

# GEAR TECHNOLOGY

SEPTEMBER/OCTOBER 2004

*The Journal of Gear Manufacturing*

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## FEATURES

- Surface Damage Caused by Gear Profile Grinding
- Gear Cutting Tool Materials
- Conversation with Joe Franklin, AGMA President
- Hob Cutting Edge Failure due to Chip Crush —Part 1

## IMTS 2004

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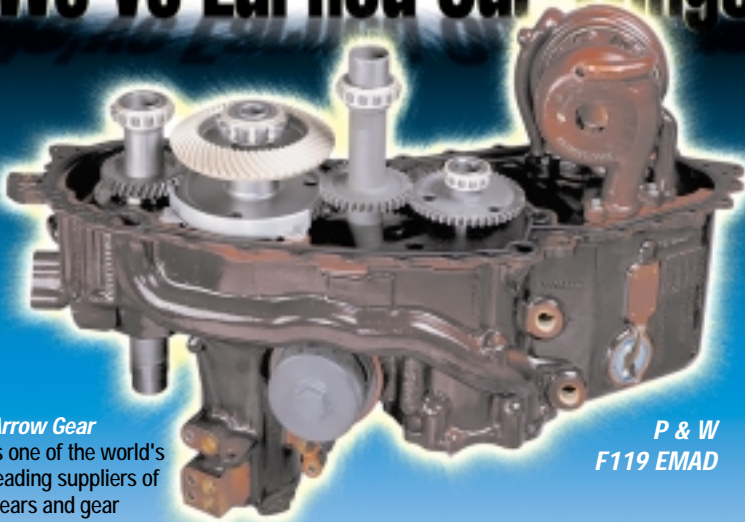
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The Journal of Gear Manufacturing

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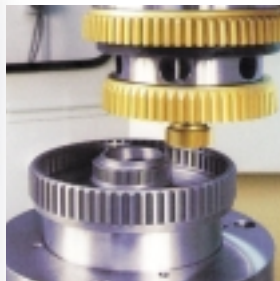
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# THE GEAR INDUSTRY'S INFORMATION SOURCE

Since our founding in 1984, *Gear Technology's* goal has been to educate and inform our readers of the technologies, products, processes, services and news of importance to the gear industry and to provide our advertisers with the most complete and current circulation of gear industry professionals available anywhere!

We call ourselves "The Gear Industry's Information Source"—and with good reason. We provide a central resource for technical information as well as a marketplace for the exchange of product information. All around the world, people who design, manufacture, test, buy, and use gears depend on *Gear Technology* to stay connected to the industry.

We'd like to invite you to our booth (B-7113) at IMTS 2004 to learn how we are reaffirming and strengthening our mission. But for those of you who won't be able to make it to the show, here's a brief summary of what it means to us to be "The Gear Industry's Information Source."

**THE** We know that you are inundated with information and that it is often impossible to sift through it all to find what's useful. That's where we come in. We're proud of the fact that most of you prefer to get your gear-related information through us. That's why *Gear Technology* is THE leading publication serving the industry. That's why our readers save and keep our issues, to refer to time and time again. When we say we're "The Gear Industry's Information Source," we mean it with a capital "THE."

And we're not resting on our laurels, either. At *Gear Technology*, we've constantly worked to introduce new products and tools that help you be more efficient at gathering the information you need.

Our websites, [www.geartechnology.com](http://www.geartechnology.com) and [www.powertransmission.com](http://www.powertransmission.com), are two examples. Our electronic version, *E-GT*, which has grown to more than 4,000 qualified subscribers around the world, is another. They allow you to obtain product and technical information at any time, anywhere around the world. Also, we have some exciting new products in store for 2005, so stay tuned to this space.

**GEAR** Our staff has many decades of gear industry experience. Like most of you, we live, breathe, eat and sleep gears, and we've done so for 20 years as *Gear Technology*. Whether you design, manufacture, process, test, buy or use gears, gear drives or related products, you can learn more via *Gear Technology*, [www.geartechnology.com](http://www.geartechnology.com) and [powertransmission.com](http://powertransmission.com) than you can anywhere else.



**INDUSTRY'S** When we say the gear industry, we mean the *whole* industry. Not just job shops, not just high-production automotive shops, but both, and everything in between. Not just in the U.S. or even North America. *Gear Technology* and its companion electronic version, *E-GT*, are read everywhere from Argentina to Australia, from Bulgaria to Brazil, from Malaysia to Mexico, from New Zealand to Nicaragua, from Swaziland to Switzerland and from Zambia to Zimbabwe—75 countries in all, where we have subscribers every issue.

And we include information from all around the world as well. We find the best technical articles with the most qualified experts as authors. This issue, we worked with some of the world's foremost authorities on their subjects, from America, Germany, and Japan.

**INFORMATION** It's not just any information that makes it into the pages of *Gear Technology*. We provide the most comprehensive coverage of the industry available. We search out the most important, relevant and best written technical articles that most of our readers wouldn't otherwise see. We include coverage of a variety of technologies—in every issue—to reflect the needs of the marketplace.

Also, we strive to provide balance. That means that we do our best to provide you with information that is useful and practical, and we try to present that information as fairly as possible. Unlike others in the publishing business, we don't trade advertising for editorial space. The articles we include are chosen because we believe they give our readers the best available information, not advertorials by the authors. We hope that our approach over the years is at least part of what has allowed us to earn your trust.

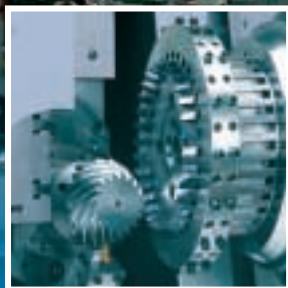
We'd also like you to know that your trust is well placed, that we'll continue to do what we've always done in presenting the best information available to the gear industry.

**SOURCE** *Gear Technology* is the place most of you look for information, but the word "source" is also important to those of you who have an influence over the purchase of products and services related to your jobs. Many of you are involved in the purchase of machine tools, cutting tools and services such as heat treating or tool sharpening. Others of you are involved in the purchase of gears, gear drives and related components. Part of *Gear Technology's* job is to provide you with a source for valuable product information, through the messages of our advertisers, the product and industry news we cover, and more importantly than ever, the buyers guides on our websites.

Of course, the direction of *Gear Technology* is largely dependent on the feedback we receive from you, the readers. We'll be asking those of you who come to our booth at IMTS what you'd like to see from *Gear Technology*. You can also drop us a line by e-mail at [editors@geartechnology.com](mailto:editors@geartechnology.com). Let us know how we can better fulfill our role as "The Gear Industry's Information Source."

*Michael Goldstein*  
Michael Goldstein, Publisher & Editor-in-Chief

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# Feedback from the Field

Dear Mr. Goldstein:

I was very pleased to see that *Gear Technology* is celebrating its 20th anniversary. May I offer my congratulations on reaching this milestone. It is an excellent journal that has achieved worldwide recognition, and I wish it continued success.

It was interesting to see the article by Bob Smith on "Single-Flank Testing of Gears" (pp. 18–21, May/June 2004), and I agree with you that its message of 20 years ago is just as relevant today. You may be interested to know that I presented much of the same message at an AGMA technical meeting even longer ago, in August 1967, entitled "Gear Transmission Error," paper No. 239.10. Bob Smith's article made use of diagrams contained in that paper and in other Goulder Mikron literature (in the 1960s and 70s, Goulder Mikron pioneered the measurement of transmission error with their opto-electronic single-flank gear tester).

The story of single-flank testing goes back still further to the 1950s, when Professor Stephen Harris at Cambridge University came up with the concept of transmission error. He went further by predicting the effects of tooth deflection under load, and the possible modes of vibration that could be excited. I was fortunate enough to work with him there from 1957 to 1964, and much of our work is referenced in the above AGMA paper.

I have always felt that the gear world did not give Stephen the recognition that he deserved, and faced with so little encouragement, he moved on to other research areas. Sadly, he died two years ago, and I wrote the following obituary for the bulletin of the British Gear Association:

*Professor Stephen Harris died in March 2002 at the age of 82. His main professional interests were teaching and civil engineering, where he enjoyed a distinguished international reputation, but for a short period he carried out some outstanding research on gear vibration and noise.*

*He qualified in engineering at Cambridge University, and returned there in the 1950s as a lecturer, where the head of the engineering department at that time, Sir John Baker, invited him to look into the dynamic loading of gears. Stephen protested that he knew nothing about gears, but was told that this was a very good reason for asking him, because a fresh mind was needed for the problem!*

*At that time, the problem was regarded as a series of isolated impacts as each tooth pair came into mesh, but Stephen discovered that even at low speeds, the problem was one of continuous vibration. The vibration was excited by a combination of tooth profile deviations (deliberate reliefs and manufacturing*

*errors) and elastic deformations of the teeth under load. He called this excitation the "static" transmission error, and by means of an elegant graphical presentation he showed how it varied with tooth load and rotations. Appropriately this presentation is now called the "Harris map."*

*Not content with this innovative achievement alone, he went on to predict what types of vibration might be excited. He suggested that the principal excitation would be at mesh frequency, but additionally the many harmonics of mesh frequency would also create excitation. Boldly, he went further to suggest that violent nonlinear vibrations might occur if the amplitudes were large enough to cause periodic tooth separation.*

*Stephen's concepts and predictions are now familiar to those concerned with gear vibration and noise, but few appreciate the magnitude of his contribution to the subject. One is left wondering what other innovative contributions to gearing would have been made if he had been encouraged to stay in this field, but we should be grateful to him for his brief period of gear research.*

I hope that the above puts the story of single-flank gear testing in its proper historical context and that it may be of some interest to readers of *Gear Technology*.

I look forward to the next 20 years of *Gear Technology*.

Yours Sincerely,  
Bob Munro, Emeritus  
Professor of Precision  
Engineering, University of  
Huddersfield, U.K. (formerly  
managing director of Goulder  
Mikron, Huddersfield, U.K.)



*Dear Colleagues:*

*My best congratulations with the 20th anniversary of Gear Technology. Your journal is the best gear technical journal in the world. On behalf of the J.F.To.M.M. Gearing and Transmissions Journal, I wish you all the best in your activity and life.*

*Sincerely yours,  
Veniamin Goldfarb  
Editor-in-Chief of the J.F.To.M.M. Gearing and  
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# SPIRAL BEVEL GEARS

(Transmissions)



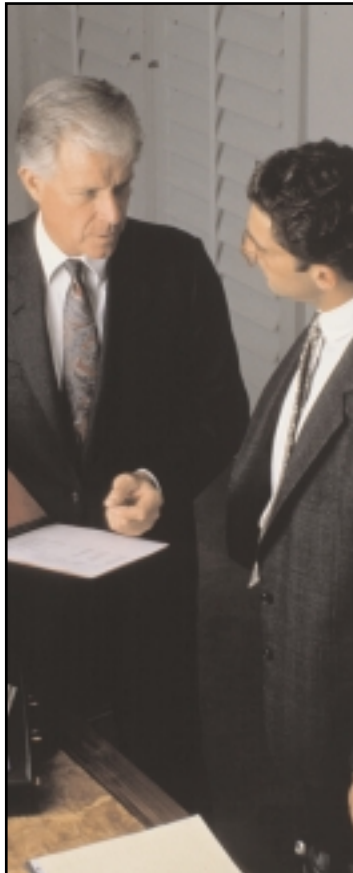
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## Clarification

The article "The Gearless Hydrostroke," from the July/August 2004 issue of *Gear Technology*, included the statement: "To date, CNC guide technology hasn't allowed shapers to be used for high production. The technology can't produce helical gears at a rate as high as a dedicated mechanical system."

The statement should have read: "*In some cases*, CNC guide technology hasn't allowed shapers to be used for high production. *Some CNC guided shapers* can't produce helical gears at a rate as high as a dedicated mechanical system."

A number of manufacturers produce CNC guided gear shapers for high production environments. We apologize for any confusion the statement may have created.  
 —The Editors

Dear Editors:

Thank you for another issue full of interest. I would like to comment on the paragraphs under the heading "Falk: A Gear Company" from the article on The Falk Corp. (pp. 9–13 in the July/August 2004 issue).

I disagree that the electric motor led to the rise of gear driven machinery at this time (the 1890s). The AC motor was introduced as a machine drive in 1887, but it was very slow to catch on. By 1909 in well over 100 gear machines, only four were available with an electric motor—one each in France and England and two in the U.S.A.

The gear market was going through a dramatic increase, firstly for chainless bicycle bevel gears, secondly for a variety of road and rail transport gears and third for helical and herringbone gears for steam turbines, electric trams and locomotives.

The herringbone patent mentioned in the article was, I deduce, for the special "Wüst" tooth form, as the herringbone gear was included in James White's "Century of Inventions" in 1821. The Wüst helical hobbing machine was made by C.E. Wüst of Zurich, Switzerland. Whereas other machines were cutting herringbone gears by the two-piece method, this was the first one-piece herringbone hobber. The cuts were staggered so the hob runs into space. It had a very large capacity, was belt-driven and, I suspect, took a great amount of skill to operate.

Yours truly,

William P. Crosher

(Editor's note: Mr. Crosher, a consultant working with Flender Graffenstaden, is also a historian of the gear industry. He is currently writing a book on gearing that includes many historical details like the ones above.)



*Do you have comments on a recent issue of Gear Technology? Do you have valuable information to add to any of the subjects we've discussed? Please send your letters and comments to:*

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# Quality Spiral Bevel Tools

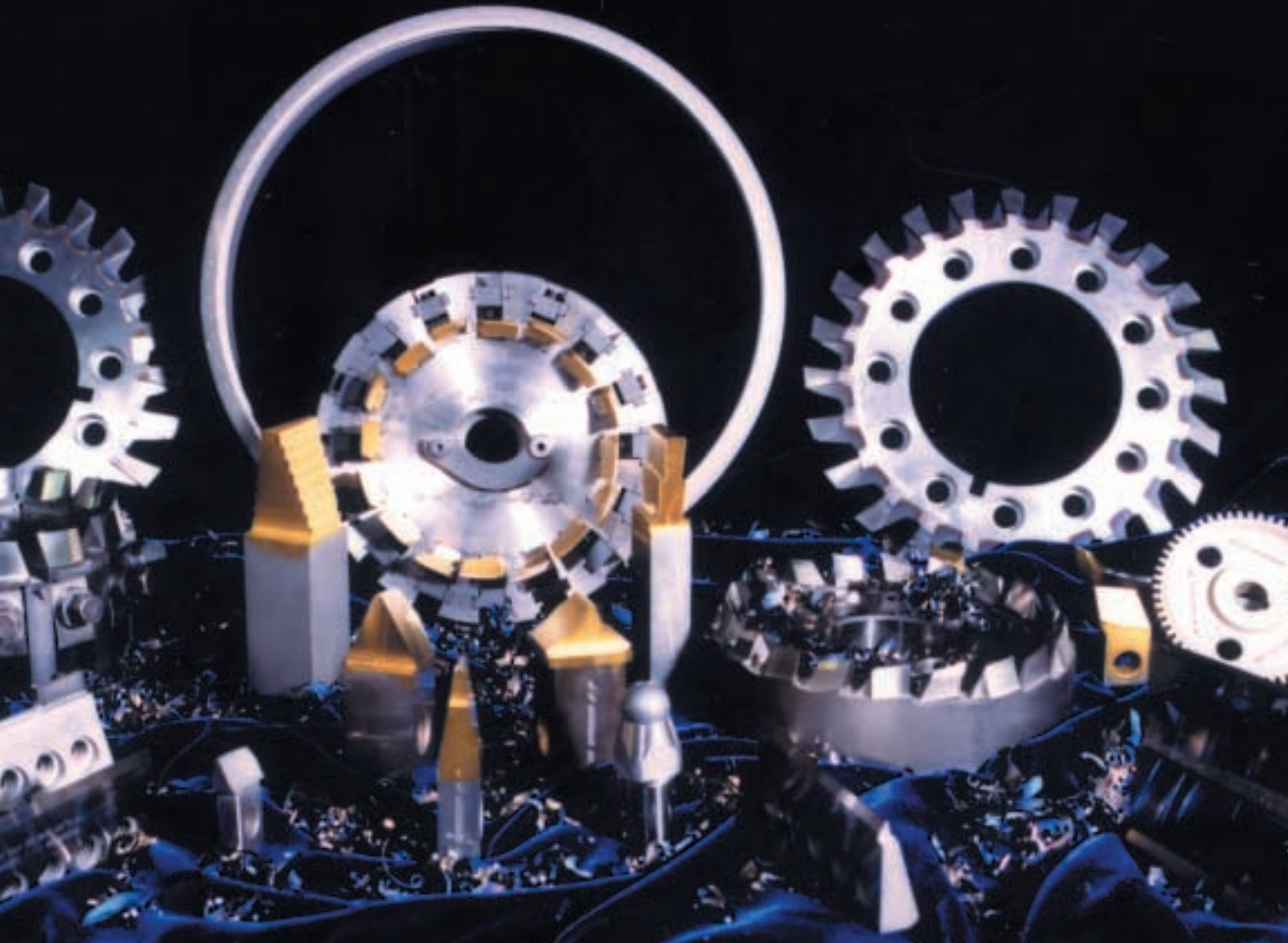
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## Sigma Pool Features New and Improved Machines

Two Sigma Pool partners will unveil a new spiral bevel gear generator and an upgraded gear measuring center at IMTS '04.

Oerlikon GearTec AG will unveil its C 27, a spiral bevel gear generator that cuts dry and uses direct-drive spindles for workpieces.

"Acceleration of the spindles to operating speed occurs in less than one second, so that non-productive times can be reduced to an absolute minimum," says Klaus Singler, vice president—sales for Sigma Pool partner Liebherr Gear Technology Co. "The maintenance-free drives, with their high positioning accuracy, guarantee high quality bevel gears during the entire lifetime of the machine."

Also, the drives have an integrated water-cooling system, largely eliminating machine variations from internal temperature changes.

The precision gear measuring center, the P 26, improves on earlier versions available to North America with a new operator interface called Gear Inspection Assistant (GINA). The center also has an extended range of applications, including non-gear related CMM-type capabilities. GINA is designed to simplify operation. The machine itself is designed for increased accuracy and faster cycle times, says Ted Klemm, a Liebherr regional sales manager.

The P 26 measures gears with outside diameters of up to 260 mm. The center can measure cylindrical gears with external and internal teeth, worms and worm gears, spiral bevel gears, rotors, camshafts, and other curved workpieces. Measuring programs are available for the most important gear cutting tools, such as hobs and shaper and shaving cutters.

Liebherr will feature its CNC generating and profile gear grinder, the LCS 300. The machine is designed to be flexible. For example, it can process a twin gear by generating grinding one gear with a dressable worm and profile grinding the other with a CBN wheel. Also, using an attachment, the machine can profile grind internal gears with diameters of 50–300 mm.

The LCS 300's optional features include intelligent software for tooth-end modifications and topological corrections and a dressing unit for sintered alumina tools.

Sigma Pool will also exhibit Liebherr's LP 200 gantry system, Lorenz tooling and CM-Digit systems.

The gantry system has an integrated drip pan that travels with the part gripper for the length of the gantry's working area. The tooling will consist of shaper and shaving cutters and master gears. Products from CM-Digit GmbH & Co. KG will include automated single/double flank and noise testing systems.

Since IMTS '02, Sigma Pool has improved its dry hobbing technology through increased use of direct drives for improved accuracy and reliability with reduced cycle times and through integrated tools for deburring, spinning and other peripheral operations.

According to Peter Kozma, Liebherr's president, Sigma Pool has much increased the reliability and maintainability of its machines, significantly reducing life cycle costs.

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## Keyseating Machines Use Fewer Fixtures for Large Parts

Mitts & Merrill L.P. will feature its L-series keyseating machines.

Unlike the K series, this series includes a post holder that's flush with the machine tabletop.

"This now allows large parts to sit directly on the table with less fixtures needed," says David G. Sabel, general manager of Mitts & Merrill, a Frömag Group company.

Also, making the post holder flush allowed the machine to use Mitts & Merrill tooling (except post) and Frömag tooling.

These electromechanical machines have two concentrically arranged ball screws for stroke movement and a PLC control unit.

According to Sabel, the L-series design offers improved tool life, reduced floor space and energy savings compared to hydraulically driven machines and older electromechanical machines.

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## Gleason 245TWG Threaded Wheel Grinder

"New machines as well as new grinding and dressing technology have combined to make possible what gear designers could only have dreamed about a few years ago," says Richard Scoda, Gleason Corp.'s product manager. "Today fast, consistent, cost-efficient production of high quality ground gears can be achieved in everyday production."

And Gleason will highlight at IMTS 2004 a machine designed for such production: the 245TWG Threaded Wheel Grinder. According to Gleason, the machine can reduce floor-to-floor times on a typical 8-inch-diameter gear from the 3-4 minutes required by a conventional grinder to 1.10-1.35 minutes. Scoda says this performance improvement isn't attributable to a single technology or process development, but rather to a number of design improvements:

- Direct-drive spindles: Grinding and work spindles use

direct-drive spindles, which allow for higher grinding wheel speeds and a wide range of speeds are possible. "Because direct-drive spindles eliminate gears, belts and other mechanical connections between the motor and the spindle, direct drives produce inherently more accurate gears. This technology eliminates the possibility of introducing transmission errors in conventional gear trains," says Scoda. He adds that higher speeds and feeds allow the machine to take full advantage of today's most advanced grinding materials.

- Multi-start grinding wheels: The 245TWG can use multi-start grinding wheels, applying a principle used for years to improve production rates in hobbing via multi-start hobs. "A grinding wheel with seven starts can improve the production rate by 5-10 times versus that of a single-start grinding wheel," Scoda says. "Dressing of multiple-start grinding wheels is a simple, straight-forward process on the 245TWG machine, with no sacrifice in quality."

- Master dressing gear process: Both CNC dressing and dressing using a master dressing gear are available on the grinder, but multi-start grinding economics are best achieved with the master dressing gear. The Gleason master dressing gear system

### Improved and Established: Gleason's Other Featured Machines

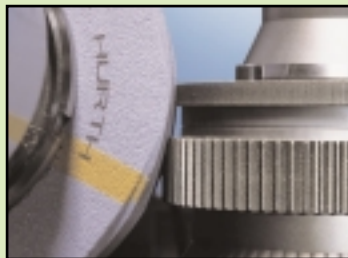
Besides the 245TWG, Gleason will introduce and demonstrate other technologies designed to speed throughput and take cost out of gear production. They'll include:

- the P 600 G Profile Grinding Machine, which has new profile grinding software to reduce manual setup and other costly non-productive time;
- the P 90 Horizontal Hobbing Machine, which is designed for dry hobbing and for improved performance through high-speed, direct-drive spindles for hob and work spindles;
- the Phoenix® II 275G Bevel Gear Grinding Machine, which uses a

monolithic column in its design to reduce floor space requirements and improve cycle times; and

- the Gleason-Mahr GMX400 Gear Inspection Machine for providing elemental inspection of all types of gears.

Gleason will also display its latest cutting tools, including new CBN-plated grinding wheels and shaper cutters.



can dress a multi-start grinding wheel in the same time regardless of the number of starts. With a standard CNC dresser, the dressing time is increased with each additional start.

"We've developed a process that allows use of a diamond master gear and roller, integrated into the clamping fixture, to engage all the threads at once, thus doing in one pass what would take many passes with a typical single diamond dressing disk arrangement," Scoda says. "This becomes an enormous factor in high-volume production applications, where dressing the wheel can occur after every 20-30 parts."

For smaller lot production, prototype work and other applications requiring more dressing flexibility, the 245TWG may be equipped with a fully automatic CNC dressing unit that dresses wheels in the conventional manner.

- Automatic loading: The 245TWG comes equipped with automated carousel loading, which is similar to the loading systems used on hobbing machines. Spin stations and other features can be added to the loader system.
- Automatic stock division: Automatic stock division is a standard feature on the 245TWG grinder. In addition, Gleason employs a portable video camera mounted on the dressing spindle to ensure that the dressing tool and the grinding wheel threads are properly aligned prior to starting the dressing cycle.

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- an optional CNC gantry automation system.

Another new Koepfer machine will be displayed by the Kapp Group in its booth, B-6931. The Koepfer-Kapp KX120, a jointly developed machine, can hard finish external spur and helical gears up to 120 mm in diameter.



