, training, and support to allow the design and analysis of the range of gear profiles that have been used throughout this paper.

And a final thank you to the British Gear Association's Special Interest Group for Modern Manufacturing for continued support and for providing a range of expertise and many years of collective experience that provided vital recommendations and advice in the design stages, with a special mention to the Newcastle University Design Unit for allowing the AMRC to adopt one of its gear profiles and for their continued support.

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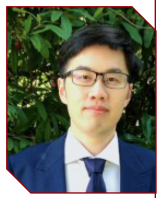

Dr. Chao Sun was a Technical Lead working within The University of Sheffield Advanced Manufacturing Research Centres (AMRC) Machining Group. He is an experienced post doctoral researcher and has been working at the AMRC for 5 years. Before he joined the AMRC, he did his postdoctoral research on machining dynamics at the University of British Columbia in Canada. He joined the AMRC as a Project Engineer working on robotic machining dynamics. Later, he worked as a Technical Lead in machining dynamics. He and his colleague developed the power skiving force simulation model and helped to optimise the power skiving process.

Dr. David R. Curtis is the Research and Technology Manager for The University of Sheffield Advanced Manufacturing Research Centres (AMRC) Machining Group and Co-Director of the Industrial Doctorate Centre in Machining Science. He joined the AMRC in 2009 and has delivered both fundamental research and industrial impact in the subtractive process technology field supporting primarily the aerospace and defence sector. His research specialism is in abrasive processes but this extends into conventional and assisted hybrid subtractive processes. His technology development focus spans new materials, processing of near net components, digital / sustainable / productive subtractive, zero defect manufacturer as well as flexible subtractive platforms.

Michael Farmery is a Technical Lead working within the University of Sheffield Advanced Manufacturing Research Centres (AMRC) Machining Group. He is an experienced Engineer and joined the AMRC in 2013 progressing to Aerofoils and Gear manufacture Project Engineer and is now technically leading the groups research in the field of gear manufacturing. His current focus is on research and development for gear manufacturing, particularly gear and spline tooth machining using novel methods such as power skiving and reciprocating broaching units primarily on multifunction CNC platforms. He is also on the Technical Research Management Committee for the British Gear Association (BGA).

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AddUp

PARTNERS WITH ECM GROUP FOR ADDITIVE HEAT TREATING SOLUTIONS

AddUp, a major player in the field of metal additive manufacturing and the ECM Group, creator of innovative thermal solutions, have signed a partnership to develop high value-added solutions for the thermal treatment of 3D printed metal parts.

AddUp's expertise lies in two additive technologies: powder bed fusion (PBF), ideal for the manufacture of metal parts with complex geometries and improved performance and directed energy deposition (DED), which is ideal for the repair of parts and adding function. AddUp is not only a manufacturer of 3D printing machines, but also a producer of industrial metal additively manufactured parts.

To manufacture a part with PBF technology, it is not enough to design it in CAD and print it in a machine. The post-processing of the part is crucial. Therefore, AddUp looked to the ECM Group to combine experience and knowledge to develop a very high value-added solution for this essential step in the AM process.

The ECM Group is a French heat treatment equipment manufacturer and is globally recognized for innovative technologies, processes, and services. ECM vacuum furnaces have been developed for more than 50 years and constitute a reference base of several thousand units sold worldwide. The ECM Group provides vacuum furnace expertise to the heat treat production needs of advanced sectors such as: medical, aeronautics, e-mobility, and renewable energies. With exceptional experience in the control of atmospheres, gases, and thermal applications, the ECM Group is a leading partner for AddUp to meet the requirements of the advanced sectors.

"At ECM, we are convinced of the potential of metal additive manufacturing, some applications of which will lead to mass production," says Yvan Trouillot, sales director for ECM. "Our alliance with the French company AddUp, a key player in this market, will allow us to bring our know-how for the development of innovative thermal solutions to this market, as we have been doing for more than 20 years in the international market of thermal treatment of conventional parts. Together, our ambition is to develop these technologies to help our customers progress by offering them the best solutions on the market."

Heat Treatment: A Crucial Step in Additive Manufacturing

During the 3D printing phase, metal parts are manufactured to

the desired shape by successive layers of metal powders fused by one or more lasers. The speed at which the laser moves creates a rapid heating and cooling of the material which can cause expansion or shrinkage. This often creates constraints inside the parts produced.

To improve the homogeneity of the material and reduce its internal stresses to obtain the right mechanical properties, it is often necessary to apply one or more heat treatment cycles to the metal parts after they are printed.

