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A Publication of
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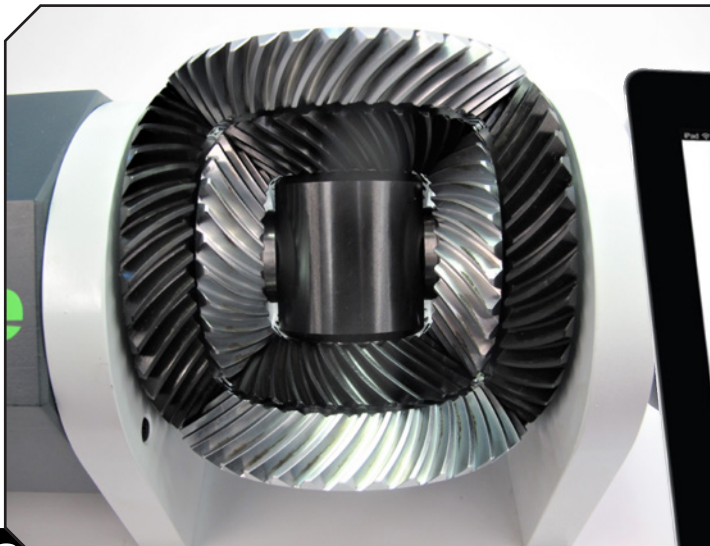

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Vol. 37, No. 6

departments

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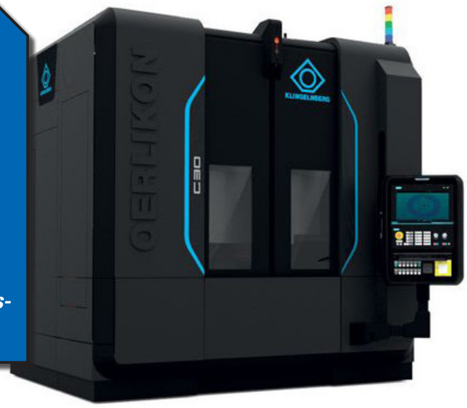
KlingeInberg SmartTooling

With the SmartTooling System from KlingeInberg, tools and fixtures for bevel gear cutting machines can be digitally identified using Data Matrix Codes and centrally managed in a database. Learn more here:

www.geartechnology.com/videos/Smart-Tools-and-Fixtures-with-KlingeInberg-/



Grinding Cycloidal Gears with Reishauer

In contrast to involute gears, cycloidal gears can provide reduction ratios from 30:1 to 300:1 in very compact package spaces. Cycloidal gears feature excellent torsional stiffness, zero-backlash over their whole service life, and very high positioning accuracy. Learn more here:

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Gear Hobbing with Heimatec

Heimatec offers tooling units that can include gear cutters. This allows the gear cutting process, or gear hobbing to be carried out without requiring an additional machine. Platinum Tooling Technologies, Inc. is the exclusive North American importer for Heimatec. Learn more here:

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

EDITORIAL

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

Senior Editor
Jack McGuinn
mcguinn@agma.org

Senior Editor
Matthew Jaster
jaster@agma.org

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

DESIGN

Art Director
David Ropinski
ropinski@agma.org

ADVERTISING

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

Materials Coordinator
Dorothy Fiandaca
fiandaca@agma.org

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

CIRCULATION

Circulation Manager
Carol Tratar
tratar@agma.org

MANAGEMENT

President
Matthew E. Croson
croson@agma.org

ACCOUNTING

Accounting
Luann Harrold
harrold@agma.org

FOUNDER

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

Anticipating 2021

Publisher & Editor-in-Chief
Randy Stott

The number 21 is usually good, right? In blackjack, 21 means you win. In life, 21 means you're officially adult enough to buy alcohol, gamble in a casino or purchase a handgun (In the United States, at least). In military ceremonies, a 21-gun salute is an honor reserved for dignitaries or heads of state.

So, yeah, 21 is usually good. It's a number that's often celebrated. Whether 2021 will be celebrated remains to be seen. But we're at the point where we've all had enough of 2020, and we need something to look forward to. Also, it's that natural time of year when we *have* to begin looking toward next year.

In publishing, we're preparing schedules, forecasting revenues, making budgets. Even though it's only August, we're well into the process of planning for next year. In much of the business world, people are doing the same.

How do you plan when life is so unpredictable? Much hinges on the COVID-19 pandemic. Will there be a vaccine? If so, will it work? Will there be a second wave that ramps up over the fall and winter? Will there be more lockdowns? Opinions on the future of the pandemic change every day – and sometimes more often than that, depending on who's giving them. Add to that an extremely divisive presidential election and social unrest unlike anything we've seen in decades. The result is widespread fear and uncertainty.

Fortunately, I had the opportunity to attend the Industry and Economic Outlook Conference held by the National Fluid Power Association. The AGMA is also a partner in this event, and the speakers included Tom Runiewicz of IHS Markit, whose presentation on the gear industry outlook provided significant insight about the stages of recovery we should expect, as well as when we'll likely see them.

According to Runiewicz, total U.S. domestic demand for gears was about \$5.7 billion in 2019. IHS Markit is currently projecting 2020 demand to finish at about \$5 billion, down 12% from last year. And although that demand varies widely by market — with gears for material handling applications expected to be down only 4.5%, but gears for construction equipment expected to be down 30% — all segments of the gear industry are down in 2020.

Next year, though, we should see some improvement, especially as we get into the second half. But the recovery won't be as fast as the decline, Runiewicz says. And some segments won't likely see meaningful growth until 2022 or later. In fact, IHS Markit isn't predicting U.S. gear demand to hit \$5.7 billion again until at least 2023.

Of course, projections are only as good as long as the current trends hold true. Significant changes in consumer confidence, industrial production and the overall economy can and will be affected by the pandemic, the election and possibly other factors we haven't anticipated.

So what does all of this mean? To me it means we should probably expect the next six, nine or twelve months to continue to be challenging, but that at some point in 2021, we have reasonable hope for some relief.

One thing is clear, though. Access to high-level, in-depth analysis like that provided by IHS Markit specifically for the gear industry is invaluable. The actual presentations at the August conference included much more information than I've been able to share here, including specifics about each market segment, alternative scenarios and probabilities, as well as presentations on other industrial segments such as machine tools, aerospace and so on. If you are a member of AGMA and/or NFPA, these are the kinds of programs you should be taking advantage of. Visit *www.agma.org* for more information.

Will 2021 be a year to celebrate? If we experience anything resembling a return to normalcy over the next 12 months, I'm hopeful. And if demand for gears comes back in a big way by the end of next year, I may even organize the 21-gun salute myself.

Randy Stott

FVA

PRESENTS LOCAL LOAD CARRYING CAPACITY ADVANTAGES COMPARED TO STANDARDIZED METHODS

The *FVA-Workbench* is a manufacturer-independent tool for the simulation and calculation of transmission systems. As product development cycles become shorter, powerful modeling approaches and calculation algorithms become increasingly important. The predominantly analytical approaches in the *FVA-Workbench* deliver fast and reliable solutions to all important issues related to drive technology. For bodies that cannot be accurately described analytically, the results are supplemented by suitable numerical methods. The intuitive modeling techniques in the *FVA-Workbench* enable simulation of consistent, valid, and manufacturable gears every time.

The calculations are developed, analyzed, and validated in research projects by Forschungsvereinigung Antriebstechnik e.V. (FVA, the Research Association for Drive Technology). Through member contributions and public funding, the FVA is able to organize 17 million euros annually in research projects at leading German universities, chairs, and research institutions. The FVA-Workbench serves as a knowledge platform that makes the results of FVA research projects available and accessible to all engineers, without having to read through and study countless pages of scientific documentation.

Cylindrical gear calculations in the FVA-Workbench

The *FVA-Workbench* features the world's most comprehensive library of standard methods for calculating the load carrying capacity of cylindrical gears. In addition to the latest national and international standards such as ISO 6336, DIN 3990, and AGMA 2101, the library also includes calculation guidelines for all major classification societies, the calculation of plastic gears according to VDI 2736, as well as all older versions of these standards.

The load capacity calculation is always preceded by a rolling simulation with one or two tools to determine the cylindrical gear geometry. This ensures that the gear can realistically be manufactured and will run as intended.

In addition to the geometry and the material used, the load distribution during mesh has a significant influence on the load capacity of a cylindrical gear. In the calculation, the influence of uneven load distribution across the face width is taken into consideration via the face load factor KHß (DIN 3990 and ISO 6336) or KH (AGMA 2101). However, the formulas included in the standards only provide a very rough estimation. A detailed deformation analysis of the complete gear system is necessary to be able to quantitatively evaluate the effective influences on the load distribution across the face width.

In the *FVA-Workbench*, the total gear deformation is calculated based on a method developed for FVA and validated using deformation measurements at the Technical University of Munich Institute of Machine Elements, or FZG (see Figure 1 and 2). The following elastic deformations and static displacements can be taken into account, among others:

- Gear stiffness
- Flank modifications
- Shaft deflection and torsion
- Deflections and clearances of rolling and plain bearings
- Casing deformations
- Manufacturing deviations

The deformation analysis in the *FVA-Workbench* can be performed in a few seconds, even with complex gear structures. The face load factor is automatically determined for each cylindrical gear stage and can be taken into account in the selected load carrying capacity calculation.

The calculation of the load distribution across the face width of a planetary stage can be used as an example (Figure 1). If the load distribution across the face width in this stage is calculated based on the torsion of the sun pinion, as in a simplified calculation according to the standard, the result for this example is a face load factor of KHß = 1.83 with a maximum load on the output side of the sun pinion (Figure 2a). However, if the tilting of the planet gears due to deformation, the play of the planet bearings, and the elastic deformation of the planet carrier including the deformation of the pin are also considered, the result is a face load factor of KHß = 1.65, and with the maximum load located on the

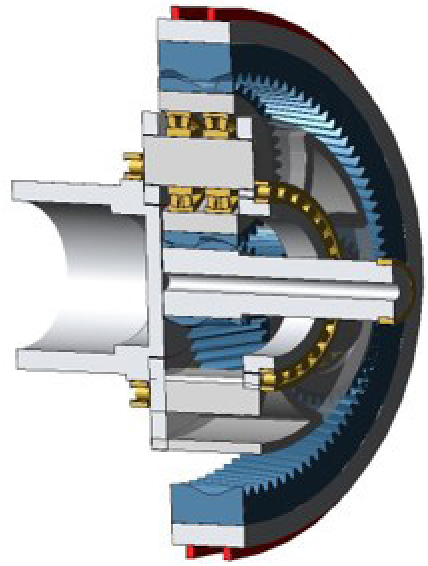

Figure 1 **Example of a planetary stage (Source: FVA-Workbench 3D model).**

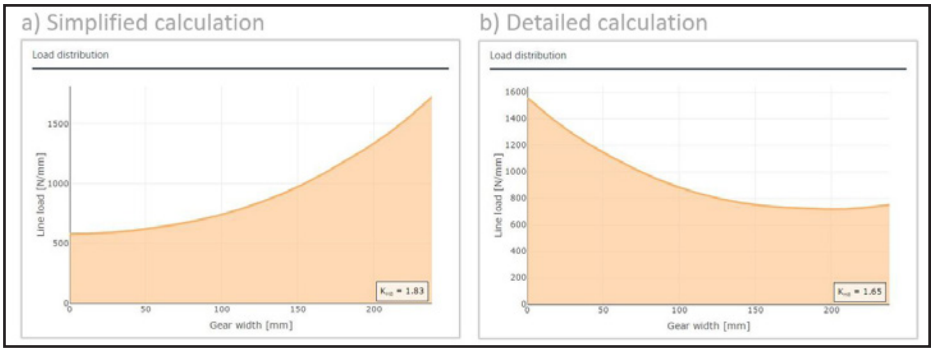

Figure 2 **Comparison of the face load factors for a simplified (a) and detailed (b) deformation calculation (Source: FVA-Workbench reporting).**

opposite end of the gear (Figure 2b).

The detailed system-wide deformation calculation in the *FVA-Workbench* enables a more precise calculation of the load carrying capacity and a practice-oriented optimization of face modifications. This can be used not only to avoid damage, but also to identify hidden load carrying capacity reserves. Cost savings can then be achieved by reducing component sizes and the associated reduced resource usage.

While the influence of uneven load distribution across the face width can be evaluated in standard load carrying capacity calculations using the face load factor KHß, as described above, uneven load distribution across the tooth depth cannot be represented in detail. The following factors can lead to increased flank pressure in the tooth root area of the flank:

- Edge stress in the contact area of the tooth tip edge for helical gears
- Load peaks due to short lines of contact at the start and end of contact for helical gears
- Small radii of curvature at the pinion base with large tooth ratios
- Small radii of curvature near the base circle of a gear mesh

The standard methods assume a suitable profile modification. Only in ISO 6336 (2019) /3/ does the newly introduced fZCa factor lead to a somewhat qualitative consideration of a non-existent or non-optimized profile modification. With the *FVA-Workbench*, on the other hand, the influence of uneven load and pressure distribution over the tooth depth can be more closely examined during the design of a gear.

The local load of each point on the flank is calculated for this purpose. Here, too, proven calculation methods from /1/ are applied, in which the local gear tooth stiffnesses are calculated on an analytical basis using a plate model. This analytical approach allows a very high resolution with a short calculation time. In addition, the *FVA-Workbench* also offers an FE-based approach, which was developed in FVA Research Project 128 at the Laboratory for Machine Tools and Production Engineering (WZL) of RWTH Aachen University. The local load distribution determined in this way forms the basis for additional local load parameters:

- Local flank pressure

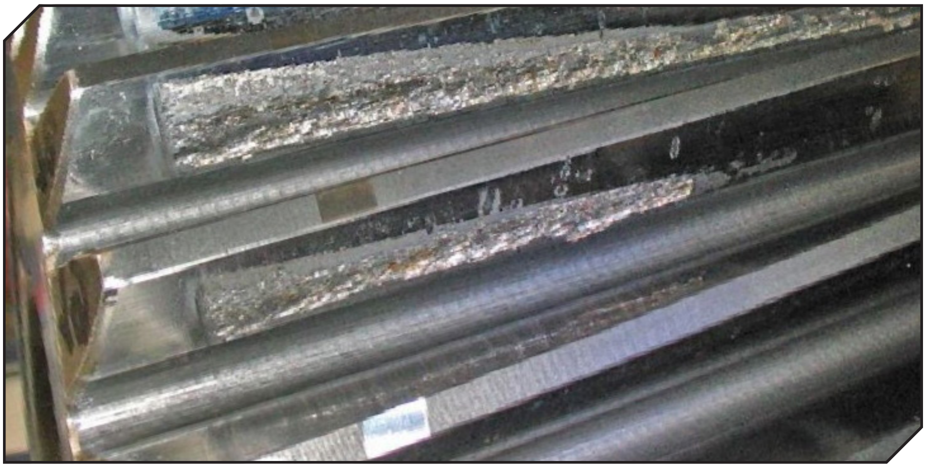

Figure 3 One-sided pitting on a sun pinion shaft in a wind turbine gearbox (Source: GearConsult).

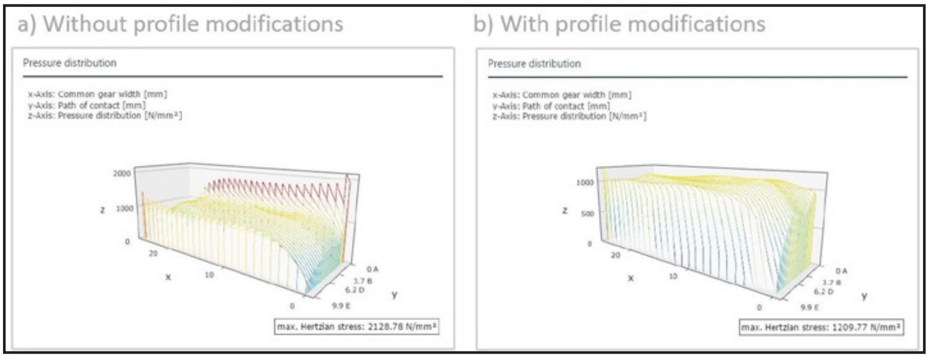

Figure 4 **Pressure distribution of a helical gear with tooth ratio 4 (Source: *FVA-Workbench* reporting).**

- Local tooth root stress
- Local sliding speed and lubricant film thickness
- Local contact temperature
- Local safety against micropitting

Figure 4 shows an example of the pressure distribution of a helical gear with a tooth ratio of 4, with and without profile modification, calculated with the *FVA-Workbench*.

It can be seen that the local pressure increases as the equivalent radius of curvature decreases toward the tooth root of the pinion. Together with the edge stresses simultaneously occurring in the contact area of the tip edge of the mating gear, this leads to very high local pressure peaks which make a profile modification necessary. The required profile modifications can be easily designed with the *FVA-Workbench*, which then lead to uniform pressure distribution and thus uniform material utilization across the tooth flank (Figure 4b). In this way, damage resulting from these locally overloaded areas in the contact area of the tip edge of the mating gear, such as the triangular flank chipping shown in Figure 5, can be reliably prevented.

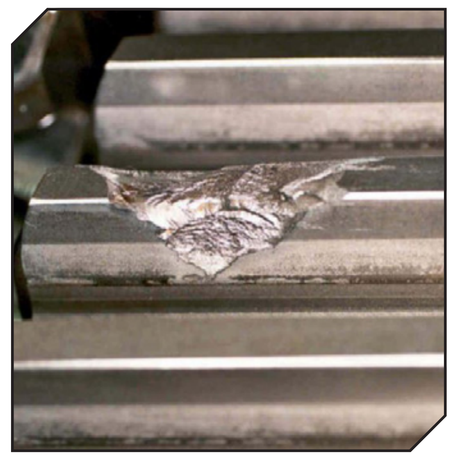

Figure 5 **Triangular flank chipping (Source: GearConsult).**

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1. FVA-Projekte 30 I – IX: Entwicklung und Erweiterung des Programms RIKOR.
2. M. Otto, U. Weinberger, K. Stahl: Full Contact Analysis vs. Standard Load Capacity Calculation For Cylindrical Gears, *Gear Technology* (November 2018).
3. ISO 6336:2019 – Beuth-Verlag.

For more information:
FVA GmbH
Phone: +49 69 6603 1663
www.fva-service.de

EMAG

VL 1 TWIN ENHANCES CYCLE TIME FOR BEVEL GEARS

With its twin-spindle pick-up turning machine — VL 1 TWIN, EMAG has developed a solution to simultaneously machines two identical bevel gears at high speed within the same machining area. A robot cell and swivel table can easily load this machine. All this brings the cycle time down to 4.5 seconds.

"It's about managing very large quantities cost-efficiently, quickly, and free of defects," explains Daniele Loporchio, technical sales manager at EMAG. "That is exactly why we designed the VL 1 TWIN. The machine is perfect for soft and hard machining of a wide variety of bevel gears up to 75 millimeters in diameter (3 in)."

The basic principle of this pick-up turning center plays a decisive role. It features two pick-up spindles (9.9 kW/136 Nm at 40% duty cycle) that are used to always machine two identical bevel gears in parallel at high speed (OP 10 – OP 10). The two spindles load and unload the machining area in just five to six seconds. The machining steps described above are then performed successively and in a single clamping operation with a total cycle time of about 25 to 40 seconds (depending on type and size of part). The average chip-to-chip time is just under six seconds. A special clamping solution reproduces the negative image of the component's gearing and holds it firmly in place for the entire time. Additionally, the VL 1 TWIN is able to drill into solid material, which is how the bevel gear's center bore is produced.

This machine's whole approach leads to fast production and high output quantities, while significantly reducing the price per spindle with rigorous cost controls — contributing to the low unit costs.

With EMAG equipment, there are a range of standard features that ensure component quality and reliability. For instance, the VL 1 TWIN has a machine base made of MINERALIT, which significantly reduces vibrations during the turning process, leading to longer tool life and lower tool costs. Headstocks

can traverse autonomously, allowing the diameter and length (X/Z directions) of both components to be adjusted independently of one another if there any deviations, e.g., following the change of an indexable insert. The wear-free linear drive in the X-axis, including the direct distance measuring systems, is equally important. It has an acceleration of 8 m/s^2 (1,575 fpm) with precise long-term accuracy. The roller guides in all linear axes guarantees further precision.

EMAG's developers can also combine the VL 1 TWIN with a powerful robot cell and a swivel table. In this case, the gripper is precisely adapted to the shape of the component. Pre-positioned component containers simplify transport as well as loading and unloading. This allows the cycle time to drop all the way to 4.5 seconds and individual process flows are easily reproducible. Additional processes, such as measuring, marking and cleaning, can be integrated in the same cycle time.

In addition to this, two VL 1 TWINs can be loaded with the robot cell mentioned earlier or with EMAG's TrackMotion automation system (OP 10 – OP 10, OP 10 – OP 10). In the latter case, the TransLift (a lifting and rotating device with an electric gripper) picks up raw parts from a feeding conveyor and transports them to the machines. Both machines are loaded very quickly — a solution for four spindles that is both powerful and very compact.

Low investment and production costs, short cycle times and high process reliability — provide a base that allow machinery manufacturers to feel equipped to produce bevel gears.

"From classic combustion engines to purely electric drives, differentials remain relevant regardless of drive type. Whoever wants to modernize their production now and prepare for growing unit volumes should take a closer look at this technology," said Loporchio. "We're convinced that the VL 1 TWIN is an ideal solution for many bevel gear manufacturers."

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

Marposs

ANNOUNCES GEMGP STAND-ALONE TOOL MONITORING SOLUTION

Marposs has announced its new Artis GEMGP stand-alone solution for detecting process anomalies during metal cutting in machine tools. By measuring force and strain, GEMGP is able to detect and report on tool breakage, missing tools, overload, tool wear and fluid flow in real time. This helps to prevent damage to the machine, reduce scrap and improve productivity.

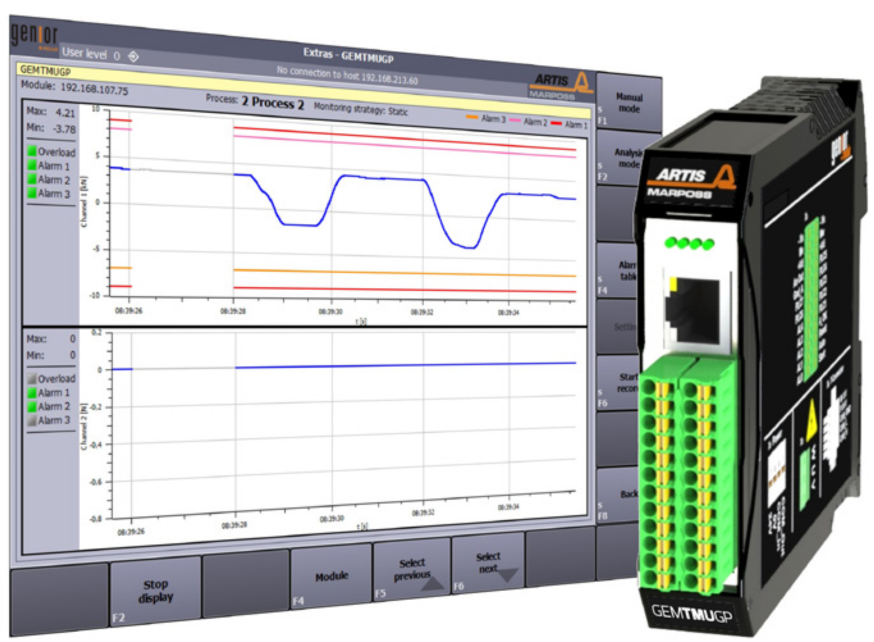
The GEMGP can accommodate two sensors for measuring force and strain values obtained from the spindle during the machining process. A highly flexible solution, the GEMGP offers three different monitoring strategies and can handle up to 127 different cutting cycles with varying types of limits for each cycle. Any events that exceed the pre-fixed limits are recorded in a log-file.

The compact GEMGP is designed for easy installation and operation and can be housed within machine electrical cabinets, robots, handling systems or other devices. All necessary functions and interfaces are integrated in the module. Featuring a digital I/O interface, the GEMGP is independent of the NC type and can be run from any PLC, enabling a discrete connection to the module.

The GEMGP can be used in standalone mode with the operating software run on Windows (WIN 7/10) machine control panels or Siemens Linux systems (TCU). The software can be installed on industrial PCs from Marposs or on any Windows PC (WIN 7/10).

As part of the Genior Modular product family, the GEMGP capability can be built upon or integrated into the Genior Modular system for process monitoring purposes, delivering the strain, force and flow data to the processing unit for further evaluation.

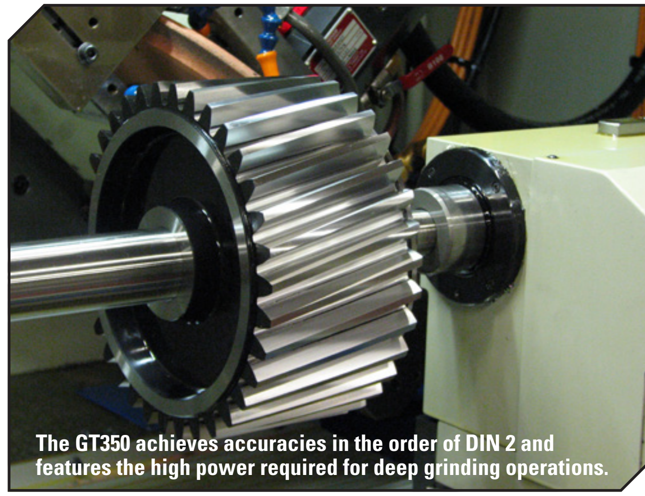
For more information:
Marposs Corporation
Phone: (248) 370-0404
www.marposs.com



PTG Holroyd

INTRODUCES NEW GEAR GRINDING CENTER

A brand-new gear grinding center from Holroyd Precision promises to bring even higher levels of intelligence and efficiency to the production of specialized gears and tooth forms. Called the GT350, this latest machine from the Precision Technologies Group (PTG) company has been developed for one-off and batch grinding of precision spur and helical gears, worms, and screws of up to 350 mm in diameter. It can also be used to precision grind compressor rotors.


The GT350 achieves accuracies in the order of DIN 2 and features the high power required for deep grinding operations.

Replacing Holroyd's GTG2 model, the GT350 achieves accuracies in the order of DIN 2 and features the high power required for deep grinding operations. A specially developed extended machine bed allows screws and worm shafts of up to one meter in length to be accommodated. Dedicated software compensates for helical twist, and full topological capability comes as standard.

It is the GT350's data collection and transfer capability, however, that could be of greatest interest to users. IO-Link communication technology, for example, is available with all new GT350 machines. "We selected IO-Link for its data-handling capabilities and its ability to communicate at every level of the production process," says Holroyd Regional Sales Director, Steven Benn. "RFID scanning is a further option that will assist GT350 users in achieving new levels of performance. Particularly suitable for machines destined for production cells, the feature will all but eliminate human error by helping ensure that chuck, collet, cutter and tailstock, in fact virtually any component or tooling item that needs to be switched between manufacturing cycles, is correctly changed for each gear grinding operation."

Maintaining the Holroyd tradition of building machines that simplify even highly complex manufacturing processes, the GT350 combines extreme rigidity with high power for both CBN and conventional deep grinding operations. Setup is rapid for optimized productivity and customers have the choice of either Siemens' 840D controller or Holroyd's in-house CNC and HMI system. On-board features include: automatic coordinate adjustment, in-cycle wheel dressing, integrated profile management and coordinate measurement.