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**Zeiss' ACCURA Measures in Many Ways**

Carl Zeiss Industrial Measuring Technology will feature its new coordinate measuring machine, which has probing processes that include active scanning, single-point and optical measurement.

The ACCURA is a bridge-type CMM with a fully enclosed X-axis to reduce service and maintenance. It can be equipped with a variety of touch-trigger and passive scanning probes from Zeiss and other manufacturers.

The probes can be automatically exchanged using an RDS probe change magazine and include VAST® probes featuring active scanning technology. Also, high grade ceramic and carbon fiber materials provide stiffness necessary for fast, accurate scanning.

Each ACCURA model has a vibration isolation system, so the machines can be installed close to the production floor. Also, they offer x, y, z measuring ranges from 700 x 900 x 500 mm to 1,600 x 4,200 x 1,400 mm.

The CMM is available with CAD-based CALYPSO software. This software can be combined with HOLOS, which is designed for measuring 3-D surfaces, and with DIMENSION, which is designed for reverse engineering tasks.

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**Star Cutter, Star SU Offer  
New Tool and Cutter Grinders**

The Star Cutter Co. and Star SU LLC will unveil a new series of 5-axis, NUM CNC-controlled tool and cutter grinding machines.

The Star PTG series features 20 hp drives (continuous from 4,000–10,000 rpm), a 10" maximum wheel diameter, linear glass scale positioning, automatic wheel probing systems, direct-drive digital head stocks with a maximum of 1,000 rpm with 350 in./lbs. of torque for heavy fluting, and NUMROTOplus® software.

The series can also be equipped with an optional 3-D virtual grinding simulation and optional auto loading systems for unattended operation.

The machines were designed for solid carbide tool manufacturers and special application grinding companies.

"The machine series design and power are targeted to address the serious manufacturers of high quality cutting tools," says Brian Cluff, vice president of sales & application engineering for Star SU LLC.

The PTG-2 has a direct-drive, double-ended grinding spindle, a proprietary indexing mechanism pivoting the grinding spindle to the desired end, while maintaining the grinding wheel in the normal position of the CNC-controlled "B" axis. The system is designed to minimize the moment of error and overall distance between wheel packs.

"The result is outstanding accuracy and surface finish," Cluff says.

Also, the machine automatically probes all abrasives mounted on either end of the double-end spindle.

The PTG-4 offers a single-end, direct-drive grinding spindle with auto/HSK wheel mounting, a four-position wheel change mechanism to pre-position the selected wheel packages and coolant manifolds. The wheel change system is outside the grinding environment with interlocking operator access. All wheel and coolant exchanges are controlled via NUMROTOplus.

This software includes grinding wheel management, grinding process management for maximum cycle time development before manufacturing, single command tool file conversion from manufacture to recondition and from right hand to left hand, 2-D simulation with zoom and measurement to within 0.0001", the creation and import/export of DXF files, variable helix, and flute form adaptation.

The PTG-2 and NUMROTOplus will be interfaced with a Zoller "genius" inspection unit at IMTS '04. The combination provides complete integration for producing cutting tools, with NUMROTOplus placing the tool and the HSK Schunk "Quick Change" workholding in the "genius" unit, and automatically inspecting and adjusting the selected parameters based on inspection results.

The S130 hobber will also be exhibited. This CNC machine is designed for dry hobbing, uses a high-speed automatic loading device suitable for robotic loading, and has a modular platform that's the same as the S100's.

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**TTB Engineering to Exhibit Micro Tool Grinding**

A Swiss-made micro tool grinder will make its way across the Atlantic Ocean for introduction to American customers.

The CNC micro precision tool grinder comes with either five or six axes. The TGC 5 has a grinding wheel turret arrangement that allows for up to 15 grinding wheels and can grind tools with diameters of 0.0008"-0.551".

Also, NUMROTO and NTI software can handle a wide range of cutting tools, including drills, milling cutters and profile tools, whether cylindrical or tapered with square, corner or full ball nose ends.

TGC is available with either a GE Fanuc or a NUM control and can be configured with auto loading.

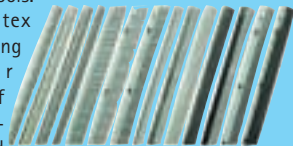
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**Andantex Racks & Pinions:  
For Linear Motion**

Andantex USA Inc. will feature high-performance, zero-backlash rack & pinion drive systems for providing linear motion in CNC machine tools.

Andantex is offering modular systems of racks, pinions and reducers, as well as lubrication systems. These building blocks are standardized and allow OEMs to build an axis of various lengths and move a range of weights, from 100-100,000 lbs. with axis drive forces from 5-15,000 lbs.



The racks are available in modules from 2-10 in lengths of 500 mm, 1,000 mm and 1,500 mm with spur or helical teeth in standard quality levels up to DIN 6 (~AGMA Q12). These racks can be linked together to form an axis of the required length, with companion racks to ensure proper tooth spacing.

"The modular design of the rack system allows a machine tool builder to design machines in sections," says David Regiec, Andantex's vice president-engineering, "so that they can provide different length axes to meet their customer requirements."

According to Regiec, the standard hardened, ground AGMA Q12 rack has a pitch error of 0.022 mm/300 mm (0.00087 in./ft.), which is equivalent to a precision-ground ball screw.

Because the racks are installed in modular sections, it is now possible to connect sections so the total error over four meters is less than the accumulated error of a 4-meter-long ball screw.

Please visit [www.powertransmission.com](http://www.powertransmission.com) for a longer article on this topic. Andantex USA Inc. (Booth D-4788)  
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**All About Honing: Sunnen  
Mandrels, Tools and  
Machines**

Multi-stone superabrasive mandrels for honing pinion gears, diamond-plated helix honing tools for sprockets and gears, and a honing machine for bore sizing and finishing are the new offerings that Sunnen Products Co. will highlight.

The mandrels are for bore sizing and finishing of pinion gears for automotive and industrial transmissions. The Single Stroke® honing tools are for progressive honing. And the honing machine, the VSS-86, features an eight-station rotary table and six-spindles for progressive honing.

Sunnen will also feature two new vertical spindle machines for medium- to high-production bore sizing and finishing of parts with large diameters (up to 200 mm) and small diameters (less than 65 mm). The machines use servo axis control with Windows-based software and a color GE Fanuc touch-screen display for their vertical motion control.

Five other machines for bore sizing and finishing will be displayed: the ML-2000, ML-5000, SV-200, SV-1005, and HTC-2120.

Since IMTS '02, Sunnen has invested in tooling development and manufacturing production of tooling for medium- to high-production honing (bore sizing and finishing) of fuel injectors, hydraulic valves, gears of all types, and other applications.

"The cost to hone, bore size and finish, a workpiece depends on the labor cost and abrasive cost," says Gary Schnitzler, Sunnen's senior product manager-machines. "Sunnen has invested in the tooling and abrasives product development required to optimize the customer's cost per bore."

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## A Linear Guide System, A Cable Carrier: igus' New Products

igus Inc. will feature two products introduced earlier this year, the DryLin® W and the Triflex® R. The DryLin W is the newest addition to the DryLin group of linear bearings and slides with plastic glide elements. DryLin W is available in multiple rail configurations to provide more design options. It comes as a combination of two supported round shafts in one profile, or in a split rail configuration. And it's well suited for automation, packaging, textile and medical applications.

Triflex R, igus' new robotic cable carrier product line, will be highlighted through demonstration. This cable carrier has 3-D and multi-axis freedom of movement and can twist up to 380° per yard. While it protects moving cables and hoses, Triflex R's tubular design allows it to glide over a robot's exterior without catching or tilting.

Also, Triflex R has a trailer hitch (ball-in-socket) design, providing tensile strength and flexibility without needing steel inserts.

The carrier line is well suited for robotic applications that involve linear and radial movements in a confined space.

"Now customers gain the benefits of a fully protected energy supply system that can twist in any direction," says Farrah Phillipo, igus' public relations representative.

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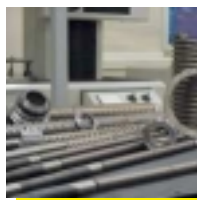


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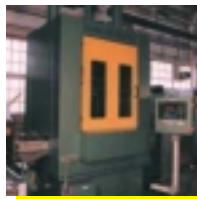
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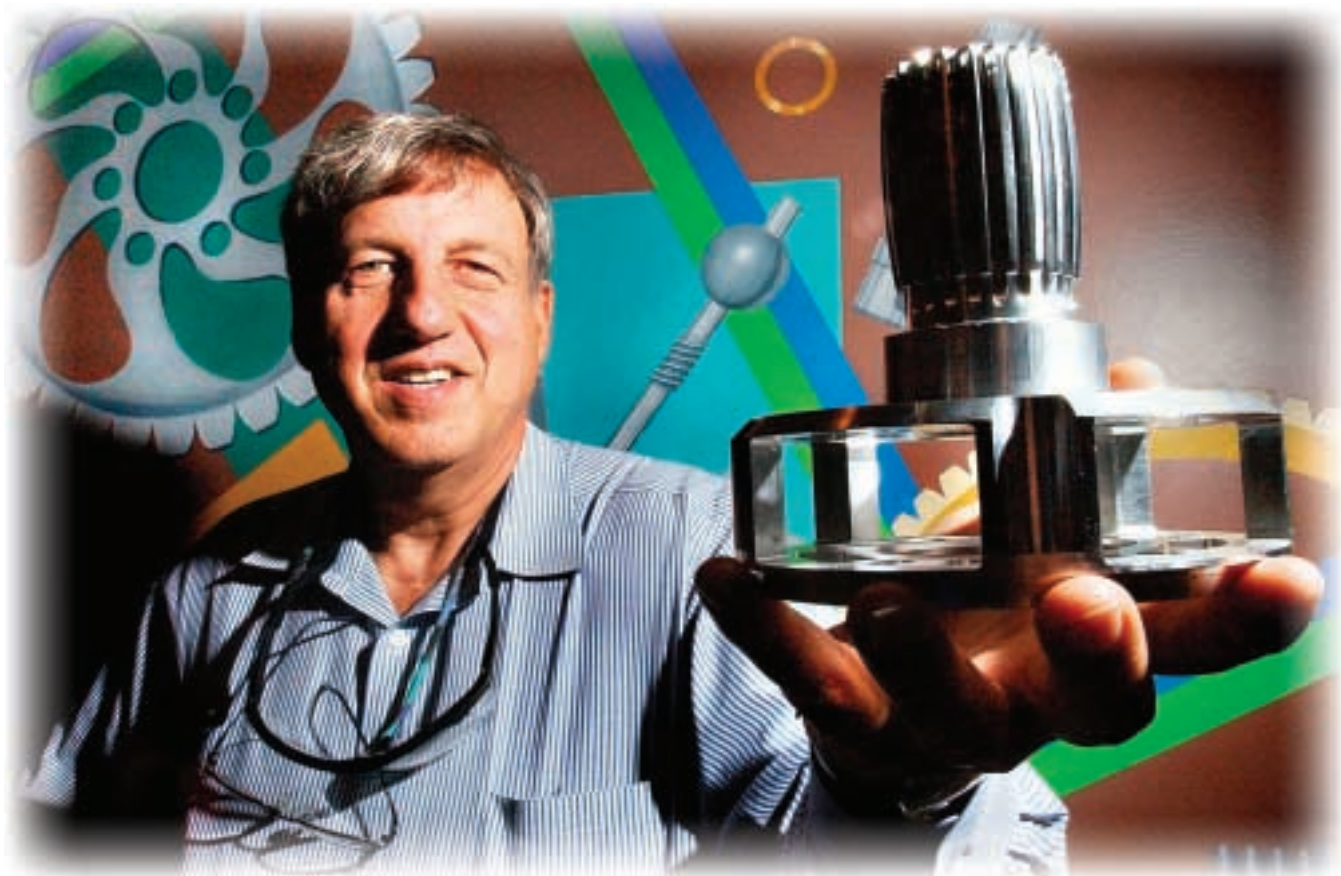


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### Timken Rolls Out New Ceramic Bearings

The Timken Co. will unveil its hybrid ceramic tapered roller bearings for high-speed spindle applications.

The bearings are designed for maximum capacity and stiffness, to allow for higher speeds and lower heat generation than other tapered roller bearings. Also, the bearings include improved wear resistance and lubrication characteristics to extend their service lives.

Timken will also feature Fafnir® THSS super precision angular contact ball bearings, a full range of single- and double-row ball screw bearings, and pre-assembled cartridge units. The contact ball bearings are designed to deliver accuracy and reliability at today's high spindle speeds.

The ball screw bearings include integral, low-torque contact seals to exclude contaminants for reliable operation and extended service life. ABEC9/ISO P2 axial running tolerances reduce runout to deliver accuracy for precise tool positioning and repeatability.

"Timken has improved its friction management technology through advanced materials," says Anthony Romero, Timken's North America marketing manager for applications engineering—super precision. The materials include ceramics for bearing rolling elements, seals for low-torque/high-speed designs, steels, and engineered surfaces that may be applied to steel and other metals to reduce wear and corrosion while reducing friction.

Also, Timken engineers researched the causes of field failures in spindle bearings, learning that hard contamination was the most common cause. So they designed WearEver™ bearings, which resist contamination-induced surface damage. Romero adds that the bearings feature a silicon nitride ceramic ball complement and an advanced new steel that resists wear debris and hard contaminants for extended service life.

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Meccanica Nova's products include internal, external and combined-operation CNC grinding machines, typically used in the automotive, anti-friction bearing, aircraft, aerospace, and general mechanical industries.

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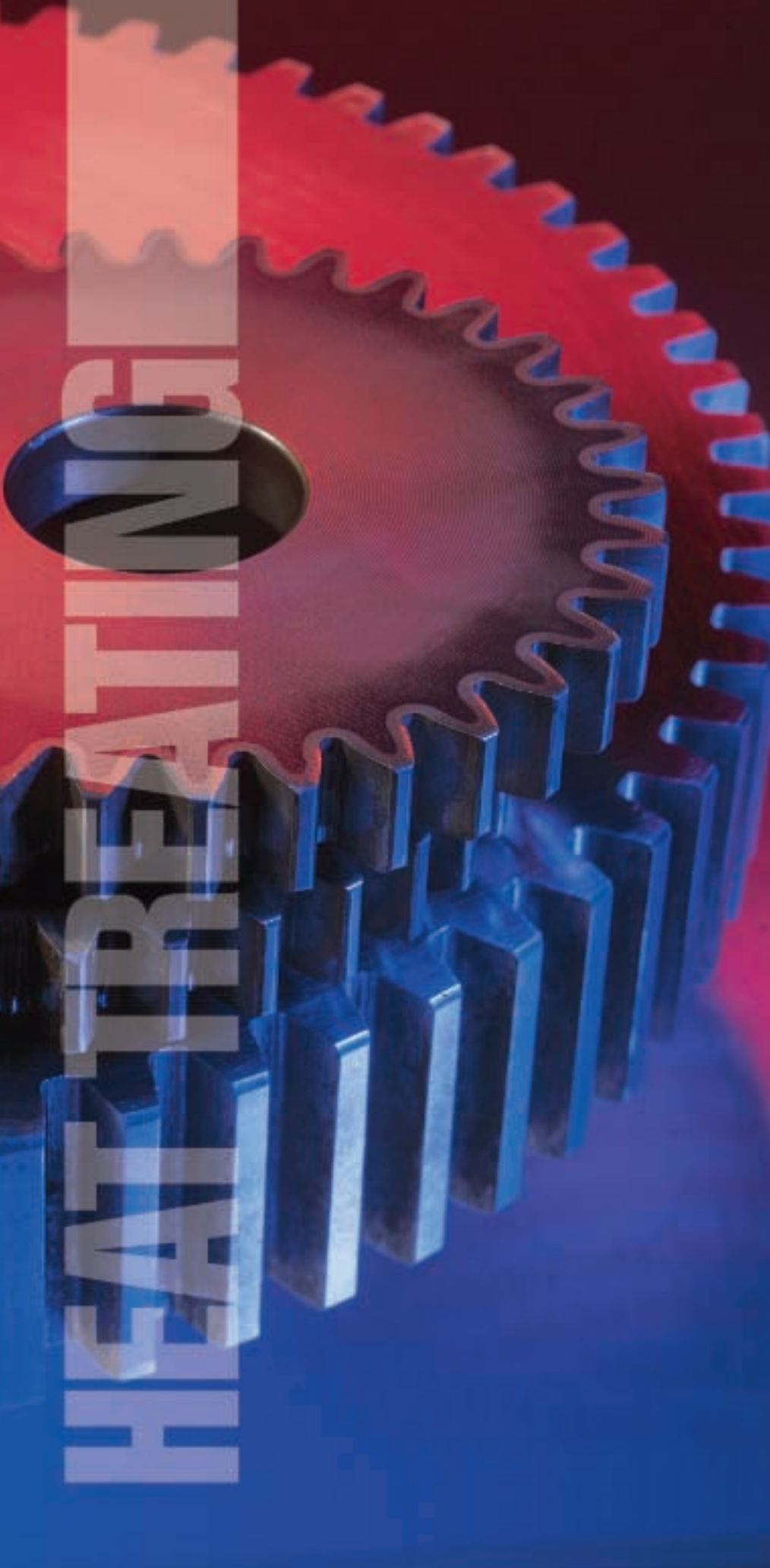
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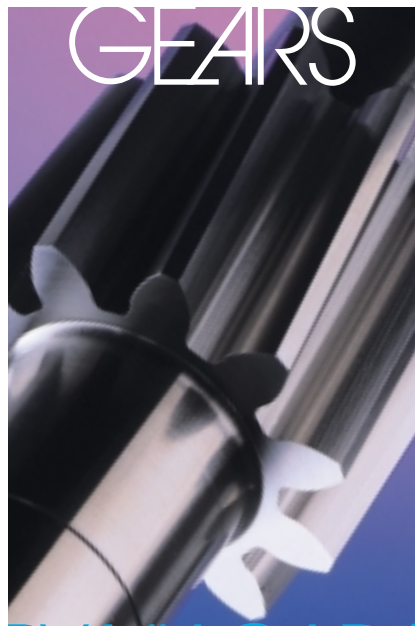


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## IMTS COVERAGE

### Hangsterfer's Offers New Straight Oil

Hangsterfer's Laboratories Inc. will feature its highly advanced straight oil, Hard Cut NG. The oil contains synthetic and vegetable compounds and derivatives combined through infusion, a process that blends and aligns molecular structures. The process allows for a low viscosity without compromise to lubricity or flash point levels.

The company will also emphasize a second new product, SuperAllTap, a heavy-duty compound used for severe thread-cutting and thread-forming operations.

"Due to its ability to emulsify into water, SuperAllTap is excellent for machines using coolants since it will easily wash off into the coolant system," says Tina Seitzinger, Hangsterfer's marketing coordinator.



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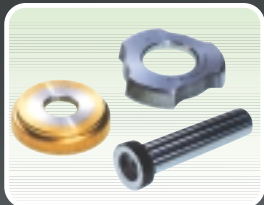
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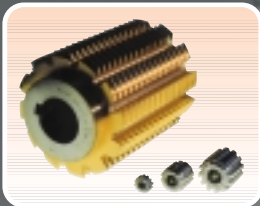
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## SureFire: Bijur's New Lubrication System

Bijur Lubrication Corp. will feature its new SureFire lubrication system, consisting of the SureFire automatic lubricator and the ZEM series positive displacement injectors.

The lubricator can pump oil and soft grease to as many as 100 lubrication points. It's a self-contained, electric-motor-driven gear pump that can adapt to a range of production machinery and is available in three reservoir sizes: 1.8 liters, 2.7 liters and 6.0 liters.

The injectors are pre-fixed volumetric injectors that help ensure each lubrication point receives the right amount of lubricant. Users can choose the number of injector outlets. The four series of injectors are available with 10 output volumes ranging from 0.01 cc to 1.5 cc per lubrication cycle.

Also, the injector's modular design allows for different outputs within a single manifold.

"It will help customers increase their productivity and lower maintenance costs and downtime," says Thomas W. Arndt, Bijur's president and COO about the lubrication system.



Bijur Lubrication Group (Booth D-4148)  
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## Leistritz to Make Worms by Whirling

Leistritz Corp. will demonstrate the whirling process at IMTS '04 by making a three-start worm used in an automotive steering system.

The company will do this with the PW-90, a CNC whirling machine, which will be integrated with an automatic parts loader.

Whirling is a machining operation in which profiled cutters remove material by passing over a workpiece moving at cutting speeds of 350-650 SFM and advancing so a helical form results.

Whirling removes material like milling, using carbide cutters arranged along a ring's inside to a predetermined cutting circle diameter calculated from worm data.

In this process, worms are machined to their finished tolerances and surface roughnesses, then are induction hardened. According to Leistritz, the worms are produced faster, less expensively, and with fewer handlings.

Also, whirling doesn't require undercuts at the ends of a worm's area, so the worm face width can be optimized and overall shaft length reduced. According to Leistritz, the optimizing and reducing make for a more rigid, compact and stronger design.

The result, says the company, is a speed reducer drive with higher efficiencies, greater power ratings and lower weight.

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 1600 Douglas Ave.  
 Kalamazoo MI 49007

# Workholding

## For Hobbing, Grinding: Riten's New Mechanical Face Driver

Riten Industries Inc. will introduce a new mechanical face driver custom designed for gear hobbing and grinding applications.

"This driver gives the user the opportunity to drive the shaft from the face, exposing the entire outside diameter for gear cutting or grinding," says Travis Horton, Riten's national sales manager.

The workholding company will also unveil a new line of actuated face drivers.

"The new Riten actuated face driver has a fixed center point that allows the workpiece to be machined from a fixed datum, while offering drive pins that are actuated by the draw tube of the machine," Horton says.

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 Internet: [www.riten.com](http://www.riten.com)



## Three Chucks and a Table: LMC Workholding's New Products

LMC Workholding will introduce four new products at IMTS 2004: a three-jaw chuck, a rotary table and two wheel chucks.

The GHA6-8-66 is a big-bore, three-jaw chuck. At eight inches, the high-speed chuck offers a 66 mm thru-hole capacity to allow chucking of larger parts and larger diameter bars. Clamping repeatability of less than 10 microns ensures greater repeatability and improved quality parts, according to Jay Duerr, sales & market manager for Logansport Matsumoto Co.

For two-axis EDM applications, there's the MDET rotary table with a 5.91" diameter table and two-axis control with manual tilting/NC rotary axis operation.

"The MDET rotary table is an affordable answer for two-axis submersible EDM work," Duerr says.

Two new lines of wheel chucks will round out LMC's display: the WTI and WDF series. Model WTIQ-323 is for quick changeover—from one wheel size to the next can take less than five minutes—and it can chuck wheels with 15"–25" diameters at up to 2,800 rpm.

The WDF deflash/degate wheel chuck is suited for pre-machining operations for removing the flash and gating from cast aluminum wheels. The WDF series chucks wheels in diameters from 15"–24" (all on a single chucking).

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# Workholding

## Pratt Burnerd Introduces a New Power Chuck

Pratt Burnerd/Atlas Workholding will introduce a new self-contained pneumatic power chuck best suited for machines that lack hydraulic systems.

The new MK5 model improves on Pratt's previous model with a higher rpm rating and larger thru-holes, says B.J. Lillibridge, vice president of Pratt Burnerd America.

"The MK5 will save you money," he says, "because you won't have to purchase an expensive hydraulic pump, tank and control unit or expensive hydraulic actuator or a custom-made drawtube and hydraulic actuator mounting adapter."

Also, the new chuck is controlled by a push button, which is located on top of the chuck's distributor ring for easy operator access. Foot pedal control is optional. No drawtube or rear-actuating cylinder is needed, allowing full use of the machine's thru-hole.

Pratt Burnerd/Atlas Workholding (Booth E-2801)  
1919 N. Pitcher St., Kalamazoo, MI 49007  
Phone: (269) 384-2225 • Fax: (269) 384-3201  
E-mail: info@prattburnerd.com • Internet: www.prattburnerd.com

## Schunk Presents New Chucks, Toolholder

Schunk Inc. will present a toolholding system with clamping based on the principle of a stiff body as a clamping medium.

"The holders can easily be actuated with a wrench to clamp the tool," says Matthias Koch, Schunk's marketing manager.