"Heat treatment operations are just as important as the 3D printing phase itself, both to reduce the internal stresses generated during the "lasering" phase and to adapt the microstructure of the material and its properties," said Jean Rivoire, parts production manager at AddUp. "This is why, within AddUp, we are seeking to strengthen this expertise with one of the market leaders; both to reinforce our internal production capacities and to offer a complete solution to our customers wishing to integrate the production of parts made in 3D metal."

Reduce Manufacturing Costs and Improve the Performance of 3D Manufactured Parts

The ECM Group and AddUp will create and develop solutions that will help current and prospective customers reduce their manufacturing costs and lead times, while improving the performance of their parts produced using additive technology.

The two groups will work jointly on a development program to define the appropriate specifications for a heat treatment solution adapted to additive manufacturing applications. Next, the ECM Group will design and industrialize a suitable vacuum furnace system according to the specifications defined during this joint development program.

ecm-furnaces.com
addupsolutions.com

Star Cutter

INCREASES COMMITMENT TO ALPENA COMMUNITY COLLEGE CENTER FOR MANUFACTURING EXCELLENCE

Star Cutter Company has announced that it will be continuing its support of Alpena Community College's manufacturing programs through increased monetary and equipment donations to the college. The donations will be supplied over a two-year period of time, helping to bring state-of-the art manufacturing equipment, such as grinding machines and optical comparators, to the center for hands-on training opportunities.

"Manufacturing is core to the local economy, and we understand the importance of attracting talented young people into the skilled trades," said Jeff Lawton, Star Cutter president and COO. "Our relationship with Alpena Community College enables students to train on advanced equipment, preparing them to work for companies such as Star Cutter. To us, investing in the school is an investment in Star's future."

Star Cutter has three manufacturing facilities located near Alpena Community College, all of which work with the school to leverage educational opportunities as well as recruiting and hiring graduates from the manufacturing programs. These facilities include H.B. Carbide in Lewiston, Mich., a manufacturer of carbide blanks and pre-form tools; Tawas Tool, a manufacturer of gear tools; and Ossineke Industries, which manufactures custom tooling for a variety of applications.

starcutter.com

DN Solutions

OPENS NEW TECHNICAL SUPPORT OFFICE

DN Solutions (formerly Doosan Machine Tools) recently announced the opening of a Technical Support Office in Troy, Michigan. The new location will provide process improvements and technical solutions to both dealers and customers.

"As our business continues to grow, we plan to open additional service centers like this one to ensure that fast,

dependable DN Solutions technical support is always accessible," said Jim Shiner, vice president of sales and marketing at DN Solutions America. "With a location well positioned to offer technical support in the central United States, this office is staffed with a team of experts who are on a mission to provide support when and where you need it."

dn-solutions.com

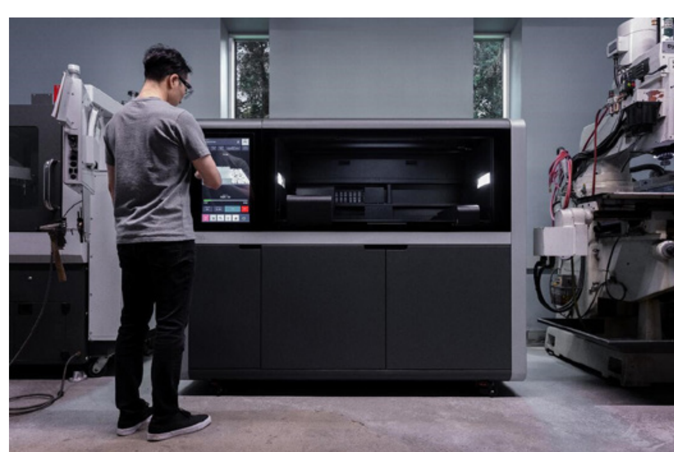
Desktop Metal

EXPANDS GLOBAL PARTNERSHIP WITH SOLIDCAM

Desktop Metal has announced it has expanded its relationship with SolidCAM.

SolidCAM, which was founded in 1984, has offered Desktop Metal products in Germany since 2021. Now, it will offer Desktop Metal solutions for direct printing of metal to customers in the United States, where SolidCAM has technology centers at its U.S. headquarters in Newton, Pa., and Rancho Cucamonga, Calif., as well as the United Kingdom, Israel and India. In all, SolidCAM has about 100 direct sales team members worldwide.

