gear TECHNOLOGY INDIA

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A primer on Industry 4.0, powered by IoT

Find out what it means for the gear industry

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Anitha Raghunath
Director
Virgo Communications and Exhibitions Pvt.Ltd

Dear Reader,

You've known us, at Virgo Communications, as the organizers of IPTEX/ GRINDEX since 2010. And now, we're extending our connect with the community with yet another new initiative. Welcome to Gear Technology India (GTI), a dedicated media platform for the Indian gear industry, in partnership with the American Gear Manufacturers Association (AGMA).

Let me introduce GTI to you. We are a first-of-its-kind digital media platform for the Indian gear manufacturing industry. That includes a dedicated website, a quarterly e-magazine and knowledge and training programs.

We're on a mission to become the number one medium to connect all the stakeholders, and form a community that can learn from, and grow with, each other. There is immense knowledge, expertise, technological capability and innovation within the Indian gear ecosystem. But there was never a dedicated place for all this to converge, and be showcased to the world. Not anymore – GTI will be that forum. GTI will publish news updates, technical articles, whitepapers, product and company profiles, thought leadership articles, interviews with industry leaders and stalwarts, events and much more. We will showcase the best of the Indian and international gear industry, and offer opportunities for continuous upskilling and education via AGMA's courses and offerings.

In this launch issue, you'll find a broad spectrum of articles, from the role of IoT in Industry 4.0, to trends such as 3D printing in gear manufacturing. There is an article on Herringbone Gears, and why their unique shape and design offers benefits in terms of maintenance time, effort and cost. We have interviews with the top brass of Dontyne Systems, and ESENPRO, who introduce us to their respective companies, their capabilities, and their offerings, among other things. Industry expert KP Soundararajan writes about innovations in Helical Gear Hobbing, and how they can improve productivity. Read a technical paper on Unconventional Gear Profiles in Planetary Gearboxes. There's lots more, once you turn the page.

We invite leaders from the gear manufacturing industry and suppliers to participate in this journey, by sharing your knowledge in the magazine. We also encourage you to advertise with us and subscribe to GTI. Please share your feedback at editor@geartechnologyindia.com.

Happy reading!

Anitha Raghunath

gear TECHNOLOGY INDIA

Gear Technology India is a quarterly magazine published through a partnership between American Gear Manufacturers Association (AGMA) and Virgo Communications & Exhibitions. The magazine will be the industry's go-to platform for world-class news, information and technical articles from the world of gears.

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INDUSTRY 4.0, POWERED BY IOT, IS IMPERATIVE FOR SUCCESS

IoT is at the center of the transformation in manufacturing, enabling the move towards Industry 4.0

By: Sendhil Vel

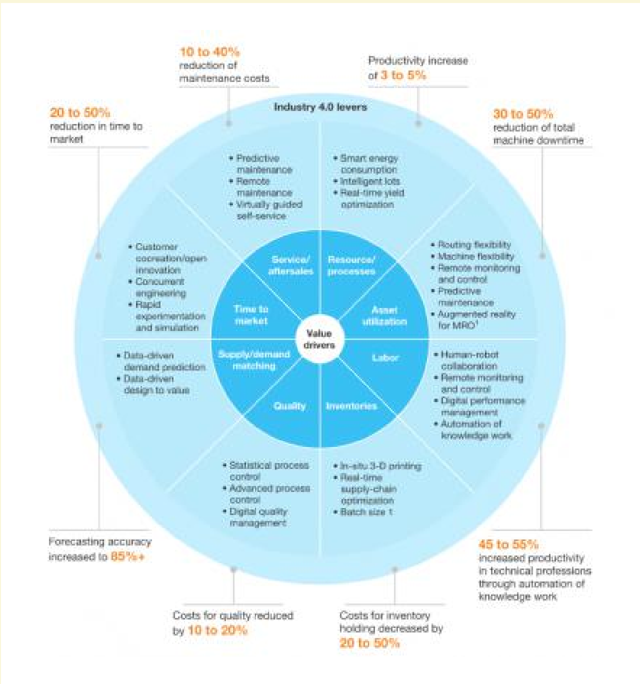
Industry 4.0 is bringing a big shift in terms of technology, industry practices, operational efficiency and business models. It is also changing the way companies manufacture, improve, and distribute their products. Internet of Things (IoT) is at the center of this transformation, along with cloud computing, analytics, Artificial Intelligence (AI) and video analytics.

Cloud computing costs have reduced significantly. In addition, shortage of labor is pushing manufacturers to digitize rapidly to keep operations efficiency. Industry 4.0 collects data from machines at high frequency – typically every second – from sensors, PLCs, machine controllers and existing SCADA. This large data, typically referred to as Big Data, is analyzed, and insights for improvements in operations are given in real time.

The existing Enterprise Resource Planning (ERP) system will remain and will be the backbone for all accounting and compliance-related issues. IoT will be a digital layer over ERP, which will bring speed and accuracy to Manufacturing Execution System (MES), which has so far been manual.

Industry 4.0 Levers

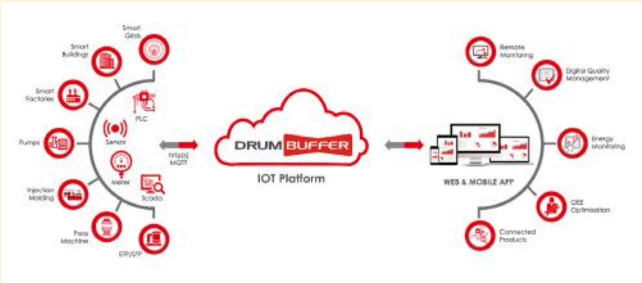
The figure on the right shows areas where IoT can be applied and the benefits that can be achieved from existing operational efficiency levels. Typically, these IoT projects pay off in less than 18 months. Factories usually start with one area and experiment in a small way before moving to full-scale adoption. Factories which have applied IoT and analytics in multiple areas are referred to as Smart Factories.



McKinsey has captured the areas impacted by Industry 4.0, referred to as Industry 4.0 Compass. Image Courtesy: McKinsey

How does it work ?

The below infographic shows how a typical IoT project is applied in various use cases in the factory. IoT is industry agnostic and can be applied to any industry – buildings, factories, ETP/STP plants and hospitals. The modus operandi is to acquire data from the devices, equipment and legacy systems, and store it in an IoT platform. This data is then analyzed to provide solutions to various use cases. Use cases revolve around existing pain points for the industry or



Use cases of IoT. Image Courtesy: DrumBuffer Analytics

the customer, which can provide a suitable Return On Investment (ROI) when investment is made in an IoT project.

The key challenges that the IoT platform solves for the customers is the ability to acquire data from any machine, any protocol, and securely transfer and store data in cloud or a local server. Equipment comes with multiple protocols. Some typical protocols in equipment include MODBUS, MT Connect, Profibus, MELSEC and OPC UA.

The platform should also have a rule-driven mechanism to analyze the data coming in – which can be discrete or streaming – and analyze the same on the go. Alerts to users based on application of rules is an important part of IoT platform.

Popular use cases

Overall Equipment Efficiency (OEE)
OEE is a popular use case, which is used to measure the efficiency of a machine, an assembly line, or a factory. The concept is not new to industry. IOT has made the job of measuring OEE easy and fast by acquiring data from the machine in real time.

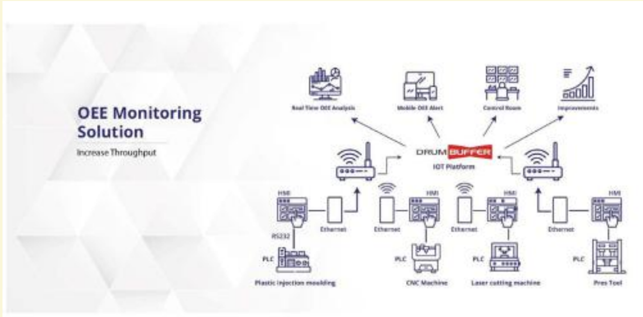
The OEE Solution provides a control room for the Plant Manager to monitor and manage all shopfloor activities in real time. It provides real-time OEE analysis and loss matrix so that engineers can focus on improvements in real time. Supervisors get alerts on common rule-based tasks to ensure completion in time.

Predictive maintenance
Predictive maintenance has its origin in condition monitoring. IoT has made predictive maintenance and condition monitoring in real time, affordable. Typically, vibration analysis and motor current signature analysis are done in this use case.

With IoT, high frequency data is used along with AI/ML models to predict machine failure. Models can predict the method of failure and the part that fails. This will be useful to extend the life of equipment and manage inventory.

Energy management
Energy consumption details from meters attached to equipment is collected at frequent intervals. This data is used to analyse trends and patterns in consumption. Anomaly in consumption is identified through data analysis, and an alert is sent to users. Typically, customers get 5% savings in energy bills over an 18-month period.

Bureau of Energy Efficiency (BEE) has published standards for Energy Performance Index for various Industry. This standard is used to benchmark with actual performance, and improvement projects are implemented.



Infographic of a typical OEE implementation.
Image Courtesy: DrumBuffer Analytics

Digital Quality
Quality assurance in shopfloor comprises lot of manual work – measuring parts through equipment and gauges, plotting control charts, and calculating Process Capability Index. Digital quality digitizes these activities and makes it easy, so that engineers spend time on interpreting data rather than plotting and calculating metrics. (A separate article on this will be carried in a later publication)

Conclusion

Industry 4.0 driven by IoT is an imperative for the industry to improve efficiency and capability to meet customer requirements. Companies implementing Industry 4.0 will be competitive and will come out with new business models, creating new revenue streams. With increasing cost pressure and compliance requirements, companies will need to adopt Industry 4.0 to succeed.

The author, Sendhil Vel, is Founder, DrumBuffer Analytics, an Industry 4.0 Solutions provider

The benefits of 3D printing for the gear industry

Why Additive Manufacturing is set to revolutionize the gear industry

By: Yathiraj Kasal

Exhaust Casing is part of C20 Engine. ISRO has conducted hot testing on this part

Additive Manufacturing, also known as 3D Printing, is a process that creates a three-dimensional component by building up successive layers of material. The technology has been around since the 1980s, but is being adopted by the industry rapidly in recent years, due to advances in materials, software, and hardware. This technology offers several advantages such as cost-effectiveness, speed, performance improvement and design freedom. Design freedom enabled by Additive Manufacturing has resulted in innovations in almost every industry application. The gear manufacturing industry can also benefit greatly, as 3D printing offers many benefits for the production, prototyping and repair of gears and related components.

Applications in the gear industry

Additive Manufacturing has delivered multiple benefits to various industries. Space and Aviation, for example, has leveraged design freedom enabled by Additive Manufacturing.

Prototyping: Additive Manufacturing is an excellent option for creating prototypes of gears and related components. The process allows designers / manufacturers to quickly and inexpensively produce a working model that can be tested and evaluated. This can save time and money compared to traditional manufacturing methods and also help to identify and resolve design issues before mass production begins. The reduction in cycle time will allow designers to do more iterations, and optimize the performance further. The reduction in cycle time would also allow companies to quickly introduce their products to market.

Customization: Additive Manufacturing offers the ability to produce gears and components that are customized to specific applications. For example, a gear with a unique tooth profile or an unusual shape can be designed and printed quickly and easily. This can be a big enabler in Electric Vehicles, Drones, Automation, and other such industries.

Short-run production: Additive Manufacturing is useful in short-run production of gears and components, allowing manufacturers to produce small quantities of parts as needed. This reduces the need for large-scale investment in tooling and machinery, and enables companies to quickly respond to market demands. This can be especially useful for manufacturers that need to produce specialized parts for niche applications.

Tooling and Fixtures: Additive Manufacturing can be used to produce custom tooling and fixtures such as jigs and mandrels for gear production. This can reduce production time and improve accuracy compared to traditional manufacturing methods.

Replacement Parts: In case of breakdowns or wear and tear of gears, Additive Manufacturing enables the production of replacement parts on demand. This can save time, and reduce downtime for companies, improving their overall productivity.

Materials used in 3D printing for gear manufacturing

A variety of materials can be used for 3D printing gears and related components for various applications. Following are the broad material groups being used in Additive Manufacturing:

Polymers: Various polymer materials are a common choice for 3D printing gears and related components, as they are lightweight, low cost, and easy to work with.

Metals: Titanium alloys, nickel-based super alloys and aluminum alloys are widely used in Additive Manufacturing for space, aviation and medical industries. There is a good range of tool steel and stainless steels, which are routinely being used in Additive Manufacturing. More focus is needed in bringing gear steels to Additive Manufacturing. Metal powders for some gear steels such as AISI 8620, 16MnCr5 and 20MnCr5 are available today.

Composites: Composites are a combination of two or more materials and can be used to create gears and components with specific properties. For example, a carbon-fiber reinforced polymer can be used to produce a lightweight, high-strength gear.

The future of 3D Printing in gear manufacturing

There is an increasing interest in using Additive Manufacturing for various gear applications. It has a proven track record in other industrial applications, and it only makes sense to induct Additive Manufacturing as another viable option in gear applications. Here are a few areas where one can expect to see more action in the near future:

Innovation: In gear applications, Additive Manufacturing can be disruptive by enabling design and manufacturing of features such as internal channels, which can be used for either cooling or lubrication. The lightweight gear system could be a great value-add to applications such as drones, to increase the range of the drone system. Various other innovations to improve performance of gear systems could be realized, as Additive Manufacturing promises to deliver the manufacturing ability of many complex features. Further, through the innovative use of materials or a combination of materials, there could be many more possible innovations.

Improved materials: The development of new and advanced materials for Additive Manufacturing will further enhance the capabilities of this technology. This will result in gears with

Feed Cluster is part of GSAT-19 Satellite launched on 5th June 2017. This was the first 3d Printed part from India to reach space. This is a part of Communication Satellite

improved strength, durability, and wear resistance, making them suitable for a wider range of applications.

Integration with traditional manufacturing methods: In the future, Additive Manufacturing is expected to be integrated with traditional manufacturing methods such as casting, forging, and machining. This will enable the production of gears with improved accuracy, strength, and surface finish, further enhancing their performance.

Increased adoption: With advancements in Additive Manufacturing technology, the adoption of this technology in the gear manufacturing industry is expected to increase. This will enable companies to improve their competitiveness and offer more advanced products to their customers.

In conclusion, Additive Manufacturing has the potential to revolutionize the gear manufacturing industry. With its numerous advantages, it has the potential to change the way gears are designed, produced, and used. As the technology continues to advance, it will offer new and exciting opportunities for companies in the gear manufacturing industry to improve their competitiveness and offer innovative products to their customers.

The author is Yathiraj Kasal General Manager, Wipro 3D, Bangalore

"With advancements in Additive Manufacturing, the adoption of this technology in the gear manufacturing industry is expected to increase

HIGHLIGHTS

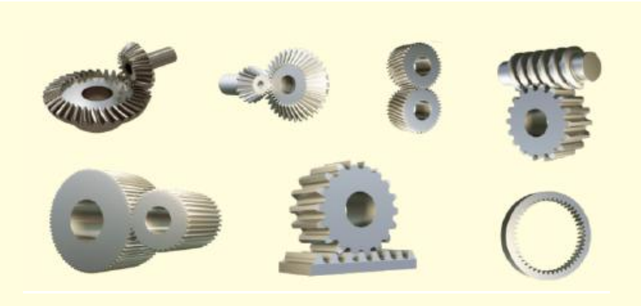
Additive Manufacturing offers the ability to produce gears and components that are customized to specific applications.

For example, a gear with a unique tooth profile or an unusual shape can be designed and printed quickly and easily. This can be a big enabler in Electric Vehicles, Drones, Automation, and other such industries.

THE ADVANTAGES OF TOOL COATING

A machinability study at Ratna Gears, Pune, demonstrates that coating cutting tools is directly linked to an increase in productivity

By: Dr Atul Kulkarni, Niranjan Upadhye



The rising demand for gears across a variety of sectors is anticipated to fuel the market for gear manufacturing in future years. With numerous companies offering a variety of products to meet the various needs of end consumers, the market is quite competitive. Based on the type of gear, the market may be divided, and Asia-Pacific is expected to dominate. The use of industrial automation is one of the main drivers fueling growth in the gear manufacturing market.

On the other hand, the gear cutting tool market is also expected to grow steadily in the coming years due to the increasing demand for gears in various applications, such as automobiles, aerospace, and industrial machinery. The market is highly competitive, with several players offering a range of products to cater to the diverse needs of end-users.

In 2021, the market for gear-cutting tools was estimated to be worth USD 700 million, and it was expected to grow with a CAGR of 1.9% in the coming years, to reach 785.45 million USD in 2027. However, between 2021 and 2026, the market is projected to develop at a CAGR of 5.7%, with the gear manufacturing market share estimated to rise by USD 74 billion, as reported by market research agencies.

Spur gears, helical gears, bevel gears, worm gears, and other types of gears can be used to segment the market Spur gears command the largest market share, followed by helical gears. Gear hobbing tools, gear shaping tools, gear grinding tools, gear shaving tools, and gear honing tools are the various types of gear-cutting tools available in the market. Gear hobbing tools have the largest market share, followed by gear grinding tools.

Different gears and gear cutting tools

Region-wise, Asia-Pacific is expected to dominate the gear cutting tool market due to the increasing demand for gears in various industries. Some of the major players operating in the gear cutting tool market and gear manufacturing market include Sandvik, Kennamental, Kyocers, Gleason Corporation, Kapp Werkzeugmaschinen GmbH, Klingelnberg AG, Liebherr-Verzahntechnik GmbH, Mitsubishi Heavy Industries, Ltd., and Samputensili S.p.A., BMT International S.A., Gleason Corporation, Klingelnberg AG, Koyo Machinery USA Inc., Mitsubishi Heavy Industries, Ltd., and ZF Friedrichshafen AG.

The primary function of the gear system is to transmit the motion and require torque with greater flexibility to adapt to different needs. The gear optimization study not only considers gear ratio, but also considers strength, weight, cost, noise, energy loss, etc. These factors influence the selection of workpiece material, manufacturing process, and cutting tool. Gear cutting is one of the processes of manufacturing in which the desired shape is imparted to the workpiece by removing the surplus material. Conventionally, this surplus material from the workpiece is removed in the form of chips by using an appropriate cutting tool.

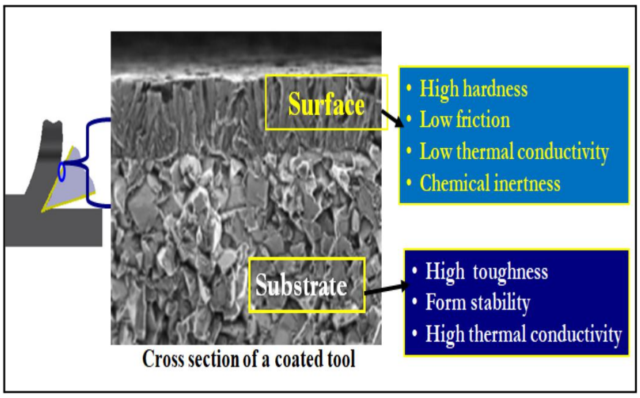
For a given work material, success in gear cutting depends on the proper selection of cutting tool material, machine setting, and its geometry. The term machinability is often used to describe the ease or difficulty with which a material can be machined. A wide range of cutting tool materials and work materials are available with different combinations of properties, performance capabilities, and costs. The machined surface quality has a significant impact on gear-matching accuracy, wear resistance, fatigue resistance, corrosion resistance, and transmission performance.

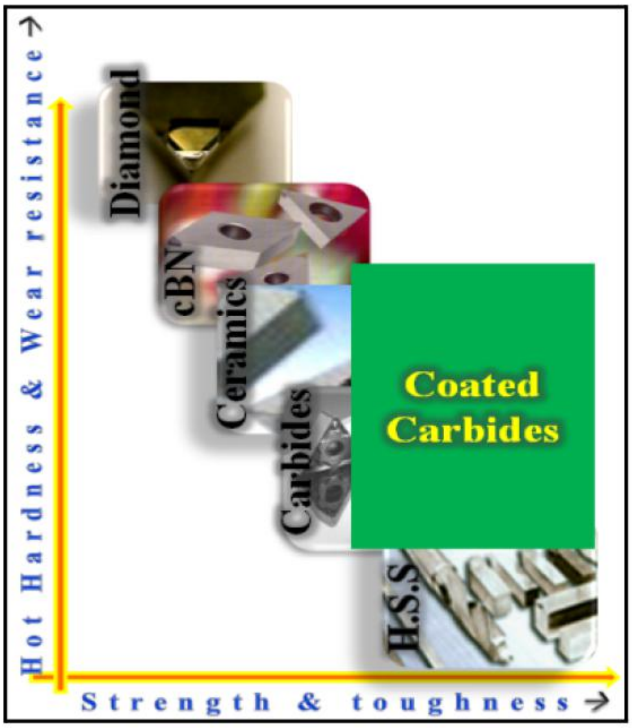
The manufacturing accuracy of gears has a direct impact on the machine's transmission efficiency, noise, motion accuracy, and service life. Several researchers have worked on improving the surface quality and productivity of gear manufacturing processes. However, limited research is available on the selection of cutting tool material and appropriate tool coating for improvement of gear cutting performance. Cutting tool material and tool coating plays a very important factor in improving the productivity of gear manufacturing.

The creation of novel tool materials has been hastened by the pressures of economic competitiveness and technological evolution. A variety of various materials have been tested for this purpose. The tool materials that have endured and are currently commercially available are those that have proven to be the best at meeting the demands placed on them in terms of tool life, rate of metal removal, surface finish produced, ability to give satisfactory performance in a variety of applications, and cost of tools made from them. These tool materials should possess some important properties such as hot hardness, toughness, wear resistance, and chemical stability.

Different tool materials available in the market include high-speed steel (HSS), cemented carbide, cermet, ceramics, cubic boron nitride, and diamond. Despite these materials, HSS and cemented carbide tools/cutters are the most demanding cutting tools used in gear cutting. Both materials have limitations on thermal stability during cutting, which eventually affects the production rate.

It was observed that during cutting, the surface and bulk requirements of a cutting tool and work materials are different and conflicting. Generally, the surface should have low thermal conductivity. This is because the temperature generated during cutting should be carried away by the chips and not allowed to penetrate the cutting tool. On the other hand, the bulk should have high thermal conductivity to carry away the heat that penetrated the cutting tool in severe cutting conditions. Coated cutting tools contribute highly to the conservation of coating materials, because coating generally requires a very thin film to be deposited on the cutting tool substrate, which is usually a few microns thick.





The need for coating and different cutting tools

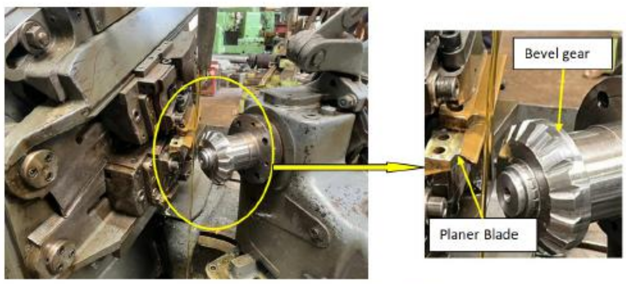
The specific purposes of coating are to reduce cutting forces, reduce cutting edge temperature, increase abrasion resistance and act as a diffusion barrier. The figure shows the different requirements for cutting tools. It has been proven by many researchers that HSS and carbide cutting tools with different coating materials has increased productivity and tool life in gear cutting. The different cutting materials with different types are deposited on the cutting tool, as shown in the table below. The popular coating techniques are Chemical vapor deposition (CVD) and Physical Vapour deposition (PVD).

Sr No	Type of Layer	Coating	Coating Technique
1	Single Layer	TiN, TiC, CrN, TiCN, Al_2O_3, HfC, HfN	CVD and PVD
2	Double Layer	TiN/TiAlN, TiN/ Al_2O_3	CVD and PVD
3	Gradient Layer	CrN-based, TiN Based	CVD and PVD
4	Multilayer	TiC/TiCN/TiN, TiC/TiN/Al_2O_3, TiC/TiCN/TiN/Al_2O_3	CVD and PVD

Case study

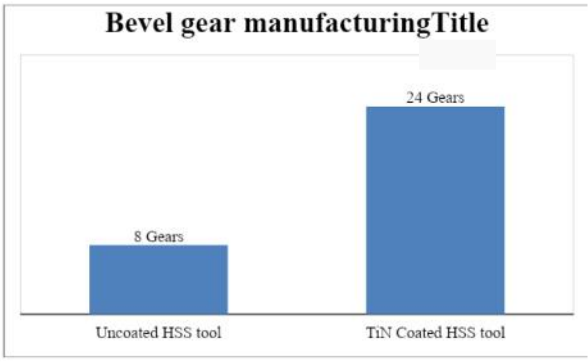
Below are the details of a machinability study, which was done at Ratna Gears Pvt Ltd. Ratna gears (https://www.ratnagears.com) is a Maharashtra, India-based ISO 9001:2000 certified company dealing in manufacturing and supplying a comprehensive range of gears such as spiral bevel gears, spur gears, helical gears, worm wheels, and washing machine gearboxes.

The present study was conducted during the process of Bevel gear manufacturing, to measure how tool coating contributes to an improvement in productivity. The Gleason Straight Bevel Gear Planer was used as a machine tool, and HSS M2 Gleason planer tool blade was used as a cutting tool. The following figure shows the machine tool with the product and another figure shows the coated and uncoated HSS tool which was used for bevel cutting.



Bevel Gear manufacturing machine tool

TiN Coated HSS Tool   Uncoated HSS Tool



Bevel Gear manufacturing machine tool

It was observed that the uncoated tool produced around 8 to 9 bevel gears per setting. The tin coated tool (the coating was done at the Pune Carbide company at Pune, which has Cemecon coating systems), on the other hand, produced 24 to 26 bevel gears per setting with the same cutting parameters. This is a production increase of almost three times.

This is mainly due to the deposition of wear resistant tin coating. This coating acts as a thermal and chemical barrier. In addition, the coating also acts as a lubricant due to the low coefficient of friction. It has better thermal stability compared to the uncoated tool, which results in an increase in the life of the tool. It further increases productivity.

Further study is needed on optimization on the parameters, but the study proves that tool coating increases productivity.

In 2021, the market for gear-cutting tools was estimated to be worth USD 700 million, and it was expected to grow with a CAGR of 1.9% in the coming years, to reach 785.45 million USD in 2027. However, between 2021 and 2026, the market is projected to develop at a CAGR of 5.7%, with the gear manufacturing market share estimated to rise by USD 74 billion, as reported by market research agencies

The results of the study are amazing. It proves the importance of tool coating. This finding will help us in the future. We will implement it across all types of gear cutting tools.

–Nitesh Mahajan, Director, Ratna Gears

The specific purpose of coating is to reduce cutting forces and cutting edge temperature, and increase abrasion resistance and act as a diffusion barrier. It has been proven that HSS and carbide cutting tools with different coating materials showed increased productivity and tool life in gear cutting

The author, Niranjan Arun Upadhye, is an accomplished leader in supply chain management, operations & business development, and has over 30 years of experience across industries

The author, Dr Atul Kulkarni, is working as a Professor and Dean of Industry Relations in Vishwakarma Institute of Information Technology since 2007

WHAT ARE SOME KEY GEAR MANUFACTURING PROCESSES?