Grinding cycles are included for: spur gears; helical gears; crowned helical and spur gears with root or tip relief; worm gears of the form ZK, ZI, ZN and ZA; dual lead (duplex) worm gears; splines.

The GT350 also features Holroyd's Profile Management System (HPMS) for highly accurate profile grinding, while an advanced touch-screen interface allows the operator to enter design drawing coordinates directly into the machine. Additionally, all gear, worm and spline profiles can be verified using the integrated Renishaw probing system, enabling automatic on-machine corrections to be made if necessary.

Holroyd's design engineers have ensured that the GT350 automatically corrects the problem of helical twist — a condition that occurs when helical gears are 'lead crowned' to improve meshing and to reduce noise and wear. This is achieved through the use of specially written, dedicated software that both calculates and controls additional motions of the grinding wheel during the grinding operation. During the machining process, the workpiece is rotated about its axis and the tool moved so as to vary the angle of inclination of its axis relative to the axis of the workpiece. As a result, generated errors are reduced along each line of instantaneous contact between the tool envelope and groove surface being machined. The result is better tooth contact during meshing and improvements in torque transfer efficiency.

For more information:
Precision Technologies Group (PTG)
Phone: +44 (0) 1706 526 590
www.ptgltd.com

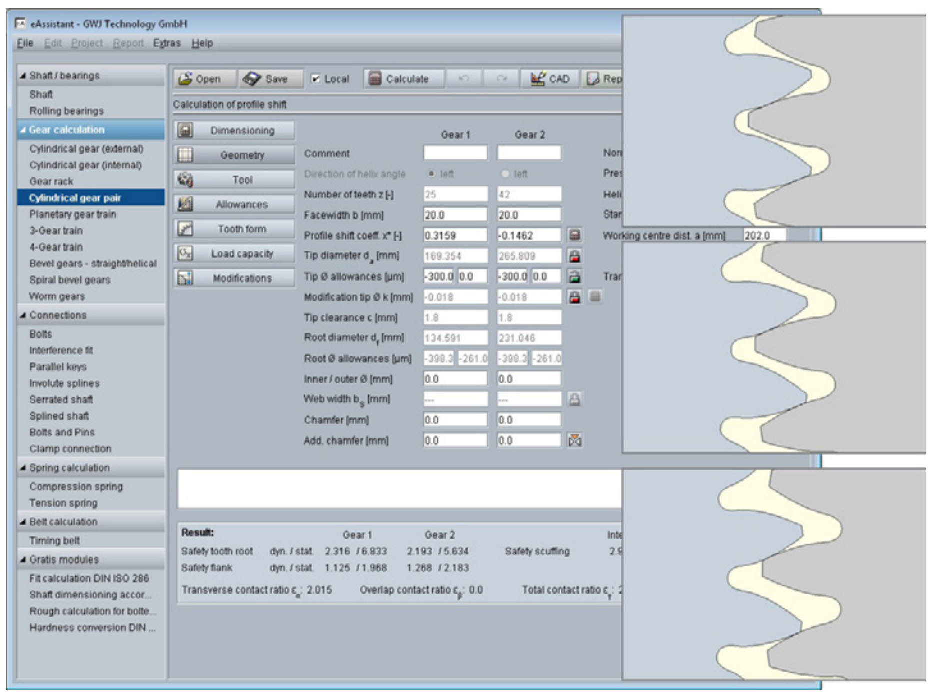
GWJ Technology

OFFERS ENHANCED CALCULATION OF CYLINDRICAL GEARS

GWJ Technology GmbH from Germany has updated the calculation module for cylindrical gears in its web-based software solution *eAssistant*.

In addition to various dimensioning functionalities for the distribution of the profile shift, a new function for disconnecting the center distance from the profile shift was added. By using the function "Fixed working center distance (recalculation)," the profile shift coefficients can be defined independently from the center distance. This enables, hfMP0* can also be defined by clicking the "Lock" button so that the dedendum coefficient hfP0* of the converted, non-shifted basic rack profile is always 1.0 according to DIN 867.

The option "Full radius" for the tip form of gear shaper cutters has now also been added to hobs. For the definition of load spectra, the user can specify the face coefficient KHbeta and the temperature for each load case. This enables the automatic transfer of values directly from the system extension



for example, the calculation of existing gear pairs that are to be installed in the housing with the "wrong" center distance. Transverse contact ratio, backlash and load capacity are also calculated correctly in this case. This function can also be used for the calculation of small-module gears.

The functionality of tools with shifted profile reference line has been extended. Additionally to the addendum coefficient haMP0* of the shifted profile, the dedendum coefficient hfMP0* is displayed and visible in the calculation report. The dedendum coefficient "SystemManager" to the "Cylindrical gear pair" module in the background. The user can see directly the effects of flank modifications on the root and flank safeties of the gear in the system.

In addition to the common calculation methods for the load capacity DIN 3990, ISO 6336 and ANSI/AGMA 2101, the calculation method VDI 2736 for plastic gears was added to the cylindrical gear module.

For more information:
GWJ Technology GmbH
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www.gwj.de

Big Kaiser

EXPANDS JET-THROUGH HYDRAULIC CHUCK LINE FOR 5-AXIS MACHINING

Big Kaiser expands its jet-through hydraulic chuck line to include the BCV interface and additional inch sizes.

The HDC jet-through type holders are ideal for high-precision 5-axis machining with maximum rpm of 35,000 and clamping range of ¼" to ½" and fit nearly any application in the automotive, aerospace, medical, and die and mold industries.

An exclusive thread features allows for convertible coolant delivery between jet-through coolant and center-through coolant. Jet-through hydraulic chucks are ideal tool holders for finishing applications that would benefit from improved coolant delivery. The coolant flows through the end of the tool holder and is angled to direct coolant to the cutting tool tip, greatly improving surface finish and tool life.

Big Kaiser HDC tool holders are simple to use; only 1 hex key wrench is needed to clamp or loosen the cutting tool, making tool changes fast and easy without special equipment. Every HDC toolholder is guaranteed to .00012" TIR at 5 times diameter.

For more information:
Big Kaiser
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2020 Powder Metal Trends

Edited by Matthew Jaster, Senior Editor

20/20 is considered to be perfect vision, but the year 2020 outlook is quite obscure. We can view the current state of the PM industry through short-term, fear-tinted glasses or gain a clearer picture of long-range opportunities. Just like U.S. manufacturing in general, the PM industry has been impacted negatively by the pandemic.

Many economists forecast a gradual "U" or "W" recovery resulting in a North American recession that will limit new housing builds and automotive production. The U.S. has witnessed high unemployment rates nearing the level of the Great Depression. Elk County, Pennsylvania, for example, where the PM industry's hub St. Mary's is located, approached 26% unemployment earlier this year, the highest unemployment rate per capita in Pennsylvania. These economic events, unprecedented in modern times, are testing the public consumer and corporations alike.

Dean Howard, PMT, President, MPIF.

Cautionary signs seeded the new year with companies forecasting a range of options: low single-digit gains, flat sales, or modest declines in the first quarter. January and February iron powder shipments for PM applications decreased by 5%, before a 19.2% year-over-year plunge in March, a foreshadow of the COVID-19 pandemic. Copper powder and stainless steel forecasts remained flat just before the pandemic storm mutated into a deadly hurricane in April devastating the entire domestic and global economies. In many areas across the U.S., manufacturing companies were deemed "non-essential businesses" and forced to close their operations to adhere to local government regulations. Companies that had less than 500 employees were eligible for government programs, such as the Payment Protection Program, but many were forced to furlough or lay-off employees.

As signs of the pandemic subsided, shuttered since March, the North American automotive industry resumed production in mid-May. New safety policies, self-distancing protocol, and a disrupted supply chain posed more challenges than expected resulting in the month ending in serious negative territory. Some U.S. factories explored alternative suppliers to compensate for plants that remained cindustrylosed or were overwhelmed by orders for parts in high demand. General Motors for example, reportedly delayed plans to increase production of pickup trucks in May because of a shortage of parts from Mexico. Many manufacturing plants in Mexico, which surpassed China as the top trading partner to the U.S. last year, were ordered closed early during the pandemic.

Overall, the second quarter appears to be a lost cause for most of manufacturing, including PM companies.

However, on a positive note, U.S. jobs increased by 2.5 million in May, by far the biggest one-month jobs gain since at least the Great Depression. This gain decreased unemployment to 13.3%, far better than the 19.5% economists had projected. PM equipment suppliers hunkered down as well. A veteran toolmaker reports PM tooling builds are down as much as 75%. Some press and furnace suppliers reported providing start-up services to their customers as most equipment had not been in operation for nearly 2 months.

Traditional PM parts makers are hanging on in a survival mode, especially those connected to automotive OEMs. However, the smaller family-owned shops that are more diversified seem to be doing better.

HVAC manufacturers are still ordering furnaces and air conditioners, along with agricultural, lawn & garden, and medical equipment customers for parts going into hospital beds and wheelchairs. Gym equipment for home use continues to expand and could be an interesting new market for conventional PM due to shelter-in-place orders.

One family-owned company executive reports some customers have moved up ordering to build up inventories

The PM industry hopes to return to its normal trade show schedule in 2021 (all photos courtesy of MPIF).

The PM industry is well-equipped to handle the current challenges in 2020.

for the future. As a result, he sees June orders rebounding somewhat. He is also making lemonade from the lemons he is dealing with by investigating process improvements, such as reducing scrap. In another facility, company engineers are devoting time to installing and qualifying new robots connected to compacting presses, furnaces, and machining centers. Automation will continue to be utilized industry-wide.

Another family-owned facility recently experienced a surge in new, mostly non-automotive parts. They also reported an increase in former customers investigating the option of reshoring parts that were lost to low-cost suppliers over the past decade.

MIM and metal AM markets have a brighter outlook in 2020. The firearms and medical markets will dominate MIM production again. Firearms sales, for both handguns and long guns, are expected to be robust in response to recent social injustices and this Fall's presidential election. Medical and dental shipments could suffer a slight downturn as elective medical/dental procedures were prohibited due to state lockdowns. At best, MIM parts sales may increase by single digits or stay even with last year.

Metal AM continues to be on a roll, especially for aerospace and medical applications such as custom implants that replace forgings. Some common metal AM materials include nickel-cobalt alloys, aluminum-silicon-magnesium alloys, low-alloy steel, stainless steel and Inconel. Without a doubt, the global automotive market is changing. Long standing PM champions face a shrinking universe of opportunities.

While the Detroit 3, General Motors Corporation, Ford Motor Company, and Fiat Chrysler Automobiles, restarted production in mid-May, forecasts for light vehicle sales and production still look gloomy. Who would have thought that we would be offered incentives to purchase vehicles that included no interest for 84 months, no down payment, and 120 days before the first payment? During the midst of the shutdown, IHS Markit forecasted a 26.7% sales collapse in North America directly related to the pandemic. The result is the U.S. auto market sales dropping to 12.5 million units and production declining to 12.2 million units.

We need to keep an eye on this as we are nearing record levels of unemployment that will also negatively affect automotive sales.

As of July 1, 2020, new rules now govern how vehicles are produced as a result of the United States–Mexico–Canada Agreement, or USMCA, including that rules of origin are to be met on automobiles, specifically that 75% of the finished vehicles' value is to come from within the USMCA governed region: an increase of 12.5% from the previous North American Free Trade Agreement, or NAFTA. This could be a great opportunity for re-shoring parts and assemblies.

Opportunities still exist for new PM designs outside of engines and transmissions. There could be a new metric rising besides focusing on pounds per vehicles based on large parts. Are there opportunities in smaller more highly engineered PM parts in non-drivetrain systems? Have we begun to tap the hybrid vehicle and electric vehicle markets? Low gasoline prices will delay the move from larger to smaller engines, but gaining acceptance of PM in 3- and 4-cylinder hybrid vehicles should be a primary focus.

And what about the millennials?

Will they continue to choose ride-share services, rental cars, bicycles, and electric scooters over car ownership? Many news reports suggest that the COVID-19 pandemic has changed the minds of many millennials who will prefer their own automobile and house over the risk of cross-contamination and recirculating air in apartments and condominiums.

The PM industry has a strong technology base, built on the interaction of manufacturers, academia, and research organizations. As a maturing industry, we must not let this diminish as every industry needs to continue to evolve or it will simply die. Investments in R&D for new materials, equipment advancements, and process refinement will need to remain strong. Metal powder producers are actively working on high-performance materials. For example, one powder producer is focusing on a specialized material with high-apparent density to improve die-filling for thin-walled parts and faster production rates. Another powder producer is launching stearate-free lubricants for medium to high-density compaction. A third powder producer is focusing on advanced machinability additives to improve tool life and productivity by reducing machining cycle-time.

Compacting press and sintering furnace suppliers are also dedicated to improvements. Some advancements include faster tool exchange systems, electric presses for high-production manufacturing of smaller PM parts, and implementation of robots. Sintering improvements include a new approach to remove lubricants from green compacts thoroughly prior to sintering and reducing energy expenses by up to 80%.

Metal AM could become a significant growth market for aluminum powders as customers explore the light metal's environmental and light-weight benefits. Metal AM trends in the next decade will focus on enhancing throughput, printing larger parts, multi-material printing, and repairing and refurbishing expensive parts and tooling.

There continues to be tremendous activity in the metal AM sector. From one manufacturer concentrating on making large parts, up to 450 kg (992 lb), for the aerospace and defense industries, to another developing binder-jet printing of tungsten heavy alloys and the directed energy deposition of molybdenum, there are a lot of opportunities for this exciting sector. In addition, advances continue for metal AM processes such as binder jetting, material extrusion, and material jetting, all of which are de-bound and sintered, leveraging the successes of the MIM technology.

The one certainty for 2020 is uncertainty. The future is bright for manufacturing adaptation and the PM industry. Despite armies of naysayers from every political persuasion, positive signs are flashing on the horizon for U.S. manufacturing. Ugly short-term tremors cannot define us. Fortunately, throughout its history, the PM industry has survived the ups and downs of the macro economy. The industry is well-prepared for whatever comes our way and well-equipped to shape the future. We will improve the technology through R&D, education, and cooperative efforts, while adapting our resources to ensure we can respond in an agile manner to forces beyond our control, such as the COVID-19 pandemic.

The entrepreneurial spirit embedded in PM's DNA is still alive. Opportunities are waiting to demonstrate PM's problem-solving advantages for now and the future.

For more information:
Metal Powder Industries Federation (MPIF)
Phone: (609) 452-7700
info@mpif.org
Mpif.org

PM Design Excellence Awards 2020 - Automotive

Innovation is at the hub of powder metallurgy (PM) manufacturing advancements in the automotive market. PM materials and consolidation processes are utilized to support the most demanding applications. Transmissions, engines, and chassis rely on performance components to provide durability and consistency.

Automotive Grand Prize Awards

The Grand Prize in the Automotive — Engine Category for Conventional PM components has been awarded to Porite Taiwan Co. Ltd. and their customer Schaeffler Technologies AG & Co. KG, for a VVT sprocket used in a new generation E-VVT design that integrates a sprocket with the stator, and the function of the internal rotor is provided by the gear box.

A Grand Prize has been awarded to PMG Indiana Corporation in the Automotive — Transmission Category for Conventional PM components for a torque converter one-way-clutch stator assembly used in an 8-speed transmission made for FCA US LLC. In the locked position the part is subjected to a 350 Nm torque and traditionally the races are manufactured from wrought steel, or powder forged, and case hardened to handle the high stress.

In the Automotive — Transmission Category for MIM components, a Grand Prize has been awarded to Phillips-Medisize — Metal Injection Molding for an actuator arm supplied to Means Industries and used in a 9-speed forward transmission assembly for General Motors and Ford Motor Co. The actuator arm is part of a Means patented selectable one-way clutch that replaces the reverse clutch.

Automotive Awards of Distinction

In the Automotive — Engine Category for Conventional PM components, an Award of Distinctions has been given to Nichols Portland LLC for a variable displacement vane-pump rotor used in an automotive engine lubrication system. The three-level part possesses numerous critical tolerance features achieved with minimal secondary operations.

The second Award of Distinction in the Automotive — Engine Category for Conventional PM components. This was given to MPP for a high-strength camshaft-bearing cap. The part is made using a PM aluminum-copper-magnesium alloy. The machinability of the PM aluminum alloy closely matches that of the cast aluminum heads, permitting consistent line boring prior to installation of the camshaft.

An Award of Distinction in the Automotive — Engine Category for MIM components has been given to Indo-MIM Pvt. Ltd. for three min-flow setting devices used in the turbocharger of a four-wheeler vehicle. The parts are made using MIM-316L and replaced components that were machined in multiple steps.

In the Automotive — Transmission Category for Conventional PM components, an Award of Distinction has been made to Allied Sinterings Inc. for a sear pin assembly. The part is used in a shift-by-wire automotive transmission actuator that causes an output shaft to rotate the sear pin, allowing a pawl to engage a default-to-park during a catastrophic transmission failure.

In the Automotive — Transmission Category for MIM components, an Award of Distinction has been given to Indo-MIM Pvt. Ltd. for a park lock lever manual override used in a vehicle handbrake.

An Award of Distinction has been given to Indo-MIM Pvt. Ltd. in the Automotive — Chassis Category for

MIM components, for left- and right-hand-side cable guides used in a four-wheeler roof assembly. The MIM parts are made in a two-cavity mold and replaced expensive machined components.

PM Design Excellence Awards 2020 — Special Technologies

From prototypes to mass production, powder metallurgy (PM) technologies like metal injection molding and metal additive manufacturing have been changing the manufacturing landscape across market segments.

Aerospace and defense have utilized PM technology for incredible innovations, the use of PM in the electronic and electrical market impacts our daily lives, and PM in the medical and dental field enhance patient care and quality of life every day.

It is with great pleasure that the Metal Powder Industries Federation announces the winners of the 2020 Powder Metallurgy Design Excellence Awards Competition in the special technologies market segment.

Grand Prizes

The Grand Prize in the Aerospace/Military/Firearms Category for MIM components, has been awarded to Advanced Powder Products Inc. for a trigger mechanism housing for a new 9-mm sub-compact pistol produced for O.F. Mossberg & Sons Inc. The component originally comprised two pieces (metal and plastic), and was re-designed as a single MIM part. Over 5,000 rounds were fired to test the part and no failures were observed.

Advanced Powder Products Inc. also received the Grand Prize in the Medical/Dental Category for MIM components, for a guide tube used in dental surgery. This extremely small part has very thin wall sections and a built-in impingement plate on the inner diameter of the tip. This impingement plate has a Gaussian curvature that can only be formed economically by metal injection molding.

Awards of Distinction

In the Aerospace/Military/Firearms Category for MIM components, an Award of Distinction has been given to Alpha Precision Group — Metal Injection Molding for a shroud that houses the firing pin and firing pin collar in a bolt-action rifle.

An Award of Distinction in the Aerospace/Military/Firearms Category for MIM components, has also been given to ARC Group Worldwide for lever actuators for vanes in a turbo-prop engine. The actuators control the angle of the variable inlet guide vanes and the variable stator vanes.

An Award of Distinction has been given to 3DEO in the Aerospace/Military/Firearms Category for metal AM components, for an anchor link used in a firearms application. A hybrid metal AM process is used to make the parts.

In the Medical/Dental Category for MIM components, an Award of Distinction has been given to MPP and their customer Coracoid for a buckle used in an implanted shoulder repair device. Several technologies were considered for making the part but MIM processing was the only one that produced a part that could withstand the stresses induced during the cinching of the device during surgery and the placement of the cleat.

An Award of Distinction has also been given in the Medical/Dental Category for MIM components to OptiMIM and their customer Atricure for one of two jaws of a surgical device for deploying a clip around a heart's left-atrial-appendage. The mold produces two parts that are mirror images of one another.

An Award of Distinction has been made to ARC Group Worldwide and their customer Cutsforth Inc. in the Electronic/Electrical Components Category for MIM components, for a lower beam EZ change holder for removable brush holders. They are used in brush excitation maintenance on turbine generators in the nuclear, gas, coal, wind,

and hydro industries. (*www.mpif.org*)

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That Industry 4.0 Digital Factory Thing

I'd like to tell you a story. *While this story is not the recounting of an actual single event, the questions and concerns about Industry 4.0 are derived from several conversations with our clients.*

One afternoon, I called one of my clients to touch base and see how he was doing. Right off the bat, he sounded very distracted, which was unusual for him. I immediately assumed COVID-19 related problems. Concerned, I asked, "Phil, you sound a bit preoccupied. I hope everything is okay." He paused for a moment before continuing.

"To tell you the truth, Joe, I'm really concerned about my company's future."

"What's the problem?" I replied.

"It's that Industry 4.0 Digital Factory thing," Phil replied. "We had some people out this week talking about what we need to be doing. And while it all sounds great, we simply don't have the millions required for this kind of investment. The problem is that from everything I hear and read it appears everyone is going in this direction. If we don't keep up, they make me believe we're not going to survive."

"Hang on there, Phil," I said. "First of all, how familiar are you with Industry 4.0?"

"I've read the articles in the trade journals," Phil replied. "I've seen quite a few *YouTube* videos. I know about the benefits of the robust computerization, data analytics, and network connectivity. I'd also say I was up to speed on the integration of robotics and the Internet of Things. But the more I learn, the more I get this sick feeling because we don't have the money for a major investment like this."

"Let's take a time-out here," I said. "I know someone who can shed some light on this subject. His name is Chuck Gates and he has a long background of leadership roles in the power transmission industry. In fact, he teaches courses on the subject of Industry 4.0 at the Illinois Institute of Technology here in Chicago. Why don't we get a Zoom meeting going with Chuck?"

To quickly interject, Chuck Gates, as a real person, is a factual component of the story. He knows a great deal about Industry 4.0. Please be sure to read more about Chuck at the end of this article. Now, let's continue.

Having become quite adept lately at using Zoom, like many others, within a few minutes we were connected with Chuck, each with our video turned on and our microphones unmuted.

After a brief introduction and a summary of our discussion thus far, the Q&A between Phil and Chuck began.

Phil: So Chuck, how do I get on the Industry 4.0 bandwagon when I don't have millions of dollars to invest?

Chuck: Well Phil, to begin let's take a few steps back. The first basic question is whether or not gear manufacturing is essential. The good news is that since the laws of physics are not changing, gears and related components will continue to

Previous Arvin's Angle Articles

In case you missed any of them, here's a list of previous articles by Joe Arvin, with issue and page number:

*Visit **www.geartechnology.com/issues** to browse the archive.*

be needed for the foreseeable future as an essential component of the economy. There is no technology to replace gears as a key source of motion for so many essential products. So the answer to this first question is yes.

Industry 4.0 or the Fourth Industrial Revolution could be viewed as an essential driving force to remain competitive in the gear industry. But the next question we need to ask is this: Do gear manufacturers *really need* to embrace Manufacturing 4.0 and Quality 4.0 to compete in the future?

Phil: Exactly. Do I need this to be competitive?

Chuck: I've had many clients ask me this same question. To provide a meaningful answer, I recommend an approach consisting of four fundamental phases for evaluating and potentially moving forward with Industry 4.0. These are:

Phase 1 - Readiness
Phase 2 - Action Plan
Phase 3 - Implementation
Phase 4 - Step It Up

In this meeting today, why don't we just focus on Phase 1? While this can be quite a bit involved, I'll just hit the highlights. Sound good to you?

Phil: Certainly. Please proceed.

Chuck: Okay. First of all, it's important to understand that the digital transformation of a manufacturing operation is basically the implementation of selected hardware, software, networks, and systems. The ultimate goal of this digital transformation is to more effectively and efficiently meet your customer expectations and continuously improve net income.

This leads us to the first phase which I previously mentioned, this phase is entitled READINESS. As with any change or improvement, particularly one that will cost time and money, it's really important to understand if you actually *need* to adopt digital transformation. To do this you need to take a close look at the current state of your business and then fully understand the value of Gear Manufacturing 4.0.

In essence, going through this first phase provides the proof as to whether you need digital transformation or not. You can't automatically assume that moving into a more advanced digital transformation is an absolute requirement. Buying into the notion that your business cannot survive without the investment of advanced technology can be a costly mistake if doing so does not yield significant beneficial results. This first phase will help you understand more clearly what is needed to accomplish your goals. Some businesses may already be extremely advanced in flexible and agile manufacturing. If these businesses have long-term projections which show no need for investment, then it might be a good idea to avoid any changes and stay the course.

On the other hand, if your business is very reactive, struggles with meeting customer demand, and the profitability is lower than expected, you may want to consider a digital transformation strategy. In the end, don't do digital transformation just to be fashionable or out of the fear of being left behind. Do digital transformation because it provides an acceptable rate of return and maintains your ability to compete.

One point I'd like to make here, it's been proven that the key to remaining competitive is the ongoing reinvestment in your machining capabilities. That has not changed in the era of the modern digital factory. Ongoing investment in equipment should remain as a main focus. But keep in mind that many of these new digital factory technologies will likely be built into the new equipment or it can be retrofitted into your existing equipment.

Let's take a more detailed look at the main four steps suggested in this first phase of READINESS. I believe these steps provide a common-sense approach to establishing the foundation and value of digital transformation for each individual company. Each company is unique and the digital transformation requirements will most likely be different as well. One size does not fit all. It's not about Go Big or Go Home. It's about Go Smart.

Phil: I like what I'm hearing. So what are the steps involved in this first phase?

Chuck: As I said before, these are just the highlights. In Step One, your company leadership needs to be aware of the advanced manufacturing and smart factory enabling technologies that can be implemented to improve your ability to handle product variety and volume more effectively and efficiently.

It's important to have a good understanding of the available enabling technologies such as digital, automated, and additive manufacturing tools. There's plenty of information available online about these technologies so we don't need to get into that right now. I would just recommend that you and your team do the research to be sure you have a solid understanding of these technologies and how they can help you improve in areas that need to be improved.

Phil: That sounds reasonable. We can form a committee and collectively task them with this research and evaluation.

Chuck: The second step of Phase 1 involves detailing the current state of your business. This process will provide a comprehensive starting point for describing your business as it is today. The current state of your business is most likely something you already know on an intuitive level. However, formally taking this step is essential for clearly and completely defining your operation. This helps you to define and document your customer base, your demand forecast accuracy, your on-time delivery performance, your financial health, your key results achieved, and your process flow. This step may also provide some revealing insights about managing your business more proactively.

Phil: This is good stuff Chuck. What's next?

Chuck: This takes us to the third step of Phase 1. Here you will need to create the future state of your business. Use all of the same elements that were listed for the current state of your Business to create the future state. This will provide a clear picture of where you want to be in the future. In other words, the intent is to validate that you are on the right track for continued success.

These steps of the READINESS Phase can be deployed to assess your ability to document and analyze your future strategies. Most companies have already decided their future path. For others, these steps of the READINESS Phase can lead to a call to action or a newfound motivation to change for the better.

Phil: Here again, this makes a lot of sense. I'm guessing the next step of this phase is to compare the current and future states of the business?

Chuck: You're right Phil. In the fourth step of Phase 1, you'll compare the current state and the Future State to look for gaps. If there are no gaps, this can confirm that your current state is actually, in essence, your future state. This means you're clearly on the right track. However, if there are gaps, make a detailed list of them and these will be addressed in the next or second phase, which is entitled ACTION PLAN.

