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FINDING THE IDEAL MATERIALS FOR GEARS

When designing and manufacturing gears, the materials used will depend on what type of gear is being made and how and where it will be used.

NONLINEAR DYNAMIC CHARACTERISTIC ANALYSIS OF A COATED GEAR TRANSMISSION SYSTEM

The nonlinear dynamic characteristic of a DLC-coated gear transmission system is analyzed by using a numerical integration approach, and the effect of the coating elastic modulus on the dynamic response is investigated.

ELECTRIFICATION IN THE AUTOMOTIVE DOMAIN

Electric vehicles are set to disrupt automotive industry trends over the years ahead, which will have an effect on gear manufacturing.

A LEADING GEAR MANUFACTURER THROUGH MANY GENERATIONS

COMPANY PROFILE  Gear Motions specializes in supplying custom-cut and ground gears for OEMs across the globe and is capable of manufacturing all types of custom gears.
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JIM ALBERTSON
ENSURING SUPPLY CHAIN CONTINUITY CREATES VALUE FOR CUSTOMERS
In gear design, incorporating the best raw materials is critical for high performance. Removing potential barriers to access those materials can streamline production and save on overall costs.

BRIAN DENGEL
DOES ALL LEARNING HAPPEN IN A CLASSROOM?
Education, mentoring, and institutional knowledge contribute to our understanding of the world, including the business world.

D. SCOTT MACKENZIE
NON-DESTRUCTIVE TESTING PART IV: ULTRASONIC TESTING
Basic operating principles include transducers, the need for calibration, limitations of reference standards, and advantages/disadvantages of the process.

Collaboration helps military veterans move into NDT careers.
ANCA launches new era of automation, intelligent solutions.
Setting our sights on 2021

Happy New Year to all our readers in the gear-manufacturing world, and, although New Year’s Day wasn’t a reset button, it did serve as a turning point into what we all hope will be a brighter future in 2021.

2020 may have been a terrible 48 months (That is how long the year lasted, right?), but Gear Solutions didn’t let that keep us from our mission of bringing the best manufacturing news and information directly to your mailbox, inbox, and browser.

Despite the pandemic, we’ve been looking forward to 2021, and we’re all hoping that the world gets back to normal as soon as possible.

As it is every year, there are some big things coming to the gear manufacturing industry in 2021, and now that the new year has arrived, we can take a moment to reflect on what’s on the gear horizon.

With things moving into a more normal mode, I hope to see all of you at the Motion+Power Technology Expo September 14–16. This year, it’s going to be in St. Louis, Missouri, and I’m excited about getting the chance to visit this city for the first time.

It’s a chance to network and reconnect with established contacts and make some new ones, and it will be a welcome return to face-to-face interaction.

More than 300 exhibitors from across the supply chain including gear companies, machine tools suppliers, and electric drive solutions will showcase new products and services from industry leaders Timken Power Systems, Meritor, EMAG LLC, Gleason Corporation, Kapp Group, Mitsubishi Heavy Industry America, and others.

In the coming months, make sure you keep wearing those masks and social distancing, so we can all enjoy and take advantage of what this massive trade show can offer all of us in September.

That’s definitely something to look forward to, but as far as our January’s issue is concerned, there is quite a bit of content to sift through, including:

Regular columnist Brian Dengel took on double duty this month and penned an article on raw material used in gear manufacturing.

On the topic of coating and finishing, Yangyi Xiao, Liyang Fu, Jing Luo, Wankai Shi, and Minglin Kang share their insights on the nonlinear dynamic characteristic analysis of a coated gear transmission system.

And make sure you check out what our columnists have cooked up for January as well. They are always sharing some fascinating information.

And since it is the first of the year, I will take this opportunity to remind all of you that I am always on the lookout for articles and other submissions. It’s a great way to share your expertise while shining a spotlight on you and your company at the same time. Hit me up if you have an article idea.

Take stock in the fact that we made it through 2020, so join me and my team as we look to make 2021 even better. It shouldn’t be too hard, right?

Happy New Year, and, as always, thanks for reading!
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WE OWN WHAT WE SELL, AND WE KNOW WHAT WE’RE SELLING!
Collaboration helps military veterans move into NDT careers

Olympus, a leading manufacturer of nondestructive testing (NDT) equipment, is supporting training school Warrior To Inspector’s mission to help transition retiring military veterans into a new NDT career by providing advanced inspection instruments for their ultrasonic testing (UT) courses.

Transitioning into an NDT career can be challenging without the right training, certifications, and hands-on experience. Warrior To Inspector helps veterans find job success through their three semester, full-time NDT program that offers classroom and field training on real-world job sites. This ASNT CP-189 compliant program includes certifications in magnetic particle testing, ultrasonic thickness testing, ultrasonic shear-wave testing, phased array ultrasonic testing, and Creaform laser profilometry.

This collaboration will enable veterans to train with Olympus’ cutting-edge UT equipment used in the NDT field today. “We’re very excited to contribute to the Warrior To Inspector mission,” said Dave Menne, VP of sales and marketing at Olympus. “Kenny Greene and his team are exceptional trainers with a unique educational approach. The veterans and other civilians in the class are clearly energized to be in such an impressive program.”

Kenny Greene, resident and lead instructor of Warrior To Inspector, explained how Olympus has remained a vital resource for their programs. “During a significant project in 2004, Olympus showed how committed they were to customer service. Olympus brought in as much demo equipment as we had purchased to help ease the burden of outfitting a team of shear-wave technicians. Again in 2011, I was part of another quickly growing NDT department in need of phased array equipment. This led to a very large purchase of OmniScan™ MX2 flaw detectors, and the Olympus team exceeded all expectations again,” said Greene.

“As I am tasked to create an NDT and Pipeline Integrity Trade School that the industry has been demanding for decades, Olympus is once again there for us as we help meet the needs of military veterans and civilians and join their commitment to training tomorrow’s inspectors.”

MORE INFO www.olympus-ims.com/training-members

Big Kaiser launches online customer chat to access company experts

In order to help current and future customers with inquiries, Big Kaiser Precision Tooling has introduced an easy and convenient way to directly access the company’s experts. LiveChat is available now on bigkaiser.com.

No matter which page a customer is on, they can connect directly and instantly with one of the company’s agents in just a few clicks. Agents will be available during normal business hours and customers can leave a message after hours for help with questions on topics including:

- Application support.
- Tool presetting.
- Pricing and availability.
- Order status.
- Equipment maintenance.

Users can save a transcript of their chat for future reference. The chat feature appears on the lower right of any page on bigkaiser.com.

Big Kaiser is a worldwide leader in high-precision tooling systems and solutions for the metalcutting industry that guarantee extreme accuracy and repeatability. Big Kaiser is the North American representative of Speroni tool measuring machines, Sphinx high performance drills, mptec measuring stands, Tekusa spindle cleaners, and the...
ANCA launches new era of automation, intelligent solutions

ANCA’s launch of integrated solutions with AIMS connects sequential processes in tool manufacturing to bank the benefits of automation and integration. AIMS facilitates streamlined tool production, linking separate processes to each other and factory IT systems. AIMS provides versatile, modular options for common manufacturing challenges to optimize cutting tool production.

AIMS offers functionality that is adaptable to each factory’s needs; from smaller scale, data-based options to the full AIMS setup across a series of machines with endless possibilities. Central to any AIMS system is the AIMS Server that manages data flows between the elements of the AIMS system and established IT platforms, such as an ERP system. Building on this, customers can choose from a suite of “auto” solutions for reducing production costs, resolving labor challenges, and integrating systems to improve product and process quality. From transferring tools between operations with AutoFetch robot options to fully automated tool measurement and process compensa-

tion using AutoComp to managing data via the AutoSet hub — AIMS delivers streamlined manufacturing, with connected tool production processes integrated to IT systems that takes tool production to the next level.

“ANCA is here to provide tool manufacturers with solutions to support production that work across all industries and applications and expand to complete tool production needs. This is a new landscape for interconnected technology, working end to end,” said Chris Hegarty, ANCA Group CEO. “Integration and automation solutions provide infrastructure to manufacture tools with increased productivity and higher quality. ANCA has the industry-leading software and control capabilities to deliver a system for production management that tackles time, cost and labor inefficiencies where it counts. We are delighted to be accelerating into the fourth industrial revolution with advanced, smart factory solutions for cutting tool makers — intelligent automation for connecting processes and data management.”

More than 70 percent of ANCA customers seek machines with robotic functionality. ANCA’s world-first technology developments use automation to gain efficiencies and have helped reduce production costs by 50 percent.

The AIMS online demo exhibits interconnected grinding technology solutions that eliminate wasteful manual handling, reduce machine downtime in between batches, and take away the need to have operators constantly monitoring and adjusting production machines.
The new AutoMarkX is ANCA’s tool marking solution designed particularly for the needs of cutting tool production. ANCA already has it covered with critical tool grinding processes; CPX for blank preparation, and tool grinding on ANCA’s TX, MX, and FX tool and cutter grinders. AutoMarkX will work seamlessly alongside ANCA CNC grinders and automates the tool marking process, further extending unmanned production operations.

Tool manufacturers are seizing options that streamline processes and save labor costs. AutoMarkX is capable of automated pallet loading and takes care of the tool laser marking process, freeing up operators to perform more value-adding tasks. AutoMarkX is designed for integration with AIMS, being able to automatically receive and dispatch pallets from AutoFetch, while connectivity to the AIMS Server provides details of the message to be marked on the tools.

“This machine is efficient and compact — but more than that, it can be integrated with your ERP and AIMS, so that technology can work together. Removing the need for manual handling, our new laser marking solution pushes tool marking capabilities into lights-out production,” said Jan Irzyk, product manager.

With more than 45 years’ experience delivering CNC grinders to customers around the world, ANCA carries a reputation for delivering customer-focused innovations that meet market needs.

**MORE INFO** wwwanca.com

**AM Solutions has new technology and test center for Rösler brand**

The new technology and test center of AM Solutions — 3D post-processing technology represents a significant milestone in the development of processes and products for the post processing of products created with AM methods. The new center is outfitted with state-of-the-art engineering software and various 3D printing systems. However, the main focus is on an exceptionally well-equipped post processing section, where AM Solutions — 3D post processing technology can demonstrate an impressive range of machinery for post processing of 3D-printed components.

Additive manufacturing allows the quick and flexible production of metallic or plastic components with precisely defined material characteristics. All these components have one thing in common: Their surface requires different kinds of finishes, which must comply with the most stringent finishing specifications. These requirements pose a special challenge for the post processing of 3D-printed components. AM Solutions — 3D post processing technology is meeting this challenge head-on with its new, generously equipped technology and test center in Untermerzbach, Germany.

In its new test center with a total area of 400 square meters, the Rösler division specializing in 3D post processing solutions, can demonstrate the complete process chain of additive manufacturing. Manuel Laux, Head of AM Solutions — 3D post processing technology, explains: “It is our declared goal to develop the best possible process solutions for our customers. To do this we must be able to fully understand every detail of the additive manufacturing process and must actually be in a position to demonstrate the various manufacturing stages. Only with such a hands-on approach will we be able to take into account all the facets of additive manufacturing.” The new test center is not only equipped with the latest engineering, printing and post processing hard- and software, but the actual building was also carefully prepared, for example, suitable air intake and venting systems were installed to maintain exact temperature and humidity levels in the pressure area.

For engineering and topology optimization the center is using NX CAD software from Siemens. The 3D scanner Atos from GOM allows quick and precise optimization of engineering operations. In addition, it is also used for quality control. The printing sections are strictly separated by material categories, and the actual printing equipment is placed in vibration absorbing areas. Metallic materials are printed with an EOS M 290 system, whereas for the creation of plastic components a Polyjet printer Objet 260 Connex 3 from Stratasys, a Multi Jet Fusion printer HP Jet Fusion 3D 5200 and a FDM printer are available.

To allow test trials for the development of optimum, automated post processing solutions and to select the most suitable equipment, AM Solutions — 3D post processing technology installed its own post processing equipment line in the form of the models S1, S2, and S3 as well as M1, M2, and M3. Moreover, the test center is equipped with various post processing systems from the AM Solutions partners GPAINNOVA and PostProcess Technologies. These include a GPAINNOVA DIlyte 100 and the first instal-
Mazak unveils new Ez Machine Series and Smooth Ez Control

With both affordability and high performance for job shops in mind, Mazak has officially launched the new Ez machine series, the new MAZATROL SmoothEz control, and the accompanying MazakUSA.com/Ez website. The new machine family and control were developed specifically to help remove the cost barriers to acquiring the latest manufacturing technology without sacrificing machine capability or production performance, while the new Ez website further streamlines the customer experience and offers visitors focused access to Mazak’s newest product line.

Machine configurations within the new series include both horizontal turning and vertical machining center models, all of which feature the MAZATROL SmoothEz control and are designed and built in Kentucky. Among the turning center configurations are the QT-Ez 8, QT-Ez 10, and QT-Ez 12 models each offered in a 2-axis, M, MY and MSY versions.

M versions include milling capability. MY machines feature milling and Y-axis off-centerline capability, and MSY machines are a combination of both milling and Y axis capability paired with second turning spindles for complete DONE IN ONE® part processing. For further increased productivity and unmanned operations, the machines seamlessly integrate with bar feeders and robots.

Each QT-Ez model number indicates the standard chuck size, but Mazak also offers a smaller size optional chuck for each machine to provide greater maximum rpm capability. These include a 6-inch chuck option for the QT-Ez 8, an 8-inch for the QT-Ez 10, and 10-inch for the QT-Ez 12. Each model is available in a 20-inch bed length and an optional 40-inch bed length for the QT-Ez 12 model. Available machine turrets include 2-axis drum style with a bolt-on or BMT55 turret for rotary tool applications, and tailstocks are offered with either manual positioning with hydraulic quill or servo positioning capability.

Mazak’s VC-Ez Vertical Machine Series begins with the initial introduction of the VC-Ez 20, and soon will include both smaller and larger machines — the VC-Ez 16 and
VC-Ez 26. All VC-Ez Series machines sport C-frame designs with X- and Y-axis motion via moving table and saddle along with Mazak’s high-rigidity MX linear systems and pre-tensioned ball screws that together ensure rigidity, accuracy, and reliability.

Axis travels for the VC-Ez 20 measure 41.34 inches in X, 20.08 inches in Y, and 25 inches in Z that allow the machine to accommodate maximum workpiece sizes of 49.21 inches long, 19.37 inches wide, and 22.4 inches tall and weighing up to 2,204 pounds. This is all within an ergonomically designed machine that has a 26.5 percent smaller foot as compared to other models and one that measures only 102.65 square feet for significant floor space savings.