Schunk will also present a new lathe chuck, a new generation of its THWplus quick-jaw change chuck, and a new set-up unit for its TRIBOS product line.

The new two-jaw wedge hook chuck, the ROTA 2-B, is designed for normal applications and for stationary applications because of its low height. According to Koch, it also offers a large jaw stroke and high clamping forces.

The THWplus was designed with a larger through hole, improved grease retention and better sealing against particle/coolant intrusion. Other new features include a jaw installation safety system: an internal interlock prevents removal of the chuck wrench unless the quick-change jaw is properly installed. After proper installation, the wrench is automatically ejected from the chuck body.

Also, the chuck's center sleeve is removable from the front and available in many configurations including through hole, closed, adjustable coolant, adjustable stop and part ejector.

The SVP-3 is an automated set-up unit, further facilitating tool change for the TRIBOS system. The complete TRIBOS line has been extended with a variety of CAT tapers. Schunk will present the TRIBOS' new holder size, which allows for clamping of tool diameters as small as 0.3 mm.

Since IMTS '02, Schunk has redesigned its TENDO hydraulic toolholders, which now can clamp many types of tool shanks directly in the hydraulic holder without needing an intermediate sleeve. Also, the TENDO program was expanded with American mounting shanks to meet market demand.

Schunk Inc.  
211 Kitty Hawk Drive, Morrisville, NC 27560  
Phone: (800) 772-4865 • Fax: (919) 572-2818  
E-mail: info@schunk-usa.com • Internet: www.schunk-usa.com

## SMW to Unveil Two Series of Sealed Chucks

New, sealed-body lathe chucks will be displayed by SMW Autoblok Corp. at IMTS 2004.

The AP and NT series' internal parts are sealed and operate in a grease bath, so clamping force is constant, says Sidney Roth, SMW's president.

"The result," he adds, "is reduced maintenance, less scrap and higher productivity."

The two series are closed center with standard sizes from 6.5"-16" and can accommodate coolant or compressed air through the chuck body. They also have case hardened bodies for rigid, accurate workholding.

The AP series is designed for high-speed turning and is available in inch or metric, serrated or tongue-and-groove jaw configurations. The AP chucks are also available as quick-jaw-change chucks using a newly developed angled t-nut mechanism, suiting them for pick-up machines as well as horizontal or vertical operation.

The NT series is available in the same configurations as the AP but features a centrifugal force compensation when operating at high speeds.

SMW Autoblok Corp. (Booth E-2207)  
285 Egidi Drive, Wheeling, IL 60090  
Phone: (847) 215-0591 • Fax: (847) 215-0594  
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Telephone: (269) 345-7151  
Fax: (269) 345-1710  
E-Mail: sales@roto-finish.com  
Internet: www.roto-finish.com  
**Booth: B-6852**

**Saacke GmbH & Co KG**  
3939A Benchmark Dr.  
Ladson SC 29456  
Telephone: (843) 329-8876  
Fax: (843) 569-2425  
E-Mail: haas@saacke-usa.com  
Internet: www.saacke-usa.com  
**Booth: B-7541**

**Saazor-Walztechnik,  
Zorn GmbH & Co. KG**  
Eutinger Strasse 164  
D-75175 Pforzheim  
Germany  
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Fax: (49) 7231-952-090  
**Booth: B-6907**

**Samputensili SpA**  
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Fax: (39) 051-434-149  
E-Mail: info@samputensili.com  
Internet: www.samputensili.com  
**Booth: B-6912**

**Schunk Inc.**  
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Internet: www.schunk-usa.com  
**Booth: E-2869**

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4055 Morrill Rd.  
Jackson MI 49201  
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E-Mail: davidtgm@acd.net  
Internet: www.schuttetgm.com  
**Booth: B-7554**

**Solar Atmospheres Inc.**  
P.O. Box 64476  
Souderton PA 18964-1021  
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Fax: (215) 721-6460  
E-Mail: info@solaratm.com  
Internet: www.solaratm.com  
**Booth: B-6338**

**Star SU LLC**  
5200 Prairie Stone Pkwy., Suite 100  
Hoffman Estates IL 60192  
Telephone: (847) 649-1450  
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E-Mail: sales@star-su.com  
Internet: www.star-su.com  
**Booth: B-6912, E-2700**

**Star Cutter Co.**  
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Internet: [www.samputensili.it](http://www.samputensili.it)  
**Booth: B-6912**

**Suhner Manufacturing Inc./SU-Matic**  
P.O. Box 1234  
Rome GA 30162  
Telephone: (706) 235-8046  
Fax: (706) 235-8045  
E-Mail: [info@suhnerusa.com](mailto:info@suhnerusa.com)  
Internet: [www.suhnerusa.com](http://www.suhnerusa.com)  
**Booth: E-2000, E-2569**

**Sunnen Products Co.**  
7910 Manchester Dr.  
St. Louis MO 63143  
Telephone: (314) 781-2100  
Fax: (314) 781-5791  
Internet: [www.sunnen.com](http://www.sunnen.com)  
**Booth: B-7200**

**The Timken Co.**  
P.O. Box 6932  
Canton OH 44706  
Telephone: (330) 471-3000  
Fax: (330) 471-7032  
Internet: [www.timken.com](http://www.timken.com)  
**Booth: D-4585**

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Internet: [www.toolmex.com](http://www.toolmex.com)  
**Booth: A-8163**

**Toshiba Machine Co. America**  
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Internet: [www.toshiba-machine.com](http://www.toshiba-machine.com)  
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Miamisburg OH 45342  
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Internet: [www.grinding.com](http://www.grinding.com)  
**Booth: B-6700**

**WMW Machinery Co.**  
44 W. High St., West Nyack NY 10994  
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**Booth: A-8164**

**WTO Inc.**  
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Internet: [www.wto.de](http://www.wto.de)  
**Booth: E-2816**

**Yaskawa Electric America Inc.**  
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Internet: [www.yaskawa.com](http://www.yaskawa.com)  
**Booth: B-6400**

**Zygo Corp.**  
21 Laurel Brook Rd.  
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Internet: [www.zygo.com](http://www.zygo.com)  
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**VISIT  
GEAR TECHNOLOGY**



**BOOTH B-7113**

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- Renew Your Subscription

AND... see why we're

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**THE GEAR  
INDUSTRY'S  
INFORMATION  
SOURCE**

## A/W Systems

**Booth Number: B7218**

### Description:

A/W Systems manufactures a complete line of tooling for both straight and spiral bevel gearing. Most notable is our line of Face-Hob Cutter Bodies, which are available in all of the most common U.S. blade and size combinations (e.g. 11/64, 13/76, 17/88, 13/105, 19/105). Our In-House blade grinding capacity allows us to provide fully sharpened and coated stick blades, in M2 HSS, Rex 76, Ultra-fine grain Carbide, or any other customer desired substrate. Of course, a variety of coatings are also available.

Additionally, A/W Systems has entered into a partnership with Klingelnberg-Oerlikon Tech Center to provide state-of-the-art hypoid gear tooling technology and services to the U.S. gear manufacturing market.

Our booth will display a wide variety of gear tooling, as well as provide technical materials.



**Contact:**  
**A/W Systems**  
**612 E. Harrison**  
**Royal Oak, MI 48067**  
**Phone: (248) 544-3852**  
**Fax: (248) 544-3922**

## Gleason Cutting Tools CORPORATION

**BOOTH #B-6902**

**More lean, less leadtime.** Gleason Cutting Tools Corporation is leading the industry in Lean Manufacturing methods and applying advanced equipment at its ultra-modern facility in Loves Park, IL to speed deliveries and improve efficiency. Today, with so much riding on shortening leadtimes and improving quality, Gleason Cutting Tools is your single best source for:

- Hobs • Shaper Cutters • Shaving Cutters • Bevel Stick Blades
- Plated CBN Wheels and Plated Diamond Rolls • Form-Relieved Milling Cutters

A host of contract services are available as well, including tool resharpener, advanced coatings, heat treat, metallurgical lab analysis, workholding repairs, pickup/delivery and technical gear schools.



**4 week delivery on shaper cutters (2 weeks for PDQ shapers); 5 weeks for hobs (3 weeks for PDQ hobs)!**



For more information, visit [www.gleason.com](http://www.gleason.com)

## Gleason Corporation

**BOOTH #B-6902**

**Keeping the World in Motion.™** Today Gleason stands virtually alone in its ability to deliver the complete array of technologically superior gear-producing solutions. You can see many of the latest breakthroughs up close and in action at IMTS '04, including:

- PHOENIX® II 275G Bevel Gear Grinding Machine, working in concert with Gleason-Mahr's new GMX 400 Gear Inspection Machine and GEMS (Gleason Expert Manufacturing System) software to 'close the loop' on bevel gear quality.
- P 600 G Profile Grinding Machine, using new patent-pending profile grinding software to greatly reduce non-productive time and improve quality.
- P 90 Horizontal Hobbing Machine, featuring improved direct-drive spindle performance.
- The 245TWG High Speed Threaded Wheel Grinder, making hard finishing in high volumes economical.



For more information, visit [www.gleason.com](http://www.gleason.com)



## Star-SU

Booth Number: B6912



STAR-SU OFFERS A COMPREHENSIVE LINE OF GEAR MANUFACTURING EQUIPMENT:

### Machine tools

- Cylindrical gear hobbing
- Bevel gear cutting
- Shaping
- Profile grinding
- Continuous generating grinding
- Shaving cutter grinding
- Hob grinding
- Universal tool grinding
- Carbide tool grinding
- Chamfering and deburring

### Cutting tools and services

- HSS and carbide hobs
- Shaper cutters
- Milling cutters
- Rack and saw cutters
- Shaving cutters
- CBN profile grinding wheels
- Master gears
- Chamfering and deburring tools
- Regrinding of gear cutting tools
- Coating of gear cutting tools
- Replating of grinding wheels

### Pickup and delivery services

### Commodity Management Services

### Round tools

- Single and double flute gundrills
- Solid carbide gundrills
- Two-fluted milled style deep hole drills
- Solid carbide drills and reamers
- Pressure coolant drills and reamers
- "PCD" drills and reamers
- Integrated holder "PCD" tooling

Visit our website to download our complete program of products and find the match for your particular need.

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 Phone: 847-649-1450  
 Fax: 847-649-0112

[www.suamerica.com](http://www.suamerica.com)  
[www.starcutter.com](http://www.starcutter.com)  
[www.bourn-koch.com](http://www.bourn-koch.com)

See us at IMTS 2004,  
 in Booth 6912, North Hall

## M&M Precision Systems Corp.

Booth Number: B-7107

M&M Precision Systems will display the industry's largest variety of functional and analytical gear inspection products at IMTS 2004. Products exhibited will include the popular MicroTop CNC Gear Analyzer, two models of M&M's full range Sigma CNC Gear Inspection Systems, the ODS 6 and DOP 150 Dimensions-Over-Pins Gauges, the GRS-2 Double Flank Roll tester with integrated PC analysis software and a full display of our Master Gears and Spline Gauge products.

M&M will also provide information regarding the ISO 17025 accreditation of its master gear/gear artifact certification laboratory, the industry's first such facility dedicated to gear inspection. For more information, visit [www.mmprecision.com](http://www.mmprecision.com).



## Marposs Corp.

Booth Number: D4514

### Need to Check Gears?

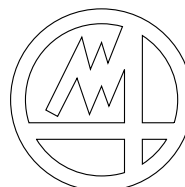
Looking for an easy, cost-effective way to check gears? The Marposs M62 bench gauge system with optional noise detection is accurate, easy to use and quickly re-toolable using ordinary hand tools. You'll save time and the cost of dedicated gauges. With the M62 you can measure:

- Radial composite deviation
- Radial runout
- Tooth to tooth radial composite deviation
- Tangential composite deviation
- Nicks
- Optional measurements include center distance, bore diameter and perpendicularity of bore to gear face.

All functional checks can be displayed on the rugged Marposs E9066 industrial PC system that offers a linear graphic display with full SPC functions.



### Contact



### MARPOSS

3300 Cross Creek Parkway  
 Auburn Hills, MI 48326-2758  
 1-888-627-7677 • 1-248-370-0404  
 Fax: 248-370-0621  
 E-mail: [marposs@us.marposs.com](mailto:marposs@us.marposs.com)  
[www.marposs.com](http://www.marposs.com)

## LIEBHERR GEAR TECHNOLOGY CO.



**Booth Number: B7016**

Sigma Pool partners Liebherr and Klingelberg will be exhibiting the following machines:

**Liebherr LCS 300 CNC Generating and Profile Grinding Machine**

Flexible design allows use of CBN or dressable grinding worms or wheels, *plus* an Internal grinding option

**Klingelberg P26 Precision Gear Measuring Center**

Increased accuracy, simpler operation and faster cycle times with an extended range of applications, including non-gear related CMM type capabilities

**Klingelberg Oerlikon C 27 Spiral Bevel Gear Generator**

Dry cutting excellence with extremely short cycle times, using advanced direct drive technology

**Contact:**

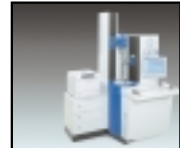
Liebherr Gear Technology Co.

1465 Woodland Drive, Saline, MI 48176

Phone: 734-429-7225 • Fax: 734-429-2294 • Email: [info@lgt.liebherr.com](mailto:info@lgt.liebherr.com)



Liebherr LCS 300



Klingelberg P 26



Klingelberg Oerlikon C 27

## BOURN & KOCH INC

Bourn & Koch Inc. of Rockford, Illinois, will be introducing two NEW machines at IMTS 2004. They are:

- the NEW 100H Series II Gear Hobber, which incorporates many of the standard features and performance of the 200/400H at a very economical price.
- the NEW Fellows HS650 Gear Shaping Machine. The new design has 50% fewer mechanical parts than its FS series predecessors.

Also, be sure to ask about our other products and services, including complete rebuilding and retrofitting of machine tools.

Bourn & Koch, Inc.

2500 Kishwaukee St., Rockford, IL 61104

Phone: (815) 965-4013 • Fax: (815) 965-0019

Email: [bournkoch@worldnet.att.net](mailto:bournkoch@worldnet.att.net) • Web: [www.bourn-koch.com](http://www.bourn-koch.com)



**Booth Number: B-6912 North Hall**

## REISHAUER

**Booth Number: B7005**

Reishauer never sleeps when there are new machines and processes to be developed. If hard finishing of small gears is on your radar screen, you'll not find a more productive or accurate grinder on the market. We've drawn upon more than five decades of experience building gear grinding equipment to develop a compact machine that offers flexibility, grinding speed, ease of setup and accuracy. The RZ 150 sets a new industry standard for gear hard finishing equipment.

**Contact**

Reishauer

1525 Holmes Road

Elgin, IL 60123

Phone: (847) 888-3828

Fax: (847) 888-0343

[www.reishauer.com](http://www.reishauer.com)

[reishauer-us@reishauer.com](mailto:reishauer-us@reishauer.com)



Technical data:

Workpiece outside diameter 150 mm / 5.9"

Number of teeth 6-150

Module/DP 1-3 / 25.4-8

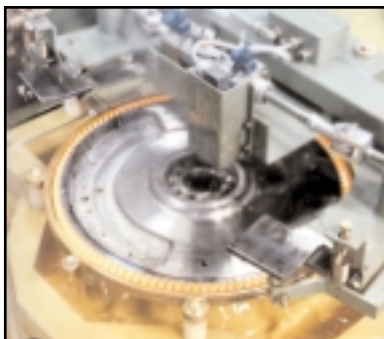
Helix angle  $\pm 40^\circ$

Workpiece weight maximum 3 kg / 6.6 lbs



## INDUCTOHEAT

An Inductotherm Group Company



### Booth Number: B7153

Inductoheat Inc., Madison Heights, Michigan, and Radyne Corporation, Milwaukee, Wisconsin will showcase the latest in gear heat treating technology at IMTS 2004, including single frequency, variable frequency and Simultaneous Dual Frequency (SDF).

SINGLE FREQUENCY gear hardening for high volume dedicated applications allows for manual tuning, while VARIABLE FREQUENCY allows for tuning with a push of a button by matching frequency to a diametrical pitch.

The SDF induction gear hardening process improves quality and efficiency, yet yields better results and higher production rates than conventional heating processes. SDF is easily integrated into new or existing manufacturing lines as a flexible workcell.

In addition, Inductoheat and Radyne feature a fully functioning metallurgical laboratory and aftermarket support. They also produce induction scanners for general purpose heat treating and the Flexitune® induction heating power supply.



## INDUCTOHEAT

An Inductotherm Group Company

## RADYNE

An Inductotherm Group Company

Inductoheat and Radyne are Inductotherm Group companies. They will be at booth B-7153 near the Gear Pavillion.

Inductoheat, Inc.  
Madison Heights, MI  
Phone: 248-585-9393  
Internet: [www.inductoheat.com](http://www.inductoheat.com)

Radyne Corporation  
Milwaukee, WI  
Phone: 414-481-8360  
Internet: [www.radyne.com](http://www.radyne.com)

# KAPP

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# KOEPPER

### Booth Number: B6907

Koepfer America, L.L.C. is the exclusive distributor in North America for the MIRA product line by Tyrolit. Tyrolit is a world-class manufacturer of vitrified and abrasive products. The MIRA product line covers all products related to the manufacturing of gears, which includes tools for Gear-Honing and Gear-Grinding.

The tools for the Gear-Honing process include both positive- and negative-plated diamond dressing gears, diamond dressing rings, and honing wheels.

Tyrolit also manufactures grinding wheels for the Gear-Grinding process. This includes wheels for continuous generating grinding, as well as single profile wheels for index form grinding or index generating grinding.



### Contact:

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635 Schneider Drive  
South Elgin, IL 60177  
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E-mail: [sales@koepferamerica.com](mailto:sales@koepferamerica.com)  
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## Dura-Bar

Booth Number: E2172



### Continuous Cast Iron

Dura-Bar is the only manufacturer of continuous cast iron bar stock in North America, and is the largest in the world. Rounds, squares, rectangles, tubes and special shapes are supplied through a nationwide distribution network. Inherent properties include noise and vibration damping, machinability, strength, and wear resistance, making our bar stock an alternative to steel and other metals in fluid power, gear and other applications. New Dura-Bar Plus is an engineered iron that machines better than carbon and alloy steels and other grades of continuous cast iron. A material of uncompromising consistency, it allows metal component manufacturers to machine more parts per hour, thereby decreasing cycle time, increasing productivity, and boosting profitability.



**Dura-Bar**  
**1-800-BAR-MILL (227-6455)**  
**www.dura-bar.com**  
**sales@dura-bar.com**

## CERATIZIT

Booth Number: E-2377

**CERATIZIT Solid tungsten carbide blanks for hobs: Profit tooth by tooth!**

CERATIZIT has produced blanks for solid tungsten carbide hobs for many years. Every hob is an individually manufactured high-tech product based on our customers' drawings. Furthermore we offer tailor-made CERATIZIT tungsten carbide grades—a guarantee for reliability and maximum output.

### Convincing advantages:

- near-net-shape technology, with tight tolerances and improved grinding allowances
- efficient, homogeneous submicron tungsten carbide grades
- prompt delivery
- member of WZL Gear Circle

Ceratizit USA Inc.  
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 E-mail: [info.usa@ceratizit.com](mailto:info.usa@ceratizit.com)  
 Internet: [www.ceratizit.com](http://www.ceratizit.com)



## KOEPFER

Booth Number: B6907

IMS Gear of Eisenbach, Germany, and Jos. Koepfer of Furtwangen, Germany, have joined their cutting tool divisions to create [ims.koepfer.cuttingtools.com](http://ims.koepfer.cuttingtools.com). This company provides a more comprehensive cutting tool program and improved customer service with a wider presence throughout Europe and North America. An expanded range of tools are now offered, including high-speed steel and carbide hobs that can be manufactured in bore and shank type designs. A maximum diameter of 180 mm (7.087 in) and a total length of 400 mm (15.748 in) is offered. The maximum pitch is extended to 8 module (3.175 DP).



**ims.koepfer.**  
 cutting tools gmbh

### Contact:

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 Internet: [www.koepferamerica.com](http://www.koepferamerica.com)

# Beginnings & Endings...

## Lees Bradner Line Sold to Industrial Products

Fayscott LLC and Industrial Products announced the sale of the Lees Bradner line of gear hobbers and thread cutting machines to Industrial Products, which will do business under the Lees Bradner name.

According to the Lees Bradner press release, the daily operations will be relocated to Kennewick, WA. During the transition period, Fayscott will continue to provide parts and services.

Lees Bradner will continue to support the gear hobber product line as well as streamlined parts to support the thread millers indefinitely.

## Balzers Begins New Coating Research

Balzers, along with cooperating partners Plansee AG, the Montan University Leoben and University of Innsbruck, began developing new thin coatings for tools.



**Robert Bergmann, 75, a former president of the American Gear Manufacturers Association, died June 10.**

**Bergmann was CEO of Abart Gear & Machine Co. for 17 years before starting a consulting firm.**

**On the memorial website created by Bergmann's family at [www.geocities.com/jmahn44/RBERGMANN](http://www.geocities.com/jmahn44/RBERGMANN), Fred Young of Forest City Gear said, "On a personal basis, I recall his words of wisdom to me as I rotated through the AGMA hierarchy and as the president of a gear company. We shall miss our friend, but know he is where there is never a rejected gear or a mean customer."**

## Houghton Ships Record Number of Fluids

**Houghton International has shipped 3 million gallons of Hocut 795 biostable coolant, achieving an industry milestone for sales of grinding/cutting fluid, according to Houghton's press release.**

**The coolant is used nationwide in aerospace, automotive, appliance and off-road equipment applications. The coolant is biostable, preventing the growth of mold, fungus and odor that cause bacteria without adding sumpside biocides.**

**The product line includes a semi-synthetic cutting and grinding fluid that makes it compatible for use with metals like cast iron materials. In addition, it contains a coolant specially formulated for machining red metals.**



According to the company's press release, scientists will analyze the composition and structure of coating materials, coating growth and induced coating structures as well as real-world applications.

Balzers is a global supplier of PVD coatings for precision components such as metalworking and plastics processing tools.

## Xtek and Metlab Form Alliance

Xtek Inc. and Metlab formed a strategic partnership that leverages Metlab's carburizing furnaces to expand the capabilities of both companies.

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# Surface Damage Caused by Gear Profile Grinding and Its Effects on Flank Load Carrying Capacity

Prof. Dr.-Ing. Fritz Klocke and  
Dr.-Ing. Heiko Schlattmeier

## Management Summary

Instances of damage to discontinuous form ground and surface-hardened gears, especially of large scale, have recently increased. This may be attributed partly to a faulty grinding process with negative effects on the surface zones and the surface properties.

The studies reported in this article are intended to contribute to the knowledge of the interrelationships between surface zone damage and the effects on flank load-carrying capacity for the case of profile grinding.

## Introduction

In addition to its high accuracy, discontinuous form grinding is characterized by high material removal rates because of the line contact between grinding wheel and tooth flank. The efficiency and reliability of the process are affected not only by the use of optimized grinding wheel specifications and machining parameters, but also by the risk of local surface zone damage in the form of grinding burn on the tooth flank.

The location and onset of local grinding burn damage have seemed for a long time to be random and unpredictable, for which reason the feed rates and material removal rates have been increased only incrementally in procedures used in industrial practice.

Grinding tests have been conducted in order to investigate more closely the occurrence of surface properties in the form of grinding burn as a function of grinding parameters. Further studies of the flank load carrying capacity of case hardened gears subjected to different surface properties are intended to provide a more detailed analysis of the interrelationship between gear geometry and different surface properties during the grinding process.

## Research of Grinding Burn at Tooth Flank Profile Grinding

Nital etching is used in a lot of industrial applications to review a ground gear regarding structural damage caused by grinding burn (Refs. 6, 8). This method shows a positive result if the surface zone of the ground gear shows light and dark differences. Although different grinding processes cause different distributions and intensities of structural damage, those distributions are not taken into account for the estimation of the load carrying capacity.

The target of a first step is to examine the area where the thermal damage occurs at the flank by systematic tooth profile grinding. In addition to grinding the tooth flanks of the gear wheel, grinding the tooth root will also be considered. The grinding tests may give further information, regarding which areas of the tooth flank and the root are susceptible to thermal damage by grinding burn.