Phil: Excellent. This is the data-driven approach that all of us here can be very comfortable with in evaluating this potential investment in our future.

Chuck: Yes Phil. Phase 1 is critical to establishing the basis for moving forward with a strategy for digital transformation.

Why don't we do this? After you've completed Phase 1, let's talk again and we can go over the steps of Phase 2 in another Zoom meeting.

Phil: Great. I'll let you know if I have any questions.

Final Words

In the next part of this article series, we will hear what Phil uncovers in Phase 1 and then we will hear from Chuck Gates again on the steps involved in Phase 2.

I hope this story provides some valuable insights into your evaluation of the digital transformation of your operation. Please look for the continuation of the story in the next installment of Arvin's Angle in *Gear Technology*.

Finally, I would like to thank Chuck Gates for his valuable assistance in the development of this article.

Of course, if you have any questions or comments, please contact me at *ArvinGlobal@Gmail.com*.

ChuckGates received his Bachelor of Science degree in Management from the University of Illinois and his Master of Science degree in Industrial Technology from Purdue University. Chuck worked at Caterpillar for forty years in numerous roles encompassing Gear Machining, Gearbox Assembly, Quality, Engineering, Training, and Management. He has received numerous Professional Certifications and Awards including that of Certified Manufacturing Engineer CMfgE. In addition to teaching a wide variety of Professional Certification Review Courses, he has taught at the college level as an adjunct professor since the 1990s. Chuck is on the roster of consultant resources for Arvin Global Solutions.

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

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IMTS Future Tech

The Digital Manufacturing Revolution Evolves in 2020

Matthew Jaster, Senior Editor

IMTS will offer two comprehensive digital programs, IMTS Network and IMTS Spark to assist exhibitors and the manufacturing community. IMTS is fully committed to returning to McCormick Place as scheduled for its normal rotation, September 13-18, 2022.

"The show has been held uninterrupted for more than 80 years, but now the global coronavirus health crisis requires the cancellation of what would have been the 34th edition of IMTS for the health and safety of our exhibitors, audiences and local business community," said Peter Eelman, vice president and CXO at AMT – The Association For Manufacturing Technology, which owns and produces IMTS. "Our organization and its members take immense pride in presenting one of the world's largest manufacturing technology events, one that dates back to 1927. The cancellation is especially poignant because the show was poised to offer an unmatched breadth and depth of resources to help industry rethink, reestablish and reengage with supply chains disrupted by COVID-19."

While acknowledging that an in-person show can never be replaced with a digital event, Eelman said IMTS feels a responsibility to provide exhibitors and visitors a way to connect. "IMTS Network and IMTS Spark will provide the IMTS exhibitors and visitors with connections, networking opportunities and technical knowledge," said Eelman.

The IMTS Network will live-stream a wide variety of features and human-interest stories from the Manufacturing Technology sector. IMTS Spark, a new program, will be a comprehensive digital platform that connects IMTS exhibitors and visitors, provides educational and networking opportunities.

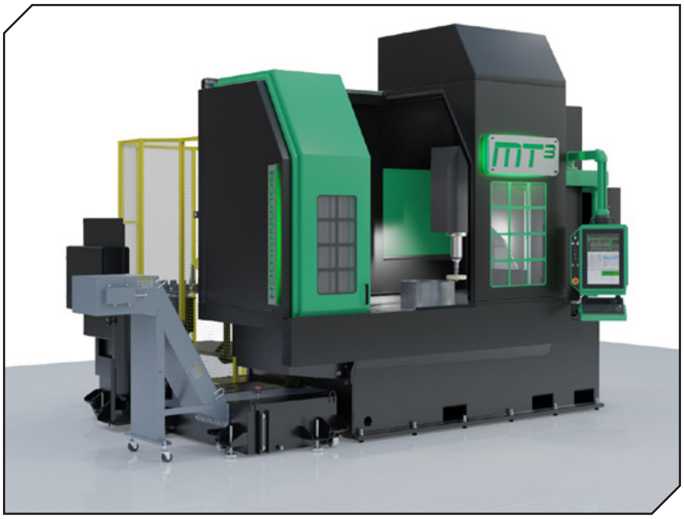
Typically, *Gear Technology* and *PTE* fills the August and September issues with IMTS Booth Previews and the latest relevant products and technologies. In 2020, we're taking a similar approach offering our **Technology Showcase** which is the digital equivalent of our regular IMTS coverage. Check back on the websites throughout August and September for additional information.

Bourn & Koch

OFFERS TWO FLAGSHIP GEAR MANUFACTURING MACHINES

Bourn & Koch had planned to feature their two flagship gear manufacturing machines, the 400H & Fellows 10-4 retrofit, their newly redesigned and re-engineered Blanchard 22AD-42 and, a brand new multifunctional machine tool platform, the MT^3 at IMTS 2020. Each of these machines has new features and functions that are sure to provide a best-in-class machine tool solution, offering increased productivity and quality.

The Bourn & Koch 400H horizontal gear hobber provides high quality gears in a compact foot print. The 400H can produce AGMA Class 10 gears on parts up to 406.4 mm in



diameter with a standard axial travel of 1,930 mm. A max 6.4 mm module gear can be cut on the machine. In recent years, Bourn & Koch has focused refining the programming software for their gear hobbing machines. The latest iteration of their gear hobbing human machine interface (HMI) allows for users to conversationally program the machine via 19.5" touch screen interface for entering all gear data and tool data. Up to six surfaces can be programmed on one gear with up to six cuts per surface, allowing for maximum control over the hobbing process. The HMI also features an Expert Mode, that allows for even more control over the process for well experienced operators. The 400H has available 5:1 and 12:1 hob heads with six axes of CNC control. The machine comes standard with a programmable CNC tail stock, automatic hob shift, and hob swivel. The 400H's work spindle is accurately driven by an integral motor and is compatible with tooling from Barber-Colman gear hobbers, making the upgrade to CNC a less costly endeavor.

The Fellows 10-4 Retrofit gear shaping machine is an update to modern technology on a classic piece of American-Machine tool ingenuity. Bourn & Koch has had a long history of providing high quality new and remanufactured models of Fellows gear shapers. This latest offering to the market provides the same quality that we have become known for in a more compact, maintainable, and economical package. The 10-4 Retrofit features a Fanuc 35i CNC control making effective use of Macro Executor to provide a familiar programming interface for those that have been using Fellows gear shapers for decades. The machine's new guarding package and smaller hydraulic unit reduces the footprint by 16 square feet. The machine comes standard with a mechanical guide and t-slot worktable. Additional custom workholding options are available based on application. The machine is now more adjustable via numerous improvements in design. The table infeed and work spindle are now converted over to direct drive design as well, further reducing the amount of mechanical components and increasing machine accuracy to produce high quality shaped gears.

Blanchard is a name synonymous with surface grinding. The famous "Blanchard grind" is easy to spot as a mark of quality and accuracy. Bourn & Koch's newly redesigned Blanchard 22AD-42 takes the rugged, heavy duty design of their rotary surface grinder and updates it to today's standards. The new machine comes with a full stainless steel enclosure featuring an automatic roll up door. The new enclosure design is leak proof, allows for easy mist collection, and has the potential for automation. One of the most exciting features of the new Blanchard 22AD-42 is the power dresser, which allows operators to dress the grinding wheel at a pre-programmed amount with the push of a button. Many upgrades the machine's design were incorporated as well, including direct drive updates to the grinding spindle and work table, addition of polymer concrete for vibration damping, a base flushing system to aid in cleanliness, and a new Blanchard grinding HMI that is easy to learn and program. The machine comes standard with a 50 hp spindle motor with the option to upgrade to 100 hp, effectively doubling the machine's productivity.

The newest addition to Bourn & Koch's line-up of American-Made machine tools is the MT^3, a multifunctional machine tool platform capable of performing grinding, milling, turning, and drilling/tapping machining operations on a workpiece in one set-up. The machine is primarily designed as a value engineered vertical cylindrical grinder, supplementing Bourn & Koch's current VBG offering in that arena. The MT^3 comes standard with a 42" diameter t-slot worktable and precision grinding spindle with an HSK-50A connection. The machine's spindles are interchangeable via the innovative HBK-200 clamping system, allowing for the right spindle to be used for the application. The machine will be equipped with custom workholding from Advanced Machine & Engineering to manufacture a hob spindle cartridge from one of Bourn & Koch's 400H hobbers in one setup. The machine is expandable from a vertical grinder to a "one and done" machine tool system, incorporating various spindles and tools into an added optional cell that are automatically changed via Fanuc R2000 robot and Bourn & Koch' Alien Claw end of arm tooling, allowing for quick change of most tools and spindles. A spindle rack and disc style tool changer are incorporated to the cell to manage the various tools and spindles for the required operations. The machine is programmed via combination of Bourn & Koch's grinding HMI and Fanuc Manual Guide-i, employing a Fanuc 0i CNC control for all machine functions. A virtual Y-Axis allows for the machine to perform standard milling functions. The MT^3 spindle features a powerful Fanuc Beta-il 160 M motor capable of producing 30 kW from 2000-10,000 rpm, providing ample power and range for a wide variety of grinding, milling, and drilling/tapping applications. This machine platform is modular with future plans for a vertical gear hobbing machine and a five-axis machining center in the works.

Virtual demonstrations are currently available. An open house will be held at Bourn & Koch to show off the new MT^3, gear manufacturing machines, and new Blanchard once Stage 5 recovery has been achieved. If you would like to schedule a virtual demo or learn more about MT³ and receive a complimentary anti-microbial brass "hands free" key, contact *machinesales@bourn-koch.com* for details.

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Dillon Manufacturing

OFFERS SPECIAL TOP JAWS

Special Top Jaws from Dillon Manufacturing can be manufactured from copper, brass, delrin, tool steel, 1018, 1045, 4140, 8620, A-2, 6061 aluminum, and stainless steel, in configurations to grip a components ID, OD or a combination of both, to suit any workholding application. Available in soft or hard jaws, or full grip jaws, for virtually any chuck manufacturer. A comprehensive website (see below) provides complete details and includes an "easy quote" format with "fill-in-the-blanks"

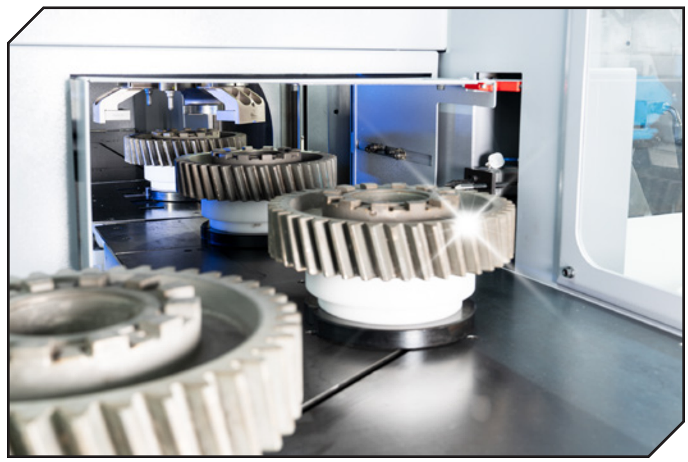
convenience. Dillon standard and custom chuck jaws and collet pads and jaws are ideal for high speed machining, as well as precision boring, tapping, drilling and finishing across virtually all industrial markets. Dillon custom, special, or modified hard, soft or full grip top jaws are manufactured with industry-best turnaround time, which saves time and money by reducing downtime.

For more information:
Dillon Manufacturing, Inc.
Phone: (800) 428-1133
https://dillonmfg.com/special-jaws

EMAG

INTRODUCES VLC 350 GT

What will the cars on the street look like in the future? A new study by the Boston Consulting Group forecasts a mix of gasoline and diesel engines (48 percent), hybrid vehicles (33 percent) and completely electric (19 percent). For OEM's and supply companies, this means that there will be a variety of conventional components, such as transmission gears, as well as new transmission components, produced in the future – in alternation and with a large amount of cost-pressure. The EMAG VLC 350 GT turning/grinding machine shows how this challenging task can be implemented, efficiently, in production. Different hard machining processes are performed on chucked components with a maximum diameter of up to 350 millimeters in succession and in a single clamping operation.



Large output quantities, precise machining processes and massive cost pressure— transmission manufacturing requirements are demanding, and will only become more demanding in the future as the automotive industry continues to evolve in this area. It is likely that in the future, there will be even more transmission variations to consider. How can manufacturers meet these challenges? EMAG provides a striking answer to this question with its VLC GT series, one of the most successful innovations released by the South German company in recent months. Two years ago, the VLC 200 GT was released - the "GT" in the name stands for "grinding" and "turning". It hints at the main strength of this machine: the combination of grinding and turning (and additional processes) with the proven pick-up automation from EMAG, allowing for countless manufacturing solutions. This variety of technology allows the machine to cover the entire range of machining operations required for transmission components.

With the introduction of the VLC 350 GT machine to the market, EMAG is expanding on the capabilities of the VLC 200 GT and can machine components up to 350 millimeters (14 in) in diameter. With this system, for the first time ever EMAG can offer the option of integrating a grinding spindle with an NC swiveling axis. This can hold, for example, cylindrical grinding elements for grinding internal bore holes. What is the overall strategy behind this new development? "Among other things, we are aiming at developing solutions for manufacturing

processes with smaller batch sizes that inevitably involve many retooling processes," explains Marina Manger from EMAG Sales. "In these applications, the fact that the machine includes several different grinding spindles from the outset is an obvious advantage. The machining area also provides plenty of space, so the machine is ready to handle any task."

The VLC 350 GT performs the traditional hard machining of gears—from hard turning of end faces to pre-turning of the bore hole, and outer synchronizing taper to finish grinding of these contours—as well as of many other chucked components with internal taper. For the latter, the internal grinding spindle with NC swiveling axis pays off:

End face turning: Loading (and subsequent unloading) is performed at high speeds with a pick-up spindle. The machining operation starts with hard turning of the end faces.

Contour turning: Depending on the component geometry, inner contours (with one or two tapers), a cylindrical borehole and the outer synchronizing taper can be pre-turned in the second step.

Inner contour grinding: The use of a cylindrical grinding element on the swiveling NC axis makes it possible to machine various internal taper angles. To do this, the grinding spindle is swivels precisely to the required angle in each case. Any required boreholes are completed like this (with a zero-degree grinding angle).

Outer counter grinding: The final operation consists of grinding the outer synchronizing taper with the external grinding spindle.

"If a customer wants to machine a wide range of parts with many different bore holes, we can also integrate two internal grinding spindles in the VLC 350 GT," says Marina Manger. "The reason for this is that smaller boreholes require the grinding element to operate at higher speeds, while large borehole diameters instead require a lower speed. In certain circumstances, this cannot be achieved with a single grinding spindle."

In addition, it is crucial that the combined machining operation consisting of (hard) turning and grinding ensures fast processes and high machining quality: The residual machining allowance after turning is only a few millimeters. The grinding process with corundum or CBN grinding wheels is significantly shorter. Considering the low residual machining allowance, the specification of the grinding wheel can also be geared more specifically toward final quality. An integrated measuring probe checks the diameter and length of the component after the process. In addition, a linear motor in the X-axis ensures short chip-to-chip times, because it moves the components to the machining position particularly fast.

There are a variety of possible applications for the VLC 350 GT, with respect to desired production volume for example, as Manger stresses: "Owing to its performance, the machine is perfect for medium and high-volume production. Its ease of tooling, including two large doors and accessible tools, as well as its flexibility in terms of configuration, as mentioned above, nevertheless also make it interesting for small batch sizes with frequently changing production tasks." The machine can be loaded manually or integrated in production lines.

Last but not least, EMAG offers the VLC 350 GT to its customers with an attractive price-performance ratio. This is made possible by using tried-and-tested standard components. "We are very optimistic that this approach will establish itself in the market," concludes Manger. "The combination of fast processes, low tool costs and flexible application options has already convinced many production planners of the predecessor machine."

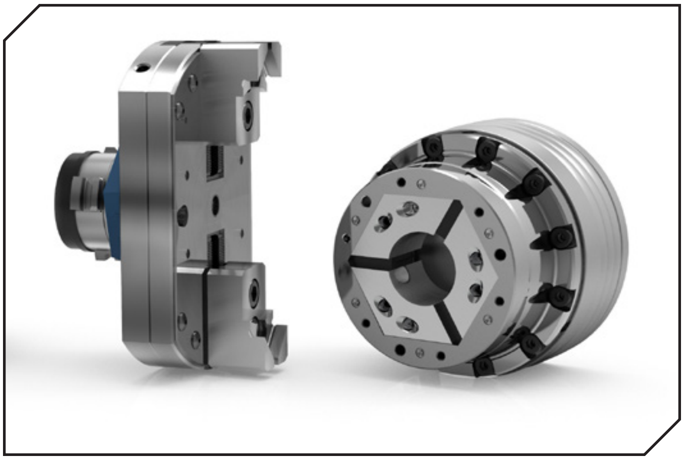
For more information:
EMAG LLC
Phone: (248) 477-7440
www.emag.com

Hainbuch

OFFERS 2-JAW MODULE SYSTEM

Hainbuch recently introduced the 2-jaw module, a small alternative to the large centric vice. Round workpieces are clamped from the outside with clamping heads (collets) within the collet chuck. Larger diameter workpieces, beyond the capacity of the collet chuck, can be clamped with the 3-jaw module. For cubic parts that are positioned centrically on machining centers and milling machines, the new 2-jaw module is now an option. Changeover from clamping round parts to cubic ones is possible in less than two minutes.

The 2-jaw module can handle turning applications up to 1,500 rpm. The 2-jaw and 3-jaw module use the Hainbuch collet chuck as their base. Changeover is possible without removing the collet chuck and realignment thanks to Hainbuch's Centrex quick-change interface.



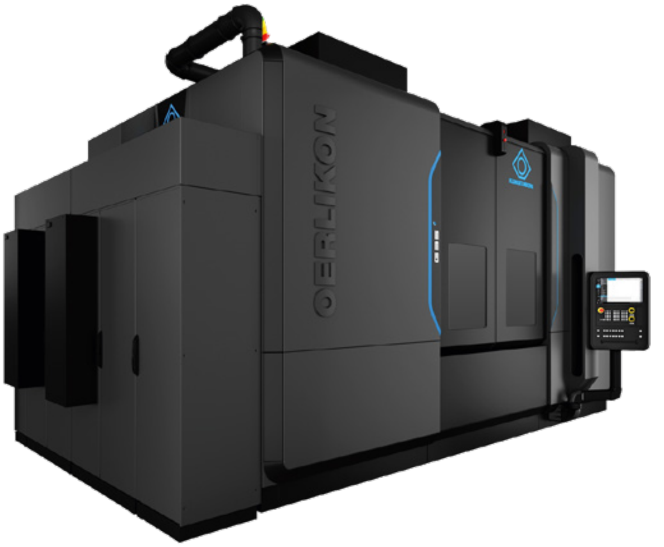
Hainbuch's modular solution, consisting of a chuck and jaw module, no longer compare to the large and heavy vises that are found in many shops and whose size is more of an obstacle than an advantage. As is often the case, the workholding is much larger than the part to be machined so interference is an issue. Special, longer tools are then needed and there's a risk of a costly collision. The Hainbuch modular system, on the other hand, is just as efficient and flexible as your multitasking machine tools are today.

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

Klingelnberg

INTRODUCES LATEST MACHINING TECHNOLOGY

With the Oerlikon Bevel Gear Grinding Machine G 35, Klingelnberg has implemented a new machine design for the

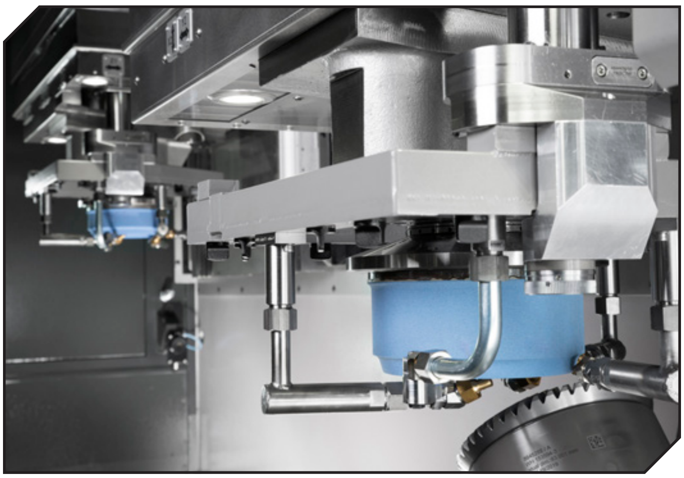


5-cut method. As a result, the manufacture of aviation gearing as regards efficiency is really taking off. To achieve this, the system provider has combined proven technology with new ideas. Bevel gears manufactured using the 5-cut method with a fixed setting are used in the aviation industry. This entails the consecutive machining of convex and concave pinion flanks, with different tools and different machine settings. Due to complex certification procedures for aerospace applications, changing to another gearing is not an option. However, the newly developed Oerlikon Bevel Gear Grinding Machine G 35 makes the production of aerospace gearings much more efficient thanks to its technology: with its two vertically arranged grinding spindles, it is specially tailored to these requirements. In contrast to older dual-spindle concepts with fixed grinding spindles, the G 35 is equipped with two grinding heads that are positionable independently of each other, thus enabling maximum flexibility.

The high rigidity and thermal stability ensure optimum machining results and, thanks to the advanced vertical concept, grinding sludge deposits in the working chamber can be avoided. Its name, "Clean Cabin," is thereby justified. The machine's operating concept is based on the *KOP-G* software interface, which is operated intuitively via a high-resolution touch screen. Function keys on the control panel thus provide direct access to frequently used setup functions.

Complete measurement (Done-in-One) of complex components in a single stage

Whether turning blanks, ground workpieces or roller bearings – Klingelnberg G variant Precision Measuring Centers are specifically designed for use in the production process of axially symmetrical components. With these machines, Klingelnberg follows the approach of executing various measurement processes in one stage as a complete measurement (Done-in-One). A Klingelnberg Precision Measuring Center is capable of fast measurement of dimensions, shape, contour and surface roughness in one automated cycle. This reduces the investment costs and helps to reduce the process costs. Furthermore, Klingelnberg Precision Measuring Centers also ensure the required measuring accuracy if they are used directly in production. As a result, not only does this save on air-conditioning costs, but the measuring center can also be directly integrated into the production process. This eliminates the need to set up several different machines, saving valuable production space. With its G Variant Precision Measuring Center, Klingelnberg is therefore making a significant contribution to reducing quality costs.



With the "Done-in-One" principle, complete measurement of axially symmetrical parts on one machine, the G-Variant of Klingelnberg Precision Measuring Centers won the Best of Industry Award 2020 (awarded by *MM MaschinenMarkt*) in the Measuring Technology category.

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

MHI Machine Tool

DEVELOPS FR SERIES TO MANUFACTURE GEARS FOR ROBOTS

Mitsubishi Heavy Industries Machine Tool Co., Ltd., a part of Mitsubishi Heavy Industries (MHI) Group, has developed new models of hobbing and gear shaping machines with highly accurate machining to manufacture precision reduction gears for robots. These new products, marketed as the “FR Series,” respond to the rapidly growing need for highly precise and efficient manufacturing of strain wave gears and other precision reduction gears for robots. The full-fledged launch will begin in August 2020, with the unveiling at an online seminar scheduled for September.

The name “FR Series” is derived from “Fine Pitch for Robot, Reducer.” The units were developed based on MHI Machine Tool’s existing models, more than 2,000 of which have been delivered to the automotive industry and other manufacturers. The market expansion for industrial and life support robots in recent years has led to a sharp rise in demand for the high precision, small module gears inside the precision reduction gears used in the joints of these robots. Two types of gears are used in these reduction gears (an external tooth gear and an internal tooth gear), and MHI Machine Tool has added to its lineup a hobbing machine to create the external gear, and a shaping machine to make the internal gear. In contrast with conventional mass-production gears typically used in the automotive industry, which have modules (gear tooth sizes) of 1-4 and accuracy requirements of ISO class 8 or 9, gears for robots require greater precision, with modules of 1 or below, and an ISO class of 3 to 6. The FR Series was specifically designed to meet these demands.

MHI Machine Tool’s hobbing machines utilize direct-drive motors for both the main spindle to which the cutting tool (hob) is attached, and the work table spindle holding the workpiece, along with advanced control technology. By limiting the machine tool error to the greatest extent possible, this system achieves a pitch error of just 1 micrometer (μm). Compared with precision gear cutting, accuracy has been raised three classes (from around ISO 6 to ISO 3). Also, the fast cutting speed with up to 8,000 rpm (revolutions per minute) shortens the processing time by around a third, contributing to greater productivity.

The shaping machines utilize high precision worm gears for the cutter head and work table that comprise the core components. Further, strict management values in the machine’s assembly precision has raised the precision class for the gear working by two levels (from around ISO 6 to ISO 4), providing high gear precision.

MHI Machine Tool is utilizing its strength in manufacturing both gear cutting machines and cutting tools to not only offer machines to manufacture the high-precision gears used in precision reduction gears for robots, but with its comprehensive solutions for gear machining, including cutting tools to ensure optimal cutting, processing know-how, and automated systems, is contributing to the manufacturing of high-precision gears.

MHI Machine Tool completed its first hobbing machine in 1962, and over nearly six decades has continually developed new products and technologies. This track record and degree of contribution to the market has raised the company’s standing, and at the end of June this year led to MHI Machine Tool being selected for inclusion in the “Global Niche Top Companies Selection 100" by the Ministry of Economy, Trade and Industry (METI). Going forward, as an industry leader, and as a manufacturer of the gear machine tools that support a wide range of industries, MHI Machine Tool will continue to lead the way in manufacturing.

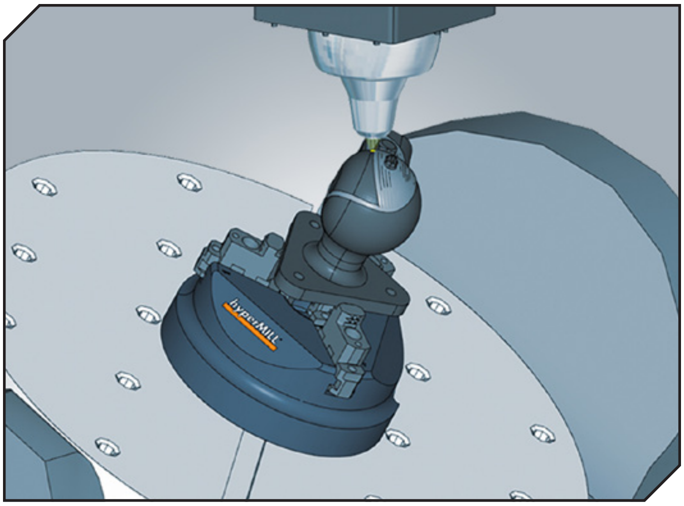
For more information:
Mitsubishi Heavy Industries, Ltd.
Phone: (248) 669-6136
www.mitsubishigearcenter.com

Open Mind

PRESENTS LATEST SOFTWARE UPGRADES AND MODULES

Open Mind Technologies AG recently announced the latest versions of *hyperMILL* encompassing a wide range of enhancements and important new machining strategies, further advancing the capabilities for accurate, efficient 3D and 5-Axis machining.