A look at the three most critical activities in the production of high-quality gears and gear boxes

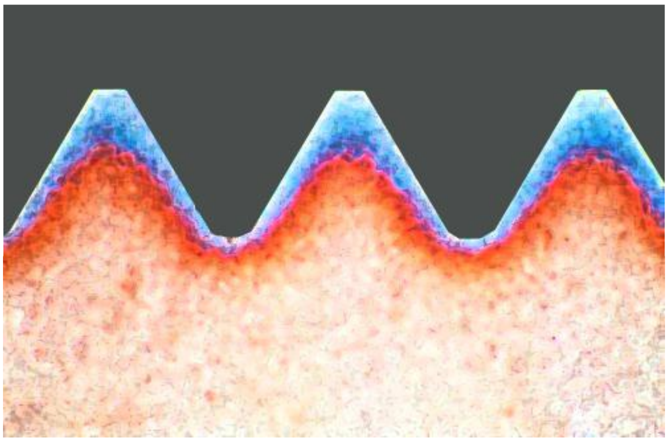
By Chinnappan Selvaraj

Steel Melting

Think gears, and you probably think cars. But gears are so much more than that. Used across a plethora of industries – from automotive to aerospace and even sugar and steel manufacturing – gears are one of the oldest, and most important mechanical components used in manufacturing. The manufacturing of gears themselves, then, is a complex and intricate process, with precision required each step of the way. Let us dive into the three key stages that make up the gear manufacturing process.

Raw Materials Manufacturing

It all begins at the design stage. Based on the safety factor required for a particular application, the correct raw materials are identified. For instance, gears and pinions are usually made out of case-hardened alloy steels. It is ideal if this alloy steel is produced using the Vacuum Degassing method.



An illustration of Case Depth Measurement

Accuracy Standard												
AGMA (USA)		16	15	14~13	12	10	10	8				
ISO (International)	1	2	3	4	5	6	7	8	9	10	11	12
DIN (German)	1	2	3	4	5	6	7	8	9	10	11	12
GOST (USSR)			3	4	5	6	7	8	9	10	11	12

During the steel smelting process, unwanted gases often get dissolved into the liquid, which could produce any number of imperfections and defects. A common method used to remove these undesired gases is Vacuum Degassing. The process is done after the molten steel has left the furnace and before being poured into ingots or introduced into a continuous caster.

During the steel-making process (while the molten steel is still in the ladle, and before it is poured), it is degassed in order to:

a) reduce/eliminate dissolved gases, especially hydrogen and nitrogen;

b) reduce dissolved carbon (to improve ductility); and

c) promote preferential oxidation of dissolved carbon (over chromium) when refining stainless steel grades.

This method enables the production of alloy steels with minimal oxygen, hydrogen and nitrogen contamination. Doing so helps avoid embrittlement of the steel. Next, the chemical and mechanical properties of the alloy steel are verified via Ultrosonic Testing. This is carried out to ensure crack-free material.

Heat treatment

Heat Treatment is a critical stage of the gear manufacturing process.

Depending on the application, designers choose Gas Carburising and Hardening, Nitriding, Induction Hardening process. During these processes, it is important to check the carbon potential on the alloy steels. Based on the gear modules, case depth must be maintained.

To ensure correct case depth, a test piece should be loaded along with the components. After carburising, this case depth should be verified. Finally, during the heat treatment process, the case depth, hardness and microstructure has to be checked. This is necessary to ensure the production of a good-quality gear.

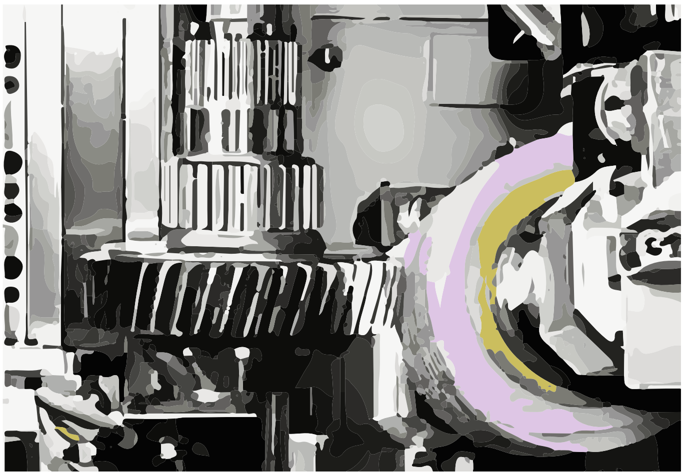
Gear Profile Grinding

This is the third critical process in the performance of a gear box. Profile grinding helps to get a better contact pattern between the pinion and mating gear, which will ensure smooth rotation and less noise during operations.

During profile grinding, the required gear profile accuracy can be ensured by dressing of grinding wheels properly. The Face Runout of the gears (the inaccuracy in radial location of the gear teeth with reference to the pitch circle, according to ScienceDirect.com) must also be controlled before starting the profile grinding.

Profile graphs must be made check the level of accuracy. Generally, the standard used is AGMA10. The chart below demonstrates some of the other country-wide accuracy standards used in the industry.

The above three major activities are critical to the production of high-quality gears and gear boxes. Paying attention to these processes will contribute to reducing gear box noise, vibration and temperature. This in turn, will have a huge impact on improving gear box life, and ensure good performance.



An illustration of Gear Profile Grinding

The author, C Selvaraj, has four decades of experience in the field of gears and gearbox manufacturing, as well as servicing of gearboxes

"India is a large market and our software relating to gear manufacture is especially useful"

Dr Mike Fish
Director
DONTYNE SYSTEMS / DONTYNE GEARS

Please tell us a little about your company. How do your offerings support the gear industry?

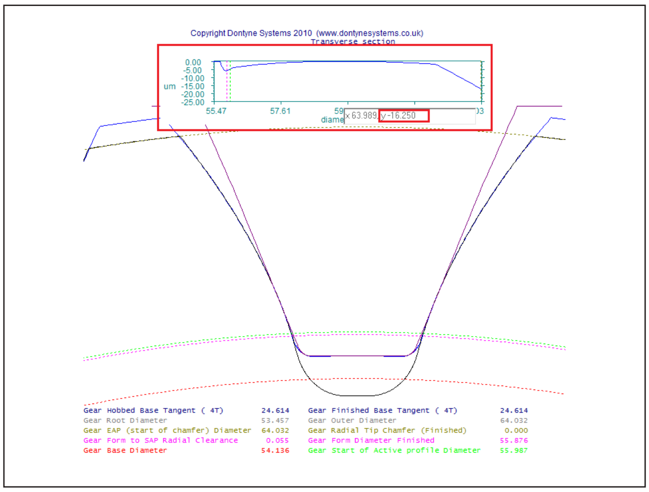
Dontyne Systems has produced software to design and manufacture gear systems since 2006. The main software package is the Gear Production Suite (GPS), which is a collection of programs of differing functionality and levels to flex to a given requirement.

In 2013 we formed Dontyne Gears to carry out design work, prototyping, and testing programs for our clients as a service. With the resources we have acquired we have been able to undertake various R&D projects of our own. The benefits of these projects are starting to be felt by our clients. We have over 200 customers worldwide, with the UK, Japan, and USA our main markets until now, but India is now on our agenda. We have been involved in R&D projects for many years that have directly helped to improve industry productivity and continue to do so with collaborations with Design Unit (Newcastle, UK), AMRC (Sheffield, UK) and AFRC (Glasgow, UK). There are references to the work, which has been incorporated into our software and services of course, on our website. Several more of our solutions are not yet in the market but will help to improve performance, lower carbon dioxide footprint, and improve production efficiency.

Dontyne designs and builds back-to-back test rigs for durability testing to validate changes in material, lubrication, or non involute profile

What are the latest advances in your field? How have you incorporated those into manufacturing?

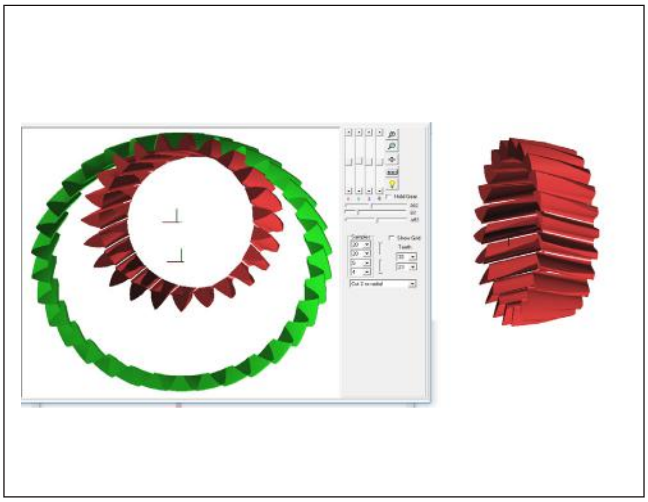
The latest advances are for close integration of design data with manufacturing equipment and for live reporting and correcting of error sources. This is at the heart of our GPS software. We are making interfaces of our functionality to Gearbox Models such as from Romax Technologies to simulate manufacture for tool design the definition of appropriate tolerances before the design is approved in order to avoid costly delays and waste in production. We are also integrating our software with hardware to generate digital twins such as G-code for multi-axis platforms and nominal files for inspection equipment from OSK and Renishaw. This allows integrated production at a cost-effective solution, rather than dedicated equipment from a single source.



Simulations of Hobbing, Grinding, Shaping, and Shaving including micro-geometry help develop and confirm accuracy of tooling and machining process before production

What are your impressions of the overall India market? What are the unique challenges and opportunities here?

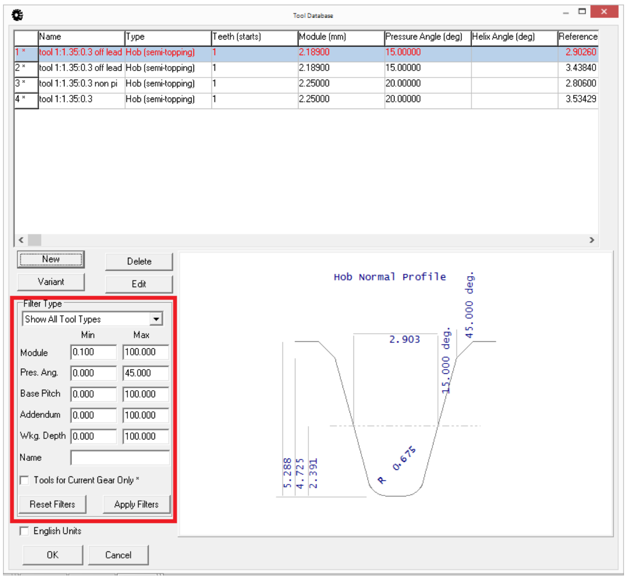
India is a large market and has good links to the UK. We anticipate new trade deals after Brexit, that will facilitate further growth in the UK and for us. We are working with Himshiv Machines, Delhi, to promote and support our products and services in India. This gives us access to good local knowledge so that we can adapt quicker than if we were trying on our own or through UK agencies. Our collective challenge is to convince the Indian market this is not a replacement for the already well-established gearbox design solutions, but is designed to work with them to facilitate tool design and process efficiency. However, the system becomes more powerful, the more our solution is used. Having been in business for 17 years now it is clear that we offer something distinct, or we would not still be in business.



Simulation of skiving process including tool design to determine accurate tooth form and machine settings for accurate gear generation on dedicated machines or multi-axis platforms.

What applications do you foresee for your products? Are there any specific machine types attracting the attention of the Indian buyer right now?

Our software is used across a range of applications with the majority of our customers in automotive and aerospace, but our manufacturing simulations for hobbing, grinding, shaving, shaping, honing and skiving will be of special interest to the Indian market also being heavily involved in manufacture.
Our software can be used to quickly layout a gearbox, check deflection, and analyze appropriate micro geometry, then define tooling for a given gear design and assess effects of machining tolerances on design performance. This can be agreed with the client in advance of manufacture. Such services can be offered to clients as an additional revenue stream and may be greatly appreciated. The software has a database to utilize existing tools, which is ideal for smaller operations. Our GPS CAM solution will be of interest to clients using 5-Axis for cylindrical or bevel in small or medium batch sizes.



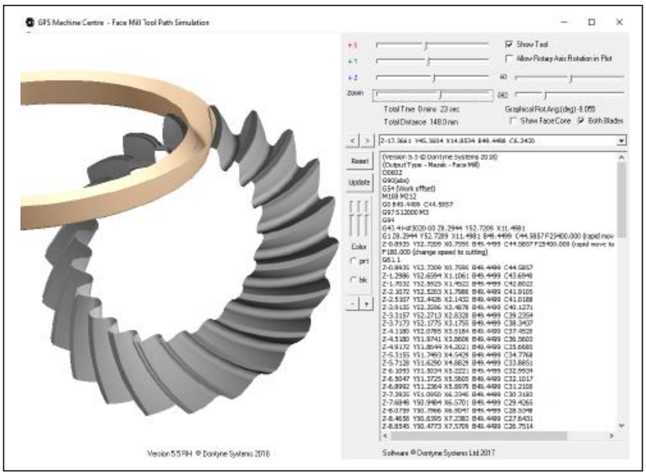
Tool database with filter system for searching thousands of existing tools

How is Dontyne addressing issues in supply-chain disruption and labor shortages caused by the Covid-19 pandemic?

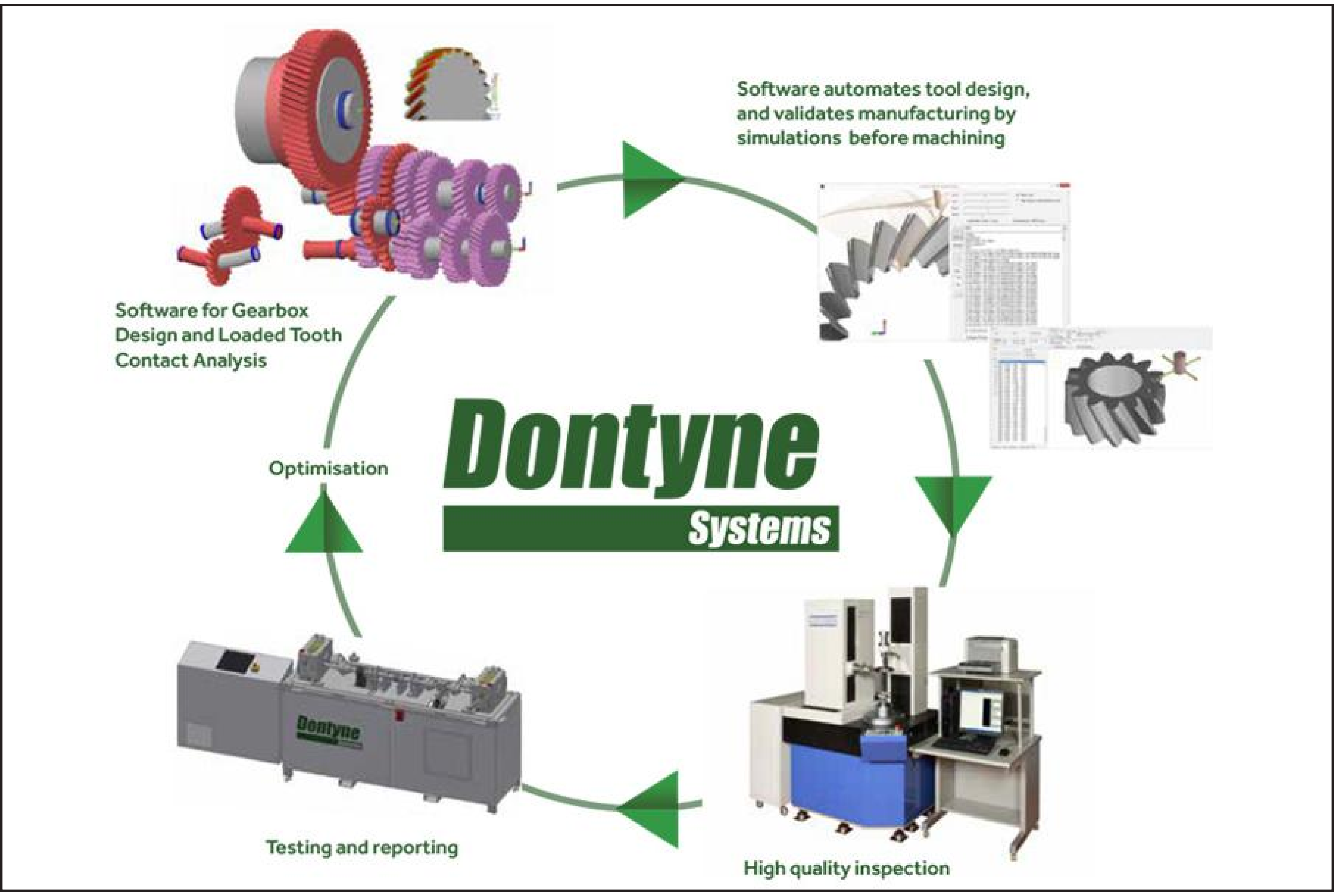
In the field of software development, we have found that there has been little disruption for us directly, but it has prevented us from getting to exhibitions for 2 years. We have lost more working days due to sickness of course than usual but this has passed now and we are back attending IMTEX and IPTEX to get to know our market requirements in meetings on site again. Exhibitions deliver our strongest business connections in customers and collaborations.

How will the launch of Gear Technology India help the industry?

We are a very small company with a wide range of clients from small design offices to Tier 1 multi nationals but we have, until now, not been very proficient at promoting ourselves as an alternative to gear software or services on the market. Promotion through Gear Technology will help greatly increase awareness of our offering.



Simulation of End Mill and Face Mill process with G-Code generation



Dontyne software integrates with machine tools, inspection equipment, and testing equipment to complete a powerful development package

INNOVATION IN HELICAL GEAR HOBBING

Innovations are taking place in gear cutting processes, to improve productivity. We explore one such method

By: KP Soundararajan

This article focuses on the theoretical analysis of the radial-axial hobbing process, since there have not been many regular practices of this process. The industrial method is more towards axial hobbing, where the travel of the axial slide of the hobbing machine increases, and the target depth of the cut is implemented. On account of shortening the machining time, the axial process can take the chosen feed only in calculation, and the rest of the factors are part and hob related. Much of the hobbing analyses are based on these. Yet, there are workpieces where the part style and cluster arrangement may pose a challenge to direct axial hobbing and call for the radial axial method. This method, though known for several years, has no adequate research or well-drafted parametric relationships towards the chip formation and characteristics. So the effect on the tool wear behavior is relatively not well-documented.

For the application of radial infeed, the recommendation can be seen in literature. The shop floor practice is generally applied based on the machining circumstances, and there is no tool or methodology for efficiently using the radial / radial axial process. The ratio of radial feed to the radial path is equal to the ratio of corresponding axial infeed. This enables us to realize the process with constant machining time. Errors could creep in while applying this, due to reasons based on available mechanisms in the machine while chipping characteristics remain underutilized towards the hob wear.

Objective

The penetration calculation method based on the geometry of the gear/ process approach allows an automated determination of chip size and its geometry, taking into consideration the infeed angle. The influence of the infeed angle on cutting conditions is analyzed by a special program SpartAPRO theoretically, for different process designs, and calculates the cutting load on the hob for consideration.

Determination of position of axial slide for profiling

The following are the various process and geometric parameters which come into the determination of initial position of the hob and its axial slide.

The parameters and symbols used are as follows:

Hob diameter - d_{ao}

Enter distance - a

Hob axis position or center of hob - TCP

Radial displacement / offset position X_R

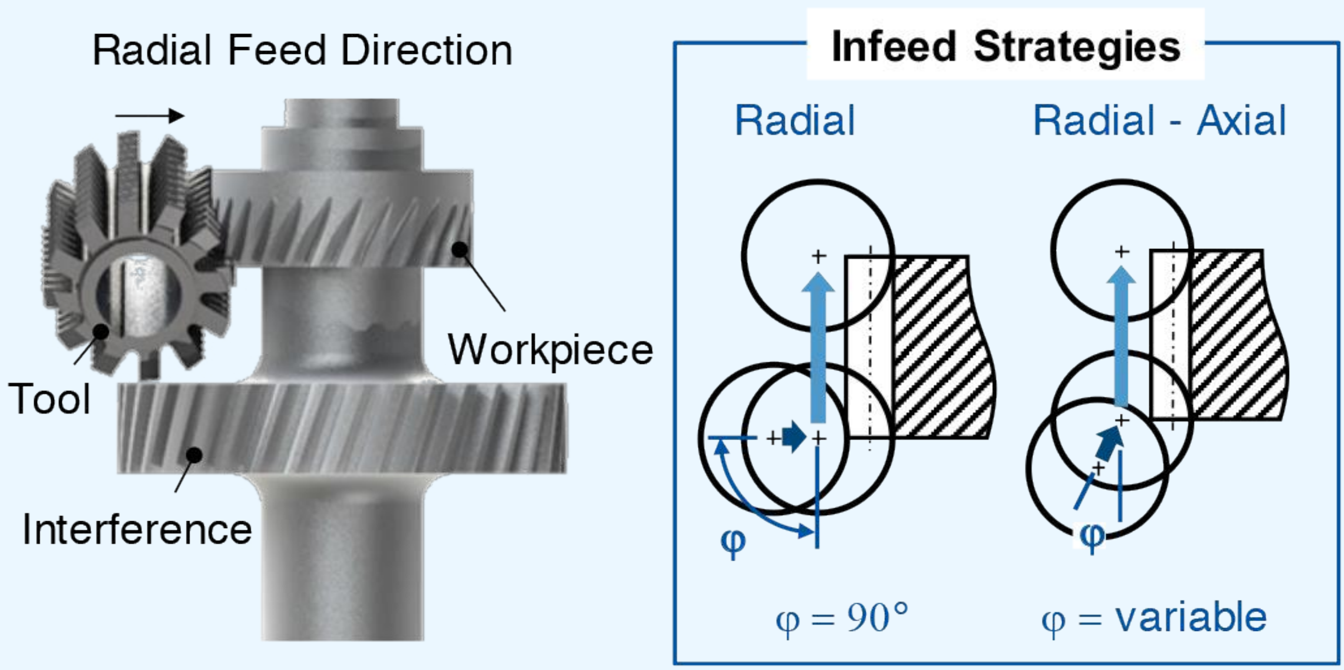


Fig.1: Infeed strategies for collision avoidance

Initial position of hob center corresponding to maximum level of highest point on penetration curve - Z&h

Approach path - E_2

Infeed angle - (ϕ)

Hob head swivel angle - (η)

Profile forming length - l_{po}

Total/ whole depth of the tooth - T

Workpiece / Gear diameter - d_{a2}

Hob lead angle - γ_o

Determination of infeed path for variable infeed angles

The starting position is the position at which the penetration curve coincides with the gear lower phase in the fixture. In addition to the end position, the axial and radial start locations should be determined for the given setup considering the hob diameter, target depth or infeed path to coincide the end of the radial path with the beginning of axial feed to complete the face width.

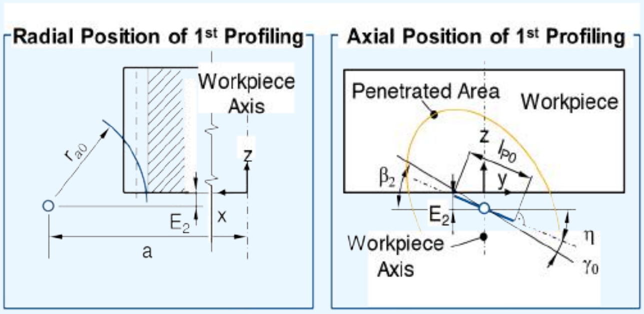


Fig 3: Determination of the position of first profiling

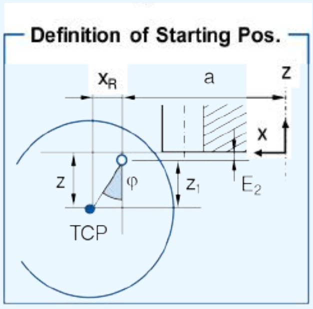


Fig 4: Determination of the starting position

Involved mathematical equations

$$l_{p0} \leq 2 \cdot \frac{h_{a0}+|x|\cdot m_n}{tan(\alpha)} \cdot cos(\gamma_0) \quad (1)$$

$$E_2 = \frac{1}{2} \cdot l_{P0} \cdot sin\,(\eta) \quad (2)$$

$$h \approx tan(\eta) \cdot \sqrt{(T - x_R) \cdot (\frac{d_{a0}}{sin^2(\eta)} + d_{a2})} \quad \text{for } \eta \neq 0 \quad (3)$$

$$z \overset{!}{=} h \quad (4)$$

$$z = z_1 + E_2 \quad (5)$$

$$z_1 = \frac{x_R}{tan\,(\varphi)} \quad \text{for } \varphi \neq 0 \quad (6)$$

$$\frac{x_R}{tan\,(\varphi)} + E_2 = tan(\eta) \cdot \sqrt{(T - x_R) \cdot (\frac{d_{a0}}{sin^2(\eta)} + d_{a2})} \quad (7)$$

$$x_R = -\frac{2\cdot\psi+\phi}{2} + \sqrt{\left(\frac{2\cdot\psi+\phi}{2}\right)^2 - \psi^2 + T\cdot\phi} \quad \text{for } \varphi \neq 90° \quad (8)$$

$$\phi = tan^2(\varphi) \cdot tan^2(\eta) \cdot \left(\frac{d_{a0}}{sin^2(\eta)} + d_{a2}\right) \quad (9)$$

$$\psi = tan(\varphi) \cdot E_2 \quad (10)$$

Process description on influence of infeed angle on chipping characteristics:

A) Constant path feed rate

a) As infeed angle increases, number of cuts decrease and required infeed distance decreases.

b) Hob has to travel a short distance, and the number of workpiece revolutions is relatively less. The hob reaches the target position in radial direction in a shorter time.