Additionally, new CNC + AM Center of Excellence showrooms are currently being completed in Pennsylvania, Germany, and the UK to demonstrate how Desktop Metal's AM 2.0 solutions complement traditional subtractive machining



technology and workflows. Additional facilities are also slated for completion in California, Israel and India.

"The Desktop Metal team is delighted to announce an expansion of our relationship with SolidCAM, a brand that is long trusted by machinists worldwide," said Ric Fulop, founder and CEO of Desktop Metal. "This expanded partnership means that more CNC professionals will learn how easy it is to 3D print and sinter complex designs on our Studio System and Shop System metal AM offerings, freeing up capacity on CNC equipment, as well as machinist's time. Additive manufacturing technology is truly complementary to machining, and we're eager to deliver that message to the market in partnership with SolidCAM."

"Our Schramberg Technology Center has already added a Desktop Metal Studio System to its current CNC machines, and we're in the process of adding more Studio System and Shop System printers to our facilities worldwide so we can demonstrate how this additive manufacturing technology is complementary to CNC machining equipment," said Dr. Emil Somekh, founder and CEO of SolidCAM. "The growing impact of additive manufacturing has been well documented. During the COVID-19 epidemic, 3D printing played a critical role in repairing vulnerabilities in supply chains, especially in the medical sector, and we think it can help improve the throughput of supply chains that remain challenged today."

SolidCAM will be showcasing Desktop Metal equipment and solutions at IMTS 2022 in Booth #134502. Desktop Metal will also have two booths at the show, #433103 #432212, where it will be showcasing its metal, polymer, and digital metal casting Additive Manufacturing 2.0 solutions.

desktopmetal.com

Index

ESTABLISHES SERVICE TO REBUILD TOOL HOLDERS IN NORTH AMERICA

Index has established a dedicated service department to rebuild tool holders at its North American headquarters in Noblesville, Indiana. Previously, the company processed all such rebuilds at its parent company in Germany. By investing in bringing this capability to the United States, Index expects to cut lead times for rebuilds by 50–70 percent.

When Index rebuilds one of its tool holders, engineers fully disassemble the unit and inspect the housing and shafts. Any internal mechanical component demonstrating signs of wear is replaced, ensuring that the tool holder is fully restored to its original operating condition. Index offers this service for tool holders sold with any of its machines, including its production turning centers, turn mills, CNC multi-spindles and the Traub line of sliding-headstock lathes. Furthermore, each rebuilt tool holder is backed by a 6-month warranty.

"We are constantly looking for ways to more comprehensively meet our customers' needs," said Matt Voyles, director of customer support and operations at Index. "We've had a lot of customers tell us that they want the level of quality we provide when rebuilding a tool holder, but that they can't wait the amount of time it takes to send their unit to Germany. The investment we've made in creating a US-based tool holder rebuild department provides an immediate and clear benefit to customers."

us.index-traub.com

FANUC Mexico

ANNOUNCES NEW HEADQUARTERS

FANUC recently hosted a grand opening and technology open house at its new robotics and automation headquarters in Aguascalientes, Mexico. The new 109K square foot facility will provide sales, demonstrations, training, engineering, and customer service. The grand opening included welcome remarks from the governor of Aguascalientes and FANUC corporate executives, followed by a ribbon cutting ceremony, facility tours, and a large showroom filled with robotic and CNC demonstrations.

"We're expanding to better serve our customer base of automotive, aerospace, consumer goods, and other manufacturers in Mexico and Latin America looking for automation solutions," said Mike Cicco, president and CEO, FANUC America. "We've seen a significant increase in demand for our products in this market, so having a larger facility underscores our commitment to helping companies improve their production processes and compete on a global scale."

FANUC Mexico demonstrated a variety of automation technologies designed to help customers increase their production capabilities, overcome labor issues, and remain competitive.

fanucamerica.com/fanuc-mexico

Velo3D

PROVIDES ADDITIVE SOLUTION TO PRATT & WHITNEY

Velo3D, Inc. recently announced that Pratt & Whitney has acquired an end-to-end solution from Velo3D to evaluate the Sapphire printer for manufacturing production jet engine components. This is the first Sapphire printer to be located at Pratt & Whitney; it previously utilized Velo3D's contract manufacturer network to produce printed and finished parts.