Developed with Industry 4.0 in mind, *hyperMILL VIRTUAL Machining* features a *VIRTUAL Machining Optimizer* which provides innovative solutions over and above simulation and



identifying error conditions. These capabilities improve toolpaths that are traditionally calculated in the CAM engine, and incorporate knowledge of the part model, tooling, the toolpath calculation and collision check engine, and the machine tool model with its physical constraints. The *hyperMILL VIRTUAL Machining Optimizer* enables individual part programs to be linked with smooth and safe connections, enabling the cutter to remain close to the workpiece.

A new *hyperMILL Automation Center* allows users to automate the job list creation processes in *hyperCAD-S*, serving as both a development and runtime environment. New features also include the ability to select and position the clamping device, as well as define a uniform process for all programmers.

The ADDITIVE Manufacturing process in *hyperMILL CAM* software supports 3D printing and subtractive machining on one machine tool. This technology offers flexible strategies for additive material applications, including filling strategies for both planes and free-form shapes, and in 2D and 3D sections. Applications also include hybrid machining to fix damaged parts and additive machining of an existing component.

The latest software offers 5-axis strategies for fast, easy-to-use programming, resulting in reduced cycle times and high-quality surface finishes. The integrated *hyperMILL MAXX Machining* finishing module, a performance package of the *hyperMILL CAM* software suite, is the CAM programming source enabling the use of conical barrel cutter technology to reduce machining cycle times by over 90%. It is ideal for planar, ruled, and curved surfaces often found in complex 5-Axis components. Three modules are available including finishing, roughing, and drilling.

For more information:
Open Mind Technologies
Phone: (339) 225-4557
www.openmind-tech.com

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Sandvik Coromant

OFFERS ONLINE APPLICATION TRAINING PROGRAM

Sandvik Coromant has launched a new online application training program to share knowledge and best practices for metal cutting operations. The eight-part program has been released online and is accessible via the Sandvik Coromant website. Customers will develop theoretical and application-based knowledge in turning, milling, drilling, and threading for both indexable and solid round tools. Communicated through pre-recorded presentations, the online training courses will provide customers with valuable insights into the best practice strategies for machining.

The program consists of eight separate modules, including specialist topic areas such as solid round tools for drilling, milling, and tapping. The three Solid Round Tools modules will be led by expert, Ben Lodge, solid round tools product specialist for North Europe at Sandvik Coromant. During these sessions,

customers will learn the fundamentals for successful metal cutting, including the importance of process control and developing the correct machine set up.

A module on indexable drilling will be led by Mikael Carlsson, indexable drilling and boring specialist for North Europe at Sandvik Coromant. Here, learners will develop an understanding of the vital process considerations for drilling deep holes and how to optimize chip formation for different drills and workpiece materials. A separate module on indexable milling will be hosted by Barry Cahoon, Sandvik Coromant's indexable milling specialist for North Europe.

Lee Kendall, turning product specialist for North Europe at Sandvik Coromant will deliver modules on parting and grooving, thread turning and general turning. Here, learners should expect to develop new knowledge of different insert geometries and grades.

For more information:
Sandvik Coromant
Phone: (201) 794-5000
www.sandvik.coromant.com

Selecting Correct Size of Hob/Gashing Cutter

QUESTION

How does one select the correct size of hob/gashing cutter like hob OD, length and number of flutes for teeth cutting process based on tip circle diameter and face width of job?

Expert response provided by Jin Zhou, gear tools engineer Nachi America. Solid hobs can cut a wide variety of cylindrical workpieces, including involute gears or splines, straight-sided splines, roller chain sprockets, worm gears, other special forms, etc., and non-cylindrical workpieces like racks. The detailed optimal features of the hob for each job should be evaluated individually, and often, it's even debatable what the optimal set of selection is.

However, there are some generic criteria for reference, focusing on hob OD, length and number of flutes.

Machine and fixture limitations (from tool layout drawings and machine manuals, arbor and keyway sizes for shell-type hobs), combined with the process (climb or conventional hobbing, etc.), will decide the boundary conditions such as maximum and minimum OD and length (OAL, or overall length for shell-type hobs and teeth length for shank-type hobs). Careful check is needed for a retrofitted or converted machine.

Within this narrowed range, a user can choose hob OD and length first. By and large, they are in proportion to the part teeth size (e.g., module or diametral pitch for involute parts, circular pitch for straight-sided splines and sprockets). With a larger OD, more cutting teeth with larger land widths are available to achieve better tool life, and more material between hob flute/gash bottom and keyway corners/bore to enhance hob strength for shell type

<table>
<tr><th>Module
m</th><th>Diametral Pitch
LW</th><th>Outside Dia.
D</th><th>Overall Length
L</th><th>Bore diameter (d)
Type A</th><th>
Type B</th><th>No. of Flutes
N</th></tr>
<tr><td></td><td>26</td><td>50</td><td>50</td><td rowspan="11">22</td><td rowspan="11">22.225</td><td rowspan="7">12</td></tr>
<tr><td>1</td><td>24</td><td>50</td><td>50</td></tr>
<tr><td></td><td>22</td><td>50</td><td>50</td></tr>
<tr><td>1.25</td><td>20</td><td>50</td><td>50</td></tr>
<tr><td></td><td>18</td><td>55</td><td>55</td></tr>
<tr><td>1.5</td><td>16</td><td>55</td><td>55</td></tr>
<tr><td>1.75</td><td>14</td><td>55</td><td>55</td></tr>
<tr><td>2</td><td>12</td><td>60</td><td>60</td><td rowspan="11">10</td></tr>
<tr><td>2.25</td><td>11</td><td>60</td><td>60</td></tr>
<tr><td>2.5</td><td>10</td><td>65</td><td>65</td></tr>
<tr><td>2.75</td><td>9</td><td>65</td><td>65</td></tr>
<tr><td>3</td><td>8</td><td>70</td><td>70</td><td rowspan="7">22</td><td rowspan="7">26.988</td></tr>
<tr><td>3,25</td><td></td><td>70</td><td>70</td></tr>
<tr><td>3.5</td><td></td><td>75</td><td>75</td></tr>
<tr><td>3.75</td><td>7</td><td>80</td><td>75</td></tr>
<tr><td>4</td><td>6</td><td>85</td><td>80</td></tr>
<tr><td>4.5</td><td>5½</td><td>90</td><td>85</td></tr>
<tr><td>5</td><td>5</td><td>95</td><td>90</td></tr>
<tr><td>5.5</td><td>4½</td><td>100</td><td>95</td><td rowspan="7">32</td><td rowspan="7">31.75</td><td rowspan="9">9</td></tr>
<tr><td>6</td><td></td><td>105</td><td>100</td></tr>
<tr><td>6.5</td><td>4</td><td>110</td><td>110</td></tr>
<tr><td>7</td><td>3½</td><td>115</td><td>115</td></tr>
<tr><td>8</td><td>3</td><td>120</td><td>130</td></tr>
<tr><td>9</td><td>2¾</td><td>125</td><td>145</td></tr>
<tr><td>10</td><td>2½</td><td>130</td><td>160</td></tr>
<tr><td>11</td><td>2¼</td><td>140</td><td>175</td><td rowspan="6">40</td><td rowspan="6">38.1</td></tr>
<tr><td>12</td><td></td><td>150</td><td>190</td></tr>
<tr><td></td><td>2</td><td>170</td><td>200</td><td rowspan="8">8</td></tr>
<tr><td>14</td><td></td><td>170</td><td>210</td></tr>
<tr><td></td><td>1¾</td><td>190</td><td>220</td></tr>
<tr><td>16</td><td>1½</td><td>190</td><td>230</td></tr>
<tr><td>18</td><td></td><td>210</td><td>250</td><td rowspan="4">50</td><td rowspan="4">50.8</td></tr>
<tr><td>20</td><td>1¼</td><td>220</td><td>220</td></tr>
<tr><td>22</td><td></td><td>230</td><td>300</td></tr>
<tr><td>25</td><td>1</td><td>250</td><td>320</td></tr>
</table>

hobs; this also results in less production efficiency. The recommended cutting speed is decided by the part material, with hardness, hob material and coating, and cutting condition (dry or wet) to avoid excessive wear rate. The hob rpm can then be calculated from the cutting speed and hob OD. For a hob with a larger OD but other features the same, usually a lower rpm is used to maintain the same cutting speed, which increases the cycle time. In addition, a larger hob OD may increase the torque on the hob spindle. In a similar manner, the larger hob length achieves a longer tool life, but also with more manufacturing errors related to flute lead and higher hob deflection during cut to potentially cause accuracy issues. Depending on the production volume, the trend of the industry is to maximize the tool life.

For a given OD, a user can pick the number of threads and flutes based on part in-process quality and process cycle time requirements. If the same machining parameters are used, the hob with a greater number of threads will generate the part faster, yet with lower accuracy. The hob with a greater number of flutes will give higher tooth form accuracy, but the hob tooth land width must be reduced for chip evacuation, thus resulting in a smaller number of sharpenings. The chip thickness can be estimated to prove the selection will not cause excessive cutting forces.

There is a small optimal range for each hob feature for a certain application. Most hob manufacturers established standard selections for commonly used part ranges through years of experience — and this is a good starting point for most users.

Other factors not directly on the hobbing operation could be considered as well, i.e. — can the larger hob's longer tool life translate into a lower piece cost from the quoted price? Can the weight of a larger hob (with or without arbor) satisfy safety/ergonomic standards or does it requires some lift assist equipment? Is there any process before or after hobbing on the same production line that the user needs to coordinate tool change to reduce the line downtime? Each application may have some unique situations.

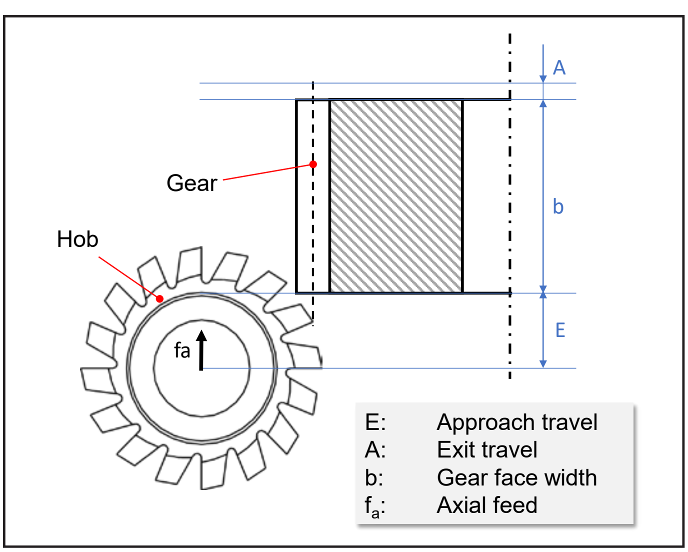
If a user has a special part material — especially non-ferrous based, or a job with very tight tolerance, or a very high production volume, or any other exceptional conditions — a thorough planning with hob manufacturer (also with hob machine OEM, fixture manufacturer, and process/product engineers as necessary) would ensure the best selections made and regrettable mistakes avoided.

To sum up, one should select the hob features based on several critical elements: machine and fixture limitation; part teeth size; part material machinability; hob material and coating; hob process condition; part in-process quality; cycle time; etc. And if the user has a common job, the hob manufacturer's standard hob size selection can be used as a starting point. But if the user has a unique application, a detailed discussion with the hob manufacturer should be conducted. The goal is to minimize tool costs and cycle time while meeting all quality specs, with the understanding that the end user's preference might eventually be the dominant deciding factor.

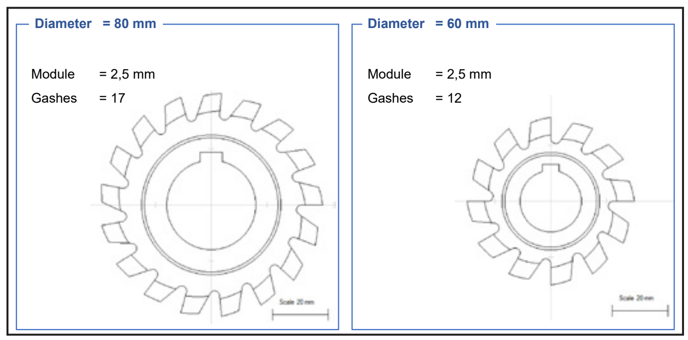
For More Information

Jin Zhou
Gear Tools Engineer
Nachi America, Inc.
46200 Twelve Mile Road, Novi, MI 48377
Cell: (248) 875-1858
www.nachiamerica.com

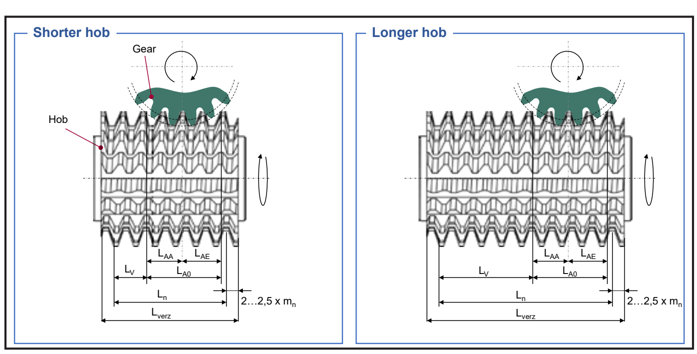
Second Expert Response provided by Dr.-Ing. Deniz Sari Star-Su. A question about the chosen size of a hob does not have just one single answer. It depends on several boundary conditions for the particular application. Starting with the choice of the hob's diameter, the diameter has to be chosen to provide required space and stability for the teeth and taking into account being a bore-type or a shank-type hob. Furthermore, the hob's diameter does have a direct impact on the productivity of the process. The picture below shows the different travel path sections a hob has to go through during gear cutting. Besides gear's face width b, the hob has to travel through the approach length E and the exit travel length A. Especially, the approach length is impacted by the hob`s diameter. To increase the productivity, the relation between A+B should be as small as possible. This explains the pursuit to keep the diameter smaller.



At the same time, a decreasing diameter of the hob leads to the fact of decreasing space for our gashes. Our example in the next picture shows two different hobs for the same application for a module 2.5 mm gear. The hob with a diameter of 80 mm does have 17 gashes. To ensure the same amount of *usable life* on the 60 mm hob, the number of gashes has to be reduced to 12. In case the hobbing application is set up to generate the same maximum chip thickness, the tool with a smaller number of gashes needs to run with a lower axial feed, which also could impact productivity. Furthermore, less gashes means a smaller number of teeth in contact, which reduces the possible numbers of gears to be cut until the hobs need to be reconditioned.



If the diameter has been chosen, the hob`s length is next to be defined. First, it is important to be able to cover the full generation length between hob and gear L_{A0}. Additionally, on the left and right side of the hob, a certain security value needs to be added which is in the range of 2 to 2.5 x module. With such a hob, now it is possible to cut the gear. But to increase tool life, a shifting length L_v is needed, which allows cutting the following gears on different hob positions and levels the tool wear along the tool's length. Simply said, with a longer hob, more teeth can be realized that can be used to cut the parts. How long the complete hob length will be depends on the customer's needs. If the customer is looking to produce a low number of gears, or just prototypes, the hob can be smaller. But if a large batch or a repeated production shall be realized, the hob length needs to be increased to be able to cut as many gears as possible before the tools need to be reconditioned.



Both questions — regarding hob diameter and length — do have an impact on a tool's investment as well. Therefore our goal for our customers is to get a tool dedicated to their needs, offering the best tool life for the application but keeping the investment as low as possible.

Finally, further boundary conditions for a hob's dimensions can be the hobbing machine, the clamping or the gear itself. If one of these gives a limitation for tool size, this must be respected and the best compromise needs to be found. To find the best compromise, a tool supplier needs to stay in close contact with the customer and to analyze the particular application in detail. Our experience in being the interface between the part, the machine and the hob itself gives us a huge opportunity to offer the best fit hob dimensions for our customers to have the highest productivity and tool life for their needs.

For More Information

Dr.-Ing. Deniz Sari
Star SU Group Technology Manager
5200 Prairie Stone Parkway, Suite 100
Hoffman Estates, IL 60192 USA
Phone: (847) 649-1450
Web: www.star-su.com

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Optimization of Generation Gear Grinding Process

Ankit V. Gujrathi, Abhijeet Dalvi and Abhijit Wagh

Introduction

With an increase in the demand of a stringent gear quality to enhance the life of gearboxes and to reduce the noise level, the continuous generation grinding process has gained much demand (Ref. 2). This process uses a threaded grinding wheel (abrasive material) and a diamond dresser as cutting tools for the grinding process. Although this process has been a well- established process, only limited scientific knowledge of the process exists (Ref. 1). Grinding is an abrasive machining process which uses a grinding wheel as a cutting tool. It is suited for machining of hardened parts. Each grain of grinding wheel acts as a single point cutting tool and removes material in the form of tiny chips. It employs the use of the abrasive wheel in controlled contact with a workpiece. The cutting modes in the grinding process correspond to heat dissipation. Since this energy is not consumed for chip formation but also by friction and the penetrated and plastically deformed workpiece, the heat is distributed in varies ways depending on the interaction on the tool and the workpiece. The different zones shown in the figure below correspond to the various zones such as 1-elastic deformation, 2-elastic and plastic deformation, and 3-elastic and plastic deformation and chip formation (Ref. 11). When an excess of heat is transferred to the workpiece and the critical temperature is reached, the thermal overload can cause various surface undulations, the majority of them being the grinding burn.

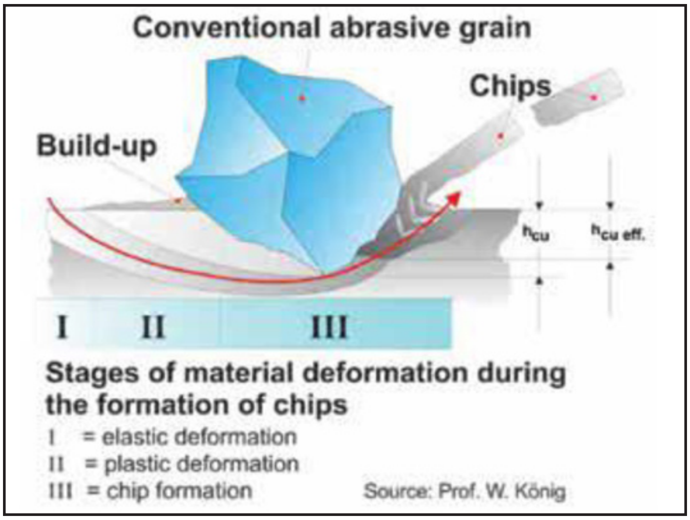


Figure 1 Stages of material deformation during formation of chips.

To date, grinding was considered as a process where machining takes place with the help of geometrically unspecified cutting edges, as specified in DIN 8580. But with the new Precision-Shaped abrasive Grains (PSG) developed by 3M, grinding with "geometrically defined cutting edges" is possible. The PSG wheels, also known as Cubitron II wheels, generate a free-flowing chip during grinding similar to that in milling, but much finer. These chips no longer clog up the grinding wheel thereby preventing the loss in cutting ability of the grinding wheel and reducing the risk of grinding burn with better profile accuracy (Refs. 9, 11).

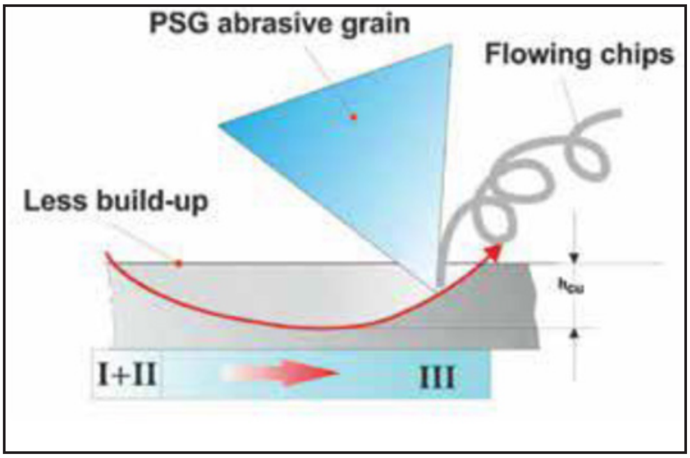


Figure 2 Less material deformation and lateral build up.

Each individual ceramic of the Cubitron II wheels are identical in size and are precisely formed triangles of sintered aluminum oxide. The heat generated is dissipated directly through chips, hence minimizing the risk of thermal damage (Ref. 10). While dressing these PSG's break as minute triangular shaped particles compared to the irregular pattern of regular ceramic wheels. This results in an improved dressing cycle and reduces the load on dresser (Refs. 9, 11).

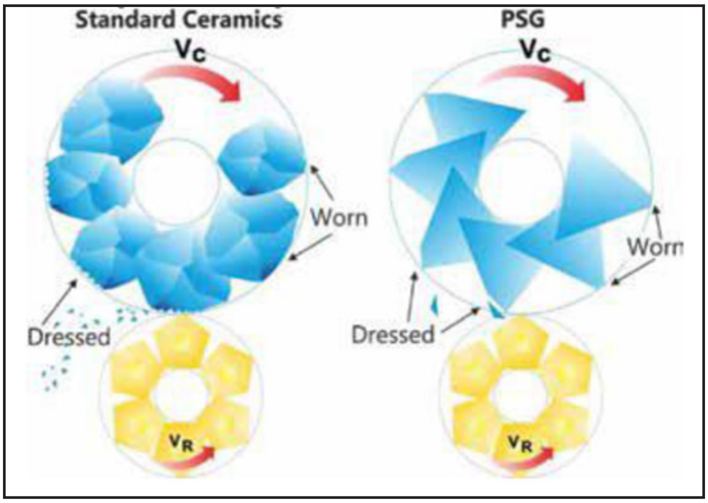


Figure 3 Dressing of standard ceramics and PSG wheel.

Problem Identification

As the grinding process is dynamic, or create a parasitic or ghost frequency, which severely deteriorates the gear life (Ref. 7). Improper gear grinding results in following issues:

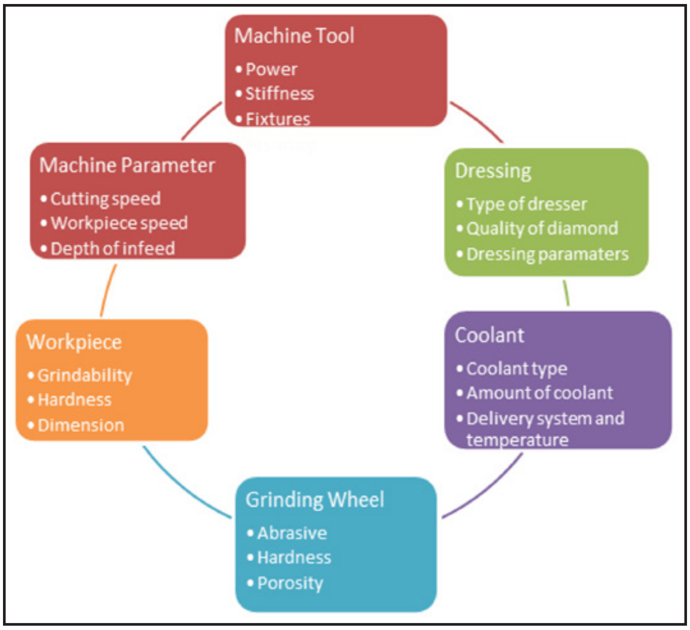


Figure 4 Essential variables influencing the grinding process.

Grinding burn. It is the interaction between the abrasive grains of the grinding wheel and the flank of workpiece (Ref. 3). At the onset of grinding burn, the grinding forces and the rate of wheel wear increases abruptly, thereby deteriorating the surface finish of the gear flank (Ref. 4). It generates a re-hardened zone near to the surface and a softened, tempered zone beneath it (Refs. 4, 12).

Variation in profile and lead accuracy. Due to contacting conditions for continuous gear grinding, changing cutting forces can result in an unfavorable process dynamics and deviation in lead and profile accuracy (Ref. 1).

Required surface roughness. One can define the characteristics of grinding wheels for optimal grinding process by keeping in mind the relation between the grit size of the wheel and the achievable surface roughness on gear (Ref. 6).

Variation in case hardness. Abusive grinding of the workpiece leads to tempering of the gear and reduces surface hardness. Severe tempering often causes local re-hardening which in turn results in surface cracks (Ref. 8).

The impact of cutting speed and the axial speed have been studied so as to achieve a benchmarking result in a continuous gear grinding process. To achieve an optimal working condition, one needs to understand the relationship of grinding parameters like chip thickness, surface speed, specific material removal rate and the maximum material removal rate (Refs. 2, 5, 10).

Experimentation

In order to study the impact of the process parameters on the grinding process, five components were selected, as per the gear geometry and case depth requirement. All the components have been worked with the Cubitron II grade wheels manufactured by 3M. This experiment was carried out on a Liebherr LCS 380 gear grinding machine ($vc\ max = 63$ m/s) and conducted at K-96 plant, Gear Excellence Division, of Sanjeev Auto Parts Manufacturers Pvt. Ltd. with the help of 3M working program.

1	Geometric		4661.372.023	4950.302.008	1304.304.543	1324.304.015	1324.304.021
1.1	No. of teeth	z	65	35	37	30	35
1.2	Normal module (mm)	mn	3.1	4	4.8	4.21	4.8
1.3	Pressure angle (°)	α	20	20	24	20	24
1.4	Helix angle (°)	ß	10	25	11.5	27	11.5
1.5	Gear OD (mm)	da	203.1	165.42	197.73	156.27	177.73
1.6	Face width (mm)	b	30	41	26.6	34.4	24.4
1.7	Wheel dimensions (DxWxB) (mm)		240x230x110	240x230x110	240x230x110	240x230x110	240x230x110
1.8	No. of starts of the worm	gg	3	3	3	4	3
1.9	Wheel specification		91NDA120/120	93DA80/80	93DA80/80	93DA80/80	93DA80/80
1.10	Grit size		J18VPLF68/602W	J18VPLF29/601W-80M/S	J18VPLF29/601W-80M/S	J18VPLF29/601W-80M/S	J18VPLF29/601W-80M/S
1.11	Material		ZF 7B	ZF 7B	ZF 7B	ZF 7B	ZF 7B

Figure 5 Geometric data of gears.

2	Machining process		4661.372.023	4950.302.008	1304.304.543	1324.304.015	1324.304.021
2.1	**1st cut- Roughing**						
2.1.1	Cutting direction		Climb	Climb	Conventional	Conventional	Climb
2.1.2	Cutting speed (m/sec)		58	63	58	58	58
2.1.3	Axial feed (mm/TR)		0.42	0.53	0.53	0.46	0.53
2.2	**2nd cut- Roughing**						
2.2.1	Cutting direction		Conventional	Conventional	Climb	Climb	Conventional
2.2.2	Cutting speed (m/sec)		58	63	58	58	58
2.2.3	Axial feed (mm/TR)		0.38	0.47	0.47	0.41	0.47
2.3	**3rd cut- Finishing**						
2.3.1	Cutting direction		Climb	Climb	Conventional	Conventional	Climb
2.3.2	Cutting speed (m/sec)		58	63	58	58	58
2.3.3	Axial feed (mm/TR)		0.37	0.37	0.37	0.27	0.37

Figure 6 Process parameters.

Maximum material removal rate **(Q_{max})**. It ascertains whether the performance potential of a given machine model has been fully used. It removes the chip volume in mm³ that can be removed in one second.