The VC-Ez 20 features a powerful 40-taper, 12,000-rpm, 25-hp spindle and 30-tool magazine automatic tool changer. Options include a versatile 15,000-rpm, 29.5-hp spindle with 81.13 ft-lb torque and a 50-tool capacity tool changer.

For fast and easy QT-Ez and VC-Ez machine programming, Mazak’s new MAZATROL SmoothEz CNC provides dual 800 MHz processors, 512 MB of RAM and a vibrant 15-inch capacitive touch screen that includes a full keyboard and displays up to 60 lines of code. Within the control, EIA/G-code and MAZATROL programming languages support a full range of programming options directly on the machine, while the MAZATROL TWINS function enables offline programming and simulations that draw real-time condition and performance data directly from the machine.

The MAZATROL SmoothEz control also features Mazak’s new LAUNCHER interface, accessible in every screen, that uses the entire display to make screen selection smooth and seamless. To further streamline production, the control’s QUICK MAZATROL function simplifies program creation and confirmation through touch screen editing and confirmation of 3D models.

To support the Ez machine series, Mazak’s new Ez website provides customers across the U.S., Canada, and Mexico complete and concise information about Mazak’s newest product line. Launched alongside the new Ez series, the website includes in-depth details on all series machines and on the MAZATROL SmoothEz control. Site visitors can also learn more about the Kentucky manufacturing expertise that Mazak invested in the new machine tools and information about the customer support and financing packages that make owning the machines easy and affordable.

Business magazine names Motion Industries’ Breaux CEO of year

Motion Industries President Randy Breaux is a 2020 award recipient of CEO of the Year from the Birmingham Business Journal. The presentation honored winners and finalists — elite leaders from a range of industries — at a virtual event in December.

Motion Industries, Inc., is a leading distributor of maintenance, repair, and operation replacement parts and a wholly owned subsidiary of Genuine Parts Company.

The CEO Awards recognize excellence among top executives in the Birmingham metro area for businesses of all sizes. Breaux was named CEO of the Year in the category of Companies with more than 300 Employees.

Breaux has four decades of experience in the industrial manufacturing and distribution markets. Before becoming the company’s president in December 2018, he played a key role in setting corporate strategy, key acquisitions, growing supplier relationships, advancing marketing activities, and overseeing corporate operations as executive vice president. He joined Motion Industries in May 2011 after 21 years with ABB/Baldor Electric Company, a leading manufacturer of industrial electric motors, drives, and mechanical power transmission components, based in Fort Smith, Arkansas.

Breaux serves on several nonprofit boards in the Birmingham area. He has held committee and board positions in numerous industry associations, including past chairperson of the manufacturing council for the Power Transmission Distributors Association.

The Birmingham Business Journal is one of 40 Business Journal newspapers published across the United States. The Business Journals feature local people and decision makers who are leaders in their business communities.

With annual sales of $6 billion, Motion Industries is a leading industrial distributor of bearings, mechanical power transmission products, electrical and industrial automation components, hydraulic and industrial hose, hydraulic and pneumatic components, industrial and safety products, as well as material handling products and solutions.

Forest City Gear engineer authors white paper on double-helical gears

Forest City Gear is proud to share a white paper titled A Note on the Design of the Gap Between Helices on a Double-helical
The joint objective of WBA and Moulding Expo is to develop theme days with a specific focal point and offer talks, podium discussions and opportunities for the exchange of experiences. (Courtesy: Moulding Expo)

Moulding Expo sets 2021 event with theme ‘Together for tool making’

Moulding Expo will again become the industry and idea marketplace for tool, pattern, and mold making June 8–11, 2021. With its wide range of topics showcasing the latest developments in the industry, the accompanying program will be a valuable contribution to the trade fair. In its capacity as the technical partner for Moulding Expo, WBA Aachener Werkzeugbau Akademie GmbH will play an important role in the organization of the accompanying program.

The joint objective is to develop theme days with a specific focal point and offer talks, podium discussions, and opportunities for the exchange of experiences. “Thanks to its community, WBA has a special insight into the current challenges facing the tool making industry. We want to use our unique position to provide valuable impetus for the future-oriented direction of the industry,” said Prof. Dr.-Ing. Wolfgang Boos, managing shareholder of WBA. “This includes both strategic and technological action recommendations in order to make the tool making industry ready to cope with current and future challenges. Moulding Expo will provide us with an ideal platform in this respect.”

Trade visitors can look forward to topics such as sustainability in tool making, global tool making markets, the digital transformation of tool making and employee training, but also innovative concepts in tool technology and innovative and alternative production methods.

“We are delighted to have acquired WBA as another experienced partner with high tool making expertise that will enable us to gear Moulding Expo even more closely to the current needs and challenges in the industry,” said Florian Niethammer, project manager for Moulding Expo at Messe Stuttgart. With more than 80 member companies in the business areas of industrial consulting, advanced training, research, and software development, WBA is one of the leading partners for the tool making industry.

The focal point of Moulding Expo is the
Tormach Inc., a leading supplier of affordable and compact CNC machines, now offers the xsTECH Router Mill, a ready-to-use tabletop system with full CNC capabilities. The xsTECH is small but features big capabilities for cutting plastics, wood, and aluminum.

An ideal starter CNC system for students learning CNC fundamentals, the xsTECH comes ready to run and requires no assembly. It plugs into a standard 120V wall outlet and for those outside of the U.S., a 230V version is available. The xsTECH comes complete with a wide variety of features including:

- 10.4” Touchscreen PathPilot controller.
- Keyboard, mouse, and jog shuttle.
- WiFi module.
- Electronic tool setter.
- 16-Piece carbide cutting tool set.
- ER11 collets.
- See-Through Enclosure for Dust Control and Safe Use.

“Teachers are using PathPilot HUB to teach students remotely,” said Bufalo. “When they are able to come into school to use the Tormach mills, the students have already learned their programming skills and can make their proven parts.”

Ideal for teaching the basics of CNC, teachers and students can simply create their accounts on Tormach’s PathPilot HUB site. This allows them to do anything they could do on the actual machine, only it’s a digital twin. Best of all, PathPilot HUB is completely free to use.

Located in Waunakee, Wisconsin USA, Tormach Inc. is dedicated to providing exceptionally engineered products, technical support, and customer service at the lowest possible cost. Our focus is to help our customers realize goals in CNC by providing tools and resources to help transform concepts into real products.

As part of the program, Senvol will develop a qualification plan for AM that leverages machine learning (ML) algorithms. The qualification plan will be flexible (i.e. can be applied to any part using any AM process and any AM machine). By leveraging ML algorithms, the qualification plan will also be notably more efficient than more traditional qualification plans (i.e. require fewer builds and less time).

Stephanie Koch, ARL’s Advanced Manufacturing, Materials, and Processes Program (AMMP) Manager, said, “Additive manufacturing is a promising technology that could be used to enable multiple Army Modernization Priorities applications. Despite the potential that additive manufacturing offers, the rate of adoption is very slow due to the high cost and time associated with the design, qualification, and certification of additively manufactured parts. We are very encouraged with Senvol’s approach, and look forward to seeing how we can leverage machine learning to improve processes.”

The Senvol ML software supports the qualification of AM processes and the development of AM-specific material design allowables while simultaneously minimizing data generation requirements. The software is flexible and can be applied to any AM process, any AM machine, and any AM material.

Senvol President Annie Wang said, “Senvol will implement data-driven machine learning technology for the U.S. Army that will substantially reduce the cost of material and

MORE INFO www.tormach.com

MORE INFO www.moulding-expo.com
part qualification. The significant reduction in cost and the increase in speed will allow the Army to support warfighter readiness by unlocking the full transformative potential that additive manufacturing offers.”

Senvol’s partners on the program include Lockheed Martin Missiles and Fire Control, EWI, and Pilgrim Consulting. The contract is administered by the National Center for Manufacturing Sciences (NCMS) through the AMMP program.

Dr. William E. Frazier, retired chief scientist for material engineering at NAVAIR and currently president of Pilgrim Consulting, said, “I’m very pleased to be supporting Senvol on this program. In particular, I’m looking forward to the demonstration. The plan is to fabricate a missile part and evaluate how close the actual performance requirements are compared to those predicted by the Senvol ML software, and to ultimately determine whether or not the part should be qualified.”

Users of Senvol ML include organizations in aerospace, defense, oil & gas, consumer products, medical, and automotive industries, as well as AM machine manufacturers and AM material suppliers.

MORE INFO www.senvol.com

ARCH Cutting Tools takes top place in ANCA’s third TOTY contest

With 28 entries, 1.2 million social impressions, and almost 4,500 votes, ANCA’s Tool of the Year celebrated the contribution modern cutting tools make to manufacturing, surgery, woodworking, and other diverse industries. ANCA is a manufacturer of CNC grinding machines.

Overall winner ARCH Cutting Tool’s entry demonstrated excellent use of multiple iGrind operations with several complex profiles. The tool came out in front of others when compared to the DXF and measured on the Zoller for Profile OD and Runout. The surface finish measurement on the Alicona produced a superb result. The tool also stood out in terms of complexity of grinding and was a large diameter (1”) multi-functional cutting tool with many features. Overall, the tool was complete, an exceptional effort from the team at ARCH, which ticked every box to be the Tool of the Year winner.

ARCH Cutting Tools is the third American company in as many years to take out the accolade, highlighting that the skill and craftsmanship of the U.S. cutting tool industry is alive and well.

“We entered to present and showcase our capabilities as a cutting tool manufacturer and to demonstrate the complex capabilities of the ANCA Tool and Cutter Grinder,” said Jim Gray, president and general manager, ARCH Cutting Tools – Latrobe. “Additionally, we entered to share with customers our own custom capabilities with solid carbide tools. Our entry was based on what we provide for our customers. It’s multi-functional, providing the customer a single high-performance tool that’s multiple tools in one. A solution-driven tool that reduces the need for tool changes and increases productivity.”

ZMK received the runner-up award in this category for another outstanding effort with its contribution.

Pat Boland, ANCA co-founder said, “The cutting tool sector has faced a significant challenge with the onset of COVID-19. In these conditions, it is even more impor-
tant to promote and recognize our contributions as an industry. This year we saw the most complex and sophisticated entries to date. Having been part of the industry for over 40 years, the technical advancements demonstrated by cutting tool manufacturers continue to amaze.”

WINNERS OF VIRTUAL TOOL CATEGORY – JG GROUP AND TURCAR
The entries for the Virtual Tool category were so impressive that the judges found it impossible to split JG Group and Turcar’s submissions. They agreed that both virtual tools were complex and demonstrated great use of different cycles and operations.

The Tool of the Year must be a ground tool that is functional, high quality and complex. A panel of expert judges consider the surface finish, tolerance and functionality. This year the industry-first competition had two categories.

Winner of ANCA Tool of the Year: ARCH Cutting Tools.

Runner-Up: ZMK.

Winners of Virtual Tool Category:

- JG Group, Poland.
- ARCH Cutting Tools, USA.
- Aayudh Tools, India.
- Ocmandy, France.
- MASTERMET, Poland.
- ZMK, Poland.
- Guidolin Affilatura Utensili (Pat’s Pick), Italy.

Virtual Tool Finalists:

- JG Group, Poland.
- Aayudh Tools, India.
- Turcar, Turkey.
- Miltas (Pat’s Pick), Turkey.

ANCA’s annual competition gives cutting tool manufacturers a chance to not only build brand recognition within the industry, but to also push the boundaries and showcase the beauty of performance expected from ANCA machines in the cutting tools industry. The main winner receives $10,000 AUD worth of ANCA parts, accessories or software and the winner of the most innovative virtual tool receives the full CIM software package.

Members of the judging panel were Pat Boland, co-founder and managing director at ANCA; Jason Allen, managing director, ISCAR Australia; Peter Sutton, managing director, Sutton Tools; Alicona, measurement of surface finish; and Zoller, measurement of profile and diameter.

More Info: www.anca.com
The recent relief of 2020 ending provided a short reprieve for people all around the world, but in truth, our problems didn’t disappear on January 1 at midnight. If 2020 has taught us anything in the power transmission industry, it is that we don’t have the ability to keep doing things the way we always have, and innovation is our biggest defense against uncertainty.

We know that budgets are tighter; all memberships have been put under the microscope, and some of you have had to say goodbye to close colleagues due to the cutbacks during this pandemic. It is not lost on us the impact that this all has on your daily ability to do business. As an association with more than 100 years representing and providing resources for people and companies in the gear industry, we have seen quite a bit to understand that we have the ability to help you move forward.

So, we invite you to make 2021 the year to double down on your membership and really use the benefits we offer. To start, we want to make sure you really understand what being an AGMA member means. Here are some benefits that you might not yet be taking advantage of:

- Free full set of AGMA standards and updated information sheets every year.
- Direct participation in the AGMA standards process allowing a voting position to make the gearing standards in the U.S. and internationally.
- A 15- to 50-percent savings on education courses (face-to-face and online).
- Complimentary participation and results in the AGMA Operating Ratio Report where you can benchmark how your company is doing in comparison to others in the industry.
- Exclusive access to the AGMA Gear Market report where you will receive the latest information on U.S. economic conditions, gear industry conditions, gear market bookings, and gear market shipments beyond the macro level.
- Member discounts on advertising with AGMA media (Gear Technology and Power Transmission Engineering).
- Unlimited and free use of the online workforce training series that has been downloaded more than 800 times.
- No-cost subscription to AGMA’s bi-monthly Member Newsletter and weekly Industry Newsletter.
- Ability to post unlimited job openings at your company to reach thousands of AGMA followers and potential employees.
- VIP invitations to industry plant tours through the Annual Strategic Resource Meeting.
- Daily news about emerging technology and weekly videos sharing the latest in automation, 3D-printing, materials, electric vehicles, and IIoT.
- Opportunities to join AGMA committees that direct the programming and strategic plan of the association for its members.
- Unmatched networking opportunities with industry executives at the AGMA/ABMA Annual Meeting (on-site and through virtual CEO Roundtables).
- Incredible savings and discounts on the Motion + Power Technology Expo trade show booths.

This list is just the beginning. We know the changing markets coupled with the emerging technologies in manufacturing are making it difficult to predict what is going to happen. At AGMA, we want to take some of that burden off you by supplying the business intelligence and resources you need to be successful. Make 2021 the year you work with an association that exists solely to benefit your company, your employees, and the future of the gear industry. Please feel free to reach out to Rebecca Brinkley, Director, Member Engagement & Communications to set up a free video call to discuss AGMA’s resources or contact any of our team members today and see how we can help you.

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Navigating Through Social Media for Marketing
January 13, 2021, 1-2 p.m.
Expert: CSG Creative
Staff: Rebecca Brinkley, Director of Marketing & Communications, AGMA
Facebook, Twitter, Instagram, LinkedIn, YouTube, and many more social platforms exist that you can use to help grow your brand recognition and network with peers and potential customers. But which one is beneficial for your company? Attendees will learn the best way to get started on social media and how to develop a social strategy that will get your customers engaged with your company and employees.