Pratt & Whitney and Raytheon Technologies are experienced and accomplished users of Additive Manufacturing (AM) technologies with extensive knowledge across various platforms and applications. Raytheon Technologies is a launch participant of President Biden's AM Forward initiative, a new program encouraging companies to explore the use of additive manufacturing to transform supply chains and drive innovation. Raytheon Technologies' commitment includes seeking small-medium-enterprise manufacturers' involvement in over 50 percent of its requests for quotes on products manufactured using additive technologies, as well as seeking to simplify and accelerate the procurement process of AM parts.

"Metal additive manufacturing can transform aviation and space systems by delivering unprecedented part consolidation, lighter weight components, and more efficient systems," said Benny Buller, Velo3D founder and CEO. "We're pleased to see Pratt & Whitney move forward with their own Sapphire XC printer. We're eager to see how they innovate their most mission- critical designs using our end-to-end solution, and how the economies of scale of an in-house system help increase addressable use-cases."

"Pratt & Whitney looks forward to future applications using the Sapphire XC printer, and collaborations with other potential suppliers with the Velo3D capability, for Pratt & Whitney GTF and advanced engine programs," said Jesse Boyer, fellow, Additive Manufacturing, Pratt & Whitney.

The company's new Sapphire XC printer is calibrated to print in Inconel 718, a nickel-based superalloy well-suited for extreme temperatures.

The Raytheon Technologies Research Center is the company's central innovation hub where engineers, scientists and researchers explore and develop new, transformative technologies. The center provides the company's businesses with

innovations and solutions to critical customer problems in a wide range of research areas, including complex integrated systems, advanced materials and manufacturing, autonomy-enabling technologies, electrification, and sustainability.

This is made possible by Velo3D's end-to-end solution, which includes Flow print preparation software, the Sapphire family of printers, Assure quality assurance software, and Intelligent Fusion underlying manufacturing processes. The system uses a set of known recipes to achieve the geometries desired without using supports and monitors the build process layer-by-layer to ensure the highest quality.

velo3d.com

Winsmith

REDESIGNS WEBSITE AND LAUNCHES NEW PERFECTION GEAR WEBSITE

Winsmith, a diversified manufacturer of highly engineered gearing products, recently announced the redesign of their website and the launch of a new Perfection Gear website.

The updated Winsmith website re-organized the product pages by gearing type and includes new content and product images. Additionally, Winsmith product configurators are more easily accessible.

Perfection Gear products now have their own website for swing and rotation drive solutions. The new website (perfectiongear.com) features dependable gearing solutions for aerial trucks and lifts, service trucks and other lift equipment.

"Our websites have been designed to help visitors quickly find information on the gearing or drive solutions they need." said Alan Kupchanko, product manager, Winsmith. "And we have a system in place for customers to quickly reach out to our team with product inquiries and other questions."

winsmith.com

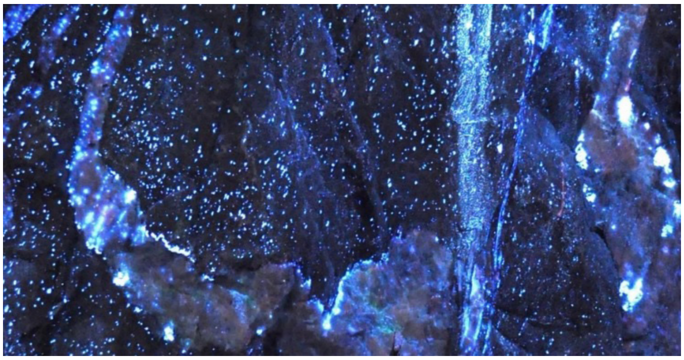
Tungsten Industry

UPDATES CONFLICT MINERALS LEGISLATION COMPLIANCE FRAMEWORK

The Tungsten Industry Conflict Minerals Council announced the release of an updated version of its Tungsten Framework document.

Supported by two leading tungsten industry trade associations, the International Tungsten Industry Association (ITIA), London, England, and the Refractory Metals Association (RMA), Princeton, New Jersey, a working group of tungsten refiners established an Initiative that provides a mechanism for industry members to demonstrate their compliance with Security and Exchange Commission regulations under Section 1502 of the Dodd-Frank Wall Street Reform and Consumer Protection Act. The Initiative will be administered by the Tungsten Industry Conflict Materials Council (the "Council" or "TI-CMC").

Under the Initiative, as monitored by the Council, assurances are provided to the tungsten supply chain that conflict minerals, as defined in the regulations, processed at the smelter/refinery level are in compliance with those regulations. This Initiative offers a straightforward approach for firms that must make declarations on their supply chains.