$Q_{max} = ((a_{emax} * h_{ev} * n_s * gg * f_{zmax} * 30)/\cos ß)$

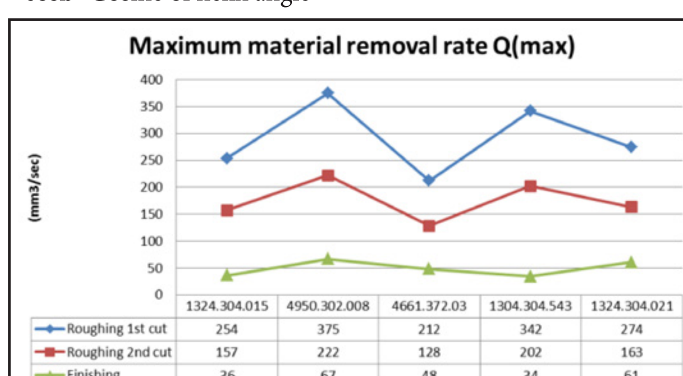
$H_{ev} = 2.25 * m$

n_s – rpm of the worm wheel

gg – No. of starts of the grinding worm

f_{zmax} – Max axial feed rate of the workpiece (mm/rev)

cosß- Cosine of helix angle



Graph 1 Achieved max. material removal rate.

Specific material removal rate (Q'w). It indicates how many mm^3 one (1) mm wheel width removes per second ($mm^3/mm/sec$).

$Q'w = a_e\ effective * v_f$

$a_{e\ effective} = \sin \alpha_n a_x$

$v_f = ((z*z_g*n_s*s_z)*60*\cos\beta)$

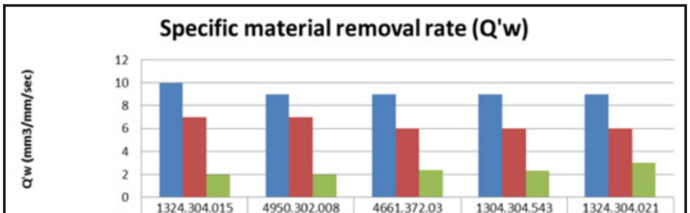
z - No. of teeth on workpiece

z_g - No. of starts on grinding worm

s_z- radial feed in mm/rev of workpiece

a_x- Total depth of cut (mm)

$\sin \alpha_n$ – sine of pressure angle



	1324.304.015	4950.302.008	4661.372.03	1304.304.543	1324.304.021
Roughing 1st cut	10	9	9	9	9
Roughing 2nd cut	7	7	6	6	6
Finishing	2	2	2.4	2.3	3

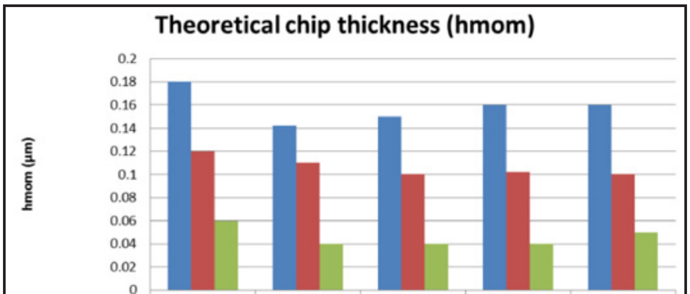
Graph 2 Achieved specific material removal rate.

Theoretical average chip thickness (h_{mom}). It is the most important parameter for the setting up and evaluation of all grinding processes. During the grinding process chips are compressed, pulled and/or welded together in a manner that cannot be established mathematically. The h_{mom} together with the given parameters such as depth of cut a_e, feed rate v_w, and surface speed v_c, corresponds to the resulting depth of penetration of the individual grain halfway to the arc of contact.

$h_{mom} = (1000*Q'_w)/v_c$

Q'_w - Specific material removal rate ($mm^3/mm/s$)

v_c – Surface speed of grinding worm



	1324.304.015	4950.302.008	4661.372.03	1304.304.543	1324.304.021
Roughing 1st cut	0.18	0.142	0.15	0.16	0.16
Roughing 2nd cut	0.12	0.11	0.1	0.102	0.1
Finishing	0.06	0.04	0.04	0.04	0.05

Graph 3 Achieved theoretical chip thickness.

Process Validation

Gear accuracy. The components processed with the optimized parameters have been inspected on the Klingelnberg P40 machine and the results for the angular errors (fH_α and the $fh\beta$) have been shared. Furthermore, the results of standard deviation for profile ($f_{\sigma\alpha^*}$) and lead ($f_\sigma\beta^*$) have been studied and recorded. The standard deviation is the total displacement of the actual angular error caused during the grinding process. It gives an indication of the process variation and is a crucial parameter for establishing a stable process.

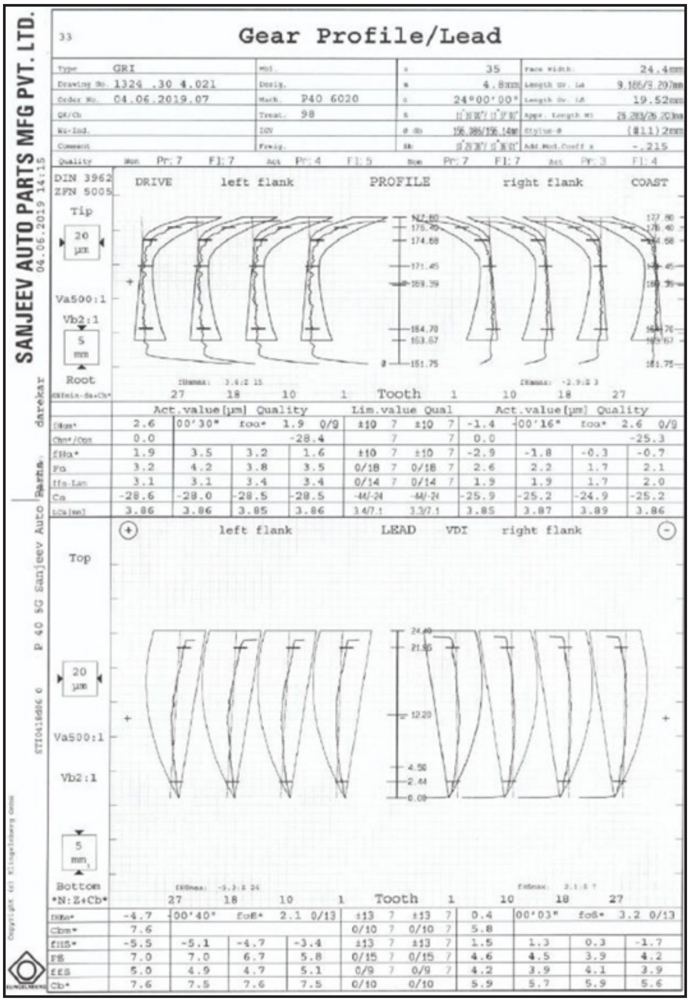
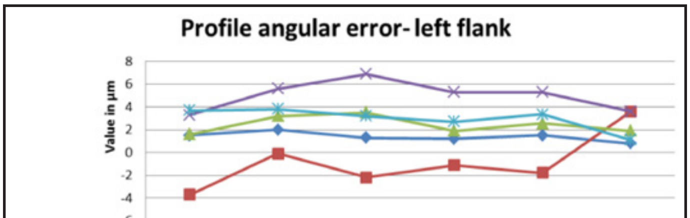
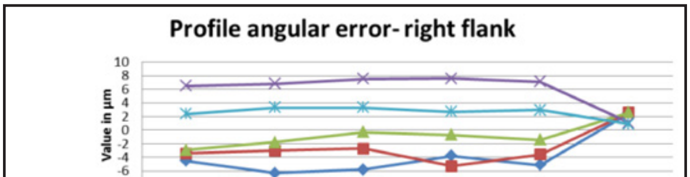


Figure 7 Lead and profile graph of component 1324.304.021.



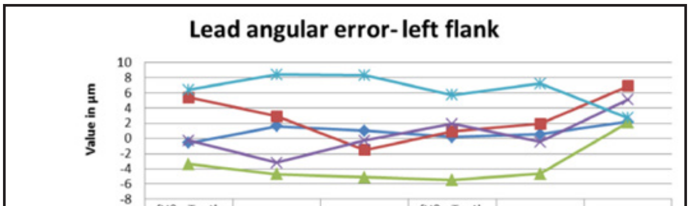
	fhα - Teeth A	fhα - Teeth B	fhα - Teeth C	fhα - Teeth D	fhm	foa
1304.304.543	1.5	2	1.3	1.2	1.5	0.8
1324.304.015	-3.7	-0.1	-2.2	-1.1	-1.8	3.6
1324.304.021	1.6	3.2	3.5	1.9	2.6	1.9
4950.302.008	3.3	5.6	6.9	5.3	5.3	3.6
4661.372.023	3.7	3.8	3.2	2.7	3.4	1.1

Graph 4 Variation in *fHα* - left flank.



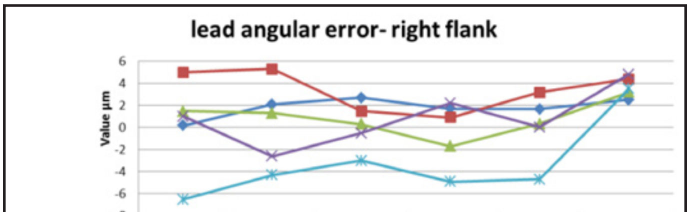
	fhα - Teeth A	fhα - Teeth B	fhα - Teeth C	fhα - Teeth D	fhm	foa
1304.304.543	-4.5	-6.3	-5.8	-3.8	-5.1	2.5
1324.304.015	-3.4	-3	-2.7	-5.3	-3.6	2.6
1324.304.021	-2.9	-1.8	-0.3	-0.7	-1.4	2.6
4950.302.008	6.5	6.8	7.5	7.6	7.1	1.1
4661.372.023	2.4	3.3	3.3	2.7	2.9	0.9

Graph 5 Variation in *fHα* - right flank.



	fHβ - Teeth A	fHβ - Teeth B	fHβ - Teeth C	fHβ - Teeth D	fhm	fαb
1304.304.543	-0.6	1.6	1	0.2	0.6	2.2
1324.304.015	5.4	2.9	-1.5	0.9	1.9	6.9
1324.304.021	-3.4	-4.7	-5.1	-5.5	-4.7	2.1
4950.302.008	-0.3	-3.2	-0.3	1.9	-0.5	5.1
4661.372.023	6.4	8.4	8.3	5.7	7.2	2.7

Graph 6 Variation in *fHß* - left flank.



	fHβ - Teeth A	fHβ - Teeth B	fHβ - Teeth C	fHβ - Teeth D	fhm	fαb
1304.304.543	0.2	2.1	2.7	1.7	1.7	2.5
1324.304.015	5	5.3	1.5	0.9	3.2	4.4
1324.304.021	1.5	1.3	0.3	-1.7	0.4	3.2
4950.302.008	1	-2.6	-0.5	2.2	0.0	4.8
4661.372.023	-6.5	-4.3	-3	-4.9	-4.7	3.5

Graph 7 Variation in *fHß* - right flank.

Surface roughness of flank. The surface roughness has been measured across the gear and along its face width. Their measuring data has been recorded and the achievable surface roughness is between 2.1–3.6µm.

Nital etching test. As the gear grinding process involves high contact between workpiece and wheel, it is extensively sensitive to grinding burn; hence, micro-etching with dilute HNO3 is to be done.

The following sequence illustrates the setup of the nital etching procedure carried out on Reischauer nital etching equipment. The workpiece is immersed in a prescribed sequence in tanks containing different acid solutions and intermittent water tanks for cleaning and neutralizing. This procedure makes grinding burn visible.

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Burn Test Procedure

Sr.No.	Process	Solution	Bath Temprature	Process Time
1	Cleaning Of Component	Biological Solution	Room Temperature	10 Sec - 15 Sec
2	Rinsing	Warm Water	35°C-45°C	10 Sec - 15 Sec
3	Drying	Dry Compressed Air		10 Sec
4	Degreassing	Potassium Hydroxide Amines Salt Of Organic Acids	Room Temperature	2 Min
5	Rinsing	Warm Water	35°C-45°C	10 Sec - 15 Sec
6	Drying	Dry Compressed Air		10 Sec
7	Etching	Denatured Ethyl Alcohol Nitric Acid 8% Vol.	Room Temperature	2 Min 30 Sec - 2 Min 45 Sec
8	Rinsing	Warm Water	35°C-45°C	10 Sec - 15 Sec
9	Drying	Dry Compressed Air		10 Sec
10	Bleaching	Denatured Ethyl Alcohol Hydrocloric Acid 8% Vol.	Room Temperature	1 Min 30 Sec - 1 Min 45 Sec
11	Rinsing	Warm Water	35°C-45°C	10 Sec - 15 Sec
12	Cleaning	Isopropenol		10 Sec
13	Drying	Dry Compressed Air		10 Sec
14	Visual Inspection for Burns			

Figure 8a Sequence of grinding burn testing.

The above procedure is in accordance with ZFN 5013 and ISO 14104. Grinding abuse becomes noticeable where a black color shows the areas affected by the grinding abuse.

Figure 8b Image of gear flank after grinding burn test.

Metallurgical inspection. The metallurgical inspection of the above components has been done and the data for parameters have been recorded. The testing of these parts has been done in the met-lab facility available at C4 plant of Sanjeev Auto parts.

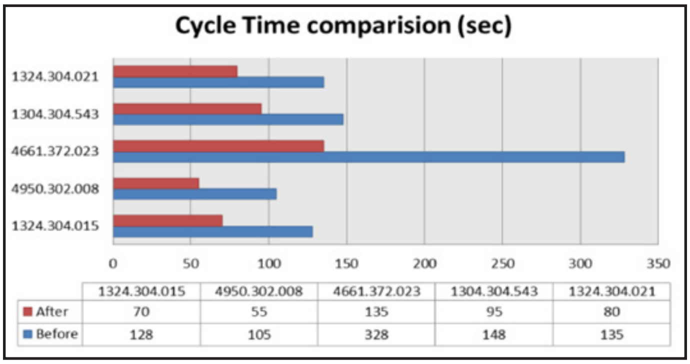
COMPARISION OF THE METALLURGICAL REPORTS

	Parameter	Specification	Observation
4950.302.008	Case depth at Teeth PCD @610 HV1 (mm)	0.6-1	0.7
	Case hardness at distance of 0.1mm from gear PCD (HV1)	700	714
	RA in case (%)	5-30	8-10
4661.372.023	Case depth at Teeth PCD @610 HV1	0.4-0.8	0.583
	Case hardness at distance of 0.1mm from gear PCD (HV1)	700	714
	RA in case	5-30	8-10
1324.304.015	Case depth at Teeth PCD @610 HV1	0.6-1	0.93
	Case hardness at distance of 0.1mm from gear PCD (HV1)	700	734
	RA in case	5-30	6-7
1304.304.543	Case depth at Teeth PCD @610 HV1	0.6-1	0.73
	Case hardness at distance of 0.1mm from gear PCD (HV1)	700	721
	RA in case	5-30	6-7
1324.304.021	Case depth at Teeth PCD @610 HV1	0.6-1	0.73
	Case hardness at distance of 0.1mm from gear PCD (HV1)	700	758
	RA in case	5-30	6-7

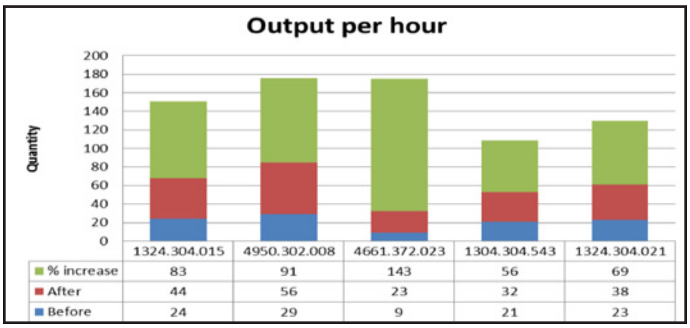
Figure 9 Metallurgical data results.

Results and Conclusion

The material removal with each abrasive grain on grinding wheel surface is the fundamental of grinding. During grinding, rubbing and ploughing are ineffective in terms of material removal; only cutting action is ideal (Ref. 11). The above results conclude that the above-conducted experiment has been successfully validated. The achievable Q_{max}, Q'_w and h_{mom} with the use of Cubitron II wheels has substantially increased and has delivered successful results. The comparision of cycle time and ouput-per-hour, before and after conducting this experiment, have been shared here.



Graph 8 Comparison of before and actual cycle time.



Graph 9 Increase in the output-per-hour.

Acknowledgment. Our sincere thanks to all the members of the K96 unit and C4 unit for their support in the study and experimentation. A special thanks to our HOD, Mangesh M. Kulkarni and our manager VK Deshapnde Sir for their support and gratitude.

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Ankit Gujrathi received his bachelor of engineering degree in 2016 at MGM's Jawaharlal Nehru College of Engineering, focusing upon IC Engine, Automotive Engineering and Engineering Mathematics. His work experience includes (2016–2019) Junior Engineer in New Product Development Department for Sanjeev Auto Parts Manufacturer Pvt. Ltd., Aurangabad (India). His duties there include process establishment of new components, especially of shafts and gears, by providing technical support; responsible for APQP and PPAP documentation; installing automation setup in order to displace manual loading and unloading of component, thereby improving efficiency of production line and ultimately leading towards Industry 4.0; core member of NIRMAN project team, a Product Life Management system, which aids in smooth workflow of all New Product Development activities and providing live tracking of ongoing projects; implementation of alternative cutting tools in order to reduce cycle time and improve tool life; create micro level activity plan and provide estimated budget for a particular project; and planning of suitable cutting tools, fixtures and gauges based on component geometry to achieve required quality. Currently (since 2019) Gujrathi is a research engineer at Varroc Engineering Limited, Aurangabad (India), serving as a process engineer responsible for PPAP and APQP documentation as well as handling RFQ inquiries and preparing CAPEX.

Abhijeet Subhash Dalvi has an MBA in finance from the Rajarshi Shahu Institute of management and a B.E. in Mechanical Engineering from M.I.T college, Aurangabad. From 2018 until present he has worked at Sanjeev Auto parts Mfg Pvt Ltd. as a senior engineer (IPD –Integrated Product Development Department). His duties there include reading drawings from customers of the components to be developed; checking the feasibility of the components; preparing process charts for the components to be manufactured; processing the manufacturing of the tools, jigs, fixtures, gauges of the product; controlling the documents and drawings of components and tools; and preparing the required files and documents of the components developed. Dalvi previously (2014–2018) he worked at Metal Man Auto Pvt. Ltd., as a development engineer focusing on checking the feasibility of components; implementing ECN to customer requirements; layout preparation and implementation of layout to product requirement and hand off to production with all required documents; working knowledge of fully automated robotic lines; and preparing model and prototypes of the products and confirming requirements.

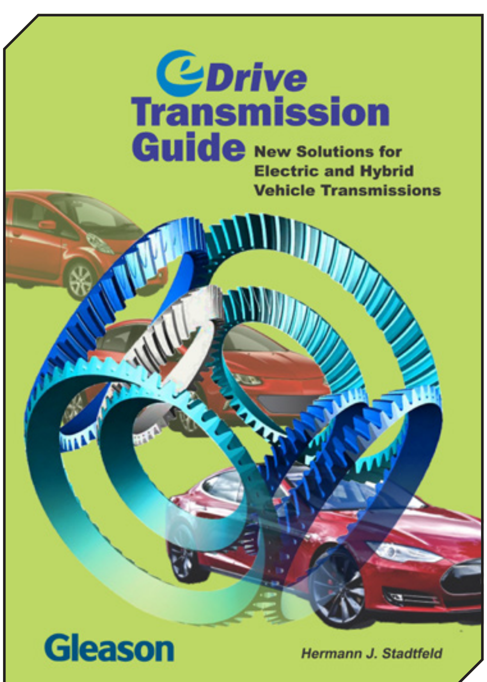
Abhijit Gokul Wagh received Bachelor of Technology degree (2017) at Maharashtra Institute of technology, Aurangabad, Maharashtra. He is a new product development engineer at Sanjeev Auto Parts Manufacturers Pvt. Ltd. He earned a bachelor of technology (Mechanical) degree (2017) at Maharashtra Institute of Technology, Aurangabad, Maharashtra. Upon graduation he joined Sanjeev Auto parts Mfg. Pvt. Ltd., project executions, production management, operations management, quality management and process planning / control. His core competencies include establishing time plans for project execution to customer requirements; identifying the needs for projects, after considering budgetary parameters; preparing models and prototypes of the products and confirming their requirements; preparing the required files and documents of the components developed. Wagh works closely with manufacturing engineers and quality engineers to address and resolve product quality and process issues.

Double Differential for Electric Vehicle and Hybrid Transmissions

Dr. Hermann J. Stadtfeld

There's never been a better time to put the spotlight on e-drive transmissions and electric vehicles. They're obviously not just coming—they're already here. Just check out any auto show or showroom. That's why ***Gear Technology*** magazine is pleased to present the first installment in a series of chapters excerpted from **Dr. Hermann J. Stadtfeld's** newest book, ***E-Drive Transmission Guide—New solutions for electric- and hybrid-transmission vehicles.*** As always, our thanks to Dr. Stadtfeld and **Gleason Corp**. for their kind permission in allowing us (and AGMA Media) the privilege of sharing this valuable and timely information with our international readership.

Printed copies of the book are readily available on the Gleason website (*Gleason.com; click on Gleason Library*) for $55 including shipping and handling, and "€"55 Europe/CIS. Or, you can view and read the book free of charge at the Gleason site. Our first selection is one of the book's most important chapters: **"Double Differential for Electric Vehicle and Hybrid Transmissions."**



What are the Common High Reduction Transmissions?

The duty of high reduction transmissions is reducing high input rpm into lower rpm's, for example to propel the wheels of a vehicle or the rotor of a helicopter. The output rpm of such a transmission is in the range between zero and 1,000 rpm. The input rpm can be 20,000 rpm and higher if the prime mover is an electric motor or a jet engine.

The conventional transmissions which can be operated with high input speeds and can accomplish high reductions are:

- Multi-stage transmissions employing cylindrical gears
- Bevel worm gear reductions with ratios of 20 in one stage
- Pericyclic transmissions with nutating bevel gears
- Cycloidal transmissions

Multi-stage transmissions employing cylindrical gears. Multi-stage transmissions with cylindrical gears require a multitude of shafts with bearings and gears. For a reduction ratio of 20, at least four stages are required. Four reduction stages require 4 shafts, 8 bearings and 4 gear meshes. Only the observation of 4 gear meshes indicates an overall efficiency of 97.6% if the efficiency of one single stage is 99.4% ($0.994^4 = 0.976$). Four stage cylindrical transmissions require a rather large transmission housing envelope.

Bevel worm gear reductions with ratios of 20 in one stage. Bevel worm gear drives are for example called high reduction hypoids (HRH) or super reduction hypoids (SRH). The worm shaped pinions have 1 to 5 teeth and the ring gears have typically 27 to 75 teeth. The maximal achievable ratios are in the range of 75. Ratios above 15 only have a reduced back driving capability. Gearsets without back driving capability are self-locking. Self-locking gearsets cannot be used in a vehicle drive train or in a helicopter main rotor drive. Bevel worm gear drives also create high sliding velocities due to the large component in face width direction. A five tooth SRH pinion, meshing with a 60 tooth ring gear creates 617m/min relative sliding between the flank surfaces with a pinion speed of 10,000 rpm (equal transmission input speed). This is higher than the maximum sliding expected in a hypoid axle drive of a sports car while driving faster than 200km/h (125 mph) with a pinion speed of 4,000 rpm. The example explains that a doubling of the transmission input will not only reduce the efficiency but also has the risk of surface damage and premature failure.

Pericyclic transmissions with nutating bevel gears. Pericyclic transmissions as introduced in (Ref. 1) can achieve very high reductions in the range of 20 to 100 without generating high relative surface sliding. As the shaft angle between two bevel gears approaches 180°, the relative sliding velocity drops down to zero. Because of shaft angles higher than 160° in the most common pericyclic transmissions, the relative sliding velocities are uncritical, even if the input speeds are 20,000 rpm or higher. Pericyclic transmissions have angled bearing seats of the nutating members and the high forces which are applied to the bearing at the angled seat have to be supported with pre-loaded tapered roller bearings. Another possible area of attention in pericyclic transmissions is the fluctuating axial mass forces the nutating members generate. High-speed pericyclic transmissions require a mirror image arrangement of an even number of nutating members as well as precise timing of the gears and precise balancing.

Cycloidal transmissions. Cycloidal transmissions are the two-dimensional analog to pericyclic transmissions. One revolution of the eccentric input shaft will rotate the output shaft by one to two tooth pitches. The radial mass forces of cycloidal transmissions cannot be compensated by a second cycloidal disk arrangement side by side. As a result, high-reduction cycloidal transmissions are only used when low input speeds are reduced in very low output speeds.

If high ratios between 10 and 100 should be achieved, designers prefer multi-stage cylindrical transmissions often combined with planetary reductions. Multi-stage transmissions are well often applied in the industry and deliver a reasonable power density.

For future high-reduction transmissions, it is desirable to create a very compact high-reduction transmission with easy-to-manufacture components and predictable operating conditions. If all involved parts are well known as standard machine design components, then the prediction of durability and endurance life is possible by applying the calculation algorithms provided by the standards of the AGMA (American Gear Manufacturers Association), ISO (International Standardization Organization) and other national standards. Those algorithms rely on tens of thousands of fatigue life testing as well as many application factors which have been evaluated for many decades. In safety engineering those proven algorithms and application factors are the engineer's most valuable tools.

Introduction to Automotive Differentials

The new development is based on the idea to realize two imbedded differentials, where one of the two outer side gears is connected to the housing and the two opposite pairs outer/inner planets are rigidly connected within each pair. Differentials are the expansion of planetary transmissions which are two dimensional into the third dimension. In planetary gears, it is possible to achieve particular ratios for example by connecting the internal gear to the sun gear or by connecting the internal gear to the housing.

The function of a standard differential can be explained (Fig. 1). The input rotation is transmitted from the final drive gear 1 via the carrier 8 to the two planets 2 and 3. The planets 2 and 3 transmit the rotation to the side gears 4 and 5 which are each connected to an output shaft 6 and 7 respectively. In the most common application in automobiles, the side gears 4 and 5 are connected to the driving wheels via the output shafts 6 and 7. If both driving wheels have the same traction while the vehicle drives straight and if both wheels have the same diameter, then there will be no relative motion between the four gears 2, 3, 4 and 5 ($\Delta\omega = 0$) and the input rotation ω_{in} is transmitted with a ratio of one to the two output shafts 6 and 7 ($\omega_{out1} = \omega_{out2} = \omega_{in}$). In case of driving through a curve, the wheel towards the outside of the curve (for example connected with shaft 6) has to drive a longer distance then the wheel towards the inside of the curve (for example connected to shaft 7). The differential enables this requirement by a rotation of the planets (in the example gear 2 rotates $+\Delta\omega$ and gear 3 rotates with $-\Delta\omega$). Such a rotation achieves that the output speed of the wheel towards the outside of the curve is $\omega+\Delta\omega$ while the output speed of the wheel towards the inside of the curve is $\omega-\Delta\omega$ which will maintain the vehicle speed (equivalent to ω) and accommodate the curve driving condition without wheel slippage or traction loss.

whereas:
ω… Carrier input speed
$\Delta\omega$… Delta rotation of the side gears

If the number of teeth of all four differential gears is identical, then the rotation of planets is exactly $\Delta\omega$ (e.g. the upper rotates in CW direction and the lower in CCW direction).