AGMA Technical Division Webinar
January 21, 2021, 1-2 p.m.
Join the AGMA Technical Team and get all your questions answered about technical committees and the standards process. Through this webinar, you will hear about:

- What the Technical Department does at AGMA and how AGMA Members benefit from this.
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- How to join a technical committee.
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AGMA was founded on the development of standards. Through the hard work of our member volunteers and industry experts, we continue to innovate and move the gear industry into the future. Join us and learn how you can be a part of this process!

What Does Your Website Say About You?
February 10, 2021, 1-2 p.m.
Expert: Christopher Mahon, Vice President, Senior Art Director & Brand Strategist, TGD
Staff: Mary Ellen Doran, Director, Emerging Technology, AGMA
The most common way for people to find your company is through an internet search — this will lead them to your website. Are you ner-
vous about the first impression that your website gives them? Then it is time to hear it from design experts at TGD to learn about how to spruce up your website to make sure that your branding really shines. From using photographs, videos, smart navigation, attendees will be able to start working that same day on improving their website for easy customer use.

Upcoming Education

Reverse Gear System Engineering
Live Virtual Online Training
January 28, 2021 | Noon-4 p.m. ET
Deadline to register for this online course is January 21, 2021.

We will discuss the basic types of reverse engineering projects (e.g. upgrading an existing system to increase power or extend operating life or improve noise level; replacing gear that has simply reached the end of its otherwise successful useful life; emergency, short term, interim gear replacement resulting from an unexpected failure; responding to a system that is not providing acceptable performance, etc.). The need for understanding the operation of the system in which the gears will be used, the conditions that led to the need for the project and especially, the specific nature of the failure that occurred, if that is the reason for the project, are key, often ignored, elements of the process.

Analytical Gear Chart Interpretation
Live Virtual Online Training
February 11, 2021 | Noon-4 p.m. ET
Deadline to register for this online course is February 4, 2021.

This course is an introduction to the methodology of analytical gear inspection and the evaluation and interpretation of the resulting data. The application of this information to identify and correct manufacturing errors will begin to be explored. Additionally, it reviews chart interpretation and applies inspection data to understand the causes and cures of manufacturing errors. Many chart examples are used to understand cause and effect.

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Where: St. Louis, Missouri.
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Whether you're looking for technical education, networking opportunities, or a way for your voice to be heard in the standards process, AGMA has something to offer you. If you would like more information on any of the following events, visit www.agma.org or send an email to events@agma.org.

JANUARY
January 14 — Metallurgy and Materials Committee Meeting — WebEx
January 27 — Plastics Committee Meeting — WebEx
January 28 — Lubrication Committee Meeting — WebEx
January 28 — Reverse Engineering Course — Online

FEBRUARY
February 2 — Bevel Gearing Committee Meeting — WebEx
February 16 — Nomenclature Committee Meeting — WebEx
February 23-25 — Gear Manufacturing & Inspection Course — Online
February 23 — Gear Accuracy Committee Meeting — WebEx
February 25 — Metallurgy and Materials Committee Meeting — WebEx

MARCH
March 2 — Bevel Gearing Committee Meeting — WebEx
March 4 — Lubrication Committee Meeting — WebEx
March 11 — Powder Metallurgy Committee Meeting — WebEx
March 25 — Nomenclature Committee Meeting — WebEx
March 30 — Metallurgy and Materials Committee Meeting — WebEx
March 31 — Bevel Gearing Committee Meeting — WebEx

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Ensure supply chain continuity creates more value for customers

In gear design, incorporating the best raw materials is critical for high performance. Removing potential barriers to access those materials can streamline production and save on overall costs.

Encountering challenges throughout the production process for any type of gear is to be expected. The steps in the supply chain—from melting the steel to delivery and assembly of the finished components—are complex and interdependent, and any quality, delivery, or supply interruption along the way could have a significant impact and require major adjustment downstream. You can help manage resources and costs for your end customers by focusing energy on developing robust planning processes and maintaining the continuity of your supply chain.

Efficient and cost-effective supply chains are comprised of a combination of factors: availability of quality materials, lean manufacturing processes, sound inventory management, efficient logistics and distribution networks, and excellence in service. Whether you’re overseeing your own supply network or working closely with a partner such as TimkenSteel to manage the supply chain for you, understanding how to effectively manage constraints across the system will help you to optimize working capital and provide unwavering supply continuity to your customer.

Points to remember when focusing on the continuity of your supply chain include:

- Develop a flawless launch plan with each supplier and establish quality metrics to monitor progress and drive long-term performance.
- Minimize the lag in demand signals from customers throughout the supply chain. This will help to ensure continuity of supply during peak customer demand periods.
- Provide real-time feedback to suppliers about their performance.

Focus on how they are helping meet customer needs. This will help to maintain consistent production schedules, ensure quality, and potentially reduce overall cost.

- Maintain a risk mitigation and recovery plan at each step of the supply chain. Having plans in place to anticipate problems is the most effective way to address them if they occur.
- Work with your suppliers to monitor their financial stability and develop contingency operating plans when needed. Again, preparing for unplanned expenditures can help to resolve them quickly if needed.

Although it may seem like “doomsday preparation” to focus so intensely on risk mitigation, having plans to address what could go wrong is key to resolving small problems before they become big ones. In addition to the above points, you can also employ tools such as advanced product quality planning (APQP) to frame various processes. These types of checks and balances will result in continuous flow and smoother transition from supplier to supplier, ultimately adding value for end customers with product excellence at less cost.

Manufacturers can help manage resources and costs for end customers by focusing energy on developing robust planning processes and maintaining the continuity of your supply chain. (Courtesy: TimkenSteel)

**About the Author**

Jim Albertson is Senior Manager of Supply Chain Strategy and Operations Advancement for TimkenSteel. He spearheads supply chain strategy and supplier development programs for a broad range of outsourced conversion services. He joined TimkenSteel in 2001 and has held various leadership positions. He holds a bachelor’s degree in marketing from The University of Akron and is a member of the American Society for Quality. Contact him at 330-471-3134 or james.albertson@timkensteel.com.
Does all learning happen in a classroom?

Education, mentoring, and institutional knowledge contribute to our understanding of the world, including the business world.

Learning takes many forms. Some methods are formal in their approach, such as elementary school and high school. Others, like mentoring, take a more informal approach. Institutional knowledge is a blend of the mentoring and formal teaching.

It is estimated there are approximately 15 million species on Earth. Most species develop a method of communication that allows all members of the species to understand one another regardless of the geographic region where they are raised. Some animals communicate using sound, and others communicate using motion. Humans are just one species in this mix. However, they have developed 7,117 known spoken languages. Although roughly 50 percent of the Earth’s 7.8 billion humans speak one of 23 unique languages, humans worldwide are not spending their time inventing the wheel over and over again. This is due to institutional knowledge.

Institutional knowledge is information that is handed down from a group of elders to a younger group, typically devoid of any documentation or data to substantiate the information being passed is true. It is typically understood that due to wisdom of the elders and their collective experiences, it is assumed that the information being passed down is true.

Formal learning can teach language, mathematics, history, and science. All formal teaching involves the transfer of facts, theories, and formulas. These formulas can take the form of a physics equation that explains the theory of relativity, or it can explain how to conjugate a verb. The questions answered by formal learning include the who, what, when, where, how, and why.

Mentoring takes many forms but is always less formal. It can be an assignment from a superior that stretches an employee’s understanding of a business process or it could be the preparation of a classic family holiday dish under the tutelage of your grandmother. In the business world, mentoring is an important part of professional development. Once formal education, whether it be high school, vocational school, or university, is completed, mentoring is necessary in order to learn the hows and whys of a business’s operations, policies and procedures.

Grandma’s mentoring is a form of institutional knowledge. While teaching you how to make that family dish, she will inevitably impart some wisdom about a secret ingredient that she includes that you would never find in any cookbook recipe. This same type of wisdom occurs in machine shops daily. Over the course of many years, lead machinists begin to know the idiosyncrasies of the various machines that they operate. When apprentices are hired, they are taught the basics of the machinery operations, but they cannot duplicate the performance of the lead machinist because they don’t know the idiosyncrasies of each machine. Even an experienced machinist will need to learn these variants in order to achieve the same results.

If you walk through any machine shop, you will notice that the emergency stop, or e-stop, button is always red. This color is not chosen at random. It is based on observations that have become institutional knowledge. The first observation is that the color red is the easiest color for the human eye to see. The second is that red occurs frequently in nature as the color of things that are dangerous. Earth tone colors such as greens and browns blend into the subconscious, but red evokes an immediate reaction.

Institutional knowledge is the reason that society does not re-invent the wheel. The downside to institutional knowledge is that it needs to be passed on in order to be of future value. Unfortunately, its true value is never known until it is gone. Corporations lose institutional knowledge when employees are laid off during mergers; they lose it when employees retire; they lose it when COVID takes an employee’s life.

Management in small machine shops realizes the value of this knowledge and work to cultivate this knowledge. Larger shops develop layers of bureaucracy that insulate management from understanding the nuances of operations that exist due to institutional knowledge. This lack of vision can contribute to the downfall of any established business.

Vocational schools and universities provide an excellent platform for formal learning. Mentoring is more subjective in its outcome as the learning is dependent on the actions of the mentor. Institutional knowledge is the most opaque form of knowledge. It can only be taught if the holder of the knowledge imparts it to others. All three are necessary for the development of exemplary employees who will drive the success of your business.

About the Author

Brian Dengel is general manager of KHK-USA, which is based in Mineola, New York. Go online to www.khkgears.us
Basic operating principles include transducers, the need for calibration, limitations of reference standards, and advantages/disadvantages of the process.

In my previous articles, I have discussed dye penetrant inspection and magnetic particle inspection. In this article, I will give a brief overview of ultrasonic testing.

**BASIC PRINCIPLES**

Ultrasonic testing uses high frequency sound waves to detect flaws or anomalies, characterize materials, and has applications in fields other than material testing. For instance, the imaging technique used to capture an image of a baby still in the womb uses ultrasonic testing. It can also be used to find sources of oil using explosives. The same basic principle is used for active sonar. The velocity of sound varies with different materials. Sound will travel faster through metal than through air.

In its basic form, ultrasonic testing consists of the part to be tested, a transducer that transmits and listens to the ultrasonic wave, a signal source, and a receiver. The signal source sends out ultrasonic pulses to the transducer, which then transmits them through the part. The sound wave is reflected from the back of the part, or from an internal flaw. The reflected wave is picked up by the transducer, and is converted into a signal, which is displayed on a screen in the receiver. The screen displays the signal strength as a function of time when the echo was received. The signal travel time is proportional to the distance the ultrasonic wave has traveled. From this signal, information about the indication can be obtained, such as size and distance from the surface. This is shown schematically in Figure 1.

When a transducer is placed on the surface of a part, there will be a thin film of air between the part and the transducer. A solid-to-air interface gives a 100 percent reflection, so it is necessary to exclude air from the transducer surface. A variety of liquids can be used as a couplant, enabling the sound to be transmitted to the part. The idea behind the couplant is to allow as much of the signal as possible to be transmitted to the part. Commonly used couplants are water, oil, glycerin, and specialized gels [1].

When inspecting the part, the NDT technician must make some decisions regarding what frequency to use. As the frequency is increased, the sensitivity is also increased. However, grain size can cause the sound waves to scatter. Castings usually require a lower frequency, while forgings or wrought products can be inspected using a higher frequency. Another thing to consider is that the penetrating power decreases as the frequency is increased.

Resolution (or the ability to distinguish between discontinuities that are close together) also increases as the frequency is increased. The resolution and the sensitivity play an important role in determining whether a flaw or discontinuity is detected. One rule of thumb is that the discontinuity must be larger than 1/2 of a wavelength to be detected [2].

**TRANSDUCERS**

Transducers are manufactured in many different configurations, depending on the application. These transducers have different frequencies, bandwidth, and focus, to ensure discontinuity detection. There are two types of transducers: contact and immersion.

Contact transducers are usually held in the inspector’s hand and are placed in intimate contact with the part after a couplant has been applied. Since the transducers are moved along the surface of a part, they often have replaceable wear plates to protect the transducer surface. The transducers are also designed so that they can be readily gripped by the NDT technician, and comfortable to use.

These transducers can have a wide variety of configurations (Figure 2) to improve sensitivity and resolution. Flat transducers are used when the part is flat. A curved transducer is used when the surface is round or curved. The transducers can aim the sound waves normal to the surface of the part, or an angle beam can be used.

Transducers can have two elements to improve sensitivity and resolution. While one element transmits, the other element receives the sound wave. These types of elements are useful for measuring

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Figure 1: Schematic of ultrasonic testing, showing the difference in time reflected from a flaw, and a part.
surface thickness of coatings or detecting near surface defects.

Angled transducers introduce a sound wave at an angle into the material, as opposed to a sound wave normal to the surface. The angled sound wave allows reflections from the back wall to detect flaws in welded surfaces or detecting near-surface discontinuities.

Immersion transducers do not contact the part. These transducers are immersed in a couplant (usually water). They are watertight and designed to be completely immersed in the couplants. Often the transducers are specially designed to focus the sound waves to improve resolution or improve sensitivity. Large automated systems for examining large parts, such as pipe, use immersion transducers to examine the pipe integrity.

CALIBRATION
In ultrasonic testing, reference standards are used to calibrate the transducer to the type of materials, and to examine the sensitivity of the transducer. These standards incorporate flaws of known sizes. The standards ensure accuracy of measurements and aid in evaluating the size of the discontinuity measured. These reference standards also allow equipment to be set up to produce identical readings, regardless of the inspector. There are many different types of reference standards, depending on the application.

The flaws introduced in test blocks are usually drilled holes or notches. Unfortunately, this type of flaw may not accurately represent the actual flaw. The artificially produced flaws in the reference stands often reflect energy more effectively than an actual flaw because of better and smoother surfaces. This limits the ability of the inspector to accurately access the size of a discontinuity in a real part.

ADVANTAGE AND DISADVANTAGES
There is no one perfect non-destructive test method. Each method has its own advantages and disadvantages.

Ultrasonic testing requires a great deal of training and skill to accurately determine discontinuities.

Ultrasonic testing is excellent for finding very small discontinuities from a single surface. The test method itself has a wide control over the testing variables. There are many transducers that are available for examining different types of flaws or configurations. The testing method is reliable and repeatable. The equipment used in ultrasonic inspection is very portable and is often handheld. Depending on the part configuration, automation of the process is possible with 3D signal processing to determine location and shape of the discontinuity, allowing a map of the discontinuity to be formed. The only consumable is the couplant.