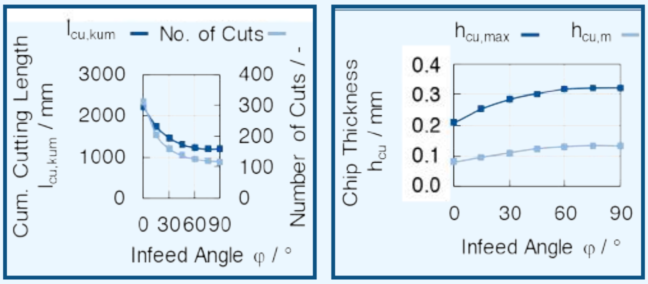


Fig 5: Chipping characteristics at constant path feed rate

B) Behaviors:

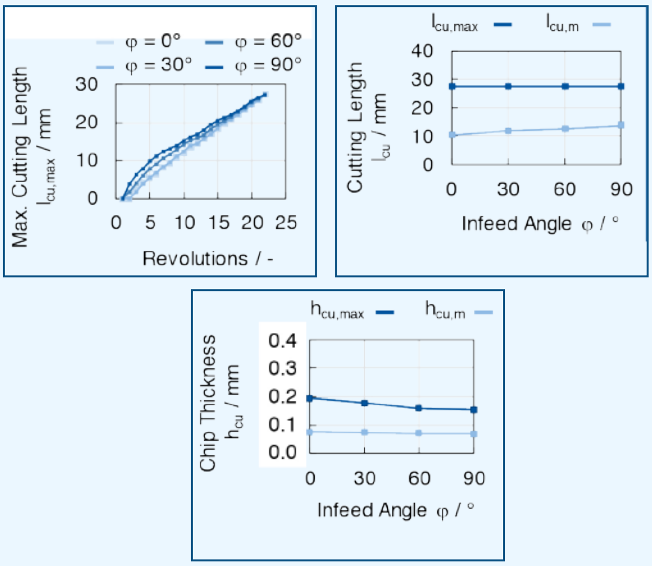


Fig 6: Characteristics at constant machining time

a) Under constant machining time, the cumulative cutting length and required number of cuts increase with increasing infeed angle.

b) Mean chip thickness and maximum chip thickness decrease with higher infeed angle

c) The above reduces the load on the hob, but the number of cuts increase along with mean and cumulative cutting length.

Conclusion

The process analysis with the developed tool provides several opportunities to explore further in the radial axial hobbing of helical gears. It opens up new trends not covered by the process know-how so far studied in axial hobbing alone by the Hoffmeister Method.

These open up many more trial opportunities to understand the analytical behavior or the process for knowledgeable application and use.

References:

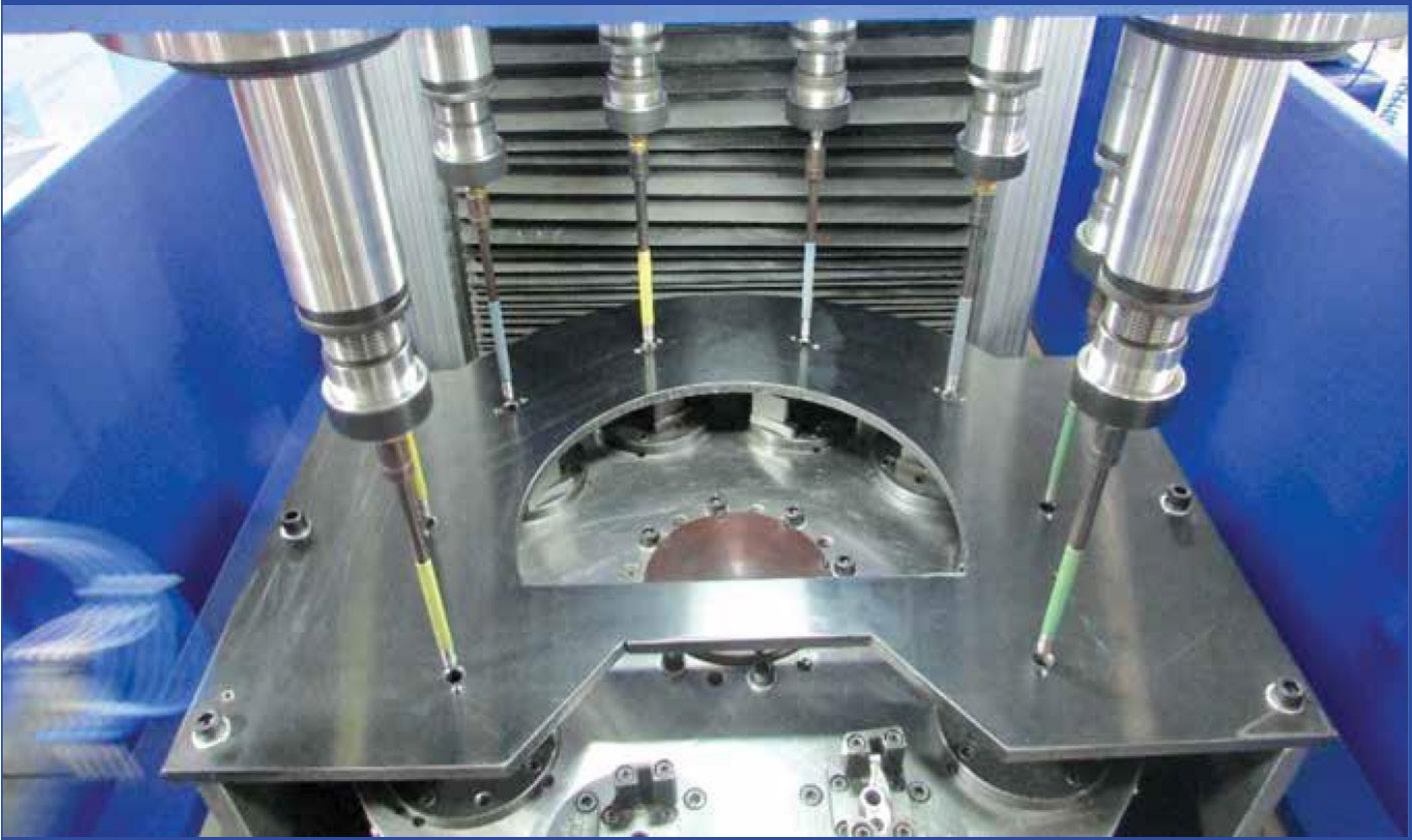
1 *ScienceDirect/ procedia CIRP 79/2019/68-73*

2 *Fette for precision / pages 128-130*

The author is former Director and General Manager of Gleason Works India. He has four decades of experience in the gear industry, with special reference to machine tools and gear processes. He is also a Fellow of the Institution of Mechanical Engineers, UK, and a registered chartered engineer.

HIGH–FINISH HONING PROCESS

By: Ajeet Samani



Modern engineering processes demand high quality and consistent performance. Naturally, the accuracy of the machining process required is very high and is difficult to achieve. Honing is one such highly accurate finishing operation.

The process

Honing is a little stock removing finishing operation that requires high dimensional and geometrical accuracies, and a good surface finish. In this process, an abrasive grinding stone is rotated and reciprocated with controlled pressure on the surface of the hole. The rotation and reciprocation of the spindle are closely monitored to achieve the desired result. In short, honing is the process of finishing a hole by removing less material. It is used for parts that require high geometrical accuracy with a good surface finish.

Typical applications

The following are typical examples of honing applications: Valve guide, cylinder liner, connecting rod, rocker arm, gear shifter fork, gear, yoke, sprocket, slider block, engine parts, hydraulic directional control valve, spool, hydraulic motor part, etc. The honing process is also used with great advantage in aerospace components, turbo charger components, fuel injection components, refrigeration components and so on.

The equipment

Khushbu Engineers initially developed the traditional manual horizontal honing machine. Manual honing is a highly skilled operation. Therefore, the productivity of the machine is lower in the case of conventional honing. Here, the accuracy and productivity are inversely proportionate. Over a period of time, customers demanded a highly productive machine with high bore accuracy. Also, operator dependency was expected to be reduced.

Combination honing

A new concept of Single Pass Honing with Multi pass Honing is developed to take advantage of close size control of the Single Pass, with a cross hatch pattern by Multi Pass Honing.

The machine has one vertical slide with 3 spindles for the Single Pass process. And the second slide is with one spindle for Multi-Pass, expansion type. The fixtures are mounted on a Rotary Indexing arrangement with 6 stations. One fixture is always available for part loading/unloading.

On cycle start after part loading, the fixture indexes to the first spindle. First, the honing pass is done. The second part is loaded in the fixture. The cycle is repeated till 3 tools are passed. For the next cycle, the part indexes to the multi-pass spindle; a cross hatch is generated while the three spindles complete the cycle.

The finished part comes out in the next cycle. The rotary indexing arrangement allows loading/unloading one part every cycle. Hence one part is completed every cycle.

Trends in technology

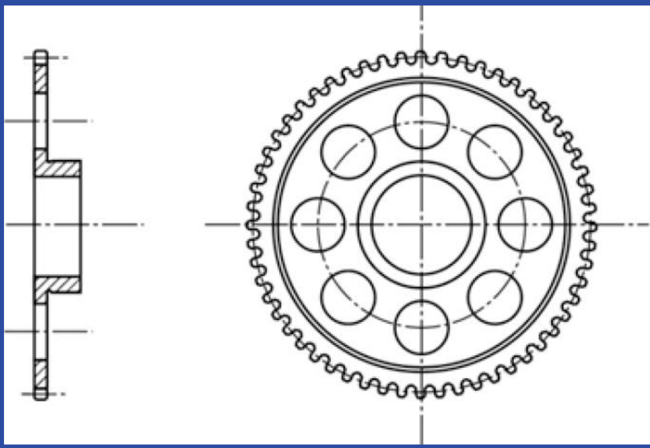
The latest development in honing is single pass honing technology. Using single pass honing technology, extremely close tolerances can be achieved repeatedly in production at a lower per piece cost. In view of the above, Khushbu Engineers developed a multi-spindle, single pass progressive honing machine. The technology used was to pass a diamond coated, pre-fixed size tool in the bore while rotating. It removes predetermined material in the bore. This is done 4-6 times in a row to remove 40 or 60 microns of material from the hole. Since the tool is diamond coated, the wear is very low. Passing the tool without expansion, one can speed up the operation. Due to the CNC System, this process is controlled with very high accuracy and consistency. The rigidity of the machine also plays a very important role.

Establishing new concepts is always difficult. With the help of the latest drafting technology and an experienced design team, we at Khushbu were able to develop the single pass progressive honing technology in the country.

At each stage of the design, it was necessary to perform a stress analysis and confirm the design. Equally important was the manufacturing part of the machine. Our first machine passed all the tests due to the selection of the right vendor who can get high specifications of manufacturing tolerance.

Key features of the machine

1. Number of spindles / tools 4,6,8
2. Maximum diameter .... 40 mm
3. Maximum depth .... 150 mm
4. Indexing accuracy .... 15 seconds
5. AC servo motor for axis movement
6. Feed .... 2500 mm / min
7. Rapid traverses 2 .... 5000 mm./min
8. Hole accuracy .... 2-5 microns
9. Size repeatability (Cpk) .. 1.33



Details

Material –Case Hardened steel

Stock for Honing - 0.040 mm

Diameter - 38.00 mm

Length- 18 mm

Number of passes- 4

Parameters (mm)	Required	Achieved
Bore Tolerance	0.020	0.003
Ovality	0.007	0.002
Taper	0.007	0.0015
Face runout	0.1	0.070-0.08
Surface finish	0.8 Ra	0.6 Ra
Productivity	-	120 parts per hour

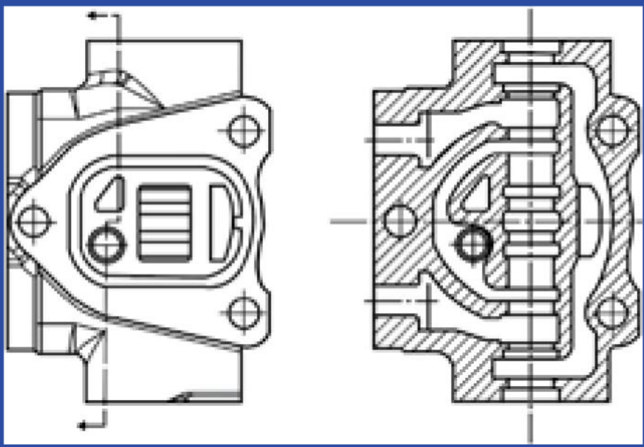
Examples

• Transmission Gear

All transmission gears are honed to get a good fit on the shaft. The result is reduced noise, improved torque transmission, and improved vehicle performance. Normally after heat treatment, the hole in the gear shrinks by a few microns and the geometric accuracy deteriorates. The honing process improves geometry such as roundness, taper and surface finish. At the same time, the bore to face run out and gear PCD run out are kept intact.

• Hydraulic Valve

Honing a Hydraulic Valve is a little difficult. The fitment of the spool in the hole of the valve body is within 4-5 microns. That is, the geometric measurements of the hole have to be within 2 microns. Also, the surface finish required is 0.2 - 0.4 Ra. Here, the input accuracy of the hole is up to 20 microns. The honing process improves the roundness and straightness of the hole up to 2 microns.



Details

Material - Cast Iron

Stock for Honing - 0.030-0.040 mm

Diameter -16.00 mm

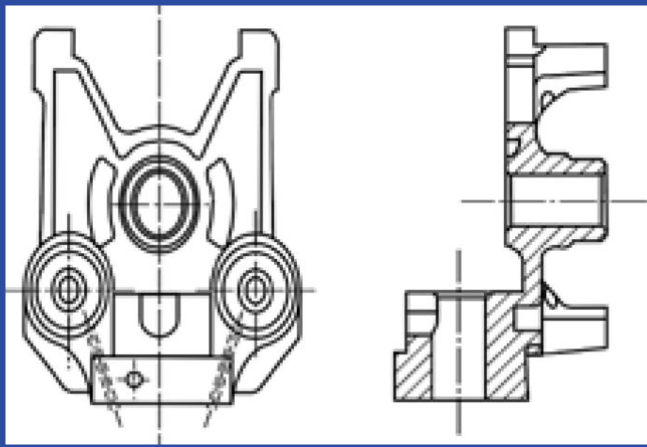
Length -127mm

Number of passes-4

Parameters (mm)	Required	Achieved
Bore tolerance	0.011	0.003
Ovality	0.003	0.0015
Taper	0.003	0.002
Surface finish	0.4 Ra	0.4 Ra
Productivity	-	66 parts per hour

• Refrigeration Compressor Body

This is the heart of the refrigeration compressor. The performance of the Air Conditioning unit depends on the accuracy and finish of the hole. Since the fitment of the piston in the hole is within 3-4 microns, the accuracy of the hole has to be in 1-1.5 microns. The Single Pass honing process not only achieves the accuracy of the hole and the surface finish of both holes, but also maintains the perpendicularity between the journal bore and the piston bore.



Details:

Material - Cast Iron

Stock for Honing - 0.030-0.040 mm

Diameter -19.00 mm

Length - 40mm

Number of passes - 6

Parameters (mm)	Required	Achieved
Bore tolerance	0.005	0.003
Ovality	0.002	0.001
Taper	0.002	0.0015
Surface finish	0.15 Ra	0.15 Ra
Productivity	-	360 parts per hour

Distinctive advantages of the Honing Process

To sum up, the following are the distinctive advantages of the Honing Process:

- High dimensional and geometrical accuracy with smooth surface finish, faster than grinding.
- Higher productivity with high accuracy at a moderate cost.
- Smaller bores of diameter 3 to 48 mm and length of 180 mm can be honed faster than grinding, with high accuracy.
- Less skilled operator also can operate the machine easily.

The author, Ajeet Samani, is Director at Khushbu Honing based in Kolhapur

The gamechanger for e-drive gear manufacturing: In-process gear inspection and noise analysis

E-drive gears differ from other gears in two essential ways: they need higher quality and excellent noise behavior. A new technology caters to this demand while changing the existing manufacturing process chain

By: Dr Antoine Türich

95% of Gears go Untested

In conventional gear manufacturing, quality control is carried out randomly, with only a few parts actually inspected. This is mainly due to the significantly longer measuring times in comparison to the actual production time, and limited overall measuring capacity to cope with increased inspection demands. In fact, it is not unusual in hard finishing operations to measure only one or two workpieces per dressing cycle. Depending on the dressing rate, this process corresponds to measuring only about 5% of the workpieces produced. Instead, in order to guarantee process reliability, statistics are used to validate the process, resulting in a significant reduction of the manufacturing tolerance in comparison to the drawing tolerance. In addition, constantly increasing power density requirements and the growing importance of excellent noise behavior of transmissions, especially in new e-drive concepts, has resulted in very tight tolerances. Relying on statistical evaluation makes the production of such gears more challenging and expensive.

A better way

A new inspection concept developed by Gleason, called GRSL (Gear Rolling System with Integrated Laser Scanning) features a combination of double flank roll testing and laser scanning. With this completely new approach, inspection now can be performed without adding to the time required for the hard finishing operation. As a result, up to 100% in-process inspection of all teeth has become a reality, eliminating the need for statistical process evaluation. Finally, there is no more need to narrow tolerances, and workpieces can be verified according to the true drawing tolerances.

The gamechanger: In-process roll testing and laser inspection

During the roll testing cycle, two laser heads move automatically into position to scan both gear flanks (left and right) simultaneously. In addition, different sections along the face width of the gear can be scanned to inspect even the lead. With laser technology, the overall inspection time is significantly reduced, compared to a standard tactile measuring system. For instance, the inspection time required for a typical, automotive planetary pinion can be reduced with laser technology by a factor of 4, down to 39 seconds.

With the inspection time being greatly reduced, this process can even add additional value by measuring profile and lead on all gear teeth – not just the usual inspection of only 4 teeth around the circumference of the gear.

With such comprehensive data available through laser scanning, it is also possible to further evaluate gears beyond standard gear inspection habits such as profile, lead, pitch, runout, and size. Understanding the profile and lead of all teeth makes it possible to calculate a so-called "advanced waviness analysis", resulting in an order analysis of the gear topography (Fig. 3).

With such an order analysis including the corresponding amplitudes, it is possible to detect potential noise issues such as ghost orders. These orders are not related to the mesh harmonics of the gear, and are typically caused by small irregularities created during the manufacturing process or by the production machine itself. Such ghost orders can cause problems once they exceed a certain amplitude. With the advanced waviness analysis and the possibility to inspect up to 100% of gears, it is possible to sort out critical parts before they are assembled into the gear box.

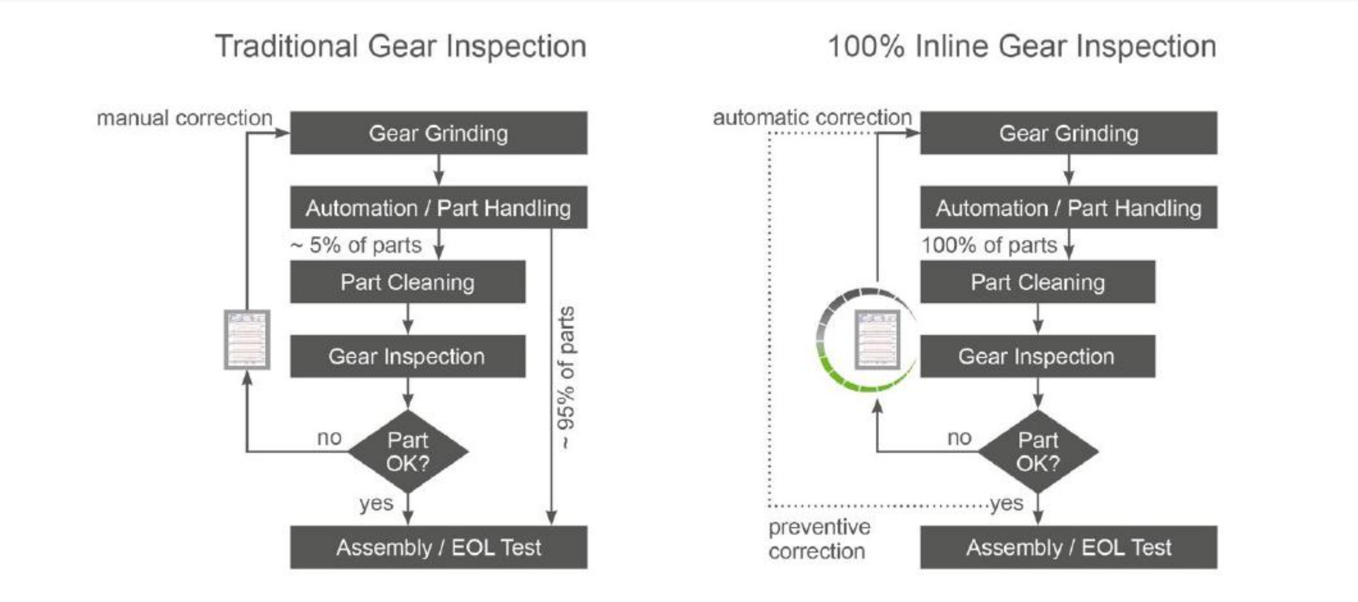


Fig 1: Traditional gear inspection versus 100% in-process gear inspection

Fig 2: GRSL – Multiple inspection methods combined in one platform, complemented by Cobot automated loading

Integrating metrology into the production flow

Gleason's Hard Finishing Cell (HFC) goes one step further than just integrating metrology into the manufacturing process. This fully automatized manufacturing cell features a highly productive threaded wheel grinding machine (Fig. 4: Gleason's 200/260GX), a washing and part marking station and a GRSL metrology system, all connected by an integrated robot loader with a basket-based palletizer system. The integrated automation is made by Gleason Automation Systems, Gleason's own automation solution provider.

The gantry loader is handling the complete workflow within the cell, including part handling and feeding machine, washing and part marking stations, as well as the inspection unit. The stacking cell accommodates baskets of various manufacturers and styles and is ideally suited for the autonomous processing of large lot sizes of gears.

The 200/260GX series uses a double spindle concept to bring down non-productive idle times to an absolute minimum, with less than 4 seconds workpiece change time. Machine setup is extremely easy and fast using Gleason's Quik-Flex® Plus Workholding, just one tool for the exchange of all mechanical components and a menu guided workflow for all necessary setup steps.

In addition to four different dressing systems for highly productive or flexible production, today's quality demands require modern grinding processes. This includes the possibility to grind gears with extremely good surfaces quality and twist control. A novelty in the industry is that neither grinding nor dressing times are negatively affected by Gleason's twist-controlled grinding process.

Gleason's Closed Loop system connects the grinding machine with the integrated GRSL metrology center. Inspection results are directly returned to the grinding machine without any involvement of the operator. The machine compares

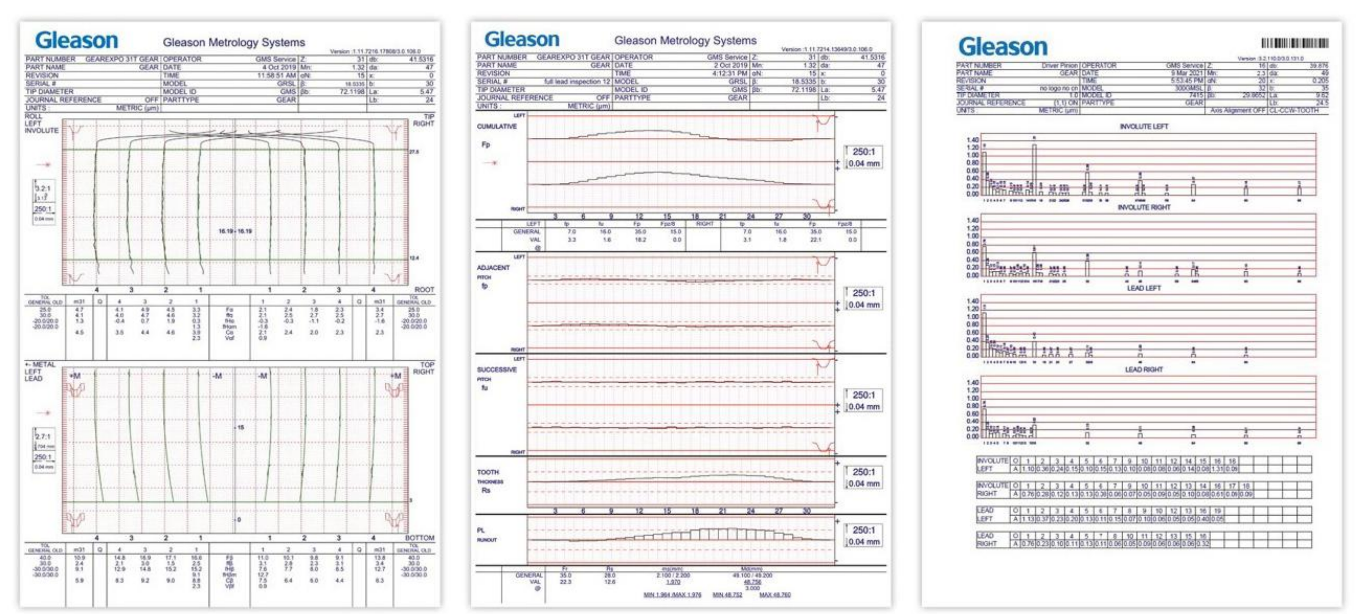
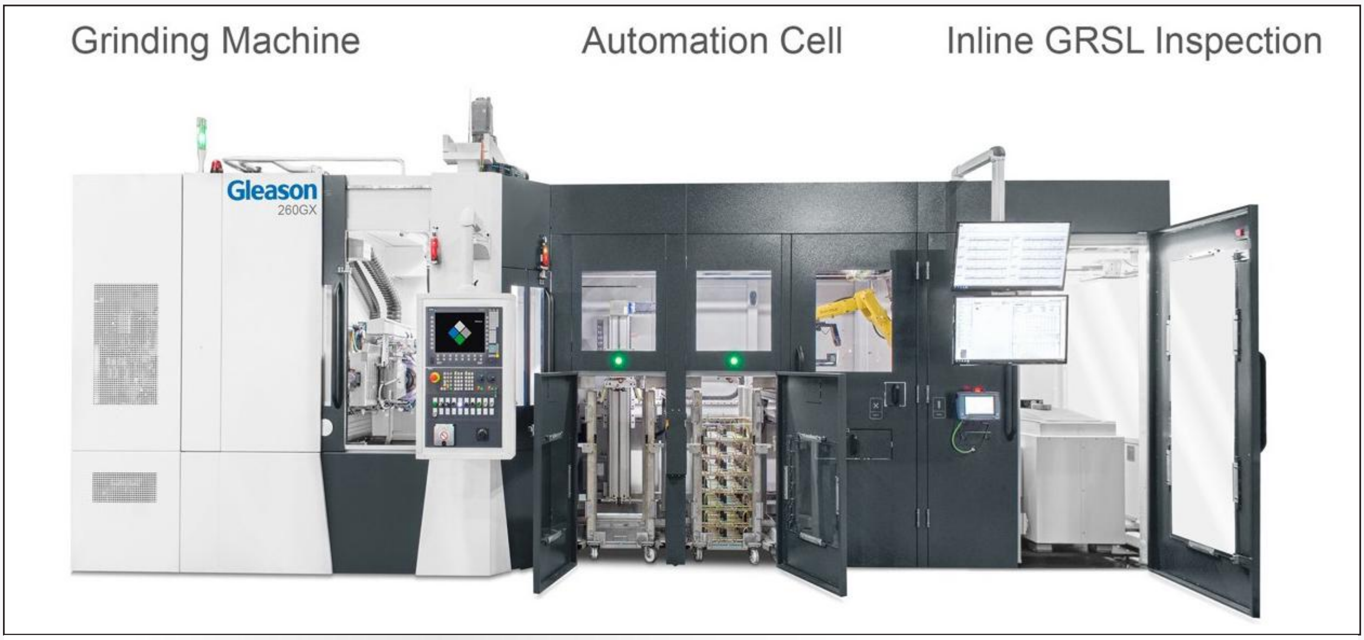


