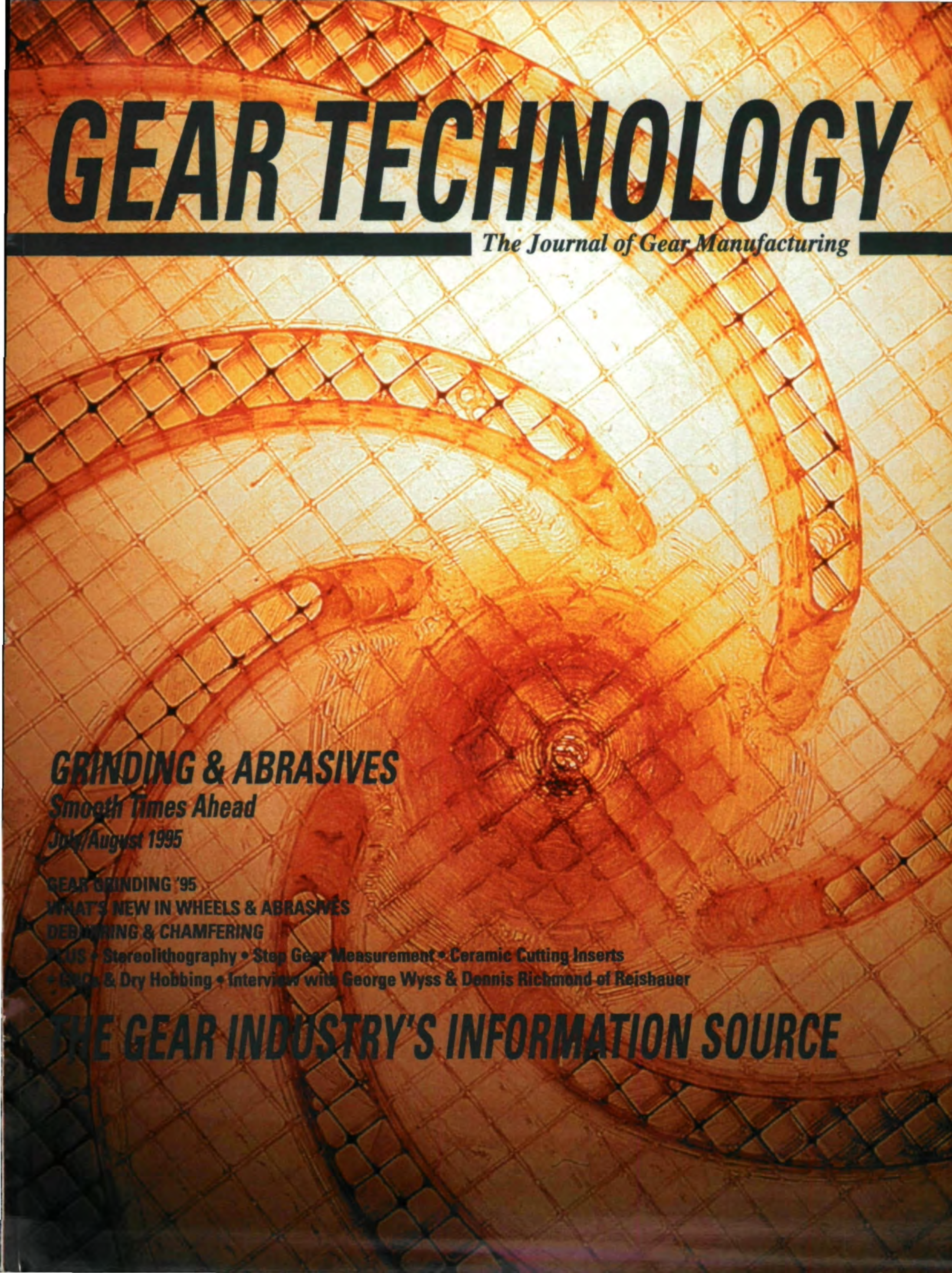
GEAR TECHNOLOGY

The Journal of Gear Manufacturing



GRINDING & ABRASIVES

Smooth Times Ahead

July/August 1995

GEAR GRINDING '95

WHAT'S NEW IN WHEELS & ABRASIVES

DEBURRING & CHAMFERING

PLUS • Stereolithography • Step Gear Measurement • Ceramic Cutting Inserts • CNCs & Dry Hobbing • Interview with George Wyss & Dennis Richmond of Reishauer