Ultrasonic testing requires a great deal of training and skill to accurately determine discontinuities. For instance, uneven scanning could render the test worthless.

It is important that any expected discontinuities be perpendicular to the incoming sound wave. If parallel with the beam, the discontinuity may not be detected. If the flaw is very similar to the parent material, it may not be detected. If the part is thin, then special techniques are required (such as a time delay) to prevent nearly instantaneous return of the signal. Because ultrasonic testing requires enhanced training and skill, misinterpretation of the signals is very possible.

CONCLUSIONS
In this short article, I have described the basic operating principles of ultrasonic testing. I’ve described the operation of transducers, and the different types available. A discussion of the requirement for calibration and limitations of the reference standards were described. Lastly, the advantages and disadvantages of ultrasonic NDT were discussed.

As always, should you have any questions or comments regarding this or any other article (as well as suggestions for new columns), please contact the editor or me. Stay safe and healthy out there.

REFERENCES

ABOUT THE AUTHOR
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FINDING THE IDEAL MATERIALS FOR GEARS
When designing and manufacturing gears, the materials used will depend on what type of gear is being made and how and where it will be used.

By BRIAN DENGEL

When designing an individual gear or a gear train, the choice of material will either be the primary factor on which the gear geometry is based or the gear performance will dictate the proper material selection. There are various raw materials that are commonly used in gear construction, and each one has a sweet spot where its mechanical properties stand out as the superior choice. The main categories of materials are copper alloys, iron alloys, aluminum alloys, and thermoplastics.

COPPER ALLOYS
When designing a gear that is going to be subjected to a corrosive environment or needs to be non-magnetic, a copper alloy is usually the best choice. The three most common copper alloys used in gearing are brass, phosphor bronze, and aluminum bronze. Brass is an alloy of copper and zinc. The amount of zinc varies in the different brass alloys, and its presence changes the ductility of the alloy.

Low zinc content maintains a high level of ductility in the brass alloy, whereas a higher concentration of zinc reduces the alloy's ductility. The copper base of brass alloys contributes to its ease of machining and its antimicrobial benefit. Gears typically produced from brass alloys are spur gears and gear racks that will be used in low-load environments such as instrument drive systems.

Phosphor bronze is another copper alloy that combines copper with tin and phosphorus. The addition of tin to the copper increases the strength of the alloy and improves its corrosion resistance. The addition of phosphorus improves both the wear resistance and the stiffness of the alloy. The increased corrosion and wear resistance make phosphor-bronze alloy an excellent choice for high-friction drive components. Worm wheels are produced using this alloy as it resists the wear generated by the friction when the wheel is in mesh with a worm, and it can resist degradation due to the lubricant.

Aluminum bronze is a third copper alloy that is found in gearing. This alloy combines copper with aluminum, iron, nickel, and manganese. Aluminum-bronze alloys have a higher wear resistance than phosphor-bronze alloys, and they also have superior corrosion resistance. The addition of the iron improves the wear resistance of this alloy. The nickel and the manganese add to its corrosion resistance. Aluminum-bronze alloys can resist corrosion due to oxidation, exposure to salt water, and exposure to organic acids.

The additional wear resistance of these alloys allows for the design of gears that can handle significantly more load than similarly sized gears made from phosphor bronze alloys. Typical gears produced from aluminum bronze alloys include crossed axis helical gears (screw gears) and worm wheels.

IRON ALLOYS
When a gear design requires a superior material strength, iron alloys are the best choice. In its raw form, gray iron can be cast and machined into gears. Typically, cast iron is used in applications where phosphor bronze is a suitable alternative, but the application is not constrained by the material's magnetic fields. Steel is an alloy of iron, carbon, and other trace elements. There are four major designations of steel alloy. These are carbon steel, alloy steel, stainless steel, and tool steel. Carbon-steel alloys are used for almost all types of gearing because they are easy to machine, they have good wear resistance, they can be hardened, they are widely available, and they are relatively inexpensive. Carbon steel alloys can be further classified into mild steel, medium-carbon steel, and high-carbon steel. Mild steel alloys have less than 0.30% carbon content. High carbon steel alloys have a carbon content greater than 0.60%, and the medium-content steels fall in between. These steels
Gears made from aluminum alloys include spur gears, helical gears, straight tooth bevel gears, and gear racks. (Courtesy: KHK-USA)

Aluminum alloys are a good alternative to iron alloys in applications that have a need for a high strength-to-weight ratio. Aluminum alloys are typically one-third the weight of steel alloys of the same size.

Gears made from carbon steels are a good choice for spur gears, helical gears, gear racks, bevel gears, and worms. Carbon steels can be induction hardened or laser hardened with a maximum hardness of HRc 55. Alloy steels like AISI 4140 contain additional elements such as aluminum, chromium, copper, and/or nickel. These other elements, when alloyed with the iron and carbon, create steels that are stronger, easier to machine, and offer more corrosion resistance than plain carbon steel. These alloys typically are used to make spur gears, helical gears, gear racks, spiral bevel gears, and worms.

In addition to induction and laser hardening, these alloys can be carburized, or case hardened. The maximum hardness for these alloys is HRc 63. The added strength allows for gears of the same size to handle additional load and resist wear for more cycles. Stainless steel alloys have a minimum chromium content of 11% and are an alloy of many trace elements including nickel, manganese, silicon, phosphorus, sulfur, and nitrogen. They are subdivided into ferritic...
stainless steels that are magnetic, austenitic stainless steel that are nonmagnetic, martensitic, and precipitation hardened. The austenitic stainless steels are designated as 300 series stainless steels, whereas the ferritic stainless steels are designated as the 400 series stainless steels. The most common stainless steel is 304 alloy. It contains 18% chromium and 8% nickel.

For gearing, 303 stainless is typically used. In 303 alloy, the chromium content is reduced to 17%, and 1% of the alloy is sulfur. Because of the addition of the sulfur, 303 alloy has improved machinability compared to 304 alloy. When improved corrosion resistance is required, 316 alloy is the better choice. This alloy has 16% chromium, 10% nickel, and 2% molybdenum; 316 and 303 alloy are used for spur gears, helical gears, and bevel gears. Gear racks are typically made from 304 alloy. 440C is the most common ferritic stainless steel, and 17-4PH is the most common precipitation hardened stainless steel.

### TOOL STEEL ALLOYS

The fourth group of alloys is tool steels. These are steel alloys with traces of cobalt, molybdenum, tungsten, and/or vanadium. These elements add heat resistance and durability to the steel.

AISI identifies steel alloys using a four-digit sequence (Table 1). The first two digits designate the alloy family, and the last two digits designate the fractional percentage of carbon. For example, a 1020 carbon steel has a 0.20% carbon content, whereas a 1045 carbon steel has a 0.45% carbon content.

### ALUMINUM ALLOYS

Aluminum alloys are a good alternative to iron alloys in applications that have a need for a high strength-to-weight ratio. Aluminum alloys are typically one-third the weight of steel alloys of the same size. A surface finish known as passivation protects aluminum alloys from...

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**Table 1: AISI identifies steel alloys using a four-digit sequence.**

<table>
<thead>
<tr>
<th>AISI Designation</th>
<th>Alloy Type</th>
<th>Chemical Composition</th>
</tr>
</thead>
<tbody>
<tr>
<td>10XX</td>
<td>Carbon Alloy steels</td>
<td>Plain carbon steel, Mn 1.00% max</td>
</tr>
<tr>
<td>11XX</td>
<td>Resulfurized, carbon steel</td>
<td></td>
</tr>
<tr>
<td>12XX</td>
<td>Resulfurized / Rephosphorized carbon steel</td>
<td></td>
</tr>
<tr>
<td>15XX</td>
<td>Plain carbon, Mn 1.00-1.65%</td>
<td></td>
</tr>
<tr>
<td>13XX</td>
<td>Manganese Alloy steels</td>
<td>Mn 1.75%</td>
</tr>
<tr>
<td>23XX</td>
<td>Nickel Alloy steels</td>
<td>Ni 3.50%</td>
</tr>
<tr>
<td>25XX</td>
<td>Ni 5.00%</td>
<td></td>
</tr>
<tr>
<td>31XX</td>
<td>Nickel-Chromium Alloy steels</td>
<td>Ni 1.25%, Cr 0.65-0.80%</td>
</tr>
<tr>
<td>32XX</td>
<td>Ni 1.75%, Cr 1.07%</td>
<td></td>
</tr>
<tr>
<td>33XX</td>
<td>Ni 3.50%, Cr 1.50-1.57%</td>
<td></td>
</tr>
<tr>
<td>34XX</td>
<td>Ni 3.00%, Cr 0.77%</td>
<td></td>
</tr>
<tr>
<td>40XX</td>
<td>Molybdenum Alloy steels</td>
<td>Mo 0.20-0.25%</td>
</tr>
<tr>
<td>44XX</td>
<td>Mo 0.40-0.52%</td>
<td></td>
</tr>
<tr>
<td>41XX</td>
<td>Chromium-Molybdenum Alloy steels</td>
<td>Cr 0.50-0.95%, Mo 0.12-0.30%</td>
</tr>
<tr>
<td>43XX</td>
<td>Nickel-Chromium-Molybdenum Alloy steels</td>
<td>Ni 1.82%, Cr 0.50-0.80%, Mo 0.25%</td>
</tr>
<tr>
<td>47XX</td>
<td>Ni 1.05%, Cr 0.45%, Mo 0.20-0.35%</td>
<td></td>
</tr>
<tr>
<td>46XX</td>
<td>Ni 0.85-1.82%, Mo 0.20-0.25%</td>
<td></td>
</tr>
<tr>
<td>48XX</td>
<td>Ni 3.50%, Mo 0.25%</td>
<td></td>
</tr>
<tr>
<td>50XX</td>
<td>Chromium Alloy steels</td>
<td>Cr 0.27-0.65%</td>
</tr>
<tr>
<td>51XX</td>
<td>Cr 0.80-1.05%</td>
<td></td>
</tr>
<tr>
<td>50XXX</td>
<td>Cr 0.50%, C 1.00% min</td>
<td></td>
</tr>
<tr>
<td>51XXX</td>
<td>Cr 1.02%, C 1.00% min</td>
<td></td>
</tr>
<tr>
<td>52XXX</td>
<td>Cr 1.45%, C 1.00% min</td>
<td></td>
</tr>
<tr>
<td>61XX</td>
<td>Chromium-Vanadium Alloy steels</td>
<td>Cr 0.60-0.95%, V 0.10-0.15%</td>
</tr>
<tr>
<td>72XX</td>
<td>Tungsten-Chromium Alloy steels</td>
<td>W 1.75%, Cr 0.75%</td>
</tr>
<tr>
<td>81XX</td>
<td>Nickel-Chromium-Molybdenum Alloy steels</td>
<td>Ni .30%, Cr 0.40%, Mo 0.12%</td>
</tr>
<tr>
<td>86XX</td>
<td>Ni .55%, Cr 0.50%, Mo 0.20%</td>
<td></td>
</tr>
<tr>
<td>87XX</td>
<td>Ni .55%, Cr 0.50%, Mo 0.25%</td>
<td></td>
</tr>
<tr>
<td>88XX</td>
<td>Ni .55%, Cr 0.50%, Mo 0.35%</td>
<td></td>
</tr>
<tr>
<td>92XX</td>
<td>Silicon-Manganese Alloy steels</td>
<td>Si 1.40-2.00%, Mn 0.65-0.85%, Cr 0-0.65%</td>
</tr>
<tr>
<td>93XX</td>
<td>Nickel-Chromium-Molybdenum Alloy steels</td>
<td>Ni 3.25%, Cr 1.20%, Mo 0.12%</td>
</tr>
<tr>
<td>94XX</td>
<td>Ni 0.45%, Cr 0.40%, Mo 0.12%</td>
<td></td>
</tr>
<tr>
<td>97XX</td>
<td>Ni 0.55%, Cr 0.20%, Mo 0.20%</td>
<td></td>
</tr>
<tr>
<td>98XX</td>
<td>Ni 1.00%, Cr 0.80%, Mo 0.25%</td>
<td></td>
</tr>
</tbody>
</table>
Aluminum alloys are a good alternative to iron alloys in applications that have a need for a high strength-to-weight ratio. (Courtesy: KHK-USA)

oxidation and corrosion. This is similar to rust on steel alloys; however, it coats the surface, protecting it from further damage. Aluminum alloys are more expensive than carbon steel but less expensive than stainless steel. However, they are easy to machine, thus offsetting the increase in material costs.

Aluminum alloys cannot be used in high-heat environments as they begin to deform at 400°F. The common aluminum alloys used in gearing are 2024, 6061, and 7075. The 2024 aluminum alloy is a cousin to aluminum bronze because it is also an alloy of aluminum and copper. However, in this case, the proportions are inverted. The copper in 2024 gives this alloy high strength but significantly lowers its corrosion resistance. 7075 aluminum combines zinc and magnesium with the aluminum to form a high strength alloy that is resistant to stress loading. 6061 aluminum is an alloy of aluminum, silicon, and magnesium. It is a medium-strength aluminum alloy that has good corrosion resistance and is weldable. All three of these aluminum alloys can be heat-treated to improve their hardness. Gears made from aluminum alloys include spur gears, helical gears, straight tooth bevel gears, and gear racks.

THERMOPLASTICS
Thermoplastics are the best choice for gears where weight is the most important criteria. Gears made from plastics can be machined like metallic gears; however, some thermoplastics are better suited for manufacturing via injection molding. One of the most common injection molded thermoplastic is acetal. This material is also known as polyacetal or polyoxymethylene (POM). Polyoxymethylene is available in two forms: It is either produced as a homopolymer (POM-H), or it is produced as a copolymer (POM-C). Gears can be made from either polymer. These can be spur gears, helical gears, worm wheels, bevel gears, and gear racks.

The advantages of POM are its dimensional stability under large temperature ranges, its low coefficient of friction, and its resistance to creep. It is an excellent material for wear surfaces because it is self-lubricating, but POM is a poor material for applications subject to shock loading due to its brittleness. For these types of applications, nylon is a better choice. Nylon 6/6 is a polyamide that consists of two monomers with six carbon atoms each. Nylon is excellent at absorbing vibration, but when exposed to moisture, it becomes dimensionally unstable. Nylon also experiences changes in dimension when subjected to significant changes in temperature. Like acetal, nylon has a low coefficient of friction. Nylon has a high mechanical strength. Nylon can be produced with molybdenum impregnated into it in order to produce a self-lubricating feature. Nylon can also be produced with fiberglass or carbon fibers embedded into the material in order to increase the strength. Nylon makes an excellent material for all types of gears including worm wheels, gear racks, spur gears, and straight tooth bevel gears.