The Initiative is based on the recognition that refiners, pivotally positioned as they are in the tungsten supply chain, can best determine the source of tungsten materials made available to the global marketplace.

Tungsten raw materials such as wolframite must undergo a complex refining process before they can be used in downstream products for industries such as automotive, aerospace, machinery and electronics. Tungsten refining is an involved chemical or pyrometallurgical process far beyond the means of artisanal operations in regions covered by the new legislation, a fact specific to tungsten on which the approach of the Initiative is based.

Firms participating in the Initiative must adhere to a supplier code of conduct, and if inquiry reveals that materials originated in concerned regions, the framework under the Initiative is consistent with the due diligence guidelines of the Organization for Economic Cooperation and Development.

ti-cmc.org/commitment.asp

October 3–5—Furnaces North America 2022

The heat treat industry comes together at FNA (Indianapolis) to deliver the latest technology on maintenance, equipment, energy, compliance, quenching, productivity, metallurgy, cleaning and more. Top suppliers will be on-hand in the exhibition hall to answer questions and discuss the future of heat treating. One of the biggest features of FNA is the quality of the technical sessions. Experts from all over the world share their knowledge on the latest trends and technologies in equipment, processes, and materials. Attendees will experience over 35 technical sessions over two days, on the latest hot topics, trends, and technology impacting heat treat operations today.

geartechnology.com/events/5035-furnaces-north-america-2022

October 17–19—AGMA Fall Technical Meeting 2022

The gear industry is faced with emerging trends and innovations challenging engineers to stay course with the latest design, quality, materials, and analysis technology. It is imperative that researchers and gear engineers communicate ideas with fellow experts in the field. AGMA's annual Fall Technical Meeting (FTM) is the forum to share research and disperse knowledge for the benefit of the global gear industry. Each year, authors selected by AGMA write peer-reviewed technical papers on gear topics such as design and analysis; manufacturing and quality; materials, metallurgy, and heat treatment; operation, maintenance, and efficiency; and gear failure. The authors will present their work at the 2022 FTM in Rosemont, Illinois (outside of Chicago). All papers presented at FTM will be indexed in Scopus, the international database of peer-reviewed literature.

agma.org/events/fall-technical-meeting-ftm/

October 18–20–AGMA Gear Materials

Attendees will learn what is required for the design of an optimum gear set and the importance of the coordinated effort of the gear design engineer, the gear metallurgist, and the bearing system engineer. Investigate gear-related problems, failures and improved processing procedures. Class takes place at the Doubletree Hilton Chicago Midway Airport Class from 8:00 a.m.–5:00 p.m.

agma.org/education/advanced-courses/2022-gear-materials/

October 24–30—Bauma 2022

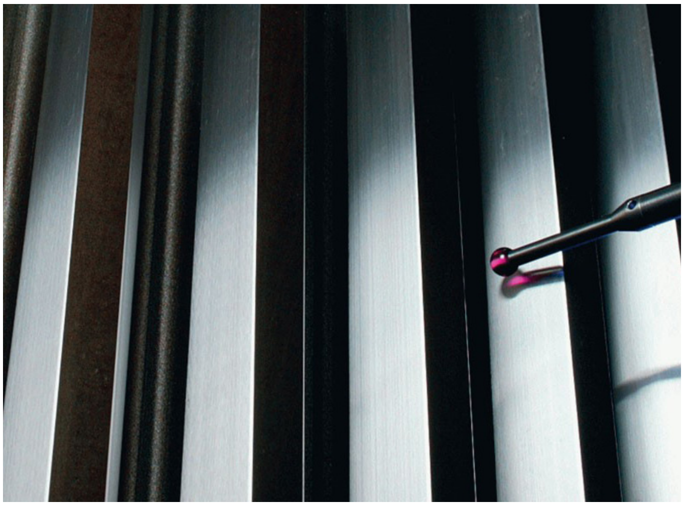
Bauma 2022 (Munich) will focus on five key topics including: Zero emissions, the digital construction site, tomorrow's construction techniques and materials, autonomous machines and mining—sustainable, efficient, reliable. The show examines the latest products and technology for construction machinery, building material machines, mining machines, construction vehicles and construction equipment. Bauma features more than 3,500 exhibitors and nearly 630,000 visitors.