THE GEAR INDUSTRY'S INFORMATION SOURCE

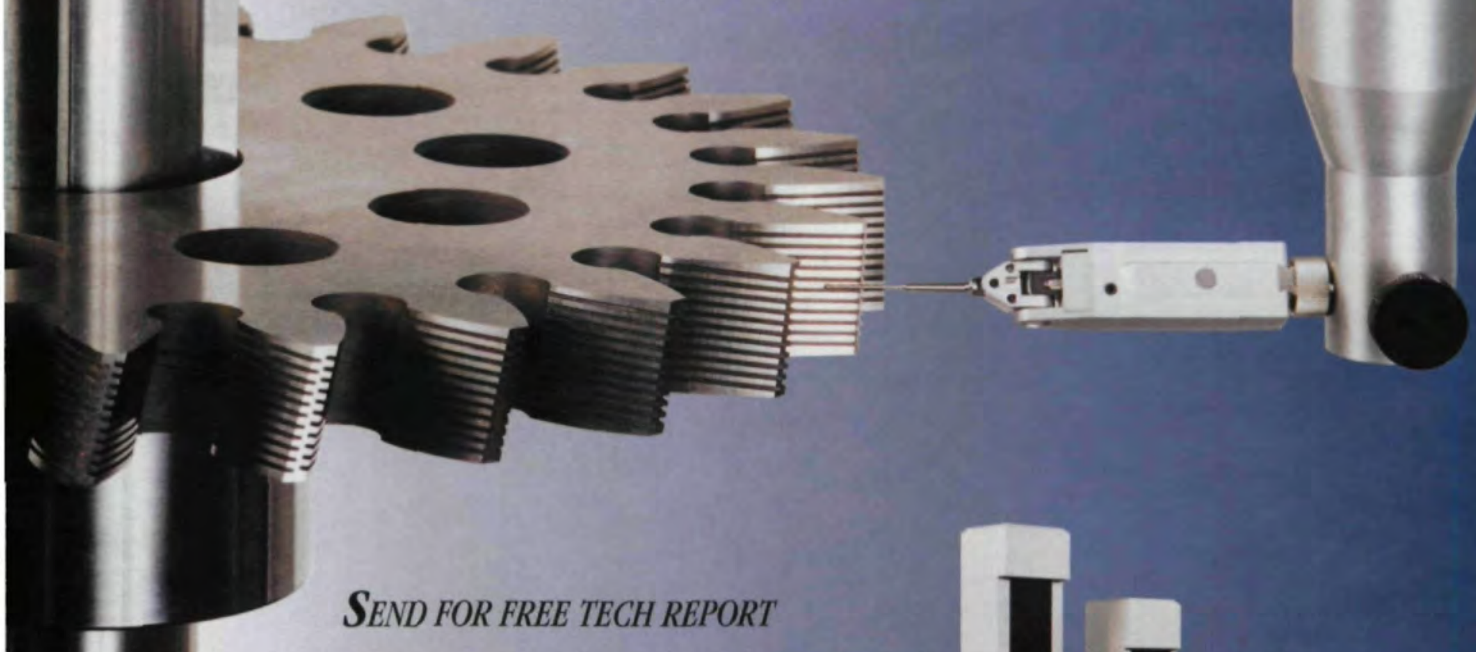

Pfauter-Maag Cutting Tools.
Where the world goes
for quality.
We're solid in carbide
Pfauter-Maag Cutting Tools is applying advanced new micrograin carbide grades, coatings, and manufacturing technology to produce a new generation of high performance solid carbide hobs.
End result: dramatic savings in your cost per piece.
Pfauter-Maag Cutting Tools
Limited Partnership
Telephone (815) 877-8900 • Fax (815) 877-0264
1351 Windsor Road, P.O. Box 2950, Loves Park, IL 61132-2950
CIRCLE A-2 on READER SERVICE CARD