## Geometrical Research of Stock Allowance

At the precutting of spur gears, different standard tool profiles can be used, depending on the chosen machining process (Ref. 10). In the case of gears to be hard finished, there remains

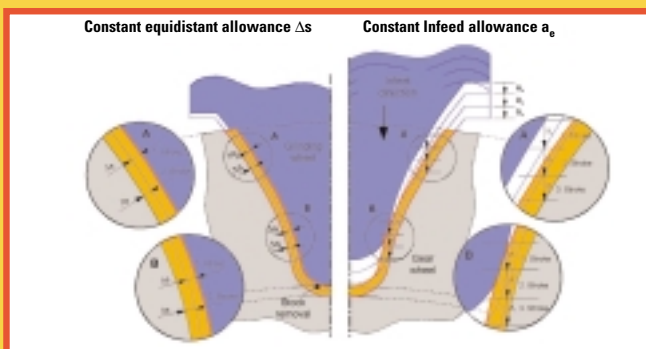


Figure 1—Stock allowance at tooth flank profile grinding.

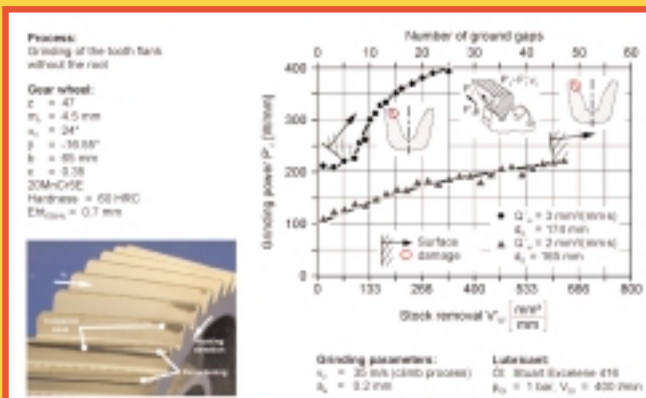


Figure 2—Grinding power and surface zone, depending on constant infeed allowance (without tooth root).

extra stock after precutting at the tooth flank. This stock can be described as a constant equidistant allowance  $\Delta s$ .

Fig. 1 gives an overview of the shape of stock allowance along the profile geometry depending on the form grinding process and the number of strokes. Also, it is necessary to distinguish between form grinding with constant equidistant allowance  $\Delta s$  and with constant infeed allowance  $a_e$ .

When grinding smaller spur gears, the stock can be removed in only one stroke of the grinding wheel. But when grinding bigger gears, a lot of grinding strokes may be required to finish the gear wheel, because of high deviations after pre-machining and carburizing. The number of grinding strokes and the geometry of the grinding wheel will determine the shape of stock along the ground tooth gap for each stroke. Additionally, the contact conditions between the grinding wheel and the tooth gap depend on the local contact conditions. These parameters should be considered when analyzing grinding trials and developing the tooth form grinding. In the case of profile grinding, including the tooth root and removing a constant equidistant allowance  $\Delta s$  along the whole profile geometry, the small figures on the left side show in detail that the stock in infeed direction  $a_e$  increases from the tip of the tooth nearly to the area of the root at the flank. Removing the stock this way is possible when using different grinding wheels with electroplated CBN or changing the wheel geometry by dressing. That is why a higher amount of material will be removed from the tooth flank near the tooth root (Ref. 11).

The removal of a constant stock in infeed direction occurs when grinding with a constant wheel geometry in more than one stroke (Fig. 1, right). This process is used in most industrial applications when grinding high module gears. The details from the tip and the root area of the flank show that the stock in equidistant direction decreases along the flank geometry. In contrast to grinding with a constant equidistant allowance, the maximum stock will be removed in the area of the tip in the last stroke.

In comparing the different forms of stock at the root of the tooth gap, the figures show that a higher stock removal happens in case of grinding with a constant infeed allowance compared to grinding with a constant equidistant allowance.

The geometrical results explain that the local stock removal varies along the profile of the tooth gap and the local strain of the flank also depends on the local stock removal and the wheel geometry. It can be expected that the area of grinding burn depends on the local stock removal and the local contact conditions between the grinding wheel and the tooth gap when grinding with different process strategies.

#### Grinding Research of Stock Allowance

For the investigations, a helical gear with a number of teeth of  $z = 47$ , a module of  $m_n = 4.5$  mm and a helix angle of  $\beta = -16.55^\circ$  was used. The pressure angle has a value of  $\alpha_n = 24^\circ$ . The material of the workpiece consists of a carburized steel 20MnCr5E, with a surface hardness of 60 HRC and a case hardening depth of  $Eht_{50HV} = 0.7$  mm. The profile and the lead are not modified.

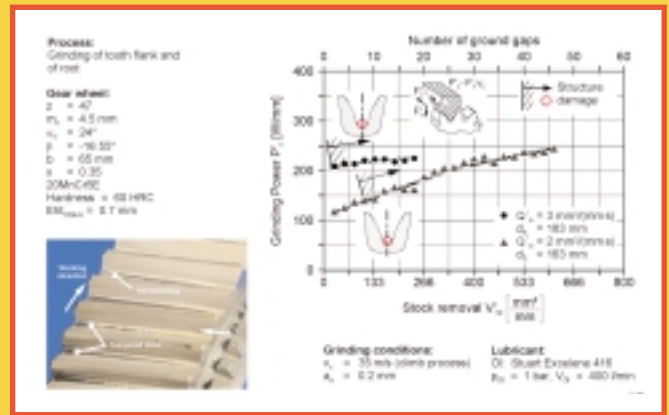


Figure 3—Grinding power, depending on infeed allowances (including tooth root).

For the grinding trials, a grinding wheel with a specification of 53A60 K5V made of conventional corundum is used. A wheel with a high bonding hardness and a cohesive structure was used. Such a grinding wheel is very likely to cause structural damages of the surface structure even with just a low amount of stock removal. The trials will be conducted on a modern gear grinding machine. To guarantee the same grinding conditions, all helical gears are pre-ground with the same dressing and grinding conditions before the trials are made.

Before the grinding test is conducted, the grinding wheel is always dressed with the same dressing conditions. According to a finishing process, the following data will be chosen—a dressing infeed of  $a_d = 0.01$  mm, a contact ratio of  $u_d = 8.0$  and a speed ratio in counter direction of  $q_d = -0.8$ . In the grinding tests, the tooth space allowance is removed consistently in one cut, at a speed ratio of  $v_c = 35$  m/s in the same direction. The cooling lubricant is supplied by two jet nozzles, which are arranged tangentially to the grinding wheel diameter.

#### Constant Infeed Allowance

In a first step, the occurrence of a structural change on the tooth flanks should be examined. The structural change is caused by grinding with constant infeed allowance of  $a_e = 0.2$  mm, without additional machining of the tooth root for a different material removal rate. According to the usual definition of the relative material removal rate,  $Q'_w = a_e \cdot v_f$ , a feed speed of  $v_f = 600$  mm/min is calculated for a relative material removal rate of  $Q'_w = 2$  mm<sup>3</sup>/(mm·s) and for a relative material removal rate of  $Q'_w = 3$  mm<sup>3</sup>/(mm·s), a feed speed of  $v_f = 900$  mm/min. is calculated.

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For the evaluation of the grinding process, the relative grinding power  $P'_c$  is evaluated over the relative equidistant allowance  $V'_w$  in Fig. 2.

The relative grinding power increases during the operating time, independently of the chosen stock removal rate. This can be attributed to the fact that, with increasing operating time, the grinding wheel topography is being changed by wear.

For instance, grain flattening causes an increase of friction in the machining process, which again causes an increase of the grinding power and a higher heat contribution to the tooth flank surface. The consequence of inserting a higher heat amount is a structural change at the tooth surface (Refs. 12, 13).

A comparison of the trials with different relative stock removal rates shows that the relative grinding power is on a lower level if a lower relative stock removal rate of  $Q'_w = 2 \text{ mm}^3/(\text{mm} \cdot \text{s})$  is chosen. This can be attributed to a lower stock removal per time unit. Beginning at a stock removal rate of  $V'_w \approx 550 \text{ mm}^3$ , which corresponds to a machining of 45 tooth spaces, an impact on the structure of the flank appears. In a trial with a higher relative stock removal rate of  $Q'_w = 3 \text{ mm}^3/(\text{mm} \cdot \text{s})$ , an impact of the structure occurs already from an equidistant allowance of  $V'_w \approx 60 \text{ mm}^3$  on, and the grinding power increases in a disproportionate manner.

In both trials, the structural damage occurs near the tooth tip, as it can be seen on the etching image of the tooth flanks with the orientated stock removal rate of  $Q'_w = 3 \text{ mm}^3/(\text{mm} \cdot \text{s})$ . The structural damage begins on the running out of the grinding wheel from the gearing on one side of the tooth flank and increases with every additional machined tooth space.

According to the machining of a tooth gap using a climb process, the beginning structural damage in the running-out of the grinding wheel can contribute to a declined coolant supply into the gap. It is furthermore visible that the extent of the flank damage is increasing up to the formation of a new hardening area, yet the location of the structural damage over the profile does not change. This phenomenon is caused by a local overload of the grinding wheel.

In the following, the grinding of the tooth root will be examined. Therefore, the tooth surfaces of the workpieces are already machined in the rough grinding process in order to guarantee constant trial conditions. Like in previous examinations, the machining is done in one cut with a constant infeed allowance of the grinding wheel of  $a_e = 0.2 \text{ mm}$ .

Fig. 3 shows the orientated grinding power over the relative removal for different orientated material removal rates.

The orientated grinding power increases during the cumulative operating time, independent of the feed speed, which is caused by the wear of the grinding wheel topography. If an orientated stock removal rate of  $Q'_w = 2 \text{ mm}^3/(\text{mm} \cdot \text{s})$  is chosen, the orientated grinding power is on a lower level compared to the trial with an orientated stock removal rate of  $Q'_w = 3 \text{ mm}^3/(\text{mm} \cdot \text{s})$ . Compared to the examinations in which the tooth root was not machined, an impact of the structure of the ground tooth profile occurs definitely earlier, not near the tooth tip but



in the tooth root.

Pictures of the etching of the experimental gears show that the structural damage in this case also begins on the running out of the grinding wheel of the tooth space, and the damage also rapidly increases to form a new hardening area in the tooth root. In this trial, a structural damage on a tooth flank does not occur.

Geometrical considerations of a constant stock infeed allowance of the grinding wheel should help to find the reason for the structural damage on the tooth tip and root (Fig. 4).

The diagram shows, by means of the chosen gear geometry, the equidistant and the infeed allowance of a grinding wheel in a normal section. The calculations are done by means of the constant infeed allowance of  $a_e = 0.2$  mm, which was chosen in the previous trial. The allowances are determined for every single point of the gear profile between the tip circle radius and the root circle radius and then removed. The diagram shows how the allowances change over the profile height.

It is furthermore visible that the equidistant allowance in the area of the tooth flank is definitely lower than the infeed allowance. Beginning from the tooth tip radius, it decreases first over the profile height in the direction of the tooth root and reaches its minimum near the tooth root form radius, where the tooth flank develops to the root surface. The equidistant allowance increases rapidly in the direction of the tooth root. On the root circle radius, it corresponds to the value of the infeed allowance.

In the trials in which the tooth root was not machined, an impact of the material structure occurs in the area of the tip flank (Fig. 3). The structural damage in this area contributes to the fact that the tip flank has more material volume which has to be removed than the root flank.

In the trials in which the root was machined as well, a grinding burn occurred in the tooth root after machining only a few tooth spaces. This can also be explained with the fact that the local material volume that has to be removed by the grinding wheel is higher than the one in the tooth flank. The results show that, in the grinding process with constant infeed allowances, the area near the tooth tip is imperiled with regard to grinding burn. If the tooth root is ground too, it can be assumed that a structural damage caused by grinding will first occur in the tooth root.

#### Constant Equidistant Allowance

Based on the examinations on the constant infeed allowance, examinations on equidistant stock allowance will be done. Since the removal of an equidistant allowance is only possible by means of a change in gear profile, the tooth flanks are preground with a higher addendum modification factor and root circle diameter.

Previous to test grinding, the grinding wheel is profiled on the final shape again and dressed with the same parameters. The grinding process is performed with a cutting speed of  $v_c = 35$  m/s using a climb process. The average infeed allowance of the grinding wheel approximately amounts to  $a_e \approx 0.2$  mm for this gear geometry with an equidistant allowance of  $\Delta s = 0.1$  mm.

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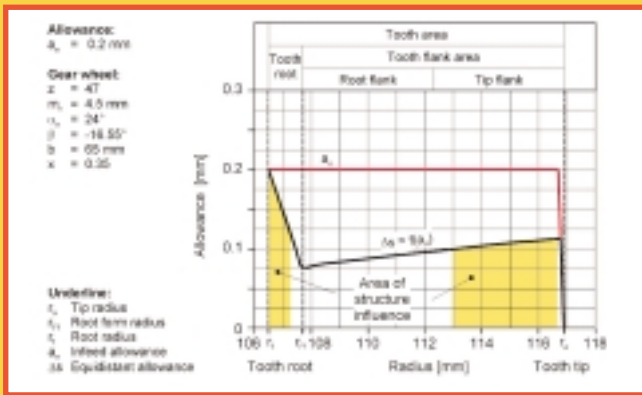


Figure 4—Equidistant allowance, depending on infeed allowances.

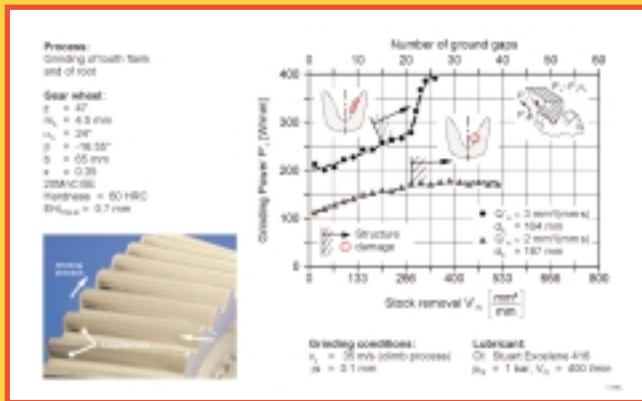


Figure 5—Grinding power, depending on equidistant allowance.

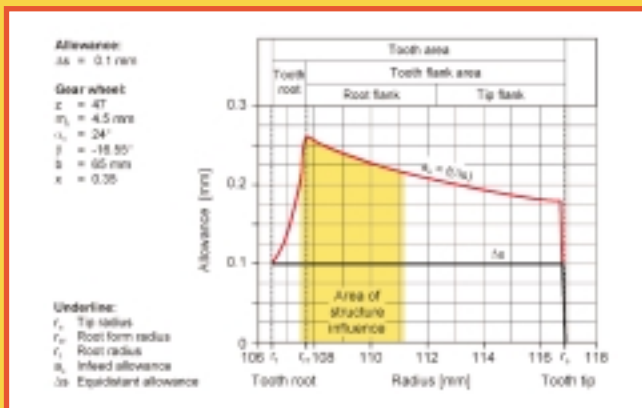


Figure 6—Infeed allowance, depending on equidistant allowances.

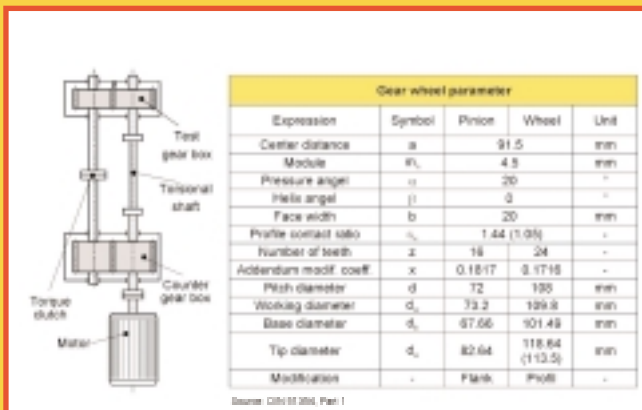


Figure 7—Gear test rig and gear geometry.

If axial advance speeds of  $v_f = 600$  and  $900$  mm/min are chosen, orientated stock removal rates of  $Q'_W \approx 2$  mm<sup>3</sup>/(mm · s) and  $Q'_W \approx 3$  mm<sup>3</sup>/(mm · s) can be calculated. The tooth root is machined as well in these examinations.

To examine the operational behavior, the orientated grinding power is applied over the orientated stock removal for different stock removal rates in Fig. 5.

For both chosen stock removal rates, the orientated grinding power increases with a constant equidistant allowance during the cumulative operating time in the grinding process due to the wear. Therefore, the grinding power in the experiment with the lower orientated stock removal rate of  $Q'_W \approx 2$  mm<sup>3</sup>/(mm · s) is running on a lower level and the structural damage on the tooth flank occurs from an orientated stock removal rate of  $V'_W \approx 300$  mm<sup>3</sup>/mm (22 spaces) on. In the experiment with a higher orientated stock removal rate of  $Q'_W \approx 3$  mm<sup>3</sup>/(mm · s), the stock removal is  $V'_W \approx 200$  mm<sup>3</sup>/mm (15 spaces) before the grinding burn occurs.

In both cases, the impact on the structure occurs at first in the area of the tooth root flank. The structure impact gets stronger for every single tooth space in the feed direction of the grinding wheel. This could also be attributed to a worsening cooling lubricant insert in the running out area of the grinding heel. Contrary to the examinations with the constant infeed allowance  $a_e$ , the surface of the tooth root is not thermally affected by the machining.

In order to interpret the location of the structural damage over the tooth profile, new geometrical considerations will be made. Therefore, the infeed allowance  $a_e$  will be calculated over the gear profile for a constant equidistant allowance of  $\Delta s = 0.1$  mm in the normal section of the gap (Fig. 6).

The diagram shows that the infeed allowance is higher than the equidistant allowance  $\Delta s$  and that it increases beginning from the tip circle radius in the direction of the tooth root. In the area of the root form circle, the infeed allowances reach a maximum. In the tooth circle radius direction, the infeed allowance decreases. After reaching the root circle radius, it equals the equidistant allowance of  $\Delta s = 0.1$  mm.

Exactly like in previous geometrical considerations, the reason for a beginning of the structural damage in the area of the tooth flank can be seen in the removal of a high local material volume in the area of the root form circle radius. Due to the low local material volume in the tooth root, there are no thermal structural damages occurring in the examinations in this area. The examinations show that, in the grinding process with a constant equidistant allowance, it has to be anticipated that thermal structural damage can occur in the area of the root flank. It is not assumed that premature structural damage can occur in the tooth root.

### Research of Flank Load Carrying Capacity Caused by Case Hardened and Tooth Flank Profile Ground Gears

The focus of this research is to show the difference between the structural damage caused on the tooth flank by grinding burns and the damage caused by the tooth flank load-

ing. Therefore, the flank loads for different torques are examined in the first step. In a second step, the flank load over the profile height should be varied through a change of the profile contact ratio.

### Testing Preparation

The research of the flank load carrying capacity of case hardened gears is conducted on a standard gear test rig according to DIN 51354 with a center distance of  $a = 91.5$  mm (Ref. 14). The torque is mechanically arranged using a torque clutch, and a capacity loop is built up over a torsion axle, a gear train and a test gearbox. In the execution of the test, the test gear wheel is actuated with a speed of  $n_1 = 3,000 \text{ min}^{-1}$ . The lubricant supply is realized using a jet lubrication with an oil temperature of  $90^\circ\text{C}$ . Tribol 1100/220 oil is chosen as lubricant because it has a high viscosity, which guarantees a high safety with regard to gray discoloration on the tooth flank.

Beside the principle test rig arrangement, the chosen gear geometry is shown in Fig. 7.

Since the flank damages of case hardened gears should be examined in their dependency of the workpiece surface changes which are caused by grinding, all used gears must have preferably consistent gearing qualities and surface roughness.

Therefore, a grinding wheel of the specification 53A120 J6V is used in the hard finishing process, because it has a small grain size, a high bond hardness and a closed structure, which all lead to structure changes on the tooth flank even if a low relative stock removal rate is being used. Furthermore, the use of this grinding wheel guarantees that the surface roughness will not be explicitly changed even if the feed speed is increased. The allowance characteristic corresponds to a constant infeed allowance, so that the structural damage occurs on the tooth flank tip. The tooth root surface is not machined. The analysis of the changes in the workpiece surface structure is conducted after the etching process (Ref. 8). The question of whether a beginning structural damage on gears leads to a reduction of the flank load carrying capacity is especially interesting in this case. Therefore gears with a low grinding burn on the tooth flanks are used in this research. For the analysis of the load carrying capacities, some additional test gear wheels are used. Some are without grinding burn and some have higher damage up to the formation of a new hardening area.

Independent of the chosen stock removal rate, comparable roughness on the tooth flank can be achieved. The values of the average roughness depth lies between  $R_z = 3$  and  $4.3 \mu\text{m}$  and the values of the arithmetic average roughness about  $R_a = 0.6 \mu\text{m}$ . The surface roughnesses are alike so that this does not influence the results. Residual stress measurements on the flank surface should confirm the different workpiece surface characteristics over the profile height, which were previously assumed by means of etching. The residual stresses, which are measured on the tip flank in the area of the grinding burns and on the root flank, are displayed in tangential and axial direction in Fig. 8.

Independent of the measuring point, compressive residual stresses are realized on the test gear wheel without a structural

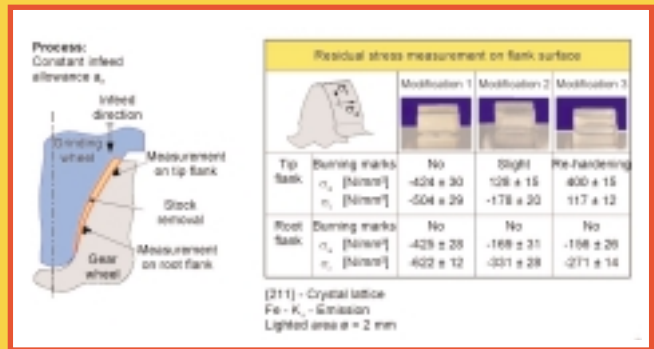


Figure 8—Residual stress, depending on tooth flank profile grinding.

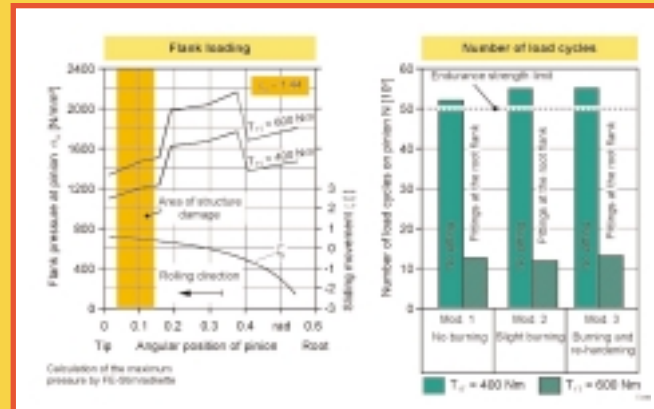


Figure 9—Flank pressure and load reversal, depending on different torques.

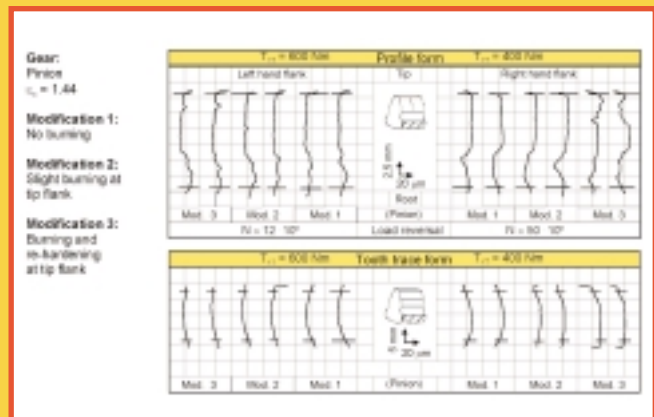


Figure 10—Test gear wheels after use, depending on different torques.