Fig 3: Chart possibilities of a GRSL including advanced waviness analysis



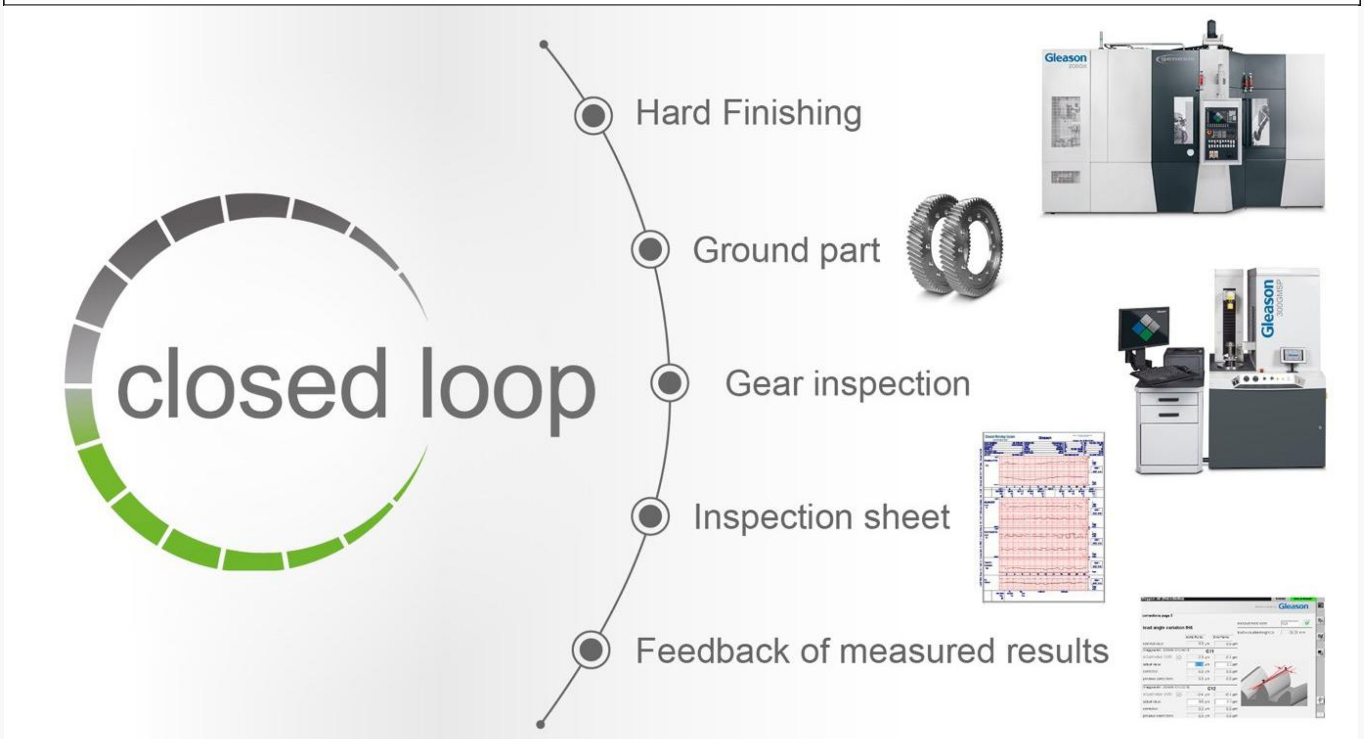
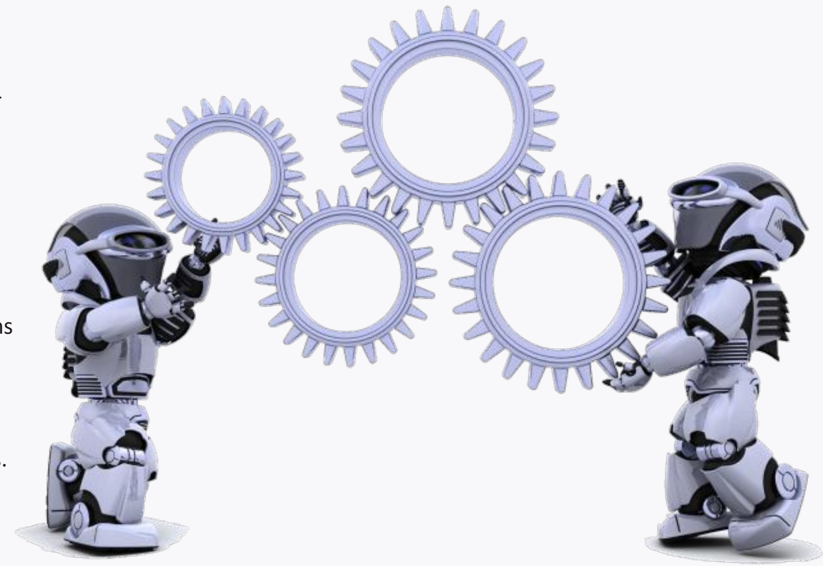


Fig.5: Closed Loop System

the measured values with the target nominal values and automatically performs the necessary corrections. With the GRSL being directly integrated in the Hard Finishing Cell, results are available right after the workpiece has been ground, typically in less than 5 minutes. Compared to the traditional approach of gear inspection in a separate inspection room, reaction time is dramatically reduced.



Summary

HFC is indeed a gamechanger for many industries and applications which require consistent high-quality results, such as the production of high precision eDrive gears with minimal noise characteristics or safety-relevant aerospace parts with strict documentation requirements. The HFC is a single, worry-free system for the documented, fast production of high-quality gears.

The author is Director, Product Management of Hard Finishing Solutions, Gleason Corporation

Setting the performance standard: Gear Skiving with process reliable simulation

LMT Tools supplies high-performance and process-reliable tools for gear skiving. They guarantee top performance in the production of internal and external gears, thanks to the special combination of excellent cutting-edge preparation and individual process simulation

In gear skiving, the tool is at an angle to the axis of the workpiece to be machined. This so-called cross-axis angle, in conjunction with a synchronous movement between the tool and workpiece axes as well as an axial feed, forms the gear teeth. It is a very precise and fast process, but places high demands on the tools used. If these are not optimally designed, wear occurs very quickly as a result of the process. As a leading manufacturer of gear cutting tools, LMT is now driving forward the development of high-performance solutions. Specially-developed simulation software supports the path from the customer drawing to safe and successful tool use.

Simulation creates reliability

The complex multi-cutting strategies typical of the process often lead to a time-consuming path to the final good part. The software allows a detailed assessment of the relevant process parameters already in the design phase, taking into account the respective customer requirements. In this way, all difficulties can be eliminated in advance, and the ideal tool can be developed and created as early as the simulation process. This creates reliability, both for the tool manufacturer and the customer, and leads to more efficient tool and process layouts.

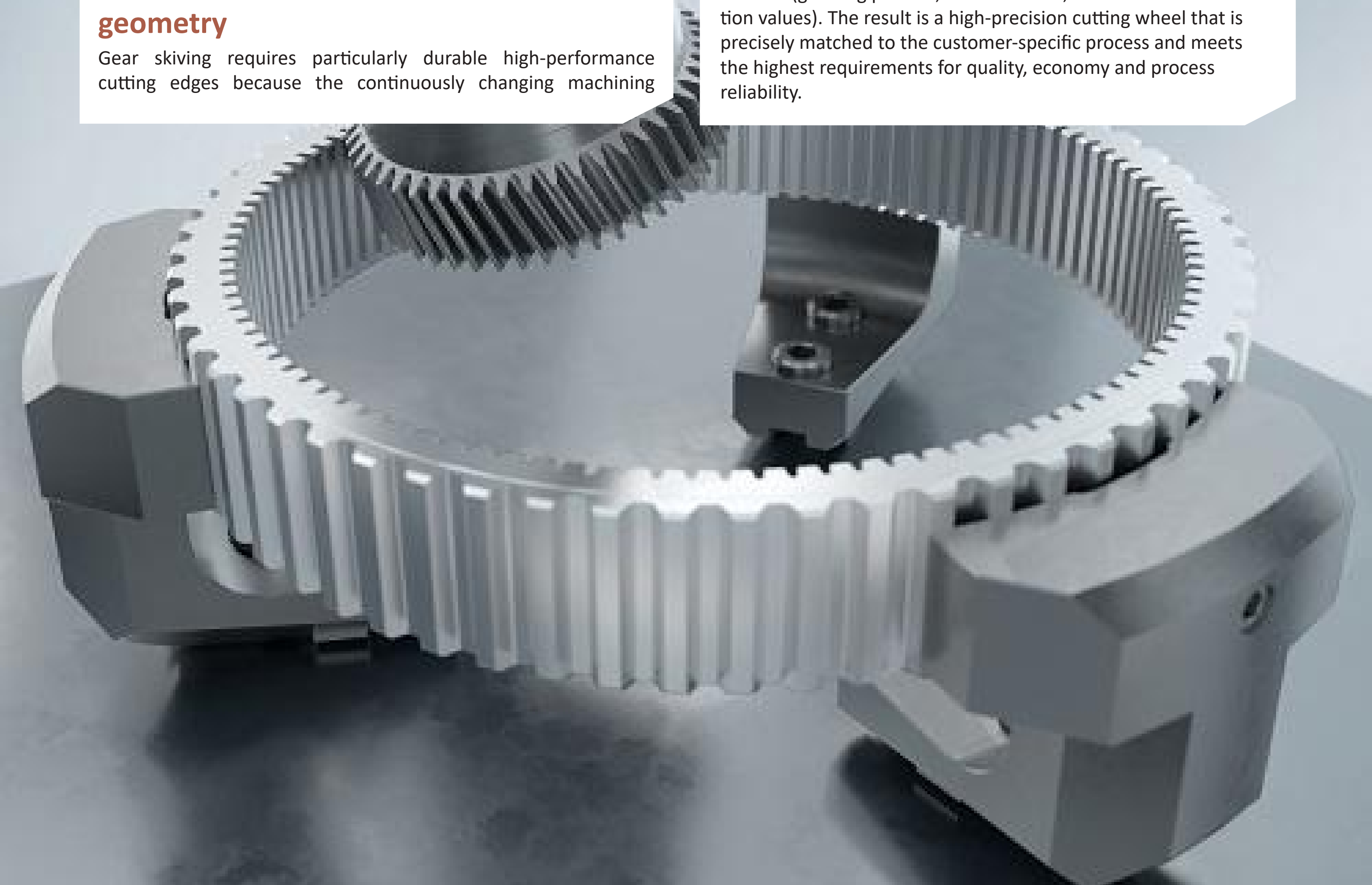
Optimal adaptation of macro and micro geometry

Gear skiving requires particularly durable high-performance cutting edges because the continuously changing machining conditions create very high stress on the tool cutting edge. LMT FETTE therefore relies on an innovative process for gear skiving cutting edge preparation. Targeted rounding ensures greater ease of cutting, and also has a positive effect on wear behavior and thus tool life. In combination with a specially-designed cutting geometry, a protective hard coating and a substrate made of powder metallurgical steel, the customized tool solutions set standards in terms of efficiency and machining reliability.

New performance standards in gear skiving

With its high performance and wide range of applications, gear skiving offers great potential for the production of internal and external gears, and is clearly superior to conventional manufacturing processes in many cases. For example, it enables faster machining times than hobbing, offers a wider range of applications than gear hobbing and, thanks to lower tool costs and the elimination of special machines, also has an advantage over broaching.

LMT manufactures all gear skiving tools using the closed-loop method (grinding process, measurement, calculation of correction values). The result is a high-precision cutting wheel that is precisely matched to the customer-specific process and meets the highest requirements for quality, economy and process reliability.

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GEAR TECHNOLOGY INDIA: THE VOICE OF THE INDUSTRY

AGMA and Virgo Communications launch GTI, the first-of-its-kind media platform for the gear industry in India. It will be a medium to connect stakeholders and build a community

By: Sowmya Rajaram

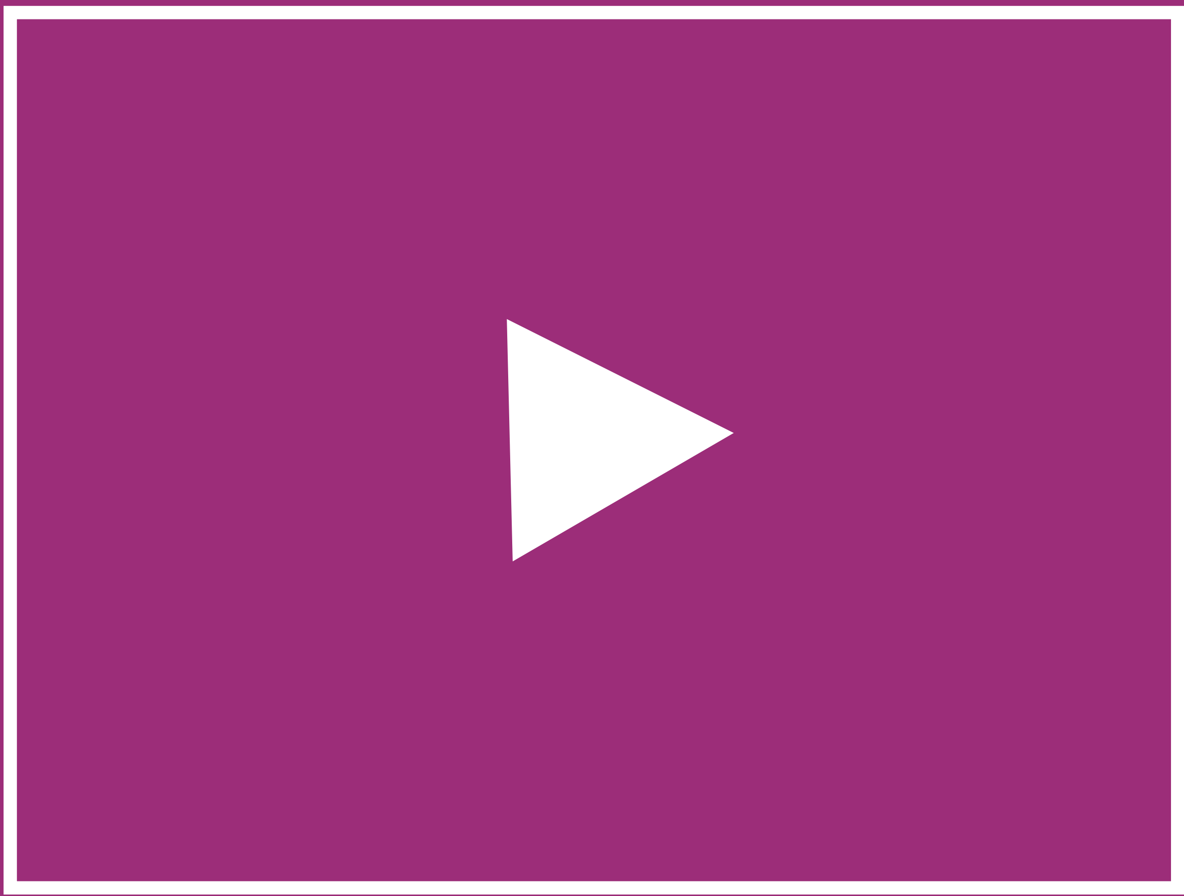
Gear Technology India (GTI) is an initiative that is the result of a partnership between the American Gear Manufacturers Association (AGMA) and Virgo Communications & Exhibitions. GTI takes off from Gear Technology USA, a 35-year-old-brand that has now come to be recognized as the premier gear-focused magazine and website.

India: A priority market

In India, GTI will be the first and only multi-faceted media platform catering specifically to the country's gear industry. This is a dedicated space for the Indian gear industry to connect, share news, information and technical articles, and build a strong community. GTI will be a partner to all the stakeholders in the Indian gear industry. It aims to offer the community in India a world-class knowledge platform with relevant content, courses and business solutions, and exposure to AGMA standards.

India was identified as a priority market because industry leaders were moving into the space. "Unlike the US and Europe, which would be considered mature markets and might see 1-3% growth, India is growing in near double digits growth, predicted at 9% this year. To this end, AGMA sees an opportunity to support the growth by sharing our standards, providing our education classes, and also sharing technical information to support engineers," Matthew Croson, President, AGMA, says.

He believes the Indian market is "unique, in that it is actively emerging, rapidly". In the long-term, the objective is to "unify the Indian gear market in order to ensure they have the proper standards to build innovative solutions, the right education to ensure continued learning in the space, and the right access to information that is important to the industry", he says. "In many ways, AGMA is simply following the same approach it took when the association was started 107 years ago. AGMA sees this effort



Matt Croson introduces Gear Technology India

as more than a five-year plan – we talk about it in terms of a 50-year plan, as we know that is how much the market can grow – a similar path that AGMA in the US took."

Learning from the best

Croson explains that Gear Technology USA was started because there was no focused magazine dedicated to the importance of gear manufacturing. He adds, "It was started as, and continues today, to be a very technical journal, with four to five technical papers in each issue, and then stories that are focused on other news throughout the gear industry in North America. It has 13,000 circulation, and 10,000 monthly visits to its website. Since 2020, AGMA has owned the brand, and it includes Gear Technology, Power Transmission Engineering and Gear Technology India magazines and supporting websites. Overall, the three magazines deliver focused gear news to more than 30,000 engineers and leaders throughout the world."

GTI will bring the same credibility and wealth of knowledge and information to the Indian gear community. It aims to become the topmost platform for communication, connection and collaboration, and to showcase company capabilities and industry leaders. As KP Soundararajan, former Director & General Manager of Gleason Works India, explains, "A lot of dynamic changes are happening in the industry now. The demand from customers is increasing, because the quality of products they need to deliver in the market is also going up. The gear industry is facing the challenge of newer expectations from their consumers. GTI is the place for integrating all this information."

A long relationship

AGMA has 15 members in India, has conducted a Trade Mission here in 2015, and has partnered with the IPTEX/Grindex trade show from its very first outing. GTI simply extends and solidifies that partnership. "We have worked with AGMA for many years, and they have been our exclusive partner in India. So it was an easy path," says Anitha Raghunath, Director, Virgo Communications & Exhibitions.

"Virgo Communications and Exhibitions has always been an organization which chooses niche segments, and creates platforms such as trade exhibitions for them. As a natural extension of our services, we have also supported these industries with trade publications. Today, we are extending our support to the gear industry and adding to our portfolio of publications, with the launch of Gear Technology India," adds Raghunath.

Although Virgo Communications conducts events where people showcase their technology and meet customers face-to-face, the gap between events (2 years) was too long. "So a platform such as GTI helps the industry to update stakeholders, buyers, consumers, and even teams within the company/ network to share what they are doing, their latest innovations, and keep tabs on industry growth," Raghunath explains. "It is a huge opportunity for global players to tie up and find partners in India."

Indeed, the Indian market is ripe for such an initiative. After the impact on China as a manufacturing hub because of Covid, India, with its qualified engineers and quality manufacturing, stands at the precipice of a great opportunity. "GTI will be the leader in connecting all the dots to make that happen," Raghunath says.

"As a past board member of AGMA I always felt that India needed to have a greater presence in the gear world. The coming together of two evolved and mature institutions such as AGMA & Virgo communications is the best vehicle to open many avenues for the world to discover India's capabilities in the gear field. This will bring many fruitful opportunities for gear companies & end users across the globe. The timing of this partnership is perfect."

–Sulaiman Jamal, Managing Director, Bevel Gears India

AGMA standards

AGMA's overall philosophy is to provide the information, training and business connections that the market needs to grow, and maintain their innovative approach. In the US, they do this by conducting more than 25 education classes, 5 different business-oriented meetings annually, and a trade show every other year. "We added our Media entities in 2020, so now we have a strong understanding of the market, and can share our information to our members who use it to grow their business. We also are heavily involved in market intelligence and emerging technology. It's a comprehensive approach that includes a global outlook," Croson says.

GTI will extend the wealth of knowledge and work AGMA has done worldover, to India. Raghunath says: "Our plan is to disseminate quality information, give experts a channel to share knowledge, and showcase India's capability to the world. Because it's a digital publication, geographical barriers dissolve and we can connect the Indian market to international players." India has huge potential and a captive audience, and GTI will bridge that gap.

Growth and learning

For GTI, the plan is to publish whitepapers, research material and technical articles, all of which contribute to highlighting the industry's excellence. Croson hopes that the local market embraces the knowledge and information they can easily gain access to, via the e-magazine and the online platform, for free. "We also think there is a strong marketing opportunity for suppliers to reach the gear community, and the gear community to reach the end users who use gears in their business. By having the marketing support in terms of money spent, we are confident we can build significant technical resources for the market."

The industry will have the opportunity to come together at conclaves such as IPTEX. "We will be launching online Fundamentals and Basics training by mid-2023. The website will be the place to access all of this information, while the e-magazines will be alerting the industry to the latest news and technology information available," Croson explains.

For India, by India

This platform is totally focused on the Indian market. Croson believes 'Make In India' is another reason why now is the best time to launch GTI. "While Make in India was launched by Prime Minister Modi in 2015, it has taken time for investments to happen in Bangalore, Pune, Chennai, Mumbai and parts of Gujarat, where the majority of gear companies are operating. Today, so many global suppliers are in the market, that it's a

Anitha Raghunath speaks about Gear Technology India

perfect time to bring everyone together to continue to grow, and share."

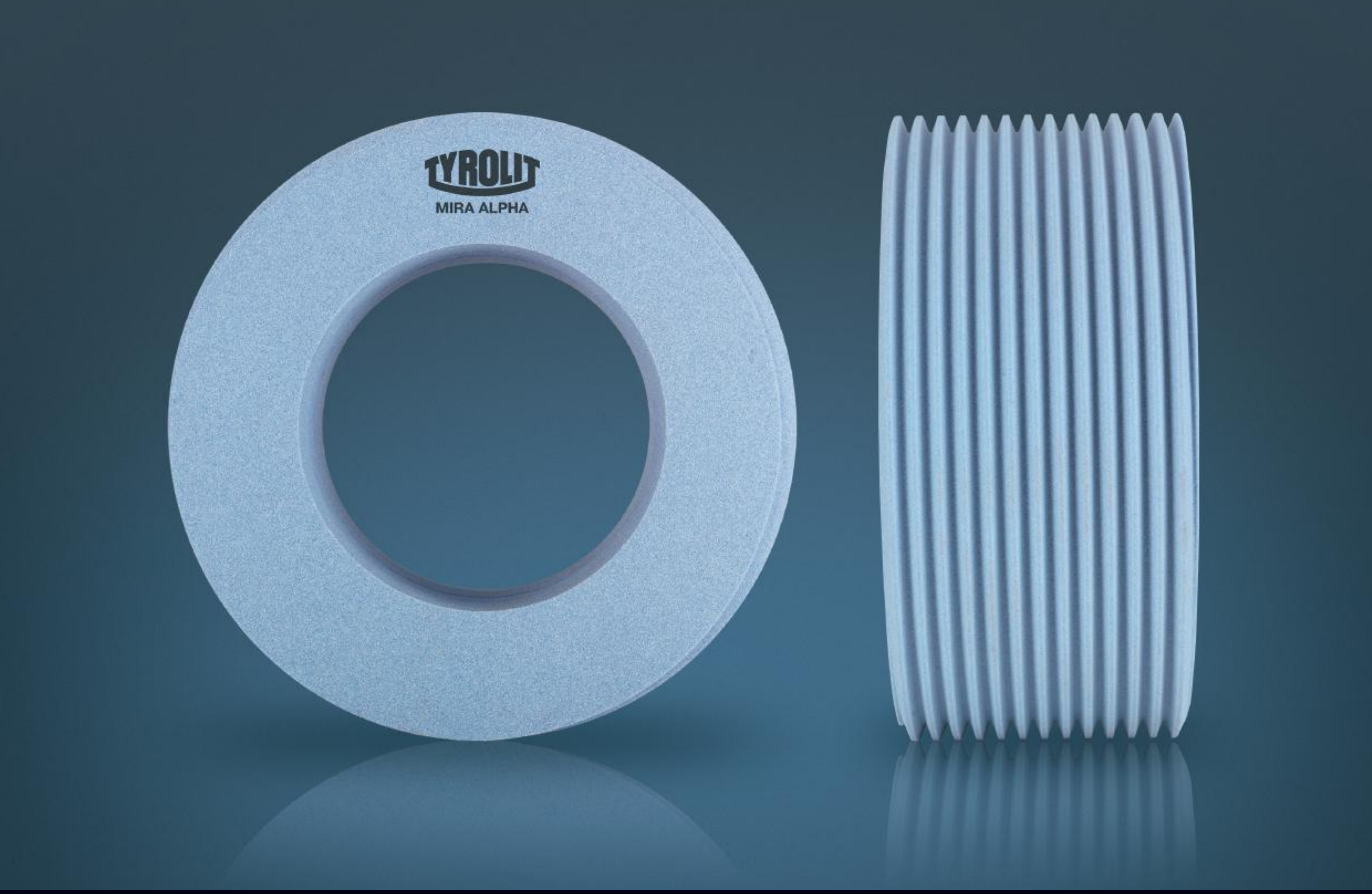
Raghunath agrees. "With the government's push to see that we manufacture here to support global companies, new technology is playing a key role in the growth of indigenous manufacturing. We have launched this initiative at the right time. GTI will be part of the journey of us becoming a global manufacturing hub."

"A lot of dynamic changes are happening in the industry now. The demand from customers is increasing, because the quality of products they need to deliver in the market is also going up. The gear industry is facing the challenge of newer expectations from their consumers. GTI is the place for integrating all this information and connecting the dots."

–KP Soundararajan, former Director & General Manager of Gleason Works India

AGMA's philosophy is to provide the information, training and business connections that the market needs to grow, and maintain an innovative approach. In 2020, it added media entities, which now gives it a strong understanding of the market

GTI is the result of a partnership between AGMA and Virgo Communications & Exhibitions. The platform takes off from Gear Technology USA, a 35-year-old-brand that has now come to be recognized as the premier gear-focused magazine and website. In India, GTI will be the first and only multi-faceted media platform catering specifically to the country's gear industry



MIRA ALPHA

The product line MIRA ALPHA has been specially developed for continuous generating grinding of gears. With the new ALPHA technology previously unattained results in terms of economy and cool grinding can be achieved.