GEAR INSPECTION CHECK LIST

GEAR MANUFACTURING PROCESS CONTROL CAN'T BE BUILT AROUND EMPTY PROMISES

You base your buying decisions on solid facts: precision, speed, reliability, service and support. So separate promises from proven performance by demanding that your gear inspection system supplier answers these questions:

- ❑ **1.** Can the system's accuracy claims be traced?
- ❑ **2.** Does the system repeat (six sigma) to sub-micron levels?
- ❑ **3.** Can the system precisely measure involute modifications?
- ❑ **4.** Is it a PC-based system with networking capability?
- ❑ **5.** Can the analysis software be tailored to meet specific needs?
- ❑ **6.** Is an extended software warranty provided?
- ❑ **7.** Can the system's reliability track record be verified?
- ❑ **8.** Does the design, assembly, software, sales and support come from one dependable source?



SEND FOR FREE TECH REPORT

Get our answers to the questions above, and see why more professionals trust M&M Precision Systems. Where you get proven results without the hype. Phone 513/859-8273 or fax 513/859-4452.

M&M PRECISION SYSTEMS Corporation

"THE METROLOGY AND MOTION PEOPLE"

CIRCLE A-5 on READER SERVICE CARD

GEAR TECHNOLOGY

JULY/AUGUST 1995

The Journal of Gear Manufacturing

FOCUS ON GRINDING & ABRASIVES

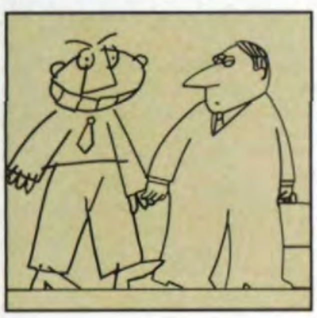
Cover photo courtesy of 3 D Systems, Valencia, CA.

SPECIAL FEATURES

30

DEPARTMENTS

39



48

GEAR TECHNOLOGY
The Journal of Gear Manufacturing

"BPA International Publication Membership Applied for September 1994."

EDITORIAL

Publisher & Editor-in-Chief
Michael Goldstein

Associate Publisher & Managing Editor
James K. Spalding, CBC

Senior Editor Nancy Bartels

Associate Editor William R. Stott

Technical Editors
Robert Errichello
William L. Janninck
Don McVittie
Robert E. Smith