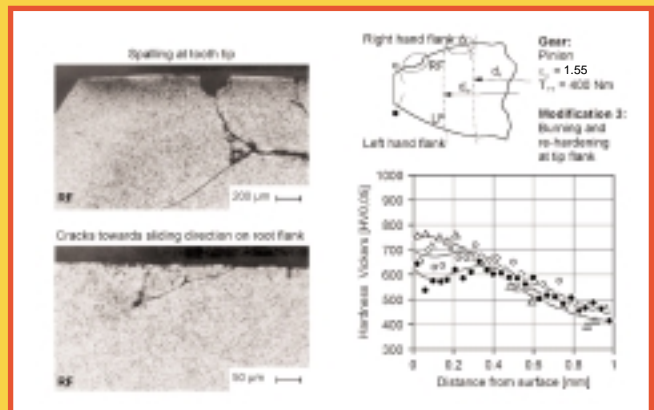


Figure 11—Structure and hardness measurements after use.

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change in axial and tangential direction in a height of  $\sigma_a = -425$  N/mm<sup>2</sup> and  $\sigma_t = -504$  to  $-622$  N/mm<sup>2</sup>. Due to the increase of the feed speed, it comes to a change of machining conditions and of the heat, which is induced into the gear surface. The compressive residual stresses are reduced on the tip flank as well as on the root flank.

The same could be realized in the examinations of other grinding processes (Refs. 7, 15, 16). In the area of the tempered zone in the tooth tip, the tensile stresses have to be measured in tangential direction with a value of  $\sigma_t = 128$  N/mm<sup>2</sup>. The measurements on the tip flank show that tensile stresses increase if a new hardening area occurs. Compared to this, tensile stresses in the root flank still cannot be measured.

### Research Depending on Different Torques

To analyze the damage that occurs on the tooth flanks in the running tests depending on different structural damages, the flank load is displayed in Figure 9 over the angular position of the pinion in a profile contact ratio of  $\epsilon_\alpha = 1.44$ . Furthermore, the figure shows the number of load cycles on the pinion that are bearable for the different used control variants. Different load levels result, depending on the chosen torque.

Single areas on the tooth flanks are differentially charged depending on their generating position during the process of generating the test gearing (Refs. 4, 5, 17). If a torque amounts to  $T_{1T} = 400$  Nm at the contact beginning, a flank pressure of  $\sigma_H = 1,500$  N/mm<sup>2</sup> is calculated. A double tooth contact occurs in this area, due to a profile contact ratio of  $\epsilon_\alpha = 1.44$ . The maximum flank pressure increases at first in the area of the double teeth contact, from the root into the direction of the tip of the pinion, until the maximum flank pressure jumps up to almost  $\sigma_h = 1,800$  N/mm<sup>2</sup> in the inner single tooth contact point.

In the following generating process of the gear, the flank pressure is reduced in the direction of the tooth tip in the single tooth contact area as well as in the double teeth contact area. This can be explained through a reduced flank curvature and a higher sustained effect on the pinion. The overlap of the normal stress and the sliding movement has an essential influence on the load bearing capacity of gears (Ref. 17). The specific sliding is therefore shown for different angular positions on the pinion. The area of the negative slippage at the involute is always situated between the tooth root of the impulsive gear and the generating point. The generating speed and the sliding speed are arranged contrary to one another in this area. Extensive research of the flank load carrying capacity shows that the pitting damage occurs mostly in the area of the negative slippage (Refs. 17, 18, 19, 20).

The diagram additionally shows the location where the structure area, which is damaged by the grinding process, is generated on the pinion. The area of the structural damage is loaded with a low flank pressure and lies in the area of the positive slippage. On the right side of Fig. 9, the number of load cycles of the pinion is applied for the different test variants depending on the torque. A pitting size of 6 mm<sup>2</sup> on a flank of the pinion is defined as the damage criterion. The examination

shows that there is no difference with regard to the bearable load reversal at a torque of  $T_{1T} = 400$  Nm, independent of a structural impact on the tip of the pinion. The experiments were aborted after a running time of 300 hours. Contrary to that, the test torque collapses early at a torque of  $T_{1T} = 600$  Nm, because of pitting damages which occur closely underneath the generating circle. Yet here is still no visible difference between the single variants with regard to the load carrying capacity.

Measurements of the profile form and the tooth trace form of the used pinion on the teeth without pitting damages show locations in which the tooth flank is mostly impacted during the operation (Fig. 10).

Independent of the test variant and the chosen torque, there are visible deviations of approximately  $10\ \mu\text{m}$  in the lower area of the root flank. The deviating point is a plastic deformation of the material during the running or at fatigue phenomena of tooth flanks (wear). The pitting in this area in experiments with a torque of  $T_{1T} = 600$  Nm can contribute to the high local flank pressure and the negative slippage (Ref. 17).

On the pinion with a new hardening area, profile form deviations occur independently of the load level at the tip flank, as it can be clearly seen on the right tooth flank after a number of load cycles of  $N \approx 50 \cdot 10^6$  at a torque of  $T_{1T} = 400$  Nm. The local generating load of the material in the area of the flank tip is lower because of the lower flank pressure and the positive slippage. The deviations therefore point at the fact, that the load carrying capacity of the material is strongly reduced in the fringe structure, which is damaged in the grinding process.

The lead trace, measured on the pitch diameter, shows no reinforced deviations compared to the gears which were not used. The convexity is still existent, so that a curtailing of the experiments through the gearing deviants in the running-in or the running-out area of the grinding wheel can be excluded.

The destructive pitting at a torque of  $T_{1T} = 600$  Nm is clearly visible in the area of the tooth flank underneath the pitch circle  $d_w$ , as other investigations show. If a torque of 400 Nm is chosen, a destructive pitting does not occur. In this case, only initial pitting or gray discoloration occur closely underneath the pitch circle.

Smaller material break-outs can be found on the tip flank of the gearing beside rills in the lead direction. Since the rills could also have been partially caused by the grinding process, the chipping could also be seen as initial pitting and attributed to the material fatigue, which is caused by the generating load. Since the little material break-outs can be found on both test gears, the damage cannot be attributed to the slight impact of the structure, which is caused by grinding.

Compared to this, in the examinations in which a torque of  $T_{1T} = 400$  Nm was chosen, the damages occur in the tip flank too. Yet, there are no damages in the area of the grinding burn, which could have led to a breakdown of the gearing within 300 hours.

The realized flank damages should be analyzed more

exactly by means of structure research (Fig. 11). The structure images show, by the means of a dark tempered zone and a thin new hardening area, the gear damage caused by the grinding process. By means of the material structure, it becomes obvious that the structural damage is strongly shaped in the area of the tip flank. Compared to the damage on the root flank, the tip flank has some deep cracks, which are processed normally to the flank surface and deeply into the surface. In a depth of approximately 6 mm, the cracks process parallel to the flank surface. The course of the cracks indicates that, during the further use of the test pinion, a massive damage in the form of a large surface of material break-outs of the tooth flank, or a break of the tooth in the tip area, could have occurred.

This realized damage could have been caused by the high measured tensile stresses in the structural damaged zone by grinding burns, which leads to an exceeding of the material stability (Refs. 7, 17).

In the area of the structural damage, the hardness on the tooth flank surface is reduced for at least 100 HV0.05, beginning from 750 HV0.05, measured on the undamaged structure in the area of the flank root. Since the stability of metallic materials depends on the material hardness (Ref. 21), the strong decrease of the hardness in the area of grinding burns indicates a reduced load carrying capacity of the surface.

Contrary to this, the area underneath the pitch circle shows only a low cleft formation in the fringe area. The cracks are running contrary to the sliding direction and are typical for gears under generating load (Ref. 17).

Metallographical examinations additionally show that a strong damaging of the fringe through the grinding process can also be recognized on used gears and that evidence is derivable on turned-out gears.

#### Research Depending on Profile Contact Ratio

In this section, the influence of an increasing flank loading, in the area of the damaged workpiece material, on the number of tolerable alternations will be shown. The area where pitting occurs does not change through an increasing torque. Therefore the test gearing needs to be modified. For that reason the contact ratio is reduced from  $\epsilon_\alpha = 1.44$  to  $\epsilon_\alpha = 1.05$  by reducing the tip diameter of the mating gear. Fig. 12 shows the resulting flank pressure versus the angular position of the pinion for a torque of  $T_{1T} = 400$  Nm.

A comparison of the distribution of the flank pressure for equal torque shows that the contact distance has decreased. The pinion's tooth root comes into contact with the tip of the mating gear at a later point in time. This reduces the area with double tooth contact significantly so that the flank pressure escalates in the area of single tooth contact. The calculations show that, in the running-in area, the maximum pressure is equal for both contact ratios. For the gear with the contact ratio of  $\epsilon_\alpha = 1.05$ , the gradient of the flank pressure is relatively constant for all angular positions and just decreases in the tip area of the pinion. The gradient of the flank pressure indicates that in the area of structural damage, the loading of the flank is sig-

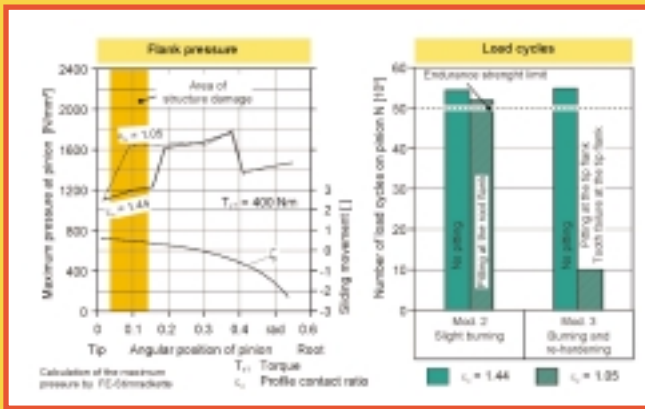


Figure 12—Flank pressure and load reversal, depending on profile contact ratio.

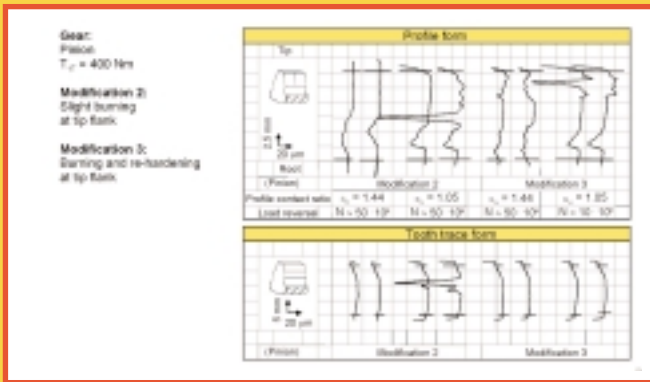


Figure 13—Test gear wheel after use, depending on profile contact ratio.

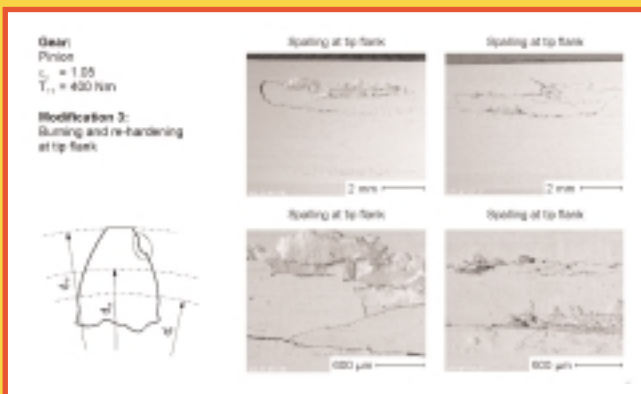


Figure 14—Damage on the tooth flank after use.

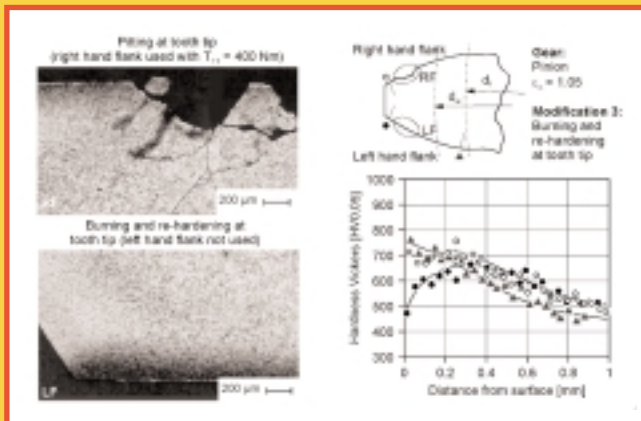


Figure 15—Structure and hardness measurement after use.

nificantly higher compared to the gearing with a contact ratio of  $\epsilon_{\alpha} = 1.44$ . The sliding movement does not change through the modification of the gear in the tip area.

The results of the gear tests with a contact ratio of  $\epsilon_{\alpha} = 1.05$  are compared to the results with a contact ratio of  $\epsilon_{\alpha} = 1.44$ . The pinion with the slight grinding burn (variant 2) does not show any significant influence of an increased flank pressure on the number of tolerable alternations. From those results, it can be concluded that the damage of the surface layer is so low that it does not reduce the bearing capacity. An enormous structural damage of the surface layer, which is shown by variant 3, reduces the number of tolerable alternations. After only a few hours of testing, there is a strong pitting at the tip flank in the area of the grinding burn. In this case, the trial was stopped due to a tooth break in the tip area.

The measurements of the tooth profile and lead show more wear on the tip flank above the pitch circle especially for the significantly damaged pinion, variant 3 (Fig. 13).

The large differences from the profile form in the tip area indicate large breakouts. The cracks must be far below the tooth surface because they do not directly show on the flank surface, as the profile trace of variant 3 shows. The pinion with the slight grinding burn (variant 2) has significantly smaller deviations of the profile form in the tooth tip area. Increasing deviations in the area of the lead trace (pinion diameter) cannot be concluded except for the deviations caused by pittings.

Figure 14 shows the damages on the tooth flanks of the pinion with a strong grinding burn. The large surface with material breakouts in the tip area and the overhanging material on the tooth flank are clearly visible. In Figure 14, a more detailed picture of a crack in the lead direction is shown.

The material structure is shown in Figure 15. The intense structural damage of the martensite surface layer and the re-hardened zone in the tip area is clearly visible. In the gear with a contact ratio of  $\epsilon_{\alpha} = 1.44$ , the cracks in the pitting area were orientated opposite of the sliding direction. In contrast, the cracks in this case are significantly longer and run deep into the basic structure. The large surface areas with material breakouts indicate a change of the surface layer properties due to grinding burns. In this case, the measurement of residual stresses could help in order to find the cause of damage.

The measurement of the hardness of the unused flank shows a decreasing hardness of nearly 300 HV0.05 in the surface layer. The zone of the influence structure is about 0.25 mm deep. The utilized tooth flank shows in the tip area, compared to the un-used flank, only a small decrease of the hardness in the area of about 50 HV0.05. This indicates a strengthening of the surface of the workpiece material during operation.

The form of the flank damage of the test gear pinion with the structural damage at the tip seems to be independent of the gear geometry. The investigations show that cracks running deep inside the part occur in the damaged zone for the gears with a contact ratio of  $\epsilon_{\alpha} = 1.05$  as well as  $\epsilon_{\alpha} = 1.44$ . Besides the results show a significant difference in the number of sus-

tainable alternations. The investigations about the load carrying capacity of case hardened gears show that a slight structural damage of the tooth flank surface layer caused by the grinding process does not necessarily lead to an early gear failure. In order to estimate the load carrying capacity, the local burden caused by flank pressure, slip and tooth flank bending have to be taken into account.

If the stresses exceed the load carrying capacity of a gear with a damaged surface zone, high wear after just a short inset can be expected.

### Conclusions

The requirements for modern automobile transmissions are increasing as well as for industrial gearings. In order to fulfill those requirements, a gear design that is beneficial for noise and load carrying capacities is gaining more importance. Recently, the number of failures has increased. This applies especially to case hardened and large module gears. The damages can partially be related to the grinding process that causes a negative influence on the material structure in the surface area of the parts. This report has shown the connection between the area of the structural damage, the kind of the flank loading and its influence on the load carrying capacity.

In tooth profile grinding, the stock removal depends on the chosen process strategy. If the tooth is ground with an equidistant stock, the structural damage is likely to occur on the tooth root. This kind of stock allowance can occur with the grinding of gears after hobbing or by using two grinding wheels with different geometries for a roughing and a finishing process. The reason for the local thermal damage is a high local stock removal, which leads to a local overloading of the grinding wheel.

Due to deviations from the desired tooth form caused by the initial gearing process and the heat treatment, gears with a larger module are usually ground in several steps with the same grinding wheel profile. This leads to constant stock removal in infed direction because the grinding wheel geometry for roughing and finishing is the same. Because of the locally higher removed material volume, thermal damage has to be expected at the tip.

Because damages have occurred mainly in large gears, the pinions were manufactured with an equidistant stock on the flanks, according to the commonly used process strategy in the industry. Therefore, different structural damages occurred in the tip area. During the use of the pinions, a conclusion between the area and the seriousness of the thermal damage depending on the local flank loading could be found.

The investigations have shown that a slight structural damage of the tooth flank surface layer caused by the grinding process does not necessarily lead to an early gear failure. In order to estimate the load carrying capacity, the local burden caused by flank pressure, slip and tooth flank bending have to be taken into account. If the stresses exceed the load carrying capacity of a gear with a damaged surface zone, high wear after just a short inset can be expected.

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# High Speed Steel Properties: Different Grades for Different Requirements

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**H**obs, broaches, shaper cutters, shaver cutters, milling cutters, and bevel cutters used in the manufacture of gears are commonly made of high speed steel. These specialized gear cutting tools often require properties, such as toughness or manufacturability, that are difficult to achieve with carbide, despite the developments in carbide cutting tools for end mills, milling cutters, and tool inserts.

High performance tools for gear-manufacturing markets have been served primarily by developments in particle metallurgy (P/M) high speed steels. Given the wide assortment of grades of high speed steels available, and the separation between the tool users and the raw material manufacturers, it is not surprising that many gear manufacturers are not intimately familiar with the details of selecting a raw material.

However, some relatively easy general guidelines may be used to guide tool users, whenever operating experience does create some interest in the makeup of a tool.

All high speed steels have the ability to reach a high hardness, often exceeding the mid-60s on the Rockwell C hardness (HRC) scale. This characteristic is the result of the high carbon content, combined with tungsten and/or

molybdenum in the appropriate proportions. Most high speed steels feature a characteristic amount of tungsten and molybdenum, where tungsten may be replaced by about one-half as much molybdenum to achieve the same result. In traditional high speed steels, this amount may be approximated by a "tungsten equivalency" (%tungsten + 2x%molybdenum) of about 16%–20%.

As an example, one of the first high speed steels invented, T1, contained 18% tungsten, but no molybdenum. M2 (HS 6-5-2)\*, one of the most common high speed steels used today, contains 6% tungsten and 5% molybdenum, or a tungsten equivalent of about 16%.

Subsequent development has produced variations on the tungsten and molybdenum balance. Other major elements added to high speed steels to enhance specific properties include vanadium and cobalt.

Vanadium is added primarily to enhance wear resistance, through the formation of particularly hard carbide particles in the microstructure. Cobalt is added to retard softening of the steel when exposed to elevated temperature—for example, to improve temper resistance or "red hardness" properties. Thus, it is often possible to judge whether a high speed steel is suited more for high cutting speed (temper

\* This is a standard European format for designating high speed steels. The numbers signify the nominal tungsten, molybdenum, vanadium, and cobalt percentages, in that order. (M2 contains no cobalt.)



resistance) or tool wear life (abrasion resistance) by observing the relative vanadium and/or cobalt contents.

In considering which high speed steel may be best suited for an application, consider the cutting conditions the tool will encounter.

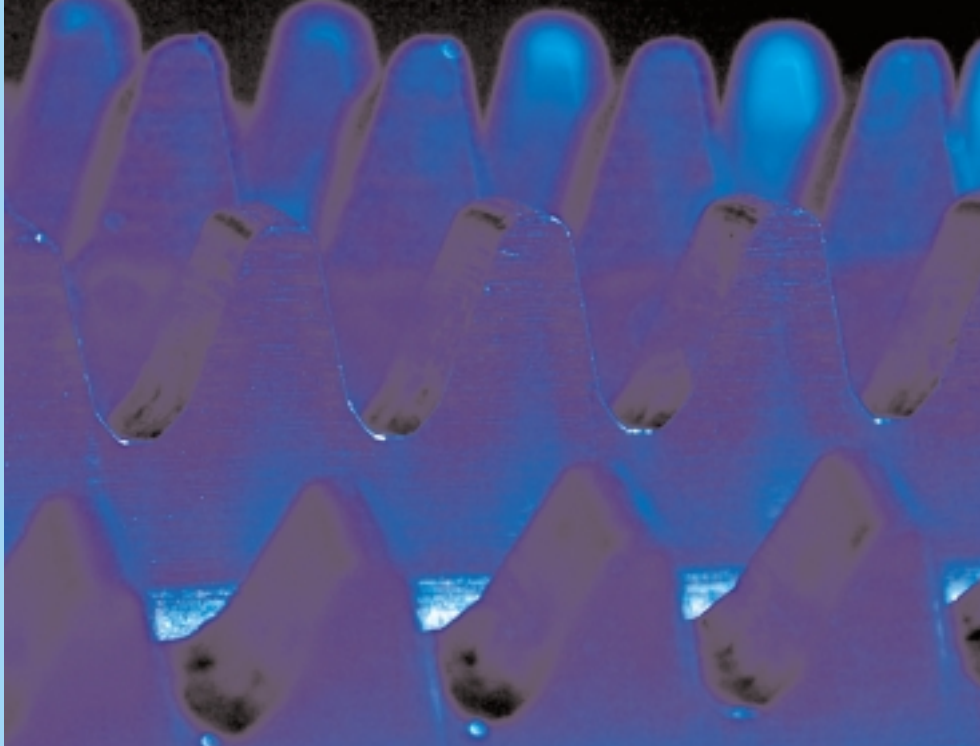
For general purpose, low-demand or short-run tools, a simple grade such as M2 may suffice. It offers the basic high hardness and wear resistance common to all high speed steels. Prior to the development of P/M-manufactured high speed steels, M2 was the basic entry-level grade for gear tooling.

For the next step up in tool performance, especially where improved toughness is required to handle interrupted cutting, machining under less than ideal rigidity, or other environments tending to chip or break tools, P/M-manufactured M3 (HS 6-5-3) and M4 (HS 6-5-4) are available. In many cases, M3 has gradually been supplanted by M4 over the years.

Because of the combination of improved wear resistance over M2 (from higher vanadium) and the improved toughness (from the P/M process), M4 has become the common base grade for many general-purpose gear cutting tools. In addition, its improved wear properties over M2 have made it popular for improved broaching performance. Because cutting speeds are not extreme, the tempering resistance of cobalt grades is not usually required, and the longer wear life of the higher vanadium M4 is beneficial.

Where faster cutting speeds or more difficult cooling conditions may place a higher thermal load on the cutting tools, cobalt-bearing high speed steels are called for. Cobalt adds heat resistance, but not significant abrasion resistance. At one time, M35 (HS 6-5-2-5), similar to M2, but with 5% cobalt, was popular.

As the base grade changed from M2 to P/M M3 and ultimately to M4, the cobalt-bearing counterpart also changed to M3 or M4 types with 5%–8% cobalt added (HS 6-5-3-8, HS 6-5-4-5) to help retain hardness during high temperature exposure. They are commonly specified



**Table 1—Grades, Uses and Properties of Steels for Gear Cutting Tools.**

Grade*	Gear Cutting Characteristics	Gear Cutting Tool Properties	Typical Hardness	Wear Resistance	Red Hardness	Toughness
M2 * (HS 6-5-2)	General purpose, low-demand or short-run tools	basic high speed steel	High	High	High	Low
M4 (HS 6-5-4)	Longer wear life than M2 under similar cutting conditions	improved toughness, improved wear resistance	High	High	High	Medium
M3+Co (HS 6-5-3-8) M4+Co (HS 6-5-4-5)	Higher temperature exposure, faster cutting speeds	improved temper resistance, slightly higher hardness	High	High	High	Medium
T15 (HS 12-1-5-5)	Machining of cast iron, cutting abrasive materials at slower speeds	high abrasion resistance, moderate temper resistance	High	High	High	Medium
M48 (~HS 10-5-3-9) T15 Mod (~HS 10-2-5-8)	High cutting speeds, dry or semi-dry cutting, high productivity & tool life	high hardness, wear resistance & temper resistance	High	High	High	Medium
Advanced grades	Highest cutting speeds, dry & semi-dry cutting	maximum hardness & temper resistance	High	High	High	Medium

\*All grades are given using standard industry (AISI or ASTM) designations. All grades, except M2, are manufactured by P/M steelmaking technology; M2 is manufactured by traditional ingot cast steelmaking.