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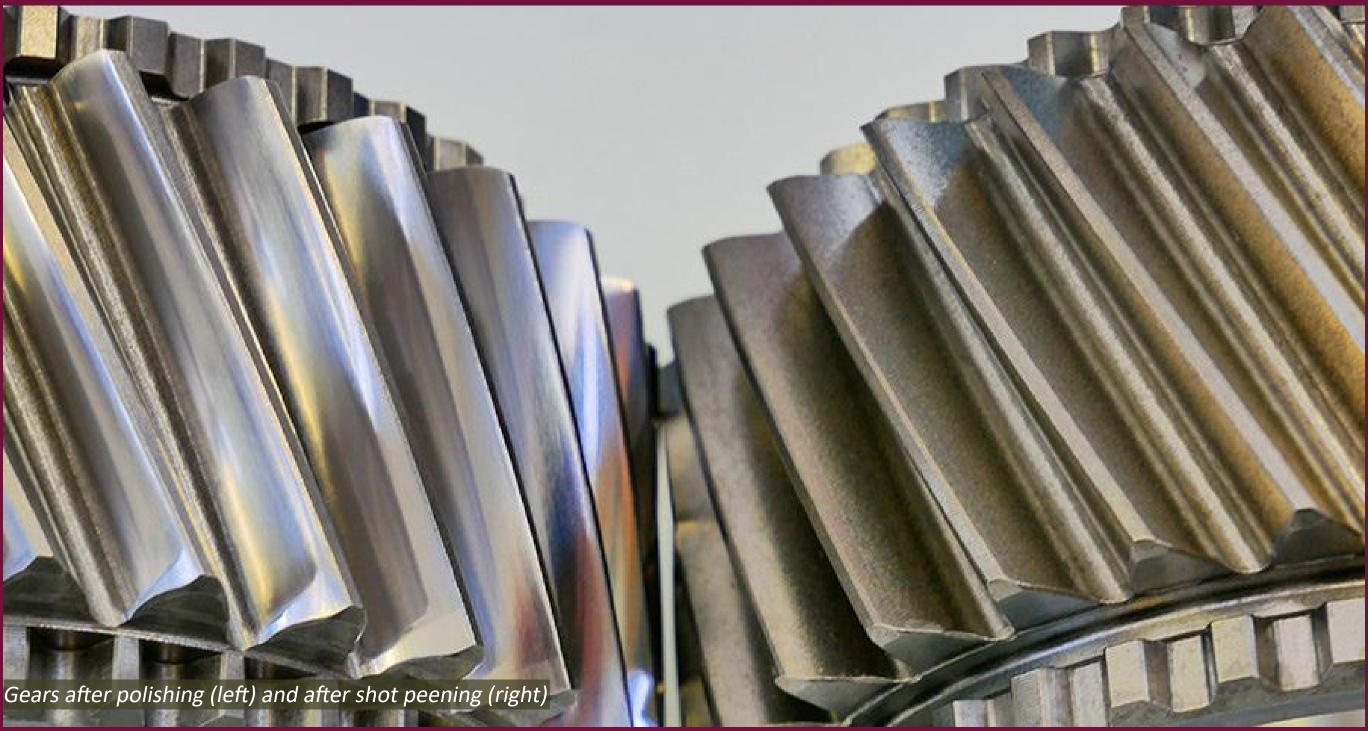


Gears after polishing (left) and after shot peening (right)

The electric motors used in e-mobility have a significantly higher efficiency compared to conventional combustion engines: Up to 80 percent of the energy stored in the battery is transferred to the wheels as kinetic energy by the highly efficient electric motors by means of a transmission. When burning fossil fuels, the yield of 30 to 40 percent is only about half.

Nevertheless, efforts are underway to further increase the energy efficiency of electric cars, especially regarding the achievable ranges. A key element is also the surface texture of the gear flanks in the transmissions used.

The process which determines the quality is the hard finishing of gears through grinding and subsequent superfinishing at the end of the gear processing chain. There are constantly increasing demands on service life, smooth running, power transmission and efficient use of the introduced energy.

Since there is no official definition for the terms of fine grinding and polishing, KAPP NILES has created a definition that refers to the achievable surface quality during generating grinding (Table 1).

Method of generating grinding	Achievable surface quality	
Conventional grinding	$R_z > 3$ µm	$R_a > 0{,}6$ µm
Fine grinding	$R_z = 1 - 3$ µm	$R_a = 0{,}2 - 0{,}6$ µm
Polish grinding	$R_z < 1$ µm	$R_a < 0{,}2$ µm

Table 1: Achievable surface qualities

The average roughness depth Rz and the average roughness height Ra were used as comparative values. However, it is understood that from certain surface qualities onwards, other values such as material ratios are better for characterizing the surface than R_z and R_a.

In order to meet the increasing surface requirements, various tools are also used in the different processes, as described below.

Conventional generating grinding

In standard generating grinding, a vitrified bonded corundum grinding worm is used, which consists entirely of one specification.

Fine grinding

In the multi-stage, combined machining process of superfinishing, a different grinding worm specification is used for rough grinding (conventional generating grinding) than in the actual fine grinding. Both specifications include a vitrified bonding but may have different types of corundum and/or grain sizes.

Polish grinding

In the multi-stage, combined machining process of polishing, a grinding worm with vitrified bonding is used for rough grinding (conventional generating grinding) and a grinding worm with a polyurethane or synthetic resin bonding for polishing.

In a one-step machining process of polishing (not in combination with direct rough grinding), a one-piece tool with polyurethane or synthetic resin bonding is used.

Fine grinding

The tool consists of two different tool specifications. In the area used for fine grinding, the feed speed is reduced during dressing

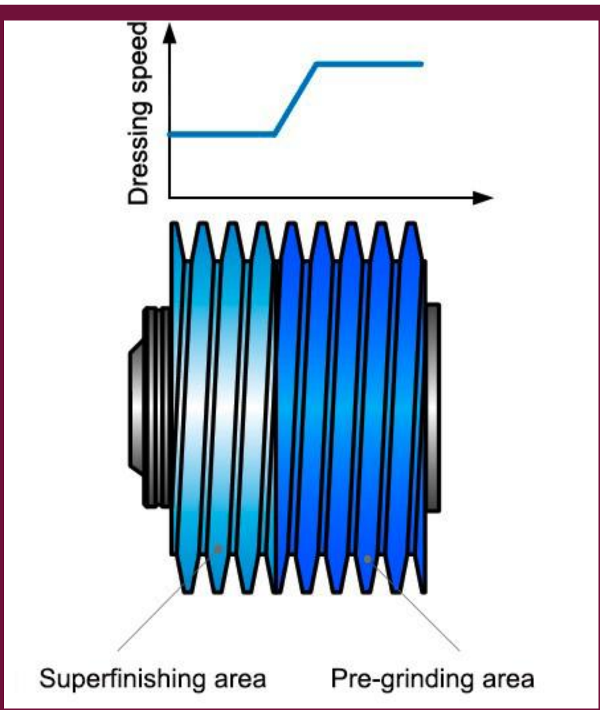


Fig 1: Reduction of dressing speed

(Figure 1). This makes it possible to influence the achievable surface quality of the workpiece. This procedure for dressing influences the surface quality of the gear wheel, even if the grinding worm consists of only a single specification.

In the following images, profile and flank line measurements are each shown before and after fine grinding. It is already apparent in the profile measurement log of the gearing measurement (Figure 3) that the profile shape deviation (ffα) could be significantly improved with this grinding / dressing technique.

As expected, there was no change in the lead measurement (Figure 5), as the grinding grooves are in the direction of the tooth width in accordance with the largest velocity vector.

From the graphical comparison of the roughness measurement (Figure 6_7), it can be seen that the surface has been smoothed. However, a roughness structure can still be seen. That is to say, the average roughness depth Rz and the average roughness height Ra could be reduced by a factor of 2 to 3. The core roughness depth Rk and the reduced center height Rpk could be reduced by a factor of 2 (see Table 2).

Polishing of shot-peened gears

Another area of application for high-precision machined gear flank surfaces are truck transmissions for both electric drives and conventional drivetrains. Nowadays, electric lorries are used in areas such as waste management or for the delivery of consumer

Comparison of profile and lead after pre-grinding and fine grinding

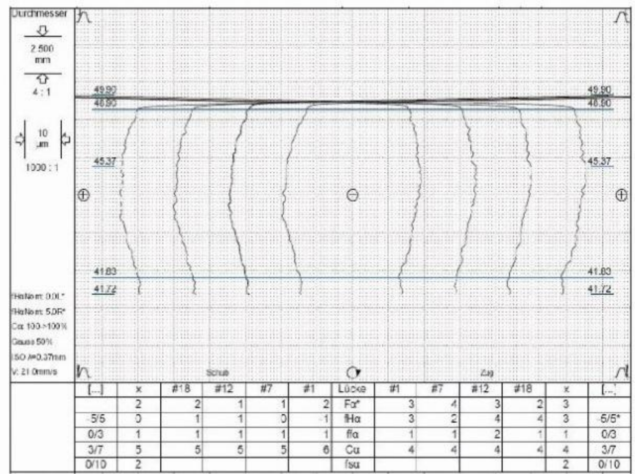


Fig 2: Profile measurement after pre-grinding

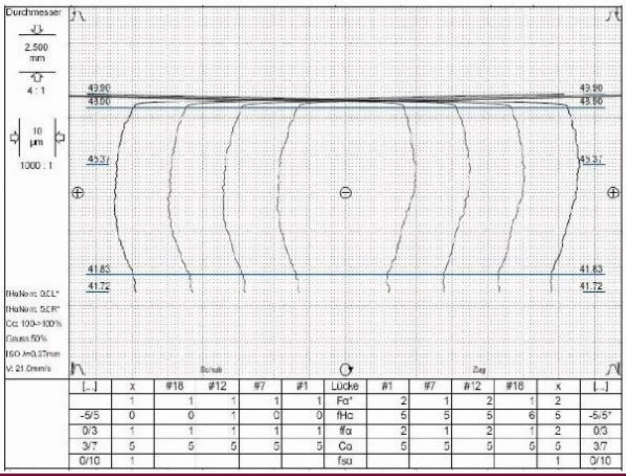


Fig 3: Profile measurement after fine grinding

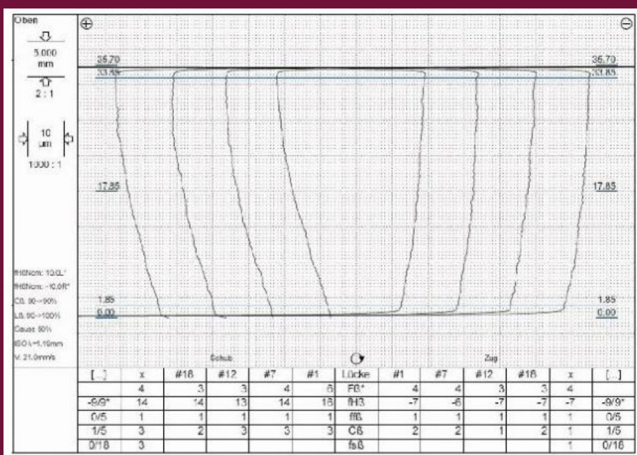


Fig 4: Lead measurement after pre-grinding

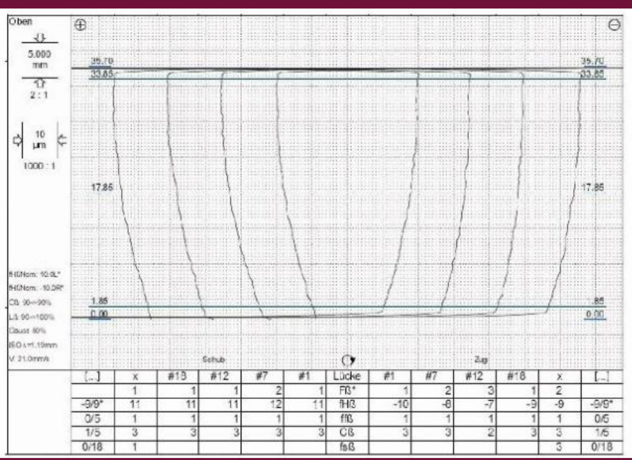


Fig 5: Lead measurement after fine grinding

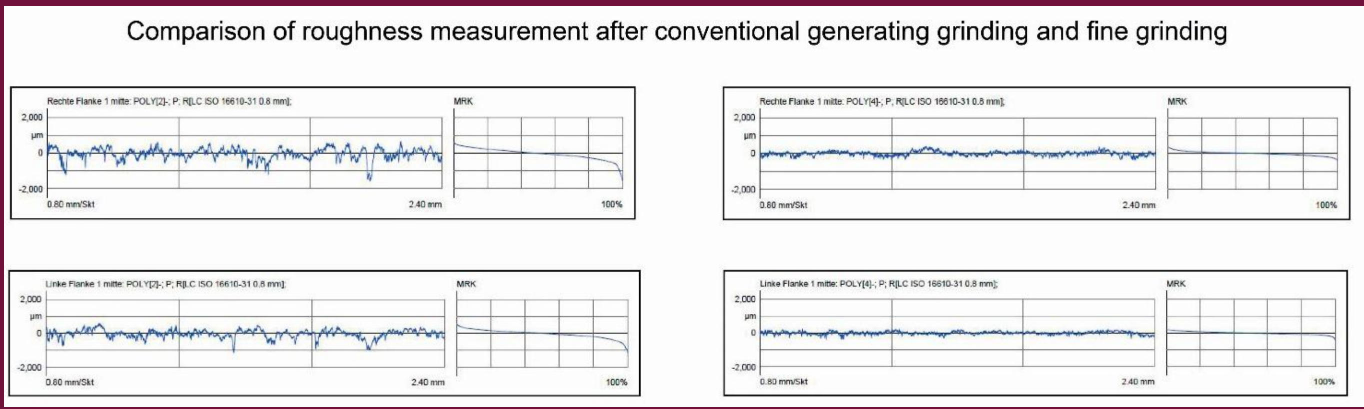


Figure 6: Conventional generating grinding

Fig 7: Fine grinding

goods in cities. Some food discounters even advertise that the transport of their goods between their stores in big cities is carried out with electrically powered trucks.

The polish grinding of shot-peened gear flanks is presented below.

The work sequence is as follows: After hardening, gears are machined as usual with the generating grinding process, using a one-piece grinding worm. As a result, the existing grinding stock including heat distortions is eliminated and the final workpiece geometry is produced. Afterwards, the gear flanks of the workpieces are shot-peened. The reason for shot-peening is the hardening of the gear flank surface, which serves to extend the service life of the gears and therefore the transmission. In the last step, the gear flanks are polished on a generating grinding machine with a one-piece polyurethane bonded tool.

By polishing, microscopic raised areas caused by shot-peening can be eliminated. It is not necessary to eliminate all indentations.

Two gears were compared in Figure 8. On the left, the workpiece is shown after shot- blasting and on the right, the workpiece is shown after polish grinding of the gear flanks.

The following two Figures 9 and 10 show the basic comparison of the profile geometry. In Figure 10, the reduction of the corrugation by polishing is clearly visible. The basic geometry of the profile is not affected. The profile angle deviation fHα, the profile convexity Cα and the tip relief Cαa are generated during conventional generating grinding processing prior to shot-peening.

Figures 11 and 12 show the comparison of the flank line geometry. The measurement log of the lead measurement after shot-peening is shown in Figure 11. Here, the lead shape deviations ffβ at approx. 7 µm are clearly visible. Figure 12 shows another workpiece of the series being machined, here the lead measurement after polishing.

The basic geometry of the flank line is not affected. The lead angle deviation fHβ and the lead convexity Cβ are generated during conventional generating grinding processing prior to shot-peening. As documented in Figure 12, the lead shape deviation ffβ is reduced by half.

As a final evaluation criterion, a comparison of the surface quality (Figure 13_14) is now carried out. After shot-peening, the average roughness height value Ra is significantly above the usually required qualities at ~0.85 µm. Likewise, at ~5.8 µm, the Rz is too large for the required application.

After polishing, the characteristic values Ra and Rz show very small values. These are no longer meaningful enough in the

	Conventional generating grinding		Fine grinding	
[µm]	Left flank	Right flank	Left flank	Right flank
R_{pk}	0,183	0,212	0,074	0,093
R_k	0,524	0,703	0,288	0,287
R_z	1,467	1,938	0,536	0,639
R_a	0,261	0,283	0,069	0,085

Table 2: Comparison of surface characteristics

Fig 8: Comparison of two workpieces

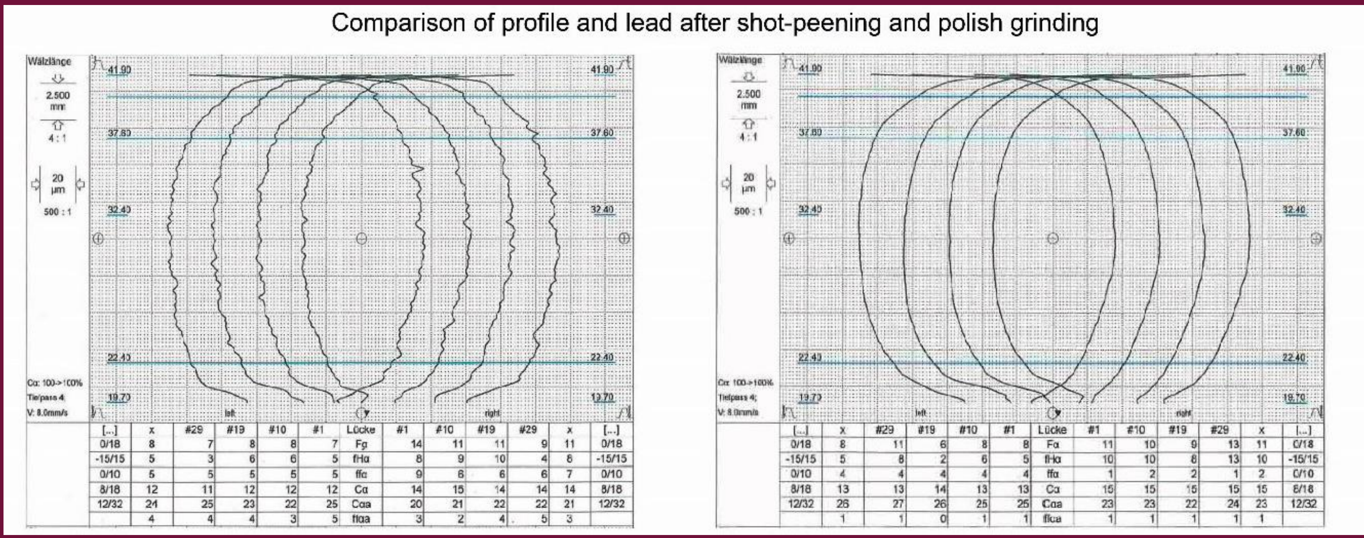


Fig 9: Profile measurement after shot-peening

Fig 10: Profile measurement after polish grinding

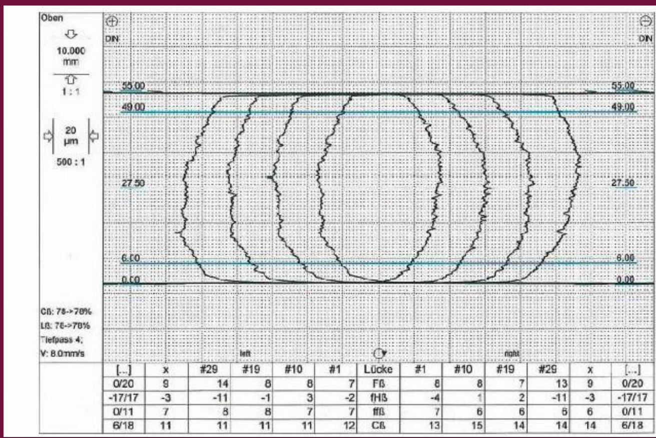


Fig 11: Lead measurement after shot-peening

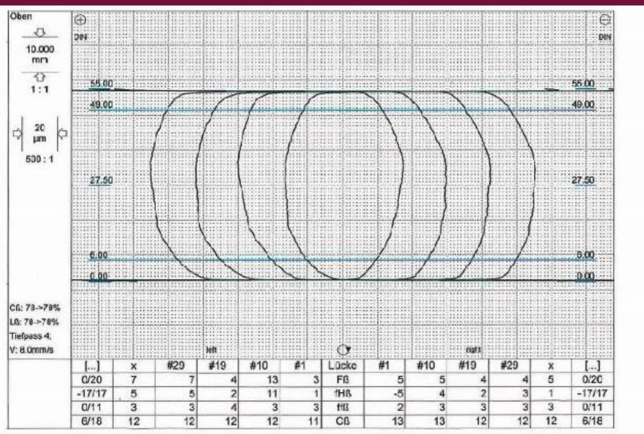


Fig 12: Lead measurement after polish grinding

description of the surface quality. Rather, material yield fraction Rmr or the "reduced peak value" Rpk together with the core roughness value Rk come into play here. In this context, there are a wide range of evaluations to describe the achieved surface quality.

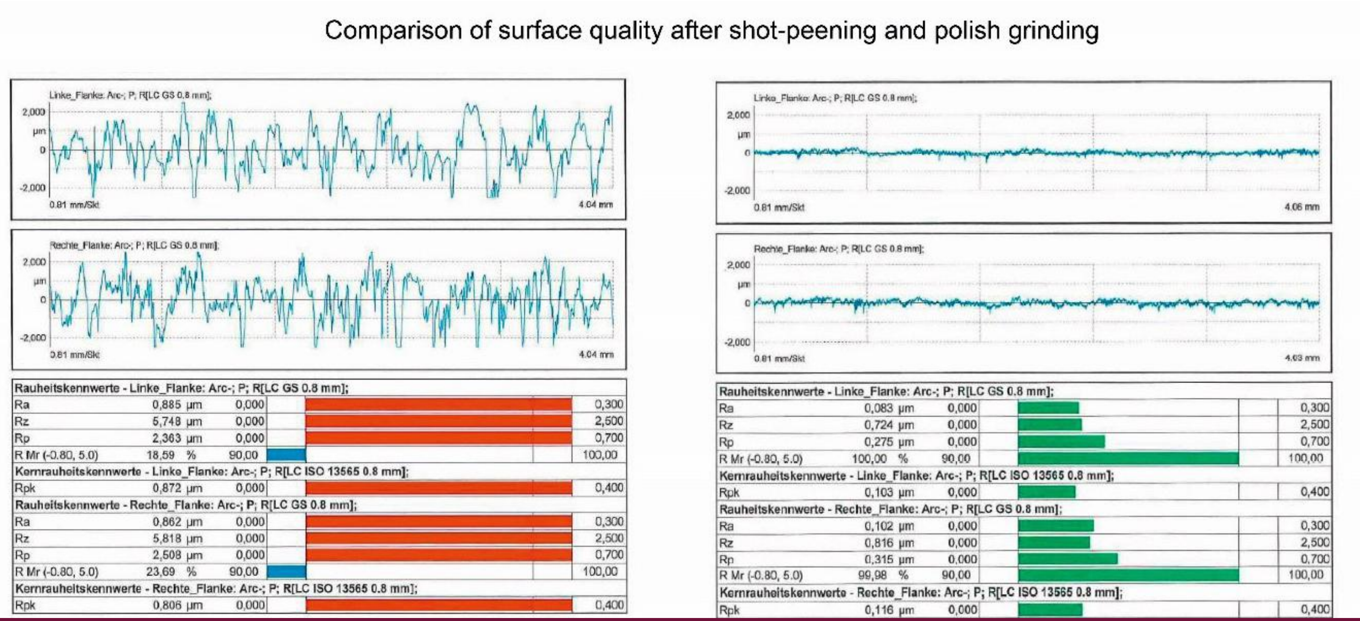
In summary, the following advantages are combined with the production sequence shown here:

Geometric accuracy through conventional generating grinding

Surface compaction through shot-peening

High-precision surfaces through polishing

This work chain contributes to increasing the efficiency and service life of the transmissions of today and tomorrow.



Rauheitskennwerte - Linke_Flanke: Arc-; P; R[LC GS 0.8 mm];				
Ra	0,885	µm	0,000	0,300
Rz	5,748	µm	0,000	2,500
Rp	2,363	µm	0,000	0,700
R Mr (-0.80, 5.0)	18,59	%	90,00	100,00
Kernrauheitskennwerte - Linke_Flanke: Arc-; P; R[LC ISO 13565 0.8 mm];				
Rpk	0,872	µm	0,000	0,400
Rauheitskennwerte - Rechte_Flanke: Arc-; P; R[LC GS 0.8 mm];				
Ra	0,862	µm	0,000	0,300
Rz	5,818	µm	0,000	2,500
Rp	2,508	µm	0,000	0,700
R Mr (-0.80, 5.0)	23,69	%	90,00	100,00
Kernrauheitskennwerte - Rechte_Flanke: Arc-; P; R[LC ISO 13565 0.8 mm];				
Rpk	0,806	µm	0,000	0,400

Fig 13: Surface quality after shot peening

Rauheitskennwerte - Linke_Flanke: Arc-; P; R[LC GS 0.8 mm];				
Ra	0,083	µm	0,000	0,300
Rz	0,724	µm	0,000	2,500
Rp	0,275	µm	0,000	0,700
R Mr (-0.80, 5.0)	100,00	%	90,00	100,00
Kernrauheitskennwerte - Linke_Flanke: Arc-; P; R[LC ISO 13565 0.8 mm];				
Rpk	0,103	µm	0,000	0,400
Rauheitskennwerte - Rechte_Flanke: Arc-; P; R[LC GS 0.8 mm];				
Ra	0,102	µm	0,000	0,300
Rz	0,816	µm	0,000	2,500
Rp	0,315	µm	0,000	0,700
R Mr (-0.80, 5.0)	99,98	%	90,00	100,00
Kernrauheitskennwerte - Rechte_Flanke: Arc-; P; R[LC ISO 13565 0.8 mm];				
Rpk	0,116	µm	0,000	0,400

Figure 14: Surface quality after polish grinding

The author is Patrick Duhre, Manager for Contracting and Test Grinding

The author is José López, Head of technology and tool development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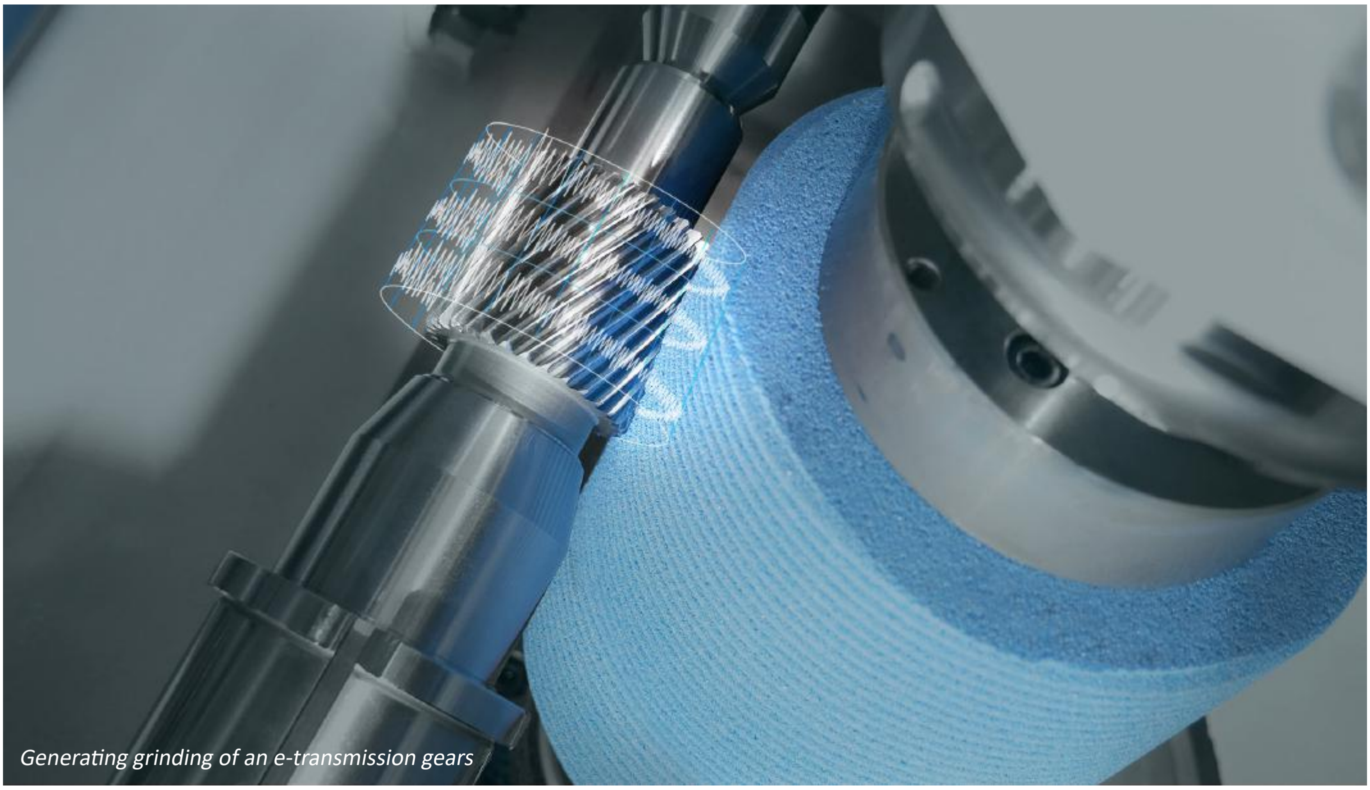
Intelligent generating grinding – quality assurance for e-transmission gears already on board


Generating grinding of an e-transmission gears

Transmissions for electric cars are much simpler in design than for conventional combustion engines, but place far higher demands on the manufacturing precision of the gears used. Thanks to completely new procedures for quality assurance directly in the final machining process, which is gear grinding, these specifications can also be met in series production.