A differential accommodates the requirement of speed compensation automatically on demand which makes it an "intelligent" mechanical unit. If, with a constant driving speed ω_{in}, shaft 7 cannot rotate with ω_{in} while maintaining the same traction torque as shaft 6, then shaft 7 requires a lower speed $\omega_{out2} = \omega_{in} - \Delta\omega$. In turn, shaft 6 requires a higher speed $\omega_{out1} = \omega_{in} + \Delta\omega$ and has to rotate faster in order to maintain the same traction torque as shaft 7. The planets 2 and 3 will automatically begin to rotate with plus or minus $\Delta\omega$ in order to maintain the torque equilibrium between the shafts 6 and 7. Differential transmissions are considered a three-dimensional version of planetary transmissions.

What is a Double Differential?

The new Gleason-developed solution for a low, medium or high reduction transmission with high power density and the application of standard design elements is the double differential shown (Fig. 2).

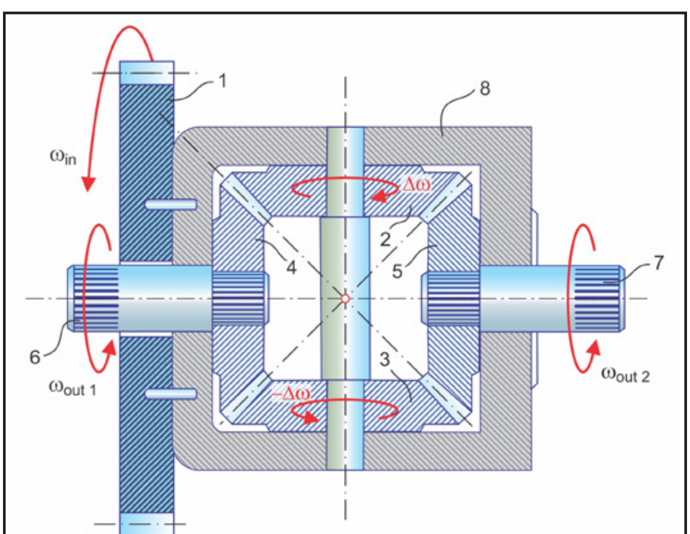


Figure 1 Automotive differential.

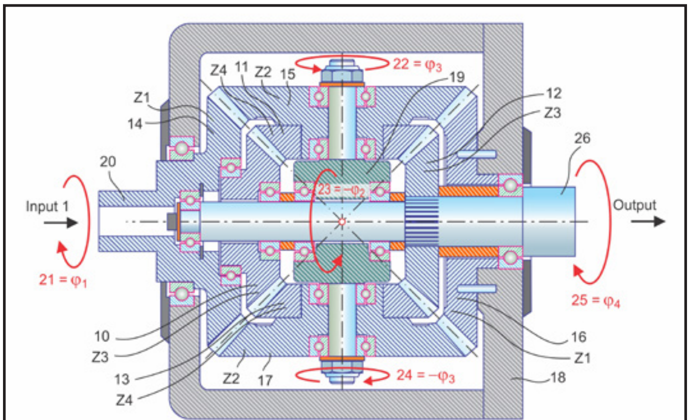


Figure 2 Double differential transmission.

The double differential transmission is symmetric and has a high power density. The input rotation 21 from shaft 20 is transmitted to gears 15 and 17 and causes a rotation 22 of gear 15, and a rotation 24 of gear 17. Gears 15 and 17 are both in mesh with gear 16. Gear 16 is rigidly connected to the housing 18. The fact that gear 16 cannot rotate will cause a rotation 23 of the carrier 19. Gears 15 and 11 as well as gears 17 and 13 are rotationally constrained with each other, for example via a spline connection. The carrier rotation 23 gives a first component of rotation to output gear 12. The rotations 22 and 24 add a second component of rotation to output gear 12. If all eight involved bevel gears have the same number of teeth, then the output rotation 25 would be zero. The explanation is that, for example a 90° rotation φ_2 of the carrier 19 would rotate gears 15 and 17 by 90° in the directions 22 and 24. The output gear 12 therefore receives a 90° rotation φ_2 from the carrier and a 90° rotation φ_3 (in the opposite direction) from the gears 11 and 13 and as a result will not rotate, independent from the input rotation 21.

While this example seems not of any obvious practical interest, the example was merely used to demonstrate the interesting functionality of double differential transmissions. In the example the ratio is $\varphi_1/\varphi_4 = \infty$.

A derivation of the equation for the ratio by using individual numbers of teeth provides the ability to find the variety of possible ratios by variation of the tooth numbers of the gears 14/16 versus 15/17 and 10/12 versus 11/13.

$$\varphi_2/\varphi_3 = z_2/z_1 \quad (1)$$
$$\text{or: } \varphi_3 = \varphi_2 \cdot z_1/z_2 \quad (2)$$
$$\varphi_4 = \varphi_2 - \varphi_3 \cdot z_4/z_3 \quad (3)$$
$$\varphi_1 = \varphi_2 + \varphi_3 \cdot z_2/z_1 \quad (4)$$
$$\text{plug (2) in (4): } \varphi_1 = \varphi_2 + \varphi_2 = 2 \cdot \varphi_2 \quad (5)$$
$$\text{or: } \varphi_2 = \varphi_1/2 \quad (6)$$
$$\text{plug (6) in (3): } \varphi_4 = \varphi_1/2 - \varphi_3 \cdot z_4/z_3 \quad (7)$$
$$\text{plug (6) in (2): } \varphi_3 = \varphi_1/2 \cdot z_1/z_2 \quad (8)$$
$$\text{plug (8) in (7): } \varphi_4 = \varphi_1/2 \cdot [1 - z_1/z_2 \cdot z_4/z_3] \quad (9)$$
$$\text{re-arranged: } R = \varphi_1/\varphi 4 = 2/[1 - (z_1 \cdot z_4)/\ (z_2 \cdot z_3)] \quad (10)$$

whereas:
z_1… Number of teeth gear 14 and gear 16
z_2… Number of teeth gear 15 and gear 17
z_3… Number of teeth gear 10 and gear 12
z_4… Number of teeth gear 11 and gear 13
φ_1… Angle of rotation gear 14
φ_2… Angle of rotation carrier 19
φ_3… Angle of rotation gear 15 (and gear 17 in negative φ_3 direction)
φ_4… Angle of rotation gear 12 (and output shaft 26)
R… Ratio of input speed divided by output speed

In the following four examples different number of teeth combinations are used to demonstrate the extremely high range of ratios which can be realized with the double differential without a significant change of the transmission size:

Example 1: $z_1 = 40$; $z_2 = 39$; $z_3 = 40$; $z_4 = 40$; Ratio $R = $ -78.000
Example 2: $z_1 = 40$; $z_2 = 41$; $z_3 = 40$; $z_4 = 40$; Ratio $R = 82.000$
Example 3: $z_1 = 45$; $z_2 = 50$; $z_3 = 40$; $z_4 = 40$; Ratio $R = 20.000$
Example 4: $z_1 = 30$; $z_2 = 50$; $z_3 = 40$; $z_4 = 40$; Ratio $R = 5.000$

Double Differential with Two Inputs

A possible expansion of the function of the double differential transmission is shown (Fig.3). In addition to the graphic in Figure 2, in Figure 3 the gears 30, 31 and shaft 32 have been added. Gear 16 is connected to a cylindrical gear 30 which is arranged rotatable to the housing 18, and in mesh with pinion 31, which is connected to a second input shaft 32. This possibility of a second input allows a variety of interesting input speed combinations with two different prime movers, e.g.—electrical motors which have different speed and torque characteristics. One motor for example can be a high torque and low speed motor which runs on a constant speed signal without speed regulation. The second motor would then, for example, rotate backwards if an output rpm of zero is required. In case of quick acceleration up to a vehicle cruising speed for example, the second motor is first turned off and the stored kinetic energy of the differential gears and the carrier is used for the vehicle acceleration. Several seconds later, when the vehicle reaches half of its cruising speed, the second motor is now actuated in positive rotational direction. During the first phase of the acceleration, high amounts of energy are drawn from the battery of a conventional electrical vehicle. The expanded double differential allows storing kinetic energy during gentle driving periods and during deceleration and breaking actions.

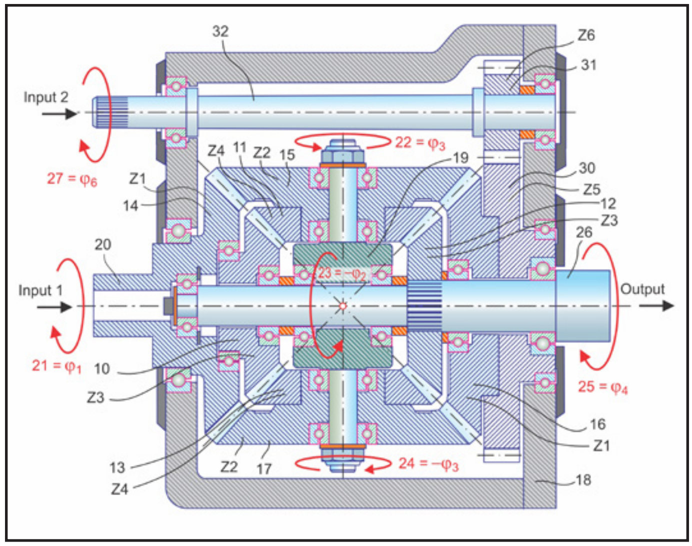


Figure 3 Expanded double differential with two inputs.

In the case of two input shafts, there is not one number for the ratio which leads to the following relationship between the output rotation to the two input rotations:

$$\varphi_2 = \varphi_3 \cdot z_2/z_1 \quad (11)$$
$$\text{or: } \varphi_3 = (\varphi_2 - \varphi_5) \cdot z_1/z_2 \quad (12)$$
$$\varphi_4 = \varphi_2 - \varphi_3 \cdot z_4/z_3 \quad (13)$$
$$\varphi_1 = \varphi_2 + \varphi_3 \cdot z_1/z_2 \quad (14)$$
$$\text{plug (12) in (14): } \varphi_1 = \varphi_2 + (\varphi_2 - \varphi_5) \cdot z_1/z_2 \cdot z_2/z_1 = 2 \cdot \varphi_2 - \varphi_5 \quad (15)$$
$$\text{or: } \varphi_2 = (\varphi_1 + \varphi_5)/2 \quad (16)$$
$$\text{plug (16) in (13): } \varphi_4 = (\varphi_1 + \varphi_5)/2 - \varphi_3 \cdot z_4/z_3 \quad (17)$$
$$\text{plug (16) in (12): } \varphi_3 = [(\varphi_1 + \varphi_5)/2 - \varphi_5] \cdot z_1/z_2 \quad (18)$$
$$\text{plug (18) in (17): } \varphi_4 = (\varphi_1 = \varphi_5)/2 \cdot [1 - z_1/z_2 \cdot z_4/z_3] + \varphi_5 \cdot z_1/z_2 \cdot z_4/z_3 \quad (19)$$
$$\text{second input rotation: } \varphi_6 = -\varphi_5 \cdot z_5/\ z_6 \quad (20)$$

whereas:
z_5… Number of teeth gear 30
z_6… Number of teeth gear 31
φ_5… Rotation Angle of gears 16 and 30

Two special cases can be encountered by applying Equation (19) for different input rotations φ_6. In case 1, the output speed (rotation angle φ_4) is equal the speed of gear 16 (rotation angle

φ_5). In this case, the output rotation φ_4 is equal the input rotation φ_1 which results in a ratio of $R=1.00$:

$$\varphi_5=\varphi_4 \text{ plugged in (19)} \rightarrow \varphi_4=(\varphi_1+\varphi_4)/2\cdot(1-z_1/z_2\cdot z_4/z_3)+\varphi_4\cdot z_1/z_2\cdot z_4/z_3 \quad (21)$$

$$\text{(21) solved for } \varphi_4\text{: } \varphi_4/2\cdot(1-z_1/z_2\cdot z_4/z_3)+\varphi_1/2\cdot(1-z_1/z_2\cdot z_4/z_3) \quad (22)$$

$$\text{or simplified: } \varphi_4=\varphi_1 \quad (23)$$

$$\text{resulting in: } R=1.00 \quad (24)$$

In case 2, the input rotation φ_5 is *zero* which simplifies Equation (19) and it becomes equal to Equation (9):

$$\varphi 5=0 \text{ plugged in (19): } \varphi_4=(\varphi_1=0)\cdot(1-z_1/z_2\cdot z_4/z_3)+0\cdot z_1/z_2\cdot z_4/z_3 \quad (25)$$

$$\text{elimination of } \textit{zero} \text{ terms: } \varphi_4=\varphi_1/2\cdot[1-z_1/z_2\cdot z_4/z_3] \quad (26)$$

Equation (9) is based on the fact that gear 16 is rigidly connected to the transmission housing, which presents the case $\varphi_5=0$, which in turn proves that Equation (19) is conclusive.

The gears in a double differential can be straight bevel gears, spiral bevel gears or face gears with cylindrical gears. In case of high-input speeds, ground spiral bevel gears will deliver the highest efficiency and the lowest noise emission in connection with a high load carrying capacity. Axial forces in a double differential are similar to such forces in an automotive differential with straight bevel gears.

Due to the fact that no hypoid offsets are used, the relative surface sliding has no component in face width direction, but consists only of profile sliding. The relative profile sliding of a spiral bevel gearset with a ratio which is close to 1.0 and an outer diameter of 120mm (typical for automotive double differential transmissions) with a speed of 1,000 rpm amounts to a maximum of about 84m/min. The relative speed between the two fastest gears (14 and 15) in a double differential transmission is only about 50% of the input speed. Equation 8, $\varphi_3=\varphi_1/2\cdot z_1/z_2$ delivers a speed of gear 15 which is only 48.8% of the input speed, if $z_1=40$ and $z_2=41$ ($\varphi_3=\varphi_1/2\cdot 40/41=0.488\cdot\varphi_1$) The relative speed between gear 14 and gear 15 is therefore in this case $\varphi_1-\varphi_3=0.512\cdot\varphi_1$.This means the relative speed between the fastest gears in a double differential transmission is typically only about half of the input speed. If the input speed is 10,000 rpm, then the double differential has only 10·84m/min·0.512 = 430.08m/min. Compared to a standard spiral bevel gear transmission, the double differential transmission has in this case only 51.2% of the sliding velocity.

An overview of the sliding velocities and efficiencies of the mentioned different types of transmissions is provided (Table 1). The sliding velocity and efficiency calculations, which Table 1 is based on, have been conducted in the commercially available Gleason *UNICAL* bevel gear analysis and optimization software.

The comparison in Table 1 clearly shows the advantage of double differential reductions to all other type of speed reducers. Lower relative surface sliding indicates lesser friction resulting in higher transmission efficiency. The calculated gear efficiencies are shown in the last column of Table 1. A high gear efficiency value of 98.8% for a ratio of 80, and at a transmission input speed of 10,000 rpm has not been reported in state of the art transmissions.

The expanded double differential allows a variety of interesting applications due to the second input (input 2). If for example input 2 is connected to a low speed high torque motor with a non-variable speed of 1,500 rpm (CW) and input 1 is connected to a variable high speed low torque motor which rotates in CCW direction, then it is possible to choose the speed of input 1 (e.g. -9,500 rpm) such that the output speed is *zero* rpm. This example is based on the following number of teeth:

$z_1=45$; $z_2=50$; $z_3=40$; $z_4=40$; $z_5=60$; $z_6=20$

with a speed of input 2 (shaft 32) of $n_6=1{,}500$ rpm CW (equal positive), and the first reduction $z_6/z_5=20/60$ the speed of gear 30 is equal to $n_5=500$ rpm. The speed of the output shaft is $n_4=0$.

Equation (19) is also valid if instead of the angles φ the rotational speeds n in rpm are used:

$$n_4=(n_1+n_5)/2\cdot[1-z_1/z_2\cdot z_4/z_3]+n_5\cdot z_1/z_2\cdot z_4/z_3\cdot n_5\cdot z_1/z_2\cdot z_4/z_3$$

$$\text{becomes: } 0=(n_1+500)/2\cdot[1-45/50\cdot 40/40]=500\cdot 45/50\cdot 40/40$$

$$\text{or: } 0=(n_1/2+250)\cdot 0.1=450$$

$$\text{resulting in: } n_1=-9{,}500 \text{ rpm}$$

The practical application of this example can be a vehicle which reduces from cruising speed to a full stop in front of an intersection traffic light (Fig. 4, left to center). When the vehicle idles at the red light, the variable speed motor rotates at −9,500 rpm. After the traffic light changes to green, n_1 can reduce from −9,500 rpm to *zero*, in order to accelerate the vehicle from 0 to 56 km/h (5 mph) (Fig. 4 center to right). During the acceleration period, the kinetic energy of the double differential assembly with gears 10, 11, 12, 13, 14, 15, 16 and 17 as well as the carrier 19 and the motor connected to input 1 is utilized to deliver the majority of the acceleration energy. Driving faster than 56km/h (35 mph) will simply require rotating the input in the opposite direction. At a vehicle speed of 112km/h (70 mph), the speed of input 1 will reach $n_1=+9{,}500$ rpm. Depending on the duty cycle of a vehicle (highway or city driving), the low-speed motor can be turned off and a (not shown here) clutch can be applied in order to lock input 2. In this case, the variable speed motor connected to input 1 will deliver all the energy required for example for a light duty city driving. The two graphs in Figure 4 show that in the energy balance a friction loss has been considered.

When attempting to constantly back-charge bursts

Table 1: Comparison of relative sliding velocities and efficiencies of different transmission types at 10,000 rpm

Gear Type	Ratio	Pinion Diameter	Ring Gear Diameter	Pinion rpm	Relative Sliding	Efficiency
Hypoid	35	50 mm	120 mm	10,000 rpm	1,450 m/min	97.9
Super Red. Hypoid	15	35 mm	120 mm	10,000 rpm	617 m/min	89.4
Spiral Bevel	1	120 mm	120 mm	10,000 rpm	840 m/min	99.3
Double Differential	80	120 mm	120 mm	10,000 rpm	430 m/min	98.8

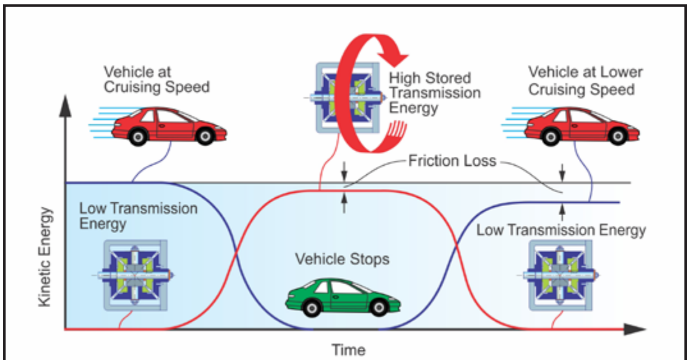


Figure 4 Energy balance—vehicle with mechanical energy storage.

of recuperative energy to a battery, the electrical efficiency becomes very low and the battery's chemical capacity to accept large amounts of energy within only several seconds is limited. A medium-size sedan which drives at 56 km/h (35 mph) has about 0.4 kWh kinetic energy. Reducing the speed rather quickly in front of a traffic light which just turned red would require recuperating the 0.4kWh within about 2 to 3 seconds. As a result, it is likely that not more than 0.10 to 0.15 kWh can be back-charged to the battery and 0.25 kWh converted to heat — either in the brake disks or in the electronic vehicle control modules. The double differential including the motor on input 1 can store about 0.24 kWh with an efficiency of about 96%, which means that 0.23 kWh are available in form of a rotation of the double differential when the vehicle comes to a full stop before the red light. This energy will be used only several minutes later to accelerate the vehicle after the traffic light turns green. Short-term energy storage cannot yet be done efficiently with existing battery technology. The double differential concept allows a size reduction of the battery by maintaining the same mileage capacity.

The combination of two input speeds is allowing a wide variety of possibilities to adopt the double differential transmission to different driving conditions by achieving an optimal motor and transmission efficiency. The additional aspect of easy energy storage in a fast rotating differential carrier unit will support the vehicle batteries especially when high energy bursts are required, for example, to accelerate a heavy truck from zero to 48km/h (30 mph). In contrast to internal combustion engines, electric motors require very little energy while they run in idle without any external resistance.

The double differential with two inputs can also be utilized to collect and transmit the energy from an electric motor and a combustion engine to the driving wheels of a hybrid vehicle. With such an arrangement, optimal speed combinations for each of the two prime movers can be found, which also allows eliminating any additional transmission in the hybrid vehicle.

Gear 10 in Figure 3 is not required for the function of the double differential. It was used to make the transmission symmetric and it was anticipated that in case of large tooth and transmission housing deformation (under high load) gear 10 would help to keep the torque on gears 11 and 13 equal. If symmetry and balance is not an issue, then gear 10 and in addition gears 13 and 17 can be eliminated in order to simplify the double differential transmission and reduce manufacturing cost.

Double Differential Inline Solution

In order to allow placing the double differential transmission between the wheels of a drive axle in a vehicle, a proposal of an additional configuration is shown (Fig. 5). The transmission in Figure 5 has an additional differential function between the two output shafts 26 and 41. Output shaft 26 remains on the right side of the transmission housing and the added output shaft 41 exits the transmission housing at the left side. Gear 10 which is not required for the correct function of the double differential has been eliminated and shaft 41 acts now as main transmission shaft, which was the function of shaft 26 in Figure 2. Gear 12 in Figure 2 was replaced in Figure 5 by gear 40. Gear 40 is hollow inside in order to create a space for the placement of

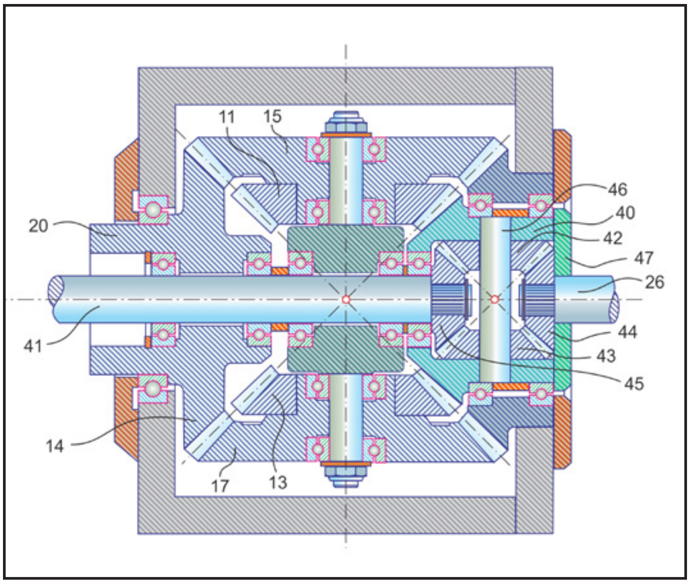


Figure 5 **Double differential with additional differential function between two output shafts.**

4 differential gears 42, 43, 44 and 45. Gears 42 and 43 are the planets which are held in position relative to gear 40 with pin 46. Pin 46 is connected to gear 40, which is the gear with the final output speed. Gears 44 and 45 are the side gears. Output shaft 26 is connected to side gear 44 and output shaft 41 is connected to side gear 45. The design in Figure 5 will accomplish the same differential function between the two output shafts 26 and 41 as explained with Figure 1 for the output shafts 7 and 6. The end cap 47 closes the differential inside of gear 40 and acts as a radial sleeve bearing of shaft 26 and as a thrust sleeve bearing for gear 44. The walls of the hollow space in gear 40 are utilized as thrust sleeve bearings of gears 42 and 43.

The additional differential function accommodates different wheel speeds while the vehicle is, for example, driving through a curve. A differential, similar to the one shown in Figure 1 has been integrated in gear 40. The transmission in Figure 5 has an output shaft 26 which could be connected to the right wheel and an output shaft 41 which could be connected to the left wheel. The input shaft 20 is still located at the left side of the transmission. If input shaft 20 is connected to an electric motor with a hollow shaft, then the transmission (Fig. 5) as well as the electric motor can be in-line with the drive axle of a vehicle. This means that output shaft 26 can be connected via a first drive shaft and CV joints to the right-side driving wheel and output shaft 41 can be connected via a second drive shaft and CV joints to the left-side driving wheel.

Back Driving Properties of Double Differentials

Back driving efficiency is a topic which has been discussed (Ref. 1) in connection with super reduction hypoids (Ref. 2). If an electric vehicle cruises downhill while the driver has the foot off the accelerator pedal (coasting), the kinetic energy from the vehicle mass and speed will, via the traction of the wheels, try to accelerate the motor rotation. If the motor function is switched to "generator," then a charging of the battery will occur while the vehicle speed reduces.

Back driving ability and "the non-self-locking" phenomenon are not based on the same physical assumptions. Not self-locking is the ability to achieve a rotation of the input shaft by applying torque to the non-rotating output shaft; this cannot be done with self-locking transmissions. However when a self-locking transmission rotates at a certain speed, it might still be possible to accelerate the rotation of the input shaft by applying a negative torque on the output. In other words, a self-locking transmission might still have a back driving ability.

Back driving is easier if the ratio is below or equal 1 (Fig. 6, cases A and B). It is more difficult as the ratio gets higher (cases C and D). Although this applies to entire transmissions with a multitude of gear meshes, it especially applies to each single stage of a transmission. This can be explained in a comparison. If a one-stage worm gear drive has a ratio of 50, the back driving is difficult — even if the unit already rotates. Small disturbances like the motion error of a worm gearset can lead to an abrupt stop during back driving. A three-stage cylindrical transmission with a ratio of 50 can be back driven, even in the case of disturbances like motion error. It is more the ratio between the involved gear pairs that makes the back driving easy or difficult.

In a double differential, the ratio between the involved gears is always close to 1 (case B). This is an ideal condition for back driving. Scientific investigations will be conducted in the near future in order to establish a calculation algorithm resulting in quantitative back driving efficiency numbers.

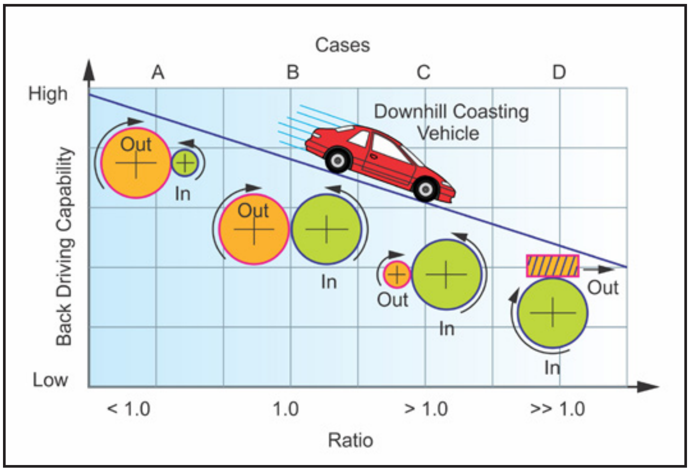


Figure 6 Back driving capability.