powertransmission.com/events/903-bauma-2022

November 9–10—Aachen Conference on Gear Production

At this year's Aachen Conference on Gear Production (ACGP), which is organized hand in hand by the Machine Tool Laboratory WZL of RWTH Aachen University and the FVA Forschungsvereinigung Antriebstechnik e.V., topics ranging from work preparation to soft and hard finishing, quality control, assembly and operation of gears will be addressed including-process design and tool design in line with requirements to the production of individual gear geometries and measures for continuous quality assurance. In addition, aspects of digitalization and improving sustainability in the production and application of gears will be presented.

geartechnology.com/events/5036-aachen-conference-on-gear-production



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Your IMTS Moment of Zen

Matthew Jaster, Senior Editor

Don't let the largest U.S. manufacturing trade show intimidate. This is an opportunity to see firsthand how manufacturing/engineering applications are evolving in real time. Here are a few stops to make along the way:

We're No Longer Entering the Digital Domain, We're Fully Assimilated

The Controls & CAD-CAM Pavilion just outside the East Building at McCormick Place is always busy during IMTS week. I've affectionately called it the "Acronym Arena" in the past where software engineers discuss the advantages of ERP, OEE, RFQ, SPC, SOP, MES and KPIs.

Here, a 15-minute presentation can jump from cybersecurity to digital twin technology in less time than it takes for me to put cream in my coffee. If you don't believe this is the future of the manufacturing shop floor, I urge you to spend half a day in the Controls & CAD-CAM Pavilion collecting brochures.

This is the sabermetrics of machine tools. This is where a plant manager goes to discover that the three grinding cells, he/she has implemented in 2022 are currently 35 percent efficient. Salespeople can tell half-truths, but the data is right there in front of you on a spreadsheet and the numbers never lie. The industry has successfully integrated machine data so that everyone from design to production to distribution to the sales team has direct access to the same information.

We celebrate this new era of data-driven manufacturing where machine vision, augmented reality, control technology and simulation are becoming the norm. According to the IMTS team, companies like Mazak, Haas and Hurco are building machine libraries using *Autodesk*. Digital resources are being acquired to increase CNC and additive manufacturing productivity. Data solutions are creating productivity benefits in machines in mere weeks instead of months.

Join the Borg and plug-in this September during IMTS!

Your Next CEO?

The Smart Student Summit brings together students from elementary school through college, scout troops, robotics and STEM clubs, home-schooled students, and educators of all levels to explore the latest Industry 4.0 digital technologies driving manufacturing today.

Students can look forward to fun, interactive, and engaging exhibits from leading manufacturers demonstrating breakthrough technologies such as artificial intelligence, augmented reality, virtual reality, generative design, digital twin, and more. Attendees will go beyond learning about manufacturing technologies to better understand how advanced machinery and software synchronize to build the equipment and infrastructure necessary for cutting-edge products and programs across industries. Who knows, your next boss could be the 14-year-old kid programming the robot in the corner of the exhibit hall.

The Conference to End All Conferences

The IMTS exhibition halls can draw in attendees like moths to the flame. They offer amazing visual machining demonstrations, virtual reality games, 3D-printing projects, and the occasional free bag of popcorn. It's hard not to feel like an engineer when you're perusing the halls even if you're simply there to write engineering stories.

You can certainly spend six days going booth to booth to better understand manufacturing technology in 2022, but don't forget to attend a conference or two during the week. IMTS boasts a comprehensive lineup of sessions on everything from IIoT and automation/robotics to artificial intelligence and material innovation. It's not hyperbole to suggest that most manufacturing sectors are represented in one form or another in the conference presentations.

Interested in solvents and chemistry? Check. System integration? Covered. Plant operations, grinding, metrology, supply chain, alternative processes? There's someone important in Chicago scheduled to discuss all these topics. Drop by a presentation or two every day to break up the chaos of the exhibition floor, your feet will thank you for it!

See you in September.

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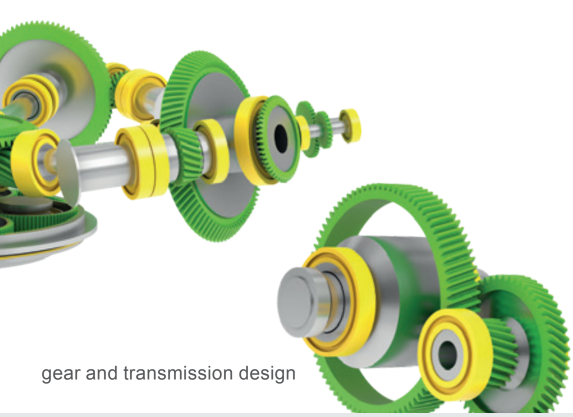

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