## High Speed Steel Properties: Different Grades for Different Requirements

at slightly higher hardness than the non-cobalt-bearing grades. The higher initial heat-treated hardness contributes to higher retained hardness at elevated temperature as well.

Because they feature improved tem-

pering resistance over M3 or M4, but not higher vanadium content, cobalt-bearing high speed steels are best suited for applications involving higher cutting speeds in similar materials. In slower cutting operations, such as

broaching, where abrasion is a more common failure mode, they may offer somewhat improved performance over M3 or M4, but may not be as effective as higher vanadium grades.

T15 (HS 12-1-5-5), with 5% vanadium and 5% cobalt, is sometimes used where moderate temper resistance but high abrasion resistance is needed, such as in machining of cast iron, or in broaching of difficult machining materials. The high vanadium content provides improved wear life, and the attainable hardness—higher than M2 or M4—can improve cutting edge integrity.

For highest productivity, or for particularly abrasive cutting conditions, various highly alloyed “super-high speed steel” grades, such as M48 (~HS 10-5-3-9), have been developed. These steels combine very high attainable hardness (usually over 67/68 HRC) with either very high wear resistance, improved tempering resistance, or both. These steels are used for high cutting speeds, dry or semi-dry cutting, or simply to provide the maximum in tool life.

Because of their high hardness and wear resistance, some of these grades are considered to provide a bridge between high speed steels and carbides. In particular, developments in P/M high speed steels in recent years have produced several advanced specialty grades, often capable of hardnesses reaching—or in some cases exceeding—70 HRC, further extending the reach of high speed steels into high performance applications.

Of course, there is also a firm market for solid carbide cutting tools of various types. Despite the advances in alloy composition of high speed steels, the wear resistance of carbide remains superior. In applications where machine rigidity and tool design permit their use, and cost can be rationalized, carbide

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Savvy gear manufacturers will discuss operating conditions, common modes of tool failure, and desired performance results with their tool manufacturers to find the best material for a given operation.

tools can offer certain performance benefits over any high speed steel, such as high hardness at elevated temperature and long term abrasion resistance.

The cost of the raw material and the difficulty of fabricating the cutting tool both tend to increase with the more highly alloyed steels. However, in most cases, improvements in productivity or tool life would pay for the additional tool cost many times over.

Heat treatment, surface finish and coatings can have a major impact on tool performance. In some cases, these factors may be more important than the choice of substrate material. The great majority of gear cutting tools are PVD-coated, with coatings such as TiN, TiAlN or other ceramic-type coatings that offer reduced coefficients of friction and enhanced wear resistance.

These factors are integral in the manufacture of any cutting tool. Savvy gear manufacturers will discuss operating conditions, common modes of tool failure, and desired performance results with their tool manufacturers to find the best material for a given operation. ⚙️

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Conversation with

# Joe Franklin,

AGMA  
President



**Q—While many readers know of AGMA, they don't know about AGMA. So, first tell us about the size and makeup of the association.**

*AGMA is becoming increasingly global in our activities and our membership; but, the bulk of members are small- and medium-sized U.S.-based companies. Today, we have about 400 members in all phases of the gear and mechanical power transmission business. Our corporate members are gear manufacturers, suppliers to the industry (machine tool builders, suppliers of tooling, materials, lubricants, bearings, heat treating services and such) and users of gearing. We also have individual members in two categories: academic members (who are professors of mechanical engineering) and individual consultants.*

**Q—What are some of the important activities in which AGMA is involved?**

*One of the primary reasons AGMA was founded in 1916 was to create technical standards. This important industry service continues to this day as one of the most important activities of the association. AGMA is the only organization in the U.S. that produces a full range of gear industry standards. Internationally, AGMA is the Secretariat, or administrator, of the ISO Technical Committee (60) for gear standards.*

*Other technical activities include a major technical conference, the Fall Technical Meeting; other technical education programs and workshops; and technical research projects, generally in conjunction with the AGMA Foundation.*

*On the business management side, we provide a number of activities to help managers benchmark their companies and improve their performance. These include the Operating Ratio Report, the Monthly Market Trend Report, our Wage and Benefit Survey and our Marketing Council meetings.*

*Networking through our technical*  
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*committees and business management councils is an important service to our members. The opportunity to discuss issues with peers from other companies, for problem solving and for staying in touch with colleagues and friends is a valuable benefit of membership in AGMA.*

*AGMA works with a number of other organizations the world over to share information and advance the art and science of the industry. A few of these include other manufacturing trade associations for products such as bearings, forging, steel and heat treating; the Gear Research Institute; the National Renewable Energy Laboratory, the Society of Manufacturing Engineers, Aachen University, etc.*

*We offer education on how to make gears—both theoretical and hands-on—at our Training School for Gear Manufacturing in Chicago.*

**Q—Tell us about the gear school. How is this connected with the association, what types of courses are taught and what was the background for forming this training facility?**

*AGMA's Training School for Gear Manufacturing is housed at Daley College, which is one of the City Colleges of Chicago. We work closely with Daley's Career and Economic Development staff, especially with those working directly in manufacturing technology.*

*AGMA provides the curriculum, the instructors and acquired most of the equipment used in the hands-on workshops. This school was created in the early 1990s for the purpose of helping gear manufacturers train their new and less experienced employees in the fundamentals of gear manufacturing and inspection.*

**Q—Who are the instructors?**

*The classroom portion of the program is taught by Bob Moderow, who has many years of experience in the gear industry, and who has taught gear fundamentals for a long time. He's one of those guys who's too valuable for us to*

*let him retire. The other key individual is Redmond Ryan, who worked many years with Brad Foote before joining the staff at Daley College. Redmond runs the shop floor portion of the program, and he has a wealth of manufacturing knowledge. He's really the oil in the system. He's our go-to guy there. Whenever they need blanks or cutting tools, Red makes sure they have them.*

**Q—And what do the students get out of this experience?**

*Typically the students are people with only a couple of months' experience, and the gear school gives them a chance to understand—and see for themselves—how gears are made. The shop is filled with mostly older machines, which is good because the students can see the interaction between the tool and the workpiece. They get a better understanding of the physics of gear manufacturing. Then, when they go to a CNC machine and push the button, they know what's going on inside the machine.*

**Q—Is the gear school open to AGMA members and non-members?**

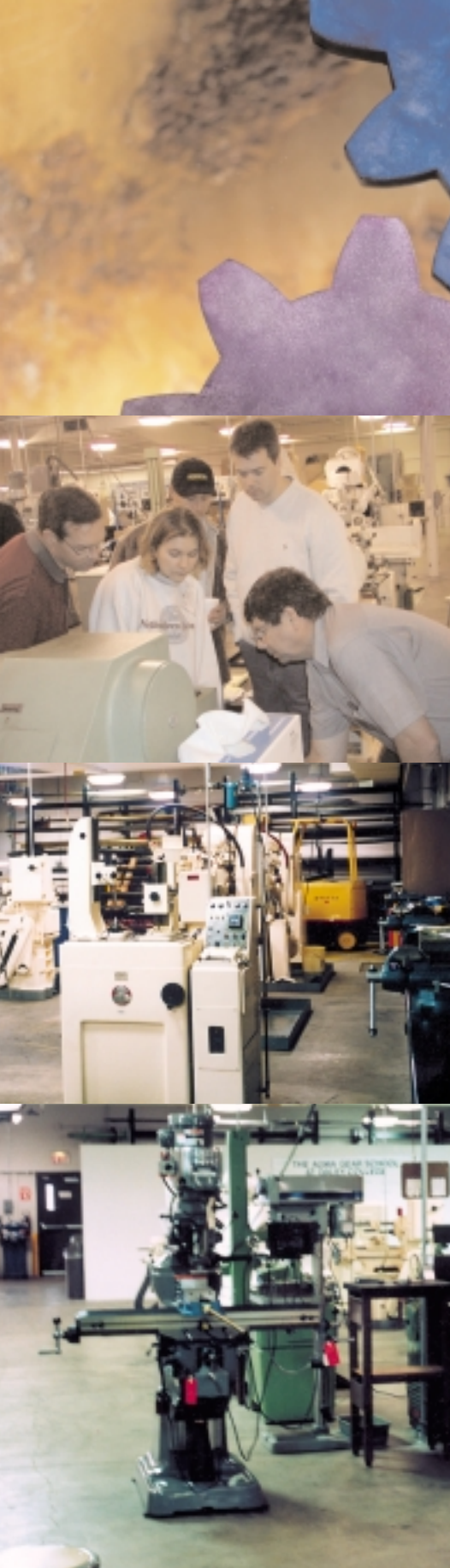
*Absolutely. About a third of the people who attend are not members of the AGMA.*

**Q—Do you have any other educational activities?**

*We provide customized in-plant training sessions and a new, computer-based training tool for the fundamentals of gearing and for inspection via [www.agma.org](http://www.agma.org). This is a new program we are just now introducing.*



**AGMA's Training School for Gear Manufacturing.**



AGMA's Training School for Gear Manufacturing includes hands-on demonstrations of gear manufacturing techniques.

**Q—Speaking of your website, how's your Internet presence going? What kind of activity are you getting?**

*Communicating electronically with members and others in the industry and making information available via [www.agma.org](http://www.agma.org) is a very active aspect of AGMA and one that is continuously growing.*

*For example, almost all of our Technical Division communication, announcements, distribution of documents for meetings, circulation of draft standards and final ballots are done electronically.*

*We host webcasts on important topics, such as Dr. Michael Bradley's Economic Forecast for the Gear Industry. Even committee meetings have been held by webcast.*

*Using the Web for these types of activities allows far more members to participate than does a meeting where everyone has to travel. In fact, we have found that participation increases by a factor of four.*

**Q—You mentioned that developing standards is still one of the most important functions of the AGMA. Can you tell us about those activities?**

*AGMA currently has 23 technical committees working to create 22 new documents and 26 revisions of existing standards and information sheets. In total, we have 79 standards and information sheets in addition to the 22 under development. To ensure that the information is current and reflects the most current state-of-the-art, we review all AGMA standards at least once each five years. Those that need updating are then revised by the appropriate committee.*

*Our committees are made up of about 200 industry experts who represent the industry and their companies in this work.*

**Q—When you say “documents,” what does that mean?**

*A document could be a technical*

*standard or an information sheet. The information sheet requires a lower level of consensus. It may not have all the empirical data that a hard standard has. In some cases, AGMA committees will release information sheets when the technology is less well proven. In part, the information sheet is an invitation for companies to gather empirical data and test the information against experience in the field. In some cases, information sheets can evolve into technical standards. But some committees, such as the aerospace committee, typically only release information sheets.*

**Q—Why is it important that AGMA be represented at the ISO?**

*Having an active role in ISO is as much a marketing and international trade issue as it is a technical one. Like it or not, we are in a globally competitive market, and technology does not respect national boundaries. AGMA has a responsibility to make sure that our members are at the table when technological and other standards issues are decided. But beyond a defensive role, AGMA also makes sure that our members' best information and practices are included in new and revised international standards.*

*We do this by having experts from member companies attend the ISO meetings as delegates from AGMA and the U.S. In addition to representing the U.S. in the international standards development process, AGMA has been chosen to administer the ISO technical committee responsible for all gear-related products.*

**Q—What about Gear Expo? What's its history and when and where is the next one?**

*Gear Expo began as a tabletop display in a Chicago hotel in 1986, became a trade show with equipment in 1987, and has grown into “The Worldwide Gear Industry Event” that it is today. It has evolved into an international exhibition, distinct in the world of machin-*

ery trade shows, as it is the only trade show in the world devoted exclusively to the complete gear manufacturing process. It is the one event that offers the best in technology, equipment and services for gearing industry professionals on display in one place and at one time.

The biennial show has been held in a number of Midwestern cities, such as Indianapolis, Columbus, Nashville and Detroit. Because of its proximity to the automotive industry, Detroit has been the anchor for the event every other show. The next Gear Expo will take place October 16–19, 2005, in Detroit's Cobo Center.

**Q—What types of products and services are exhibited at Gear Expo?**

All facets of the gearing world are on display at Gear Expo. The range of new technology, equipment and services on display runs from machine tools to forgings, lubricants, bearings and other gearing products, as well as services such as heat treating and coating. About 20% of the exhibitors are companies that manufacture gears, so users of gears can look for sources of gearing or they can look for the equipment and related products and services necessary to manufacture them.

**Q—Who should attend the Gear Expo?**

This event is the show to attend for gear industry executives, engineers and practitioners searching for the latest manufacturing innovations and the best in technical expertise. Professionals from around the world attend the show to solve their gearing problems—to see the leading equipment manufacturers, gear manufacturers and providers of services to the gear industry.

**Q—Earlier you mentioned networking. Can you tell us about AGMA activities that encourage the members to meet, mix, make contacts and do business?**



Facilitating networking is an important catalytic function of the AGMA. In fact, every meeting has an element of networking.

Over the past couple of years, we have increased the number of regional meetings and have included programs on such timely topics as gear failure analysis, gearboxes for wind turbines and gear accuracy. All have been extremely well attended by a cross section of current members as well as prospective members.

The Annual Meeting is designed for senior level managers, while the Fall Technical Meeting focuses on both the experienced technical experts in the industry and younger engineers who have the opportunity to get to know the “old timers” and learn about advances in technology and process advances. Standalone seminars such as the Gear Failure Analysis seminar are held twice each year.

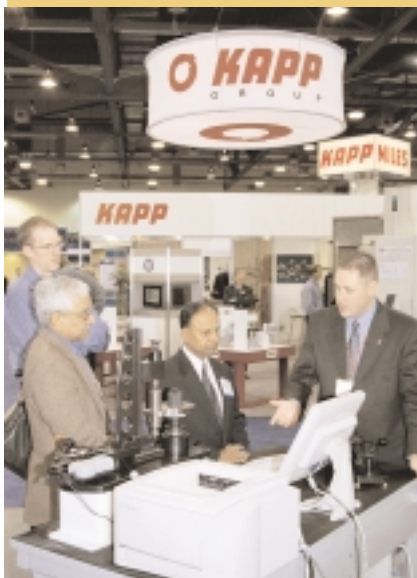


AGMA is one of the key participants of the World Gear Summit (top two photos), and the association also hosts an annual Fall Technical Meeting (bottom two photos).



## AGMA Strategic Objectives:

- Continue AGMA's leadership role in the development of domestic and international technical standards.
- Help members compete/benefit in global growth.
- Stimulate interest in careers in gears and gear/coupling-related products.
- Provide for the long-term viability of the AGMA membership through leadership development.
- Communicate important industry information in the most effective/efficient manner to get the desired positive response.
- Provide value to the organization and to meet and grow revenue through membership growth and retention.



AGMA's Gear Expo.

**Q—What activities are going on within the Association to incorporate some new gear materials and manufacturing processes, such as plastics and powder metal?**

*It is imperative that AGMA recognize the trend toward alternative materials for gearing applications.*

*Several years ago, we created an Emerging Technologies Council that evolved into two distinct groups: one for companies that manufacture or supply plastic gearing and its analog for powder metal gears. These groups are developing technical standards, have held technical workshops, and have participated in technical conferences organized by other groups. As this is a newer activity, it is growing and defining itself as it grows. We are also looking at similar groups for specific products, such as precision gear heads.*

**Q—Why should a member volunteer to work on one of the association's standards committees?**

*Members of AGMA can participate on any of our technical committees for which the primary objective is the creation and maintenance of technical standards. Many companies assign key employees to participate as a way for them to stay aware of the latest developments in the industry and to make sure that technical provisions important to their competitive position are represented.*

*Less formally, many of the industry's leading engineers tell me that—following school—this is really where they learned about gearing. Participants have the opportunity to sit at the table with the industry's top experts in every field of gearing.*

*It may not be obvious to those who do not participate, but those companies and individuals who develop a standard are the ones who know it best. You will find that the companies that are recognized as the industry's competitive and technological leaders always have a staff person at these meetings.*

*Finally, even our domestic or AGMA standard activities include participants from our international members. Several people travel several times each year to the U.S. to participate in committee meetings. Other members receive the minutes and committee documents by e-mail and participate electronically.*

**Q—Looking at the bigger picture, why should a company join AGMA?**

*AGMA offers a large number and variety of programs and activities, but members tell me that they join and continue in the association not for discounts or specific programs. Rather, they are here for three broad reasons I have categorized as access, credibility and voice.*

**Q—OK. Tell us about access.**

*You asked earlier about networking; well, that's a lot of what access is about. Members have very easy access to most other members to help solve problems, recognize best practices and advance their company's objectives. When you look closely at our membership, more of our members do not compete with each other than do.*

*Members also have access to information not commonly available to non-members through the several programs open only to members. We find that members tend to form bonds and become life-time friends with other members.*

*It is a good way to have friends who understand what you face every day. At one of our recent regional meetings, one of the participants said that the best part of AGMA meetings was being in a room full of people who understood what he was saying when he used industry jargon.*

**Q—What about credibility?**

*Credibility is shorthand for the benefits that come to those companies that openly state they are part of this industry. AGMA membership is such a statement. A few times each year, I get a frantic call from someone who "must" join AGMA immediately because a contrac-*



tor requires AGMA membership as part of a contract. (What the contractor is relying on is the presumption that AGMA members are better quality manufacturers than non-members.) Members benefit from the halo effect that being associated with the best and the most competitive manufacturers in the world enjoy.

**Q—And voice?**

Voice is the third reason. It means that AGMA is member-driven. Our board enacts policies and programs that the members want, and our staff implements them. A number of our current programs—such as the Training School for Gear Manufacturing in Chicago—are direct results of the actions of a few involved members.

**Q—There are associations in other countries that focus on gear manufacturing. How are they different from AGMA?**

AGMA is quite active with the associations in Europe and Asia. In fact, we regularly meet with a federation of the European gearing associations known as EUROTRANS. We share economic and technical information so that we all have a better understanding of the structure of the international marketplace.

In the early '90s, AGMA was the driver behind creating the World Gear Summit, in which gear industry representatives and associations from the key producing countries could get together to expand their understanding of each other and each other's markets and manufacturers. Over time, we have expanded the group and will meet next in the spring of 2005 at the Hannover Fair.

In terms of how we are the same and different, all of the associations work for the interest of their members. I think AGMA benefits because, at any meeting, AGMA members literally sit with each delegation. We have members in over 30 countries, so this international interchange is a natural and necessary part of our future.

**Q—What do you see as the future of gear manufacturing in the United States?**

For competitive manufacturers, the future is bright. Of course, we face inevitable changes in the economic structure, as we have since the beginning of our country and our association.

As the manufacturing process continues to be driven by capital equipment and less by the old-time artisans and craftsmen, manufacturers here will do well. Increasingly, supply-chain concerns will insulate good manufacturers from low-wage competitors.

**Q—Aren't some companies in low-wage parts of the world investing as much, or more, in new, productive equipment? How can American manufacturers compete?**

Recently, I had a very intriguing conversation with a large manufacturer working with a partner in China. This manufacturer had gotten some gear business by quoting "Chinese Prices." After they acquired the business, the Chinese partner went out and bought the equipment required to produce the gears. About \$120 million later, they came back and asked for a price increase. They found out that they just couldn't produce the gears the customer wanted at "Chinese Prices."

**Q—So where does this leave the American gear manufacturer?**

I think we're going to see increasingly as we get past the low-wage stage that the prices are going to come out closer. They may never be equal, but they're going to get closer.

**Q—What can American gear manufacturers do to learn more about markets like China?**

We're organizing a trade mission to China in October, focused on the PTC Asia 2004 power transmission trade show in Shanghai. I think we'll be able to provide a very successful and pretty

accurate view of the Chinese market. Our objective is to give people a better understanding of the requirements to setting up an operation in or selling into that market.

**Q—What would you like the association to accomplish in the next five years?**

The key is you have to stay fresh, and you have to stay in tune with your market. Somebody recently asked me if I thought that many gear manufacturing operations were modern, and I just about fell out of my chair. Anybody who is successful in manufacturing today is modern. The pressures on manufacturers require them to continually innovate.

The same is true of the AGMA. When we sat down recently to work on our next strategic objectives, there were two overriding themes. The first was that we need to work harder to ensure that we are broadcasting an energetic, enthusiastic, dynamic and vibrant image for the gear industry.

The second is making sure that we open the organization up to the next level of industry leaders. You see people in the industry who've been involved with the association for 20, 25, 30 or more years. Those people won't be there forever. But there are many young men and women actively involved in leadership roles at their companies who should be more involved with the association. We're going to be making a special effort to reach out to these young executives and managers. ⚙

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# Simulation of Hobbing for Analysis of Cutting Edge Failure due to Chip Crush

Masaharu Komori, Masaoki Sumi and Aizoh Kubo

## Management Summary

There are great advantages in dry hobbing, not only for friendliness toward the environment, but also for increasing productivity and for decreasing manufacturing cost. Dry hobbing, however, often causes failures in hob cutting edges or problems with the surface quality of gear tooth flanks. These difficulties are not present when hobbing with cutting oil. Pinching and crushing of generated chips between the hob cutting edge and the work gear tooth flank is considered a major cause of those problems.

In this report, a hobbing simulation program is developed to clarify the clearance between hob cutting edge and work gear tooth flank and the movement of generated chips on rake surfaces. The simulation explains the mechanism of chip crush and cutting edge failures, and a method to evaluate the probability of chipping on a hob's cutting edge by simulation is proposed.

## Introduction

Dry hobbing is more environmentally friendly than the conventional method, which uses cutting oil (wet hobbing). Dry hobbing has great advantages in increasing productivity and decreasing manufacturing cost as well (Refs. 1–2). Dry hobbing, however, often causes problems, such as chipping of the hob cutting edge or creating of coarse tooth flanks on manufactured gears. These problems are not present in wet hobbing. The pinching and crushing of generated chips between the hob cutting edge and the work gear tooth flank is considered to be a major cause of the problems.

Three types of chip crush between hob cutting edge and work gear tooth flank are possible: (1) crush during generation of chip, (2) crush of chip flying after its generation, (3) crush of chip stuck on hob tooth after a rotation of hob (Ref. 3). Item (2) can be solved by equipping hobbing machines with air blowers. The same remedy and/or selecting of adequate coating and material of hob somewhat improves item (3). But the remedy for item (1) has not been clarified because of the complicated mechanism of hobbing and chip generation.

In this report, a calculating method for the trace of each hob cutting edge relative to the work gear is developed to simulate the clearance between hob cutting edge and work gear tooth flank. Using this simulation, the mechanism of chip crush is clarified and the method to evaluate the probability of chip crush between hob cutting edges and tooth flank is proposed.

## Observation of Dry Cut Hob Failure and Generated Chips

Figure 1 shows a typical chipping failure of a hob cutting edge observed when a right-hand helical gear (module 2.75, pressure angle 20 degrees, number of teeth 62, helix angle 30 degrees and addendum modification factor  $-0.6$ ) is dry cut by a right-hand carbide hob (four threads and outer diameter 100 mm) under climb cutting (2.5 mm/rev.). Chips generated by the hobbing can be classified into types of shape, as shown in Figure 2. The fact that the types of generated chips have the same form suggests the existence of a definite mechanism for chip formation.

Figure 3 shows some examples of chips: Chips

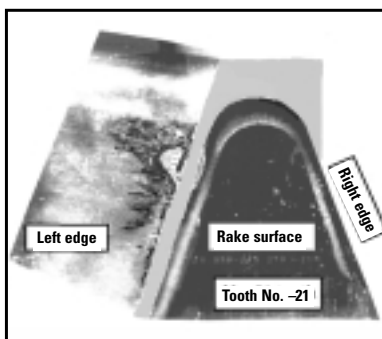


Figure 1—Typical example of chipping failure of cutting edge of carbide hob under dry cutting (example 1).



Figure 2—Classification of dry hobbled chips and their form groups.