Double Differential *KISSsoft* Animations and First Prototype

Although the functionality of the double differential development is explained in great detail, it is difficult to visualize the kinematic of this design. In order to make the high-reduction function easy to understand, KISSsoft AG provided several animated designs (Ref. 2).

The left shaft in Figure 7 is the high-speed input. The carrier with the center gears rotates in space while the right-side large blue gear is connected to the housing (housing not shown here). The right-side smaller blue gear rotates slowly and is connected to the right-side output shaft.

Another animation screen shot is shown (Fig. 8). The lower planets opposite to the upper light blue planets have been removed in this view. In addition, for better visibility through the unit, only 270° sections of the rotating gears are shown. The light gray bevel gear to the right is the slow rotating output gear which is connected to the output shaft.

The third animation (Fig. 9) has the planets of both sides visible. The ratio of the transmission in Figure 9 is +20. The ratio of the double differentials shown (Figs. 7 and 8) is −79. The

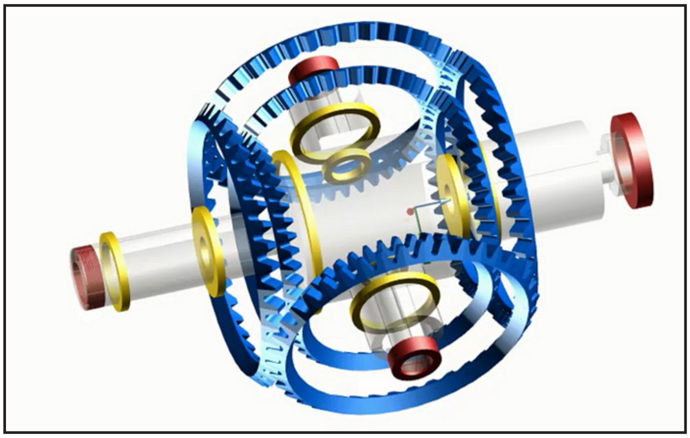


Figure 7 First animation of complete model.

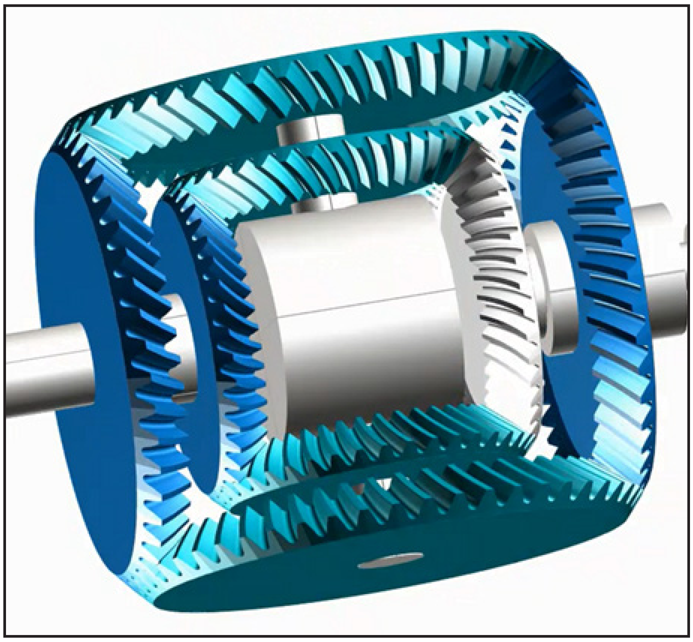


Figure 8 Second animation — partial view of double differential with 270° gear sections.

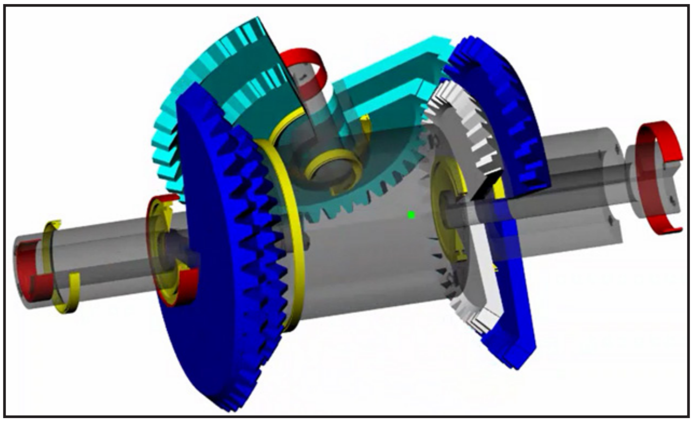


Figure 9 Third animation — partial view of double differential without sections.

different transmission views in this section are intended to deliver a variety of optical impressions for a better visualization of the double differential kinematics.

The first real-size prototype of the double differential transmission is shown (Fig. 10). This prototype achieves a ratio of 81. All eight gears are ground spiral bevel gears. Only two design calculations were required in order to manufacture the eight

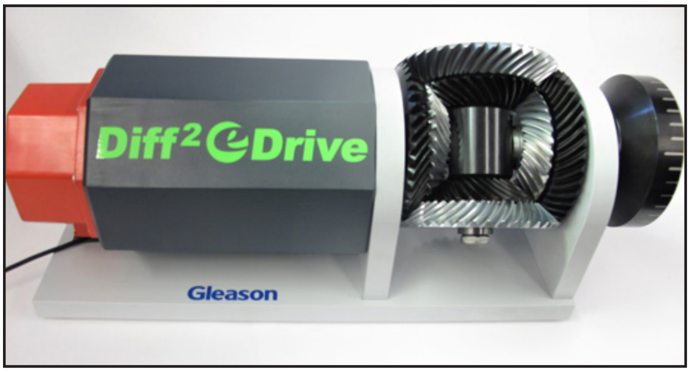


Figure 10 Prototype transmission with motor — Ratio 81.

spiral bevel gears. It is interesting to note that due to the similarity of all eight gears, only two different blade geometries (one left-hand and one right-hand) were required for the soft cutting of all members. The prototype has an electric motor attached that serves to demonstrate the interesting three-dimensional motion of the planet gears and their high-reduction ratio. It was very simple to assemble the transmission unit with the correct backlash and tooth contact. In order to make the transmission motion of the eight gears more visible, always two opposite pairs have been black-oxidized and the two opposite mating members were chrome-plated.

The animations (Figs. 7and 8) have been developed with straight bevel gear images only for simplicity. In order to live up to the requirements of electric vehicle drive technology, it is recommended to apply spiral bevel gears as shown (Figs. 9 and 10).

The video animations behind the presented screen shots can be seen in the e-book version of this book on the Gleason Corporation Website. It is also possible to request the animation videos from Gleason Corporation Sales (via the Gleason Website) or directly from the author by email.

Summary

The fascination of the automotive differential has led to the idea to build a second differential unit around a first center unit. Both units have the same axes around which they rotate with different speeds.

The potential of double differentials as ultra-high reduction speed reducers is incredible. Only the tooth-count of the gears in the outer differential unit need be changed in order to achieve ratios between 5 and 80 without a noticeable change in transmission size.

Double differentials are well-suited for high-input speeds. The fact that the carrier rotates with about half of the input speed reduces the relative motion — and with it the sliding velocity to 50% of the value of two conventionally meshing bevel gears which roll with the same input speed.

Ground spiral bevel gears are recommended for the double differential application. Due to the load sharing of the two opposite planets, the torque of each gear is only 50% compared to a conventional bevel gear mesh. This effect results in very high-power density in what is already a very compact unit.

Also the efficiency of the double differential is high in contrast to the fact that always two pairs of gears are transmitting the rotation and torque. Table 1 is based on efficiency calculations of realistically sized bevel gears. The double differential shows an efficiency result of 98.8%, which is excellent and qualifies this new transmission type very well for the speed reduction and transmission in electric vehicles and hybrids.

Although this paper concentrates on the application of double differentials to electric vehicles and hybrid cars, there are many other applications in the industry that require high ratios. Double differentials could be used in helicopters, wind turbines, agricultural equipment and many other industrial applications.

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

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

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

Gear Blank Tuning

Andy Gale, Paul Langlois and Owen Harris

Introduction

The design of gear blanks or flanges has traditionally been driven by weight reduction. Recently innovative companies have started to use the gear blank design to tune the system dynamics to reduce gear whine.

This is used successfully for EV and HEV applications where noise is critical, as there is no or less internal combustion (IC) noise to mask gear whine, and speeds and gear tooth passing frequencies are higher and can interact strongly with the gear blank dynamics.

There is potential that the inclusion of circumferential holes in gear blanks can lead to further NVH improvements. Traditional methods for modeling are adapted in this paper in order to optimize the design of these holes, while a new simulation method is introduced that can more realistically capture the modulation effects of the gear blank as it rotates.

The simulation methods presented here are implemented within SMT's *MASTA* software, a CAE tool for drivetrain design, analysis and optimization.

EV Drivetrain Model

In order to test the simulation methods presented here, a realistic single-speed, two-stage helical EV drivetrain model is used (Fig.1). The analysis model consists of an FE-based model where shafts are considered as Timoshenko beam elements, and gear mesh and bearings as bespoke non-linear contact models.

In this case the first-stage wheel blank and transfer shaft is represented via stiffness and mass matrices determined via dynamic reduction from the full FE component (Fig. 2) in order to fully capture the gears' mode shapes and deflection under load.

The motor and gearbox casing are also represented in full FE in order to compare the dynamic response of the casing for various gear blank designs under the specified loading condition.

The loading conditions and main model parameters are displayed (Table 1). For this design, the maximum input speed is 14,000 rpm, but it should be noted the trend for recently emerging and future EV's are for input speeds up to 20,000 rpm or higher. The input torque of 50 Nm represents light loading at low speed, and is typical of the vehicle's torque at high speed, meaning it gives a representative loading condition over the vehicle's speed range.

Table 1 EV drivetrain loading conditions and model parameters

Loading Conditions	
Input speed	14,000 rpm
Input torque	50 Nm
Model Parameters	
Overall gear ratio	6.535:1

Gear Blank Tuning Methods

Traditional methods for modeling. For analysis of gear whine, a frequency domain methodology well documented by Steyer et. al (Ref. 1) is chosen. This method applies the static gear transmission error (TE) at each gear mesh as a relative displacement input. The compliance at each side of the gear mesh, which can be considered as a measure of how much motion each gear mesh generates per unit force applied, can be calculated by applying a unit harmonic force in the line of action and

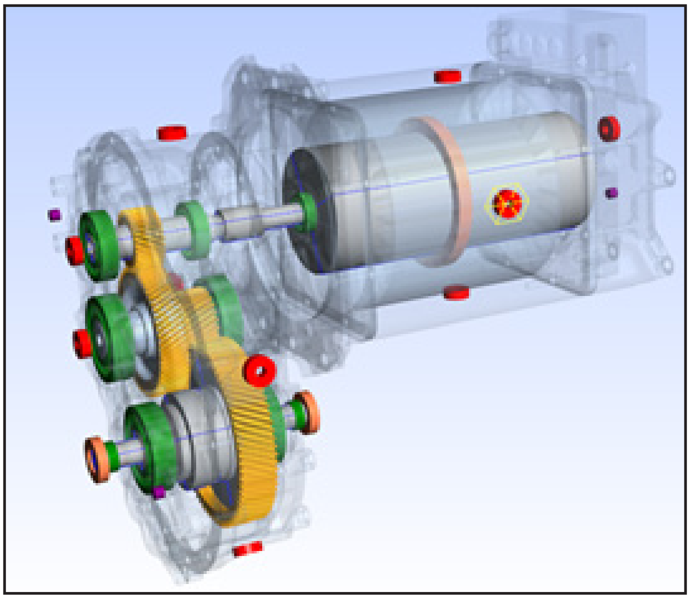

Figure 1 EV drivetrain model.

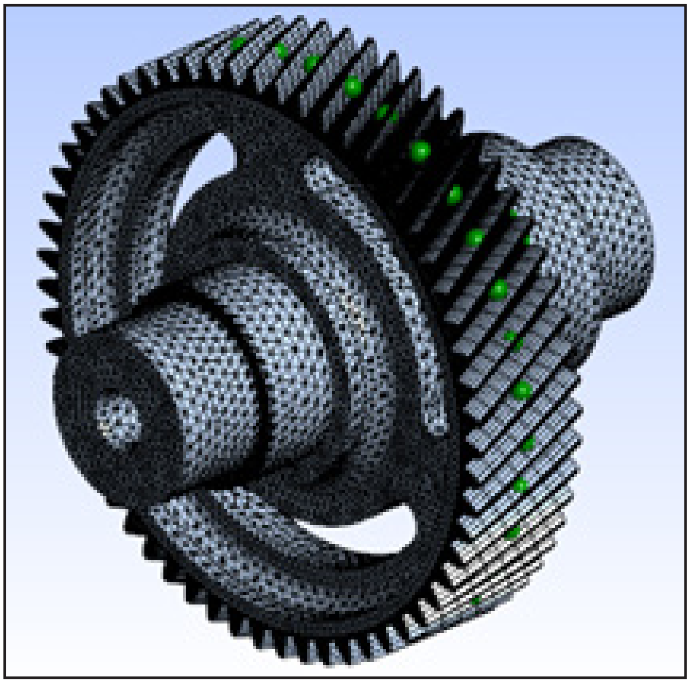

Figure 2 First-stage wheel blank and transfer shaft FE.

calculating the resulting harmonic displacement. The pinion and wheel compliances are then summed together in order to give the total compliance. The dynamic mesh stiffness is then calculated as the inverse of the total compliance.

The dynamic gear mesh force is then derived as the product of the TE and dynamic stiffness for a given harmonic of the TE and applied to the model to give the dynamic response of the whole system.

Where:

$$C_{mesh}(\omega) = C_p(\omega) + C_w(\omega)$$
$$D(\omega) = (C_{mesh}(\omega))^{-1}$$
$$F_i(\omega) = D(\omega)\,\delta_i$$

$C_{p,w}(\omega)$ - Is the dynamic compliance in the line of action at the mesh, at the pinion (p) and wheel (w) sides, at frequency ω

$C_{mesh}(\omega)$ - Is the total compliance at the mesh in the line of action

$D(\omega)$ - Is the dynamic mesh stiffness in the line of action

$F(\omega)$ - Is the dynamic mesh force for the ith harmonic of the TE

δ_i - Is the ith harmonic of the TE, transformed normal to the flank, normal to the helix

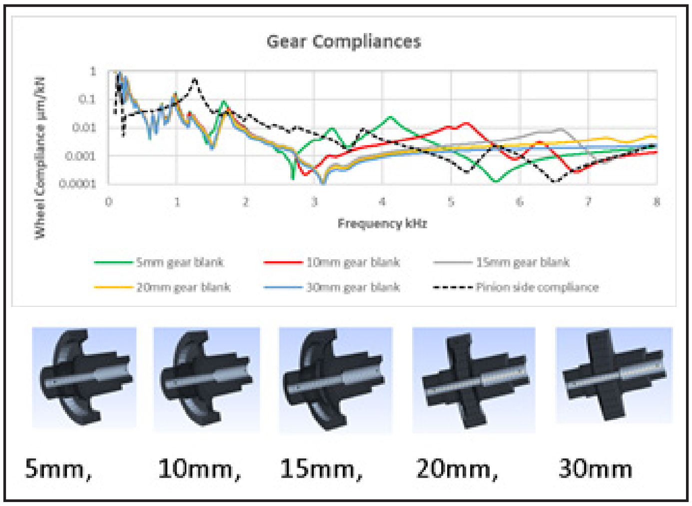

Figure 3 Compliance result for varying web thickness.

By studying the compliances, one can tune the dynamics at the gear mesh and avoid high gear mesh forces in the operating range (Refs. 2–3). This can be seen in Figure 3, where thicker blanks have modes at higher frequencies, reaching outside the operating range for blanks with a web thickness larger than 15 mm.

The characteristic gear blank mode shape causing a peak in compliance at approximately 5 kHz for the 10 mm gear blank is shown (Fig. 4).

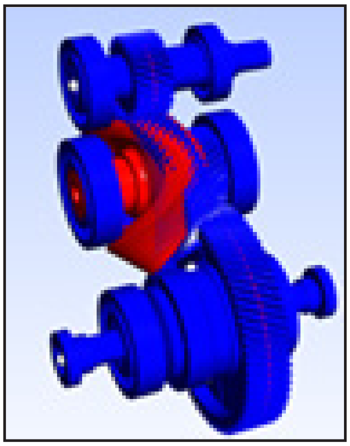

Figure 4 Gear blank 'potato chip' mode.

It can also be seen however that thicker blanks have a lower compliance, and hence give higher dynamic mesh forces within the operating range (Fig 5).

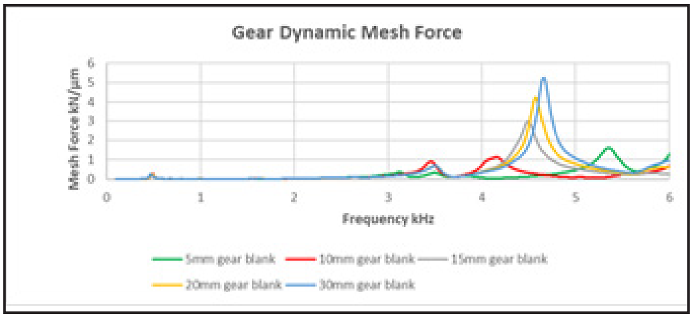

Figure 5 Dynamic mesh force result for varying web thickness.

A careful design of the blank must therefore be used to tune the driveline dynamics and reduce mesh forces. The methodology described here is in the frequency domain leading to fast analysis times and is thus well suited for optimization purposes.

Axisymmetric optimization. In order to optimize the gear blank design for NVH improvements, one must consider the system as a whole, taking into account both the dynamic mesh force at the gear mesh and the transfer path from gear mesh to components such as bearings, housing and mounts; the dynamic response at a particular location being equal to the multiplication of both these factors.

In a previous study (Ref. 3) the airborne sound power of the casing was chosen as the key metric for optimization, giving a good indication for the overall airborne noise radiated from the casing due to excitation at the gear mesh.

An automatic optimization method was utilized, whereby the gear web and rim thickness were modified within defined bounds and meshed, then the static deflections and misalignments were calculated in order to calculate the static TE. The harmonic response to the TE, in this case the sound power

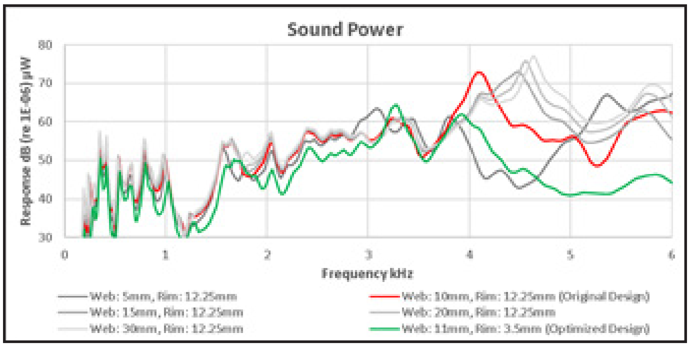

Figure 6 Axisymmetric optimization casing sound power result.

result, was then determined. This method led to a gear blank design that has over a 10 dB decrease in sound power (green) compared to the baseline (red) (Fig. 6).

It should be noted that other design targets, such as durability, should be considered in any optimization approach, and while the optimized design seen here may give large improvements in terms of NVH, the reduced rim thickness does lead to higher misalignments and stresses at the gear mesh. A trade-off of improvements must therefore be decided upon when choosing a gear blank design.

Gear blank with holes preliminary optimization using harmonic analysis. To further optimize the gear blank design for NVH, three circumferential, elongated holes were added to the previously optimized axisymmetric design (Fig. 7). The design was similar to that used in industry (Refs. 4–5) where the holes are intended to cause modulation in the mass and stiffness at the tooth contact as the gear rotates, meaning the vibration level of the gear doesn't reach full resonance before the mass and stiffness changes.

For simulation of this effect, it is suggested that a time domain solution is needed that can consider the fluctuating components of the mass and stiffness as the gear rotates (Ref. 4).

While this approach is valid and has been shown to give good correlation to test data, a full MBD time domain solution does not currently lead itself to fast simulation times and so would be impractical for the purposes of design optimization.

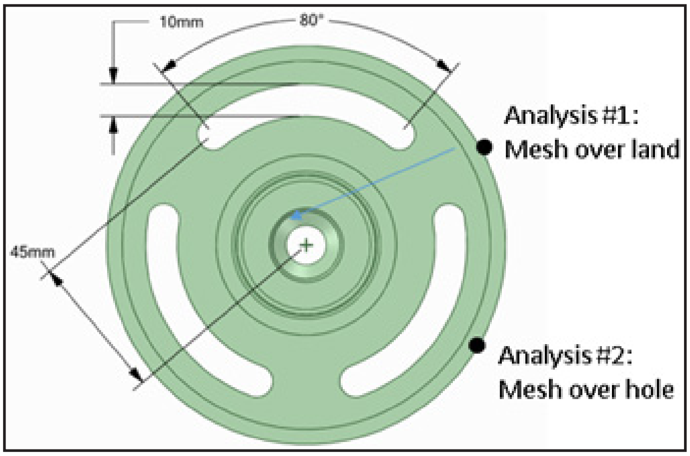

Figure 7 **Baseline gear blank design with holes.**

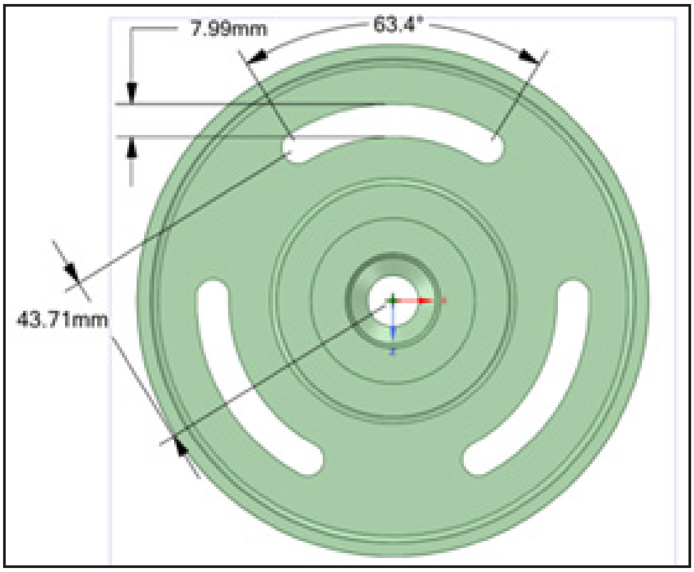

Figure 8 **Optimized gear blank design with holes.**

The optimization method thus utilized was similar to that used in the axisymmetric study, the main difference being that an analysis was performed with the gear mesh over the land and the gear mesh over the hole on each design iteration (Fig. 7), leading to two dynamic response results of airborne sound power for each design.

An optimization algorithm was employed where the design parameters (hole width, center radius, sweep angle, fillet radius and gear blank web and rim thickness) were modified in order to fulfil two design objectives of minimizing the maximum sound power result — both over the land and over the hole. The algorithm converged to a set of optimal designs shown (Fig. 9; otherwise known as a pareto front), where a trade-off between the two objectives had to be analyzed to pick the optimized design. Designs that had large misalignments were discounted from the analysis (colored in yellow).

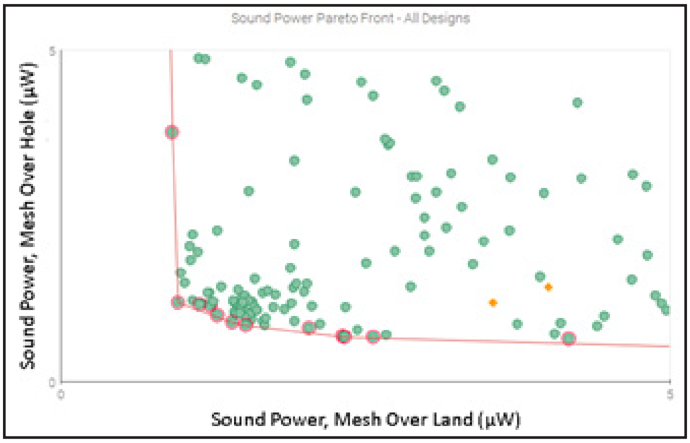

Figure 9 **Pareto front of designs.**

The chosen optimized design shown (Fig. 8) had the same web and rim thickness as the baseline design — but with a smaller hole width and sweep radius. This design gave a lower maximum sound power across the operating range, both when the gear mesh was over the land or over the hole, compared to the baseline design with holes. As can be seen (Fig. 10), it also gave a lower maximum sound power at both rotation angles compared to the previously optimized axisymmetric gear blank; units are given here in absolute scale for clarity.

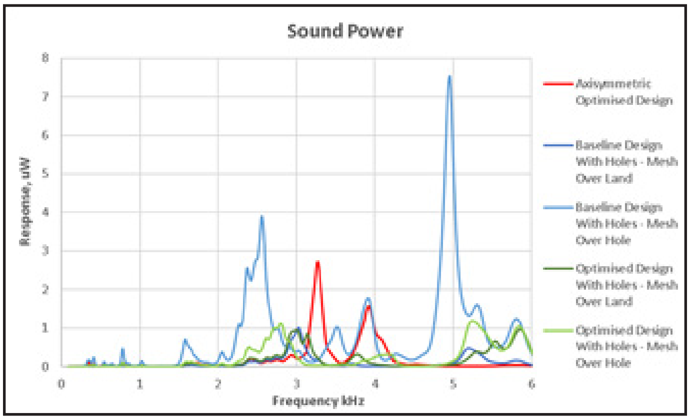

Figure 10 **Gear blank with holes optimization sound power result.**

Dynamic Solution for Modulation

Proposed dynamic solution for modulation. While the method utilized in the gear blank with holes study leads to fast simulation times and is ideal for optimization purposes, the critical phenomenon of resonance disruption from the holes is not captured and hence any design that is proposed for manufacture should be checked with a more advanced simulation that can capture this phenomenon.

A solution is proposed that utilizes the speed of a linearized modal model at a number of slow timescale steps, e.g.—hole passing angles, and a transient linear time-stepping solution of the modal model on a fast timescale, such as tooth passing. As a time-stepping simulation it does capture the resonance disruption mechanism.

The method is faster than a traditional time-stepping approach while retaining most of the simulation accuracy, meaning it can be useful as a tool for comparing a small number of gear blank designs or verifying the results of an optimization.

Dynamic response results comparison. To more accurately compare the NVH response of the axisymmetric design to the baseline design with holes, the new dynamic solution method was employed, focusing on any potential improvements to the two areas of large sound power response identified in the axisymmetric optimized design at approximately 3.3 and 3.9 kHz (Fig. 10). Acceleration response on 12 accelerometers distributed around the casing (Fig. 1) was used to compare the designs.

The TE amplitude at the gear mesh order of the axisymmetric and baseline design with holes was found to be quite similar at 0.0592 μm and 0.0628 μm, respectively. However, the gear blank with holes experiences a modulation in TE as it rotates, leading to sidebands around the gear mesh order. To negate this effect a unit TE of 1 μm was applied as the excitation at the first-stage gear mesh order in both simulations.