Fully electric vehicle drives usually make do with two-stage, non-shiftable transmissions. One would think that this greatly simplifies the production. After all, this type of transmission design has just four gears, distributed between the drive shaft, the second stage with fixed gear and intermediate shaft, and the axle drive gear. But in reality, it's not that simple: first of all, engine speeds are much higher for the e-drive than for combustion engines, at up to 16,000 rpm. This means electric motors deliver an almost constant torque over a wide speed range. Unlike combustion engines, it is applied to the transmission right from zero speed. Furthermore, there is an additional constraint that makes production much more demanding than with the conventional drive train, as Friedrich Wölfel, head of machine sales at Kapp Niles, describes: "The noise from a combustion engine masks the transmission noise, meaning it is not noticed in the first place. On the other hand, an electric motor is almost silent. Above about 80 km/h, rolling noise and wind noise are the predominant sounds, irrespective of the drivetrain. But below that speed, transmission noise can be irritating in electric vehicles. We also have to take that into account when manufacturing gears."

Of course, the flank load capacity of the gears and good running properties are also of paramount importance with e-drives. However, the almost constant torque level and the high speeds require a different gearing design, which in turn can affect the noise dynamics. Here, in particular, demands are higher than with combustion engines.

However, when it comes to the pressure to generate maximum efficiency, there is no difference at all between gears for e-vehicles and conventional drives. Accordingly, the highly productive generating grinding process is also generally used as a fine machining process in the series production of e-transmission gears.

The challenge for Kapp Niles, as a specialist in the hard fine machining of gears, is to implement a generating grinding process that is both productive and, above all, optimized in terms of noise dynamics.

Hot on the heels of transmission noises

Achim Stegner, Head of Predevelopment at Kapp Niles, describes the basics: "Depending on the modifications of the gearing defined at design stage, such as line corrections, width convexity, head retraction, as well as the profile and line interlocks typical of the process, characteristic noises occur in the transmission during meshing, which can be assigned to specific tooth meshing frequencies. The entire transmission, in turn, also exhibits characteristic properties with regard to structure-borne noise and radiation, depending on the constructive design. This is stimulated in the tooth meshing frequency and its multiples. Manufacturers try to minimize this effect as much as possible by adapting the design of transmission and gears."

For the time being, these considerations only apply to "perfect" gearing. But of course, like any other mechanical component, gears also generate variances from the ideal target geometry in series production. These have different causes and effects, as Achim Stegner explains: "In addition to the stimulation caused by the tooth mesh, there are other disturbance variables that can result in noises in the tooth mesh. These make themselves felt as 'ghost frequencies'. These are frequencies that do not coincide with the tooth meshing frequencies and their multiples, and can just be introduced into the component during grinding." Ghost frequencies are caused by minimal irregularities that are almost impossible to completely avoid in series production. It becomes particularly critical when these variances map almost exactly onto the circumference of a gear, as this results in harmonic stimulation. It takes a lot of expertise and process experience to recognize the reasons for such irregularities and, if possible, to avoid them in the first place.

The cause of such malfunctions can be found, for example, in the axis drives of the machine tool used. Electric motors have certain pendulum moments. Measuring systems work with discrete line counts and finite eccentricity errors from assembly. Last but not least, balance condition and spindle bearings can contribute to possible irregularities. Waviness as small as 0.1 micrometer can cause noise in gears. Achim Stegner explains some more causes: "Every machine has natural vibrations. For example, the typical natural frequency of a workpiece spindle is about 250 Hz. This can also be reproduced exactly on the workpiece if the speed constellation in the generating grinding process is unfavorable. We can eliminate such effects by the clever choice of a suitable speed window during machining."

Once the optimization potential on the machine side has been exhausted, there are also a number of technological options for improving component quality in terms of noise dynamics. These include, for example, the selection of the number of gears of the grinding worm, the speed ratio during dressing and grinding, the finishing speed and the feed rate.

Not all errors are the same

Roughly speaking, there are two typical types of error patterns in serial gear grinding: on the one hand, trends are emerging that show a continuous change in characteristics. On the other hand, there are individually conspicuous components. Trends are usually easier to control. They can be caused, for example, by the gradual wear of a grinding worm. If permissible manufacturing tolerances are exceeded here, it is usually sufficient to shorten the cycle between two dressing processes. They can also be easily recognized during component testing by a gradual approach of the measured values to the tolerance limit.

Component-specific defects, on the other hand, are unpredictable. They become noticeable through sudden deviations in one or even several quality criteria. This can be caused by grinding worm chipping, workpiece blank errors or set-up errors.

Since the actual machining of a gear takes much less time than the control measurement in highly efficient manufacturing processes such as generating grinding, it is also not possible to inspect every single component. In addition, as described at the beginning, quality demands for gears for e-transmissions are extremely high. "The required tolerances of profile angle, flank line angle, concentricity, two-ball dimension are in some cases smaller than in the conventional drive train by a factor of 3. For the flank line angle error fHß, a typical requirement is ± 4 micrometers; with combustion engine transmissions, this was sometimes ± 13 micrometers," says Friedrich Wölfel, describing the requirements of his customers. Together with the required machine and process capabilities, these quality requirements are testing the limits of what is technically and economically feasible. And the static and dynamic stability of the processing machine and process cannot be increased at will. The only way out is to start with the methods of analysis and control. Because otherwise: the narrower the tolerance limits become with the same machine/process capability, the greater the number of measured components must be. However, this involves a great deal of effort. And ultimately, downstream component testing does not add value either.

With regard to the approach to trend-related deviations from the target geometry in particular, the 'closed loop' has already established itself as an important tool. This accelerates and improves the feedback between downstream gear measurement and the processing machine itself. Here, the results of the inspection on the measuring machine are no longer printed out and made available to the machine operator on paper for evaluation, but are transmitted directly to the processing machine as a standardized file. The grinding machine then uses preselectable tolerance corridors to decide independently whether it needs to intervene in the process at all, for example with scalable correction values. If unexpectedly high variances from the target geometry occur, the decision on how to proceed is then up to the operator themselves (Fig. 1).

The referee at the end of the manufacturing process

At the end of the manufacturing process of a complete transmission is what is known as an 'end-of-line test bench'. It is no longer just individual gears that are tested here with regard to their quality, but fully assembled transmissions are evaluated. They go through various test cycles that simulate operating conditions in an actual vehicle. The operating noise is also recorded. Acousticians can analyze this data to extract intervention ratios, typical frequencies and possible interfering noises. "Unfortunately, this also means that gearing defects are only noticed at the end of the manufacturing process," complains Friedrich Wölfel. "The complete transmission must then be dismantled, the individual components checked and, based on this, analyzed to determine which component is responsible for the anomaly on the test bench. It could also be that a complete

Fig 1: Tolerance corridors for closed loop

batch of components can cause problems. But that only becomes apparent when the entire value chain has already been completed."

Today, it is possible to identify components that could cause noise before they are installed in the transmission. A very common procedure for e-drives is the waviness analysis on gear surfaces. Here, profile, line and pitch measurements are carried out on all teeth on the gear measuring machine and lined up in such a way that the gear is mapped over its complete circumference. The waviness on the gear wheel can be mathematically measured. However, starting with the complete measurement of the gears, this procedure is very time-consuming and thus unsuitable for testing every single piece in series production. Friedrich Wölfel on this: "The grinding time of typical e-transmission components is less than one minute, whereas the measuring time is four to six minutes; indeed, in the case of an all-tooth measurement as the basis of a waviness analysis, it can be significantly more. And ultimately, downstream component testing does not add value either. What is needed here is further development of in-process analysis, which allows conclusions to be drawn about the component quality produced during the machining itself."

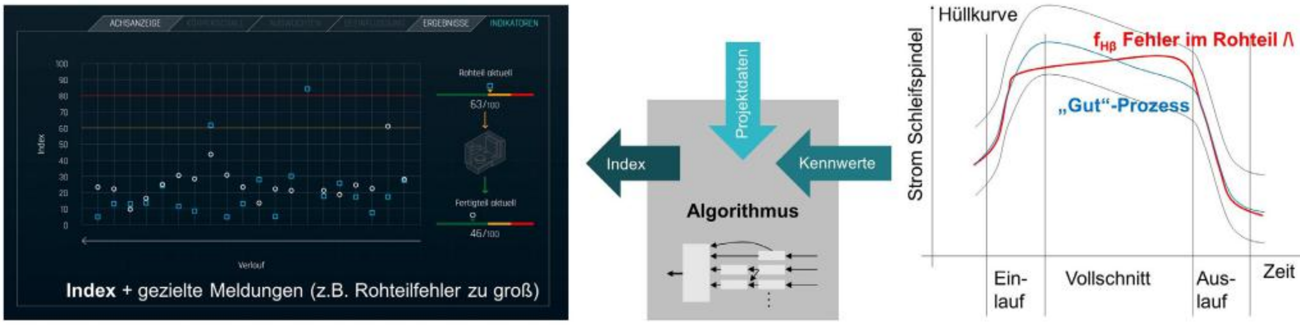


Fig 2: Error analysis and index calculation in the machining process

Identify possible noise problems at the machining stage

A promising approach is indeed to detect possible defects as early as the grinding process. Process monitoring is the buzzword. Achim Stegner explains the approach: “We already have numerous sensors and measuring systems in the machine that can provide us with many indications, measured values and information. At the moment, we primarily use it only to operate the functions of the machine. In the future, however, we also want to use it to assess the machining process directly in the machine.”

However, this does not mean integrating an additional tactile measuring function into the grinding machine in order to achieve a faster closed loop. Nor is it a question here of inspecting a ground component directly in the machine, evaluating it and correcting any discrepancies during the production of further components. The focus is rather on analyzing the machining process in real time (!) in order to detect deviations from a previously defined reference process. However, it is not enough to only define envelopes for signals from the machine to do this. This can be explained using the “power consumption of the grinding spindle” signal in Fig. 2 as an example. This signal can be used to detect a possible flank line angle error (fHß) at an early stage. Stegner: “However, the procedure via envelope detection reaches its limits here, as the error is difficult to identify. As long as the signal remains within the envelope, no alarm gets triggered. So you need a more intelligent form of evaluation. An artificial intelligence that attempts to emulate human decision-making structures. This involves making decisions based on a multitude of different information – overlaid with the person’s own experiences – upon which they act.

Process monitoring: intervene before it’s too late

Process monitoring can be defined as component-specific monitoring and evaluation of the grinding process. As described, it is not a trivial matter to generate an action instruction from the sensor signals. But it is possible. Various characteristic values can be formed from time signals. In the simplest case, these can be maximum or RMS (Root Mean Square) values of the signals. The characteristic values are then combined with the known project data via algorithms and processed into indices, for example a noise or screw breakout index. Achim Stegner explains about the transmission noises specifically: “An order analysis similar to the order spectrum on an end-of-line test rig can be created for noise-critical components via an FFT (Fast Fourier Transformation). This makes it easier to classify the recorded signals and relate them to results on the transmission test bench (see Fig. 3). Measurement data that is not processed is of no use.” In the end, especially in the manufacturing environment, only appropriate indices help to identify errors very specifically.

The benefits of process monitoring can therefore be seen in the following points:

- 100% testing of all components
- Identification of anomalies while still in the grinding process
- Detection of component-specific faults
- Targeted reporting of irregularities
- Adaptive intervention in the process
- Parts tracing

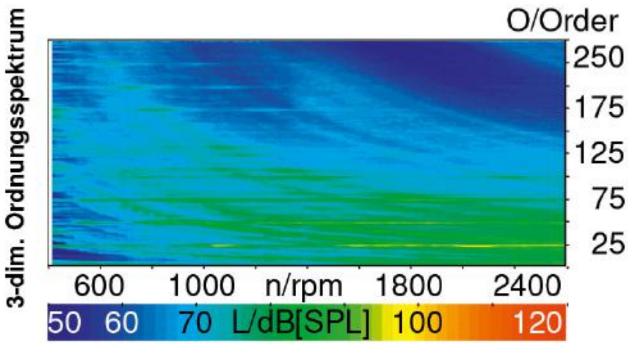


Fig3: Order spectrum, recorded on a transmission test bench

Next step: standardization

Process monitoring is not yet an app that you can simply download and use. Rather, it is a customer- and application-specific development that defines and monitors indices in relation to the respective component. But even this first step is far more than was considered feasible until only recently. Achim Stegner on this: “Several pilot customers are already using this functionality today. We are already able to detect different errors and intervene on the process side. In addition, we are already working on having the grinding machine teach itself characteristic values for new components. However, this of course requires broad empirical knowledge from error patterns, the geometric quality of the components and corresponding feedback from the transmission test bench.” Friedrich Wölfel adds:

“The next goal is that the user can also use this functionality without our component-specific support. It is also important to understand that process monitoring and closed loop are not contradictory, but complementary.”

Both approaches to process-integrated quality assurance are already available for Kapp Niles machines today and are continuously being given further functional scopes and utilization options through the experience gained from series production.

The unique benefits of Herringbone Gears

Despite the complexity in manufacturing them, Herringbone Gears offer a lot of benefits to the industry

By: Mihir Dilip Kannadkar

Herringbone Gears are a unique gear type. Many of us won't get an opportunity to see one being cut, or even used. Each groove generated by teeth cutting is V-shaped, and when all the grooves are looked at collectively, it resembles the bones of the Herring fish. Hence the name Herringbone Gears. Often, these gears are wrongly addressed as Double Helical Gears, but the apex of the Herringbone Gears is the major distinguishing factor between the two types.

Those coming from a design, engineering or production background will understand and appreciate the generation of the apex which is central to both the helixes, and the unique advantages it provides the user.

Manufacturing

Herringbone Gear cutting is an involute process, done using Sykes equipment or Sunderland gear-cutting equipment. MAAG equipment also can cut Herringbone Gears. The Sykes cutting uses a cutter which is similar to the helical shaping cutter, while the Sunderland uses a Rack type cutter for gear cutting. Usually, the helix angle is 30 degrees on Herringbone Gears. Forty-five-degree Herringbone Gears can also be manufactured. The gear-cutting process is an excellent example of kinematic synchronization for modern-day engineers to witness.

The manufacturing complexities and the limitation of not being able to grind the tooth profile of Herringbone Gear are the major reasons for limited application of these gears in modern-day scenarios.

Advantages

Still, from a design perspective, Herringbone Gears provide a major advantage. They do not produce any thrust load like the simple helical gears. This eliminates the need of thrust-bearing from the assemblies where herringbones are used.

In case of a standard helical gear, as the helix angle increases, the thrust load also increases. This limits the use of the helix to 20-25 degrees only. In herringbones, due to the opposite, i.e. LH and RH helix angles, the thrust force generated gets canceled out and allows the use of higher helix angles, which helps in reducing vibration and tooth wear significantly. It also increases the load-carrying capacity of the gear tooth.

These gears are capable of self centering/ balancing up to a limited extent. They owe this property to the design and tooth form.

Application

Herringbone Gears find applications in the oil and gas industry, the food and beverages industry, the pulp and paper industry, the pump industry, the cement industry and the steel rolling industry, among others. Herringbone Gears are specially required in high torque with relatively low-speed applications. These gears offer a very high degree of engagement between the teeth at all the times. Hence, especially in pump applications, the flow achieved is continuous, and the pump operation is completely pulse-free. The high engagement is also the reason why these gears are used where highly viscous fluids are present.

The fact that Herringbone Gears do not generate thrust load, and thereby eliminate the thrust bearing, is a major cost advantage. Heavy thrust bearing may have been required if helical gears were to be used. Along the same lines, the maintenance time, effort and cost also remain low when Herringbone Gears are used.

The author, Mihir Dilip Kannadkar, is Executive Director, SG Gears

THE ADVANTAGES OF WORM GEARED MOTORS

The versatility, affordability and flexibility of Worm Geared Motors make them a popular choice

By: Rajan Narayanaswamy

Worm gear boxes were first introduced to the market in the First World War. And even after a century, they rule the industrial segment. Originally, the products were bulky, designed as they were using cast iron, phosphor bronze and steel. Still, there is practically no segment which doesn't use worm gear boxes or geared motors. For over four decades, they have been used in sugar and fertilizer factories too, among others.

Why are Worm Geared motors popular?

Worm geared motors are versatile, affordable and flexible enough to be mounted in any position. In addition, building them requires only a few components. A worm geared motor provides a 900-degree input output orientation. The prime mover will fall in line with the equipment without projections. Hence, the complete machine looks very compact. Comparatively, alternate options such as Spiral Bevel and Hypoid Geared Motors are expensive. Also, Hypoid and Spiral Bevel Geared Motors also use a higher number of components. The process cost, such as profile generation and hardening and grinding of pinions and wheels, is also expensive, considering the process time and cost of the machinery.

What are the applications and best suited geared motor?

For equipment speed between 300 to 60RPM, Worm Geared motors offer a good solution with fairly good efficiency. In case of equipment speed under 60 RPM, Hypoid or Spiral Bevel Geared Motors offer good solutions with excellent efficiency. Where there is no space restriction, inline Helical Geared Motors can also be used. In the case of Inline Helical Geared Motors, the processing cost is comparatively less, as the gears are generated in inexpensive machines.

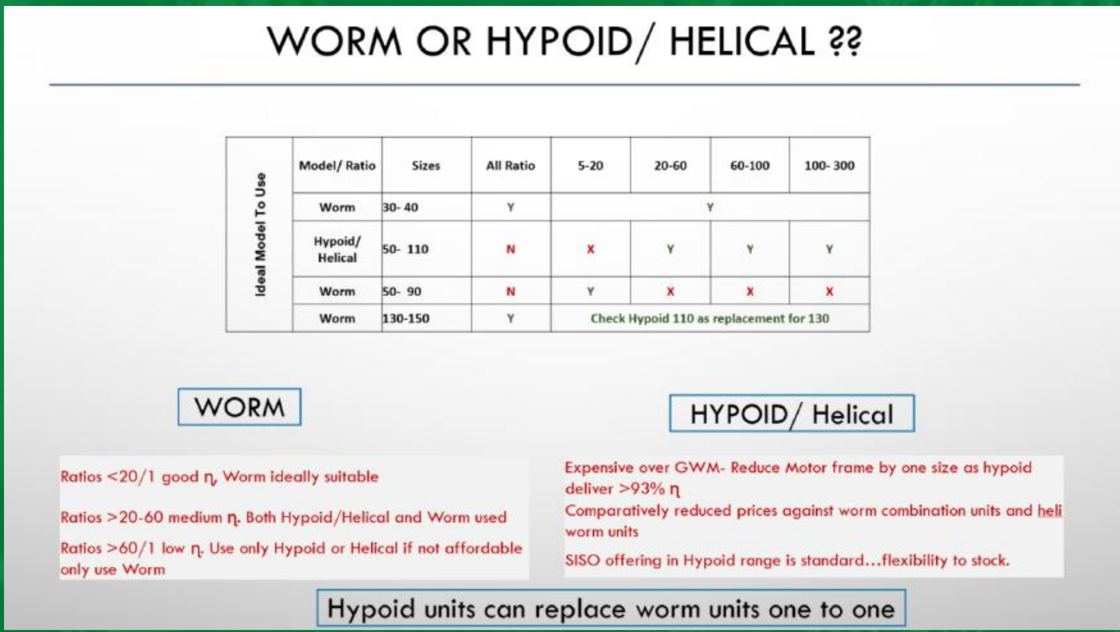
Applications

Worm Geared Motors are mostly used in continuous duty applications or stop-and-start applications with a good stop time. Generally, Worm Geared Motors are used in applications having four starts and stops per hour. In case of frequent stop and stop, the geared motor should be selected with a good service factor – close to 2. Alternatively, Hypoid, Spiral Bevel or Helical Geared Motors are used.

Worm Geared Motors can absorb a mild shock in the application as the worm wheel is made of a soft material. In the case of Spiral Bevel, Hypoid and Helical Geared Motors, through they are efficient, the load on the gears gets transferred to the bearings rigidly, leading to frequent bearing failure and pitting of the gear and pinion teeth surface.

Design of a Worm Geared Motor

Worm Geared Motors generate more heat than other types of geared motors. This is because transmission occurs through the sliding of the worm over the wheel. It's a like a thread-and-screw concept. Hence the worm gearbox casing is adequately designed to transfer the generated heat. Some of the manufacturers design the casing with many fins to expand the surface area of the gear



WORM OR HYPOID/ HELICAL ??

Ideal Model To Use	Model/ Ratio	Sizes	All Ratio	5-20	20-60	60-100	100- 300
	Worm	30- 40	Y	Y			
	Hypoid/ Helical	50- 110	N	X	Y	Y	Y
	Worm	50- 90	N	Y	X	X	X
	Worm	130-150	Y	Check Hypoid 110 as replacement for 130			

WORM

Ratios <20/1 good η, Worm ideally suitable

Ratios >20-60 medium η. Both Hypoid/Helical and Worm used

Ratios >60/1 low η. Use only Hypoid or Helical if not affordable only use Worm

HYPOID/ Helical

Expensive over GWM- Reduce Motor frame by one size as hypoid deliver >93% η

Comparatively reduced prices against worm combination units and heli worm units

SISO offering in Hypoid range is standard…flexibility to stock.

Hypoid units can replace worm units one to one

Pic 1: An inadequately designed casing

Pic 2: An example of many fins and an expanded surface area

units (Picture 2). Others cut cost by reducing or removing the fins. Such gear units are bound to heat up excessively, resulting in the lube oil losing its property within a short time. It leads to the failure of bearings, and wearing off of the worm wheel, as shown in Picture 1.

For the same reason, Worm Geared Motors are designed with breather or air vents, allowing the gearbox to breathe easily, where hot air comes out and cold air goes inside the box. If a breather or vents are not fitted, the pressure inside the gear unit can go up, leading to the lube oil seeping through the seals, causing oil leakage over a period of time. Since the air inside the gear unit is hot, the lube oil will lose its property and the worm gear will wear out faster and have a life shorter than one it was designed for.

Where to use Worm and other geared motors

It is always the application requirements that lead the way, and not the technology. The engineer selecting the gear unit has to match the application needs with the properties of the gear units and not the technology, and that makes all the difference.

The author, Rajan Narayanaswamy, is Sales Director, Gaeyah Transmission, Chennai

SMALL WORM - GREAT POTENTIAL

Generating grinding of an e-gear shaft with interference contours. (Courtesy: KAPP NILES)

Gearboxes used in electric vehicles are not only designed for high speeds and high torques – they are also very compact. This is true for the automotive sector, and above all, for innovative types of applications such as e-bikes. These small gearboxes with high-power density and electric drives inspire design engineers to come up with more creative solutions. In many cases, they comprise small components with interfering contours, which pose new challenges for production. When hard finishing these gears, the process-related potential goes hand in hand with high production costs. The most economical option is probably generating grinding. However, not all generating grinding machines are suitable for the production of the compact components. This article outlines the relevant demands and demonstrates possible solutions.

Transmission manufacturing does not have to be reinvented to become suitable for the e-mobility sector, but there are definitely some new challenges to be faced. These include, above all, the high power density and the compact installation space in which the entire power train must be accommodated. At the same time, the new areas of application are opening up new sales opportunities: e-bikes, for example, have recently gained in popularity. They significantly enhance range and transportation capacities in everyday life and during leisure time. Correspondingly high is the demand. This benefits the manufacturers and their suppliers – gearbox manufacturers among them. However, be it two or four wheels: The drive technology is sophisticated. The focus is on the required flank load capacities and the noise behavior of the gear due to the boundary conditions imposed by the electric drive motor – an almost constant high torque over the speed range of 0 – 18,000 rpm. New challenges are not only limited to the machined parts but also directly affect the manufacturing process. Due to the compact design, an increasing number of components with interfering contours emerge in the gearbox design. Large tools with standard grinding worm dimensions quickly and literally meet their limits. To avoid having to resort to more time-consuming and thus more expensive processes, the tools must also be miniaturized.

Identify and overcome boundaries

Up to now, the hard finishing of gears with interfering contours has mainly been accomplished by discontinuous profile grinding or gear honing.

Compared to continuous generating grinding, both aforementioned processes feature different disadvantages in terms of productivity, economic efficiency or quality consistency. The problem is that the common grinding worms measuring 300 mm in diameter are too large to handle components with interfering contours. At the same time, smaller tools require higher speeds in order to achieve high cutting speeds. However, previously implemented machine concepts were not designed for the high dynamic requirements regarding tool and workpiece drive. New types of high-speed spindles in combination with a dynamic direct drive of the workpiece axis offer a solution. This enables the exploitation of the advantages provided by generating grinding – a process that features shorter machining times, lower tool costs and a very high level of quality consistency. The economic efficiency of generating grinding in direct comparison to profile grinding can be demonstrated by means of the two selected components "car" and "bike" (as shown in Figures 1 and 2). The corresponding tables ("Car" and "Bike") provide an overview of the related time and cost benefits.