UNOBTAINIUM
There is one material for gears that has yet to be developed. It is the ideal material for all gear designs. This material is known as unobtainium. This material is extremely lightweight, has a hardness greater than that of a natural diamond, has a coefficient of friction of 0.001, is dimensionally stable in all environments, neither corrodes nor rusts, is easily machinable, and has a raw material cost of 1 cent per pound. Once invented, it will make all other materials obsolete and will greatly improve gear train efficiency.

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NONLINEAR DYNAMIC CHARACTERISTIC ANALYSIS OF A COATED GEAR TRANSMISSION SYSTEM
The nonlinear dynamic characteristic of a DLC-coated gear transmission system is analyzed by using a numerical integration approach, and the effect of the coating elastic modulus on the dynamic response is investigated.

By YANGYI XIAO, LIYANG FU, JING LUO, WANKAI SHI, and MINGLIN KANG

Coatings can significantly improve the load-carrying performance of a gear surface, but how they affect the vibration characteristic of the system is an urgent issue to be solved. Considering the nonlinear factors such as the variable mesh stiffness, friction, backlash, and transmission error, a six-degree-of-freedom spur gear transmission system with coatings is presented. Meanwhile, the finite element method is applied to acquire the time-varying mesh stiffness of the coated gear pair in the engagement process. With the support of the time-history curve, phase curve, Poincare map, and fast Fourier transform spectrum, the dynamic characteristics and the effects of the coating elastic modulus on vibration behaviors of a gear transmission system are minutely dissected by using a numerical integration approach. Numerical cases illustrate that the dynamic characteristic of a gear-transmission system tends toward a one-period state under the given operating condition. They also indicate that, compared with softer coatings, stiffer ones can properly enhance the transmission performance of the coated gear pair. Numerical results are also compared with previous studies and can establish a theoretical basis for dynamic design and vibration control of the coated gear transmission system.

1 INTRODUCTION

Due to the characteristics of compact structure, stable transmission, and constant speed ratio, the gear mechanism has been widely applied in various industrial fields such as automobiles, ships, and aircraft. With the progression of these fields, the geared system is developing in the direction of high speed, heavy load, and lightweight. It brings a new research task for developing innovative materials in which the surface-strengthening technology is a key. Currently, coat plating has been extensively applied in gear components to obtain higher power densities and fatigue lives [1-3]. On the other hand, with the increasingly strict restriction on transmission noise, the prediction and control of its vibration have attracted tremendous attention. Although the coating can improve the load-carrying performance of gear surfaces, how will it affect the vibration behavior of the system? The vibration mechanism of a coated gear is quite complex, which is intimately related to the gear dynamic behavior [1,4-6]. Hence, it is essential to constitute an appropriate and accurate mathematical model to obtain the nonlinear dynamic characteristic for a coated gear transmission system, which can provide theoretical supports for its dynamic design and vibration control.

The internal dynamic excitation of gear transmission systems includes variable-mesh stiffness, transmission error, and mesh impact [7,8]. In all of the sources mentioned earlier, the time-varying mesh stiffness is one of the most important excitation factors of vibration. The analytical formula method, finite element (FE) method, and analytical-FE approach are applied to calculate the stiffness excitation [9], which is the basis in the investigation of mesh stiffness of a coated gear. It is a time-varying parameter related to the comprehensive elastic deformation of a tooth in the whole meshing region [9]. The software KISSsoft [10] and ROMAX [11] can also be used to calculate the mesh stiffness, but it cannot acquire the stiffness when the coating is deposited on the tooth. Another method from the ISO standard 6336-1-2006 [12] also has limitations in calculating the stiffness, as it can only get the single and average mesh stiffness. Fakher et al. [13] determined the mesh stiffness using the material mechanics method while comprehensively considering the bending, shear, radial compression, Hertz contact, and gear-body deformations. Chang et al. [14] obtained mesh stiffness of a helical gear pair using a combination of FE method and local contact analysis of elastic bodies. Howard et al. [15] evaluated the torsional mesh stiffness of a spur gear pair in a two-dimensional FE model. Ma et al. [16] applied the FE approach to simulate the mesh stiffness with tooth-pitting defects. Wan et al. [17] acquired the mesh stiffness of a gear rotor system with tooth root crack by using an analytic method based on energy theory. The analytical formula method generally simplifies the gear tooth as a cantilever beam with a variable cross-section and provides an efficient way to obtain the stiffness. However, it is difficult for the analytical method to solve the bending and contact problems of a coated gear system, because it involves the calculation of composite materials. Compared with the analytical method, the FE approach is time consuming but is close to the real situation [9]. Moreover, from the study of Liang et al. [18], it was found that the accuracy of calculating stiffness by the FE method can be guaranteed.

A number of studies on the modeling of gear-rotor system dynamics have been proposed. Many dynamic models from single-degree-of-freedom (SDOF) to multi-degree-of-freedom (MDOF) are put forward to predict...
the gear-vibration behavior. In the early stages, the gear transmission was commonly analyzed by SDOF [19]. The nonlinear characteristics of gear systems have become increasingly refined with the development of dynamics theory. Taking factors such as time-varying mesh stiffness, backlash, and transmission error into consideration, the MDOF can demonstrate the strong nonlinear dynamic behavior of gear systems. Wang et al. [6] built a three-DOF torsional vibration model of the gear system for a railway locomotive in which the wheel/rail adhesion torque is not ignored. Wei et al. [20] developed a six-DOF dynamic model with coupled torsional, bending, and axial motions of a helical gear system. Wang et al. [5] built an eight-DOF spur gear system with bending and torsional coupling vibration, in which the nonlinear characteristic is visualized by bifurcation plot, Poincare maps, and frequency spectrums. Considering gear size, errors, and failures, Omar et al. [21] presented a nine-DOF model of a gear system. The purpose of the dynamic simulation plays a vital role in constructing and selecting a suitable model [22]. Mohammed et al. [23] found out which DOF model is more accurate for the vibration displacement of gears. Studying the influence of coating on the dynamic characteristic of a gear system is significant for the development of surface science. There exists a probability for a gear coating to affect the mesh stiffness and transmission error, which should be of concern.

Currently, the research on coated gears mainly focuses on its lubrication and failure behaviors [1-3,24] but lacks the investigation of its dynamic characteristics. From the information mentioned earlier, literature reviews demonstrate many nonlinear numerical models have been constructed to study the gear dynamics, but rarely has research analyzed the effect on the dynamic response for coated gears. Thus, in the present work, the dynamic model covering the time-varying mesh stiffness, friction, backlash, and transmission error will be established to get the nonlinear vibration response characteristics of coated gears. To logically and coherently deal with the issue, the paper is arranged as follows: The description of the nonlinear dynamic model is presented in Section 2. The time-varying mesh stiffness is calculated in Section 3. The analysis of the nonlinear dynamic responses and perorations are organized in Sections 4 and 5, respectively. Additionally, numerical results will be compared with other computational or experimental studies.

2 NONLINEAR DYNAMIC MODEL

The engagement process of a spur gear pair is analyzed on a rigid system, which is shown in Figure 1. The tooth of the driving wheel (pinion) contacts the mating tooth of the driven one (gear) along the action line \( N_p N_g \), which is the inner common tangent of two base circles. Due to the meshing characteristics of the involute gear, the actual effective action line is \( B_p B_g \), limited by each addendum circle \( 25 \). \( D_p \) and \( D_g \) are the critical points of the meshing area of single and double teeth. \( P \) is the pitch point where the relative sliding speed between the tooth surfaces reverses, resulting in an inverse direction of the friction force. Based on the Coulomb friction law, the friction forces on pinion \( (F_{pfi}) \) and gear \( (F_{gfi}) \) in the meshing tooth pairs changing in time can be described as:

\[
\begin{align*}
F_{pfi}(t) &= \lambda(t) \mu F_{pN}(t) \\
F_{gfi}(t) &= -F_{pfi}(t)
\end{align*}
\]

where \( i \) is equal to 1 and 2, representing single-tooth and double-tooth engagement areas, respectively. Theoretically, it is incorporated with the effects of both dry-contact and lubricant friction. However, lubricant friction has a very minor impact on gear-pair torsional behaviors, and the predicted motions are not prominent through different friction expressions [8,26]. Thus, a constant \( \mu \) is still used in the current paper. \( \lambda(t) \) is the direction coefficient of tooth friction, expressed by:

\[
\lambda(t) = \text{sgn}[(\phi_p - \phi_{B_g}) - \text{mod}(\omega_p t, \phi_{D_p} - \phi_{B_g})], \tag{Equation 2}
\]

where “sgn” and “mod” are the sign and modulus functions, as defined in [8,27,28]. \( \phi_p \), \( \phi_{B_g} \), and \( \phi_{D_p} \) are individually the involute outspread angles at points \( P \), \( B_g \), and \( D_p \).

The friction arms of pinion and gear with ith tooth pair can be represented by:

\[
\begin{align*}
l_p(t) &= r_p[\phi_{B_g} + \text{mod}(\omega_p t, \phi_{D_p} - \phi_{B_g})] \\
l_g(t) &= r_g[\phi_{B_g} + \text{mod}(\omega_p t, \phi_{D_p} - \phi_{B_g})]
\end{align*}
\]

\[
\begin{align*}
l_1(t) &= (r_p + r_g) \tan \alpha - l_p(t) \\
l_2(t) &= (r_p + r_g) \tan \alpha - l_2(t)
\end{align*}
\]

where \( \phi_{B_g} \) are the involute outspread angles at point \( D_g \) and \( \alpha \) is the pressure angle at the pitch point.

By simplifying the realistic gear system into a mass-spring damping system, a lumped parameter dynamic model having six-DOF (one rotational and two translational for each gear disc) is built [29]. The
model schematic diagram with the time-varying mesh stiffness, transmission error, backlash, and friction force is shown in Figure 2, where the x- and y-axes are individually parallel to the off-line of action (OLOA) and line of action (LOA) directions of the gear pair. It is composed of a spur gear pair with masses \(m_p, m_g\), moments of inertia \(I_p, I_g\), and base circle radii \(r_p, r_g\), and the two gears are supported on roller bearings.

Both the torsional and transversal motions in the system are considered in the proposed nonlinear dynamic model. In light of the second Newtonian law, the equations of motion in the \(x, y\), and \(\theta\) directions for the pinion and gear can be individually formulated as follows:

\[
\begin{align*}
    m_p\ddot{x}_p + c_{px}\dot{x}_p + k_{px}(x_p - \sum_{i=1}^{2} F_{pfi}(t)) &= 0, \\
    m_g\ddot{y}_p + c_{py}\dot{y}_p + k_{py}(y_p - \sum_{i=1}^{2} F_{gfi}(t)) &= 0, \\
    I_p\ddot{\theta}_p + \sum_{i=1}^{2} I_{pi}(t)F_{pfi}(t) + \sum_{i=1}^{2} r_p F_{pNi}(t) - T_p &= 0, \\
    m_g\ddot{x}_g + c_{gx}\dot{x}_g + k_{gx}(x_g - \sum_{i=1}^{2} F_{ggi}(t)) &= 0, \\
    m_g\ddot{y}_g + c_{gy}\dot{y}_g + k_{gy}(y_g - \sum_{i=1}^{2} F_{ggi}(t)) &= 0, \\
    I_g\ddot{\theta}_g - \sum_{i=1}^{2} I_{gi}(t)F_{ggi}(t) - \sum_{i=1}^{2} r_g F_{gNi}(t) + T_p &= 0.
\end{align*}
\]

where an overdot means differentiation with respect to time \(t\).

The damping mechanisms in the gear mesh and bearings are assumed to have a linear feature, so the meshing forces are described in the following form:

\[
\begin{align*}
    F_{pNi}(t) &= k_m(t)f(\delta) + c_m\delta, \\
    F_{gNi}(t) &= -F_{pNi}(t),
\end{align*}
\]

where \(k_m(t)\) is the time-varying mesh stiffness, which will be discussed in Section 3. \(c_m\) is the mesh damping proportional to the integral average stiffness \(k_{\text{ave}}\) and can be evaluated approximately using the following equation [23,30]:

\[
c_m = 2\xi \sqrt{\frac{k_{\text{ave}}}{1/m_p + 1/m_g}},
\]

where \(\xi\) is the damping ratio (0.03–0.17).

The nonlinear displacement function \(f(\delta)\) can be expressed as the following:

\[
\begin{align*}
    &\delta \geq b, \\
    &-b < \delta < b, \\
    &\delta \leq -b.
\end{align*}
\]

where \(b\) is half of the total gear backlash. \(\delta\) is the relative displacement along the LOA, which is also known as the dynamic transmission error (DTE), defined by:

\[
\delta(t) = y_p - y_g + r_p \theta_p - r_g \theta_g - e(t),
\]

where \(e(t)\) denotes the static transmission error (STE). It can commonly be approximated as a harmonic function:

\[
e(t) = e_0 \sin(\omega_e t),
\]

where \(\omega_e\) is the fundamental frequency of STE, \(\omega_e = \omega_p z_p \).

The dynamic equations mentioned earlier contain time-varying mesh stiffness, friction, backlash, and static transmission error, which causes the strong nonlinear problem with parametric excitation in the system.

A fourth- to fifth-order Runge-Kutta algorithm with a fixed time-step (\(\pi/(150 \omega_p)\)) is performed to numerically integrate these coupled nonlinear differential formulas [31]. The total integration time is supposed to be 100\(\pi/\omega_p\). Thus, the transient motion can be eliminated, and the steady-state forced response can be gained.

### 3 CALCULATION OF TIME VARYING MESH STIFFNESS

To find the connection between the rectilinear and the torsional mesh stiffness for gears, a method from [15,18] by using FE method is introduced. The current numerical calculations are performed via FE analysis code ABAQUS under a quasi-static condition. Table 1 lists parameters of a pair of Forschungsstelle für Zahnräder und Getriebebau (FZG) standard gear. The bore diameters of the pinion and gear are 45 and 65 mm, respectively. Since the contact ratio is 1.33, the three meshing teeth pairs of the FE model are applied to calculate the mesh stiffness. In order to decrease the element number in the model and reduce the calculation workload, it is necessary to refine the mesh locally. As seen in Figure 3, the gear-bore surface is fixed, and a torque \(T_p = 60 \text{ Nm}\) is applied on the body of the pinion. There are 302,075 linear hexahedral elements of type C3D8R in the model. The total number of nodes is 380,284, and the average aspect ratio of the elements is 5.59. The gear and pinion surfaces are guaranteed to touch each other at any time. The thickness of the gear
coating is 55 µm [32], and the coating is perfectly bonded on the gear substrate. The coefficient of friction (COF) between the coated gear surfaces is μ. The value of COF has been experimentally estimated and described afterwards.