Results from the new dynamic solution can be seen (Figs. 11 and 12). It is clear that the locations of the two large peaks in sound power response seen in the axisymmetric optimized design in Figure 10 correspond with the locations of the two large peaks in accelerometer response in Figure 11; this demonstrates the validity of comparing accelerometer response for any potential NVH improvements from the design—with holes, in this case.

Comparing the results from Figs. 11 and 12, there is a marked reduction in accelerometer response in the gear blank with holes at the problem areas of 3.3 and 3.9 kHz; showing this design is expected to lead to overall NVH improvements compared to the axisymmetric design.

Proximity analysis. Although the gear blank design with holes has shown an improved NVH response at the gear mesh order, the sideband content and its relative difference in frequency from the mesh order should also be considered.

The prominence ratio (PR) method is a way of ascertaining if a discrete tone will be heard above the levels of critical bands on either side of the critical band containing the discrete tone.

As can be seen (Fig. 13), +3 / -3 sidebands arising from the hole modulation all fall within critical band B, which is centered on the gear mesh order. This means the content of energy within these sidebands will add to the content of energy within the main mesh order and be heard by a listener as a single prominent tone. Any energy that falls within critical bands A or C, however, such as the +6/−6 sidebands, have the potential to help mask the prominence of a discrete tone in critical band B.

Future work is planned to investigate this sideband structure in more detail.

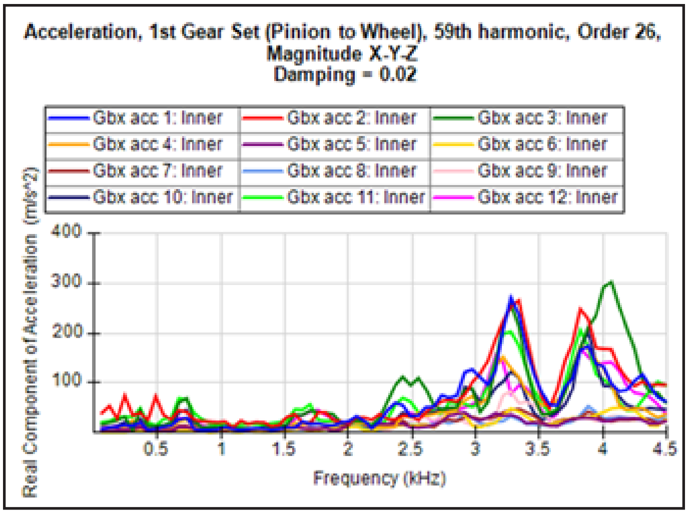

Figure 11 New dynamic solution result; response of housing accelerometers at gear mesh order with axisymmetric optimized gear blank design with no holes.

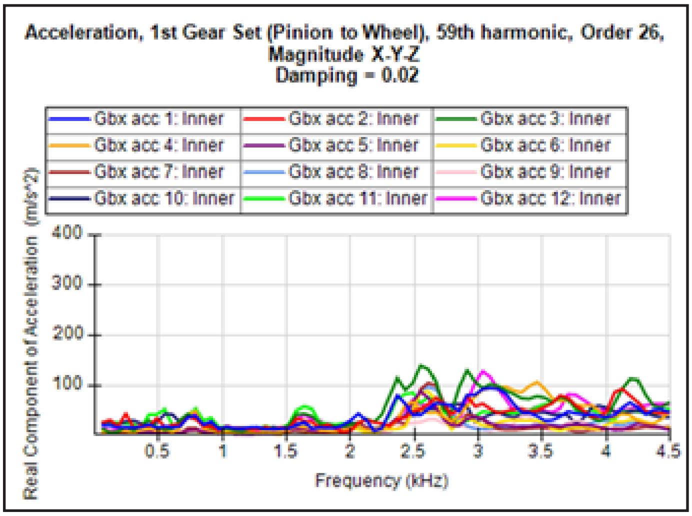

Figure 12 New dynamic solution result; response of housing accelerometers at gear mesh order with baseline gear blank design with 3 holes.

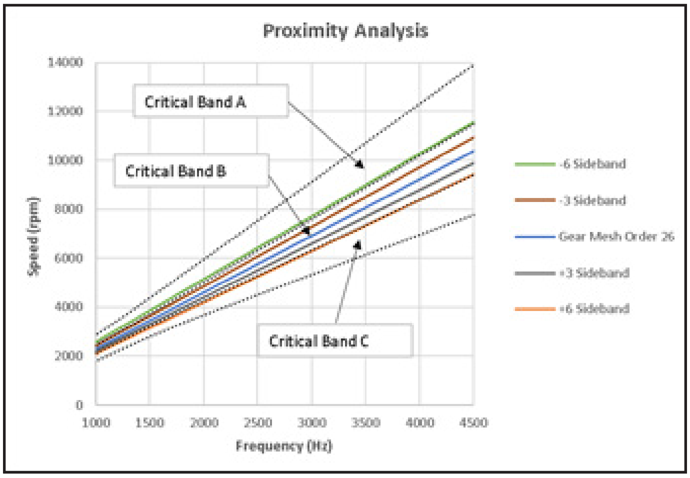

Figure 13 Proximity analysis of gear mesh order and associated sidebands.

Conclusion

A traditional simulation method has been used to optimize the hole design on a realistic EV drivetrain wheel blank for improved airborne sound power response on the gearbox and motor casing.

A novel dynamic method has then been introduced that verifies the improved NVH response from adding holes; the method being faster than a full time domain solution while retaining good accuracy.

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Andy Gale is a research engineer at SMT. He has a background in mechanical engineering, and has experience in a variety of fields including additive manufacture and NVH. He has recently been leading modal testing research and development at SMT.

Dr. Paul Langlois is the software engineering director at SMT. Having worked for SMT for 13 years, he has extensive knowledge of transmission analysis methods and their software implementation. He manages the development of SMT's software products and is a main contributor to many aspects of the technical software. As a member of the BSI MCE/005 committee, Langlois contributes to ISO standards development for cylindrical and bevel gears.

Dr. Owen Harris, a graduate of Trinity College Cambridge., has worked in the analysis of transmissions and geared systems for over twenty years. He was instrumental in writing some of the first commercial software codes for housing influence, system modal analysis and gear whine and planetary load sharing. Harris has filled many roles in over ten years working at Smart Manufacturing Technology Ltd. (SMT). He has worked on SMT's state-of-the-art MASTA software, while at the same time being heavily involved in many engineering projects. Harris's current focus is to lead SMT's research department.

Real-Time IoT in Additive Manufacturing

PILOT PROJECT AIMS TO PRODUCE MORE THAN 10,000 INDIVIDUAL AND SPARE AUTO PARTS PER YEAR

In March 2019, a consortium of 12 partners from across the additive manufacturing, automotive, research and industrial sectors launched the Industrialization and Digitalization of Additive Manufacturing (IDAM) project. At its core, the project addresses the limitations of laser powder bed fusion (LPBF) AM, including the lack of automation and high associated costs, that hinder the technology's adoption for industrial, serial production in industries such as automotive.

The IDAM project was conceived in order to confront and overcome these challenges. The 20 million euro initiative is partially funded by the German Federal Ministry of Education and Research (BMBF), and brings together 12 partners: GKN Powder Metallurgy, BMW Group, Aconity GmbH, Concept Reply GmbH, Myrenne GmbH, Intec GmbH, Kinexon Industries GmbH, Volkmann GmbH, Schmitz Spezialmaschinenbau GmbH, Chair for Digital Additive Production DAP, Fraunhofer Institute for Laser Technology ILT and Technical University of Munich, Chair of Metal Forming and Casting.

Each partner contributes in its specific area of expertise to help establish a pilot line for a fully automated, industrial-ready additive production. The goal of IDAM is to build two pilot lines—one at GKN PM's factory in Bonn, and the other at BMW Group's facility in Munich—to demonstrate a digitalized and IoT-driven production line for 3D printing automotive components. When these pilot lines are up and running, the IDAM consortium aims to produce over 10,000 individual and spare parts per year, as well as at least 50,000 mass-produced components. One of the key points that set IDAM apart from other AM automation concepts is that it is end-user-based rather than supplier-based. The IDAM pilot line will encompass an open architecture, that can be adapted for any LPBF system.

GKN PM is a key member of the IDAM consortium and a host to one of the two pilot lines at its facility in Bonn, Germany. The company is leveraging its extensive knowledge of conventional powder metallurgy serial production as well as its experience with metal additive manufacturing to create an industrialized, automated factory setting.

The modular approach within IDAM enables as well that further AM technologies within GKN's portfolio (e.g. Metal Binder Jetting, Multi Jet Fusion) will be digitally connected and benefit from the new developments. Within the framework of the IDAM project, GKN PM acts as a critical bridge between the various project members, translating process development concepts from the academic side to application-focused strategies on the industry side. GKN PM and BMW also provide vital insight into the qualification process and support the SMEs who are developing the pilot line modules.

"We are now halfway through the IDAM roadmap," says Sebastian Blümer, Technology Manager Laser AM at GKN Powder Metallurgy. "Currently, we are in the phase of checking the concepts of the pilot line modules. We are preparing to receive the remaining modules by the beginning of 2021, which will give us about a year to test and qualify them. In other words, the digital architecture is almost finished, and we are now looking to the prototype phase. We are eager to get the pilot line modules connected with our internal systems to simulate the IDAM workflow."

Over the past year, the IDAM consortium partners have made progress in the creation of the digitalized AM pilot lines by tackling a range of topics, including pre-printing, printing, and post-printing phases. Among the most critical issues addressed at this stage of the project is the creation of a digital architecture, including digital standards and an IoT-connected overview of the AM process chain. A digital architecture that covers the entire AM process is critical to ensure communication between AM process chain modules and achieving the reliability required for serial production.

GKN PM is a key member of the IDAM consortium and a host to one of the two pilot lines at its facility in Bonn, Germany.

One of the biggest hurdles in adapting the digital architecture is creating a comprehensive solution for various LPBF systems that all vary in their interfaces to the process chain. The diverse nature of LPBF systems on the market makes it challenging to implement an interface that is both reliable and flexible. GKN PM is currently validating a recently acquired EOS M300-4 quad-laser system, testing out multi-laser exposure strategies, and pushing the system's productivity. The new metal AM system was installed at the company's Bonn facility in May 2020.

As the IDAM project nears its halfway mark, one of the most notable advancements is the identification of a metal powder material by GKN PM that demonstrates excellent potential for industrialization in the automotive market. The material is DP 600, a dual-phase steel whose mechanical properties can be tuned using heat treatment methods.

The gas atomized material, which is now being validated on the EOS M300-4 system, demonstrates an elongation rate of 13% (as-built) up to 22% (with heat treatment), and a tensile strength of 950 MPA (as-built) up to 700 MPA (with heat treatment). These tunable properties make the dual-phase steel material a good candidate for several structural automotive applications, as well as for other applications in the industrial market. Further potential to reduce cost per part can be achieved by using water atomized powders for future applications. (*www.gknpm.com/en/Utilities/connect-with-an-expert/*)

McKernin

JOINS MILAN'S MACHINING & MANUFACTURING AS GEAR SALES DIRECTOR

Milan's Machining & Manufacturing Co Inc. welcomes **Michael McKernin** as the gear sales director. With 35 years in the gear industry, McKernin brings experience in all aspects of gear engineering, manufacturing and sales.

"We are really excited to have Mike on board," said Marko Pecharich, president of Milan's Machining and Manufacturing. "His experience in the gear industry will open new opportunities and provide our company with additional insight into the gear industry."

With a degree in manufacturing engineering technology from Bradley University, McKernin has been involved in all aspects of metalworking and manufacturing, with a strong emphasis on gear manufacturing. McKernin currently serves as the chairman of the Business Management Executive Committee (BMEC) for the American Gear Manufacturers Association (AGMA) — where he oversees the managerial and educational programs along with committee activity for AGMA members in manufacturing.

"I am really excited to work with the whole group at Milan's. The opportunity to help with the growth and expansion of a forward-thinking gear company is a perfect fit for my skill set." McKernin said. "Milan's has been involved in gear manufacturing for decades and recently acquired Allied Gear to open the door for rapid expansion."

With McKernin joining the team, Milan's recently joined AGMA to further promote and capitalize on critical industry resources. As members of AGMA, they will work along side other gear manufacturers to promote growth and diversity in a global supply chain for the power transmission industry and will continue to be leaders and stewards for the future of manufacturing while sharing a robust set of capabilities for customers. (*www.milansmachining.com*)

Solar Atmospheres

CELEBRATES AS9100 ANNIVERSARY

Solar Atmospheres of Western PA celebrated thirteen years of AS9100 certification. This new era is intricately woven with COVID-19, populous instability and intertwined with increasingly stringent standards, revised industry specifications, and customer requirements.

Even with these new complexities, Solar passed this milestone for more than a decade of accreditation without any major findings. The live audit, which was conducted for the very first time, used a combination of email, telephone and video conferencing to grade Solar's QMS, on recent aerospace work. The comprehensive review addressed recent events as risk and Solar's response as effective.

Melissa Gruszka, quality manager and recent edition to Solar Atmospheres of Western PA, states, "We have a great team that can pull together, under any circumstances, to get work done. Solar maintains the highest standards by keeping safety, quality, and efficiency in check and our customers in the foreground. Solar exercises a proven value system, integral to society, and empowers people, shaping a bright future." (*www.solaratm.com*)

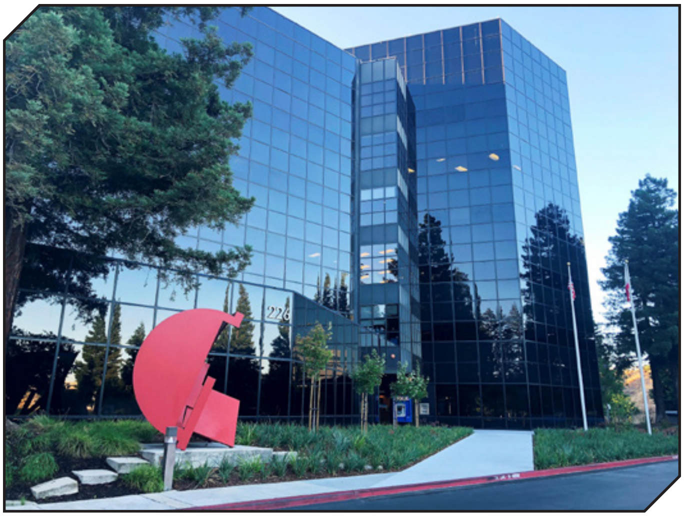
Heidenhain Corporation

OPENS EXPANDED WESTERN U.S. HEADQUARTERS

Heidenhain Corporation announces the opening of its newly completed West Coast headquarters. This includes the expansion of its executive, sales and technical support offices, as well as demo facilities in San Jose, CA.

"We completed this project as part of our commitment to continued growth objectives and support of our machine tool, position encoder and stage systems business partnerships with San Francisco Bay Area and western territory customers," said David Doyle, Heidenhain Corporation President and CEO.

This new development includes the consolidation of Heidenhain's Fremont, CA, technical support operation into Heidenhain's expanded San Jose business center offices.



"Proximity to the innovation centers and high-growth markets is important to our long-term future, including within semiconductor capital equipment, life science, automotive, robotics and general automation segments," said Doyle.

Other recent western territory additions include the opening of Heidenhain offices in the Seattle, Denver and Houston areas. Heidenhain's John Thormodsgard is newly appointed as Western Sales Director.

Heidenhain's increased Bay Area presence is another important and measured step in the long history of growth of the Dr. Johannes Heidenhain GmbH group of companies. In North America, Heidenhain Corporation represents nine brands offering various motion control product technologies: Heidenhain, Acu-Rite, Etel, RSF, Numerik Jena, Leine Linde, AMO, IMT and LTN.

"Most importantly, we value the industry relationships that we continue to develop and we welcome our customers to visit us at any of our U.S. office locations, as well as our headquarters in Traunreut, Germany, as soon as conditions allow," added Doyle. (*www.heidenhain.us*)

Furnaces North America

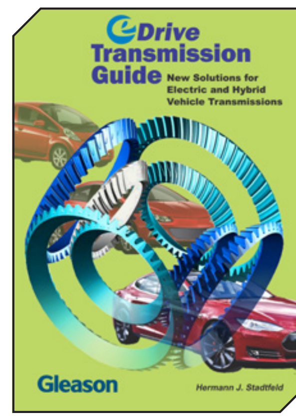
GOES VIRTUAL FOR HEAT TREAT EXPOSITION

Due to COVID-19, FNA 2020 has transitioned into a virtual conference and trade show. This development provides a great opportunity for the heat treat industry to bring the latest technical training, trends, and emerging technology right to their employee's desktop. Registration for attendees will open August 1. Don't miss this opportunity to see the latest trends, technology and equipment right from your computer by your entire team. FNA Virtual will feature 3-live webcasts panel discussions, 35 technical sessions and top suppliers in every facet of heat treating. The event takes place September 30–October 2.

(*www.furnacesnorthamerica.com*)

Gleason

OFFERS STADTFELD'S LATEST BOOK: EDRIVE TRANSMISSION GUIDE



Today Gleason has four major concepts for high reduction transmissions which are ideal for electric vehicles and hybrid cars. Gleason has begun to work with several electric vehicle OEM's on the integration of these new concepts into production vehicles.

This book *eDrive Transmission Guide* was written and published by Dr. Hermann J. Stadtfeld to give an overview of the most popular conventional eDrive solutions and to present the new Gleason developments to the automotive and transmission manufacturing industry. The book also intends to inspire mechanical and electrical engineering students with the new Gleason concepts in order to gain their interest in the many new tasks engineers will encounter in future concepts of electrically propelled automobiles, challenged by a healthy mix of Battery Electric Vehicles and Hybrids which generate their electricity "on the go."

In order to make this book readily available for every interested automotive engineer, the main publication media format is as an e-book. The e-book is available for purchase online. However, it is also possible to read the e-book on the Gleason website. For those with a fondness for having a bound book as reference in their office book shelf, a hard cover version of this book is available as well.

eDrive Transmission Guide covers 11 topics on 220 pages and has 153 figures—which provide a better understanding and easier retention of the covered material.

The content is divided in 6 parts:
- Introduction to Electric Vehicle Transmissions
- Automotive Drive Concepts
- Super Reduction Hypoid eDrives
- Reversed Pericyclic Transmissions
- Double Differentials as Ultra-High Speed Reducer
- Psychoacoustic applied to eDrives

(*www.gleason.com/en/products/training/gleason-library-fundamentals-and-advanced-gear-technology*)

Haas Multigrind

MOVES OFFICE TO NORTH CAROLINA

Haas Multigrind LLC, a provider of CNC grinding centers, celebrated the relocation of their US office from Indiana to Charlotte, North Carolina on August 1st, 2020. The 6,500 square feet facility includes office, classroom and conference space, a machine demonstration area and spare parts warehouse.

"This move represents an exciting development for Haas Multigrind, and it demonstrates our strong commitment to existing and prospective customers and strategic partners in the Americas," said Harry Schorner, general manager of Haas Multigrind LLC. "We are pleased that the new location will enable us to better serve our customers, with better proximity to a major airport and better access to talent to fill key positions within the organization." (*www.multigrind.com/en*)

Schunk

ANNOUNCES NEW VICE PRESIDENT OF TOOLHOLDING AND WORKHOLDING SALES

Schunk is proud to announce the promotion of **Allan Logan** to vice president of sales, toolholding and workholding.

Logan has more than 20 years of territory sales and team management experience in the metalworking industry. He started his career in account management for cutting tools and abrasives before holding various roles as sales engineer, aerospace industry specialist, and regional sales manager.

Logan quickly rose to the challenge of exceeding sales goals and leading focused sales teams in the field of manufacturing and machining solutions. Since joining Schunk in 2018 as the director of sales for Eastern US, Logan has managed a group of regional sales managers across 20 states. His team has been responsible for incremental sales growth in the last two years.

(*www.schunk.com*)

Michigan Metrology

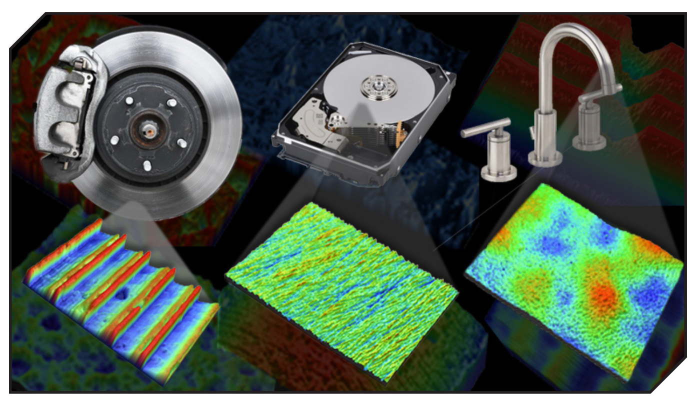
OFFERS ONLINE COURSES IN SURFACE ROUGHNESS, TEXTURE AND TRIBOLOGY

Michigan Metrology, experts in solving problems related to surface texture, wear, finish and friction, are now offering courses in surface texture analysis, friction and wear in online formats.

"These courses are designed for scientists, engineers and technicians working in medical devices, automotive, aerospace, materials, polymers, and other fields," said Don Cohen, Ph.D., who presents the courses. "We have been holding classes in surface metrology and tribology for over fifteen years. Presenting the classes online will make this fundamental material available to a wider audience of people who cannot easily travel to attend the training in person."

The Surface Roughness/Texture and Tribology courses cover measuring roughness, waviness and form, an introduction to surface measurement instruments, an overview of data analysis techniques and tools, fundamentals of lubrication and more.

A 4-hour version of the class is available via the online training site Udemy. This version of the course offers a thorough introduction to the topics above in a self-paced, downloadable format.



Dr. Cohen will also be hosting a 2-day class, live online via Webex, in a professional learning environment. The class offers a deep dive into the course topics, with access to the instructor for real-time questions about how the material applies to particular applications.

As a third option Dr. Cohen presents the course in an online format customized for individual companies, as a cost-effective means to train multiple team members dispersed across the country or world. (*www.michmet.com/classes.htm*)

gear TECHNOLOGY

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Stepping Out

VR Keeps Adults and Kids Focused on Learning During the Pandemic

Matthew Jaster, Senior Editor

What did I do this weekend? I reorganized the garage, picked up some groceries, took the kids to the lake and spent a couple of hours at the International Space Station. The week before I swam with great white sharks off the coast of Australia, visited several museums and art galleries across the globe, jumped out of an airplane, roamed around the ruins of Machu Picchu, and did some dishes—all from the comfort of my living room and kitchen.

Virtual reality won't replace world travel anytime soon, but it does provide a nice change of pace when you've been walking around your house and staring at the walls for three months.

The Addendum Team (with some help from my children) took the Oculus Quest for a test drive recently to see what virtual tours and immersive experiences it offers kids and adults in the time of COVID-19.

Preston Jaster, age 10, explores the International Space Station (ISS) on the Oculus Quest.

Mission: ISS

Roaming around 40 key areas of the International Space Station (ISS), you learn how astronauts eat, sleep, exercise, and pass time in the laboratory. The payoff comes when you head outside, floating around the exterior of the ISS, looking down at Earth, and hoping your cord doesn't snap and you float off into the unknown. Educational, exciting, and terrifying, this virtual experience puts you right in the center of the action without spending hundreds of hard-earned dollars on Space Camp.

Check out the games and apps available for the Oculus Quest at *www.oculus.com.*

Gravity Sketch

Express your brains most fantastic ideas in real-time at any scale from initial concept to model. This includes form sketches, detailed models, expansive scenes, etc. This is pretty much a full 3D vector drawing program in virtual form. I expect thousands of engineers in the coming years to toss out their sketch books and desktop computers and build magnificent machines and components in an environment like this.

Boulevard

Partnering with museums and cultural sites around the world, Boulevard takes art education to the next level. The app allows users to explore the collections and temporary exhibitions at museums and galleries around the world. Unfortunately, it takes game controls back to the early 1980s, but if the *patient* and *forgiving* techie can get through the front door and learn how to walk around inside this world, it's well worth the early frustrations.

Wander

Are you in the mood for studying Roman architecture? Interested in seeing Vietnamese mountain villages? A quick stroll around the Smithsonian campus? Wander lets you put in almost any address in the world and walk around via 360 cameras. The picture quality varies from site to site, but there's something very refreshing about picking a spot on the globe and being transported there in a matter of seconds. Educational opportunities are endless.

Down the Rabbit Hole

What virtual reality experience would be complete without a trip to Wonderland? Down the Rabbit Hole takes place prior to Alice's arrival and sends users on a journey through the secrets and puzzles that made Lewis Carrol so famous in the first place. This is pretty much an escape room intertwined with classic literature and hints at the powerful storytelling tools at the hands of VR game developers in the future.

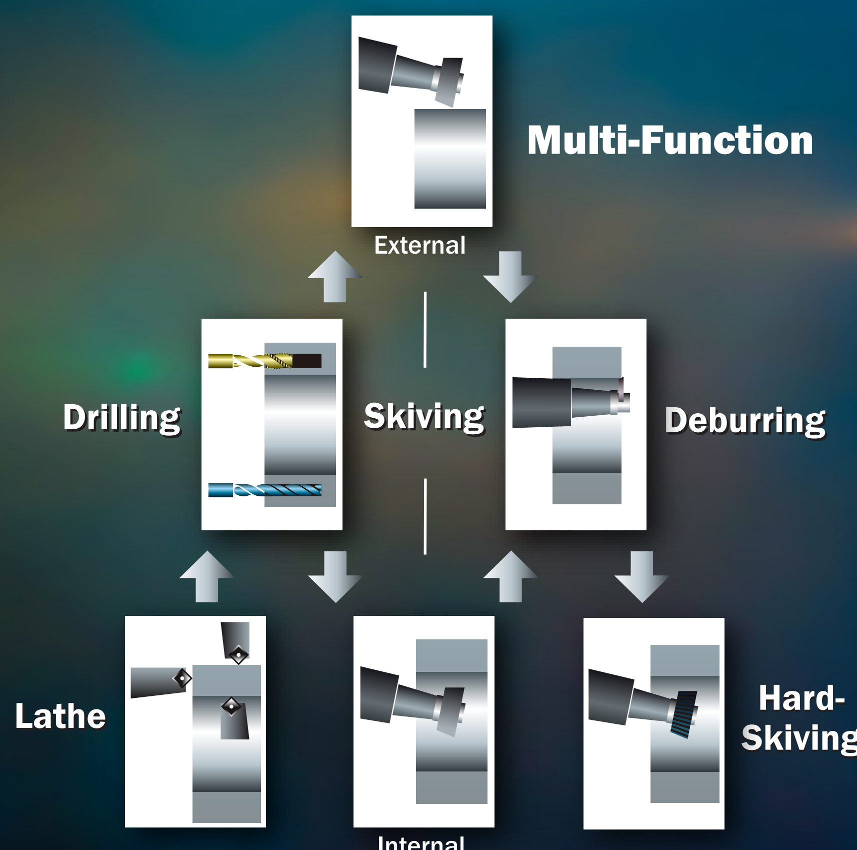
Beat Saber

Last, but certainly not least, we played a round or two of Beat Saber. The Addendum Team finds absolutely no educational or engineering value to Beat Saber. There are no museums or virtual engineering games to be found. No tours, no speeches, no gears—but you get to wield two lightsabers and that right there is worth the price of admission.

Learn more at *www.oculus.com*.

NACHI

GMS200 Skiving Machining Center for Gears



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