The right machines to cover the requirements

The Coburg-based machine tool manufacturer KAPP NILES specialised in system solutions for grinding gears offers two machine types for meeting the above-mentioned customer requirements. Both series are equipped with high-efficiency drives for the tools (25,000 rpm) and the workpieces (5,000 rpm).

The KNG 350 flex HS has a conventional design featuring one workpiece drive. The machine is available in two versions: for smallest and small lot sizes with manual loading. For higher volumes, an automated version with an integrated ring loader is available. Workpieces up to 350 mm in diameter can be processed using this machine. The machine features short set-up times, which are achieved through the use of intelligent components and unique ergonomics.

For large batch production, however, it is definitely worth taking a closer look at the non-productive times of the machine. The KX TWIN series with two workpiece drives and a loading and unloading process that is performed in parallel to the actual grinding operation offers further potential for the reduction of non-productive times. The in-line centrifugation of the components directly in the machine enables compliance with the "Clean Factory" approach across all known automation concepts.

Additional production-related requirements

In addition to the machining of compact components with interfering contours, the following additional challenges arise when it comes to the production of e-gearboxes:

• The noise behavior of the gearbox and thus especially of the gear teeth has been increasingly gaining in significance.

• As the load-bearing capacity of the gear is being continuously further improved, the topology of the tooth flank is increasingly moving into focus. During the generating grinding process, a natural entanglement occurs on the machined tooth flanks.

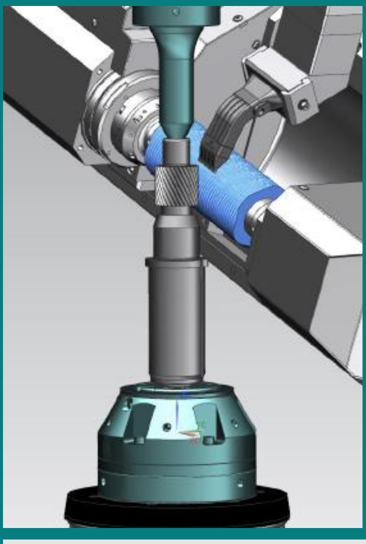


Fig 2: Workpiece "car": Tip diameter: 49.5 mm; module: 1.33 mm; number of teeth: 31, face width: 44 mm

Table Car	Profile grinding	Generating grinding
Tool data		
• Diameter [mm]	80	80
• Cutting material	CBN (galv.)	Corundum
• Groove / number of starts	1	5
Non-productive time [s]	228	53
Tool cost per workpiece [€]	0.75	0.21

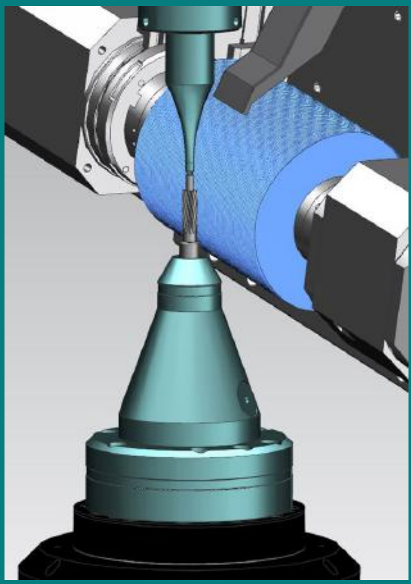


Fig 1: Workpiece "bike": Tip diameter: 11.8 mm; module: 0.72 mm, number of teeth: 13, face width: 12 mm

Table Bike	Profile grinding	Generating grinding
Tool data		
• Diameter [mm]	100	110
• Cutting material	CBN (galv.)	Corundum
• Groove / number of starts	1	5
Non-productive time [s]	75	20
Tool cost per workpiece [€]	0.17	0.04

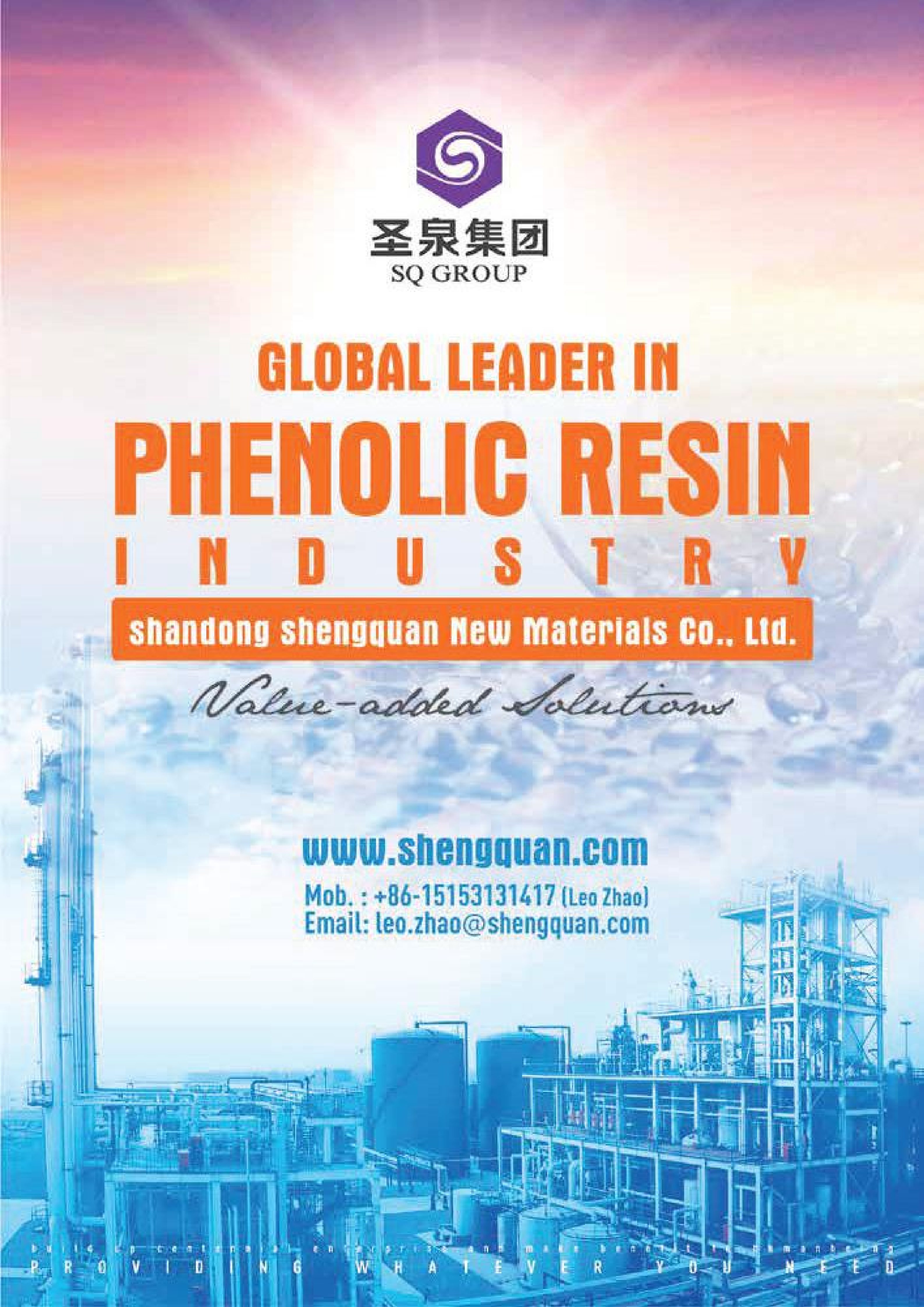
With the innovative KN grind software, this phenomenon not only can be simulated in advance, but can also be completely eliminated or precisely manipulated.

• An additional issue is the surface roughness. With a standard tool, values of an average roughness depth Rz = 2.5 – 3 micrometers can be reliably achieved with continuous generating grinding. For higher requirements, KAPP NILES offers tool sets that have two different zones: one featuring standard grit and another designed for fine or polishing grinding, depending on the surface requirements. This allows for roughness values of Rz < 1 micrometer. The significantly increased contact ratio of the tooth flanks boosts the maximum load capacity of the gear. Another advantage of this process is that it can be integrated into automated process chains with "one-piece-flow", which has not been possible with vibratory finishing used so far.

Conclusion

Extensive expertise and state-of-the-art solutions are required for the production of e-gearboxes that offer more than the technical standard of gearboxes used in conventional combustion engines. This involves challenges but also creates great opportunities for manufacturers who have mastered the deployment of the latest production methods. Generating grinding using small tools is one of the building blocks. Today, KAPP NILES offers a wide range of solutions far beyond conventional machine tool manufacturing. Process monitoring, part tracing and in-line quality assurance are increasingly becoming an integral part of modern manufacturing systems. This means that even manufacturers in high-wage locations can prevail in international competition. Especially in times when the industry has become painfully aware of the vulnerability of globalized manufacturing, this is a huge opportunity to counter cost pressures.

The authors are Graduate physicist Martin Witzsch, freelance journalist on behalf of KAPP NILES, and Ralf Dremel, Technical Product Manager at KAPP NILES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Drop-in replacement gearboxes for all brands

Jay Shah
Director
ESENPRO POWER TRANSMISSION PVT LTD

Please tell us a little about your company and its expertise.

ESENPRO, a brand of ESENPRO Power Transmission Pvt. Ltd., is one of the leading manufacturers and exporters of high quality industrial gearboxes.

We are in the business of designing, manufacturing and servicing all types of industrial gearboxes, and offer our products both in standard and customized categories.

ESENPRO executes re-engineering of existing / old gears and gearboxes for any plant and machinery, to enhance their capacity, withstand higher speed, feed, and load, within the existing mounting dimensions.

ESENPRO designs and supplies drop-in replacement gearboxes. These gearboxes replace the old gearbox exactly, without an inch of modification to the existing foundation.

In addition to the existing range of products, ESENPRO has an independent engineering team to develop planetary gearboxes for steel, power, sugar, material handling and mining.

Tell us a little about the company's production capabilities, and which industries you serve.

ESENPRO is equipped with complete in-house designing, machining, gear grinding, metrology, calibration, and assembly and testing facilities. The ESENPRO gearbox range includes helical gearboxes, bevel helical gearboxes, worm gearboxes, crane duty gearboxes, cooling tower gearboxes, extruder gearboxes, rolling mill gearboxes, and aerator gears and special gearboxes for crane, power, steel, paper, and mining industries. We also manufacture open gears as per customer design.

Helical gearbox

Helical gearbox

What are some of ESENPRO's latest product launches?

ESENPRO is a trusted brand for customized gearbox solutions. With our expert design and engineering team we are developing industrial gearboxes for high power and high torque demands.

Our latest product development includes:

1. Upgrading Cross Travel Drive for 500T Molten Metal Handling Crane
2. Helical – Planetary Hoist Gearbox for Mine Winders
3. Primary Gearbox for Rubber Calendar Machine
4. Integrated Drive System for Belt Conveyor

What are the latest technological developments/ upgrades in the company's offerings?

ESENPRO brings an innovative solution for customized gearbox requirements. We design one-to-one replacement of the customer's existing gearbox. We ensure to maintain the performance and quality standards of the same. Enhancement of power ratings of the gearbox within the same footprints of the existing gearbox is provided too. Drop-in replacements are produced for all types of industrial helical, bevel, helical and

Helical gearbox

Bevel Planetary Gearbox

Custom Design Helical Gearbox

Helical gearbox

planetary gearboxes for steel, cement, plastic, rubber, mining, power, cranes, chemical and sugar industry of any brand.

Does the company do any CSR activities, or take measures to reduce the carbon footprint?

We believe that reducing unnecessary energy inefficiencies is an important step to minimizing the carbon footprint. Switching off lights and computers when they're not required, and finding out which machines need to be on standby and which can be switched off, using transport plans logistically, minimizing water waste, ensuring proper disposal of waste generated by various grinding machines – these are areas of concentration to reduce our carbon footprint.

How will the launch of Gear Technology India help the industry?

GTI can provide real cases wherein any gear manufacturing industry has experienced an increase in efficiency, reduced noise level etc,. by virtue of having introduced any advanced technology. Articles on gear failures, heat treatment and current industry demands too will help disseminate knowledge.

UNCONVENTIONAL GEAR PROFILES IN PLANETARY GEARBOXES

Anand Varadharajan, Pablo Lopez Garcia, Stein Crispel, Bram Vanderborght, Dirk Lefeber and Tom Verstraten

Gear wheels have been used for transmitting motion since the 3rd century BC (Ref. 1). Yet, the evolution of this transmission technology continues to date and finds its inevitable need in numerous applications. The multifaceted advancements in design, material, tribology and other areas collectively help the improvement of transmission efficiency, noise vibrational performance, durability and effective manufacturability of the gears (Ref. 2). Today, gearboxes are inevitable in numerous applications requiring high power density including wind turbines, electric vehicles, cranes, robotics, etc. A combination of high-ratio gearboxes with high-speed, low-torque motors is often used to achieve high power density (Ref. 3). Planetary gear trains (PGTs) help achieve a high gear ratio in a compact arrangement. Several configurations of planetary gears are widely studied in Refs. 4–8 where the gear profiles used in these studies are primarily involute.

From simple geometries like straight profiles to cycloids and then to the involutes, the evolution of gear profile geometry has been centuries (Refs. 9 and 10). The concept of profile shifting and the CNC manufacturing process that began in the late 1970s marked an important revolution in transmission systems and helped the manufacturing of precise and mass quantities of standardized gears. To this day, involute gears have found their use in every possible application despite their continuous betterment. The strongly established standards and guidelines like AGMA have provoked the large commercialization of involute gears. Numerous computation and design software including KISSsoft, ROMAX, Simcenter, MESYS, etc. help in involute gear design and analysis. This software not only helps to design simple gear trains but also enables us to optimize the design based on the contact/ meshing performance, and manufacturability. Although the advantages of involute gears like easy manufacturability, and insensitivity to center distance deviations are critical for its choice, the well-established standards in the previous decades and mass commercialization compels the use of involute gears. Because of this, the developments on other gear profiles (non-involutes) are very limited to this date despite the enormous advancement in high-precision manufacturing technologies (Ref. 11).

The downsides in involute gears like high-sliding velocities at the meshing extremes and low surface-load capability can be overcome with other gear geometries like cycloids and circular arcs (Ref. 12). Typically, the modifications are classified based on gear profile, flank and lead parameters (Ref. 13). The research works of Parsons (Ref. 14) show lead and flank modification of gears that help increase the load-carrying capacity of gears and better noise characteristics while Shen et. al. (Ref. 15) and Berlinger (Ref. 16) employ profile modification for achieving high efficiency and load-carrying capacity respectively. Yet, increased transmission error and sensitivity to manufacturing inaccuracies deter the usage of these unconventional gear profiles.

Through this paper, a review of unconventional gear profiles in planetary gear is presented and how future research in this direction benefits several applications. The analyses of different gear profiles show that some unconventional gear profiles have better meshing efficiency and load-bearing capacity than the involute gears. However, they are heavily constrained by their high transmission error and manufacturing inaccuracies.

"Overview of planetary gear trains and increasing the overall efficiency" provides an overview of planetary gear trains (PGTs) to understand the importance of high meshing efficiency in extreme gear ratios. In "Critical parameters to evaluate different gear profiles," a short description of the evaluation criteria of different gear profiles is briefed. "Unconventional gears in PGT" reviews planetary gearboxes with non-involute gear profiles from the literature and the potential gear profiles that can help to improve the efficiency of the high-ratio gearbox. Finally, a discussion on the confrontation of different gear profiles based on the evaluation criteria is provided in "Discussion" which is followed by conclusions and recommendations in "Conclusions."

Overview of planetary gear trains and increasing the overall efficiency

Planetary gears are compactly arranged gear trains that achieve high gear ratios with good efficiency. Traditionally, large gear ratios are achieved by coupling several planetary gear stages together which is known as a stacked arrangement—refer to Figure 1 (left). The efficiency of multistage PGTs (or stacked PGTs) is high (above 90%) even at gear ratios around 100:1 (Refs. 17, 18). However, the involvement of several stages is a severe downside of these gearboxes thereby becoming a bulky, heavy, and costlier solution.

On the other hand, an extremely compact arrangement of planetary gear trains known as the Wolfrom configuration (also called coupled-PGT, differential-PGT or 3K-PGT) is an extremely power-dense transmission system that however comes at the cost of very low efficiency, refer to Figure 1, (Refs, 4, 5, 8, 19, 20).

This type of gearbox has the potential to bring a massive transformation in several applications due to its high-torque-density nature. Yet at this juncture, they are restricted to extremely poor efficiency at high reduction ratios due to latent power inherent to this configuration (Refs. 21, 22).

Wolfrom gearbox efficiency is characterized by the gear ratio and the meshing efficiency of involved gear pairs. From (Ref. 4), the Wolfrom gearbox efficiency is given as:

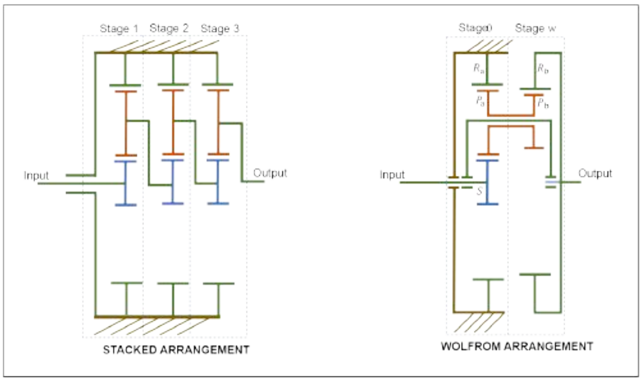

Fig 1: Planetary gear train configurations: (Left) stacked arrangement, (Right) Wolfrom-PGT

$$\eta_{Tot} = \frac{1 + \frac{H_i}{i_0} - H_e\left(1 - \frac{1}{i_0}\right)}{1 + H_i\, i_w + H_i(i_w - 1)}$$

$$H_i = 1 - \eta_i \text{ and } H_e = 1 - \eta_e$$

$$i_0 = 1 + \frac{Z_{Ra}\,Z_{Ps}}{Z_{Pa}\,Z_S}\;;\; i_w = \frac{1}{1 - \frac{Z_{Ra}\,Z_{Pb}}{Z_{Rb}Z_{Pa}}} \text{ and } i_{tot} = i_0 \cdot i_w$$

where

η_{Tot} is the total efficiency of the gearbox

i_0, i_w, i_{tot} are the gear ratios in stage-0, stage-w and total gearbox respectively

H_i, H_e are the gear loss factors in internal and external gear meshing respectively

η_i, η_e are the meshing efficiencies in internal and external gear meshing respectively

Z is the number of teeth in the respective gear wheels

This shows that in a Wolfrom planetary gear train (differential), the meshing efficiency of gears is extremely crucial as the gear ratio increases. Figure 2 is a representative example of a Wolfrom-PGT where the evolution of a gearbox efficiency is plotted in function of gearbox ratios for different meshing efficiencies (Ref. 23). For high gear ratios (e.g., 300:1), even a small increase of 0.5% in meshing efficiency will decrease the gearbox loss by more than one third of the initial loss.

High gearbox efficiency is of paramount importance not only to reduce energy losses but also to have better backdrivability. Backdriving is the principle of switching the natural input and output of the gearbox (Ref. 21). Hence the power flow from the input (motor) to the output (load) is reversed where a reducer gearbox becomes then a multiplier. This is one of the key characteristics deemed in several modern applications including collaborative robotics (Ref. 24). The gearbox in general is backdrivable when the overall efficiency is more than 50% in normal operation—forward driving—(Refs.25, 26).

Critical parameters to evaluate different gear profiles

The gear performance can be characterized based on several phenomena even if it is involute or non-involute gear. Namely

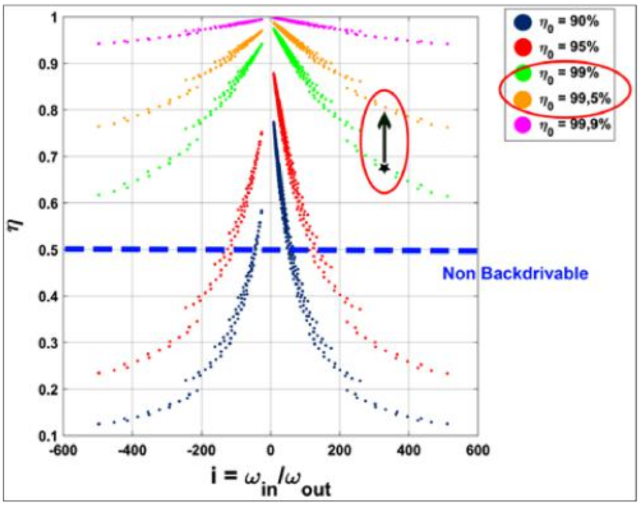

Fig 2: Evolution of gearbox efficiency for a three-stage PGT in the function of gear ratio for different meshing efficiency from (Ref. 23)

the load-carrying capacity, meshing efficiency, manufacturability, vibrational behavior and lifetime, etc. The primary criteria to evaluate the different gear profile geometry are discussed further.

Meshing efficiency

The power loss in gears is associated with both loaded and no-load conditions as described in (Ref. 27). The meshing losses can be calculated from:

where

$\eta_{i,e}$ is the meshing efficiency of gears

P_{IN} is the input power (kW)

$$\eta_{i,e} = \frac{[P_{IN} - \sum(P_{VZP} + P_R)]}{P_{IN}}$$

$$P_{VZP} = P_{IN} \cdot \int_0^b \int_A^E F_N\; v_s\; \mu\; d\theta \cdot db$$

P_{VZP} is the load-dependent power loss integrated along the path of action-AE and facewidth-b (kW)

P_R is the summation of all other losses due to gear no-load, bearings, lubrication, seals, etc. (kW)

µ is the coefficient of friction

F_N is the normal force acting on the gear tooth (N)

v_s is the sliding velocity of the gears in mesh (m/s)

$d\theta$, db are the integrating segments along the line of action (rotation) and the facewidth of the gears

Load carrying capacity

Gear wheels in action are characterized by the load transmitted and to what extent of efficiency. This is mainly dependent on the bending stress at the root and the contact stress at the surface of the teeth which influences their performance and lifetime. Considering the real operation, several factors depending on uniform/varying loads, lubrication conditions, and accuracy of manufacturing are derived from the standards and incorporated into the stress formulae.

Bending stress

The gear tooth fillet or the root stress is responsible for the breakage or tooth rip-off failure in gears. It is calculated assuming the cantilever beam principle and given by Equation 6. AGMA standards use additional factors considering manufacturing deviations, uniformity of load, distribution pattern in the helical system, fatigue profiles etc. (Ref. 28).

where

h is the height of the load point from the tooth root (mm)

$$\sigma_B = \frac{6\,hF_t}{l\,t^2}$$

F_t is the tangential force of the tooth (N)

l is the facewidth (for spur gears) or effective length along facewidth (for helical gears) (mm)

t is the thickness of the tooth at pitch circle (mm)

Contact stress

The contact stress in gears is responsible for the surface failure of the gear tooth. This failure leads to the pitting and scoring on the gear tooth affecting the lifecycles of the gears. The fatigue property of the material is critical to this stress. As a general approximation in involute gears, the contact stress is given by the Hertz formula (Ref. 28):

where

$$\sigma_c = \sqrt{\frac{F_N}{\pi\left(\frac{1-\nu_1^2}{E_1} - \frac{1-\nu_2^2}{E_2}\right)} \cdot \frac{1}{L\left(\frac{1}{\rho_1} \pm \frac{1}{\rho_2}\right)}}$$

F_N is the normal force (N)

ν_1,ν_2 are the Poisson ratios

E_1,E_2 are the Young's modulus

L is the facewidth (for spur gears) or minimum length of contact (for helical gears) (mm)

ρ_1,ρ_2 are the effective normal radii of curvatures of gears with + for external & - for internal gears

The contact stress is calculated along the tooth surface at each point of contact. In general, the maximum load point corresponds to the single tooth of action where the entire load is concentrated to one pair of gear teeth.

Transmission error

For a given gear ratio, the deviation in the rotation of the gear for an equivalent rotation of pinion is called the transmission error. Transmission error is responsible for the noise and vibration of gears. The transmission error is an effect of both the gear design aspect and manufacturing inaccuracies of gears.

The design aspect comprises tooth deflections based on the load and the profile/lead modifications done to the gear profile for uniform wear patterns, etc. (Ref. 29).

The change in relative stiffness between gear teeth is kept to a minimum level for low vibration and noise conditions in gears which is handled by maximizing the gear contact ratio (Ref. 30). However, as the contact ratio increases along the transverse plane, the meshing extremes are far from the pitch point and thus the sliding velocities are high which is a trade-off in terms of meshing efficiency. On the other hand, it can be seen as an effective length of deformation during the meshing cycle; the more the gear teeth deform during meshing, the larger the area of the wear and thus the larger the friction and the power losses are. This can also be understood with the expressions given in "Meshing efficiency" where the necessity for keeping the sliding velocity low to reduce the power loss is evident.

Unconventional gears in PGT

In recent years, non-involute gears have started finding their place in high ratio gearboxes to increase the efficiency and load-carrying capacity of gearboxes. The advancements in rapid prototyping and precision manufacturing methods further enable fabricating complex geometries in a relatively efficient manner that supports testing and advanced analyses of gears. In the following section, some planetary gear trains that exclusively use unconventional gears are reviewed and their characteristics are discussed.

PGT with nonstandard involute teeth geometry

Low-loss gears described in Ref. 31 are optimized gears for high meshing efficiency. Although the fundamental tooth shape is involute, the low-loss gears involve unconventional profile

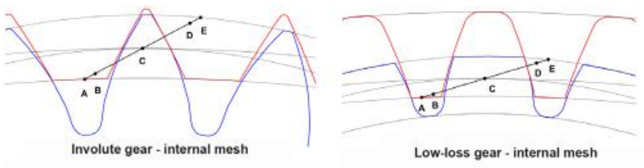

Fig 3: Internal meshing of low-loss gears (Ref. 6)

modifications to a large extent as shown in Figure 3. The tooth has reduced addendum, large pressure angle, small module and large helix angle and facewidth which contributes to decreasing the transverse contact ratio in gears. Although the increase of the helix angle, in principle, leads to a larger power loss (Ref. 31), the effect is countered by the increase in pressure angle and reduction of the gear modulus. Since the transverse contact ratio ($\varepsilon\alpha$) is kept to a minimal value, the meshing region involves a shorter approach and recess lengths leading to lower sliding velocities. To maximize the load-carrying capacity, the total contact ratio ($\varepsilon\alpha + \varepsilon\beta$) is maintained by increasing the overlap ratio ($\varepsilon\beta$) of helical gears.

Since low-loss gears have high meshing efficiency, this helps when used in a Wolfrom configuration to reach high gear ratios in a compact way and yet with good efficiency. Ref. 6 describes three different configurations of PGTs in which low-loss gears were tested initially. The results from Ref. 32 also prove that the weight of the Wolfrom gearbox is nearly reduced by 50% compared to the conventional planetary gear train of the same gear ratios although the overall efficiency deteriorates due to the configuration itself. Such a gearbox will be highly beneficial in high torque applications like wind turbines and automotive gearboxes if the efficiency could be further improved (Ref. 33).