The material of the gear substrate is 20CrMnTi manufactured by Shandong Iron and Steel Company Ltd. Laiwu Company, China. Herein, a friction-reducing coating named diamond-like carbon (DLC), prepared by Southwest Institute of Physics, Mianyang, China, is deposited on the gear surfaces. Mechanical properties of the substrate and coating materials are shown in Table 2. For a DLC coating, the multiple variety of its structures as well as its diamond bond (sp³) and graphitic bond (sp²) content lead to a diversity of mechanical properties. Its elastic modulus fluctuates from 60 to 650 GPa [33]. To get the COF, the test is performed on a four-ball tribometer [34] using GL-5 heavy-duty extreme pressure gear oil (85w-90) as the lubricant. The friction curve of the DLC-coated sample is shown in Figure 4. It can be found that the COF during the stabilization period is individually about 0.067, which is imported into the earlier numerical calculation as a constant.

The angular deflections of the measurement points on the end surface circle of the pinion bore are obtained. The angular displacement of the pinion body is denoted by the minimal angular deflection θp. The rectilinear mesh stiffness can be evaluated as follows:

\[
k_m = \frac{T_p}{\delta_p r_p^2}.
\]

The time-varying mesh stiffness is calculated by selecting 20 meshing points (evenly distributed) from the tooth root to top. To verify the correctness of the current FE method, its result is compared with that of the commercial software KISSsoft (Gleason Company in Bubikon, Switzerland) [10]. It can be seen from Figure 5 that the two groups of results have good accuracy and coincide with each other.

The curve-fitted plot of mesh stiffness variation along with the rotation angle is evinced in Figure 6. The meshing process of the gear pair inevitably appears to be alternating single and double teeth meshing. It is observed that the gear-mesh stiffness rises with the increase of coating elastic modulus. The main cause is that the deformation of the stiff coating is smaller than that of the soft one under the same load. Moreover, due to the influence of the substrate, when the coating elastic modulus is doubled, the mesh stiffness is not doubled, but the increase in amplitude is approximately the same.

### 4 ANALYSIS OF THE NONLINEAR DYNAMIC RESPONSES

The main parameters in the current dynamic model are cited from [27], which are shown in Table 3. The present section describes the influence of coating on the nonlinear dynamic responses. It is a fact that the gear transmission system may exhibit multiperiod, quasi-period, and chaos motion. To demonstrate the dynamic behaviors more visibly, different diagrams, such as the time-history curve, phase curve, Poincare map, and FFT (fast Fourier transform) spectrum, are shown in Table 3.

For the case of an uncoated gear pair (E_c = E_s), it can be found from Figure 7a that the vibration displacement of the driving wheel along OLOA is symmetrical about x_p = 0, with quasi-period characteristics, and the difference between each cycle is small. The phase

<table>
<thead>
<tr>
<th>Parameter</th>
<th>20CrMnTi Substrate</th>
<th>DLC Coating</th>
</tr>
</thead>
<tbody>
<tr>
<td>Elastic modulus (GPa)</td>
<td>210</td>
<td>105, 210, 420</td>
</tr>
<tr>
<td>Poisson’s ratio</td>
<td>0.3</td>
<td>0.3</td>
</tr>
</tbody>
</table>

**Table 2: Mechanical properties of the substrate and coating materials.**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Pinion</th>
<th>Gear</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mass (kg)</td>
<td>0.676</td>
<td>1.084</td>
</tr>
<tr>
<td>Moment of inertia (kg·m²)</td>
<td>4.07 x 10⁻⁴</td>
<td>1.168 x 10⁻³</td>
</tr>
<tr>
<td>Angular speed (rad/s)</td>
<td>50π</td>
<td>50π/1.5</td>
</tr>
<tr>
<td>Torque (N·m)</td>
<td>60</td>
<td>90</td>
</tr>
<tr>
<td>Support stiffness (N/m)</td>
<td>6.56 x 10⁷</td>
<td>6.56 x 10⁷</td>
</tr>
<tr>
<td>Support damping (Ns/m)</td>
<td>1.8 x 10⁵</td>
<td>1.8 x 10⁵</td>
</tr>
<tr>
<td>Amplitude of static transmission error (STE) (µm)</td>
<td>10</td>
<td></td>
</tr>
<tr>
<td>Backlash (µm)</td>
<td>20</td>
<td></td>
</tr>
<tr>
<td>Damping ratio</td>
<td>0.07</td>
<td></td>
</tr>
</tbody>
</table>

**Table 3: Main parameters in dynamic model.**
The vibration response of pinion \((E_c = E_s)\) along OLOA is analyzed by comparing the (a) time-history curve, (b) phase curve, (c) Poincare map, and (d) FFT spectrum.

Figure 8: Vibration displacements along OLOA under different coating elastic moduli.

With the increase of coating elastic modulus, the gear-mesh stiffness and damping increase. The amplitudes of vibration displacements and velocities along OLOA and LOA decrease, respectively. Also, the oscillating curves of DTE move down as a whole. The vibration amplitude along OLOA decreases with the growth of the coating elastic modulus.

Figure 9 shows the time-history curve, phase curve, Poincare map, and FFT spectrum of the driving gear along LOA. It is manifest from the time-history curve that the vibration displacement along LOA fluctuates around 4.8 \(\mu m\). Comparing Figure 9a with Figure 7a, the peak vibration amplitude along LOA is larger than that along the OLOA. The main reason is the meshing force along LOA is greater than the friction along OLOA. The phase curve is a banded area that is neither repeated nor closed in the space, and it is clustered and distributed in a circular shape on both sides. It can be seen from the Poincare map that the phase points are radially distributed but concentrated in a very narrow area, which shows the response of the driving wheel along LOA is a one-period motion. Figure 9c demonstrates the system also has many super-harmonic components. Similar to Figure 8, Figure 10 exhibits the vibration amplitude along LOA decreases with the increase in the coating elastic modulus.

As shown in Figure 11, the DTE fluctuates between 4.5 and 9 \(\mu m\). The phase diagram shows two concentrated areas, continuous but not repeated. According to the Poincare map, the system is still regarded
as one-period motion. As seen from the FFT spectrum, the amplitudes of the first and second frequencies are larger, while the amplitudes of the remaining components are smaller. Figure 12 shows the DTE curve of coated gear models with different elastic moduli. When the coating elastic modulus increases, the DTE of the gear pair decreases as a whole.

The dynamic meshing forces of coated gear pairs are influenced by the DTE and mesh stiffness based on Equation 5. Meshing forces under different coating elastic moduli are shown in Figure 13. The dynamic meshing force fluctuates around 1,750 N. Its amplitude decreases with the increase of coating elastic modulus.

Meanwhile, the dynamic analysis method of the cracked gear can be applied to the coated gear, because both the crack and coating affect the time-varying mesh stiffness. Under the same external load, coatings with different elastic moduli have different time-varying mesh stiffness (Figure 6). The mesh stiffness decreases with the increased length of the tooth root crack [25,31]. It is found from [17] that the amplitude of the vibration displacement declines with the increase of mesh stiffness, which agrees well with the result of the current study (Figures 8 and 10). From [35], the amplitude of DTE increases greatly when the impact of a crack on a gear body is involved. It verifies the law of the effect of the coating elastic modulus on DTE in the present work (Figure 12). Chen et al. [36] demonstrated the tooth root crack could bring serious oscillations to the gear dynamic meshing force. This means the fluctuation situation of the dynamic meshing force becomes more severe with the decrease of mesh stiffness, which is consistent with the conclusion of the research (Figure 13).

5 CONCLUSION
The nonlinear dynamic characteristic of a DLC-coated gear transmission system is analyzed by using a numerical integration approach. The effect of the coating elastic modulus on the dynamic response is investigated. Several illustrative numerical cases are introduced. According to the results, the following conclusions are put forward.

Under the given operating condition, the dynamic characteristic of a gear transmission system tends toward a one-period state, and there are many super-harmonic components in the system. With the increase of coating elastic modulus, the gear-mesh stiffness and damping increase. The amplitudes of vibration displacements and velocities along OLOA and LOA decrease, respectively. Also, the oscillating curves of DTE move down as a whole. Moreover, increasing
the coating elastic modulus can effectively reduce the amplitude of dynamic meshing force. It indicates that, compared with softer coatings, stiffer ones can properly improve the transmission performance of the coated gear system.

**AUTHOR CONTRIBUTIONS**

Conceptualization, Y.X. and J.L.; Methodology, Y.X. and L.F.; Software, Y.X. and L.F.; Validation, Y.X. and M.K.; Formal Analysis, J.L.; Investigation, M.K.; Resources, X.X.; Data Curation, Y.X.; Writing—Original Draft Preparation, L.F.; Writing-Review and Editing, Y.X.; Visualization, W.S.; Supervision, W.S.; Project Administration, Y.X.; Funding Acquisition, Y.X. All authors have read and agreed to the published version of the manuscript.

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**CONFLICTS OF INTEREST**

The authors declare no conflict of interest. The funders had no role in the design of the study; in the collection, analyses, or interpretation of data; in the writing of the manuscript, or in the decision to publish the results.
NOMENCLATURE

b: half of total gear backlash

\( c_{px} \): radial damping in \( x \) direction of pinion

\( c_{py} \): radial damping in \( y \) direction of pinion

\( c_{gx} \): radial damping in \( x \) direction of gear

\( c_{gy} \): radial damping in \( y \) direction of gear

\( c_m \): mesh damping

\( e(t) \): STE

\( e_a \): amplitude of STE

\( t \): time

\( T_p \): drive torque applied on pinion

\( T_g \): brake torque applied on gear

\( F_{pf}(t) \): friction force of \( i \)th tooth pair on pinion

\( F_{gf}(t) \): friction force of \( i \)th tooth pair on gear

\( F_{pNi}(t) \): meshing force of \( i \)th tooth pair on pinion

\( F_{gNi}(t) \): meshing force of \( i \)th tooth pair on gear

\( f(\cdot) \): nonlinear displacement function

\( I_p \): moment of inertia of pinion

\( I_g \): moment of inertia of gear

\( k_{px} \): radial stiffness in \( x \) direction of pinion

\( k_{py} \): radial stiffness in \( y \) direction of pinion

\( k_{gx} \): radial stiffness in \( x \) direction of gear

\( k_{gy} \): radial stiffness in \( y \) direction of gear

\( k_{rni}(t) \): time-varying mesh stiffness

\( k_{mm} \): integral average stiffness

\( L_{pi}(t) \): friction arm of pinion with \( \theta \)th tooth pair

\( L_{gi}(t) \): friction arm of gear with \( \theta \)th tooth pair

\( m_p \): mass of pinion

\( m_g \): mass of gear

\( r_p \): base circle radius of pinion

\( r_g \): base circle radius of gear

\( x_p \): translatinal displacement of pinion along LOA

\( y_p \): translational displacement of pinion along LOA

\( x_g \): translational displacement of gear along LOA

\( y_g \): translational displacement of gear along LOA

\( \theta_p \): angular displacement of pinion

\( \theta_g \): angular displacement of gear

\( z_p \): tooth number of pinion

\( z_g \): tooth number of gear

\( \lambda(t) \): direction coefficient of tooth friction

\( \mu \): COF of gear pair

\( \alpha \): pressure angle at pitch point

\( \phi_j \): involute outspread angle at point \( j \)

\( \psi_{pi} \): minimal angular deflection of pinion

\( \phi_{g1} \): phase angle of STE

\( \omega_p \): angular speed of pinion

\( \omega_g \): angular speed of gear

\( \omega_c \): fundamental frequency of STE

\( E_s \): substrate elastic modulus

\( E_c \): coating elastic modulus

\( L \): tooth face width

\( \delta(t) \): DTE

\( \zeta \): damping ratio


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ELECTRIFICATION IN THE AUTOMOTIVE DOMAIN
Electric vehicles are set to disrupt automotive industry trends over the years ahead, which will have an effect on gear manufacturing.

By SALONI WALIMBE

In the modern world, there is no limit to the varieties of vehicles available in the market. From variations in engine types such as gas and electric to diverse drivetrains such as four-wheel or front-wheel drives, the options for automobiles are nearly endless, designed to fulfill ever-evolving consumer needs.

Despite the diversity in terms of features and technologies, however, there is one component that is a core component of all vehicles, the automotive transmission system.

Considered one of the most complex automotive components, the transmission, also known popularly as the gearbox, is a metal case that holds a series of gears. The automotive transmission is responsible for taking power from the engine and delivering it to the wheels in order to power the vehicles. It also ensures the right amount of power reaches the wheels so as to help them operate at the desired speeds. In an automotive transmission system, each gear operates within a set ratio in order to ensure the wheels and engines are not spinning at the same speed.

AUTOMOTIVE TRANSMISSION: AN OVERVIEW

The modern automotive transmission market is categorized broadly into two types: manual and automatic. In manual transmissions, the driver is responsible for the shifting of gears, whereas automatic transmissions allow the car to execute this. The journey of gear manufacturing from the conventional manual transmission systems to the burgeoning automatic transmission technologies has been an eventful one, helped along by innovative and targeted efforts by a myriad of industry players over the years.

Cars in the early days, while mechanically simpler than their contemporary successors, were significantly complex for their time. Therefore, even in a time when cars were arguably at their simplest, vehicle transmissions were considered the most complicated vehicular component.

Early transmission technologies, first brought into existence by Louis-Rene Panhard and Emile Levassor in 1894, were all manual, varying in complexity depending on the number of gears to be handled. The original transmission by Levassor and Panhard involved the use of a chain drive and is still considered to be a basic starting point for modern manual transmission systems.

Manual transmission continued to dominate gear production trends throughout the late 1800s and the early 1900s. In 1937, however, General Motors revolutionized the automotive transmission industry by introducing the world’s first semi-automatic transmission system, dubbed the Automatic Safety Transmission. Shortly after in 1938, GM also introduced the first line of vehicles to feature automatic transmissions, known as the Oldsmobile Hydra-Matic drives.

These developments triggered a series of evolutions over the years, such as Chrysler’s introduction of a two-speed torque converter in the early 1950s, which contributed significantly to the burgeoning interest in automatic transmission systems that continues to surge even in the present.

Most vehicles in the modern era are now equipped with automatic transmission systems controlled electronically. Rapid technological advancements have paved the way for automation of torques, power transfer, and gears, among others. These advancements led to the emergence of novel transmission technologies such as CVT (continuously variable transmission), which delivers more power and fuel efficiency by leveraging a variable set of gears that allow the engine to run at its optimum RPM; dual-clutch transmission, which uses two separate clutch discs for odd- and even-numbered gears to facilitate easier gear shifting; and the semi-automatic transmission, which enables the
driver to choose between maintaining full control over shifting and putting the transmission in a fully automatic mode.