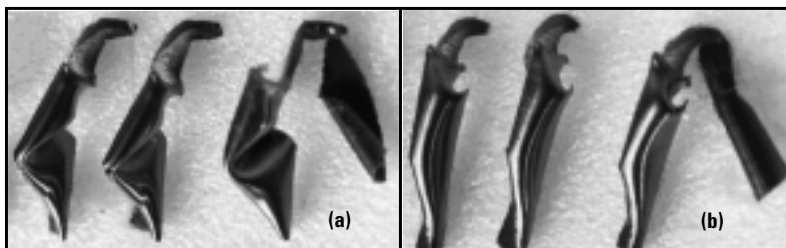


Figure 3—Bent or crushed chips observed under dry cutting: (a)—chips bent after the formation; (b)—same kind of chips as that of (a), but not bent after their formation.

on the right side in (a) and (b) show the originally generated shape. The others are parts of the original chips that separated during this observation. Chips in (a) resemble those in (b) in size and in shape, but each chip in (a) is bent. It is thought that the chips in (a) are pinched and crushed between hob cutting edges and work gear tooth flanks. Many examples of such bent chips are found in the pile of chips to be discarded. That means chip crush does not occur by accident, but some repeating definite mechanism of chip crush must exist in the hobbing process.

Each chip in Figure 4 is cut partly on the surface at the same position. Those chips are also considered to be crushed between the hob cutting edge and the work gear tooth flank during the hobbing process.

Chips in Figure 5(a) are the same as those in 5(b), but there is a difference in the right edge of the chip. The chip part in (b) is considered to be cut after its generation. Temper color is observed on that cut section. That suggests chip crush occurred under high temperature condition, i.e. as soon as the chip was generated.

Figure 6 shows a chip stuck on a hob tooth's rake surface, observed when the hobbing machine is retract-stopped in an emergency during cutting. The combination of hob material and work gear material in this case makes that chip easily stick on the rake surface. Figure 6 shows therefore a status of generation of chip on the rake surface during hobbing (Refs. 4–5). Some part of the chip is outside of the hob's rake surface. That suggests some part of the chip can be intruded into the clearance between hob cutting edge and work gear tooth flank. A hob cutting edge can be damaged if a large chip, as shown in (a), is crushed. When a small and thin chip, as shown in (b), is crushed, a part of the chip scratches the work gear tooth flank or is inlaid on the cut surface and the quality of the manufactured gear becomes a problem.

Those facts clarify that there is a steady mechanism causing chip crush between hob cutting edge and work gear tooth flank. Chipping of the hob cutting edge in Figure 1 is therefore probably caused by chip crush.

#### Calculation Method of Chip Formation and Clearance

To prevent chip crush, it is necessary to evaluate the size, shape and movement of chips on or over a hob tooth's rake surface and the condition of clearance between hob cutting edge and work gear tooth flank. A simulation method for the

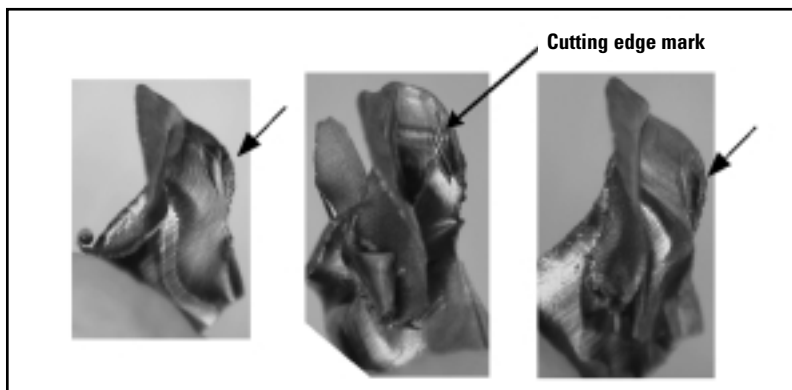


Figure 4—Cutting edge marks found on the same position of chips, observed under dry cutting.

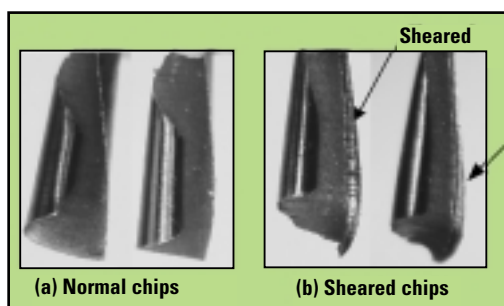


Figure 5—Shearing of chips after their formation, found among dry cut chips (compare with those found in the smallest chip group in right lower section of Figure 2).

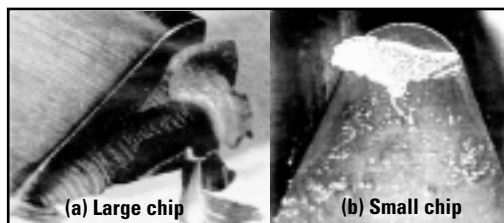


Figure 6—Chips observed on rake surface of hob tooth after emergency retract stop. This is supposed to express the status during cutting.

hobbing status is proposed by Terashima and Ueno (Ref. 6) and others (Refs. 7–10). The expression of the simulation results has been limited to the cutting depth by the hob teeth. It is difficult to understand the changing state of clearance between hob cutting edge and work gear tooth flank by this expression. Evaluation of the probability of chip crush is therefore almost impossible.

**Basic calculation of trace of a point on cutting edge.** The number given to each hob tooth is defined as shown in Figure 7. The hob tooth that generates the center of the work gear's tooth groove is called tooth No. 0, those acting before tooth No. 0 have a minus sign, and those acting after have a plus sign. Here, the side cutting edge located on the left side of the hob tooth, as seen in Figure 1, is called the left edge and the side edge on the right side is called the right edge.

#### Dr. Masaharu Komori

is an associate professor involved in research and education in the precision engineering department of Kyoto University, located in Kyoto, Japan. He has studied and specialized in load carrying capacity, vibration, simulation and troubleshooting of cylindrical gears and hypoid/bevel gears, as well as gear metrology and three-dimensional measurement.

#### Dr. Masaoki Sumi

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#### Dr. Aizoh Kubo

is a professor performing research and education in Kyoto University's precision engineering department. He has more than 30 years of experience researching gears at the university, including specialization in load carrying capacity, vibration, simulation and troubleshooting of cylindrical gears and hypoid/bevel gears, and gear metrology.

# Simulation of Hobbing for Analysis of Cutting Edge Failure due to Chip Crush

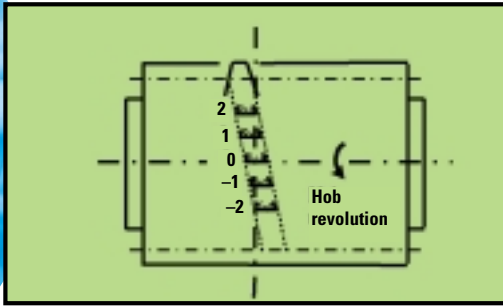


Figure 7—Definition of number given to each hob tooth.

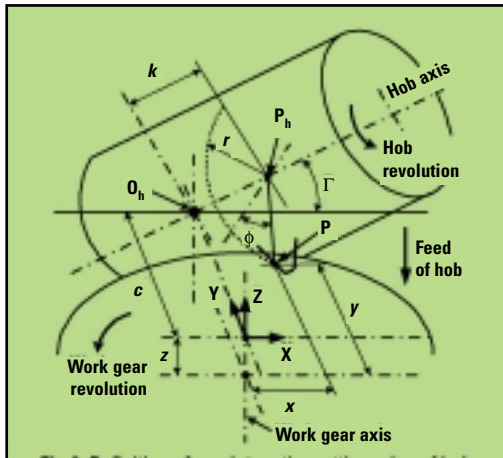


Figure 8—Definition of a point on a hob tooth's cutting edge expressed via hob coordinates and space coordinates.

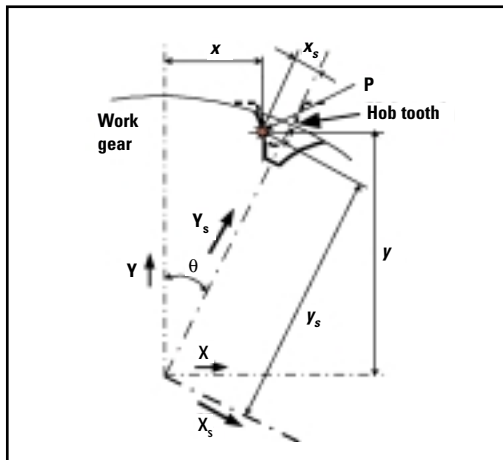


Figure 9—Relationship between gear coordinates  $\{X_s, Y_s, Z_s\}$  and space coordinates  $\{X, Y, Z\}$ . (Axis  $Z_s$  is the same as axis  $Z$ .)

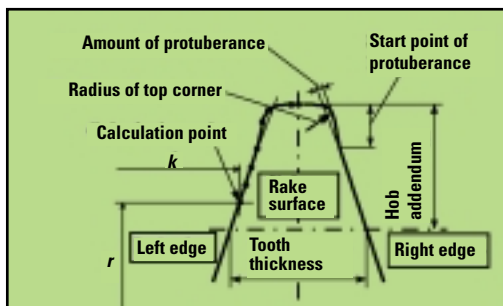


Figure 10—Profile and calculation point on cutting edge of hob tooth.

Figure 8 shows the state of cutting of a right-hand helical gear by a right-hand hob under conventional feed. Point  $O_h$  means the point corresponding to the middle point on the cutting edge of tooth No. 0, but on the hob axis. Point  $P_h$  corresponds to that for arbitrary object point P on the cutting edge of the hob tooth. Rotation angle  $\phi$  of P is defined so that the angle is 0 degrees, when line  $PP_h$  is parallel to the side of the work gear. Point P on the hob cutting edge can be expressed by hob coordinates  $\{k, r, \phi\}$ , where  $k$  is axial distance from  $O_h$  to  $P_h$  and  $r$  is radius.

Space coordinates  $\{X, Y, Z\}$  are set as shown in Figure 8 so the crossing point of the work gear axis and the gear side is its origin. Axis Y is set normal to the trace of  $O_h$ . A point on these coordinates is expressed by  $\{x, y, z\}$ . A point  $\{k, r, \phi\}$  on the hob coordinates is then converted into space coordinates  $\{x, y, z\}$  as follows (Refs. 7–8):

$$x = k \cos \Gamma - r \sin \phi \sin \Gamma \quad (1)$$

$$y = c - r \cos \phi \quad (2)$$

$$z = k \sin \Gamma + r \sin \phi \cos \Gamma \quad (3)$$

$\Gamma$  means hob set angle, which is defined here by inclination of the hob axis relative to the plane normal to the gear axis.  $c$  shows the center distance of the hob and work gear. The trace of point on the hob's cutting edge during hobbing can be expressed by space coordinates  $\{x, y, z\}$ , by calculating its movement according to hob rotation and feed by Equations 1, 2 and 3.

Gear coordinates  $\{X_s, Y_s, Z_s\}$  are set as shown in Figure 9 in order to calculate the trace of a point on the hob cutting edge relative to the work gear whose origin is the same as that of the space coordinates, and each axis is fixed to the work gear. That is, axis  $Z_s$  is the same as axis  $Z$ , but axis  $X_s$  and  $Y_s$  rotate according to work gear rotation. The position of  $X_s$  and  $Y_s$  becomes the same as that of  $X$  and  $Y$  when the rotation angle for the middle point on hob tooth No. 0's cutting edge is  $0^\circ$ . The rotation angle  $\theta$  of the work gear is expressed as follows:

$$\theta = (\omega + \phi)R_r \quad (4)$$

$\omega$  means hob rotation angle, that is the angle from the middle point on hob tooth No. 0's cutting edge to a definite object point P on the hob tooth cutting edge along the hob thread.  $R_r$  is the ratio of work gear revolution to hob revolution. Space coordinates are converted into gear coordinates by the following equations:

$$x_s = x \cos \theta - y \sin \theta \quad (5)$$

$$y_s = x \sin \theta + y \cos \theta \quad (6)$$

$$z_s = z \quad (7)$$

**Procedure to calculate traces of cutting edges.** The shape of a hob cutting edge including protuberance is expressed point by point, as shown in Figure 10. The trace of a point on the cutting edge relative to the work gear during cutting can be obtained by calculating the point's movement due to hob rotation and feed and work gear rotation. The trace of a hob cutting edge can be expressed by traces of point groups on the cutting edge.

Figure 11 shows the procedure to calculate the trace of a hob cutting edge. In step (2), fundamental quantities—such as center distance, hob set angle, range of acting hob tooth and axial cutting range of work gear during a hob rotation—are calculated. The tooth groove shape formed before the last revolution of the work gear is calculated in step (3). That shape is formed by traces of all cutting edges acting in that process. For a definite hob cutting edge, the trace of the previously acting hob cutting edge and that of the object cutting edge are calculated in step (5) and (6). This procedure is repeated for each hob tooth's cutting edge.

**Evaluation of probability of chip crush.** Cutting of the gear shown in Table 1(a) by the hob in Table 1(b) under the cutting conditions in Table 1(c) is provided as an example. Center distance is 98.975 mm, hob set angle is 16.23 degrees, acting hob cutting edge is from tooth No. -26 to tooth No. 10, and work gear axial cutting range during a hob rotation is 28 mm (Ref. 7).

Figure 12(a) shows a work gear cut by climb hobbing schematically, where the work gear is set in the front and the hob is behind, and it is observed from a viewpoint below the work gear. A straight tooth groove like that of a spur gear is shown in Figure 12 to make understanding easy even though the sample gear is helical and the actual groove exists in helix form. The trace of the hob cutting edge is here proposed to be expressed on each normal-to-gear-axis slice shown in Figure 12(b). The definition of viewpoint and slices used in this expression of the simulation result are the same for helical and spur gears.

Figure 13 shows the result of traces on the slices at  $z_s = 18$  mm and 15 mm that are normal to the work gear axis. A broken curve shows the tooth groove shape formed before one revolution

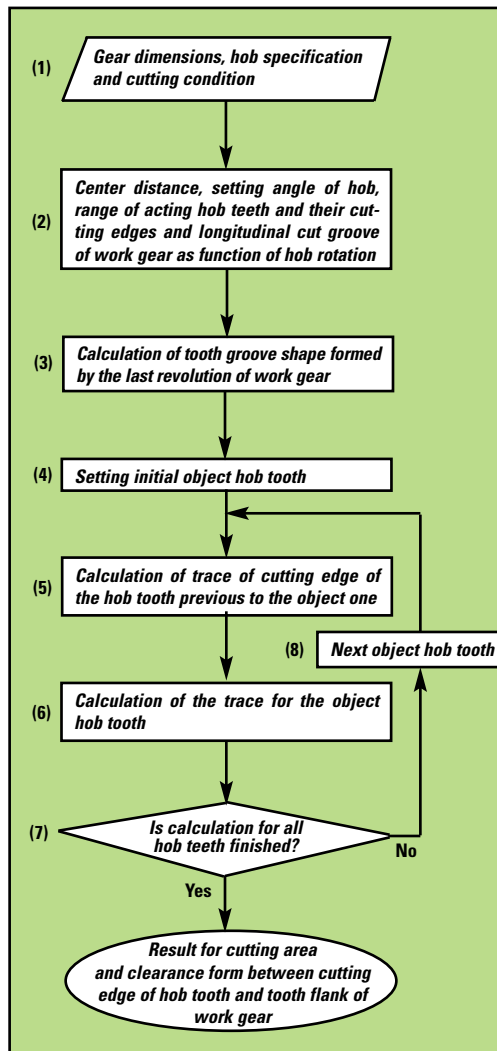


Figure 11—Flow chart for calculating the trace of a hob's cutting edge.

Table 1—Sample Specifications of Gear, Hob and Cutting Conditions.				
(a) Specifications of Gear		(b) Specifications of Hob		(c) Cutting conditions
Module $m$	2.5	Outside diameter	85 mm	Feed of table revolution 4 mm/rev.
Pressure angle $\alpha$	20°	Number of threads $z_1$	2 RH	Direction of feed Climb
Number of teeth $z$	45	Lead angle	3° 46'	Hob set angle $\Gamma$ 16.23°
Helix angle $\beta$	20° RH	Number of gashes $G_n$	16	
Cutting depth	5.875 mm	Amount of protuberance	0.05 mm	
Addendum modification factor $x$	0	Radius of top corner	0.85 mm	
Outside diameter $d_o$	124.70 mm			

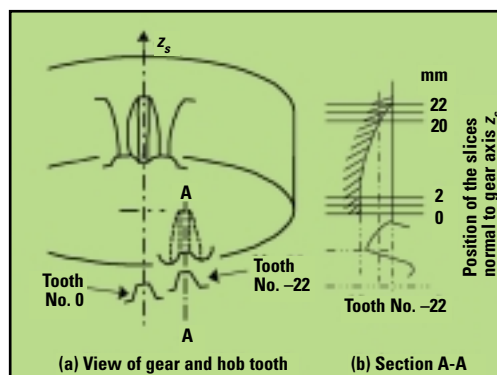


Figure 12—Definition of slices normal to gear axis.

# Simulation of Hobbing for Analysis of Cutting Edge Failure due to Chip Crush

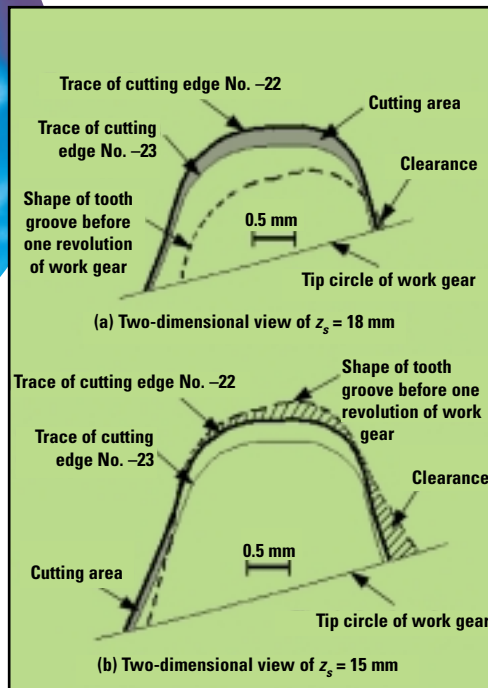


Figure 13—Expression of cutting area and clearance between work gear and the cutting edge of hob tooth No. -22.

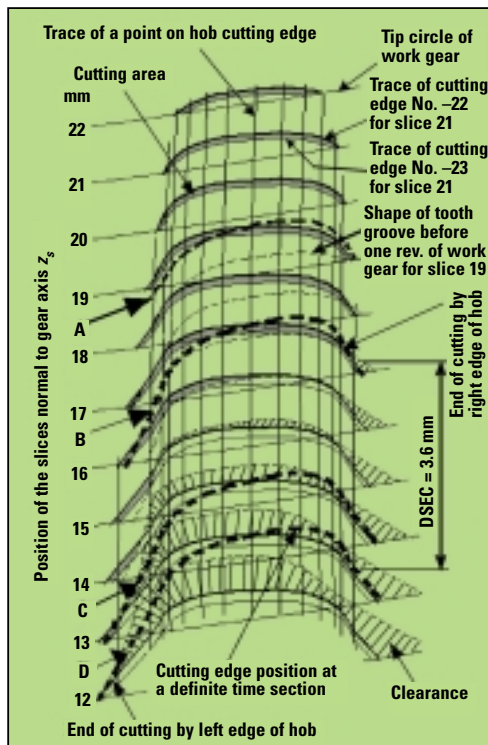


Figure 14—Expression of cutting area and clearance between work gear and cutting edge of hob tooth No. -22 (three-dimensional view). (DSEC: Distance of Single Edge Cutting.)

of the work gear, a bold curve shows the trace of the cutting edge of hob tooth No. -22, and the thin curve shows the trace of cutting edge No. -23 acting before cutting edge No. -22.

The inclined line below those traces is the tip circle of the work gear. The gray area where the trace of cutting edge No. -22 is deeper (upper in this figure) than any other trace, is cut by cutting edge No. -22. On the other hand, there is clearance (hatched area) between cutting edge No. -22 and the work gear's generated tooth flank at the area where the trace of cutting edge No. -22 is shallower than the other traces. In Figure 13(a), the whole range of the cutting edge inside the work gear's tip circle acts for cutting. At the lower  $z_s$  position, though (see Fig.13(b)), a large clearance exists near the middle and right cutting edges at a moment at which the hob's left cutting edge is acting.

Figure 14 shows the result of a simulation for tooth No. -22, which is observed from the same viewpoint as in Figure 12(a). Figures like Figure 13, but for different slice positions  $z_s$ , are arranged in a column. Actually, the position of the tooth groove on each slice is different in the circumferential direction because the sample work gear is helical. The cut groove on each slice is arranged here so that the middle position of the tooth groove on each slice is the same for easy understanding. The vertical line shows the trace of points on tooth No. -22's cutting edge, and the other types of curves have the same meaning as those in Figure 13.

The bold broken curves A, B, C and D show the cutting edge position at a definite time section. Cutting proceeds from curve A to D. Those cutting edge curves are inclined due to the hob set angle as shown in Figure 14. The hob's left edge therefore cuts each slice earlier than its right edge. The cutting edge exists as curve B when cutting by the hob's right edge finishes. Curve D exists at the end of cutting by the left edge. The left cutting edge therefore acts alone between the curves B and D. This distance BD in the work gear axis direction is called here the DSEC (Distance of Single Edge Cutting).

The movement of a generated chip on a hob tooth's rake surface depends on the acting position of the hob's cutting edge. Figure 15 shows a supposed movement of a generated chip on a rake surface at stages A, B, and C from a simulation (Ref. 11). At stage A, i.e. at the beginning of the generation of a chip, the chip flows toward the hob tooth root because the hob tip edge mainly cuts the work gear. The right edge finishes cutting at stage B and the direction of the chip movement changes. At stage C, the left edge cuts

alone and the already generated part of the chip moves toward the hob right edge.

At that stage, there is a large clearance between the hob's right cutting edge and the work gear's tooth flank. The chip could therefore intrude into the clearance. The chip could pass through the clearance if the chip is small enough and thin compared with the clearance. Otherwise, chip pinching and crushing could occur. In that case, the hob cutting edge could be damaged if the chip is thick and stiff. In case of a thin chip, part of the chip could scratch and/or be inlaid on the cut tooth flank of the manufactured gear.

It is possible to evaluate or understand the probability of chip crush between hob cutting edge and work gear tooth flank by utilizing graphical presentation for the results of the proposed analysis.

### Conclusion

Dry hobbing often causes failures of hob cutting edge or problems with the surface quality of manufactured gears' tooth flanks. Pinching and crushing of generated chips between hob cutting edge and work gear tooth flank is considered to be a major cause of those problems. In this report, a method to calculate and graphically express the trace of each hob cutting edge relative to a work gear is proposed. The following items are concluded:

- (1) Position, size and shape of clearance between hob cutting edge and work gear tooth flank during hobbing can be evaluated by the proposed simulation method.
- (2) It becomes easy to understand the state of chip generation by recognizing the size and shape of the cutting area by graphical expression of chip generation. Movement of the generated chip on the rake surface can be well imagined by calculating simultaneous cutting positions of the hob cutting edge.
- (3) The probability of chip crush can be evaluated by the size, thickness and movement of the generated chip, where the size and position of clearance are calculated from the proposed method.

The proposed simulation method is considered helpful in finding remedies for chipping of hob cutting edge and manufacturing of gears with coarse tooth flanks due to chip crush. ⚙

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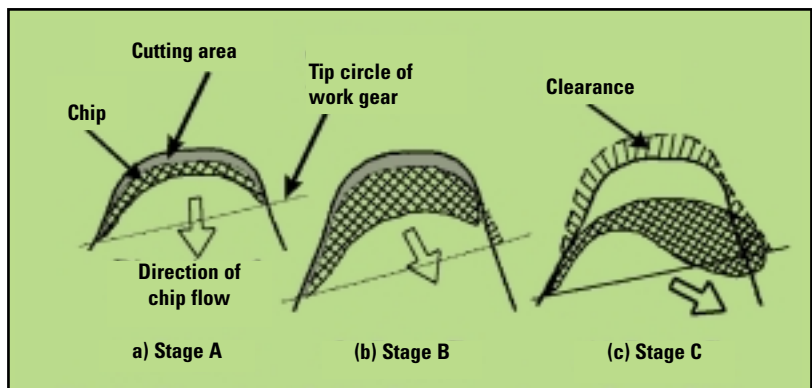


Figure 15—Direction of chip flow on rake surface of hob tooth at each cutting stage.