As the involutes are the base geometry of the gear tooth profile, the manufacturability is said to be standard. Compared to the standard involute gears, the low loss gears exhibit large meshing stiffness and are more prone to manufacturing inaccuracies (Ref. 34). With the reduction in transverse contact ratio, the contact happens thus in a small domain consequently increasing the noise generated.

PGT with cycloid teeth geometry

The convex-concave gears discussed in Ref. 35 share the basics of cycloidal gear teeth where the curve of action is an S-shape curve defined by two individual radii corresponding to the pinion and gear as shown in Figure 4.

The shape of the corresponding gear tooth following this curve of action is derived from differential geometry and gearing law (Ref.

36). The meshing efficiency of convex-concave reaches similar levels to that of involute gears for an ideal profile curvature. However, the loading condition significantly varies during the approach and recess cycle in the meshing.

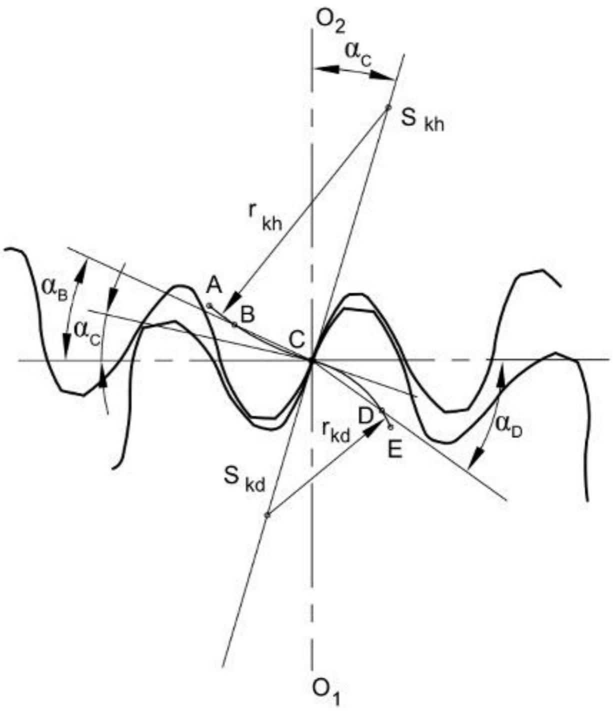

Fig 4: Meshing of convex-concave profile gears from (Ref. 35)

Compared to involutes, the convex-concave gears are gradually loaded and the peak load is taken by the tooth at the pitch point where the pressure angle is the least. Away from the pitch point, the pressure angle increases and therefore the load on the tooth is also lesser. The high sliding velocities at the start and end of meshing present in involute gears are eliminated with the convex-concave gears also due to the curved meshing action.

Brumercik et al. presented a reduced planetary gearbox with a convex-concave gear tooth profile (Ref. 37). The authors developed a small prototype to test this gear profile for a gear ratio of above 70:1 where Nylon 6.6 (PA66) gears were used. The results showed a favorable relative sliding between gears compared to the involute profile. Although the rapid prototyping method used is subject to manufacturing inaccuracies, such a small and lightweight gearbox could be used in applications such as a car's rear-view mirror.

PGT with circular arc teeth geometry

Double-circular arc gears were initially proposed by Litvin (Refs. 38, 39) which was derived based on the Wildhaber and Novikov circular arc gears (Refs. 40, 41). The double-circular arc gear proposed by Litvin is characterized by three circular arcs: one on the crown part, one on the base part and the other connecting the formers as shown in Figure 5. Later, Wang (Ref. 42) adapted this profile to overcome the discontinuity in profile curves and proposed a new type of double-circular arc gears as shown in Figure 5.

Due to the concavity and convexity nature of meshing and the resulting lower surface stress, this type of profile can handle much more torques and spans longer life compared to similar-size involute gears. Further, there is no limitation in the number of teeth, unlike involute gears. This type of gear is extremely sensitive to manufacturing inaccuracies and center distance deviations that reduce efficiency.

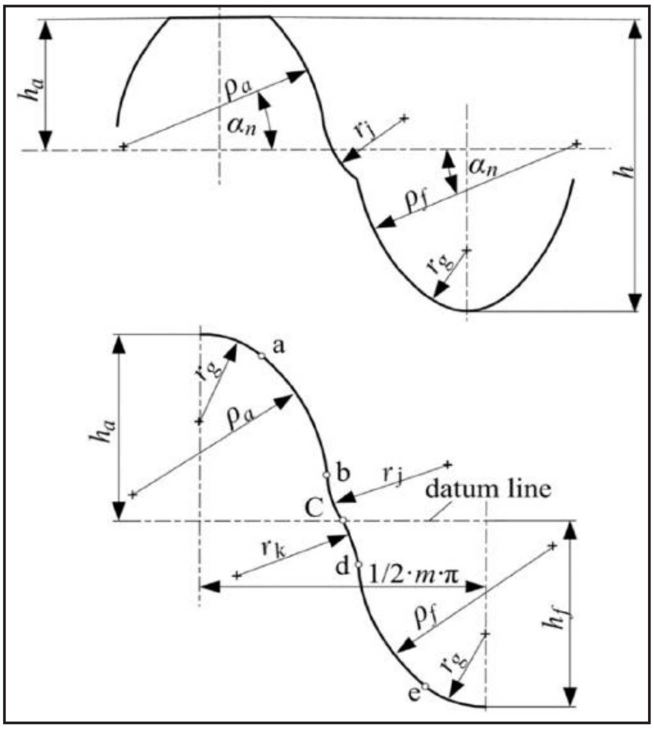

Fig 5: Double-circular arc gears proposed by Litvin (top) and Wang (bottom). Image adapted from (Ref. 52)

Wang analyzed the influence of these profiles by using them in a conventional planetary gear train (Ref. 42). The three-stage stacked planetary arrangement studied by the author had a gear ratio of 103:1 with the first two stages of 5.143:1 and the last stage 3.9:1 gear ratio respectively. Due to its lower efficiency and high load capacity, this kind of gearbox finds its better suitability in winch applications (Ref. 42).

Other gear profiles

Several other gear profiles exist apart from the ones mentioned above. A review of non-involute gear profiles by Okorn (Ref. 43) summarizes the design and capability of each profile. The unique profiles for which the meshing efficiency is deemed to be better than involute gears and can be of interest in using in Wolfrom gearboxes are discussed below:

S-gears

The S-gears developed by Hlebanja (Ref. 44) are generated by a specific rack design. The rack generates a specific concave-convex gear profile for which the meshing curve is in the shape of "S" as shown in Figure 6.

S-gears show a good load-carrying capacity because of their broader tooth root and concave-convex meshing compared to involutes. Additionally, since the relative sliding velocities are reduced during the start and end of meshing, the power loss due to friction is lower. These gears initially used in rolling mills are now finding their use in several applications. The S-gears-based high ratio gear drives described in Ref. 45 are used mainly in marine, aircraft and robotic applications.

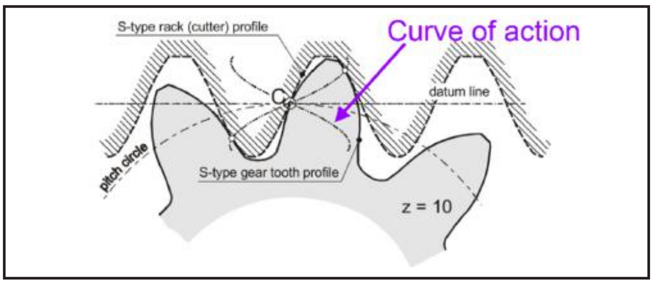

Fig 6: Rack cutting S-gears adapted from (Ref. 56)

Pure rolling helical gears

Pure rolling helical gears described by Chen et al. (Ref. 46) are based on a circular arc gear tooth geometry. The circle inscribed for the tooth geometry has the center in the tangent connecting the base cylinders of the gears in the mesh as shown in Figure 7. The radius of this circle is shorter than the length from the tangent point on the base circle to the pitch point. In other words, the radius of curvature about the pitch point is shorter compared to the equivalent involute gears. Additionally, these gears use the Hermite function to obtain the root fillet radius.

A convex-convex meshing happens and as a result, the load transmission is restricted to a very small region increasing the contact stress and promoting more rolling action in gears. The local deformations in the gear tooth still exist and minimal sliding is expected to happen. The application of this gear profile to internal gears and high-ratio gear drives has not been analyzed yet. Additionally, their experimental performances are also not known yet.

Involute-Cycloid composite gears

Cycloidal and involute gears have their own individual advantages and disadvantages. But the advantages of these two gears were combined in the involute-cycloid composite gears discussed in Ref. 47. As shown in Figure 8, the profile geometry is composed of epicycloid and hypocycloid for the addendum and dedendum extremes respectively and a portion of involute only around the pitch diameter region.

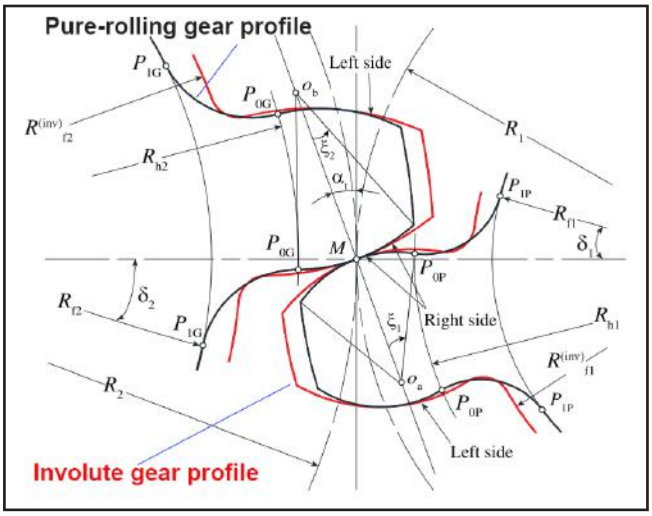

Fig 7: Pure rolling gear profiles in mesh adapted from (Ref. 46)

Because of the involute profile around the pitch diameter, the action curve is linear to a limited extent about the pitch point of the meshing curve and making this gear less sensitive to the center distance deviations. The cycloid tooth profile increases the surface-load capacity and reduces the sliding velocities considerably at the meshing extremes. Therefore, the involute-cycloid composite gears have better meshing efficiency. Due to the involvement of cycloid for the dedendum part, undercutting is avoided, and small numbers of teeth could be realized. While the contact stress values are better compared to involutes because of the convex-concave contact, the root bending stress values see a significant increase due to reduced root thickness [48].

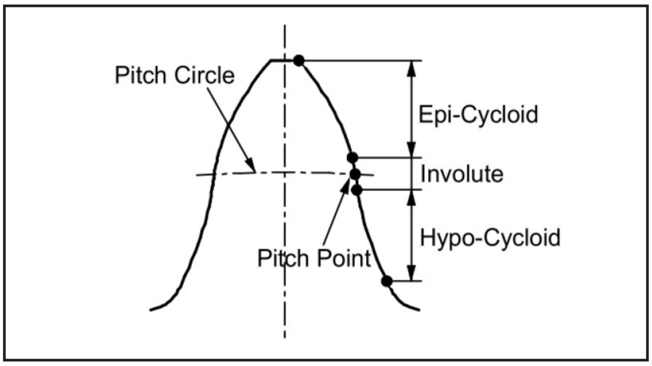

Fig 8: Involute-cycloid composite gear profile (Ref. 47)

Discussion

A comparison of high ratio planetary gear trains having different tooth profile geometries is provided in Table 1. Amongst the candidates, two variants of Planetary gear trains that were discussed initially are identified: namely the Stacked and Wolfrom arrangement. For the involute-profile PGTs, characteristic examples of commercial gear heads and novel gearboxes from the literature are also compiled. The transmission ratio of around 100:1 is observed for all the examples except one for which the gear ratio is 70:1.

Table 2 gives a comparison of unconventional gear profiles discussed in the previous section and their performance levels. The analysis shows that although low-loss gears have very good efficiency, they suffer from increased bending and contact stresses and transmission error due to a limited contact ratio, which is a strong disadvantage. The cycloid gears, involute-cycloid composite and the double circular arc gears have nearly similar performance capabilities because of their similarity in convex-concave contact between meshing gears. However, their sensitivity to center distance deviations and manufacturing errors poses limitations. Pure rolling gears and the S-gears, on the other hand, perform better in terms of efficiency and bending stress but the surface stress limits of pure-rolling gears are critically lower due to the convex-convex contact nature. Both S-gears and pure rolling gears are subject to high transmission error because of the reduced contact ratios. Even though the sensitivity to center distance deviation is influential to a limited extent in S-gears because of the local line of action (instead of a curve), S-gears are prone to manufacturing inaccuracies. The non-involute gear profiles in general, can improve meshing efficiency and load-carrying capacity of gears compared to the standard involute gears. If their transmission error and manufacturability aspects are improved compared to standard involute, their usage in high ratio PGTs could be beneficial.

Parameters	Profile Shape / Units	Involute	Involute	Involute	Involute	Low loss gears	Cycloid teeth	Circular arc
Reference	-	Neugart PLE40 (18)	ZF (49)	R2Power (26)	BDG (25, 50)	(32)	(37)	(42)
PGT type	-	Stacked	Wolfrom	Wolfrom	Wolfrom	Wolfrom	Wolfrom	Stacked
Number of stages	-	3	2	3	2	2	2	3
Transmission ratio	-	100:1	107:1	125:1	97:1	125:1	70:1	103:1
Overall dimension (ØxL)	mm x mm	40x88	220 x 114	98x68	94x62	~170x55*	~30 x 20*	n/a
Material	-	Steel	Steel	Steel	Steel	Steel	Nylon 6.6 (PA66)	Steel
Weight	kg	0.5	16	1.56	1.1	~9.9*	n/a	n/a
Max. Output torque	Nm	14	700	120	90	n/a	0.052	3.34
Torque/weight	Nm/kg	28	43.75	76.92	81.8	-	-	-
Meshing efficiency	%	$\eta_{i,e}$~99*	$\eta_{i,e}$~99*	$\eta_{i,e}$ - 99	η_e - 97.7 η_i - 99.6	$\eta_{i,e}$~99.3*	η_i - 99 η_e - 98	$\eta_{i,e}$~97.5
Gearbox efficiency	%	98	79	69	93	97.43	73.76	77.87

** estimated, n/a: information not available*
Table 1: Comparison of Planetary gear trains with non-involute profiles

Conclusion

The overall efficiency of high-ratio planetary gear trains with involute gears drops severely at reduction ratios of several hundred. Other unconventional gears could help solve this problem by achieving better meshing efficiencies than involute gears. A review of planetary gear with unconventional gears is presented in this paper. Several research groups already work individually on different non-involute gear profiles and the analyses show that the Wolfrom-gearbox—a compact type of planetary gear to achieve high ratios—is predominantly used to test the changes in gear profiles compared to the conventional stacked PGTs type.

A set of evaluation criteria that are fundamental to assessing gear profiles are briefed after which the design, performance and use of a few non-involute gear profiles are then discussed. The non-involute gear profiles like S-gears and pure rolling helical gears play a significant role in improving the meshing efficiency of the gears, while the convex-concave gears (cycloid) handle the contact loads in a better way. However, the real-time performance and absolute degree of improvement are little known yet due to

Property / Gear	References	Meshing efficiency	Bending stress	Contact stress	Transmission error	Manufacturability
Low loss gears	(6, 31, 32)	++	–	–	– –	++
Cycloid gear	(36, 37)	+	+	++	–	–
Double-Circular arc gears	(39, 51)	+	+	++	–	– –
S-gears	(52, 53)	+	++	++	–	+
Pure rolling gears	(54, 55)	++	+	– –	– –	–
Involute-cycloid composite	(47, 48)	++	+	++	–	–

Table 2: Comparison of unconventional gear profiles that are used in the Planetary gearbox or favorable to use to have better efficiency. Based on the referred articles and simulations, the candidates are rated from poor (– –) to best (++).

the unavailability of all evidence in the literature. So, a relative comparison is done, and the profiles are confronted.

The non-involute gear profiles can improve meshing efficiency and load-carrying capacity of gears compared to the standard involute gears. But the reduced contact ratio and nonstandard manufacturing techniques have a negative influence on their accuracy, noise and vibration characteristics making them less preferred. Moreover, the dominance of involute gears which are backed by well-established standards undermines the potential of other gear profiles. Leveraging the advancements in present-day manufacturing technology, future research will be focused on improving the key characteristics of gears with high meshing efficiency so that when used in a high-ratio gearbox like Wolfrom, the power loss could be reduced drastically.

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Updates from the AGMA newsletter

Lockheed Martin Enters Long-Term Agreement with Ronson Gears

Lockheed Martin Space has entered into its first-ever international Long-Term Agreement with Melbourne-based manufacturer Ronson Gears under its Global Supply Chain (GSC) Program agreement with the Commonwealth of Australia. This Long-Term Agreement will supply multiple gear and gear sets across various Space programs to enhance lead times while decreasing administrative burden.

Gleason's e-Drive Days are Here

Join Gleason's special online event to learn about the design, manufacturing, and inspection of e-Drive gears. The three-day event features one topic per day addressing the specific requirements and challenges of e-Drive transmission manufacture, with particular attention to minimizing gear noise.

NASA Awards Systems Engineering Contract to McCallie Associates, Inc.

The contractor will provide mission and instrument systems engineering services to the Mission Engineering & Systems Analysis Division and related Applied Engineering and Technology Directorate organizations at NASA. The contractor will also provide mission and instrument systems engineering services as well as guidance, navigation, and control systems, which include guidance, navigation and control systems engineering and attitude control systems analysis and algorithm/software development.

This Futuristic Air Taxi Set a Record for Longest eVTOL Flight

AutoFlight's latest Generation 4 prototype of its "Prosperity I" eVTOL (electric Vertical Take-Off and Landing) aircraft conducted a test flight on March 2, 2023, and appears to have bested Joby Aviation's flight test from July 2021. The Generation 4 eVTOL was flown 250.64 kilometers, or 156.65 miles on a single charge, according to AutoFlight.

Revolutionizing Urban Mobility

In recent years, the use of electric cargo bikes has been growing in popularity as the electric cargo bike market has seen rapid growth in recent years, with annual sales increasing exponentially between 2016 and 2019. The battery-powered cargo bicycles are ideal for quick, eco-friendly transportation and distribution of items such as food, mail, medicines and more in major cities.

Experience Counts Loudly

IoT is all about the use of internet-connected devices and smart sensors that collect and evaluate data from industrial machinery and processes. With mushrooming IIoT adoptions, industries are benefitting from serious digital transformations (which lead right to operations that are more efficiently monitored, cutdown costs, and steps forward in the evolution of autonomous operational accomplishments).

CONTD ON PG 66

CONTD FROM PG 65

Wind, Solar, Batteries Make Up 82% of 2023 Utility-Scale US Pipeline

Wind, solar, and batteries make up 82% of 2023's expected new utility-scale power capacity in the US, according to the US Energy Information Administration's (EIA) "Preliminary Monthly Electric Generator Inventory." As of January 2023, the US was operating 73.5 gigawatts (GW) of utility-scale solar capacity – about 6% of the country's total.

Stellantis CEO Gets Surprisingly Candid about Electrification

Stellantis CEO Carlos Tavares spoke recently about his company's plans around continuing electrification. He stressed the need for EVs to be affordable, to have more range—and to weigh a lot less. Tavares also talked about the need for more EV battery recycling, though admitted it will be years before there is significant supply of spent batteries in the pipeline.

Material Needs for Floating Offshore Wind Installations

Achieving the Biden Administration's goal of cutting floating offshore wind development costs by 70% will require advanced manufacturing and materials science, agency leaders said during a roundtable at the Department of Energy's Floating Offshore Wind Summit.

Stackable 3D-Printed Gearbox for Brushless Motor

Affordable brushless motors are great for a variety of motion applications, but often require a gearbox to tame their speed. [Michael Rechtin] decided to try his hand at designing a stackable planetary gearbox for a brushless motor that allows him to add or remove stages to change the gear ratio.

Spiro Gears manufactures customized gearboxes in accordance with client designs and specifications

Features:

Made utilizing certified raw materials and in accordance with client's specifications while adhering to international quality standards.

Heat treatment performed in well-calibrated furnaces to reduce distortion level.

To ensure superior dimensional accuracy, gear cutting and thread grinding are done using specialized and precise machines.

Capabilities:

Gear Box with single-stage to 3-stage reduction can be manufactured and delivered.

Our gearboxes are highly recognized and favored by the customers because of easy installation, low noise level and better results.

Assembly of the gearbox is done using proper fixtures to ensure proper fitments of gears, shafts, and bearings to maintain uniform backlash and smooth running of gears.

About the company

Spiro gears, an ISO 9001- 2015 company manufactures a wide variety of spiral bevel, spur, helical gears and shafts – hobbed, shaved, and ground quality for Earthmoving equipment, Textile machinery, Agricultural machinery, Gearboxes, Machine tools, printing machinery and many more. We also made customized gearboxes as per clients' specifications.

HIGH-PERFORMANCE TECH FOR IN-HOUSE EXCELLENCE

UCAM-Nimble Machines has launched a line-up of CNC Gear Hobbing Machines, to boost the country's Make In India initiative

VAJRA-130

With more than three decades of leadership in manufacturing precision equipment, including CNC Rotary Tables, UCAM Pvt. Ltd. is now offering CNC Gear manufacturing solutions under its business vertical Nimble Machines. Boosting the 'Make In India' vision, the philosophy of Nimble machines is to elevate the Indian machine tool industry on a global platform.

Nimble Machines offers high-speed CNC gear manufacturing solutions. Their portfolios consist of CNC gear hobbing machines – the VAJRA 130, VAJRA 250 and the VAJRA 400, capable of upto 8 modules, and 400mm diameter.

Nimble Machines also manufactures TARANG-325, a 5 axis CNC spiral bevel gear generator machine. TARANG-325 is developed using a face milling method, and teeth are generated using circular interpolation of the cutter. It is capable of machining gears up to 7 modules and 325mm diameter. TARANG was built keeping in mind ergonomic design for improved accessibility and maintenance. TARANG won the CII (Confederation of Indian Industry) Design award in 2022.

Technological solutions

With policymakers targeting the 5 trillion USD economy, along with USD 1 trillion manufacturing economy, demand for precision gears for various fields such as automobile, automation, energy and other allied sectors is set to pick up in. Additionally, the requirement of silent gears is on the rise, with the emergence of the e-mobility market.

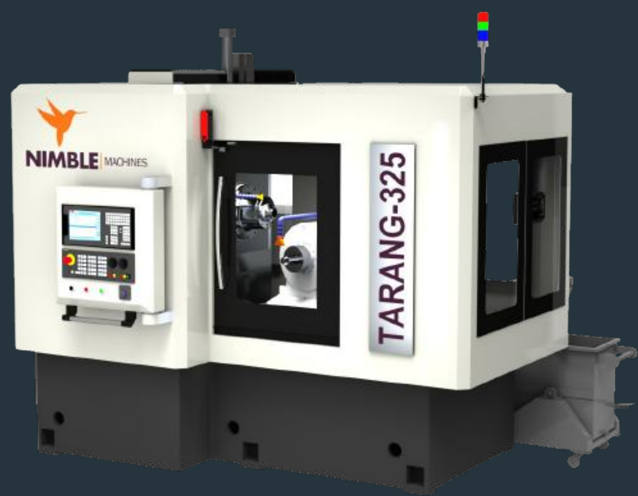
With such a need for high performance, precision and quality gears, customers expect a commercially competitive solution. Keeping these needs in mind, Nimble Machines has developed machines with various features and is able to manufacture at the lowest cost per part to the customer. Some of the technology includes Direct Drive (DDR) technology, Electronic Gearbox (EGB) and Servo tailstock with programmable clamping pressure. The machines are designed with UCRIDE® technology consisting of epoxy granite filling, to ensure reduced vibration and higher damping effect. They are also loaded with automation solutions such as Indexing Ring Loader, Component Magazine and advanced workholding solutions, which enhances the overall rate of productivity. These features enable the machines to produce high-quality gears of up to DIN7 at a higher production rate.

New launches

To cater to the demands of smaller, high-quality gears, Nimble Machines has introduced the smaller variant: VAJRA 130 high speed hobbing machine. Launched at IMTEX 2023, it is capable of both dry and wet hobbing up to module 3, and 130mm diameter. VAJRA 130 received a lot of interest and hype from industry stakeholders.

Determined to grow

Launched in 2015, Nimble Machines is steadily making inroads into the Indian gear manufacturing market and now ready for the International markets. Nimble Machines caters to customers from various segments, from Tier-1 automobile gear manufacturing companies, to SMEs catering to general engineering.



TARANG-325

SETTING THE STAGE FOR TECH INNOVATION

Virgo Communications & Exhibitions (P) Ltd. conducted the 7th edition of IPTEX: International Power Transmission Expo, and GRINDEX: International Expo on Grinding & Finishing Process, the exclusive B2B exhibition for the industry of gears and grinding technology, from April 21 to 23 2022 at the Auto Cluster Exhibition Centre, Pimpri-Chinchwad, Pune, Maharashtra.

IPTEX-GRINDEX 2022 showcased innovations by 125 leading manufacturers and suppliers of technologies for the entire gear & grinding industry. Raghu G, Director of Virgo Communications & Exhibitions (P) Ltd. said, "With four successful editions of GRINDEX, the expo is recognized by the global industry stalwarts as one of the most ideal business platforms for showcasing latest industrial products & technology in India, dedicated to Tool Grinding & Surface finishing technology." He further added that "GRINDEX is specifically designed to offer an opportunity for the manufacturing industry to explore new high-end technology, solutions, and applications, with the prime focus on increasing the cost effectiveness and process efficiency."

The exhibition presents business solutions for a wide variety of industries including automotive, machine tools, metalworking, construction, pharmaceutical, railway, food processing, steel, textile among others. And it will continue to do so, in a bigger and better manner, in February 2024.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IMTEX 2023: A SHOWCASE FOR THE GEAR INDUSTRY

Held after four years, IMTEX Tooltech & Digital Manufacturing 2023 was a big platform and opportunity for the machine tool industry this year. The 20th edition of this mega-event for the manufacturing industry was organized by IMTMA, and from January 19 to 25 at Bangalore International Exhibition Centre.

IMTEX 2023 focused on metal-cutting machine tools and manufacturing technologies. "Cutting-edge technologies are vital in addressing the need for quality and precision manufacturing in every industry sector," said Ravi Raghavan, President, IMTMA.

The gear industry was represented in full force by machine tool manufacturers, manufacturing software makers, gear companies, companies specialized in grinding tool sales, service and operations, and many more. GTI networked with gear industry leaders from across the world, who are all betting big on India becoming the next big global manufacturing hub.

The industry's best offerings were on display, from smart, cutting-edge and high-precision technologies to tools, accessories, lubrication, manufacturing software, Industry 4.0 hardware, customized solutions, advancements in measurement technology and solutions for new products, among other things.