**THE SHIFT TO ELECTRIFICATION**

The automotive industry is no stranger to evolution. This is evident from the string of emerging trends in the automotive industry over the years, the most prominent among them being the onset of the EV revolution.

Electric vehicles are set to disrupt automotive industry trends over the years ahead. For instance, in Europe, July 2020 emerged as a record-breaking month for electric vehicle registrations. According to JATO estimates, EV volumes in the month saw a year-on-year rise of nearly 131 percent, reaching 230,700 units.

This gradual transition to EVs has triggered rapid changes in the way the automotive industry and carmakers are approaching product manufacturing as well. Advancements in gear production techniques and innovations are among the major ways of helping automakers adapt to shifting trends in the market.

Suppliers and OEMs alike are having to change their processes and products in order to accommodate new automotive technologies. For instance, parts that played a key role in ICE production may no longer witness the same interest in an increasingly EV-based automotive landscape.

ICEs usually require more complex gear ratios, in order to keep an engine within a narrow range of speeds for optimum torque and power during acceleration. On the other hand, EV motors can maintain their efficiency across a broad range of speeds and can, therefore, run on single-speed transmissions. However, in order to address any potential range anxieties that may impede EV uptake, drivetrain suppliers and OEMs are working toward developing advanced multi-speed transmission systems designed for electric vehicles.

To illustrate, Canadian automotive supplier Inmotive introduced its patented two-speed transmission, dubbed Ingear, in September 2020. Invented specifically for the next-generation of EVs, the Ingear transmission is designed to be a simple and durable solution for a more efficient powertrain with an extended range at more economical costs.

Advancements in gear production techniques and innovations are among the major ways of helping automakers adapt to shifting trends in the market.

The recent developments in automotive technologies have also led to intensifying efforts by key automotive transmission manufacturers to usher in new gear manufacturing technologies to cater to the evolving automotive performance needs. For instance, in 2019, Ricardo made an investment of nearly £1.5 million toward cutting-edge gear manufacturing machine tools to enhance and expand its capabilities and productivity. The adoption of tools such as the Klingelnberg spiral bevel grinder has enabled the company to ensure rapid delivery of market-ready components for its current sports car and motorsport transmission range, in turn positioning it at the forefront of digital manufacturing.

**ABOUT THE AUTHOR**

An avid reader since childhood, Saloni Walimbe is following her passion for content creation by penning down insightful articles relating to global industry trends, business, and trade and finance. With an MBA-marketing qualification under her belt, she has spent two years as a content writer in the advertising field.
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For information on how you can participate in the GearSolutions.com community storefront, contact dave@gearsolutions.com.

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A LEADING GEAR MANUFACTURER THROUGH MANY GENERATIONS
Gear Motions specializes in supplying custom-cut and ground gears for OEMs across the globe and is capable of manufacturing all types of custom gears.

By KENNETH CARTER, Gear Solutions editor

Even with a history that stretches across more than a century, it’s been an important part of the success of Gear Motions to continue to keep a solid eye on the future.

“Our evolution has been dramatic at times and incremental at other times,” said Dean Burrows, president and CEO of Gear Motions. “We were one of the first U.S. companies to embrace precision gear grinding. We have and continue to invest in technology to provide a competitive edge. As our customers’ needs have changed, so have we. We specialize now more in smaller quantities but a high mix of part numbers. Few companies can master this complexity, but we have. With the transition to electric vehicles and non-gear power transmission, we will continue to adapt to meet this every changing landscape.”

But that evolution doesn’t mean that Gear Motions loses sight of its roots, according to Burrows.

“We do a lot of work in specialty automotive,” he said. “We always say, ‘If you’ve got an old Harley Davidson motorcycle, we make all the spare parts for every Harley Davidson motorcycle going back to 1930s.”

MANUFACTURING A WIDE RANGE OF GEARS

However, supplying specialty products to the automotive industry is just the beginning.

Gear Motions supplies custom cut and ground gears for OEMs all around the world, and the company can manufacture all types of custom gears — cut or precision ground. These products include precision ground helical gears, spur gears, pump gears, bevel gears, and worm gears, as well as multiple types of sprockets, timing pulleys, shafts, and splines.

“We do a lot of superchargers for high-end aftermarket applications,” Burrows said. “We do pump gears. We do a lot for the mining side of the industry. We don’t do a lot of military/aerospace, but we’ll do a little bit. Most of our products are precision, and we do a lot of ultra-precision. But 90 to 95 percent of what we do is precision ground gearing.”

Although Gear Motions, itself, was founded in 1973, it has since acquired multiple companies that have extended its overall expertise, as well as its history.

“Gear Motions has been a leading gear manufacturer through many generations,” Burrows said. “Oliver Haines served as chairman for the Association. I currently am chair of the AGMA Foundation. Besides these leadership roles, our team members have been actively involved in many AGMA committees, including technical committees. We exhibited at the MPT Expo in 2019 and will again in 2021.”

STRONG CUSTOMER BASE

A huge part of that success is being able to have solid customer base that come back to Gear Motions over and over again, according to Burrows.

“Many of our customers have been with us since the 1960s,” he said. “As their businesses have changed, we have grown and evolved with them as well. We’re not a big company on publicly celebrating our accomplishments. We know our accomplishments are when our customers thank us for going above and beyond, and this has been true for many years.”
CREATING A SOLID PORTFOLIO
Gear Motions was founded in 1973 by Samuel T. Haines. After purchasing Rawling Gear in the 1960s, the 10-man company served a local New England market for custom gear products. The company grew, renovated, and enlarged its facility, and began to look for new opportunities. Gear Motions was incorporated shortly after that. After joining the business, Samuel R. Haines' vision was to develop a regional network of companies whose unique specialties could be leveraged to better serve the wide-ranging needs of customers. The newly formed organization brought the management, marketing, and financial strengths of a larger size company while maintaining the unique service aspects of smaller regional shops.

Gear Motions' first acquisition was Oliver Gear, based in Buffalo, New York. Five years later, Nixon Gear was purchased out of bankruptcy. It was also about this time that Gear Motions began its sales and marketing activities in earnest, developing a national sales force providing coverage from the East Coast to Texas. In the early 1980s, the Plastic Gearing Services Division was created to provide design and development of high strength plastics gearing for the emerging business machine market. In 1988, Gear Motions acquired Gear Supply and Broaching, a California gear-manufacturing company. During the 1990s and early 2000s, these businesses were either consolidated into existing facilities or sold.

In 2005, Gear Motions transitioned from a privately held company to an Employee Owned Company (ESOP). President Samuel R. Haines’, and the Haines family, plan was to begin a 10-year ownership transition to assure the companies in Gear Motions remained in the communities that supported them during their history.

In 2012, Gear Motions acquired Pro-Gear Co. Inc., a gear-grind-only manufacturer in Buffalo, New York. This acquisition allowed Gear Motions to add more capability to its group of precision gear manufacturers that seek gear-grind-only capabilities. That same year, Gear Motions partnered with KBE+, a design and engineering firm specializing in the design, analysis, and test services for gear systems and mechanical transmissions.

In 2020, Gear Motions and KBE+ formed Kinatech, which introduced a revolutionary, newly-patented product to the market. First introduced at the 2019 Motion and Power Technology Expo, the product provides an industry shifting approach to mechanical braking and positioning.

WORKING WITH CUSTOMERS
Gear Motions’ decades-long chess game of business modeling is a large part of the company’s success, and it is paramount to how Gear Motions has worked closely with its customers in order to meet any challenge that gets thrown its way, according to Burrows.

“I know this will sound very cliché, but we first try to understand their pain,” he said. “What problem are they truly trying to solve? Is it a product performance issue, a supply chain challenge, or a new product design? Many times, this discussion reveals numerous items of concern they have and others that they didn’t know they have. We have become industry known for the depth of expertise from our engineering team. We have hundreds of years of gear-manufacturing design, process, production, and failure analysis. We very rarely ever encounter a problem we can’t solve, and if we do, we have a great industry network to tap into for expertise.”

That is an interesting philosophy for a company to take, but Burrows said, above all else, it’s important that the industry as a whole succeeds.

“When each one of us succeeds, we all succeed,” he said. “Our
doors are always open to any gear manufacturer. Competitors or not, we know if we can make someone else’s business better or they can make ours better, the industry gets stronger. We believe in collaboration and partnerships. We are proud of what we do, but we also know we can always be better.”

LOYAL STAFF
Burrows is also proud of a staff that has a staying power that few companies can match.

“From an employee-owned standpoint, we have a lot of longevity in our team,” he said. “I would say about 35 to 40 percent of our employees have seniority over 25 years. We have probably five employees with over 40 years. And we’ve had employees who have spent 65 years with us, which, I think was our highest seniority at one point when he retired.”

FULL-SYSTEM SOLUTIONS
As the industry moves to address innovations such as electric cars and other similar technologies, Burrows said the trends will move toward creating full-system solutions for Gear Motions’ customers.

“Just don’t provide me a gear; provide me the gearbox; don’t just provide me with a gear, give me a shaft gear-bearing retainer assembly,” he said. “That has a lot of our customers looking at their staff, and, with fewer people, they want to buy one part number that has 17 components, where before they would buy 18 components and assemble that in-house. They’re looking for more of that, and they’re also looking for the suppliers to be technical experts, because they don’t have the gear engineers that they used to have. They don’t have the in-house technical expertise that they used to have. And they rely more on their suppliers to have that expertise.”

That makes companies such as Gear Motions invaluable in a market where manufacturers look to outsource their components, according to Burrows.

“That’s where companies like us do very well, because we have a very, very strong bench of experienced engineers where customers come to us and say, ‘I’ve got this problem; I have this situation,’” he said. “They may have had that expertise in-house years ago, but now, they no longer do, so they have to go to companies like us to help them solve their problems. There’s not a lot of companies who have that ability, and that helps us stand out against our competitors.”

PREPARING FOR A CHANGING INDUSTRY
And that level of expertise is going to be even more important as the industry makes a dramatic transformation over the next decade or two, according to Burrows.

“I do not see the day when there will be no need for gears, but I see that the need will be less and less,” he said. “With the shift to electric vehicles, there will be fewer automotive gears. Different technologies will replace what gears currently do. Gearing will become more specialized, and the needs more niche.”

With that specialization will come the need for better and more engineering expertise, according to Burrows.

“From a Gear Motions perspective, our strategic roadmap leads us into more closed gearing and away from being mostly an open gear manufacturer,” he said. “Customers are needing more turn-key solutions. They are seeking less complexity and ease of doing business. We are positioned to tap into this trend. We are also going to be introducing our own set of products into the market. This will continue to transition from an open gear manufacturer to a closed gear one.”

MORE INFO
gearmotions.com
Exact Metrology introduces PolyScan XL 3D scanner system

Exact Metrology, a comprehensive 3D metrology service provider and hardware sales company, represents PolyScan XL. Part of the Polyrix PolyScan™ Surround 3D Scanner family, these scanners are motionless by design during the inspection. Their unique calibration avoids the need for data alignment or sticker targets, and multiple baselines increase accuracy when measuring points.

The PolyScan XL6 is designed to measure parts up to 1,600 mm, combining 12 cameras and 12 projectors to provide 210 effective scanning units. It is ideal for medium-to-large aerospace castings or automotive sheet metal components. Complete inspection of parts is achieved in only six minutes. Surround design and simplicity of automation means it can be easily integrated into a production line, while being 100 percent safe for operators.

PolyScan XL8, the larger version of XL, is designed to measure parts up to 2,000 mm. It combines 16 cameras and 16 projectors to provide 376 effective scanning units.

Surround Scanning is made possible by the huge amount of R&D that Polyrix placed on software development since 2005. The PolyScan Control Center (PCC) manages data acquisition from all scanning units, thus generating 3D models. Furthermore, PolyScan operation is made easier by the simple interface of the Automation Manager, or by third party plug-ins (e.g. Polyworks Inspector™ Plug-in).

All PolyScan scanners are simple, fast, and safe. There is no need to program inspection trajectory, unlike CMM and robotic scanning solutions. Data is quickly captured from every angle. With PolyScan, there is no risk of collision with an operator. No costly enclosure and safety systems are needed. Furthermore, the scanners offer high-inspection throughput, generating higher returns on investment. Process control is fast to obtain, since scanning is easier. Users also benefit from a quick check of their part in a matter of minutes.

Exact Metrology is ISO9001, AS9100 Certified as well as FFL and ITAR Registered.

MORE INFO  www.exactmetrology.com

Helios announces strategic approach to large-gear deburring

Chamfer-deburring of large gears — considered here to be those over 1-meter diameter — demand significant labor that comes with the risk of inconsistency and low quality. In partnership with Tecnomacchine, Helios offers an improvement to such applications.

“For very large spur and helical gears, this deburring approach cost-effectively reduces labor and increases consistency and quality," said Adam Gimpert, president of Helios Gear Products.

For such large gears, several challenges demand improved solutions. Because these gears take significant time to move and fixture, a dedicated machine for deburring such workpieces becomes impractical. This is due to complex setups and relatively expensive machine components, such as precision motors, electronics, and structural elements. To solve these challenges, Tecnomacchine has developed a solution that adds chamfer-deburring capability to a manufacturer’s existing finishing equipment, either hobbing or grinding. The key benefit to this “deburring unit” is that the workpiece remains fixtured from the prior finishing operation, and the same platform rotates the workpiece for the chamfer-deburring operation.

This added capability comes in a simple package for less than half of the cost of a dedicated machine. The deburring unit either mounts permanently to the existing hobbing/grinding machine structure or it uses a clamping system to temporarily mount for operation. Once the unit is positioned, the hobbing/grinding machine rotates the workpiece, and the deburring unit engages a disk-type cutter to shear away large burrs particularly at the root of the tooth. This allows consistent, high quality chamfer-deburring
in subsequent steps. Next, the unit simultaneously engages two tools to deburr bottom and top of the gear.

Manufacturers with large-gear finishing machinery, such as hobbing or grinding equipment, will welcome this strategic approach. Effectively, this solution simply adds to existing machinery new chamfer-deburring capability as a subsequent cycle without the need for re-fixturing. Consequently, manufacturers can have a simple, productive means for reliable, high-quality gear chamfer-deburring.

Helios Gear Products, LLC specializes in the parallel axis gear industry and offers hobbing machines with optional automatic loading systems, worm and thread milling machines, gear inspection equipment, deburring and chamfering machines, consumable tools (including hobs, gear grinding and honing wheels), hob and shaper cutter sharpening machines, and expert services for hob sharpening and part inspection.