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The paper was also presented with its current title at the ASME/AGMA 2003 International Power Transmission and Gearing Conference, held Sept. 3–5, 2003, in Chicago, IL. It was also published in *Proceedings of the 2003 ASME Design Engineering Technical Conferences & Computers and Information in Engineering Conference*.

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**September 8–14—Gear Noise Short Course.** Department of Mechanical Engineering, Ohio State University, Columbus, OH. The basic short course, which takes place September 8–10, covers designing gears to minimize the major excitations of gear noise, like transmission error and dynamic friction forces. The advanced course takes place September 13–14 and is geared towards individuals who have previously attended the basic course. \$1,300 for the basic course and \$900 for the advanced, or buy them together for \$2,100. For more information, contact the Department of Mechanical Engineering by telephone at (614) 292-5860 or by e-mail at [houser.4@osu.edu](mailto:houser.4@osu.edu).

**September 8–15—IMTS.** McCormick Place, Chicago, IL. Please see page 12 for *Gear Technology's* coverage of this event. \$50 for domestic visitors and free for international visitors. For more information, contact the Association for Manufacturing Technology on the Internet at [www.imtsonline.com](http://www.imtsonline.com).

**September 13–14—13<sup>th</sup> Annual Gear Failure Analysis Seminar.** Big Sky Resort, Big Sky, MT. Attendees will examine macropitting, micropitting, scuffing, tooth wear and breakage and their possible causes. Handouts include *The Failure Analysis Textbook* and *Gear Failure Analysis Atlas* by Robert Errichello. \$625 for AGMA members, \$795 for non-members. For more information, contact the American Gear Manufacturers Association by telephone at (703) 684-0211 or by e-mail at [tech@agma.org](mailto:tech@agma.org).

**September 15–17—PC Applications in Parallel Axis Gear System Design and Analysis.** 7<sup>th</sup> floor, School of Continuing Education, University of Wisconsin—Milwaukee, Milwaukee, WI. A new PC tool, PowerGear, is demonstrated to analyze the gear load capability evaluation from a theoretical viewpoint and to apply the concept. The seminar's main emphasis is on comprehending the design of gearing and the use of software as a tool. \$1,195. For more information, contact the School of Continuing Education by telephone at (800) 222-3623 or on the Internet at [www.sce-eng.uwm.edu](http://www.sce-eng.uwm.edu).

**September 17—2004 Inductoheat Customer Open House.** Inductoheat facility, Madison Heights, MI. From 8 a.m.–5 p.m., customers are invited to tour the newly updated metallurgical facility and coil repair/machine capabilities. Demonstrations will be held on equipment processes for powertrain applications. Technical seminars will focus on new processes and developments in heat treating. Registration is free. For more information, contact Inductoheat by telephone at (800) 624-6297.



## TECHNICAL CALENDAR

**September 21–24—Metal Gear Design & Manufacturing.** UTS facility, Rockford, IL. Curriculum includes basic gear geometry, design and manufacturing, manufacturing issues and their effect on gear design. Advanced topics include minimum weight design strategies, gear size, geometry design, rating, producibility analysis, torsional analysis, gear noise and lubrication. This course will be repeated February 8–11. \$1,250. For more information, contact UTS by telephone at (800) 435-7887 or on the Internet at [www.uts.com](http://www.uts.com).

**October 18–21—Basic Gear Fundamentals Course.** Gleason Corp. Loves Park, IL. Individuals participate in small training groups that cover gear types and ratios, involute gear geometry, gear tooth systems, general formulae and mathematics, forming/generating and hobbing/shaping of gears, tool vs. gear tolerance, gear inspection and other related topics. \$895. To register, contact Gleason Corp. on the Internet at [www.gleason.com](http://www.gleason.com).

**October 20–22—Bevel Gear Systems.** 7<sup>th</sup> floor, School of Continuing Education, University of Wisconsin—Milwaukee, Milwaukee, WI. Aimed at the gear user, designer and beginning to intermediate gear technologist, this course emphasizes the quality control, application, assembly and installation of bevel gear systems. Manufacturing and inspection are covered more briefly. \$1,195. For more information, contact the School of Continuing Education by telephone at (800) 222-3623 or on the Internet at [www.sce-eng.uwm.edu](http://www.sce-eng.uwm.edu).

**October 26–29—Plastic Gear Design & Manufacturing.** UTS facility, Rockford, IL. Basic and advanced topics are covered, from the fundamentals to profile analysis, tool design and tooling selection. Attendees will take a field trip to Forest City Gear and can opt for a day-long session on TK Solver or one-on-one time with an instructor to solve specific gear problems. \$1,250 for the basic course and \$295 extra for TK Solver training. This course will be repeated March 15–18. For more information, contact UTS by telephone at (800) 435-7887 or on the Internet at [www.uts.com](http://www.uts.com).

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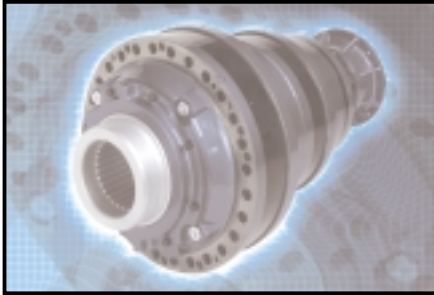
## New Gearbox from Brevini

The S Series gearbox from Brevini features an epicyclical design that increases the available power from the unit without affecting the overall weight, according to the company's press release.

The series can be utilized by OEM designers in the mobile, industrial, petrochemical, mineral extraction, marine and food processing industries. Available in eight sizes, the series contains four reduction stages and offers maximum nominal torque outputs up to 370,000 N-m.

The gearboxes employ more than four planetary gear wheels and can therefore produce more torque output than other designs of equivalent weight and size. In addition, their planet carriers have a mono-bloc design.

For more information, contact Brevini UK by e-mail at [sales@breviniuk.com](mailto:sales@breviniuk.com).



## New CMM System from Mitutoyo

The new Mitutoyo CMM auto body system is a large machine configured around a single or optional dual, horizontal CNC/CMM three-axis probe head system that operates from one or two pylons positioned alongside a large open bay.

According to the company's press release, the bay is sized to accommodate car and light truck body assemblies and other large-envelope components.

The CMM utilizes Metris LC Series high speed, non-contacting digitizing probes and a variety of scanning, vision or conventional touch probe inputs.

For more information, contact Mitutoyo America of Aurora, IL, by telephone at (630) 820-9666 or on the Internet at [www.mitutoyo.com](http://www.mitutoyo.com).



## Arrow Offers Ground Spiral Bevels as On-Demand Stock Gears

Fifty-seven combinations of ground tooth spiral bevel gears with diameters up to 16 inches, quality up to AGMA Q13, and cost savings of up to 50 percent—all available on demand as stock gears from Arrow Gear Co.

With this new line of stock gears, Arrow can offer manufacturers a low-cost way to develop prototypes or produce gears in low volumes.

"Developing a new spiral bevel gear design from scratch is very costly," says James J. Cervinka, Arrow's CEO and chairman, "and the process can take months. Using our stock products, the customer can take delivery in a matter of days."

Moreover, these stock spiral bevels can be modified to meet customers' applications. Contact patterns can be changed to meet customers' gearbox deflection requirements. Arrow engineers are available to help customers make the changes to meet those requirements, and the gear teeth are carburized and hardened—not through hardened—which can make it easier to modify the gears.

Also, according to Arrow, gear blanks can often be changed in two weeks to meet a customer's gearbox envelope requirements.

Cervinka adds that, even when the stock gears are changed, savings can still be considerable compared with other options for prototype or low-volume production runs.

"With the flexibility of our stock gear products, engineers now have the choice of using high-quality precision gearing in their prototype phase," Cervinka says. "Even in aerospace applications, our products can be used for the initial testing of their applications without the months of waiting for a completely new design."

Arrow manufactures high precision gears for various industries, including aerospace, and has offered stock gears for years. But the gears consisted of only a few sets with ground teeth; the majority were lapped teeth for less-critical applications.

This new offering is Arrow's response to manufacturers' needs for lower costs, shorter lead times, increased life, quiet operation and smooth-running systems for registry or positioning.

"In view of the brutal global competition that many companies are now facing, we feel that our product line of stock gears can serve as a powerful resource for a manufacturer's competitive posture," says Joseph L. Arvin, Arrow's president. "The ability to get your product to market faster than the other guy is a strong component for edging out the competition."

For more information, contact Arrow in Downers Grove, IL, at (630) 969-7640 or by e-mail at [bevels@arrowgear.com](mailto:bevels@arrowgear.com).



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## PRODUCT NEWS

### New Flat Honing Machines from Stahli

The Model DLM flat honing machine 705 from Stahli features a new construction and allows for faster processing speeds.

According to the company's press release, the dual wheel design enables both sides of the workpiece to be ground simultaneously. In this flat honing process, precision is achieved with fixed abrasives compared to conventional loose abrasive lapping or grinding.

Stahli adds that the need for pre-machining or secondary grinding is eliminated. Workpieces are held in carriers enabling continuous loading/unloading, which increases machine uptime.

For more information, contact Stahli USA of Wauconda, IL, by telephone at (847) 526-3527 or by e-mail at [sales@stahliusa.com](mailto:sales@stahliusa.com).



### New Metal Cutting Software from Scientific Forging

DEFORM software from Scientific Forging Technologies Corp. uses finite element simulation to predict chip shape, cutting zone temperature, tool wear and surface effects such as residual stress on the workpiece.

According to the company's press release, DEFORM, an established finite element code for metal flow analysis, is capable of both 2-D and 3-D analysis of chip forming. Its heat treatment functions can simulate microstructural transformation and recrystallization.

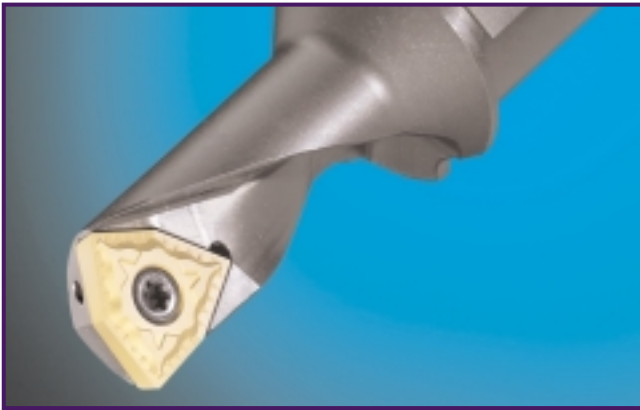
For more information, contact Scientific Forging of Columbus, OH, by e-mail at [sales@deform.com](mailto:sales@deform.com).

### New Spinning Machines from Leifeld

The new PNC 100 Series heavy-duty spinning machines have combined playback and CNC controls.

Operators have numerous options for programming. According to the company's press release, the machines' heavy rigid build can guarantee unmatched cycle times.

For more information, contact Leifeld USA of Colorado Springs, CO, by telephone at (719) 282-9061 or by e-mail at [info@leifeldspinning.com](mailto:info@leifeldspinning.com).



**New Turning Tool from LMT-Fette**

The Pentatec from LMT-Fette can perform drilling, boring, facing, turning and counterboring with a single tool.

The tool's design is based on a variation of the conventional trigon-shaped carbide insert. According to the company's press release, it is capable of drilling holes down to 8 mm or 0.315".

The tool can drill a small hole and then rough, finish and chamfer the bore. Next, it can rough and finish turn the O.D. of the workpiece face in order to reduce cycle time.

Available in two insert grades and two optimized geometries, the tool can machine steel gear blanks, carbon and alloy steels, aluminum, stainless steel and cast iron.

For more information, contact LMT-Fette of Cleveland, OH, by telephone at (216) 225-0852 or by e-mail at [lmtfette@lmtfette.com](mailto:lmtfette@lmtfette.com).

**New Finishing Process from Kapp**

The Kapp Group has introduced a combined process for hard finishing transmission gears that involves two machines, one for grinding and the other for honing via Kapp's patented process.

According to the company's press release, the two machines are coupled together. The KX300P has dressing for worms, dressing for form wheels, uses either CBN-plated worms or CBN-plated form wheels and also features on-board inspection and integrated balancing.

The CX250 is a Coroning machine designed as a mirror image of the KX300P. This machine uses the single layer plated diamond-coated coroning rings, which makes the setup time shorter. The process does not include dressing.

Motors and pumps are identical and compatible, as are the control and the human/machine interfaces.

For more information, contact Kapp Technologies of Boulder, CO, on the Internet at [www.kapp-usa.com](http://www.kapp-usa.com)

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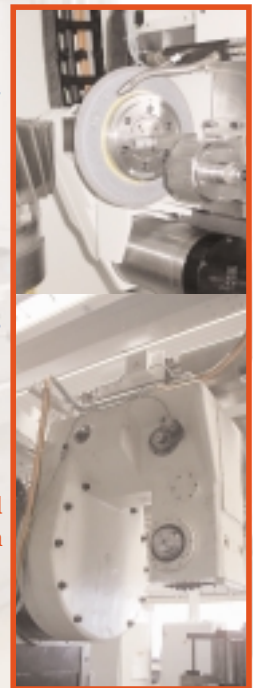
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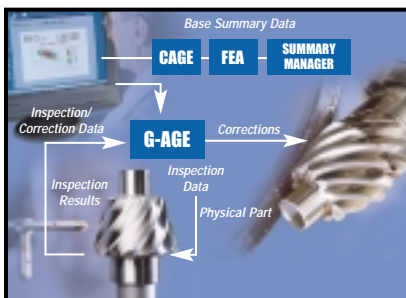
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Quality Transmission Components	70	(516) 437-6700	<a href="mailto:support@qtcgears.com">support@qtcgears.com</a>	<a href="http://www.qtcgears.com">www.qtcgears.com</a>
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SUDA International Gear Works Ltd.	47	(585) 385-8537	<a href="mailto:lgkndy@att.net">lgkndy@att.net</a>	<a href="http://www.sudaintlgear.com">www.sudaintlgear.com</a>
Tianjin No. 1 Machine Tool Works	72	(86) (22) 2493-2536	<a href="mailto:sales@tmtw.com">sales@tmtw.com</a>	<a href="http://www.tmtw.com">www.tmtw.com</a>
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# Gear Greenbacks

Imagine the \$10 bill with the face of Edwin R. Fellows on it and on the back, a picture of his invention: the gear shaping machine. Or the \$5 bill with George B. Grant and a picture of the first hobbing machine, which he built.

Or how about a coin with the profile of William Gleason, founder of the Gleason Corp?

The Addendum team thinks the United States Treasury would do well to take up any—even all—of these proposals as ways to recognize the gear industry's contributions to America.

After all, other countries have gear money.

Switzerland used to print a 10-franc note with a picture of Leonhard Euler, who's considered by some to be "the father of involute gearing." The note was recalled from circulation in 2000, but it's still legal tender until 2020. It's design even includes two meshing gear teeth.

And the United Kingdom has a new £2 coin with five gears in its design. The coin celebrates the 200th anniversary of an early steam-powered locomotive, the Penydarren, designed in 1804. The five gears are clear. Four of them are on the locomotive. The fifth is around the Penydarren and is a single railway track, but we know a geared rail when we see one.

So if the Swiss and British can have gear money, then so can the Americans.

Now the Addendum team understands that some people may have a problem with our gear-money proposals: presidents being pushed aside in favor of gear guys. We know that men like Abraham Lincoln and Franklin D. Roosevelt are famous in their own ways, but what did they ever do for gearing?

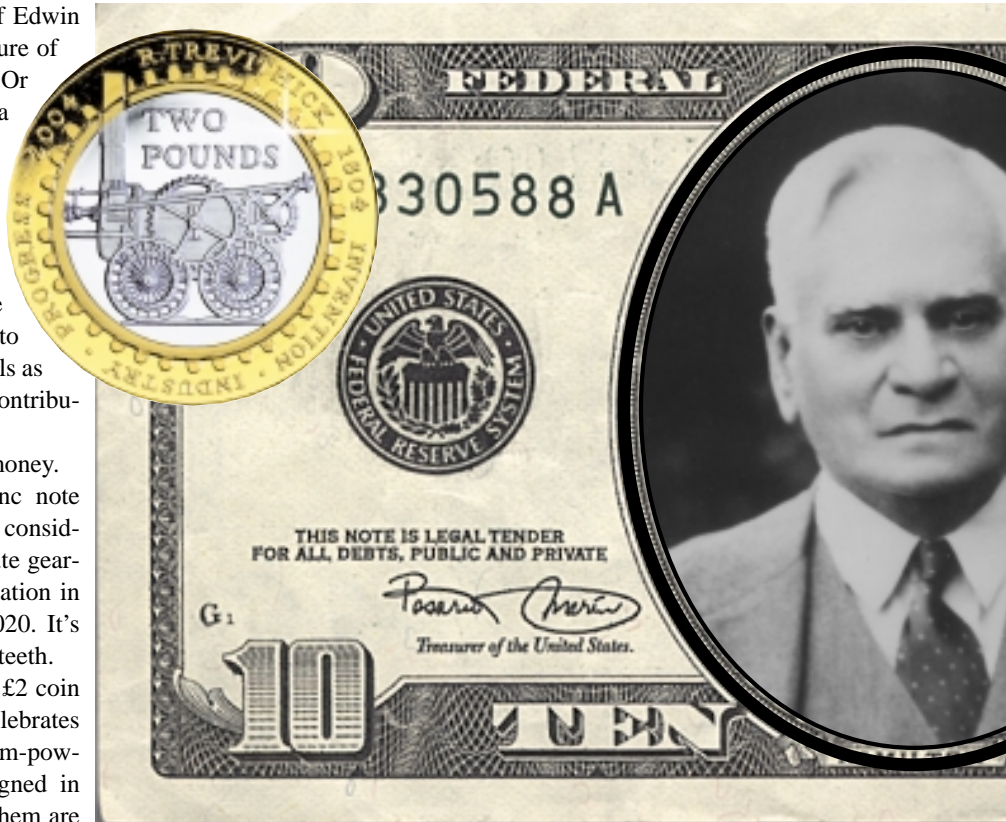
Still, we don't want to offend, so we think putting one of the gear industry's forefathers on the \$10 bill is *the* way to go.

That way we wouldn't displace any presidents. Right now, the bill features Alexander Hamilton, America's first treasury secretary. How Hamilton got on the bill, we don't know. The U.S. Treasury had plenty of presidents to choose from; there shouldn't have been a problem. Maybe they picked Hamilton because he was one of their guys, a Treasury guy.

But Hamilton made it onto the bill's face, with the Treasury Department building on the back. And there he stays, the only non-president on a widely used piece of U.S. money.

So the \$10 bill is an exception to the presidential rule. It's unique, enhancing it as *the* candidate for a gear industry forefather. After all, if we're going to create a piece of gear money, a unique bit of U.S. currency, then why not do it with a bill that's already a unique bit of U.S. currency?

We on the Addendum team think this is an excellent proposal. (We would; it's ours, after all.) Now we need a grassroots campaign from our industry. So if you want to join our campaign, give us a call; we'll give you the phone number for the U.S. Treasury.



## Tell Us What You Think . . .

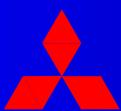
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# The Gearless Gear Shaper™

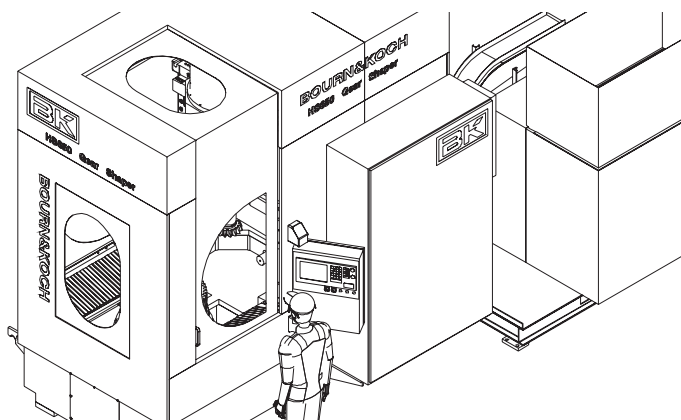
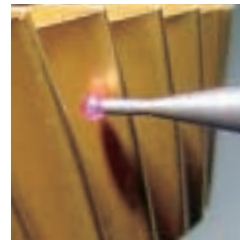
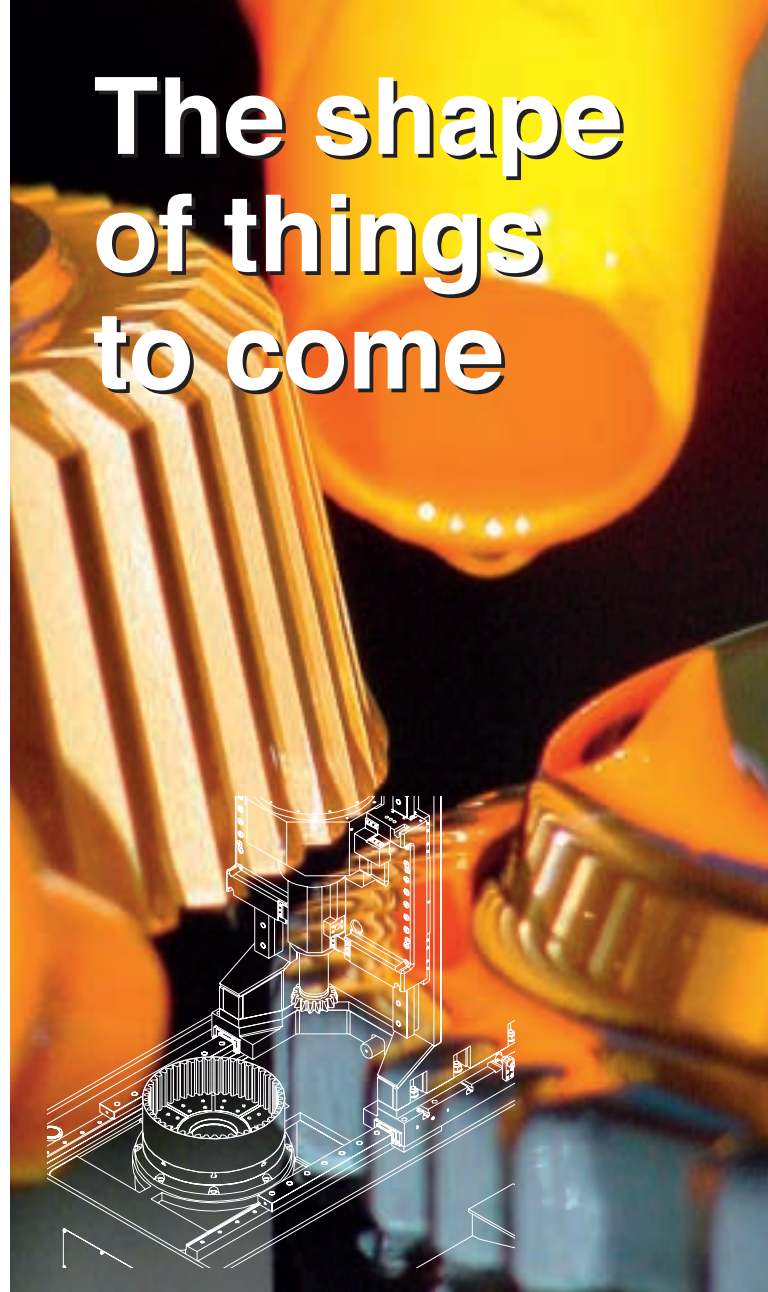
Bourn & Koch *Fellows* Division will introduce the new Gearless Gear Shaper™ gear shaping machine at IMTS 2004. The new design has 50% fewer mechanical parts than its FS series predecessors and is over 100 times more accurate on the transmission accuracy of the cutter and work axes.

Featured benefits of the new shaper design include:

- CNC Roll-Over™ external to internal gear
- Oriented Stiffness Back-Off™, CNC camless back-off
- Direct driven work and cutter spindles
- Single axis integration of positioning, stroke and Hydrostroke return ratio
- 300 mm vertical cutter spindle saddle travel
- CNC crowning
- Hydrostroke concentric force loading, quick return ratio, process monitoring, and adaptive force control features
- CNC guide
- State-of-the-art CNC control with GUI interface

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# The shape of things to come



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