MORE INFO  www.heliosgearproducts.com

Jorgensen Conveyor and Filtration Solutions’ EcoFilter conveyor

The EcoFilter® Conveyor from Jorgensen Conveyor and Filtration Solutions is the first competitively priced conveyor and filtration system for entry-level and mid-priced turning and machining centers. This patent-pending, self-cleaning design works on larger, higher-priced machines as well.

The second generation EcoFilter uses an innovative two-stage metal chip removal and coolant filtration design. A hinged steel belt conveyor handles primary removal of large chips. In a secondary process, a flow-through filtration cell separates fines from coolant. Heavy duty brushes attached to the bottom side of the belt wipe these fines from the surface of the filter cell, where they flow to the bottom of the conveyor via the patent pending CleanCleat®. Standard angle cleats on the bottom run of the conveyor belt then scrape the separated fine chips back to the top of the belt for discharge.

The EcoFilter offers numerous advantages that can increase productivity and profitability. It dramatically reduces the number of chips that migrate to the coolant tank, which decreases the frequency of tank cleanout and the amount of downtime required for maintenance at the same time that it greatly improves pump, tooling and coolant life. The environmentally friendly EcoFilter design uses no consumables, and its single-drive design reduces energy consumption. For convenience, “EcoFilter Ready” conveyors are available for field conversion to EcoFilter.

Jorgensen customers report positive results using the EcoFilter conveyor. In a high-volume operation that machined aluminum parts on a vertical machining center, a large percentage of chips filled the coolant supply tank, necessitating multiple daily clean-outs of tank baskets and screens, and weekly production downtime to clean out the tank. Chip migration into pump inlets fouled machine supply pumps and caused them to fail, forcing the installation of filters on the inlets. When blinded off, these filters caused the pumps to cavitate, producing foam in the coolant. The system frequently backed up and coolant flooded the shop floor.

With Jorgensen’s EcoFilter conveyor in place, the customer enjoyed uninterrupted 24-hour/5-days-per-week production. “The filter cell built into the conveyor has stopped the fines from getting into the tank, and the

The second generation EcoFilter uses an innovative two-stage metal chip removal and coolant filtration design. (Courtesy: Jorgensen Conveyor and Filtration Solutions)

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WeldSight software completes Olympus’ UT weld inspection solution

Olympus’ release of its WeldSight™ companion PC software for the OmniScan™X3 phased array flaw detector provides inspectors with powerful tools to push the boundaries of flaw characterization and sizing. Compatible with conventional UT, phased array (PA), and time-of-flight diffraction (TOFD) acquired data, the software enables inspectors to perform thorough post-inspection analyses that comply with strict validation requirements of international standards.

Experienced PAUT inspectors can perform advanced validation of indications using the software’s weld analysis tools. Inspectors will save time with powerful screening capabilities that cut down the need for cross validation. They can characterize and orient flaws faster, even in complex geometries, by merging distinct scan files and using multiple view options to examine the weld in detail from all sides.

WeldSight software is also equipped with an innovative geometry-based weld gate that generates a C-scan using data from inside the weld only. This as well as other exclusive post-inspection functionalities give inspectors the ability to fully exploit and fine-tune their OmniScan X3 acquired data to accurately pinpoint the areas of interest and precisely size and characterize flaws.

To enable inspectors to comply with the requirements of a specific procedure, application, or code, the software’s scan data displays can be dragged and dropped to create a customized layout. Acquisition data integrity can also be validated and improved with the missing data statistics, editable gates, and encoder recalibration tools.

Olympus’ industrial solutions range from industrial microscopes and videoscopes to nondestructive testing technology and X-ray analyzers. These products are widely used for quality control, inspection, and measurement applications.

Tormach Inc. introduces new 8L lathe that fits a variety of spaces

Tormach Inc., a leading supplier of affordable and compact CNC machines, introduced the 8L lathe, its newest machine.

The new 8L is a small machine with big capabilities, and has the ability to fill turning needs in a variety of spaces. Rigid enough to cut anything, whether it’s plastic, stainless steel, or even titanium, this machine can handle it, and at an approachable price point. Starting at $6,595 for the basic machine with tailstock and fully-assembled enclosure, an 8L lathe deluxe package with numerous features — including a robust machine stand with integral coolant tank, separate chip drawer for easy removal, storage drawers and optional side shelving, as well as PathPilot controller, tool holder/tool kit, monitor, keyboard, mouse, and more — is available for $8,875. The fully-loaded 8L build comes in under $10,000.

“We are excited to introduce this new lathe to the market,” said Cory Bailey, Tormach’s product engineer. “Tormach was founded on the idea of bringing cost-effective and capable CNC equipment to market and this one provides users with everything needed to face, turn, bore, groove, and thread. We know of no other machine that offers such advanced software and capabilities at such an affordable price.”

The 8L lathe features a 5C spindle that accommodates parts up to 1-inch diameter, which meets the needs of most lathe users. For larger pieces up to 8 inches in diameter, users can simply add a 3- or 4-jaw chuck to cut the stock. The stepper motors on the X and Z axes provide a feed rate of 150 IPM (3.8 m/min).

Like all Tormach CNC machines, the 8L lathe will be controlled by the PathPilot software system. That means users can use intuitive conversational lathe programming, do rigid tapping, and leverage built-in Dropbox™ support for transferring programs. PathPilot and PathPilot HUB has been known to be incredibly powerful for beginner CNCers, as well as veteran machinists and educators.

The new 8L is unique, not just among other Tormach machines, but also in the general machine tool market, because it offers a 1.5 HP (1.11 kW) spindle that runs at 180-5,000 RPM. It already comes with the machine in a fully assembled enclosure as part of the base model, but the footprint remains small (26” x 50”), and the lathe itself is attached to a hand-scraped 140-pound cast base. Like all Tormach machine tools, the 8L runs on standard single-phase household power (115 Vac, 50/60 Hz, and a 15 A breaker).

Travels on the 8L are impressive for its compact size. The maximum workpiece length is 10 inches with the tailstock. The X-axis travel is 4.5 inches, so users can accommodate a part that fully uses the 8-inch swing.

It’s configured for Industry Standard OXA Quick Change Tool Post. Instead of the operator needing two wrenches that turn hardware in opposite directions, the machine itself can lock down the tool holder. By allowing “one-hand tool changing,” this takes a typically inconvenient task and not only makes it easier, but also greatly reduces the time required to change the tooling.

**MORE INFO** www.olympus.com

**MORE INFO** www.tormach.com

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coolant is no longer foaming up,” the customer said. “This new EcoFilter conveyor has by far exceeded my expectations. The most problematic machine tool in our shop is now the most hassle free.”

**MORE INFO** www.jorgensenconveyers.com

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**Tormach Inc. introduces new 8L lathe that fits a variety of spaces**

Tormach Inc., a leading supplier of affordable and compact CNC machines, introduced the 8L lathe, its newest machine.

The new 8L is a small machine with big capabilities, and has the ability to fill turning needs in a variety of spaces. Rigid enough to cut anything, whether it’s plastic, stainless steel, or even titanium, this machine can handle it, and at an approachable price point. Starting at $6,595 for the basic machine with tailstock and fully-assembled enclosure, an 8L lathe deluxe package with numerous features — including a robust machine stand with integral coolant tank, separate chip drawer for easy removal, storage drawers and optional side shelving, as well as PathPilot controller, tool holder/tool kit, monitor, keyboard, mouse, and more — is available for $8,875. The fully-loaded 8L build comes in under $10,000.

“We are excited to introduce this new lathe to the market,” said Cory Bailey, Tormach’s product engineer. “Tormach was founded on the idea of bringing cost-effective and capable CNC equipment to market and this one provides users with everything needed to face, turn, bore, groove, and thread. We know of no other machine that offers such advanced software and capabilities at such an affordable price.”

The 8L lathe features a 5C spindle that accommodates parts up to 1-inch diameter, which meets the needs of most lathe users. For larger pieces up to 8 inches in diameter, users can simply add a 3- or 4-jaw chuck to cut the stock. The stepper motors on the X and Z axes provide a feed rate of 150 IPM (3.8 m/min).

Like all Tormach CNC machines, the 8L lathe will be controlled by the PathPilot software system. That means users can use intuitive conversational lathe programming, do rigid tapping, and leverage built-in Dropbox™ support for transferring programs. PathPilot and PathPilot HUB has been known to be incredibly powerful for beginner CNCers, as well as veteran machinists and educators.

The new 8L is unique, not just among other Tormach machines, but also in the general machine tool market, because it offers a 1.5 HP (1.11 kW) spindle that runs at 180-5,000 RPM. It already comes with the machine in a fully assembled enclosure as part of the base model, but the footprint remains small (26” x 50”), and the lathe itself is attached to a hand-scraped 140-pound cast base. Like all Tormach machine tools, the 8L runs on standard single-phase household power (115 Vac, 50/60 Hz, and a 15 A breaker).

Travels on the 8L are impressive for its compact size. The maximum workpiece length is 10 inches with the tailstock. The X-axis travel is 4.5 inches, so users can accommodate a part that fully uses the 8-inch swing.

It’s configured for Industry Standard OXA Quick Change Tool Post. Instead of the operator needing two wrenches that turn hardware in opposite directions, the machine itself can lock down the tool holder. By allowing “one-hand tool changing,” this takes a typically inconvenient task and not only makes it easier, but also greatly reduces the time required to change the tooling.

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**MORE INFO** www.olympus.com

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**MORE INFO** www.tormach.com
New Rollon linear guide handles higher loads, solves misalignment

Rollon has introduced its Compact Rail Plus — part of its new generation of high-performance linear guides. This rugged unit features a new design to handle higher loads while maintaining the Compact Rail product family’s self-aligning capabilities.

Compact Rail Plus is designed for demanding applications such as those involving higher loads, high speeds, fast accelerations, or harsh, dirty operating environments. Its design features double-row ball bearings for greater load capacity in both radial and axial directions, new rails with convex raceways for added rigidity, and steel sliders with longitudinal seals to protect internal components from dirt and contaminants. Induction-hardened raceways in select models ensure quiet operation and a long lifetime, and different surface treatments are available to resist corrosion.

Like its Compact Rail counterparts, this compliant guide can align itself to less-than-perfect mounting surfaces. Available with a choice of four different sliders, Compact Rail Plus allows two rails to be combined with different sliders to create a self-aligning system that can compensate for misalignment errors on two planes: axial up to 3.5 millimeters and radial up to ±1.3 degrees. Taken together, Compact Rail Plus’ features and capabilities will allow users to:

- Choose the best structure according to their accuracy requirements.
- Easily mount the linear guide on non-machined structures.
- Reduce total assembly time.
- Deploy the guide in harsh environments.

In addition to high load and self-alignment capabilities, Compact Rail Plus also offers:

- A C-profile that contains the sliders and the rolling elements, keeping dimensions compact.
- Adjustable preload.
- Nitrided, black oxidated, and polished raceways.

Compact Rail Plus is well-suited for a broad range of applications such as cutting machines, medical technology, packaging machines, photographic lighting equipment, construction and medical technology, robots, and many other automated machines and equipment.

MORE INFO
www.rolloncorp.com

This Compact Rail compliant guide can align itself to less-than-perfect mounting surfaces. (Courtesy: Rollon)

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“The big advantage is that the customer is responsible for nothing; we install it, we set the machine up, and we train the customer on the machine.”

What you do at DMG MORI?
I am the sales manager for DMG MORI Capital Rental Program. I oversee the sales of the rental contracts for the program here nationwide.

Tell us about the rental program.
The program is a pool of seven different models of machines — lathes, horizontal, vertical, and 5-axis — which is a sampling of some of our most popular models available to rent on a monthly basis. That allows our company, as a premier builder, to give our customers some flexibility and an opportunity to get our product on their floor making parts that they wouldn’t have had otherwise.

What are the program’s advantages for manufacturers?
They have the ability to get one of our machines at an obviously lower outlay of capital. The only barrier to getting one of our machines is simply the first month’s payment, signing a contract, and proof that your building is insured. It’s appealing for short-run jobs where somebody might not want to lay out a great amount of cash for a machine. They can simply rent it for a year or up to six.

We’re so flexible that we even have an aspect where they could rent by the hour. “Power by the Hour” is the program. As they use the machine, they’d be renting it rather than the machine sitting there perhaps for two weeks. They’re not paying for idle time. It’s just a more accurate way of billing them for the use of the machine, and there’s a myriad of advantages to that. There’s a minimum use on it, but the general aspect is, once they achieve the minimum usage monthly, they’re not paying for a machine that it isn’t making them money.

Usually, there’s a lot involved with leasing or financing a purchase or just simply buying a machine. With our program, again, there are simply three steps: We do a credit check; there has to be a guarantee of payment by the company, and they have to provide proof that their building is insured. Those three things are the only barrier to entry into this program. The two main types of users of our program have been companies that may be having a problem with cash flow or companies that have just started up. A company that a traditional finance institution would say no to, we say yes to.

What models of machines are available?
The models offered include the CMX 1100 V, DMU 50, NHX 4000, NHX 5000, NHX 5500, NHX 6300, and the LX 2500 SY.

Do you see more manufacturers opting to rent equipment instead of buying or outsourcing their manufacturing needs?
Yes. We launched the program officially in March, which was kind of an auspicious undertaking, considering COVID. We rented the majority of the machines in the pool through the course of this year. I think that was a combination of companies needing machines that they certainly didn’t think they were going to need due to COVID. The pandemic affected manufacturing, so some companies got sent off their traditional sources of work and said they needed a 5-axis machine for the first time, so they rented it instead of buying it.

I should add that when the rental is over, the advantage is, we take care of everything. They aren’t responsible for maintenance. We do a bi-annual check. The machine is covered by an insurance policy. And when they’re done, we come back and pack it up and ship it back to our facility. They don’t have to repair it to sell it, find a buyer, and move it. We eliminate the headache.

Could this program be used by companies to see if a piece of equipment is a good fit before they actually buy?
Certainly. In fact, there’s a rather large Midwest manufacturing company that is doing that; just to see if our 5-axis machines would be something they need — proving the ability to do the part to win the contract.

Is this a unique program or is it something that you’ve emulated?
It’s the only rental program by a builder in the country.

What’s been the market response? Has the pandemic actually boosted the program, or has it been a deterrent to it?
It’s boosted it. The response for the program, as far as inquiries, has been people are very curious about it. We’ve rented most of the machines in our set pool, which is wonderful.

But we see the program growing year to year. This isn’t something that’s going to be a short-lived program.

I think the big advantage, outside of the financial flexibility, is that the customer is responsible for nothing. We install it; we set the machine up, and we train the customer on the machine. Then, we maintain the machine, keep it within specs, and then take it all away, and they don’t have to resell it. They don’t have to worry about finding more work for it. They can extend the lease after the rent. We can change the contract as we go.

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