ART

Art Director Jean Bartz

ADVERTISING

Advertising Manager
Patricia Flam

CIRCULATION

Circulation Coordinator
Deborah Donigian

RANDALL PUBLISHING STAFF

President Michael Goldstein

Vice President Richard Goldstein

Vice President/General Manager
James K. Spalding, CBC

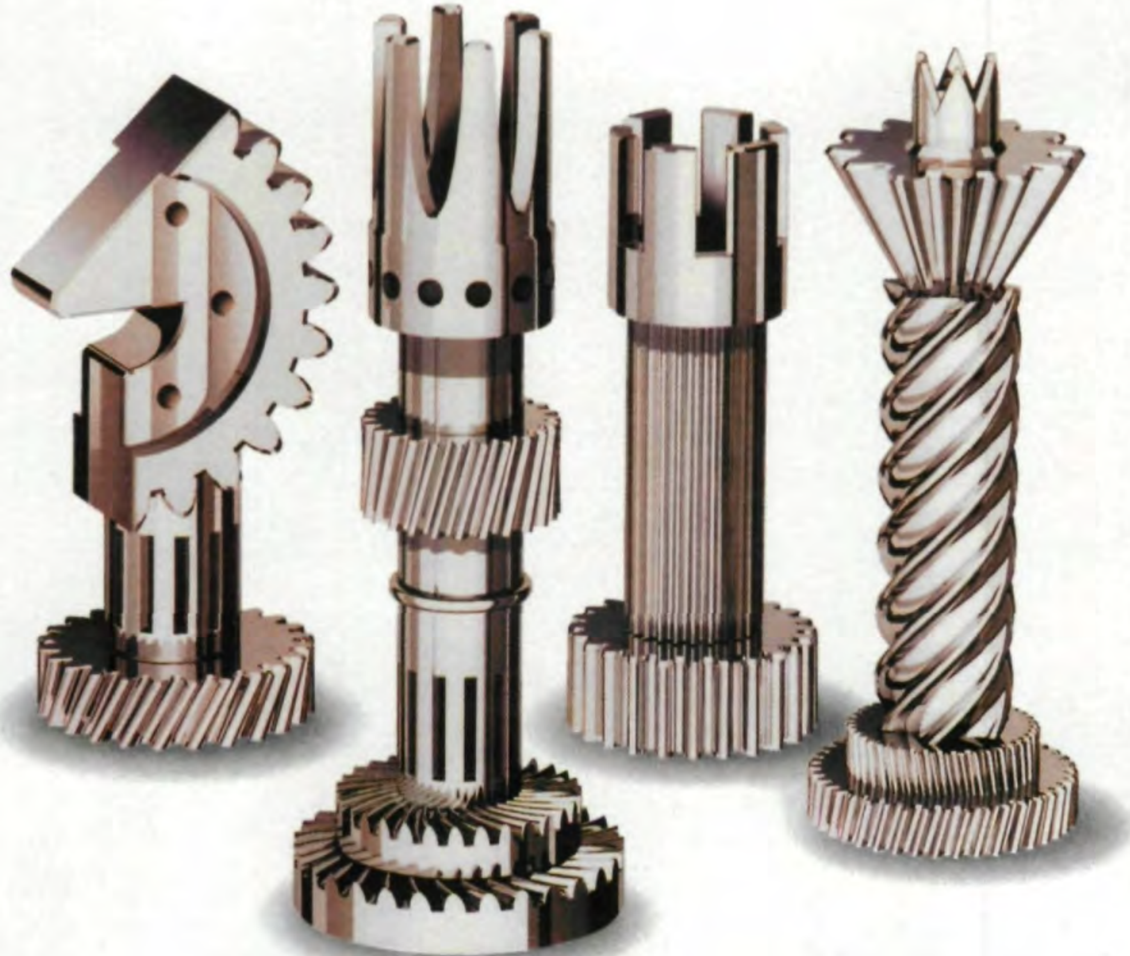
Controller Patrick Nash

Accounting Laura Manion

Art Consultant Marsha Goldstein

VOL. 12, NO. 4

GEAR TECHNOLOGY, The Journal of Gear Manufacturing (ISSN 0743-6858) is published bimonthly by Randall Publishing, Inc., 1425 Lunt Avenue, P.O. Box 1426, Elk Grove Village, IL 60007, (708) 437-6604. Cover price $5.00 U.S. Second-Class postage paid at Arlington Heights, IL, and at additional mailing office. Randall Publishing makes every effort to ensure that the processes described in GEAR TECHNOLOGY conform to sound engineering practice. Neither the authors nor the publisher can be held responsible for injuries sustained while following the procedures described. Postmaster: Send address changes to GEAR TECHNOLOGY, The Journal of Gear Manufacturing, 1425 Lunt Avenue, P.O. Box 1426, Elk Grove Village, IL, 60007.



Transitions

Many of the hot cars we lusted after in our younger (and not so younger) days have had Marcello Finateri's design engineering fingerprints all over their drivetrains.

Beginning with this issue, one of the last bits of the "old" *Gear Technology* is gone. From now on we'll be running the new picture of me you see on this page. It was time, my art and editorial staff explained to me, to move ahead with the rest of the updated art and editorial in the magazine. (I emphatically deny that the *real* motivation for the new picture was putting a stop to the ever-increasing number of jabs from certain friends about my "Dorian Gray" look.)

In the overall scheme of things, this is hardly worth noting. Still, when it's one's own photo, the change becomes a bit more personal. Studying one's portrait proofs gives new meaning to the phrase "shock of recognition." If nothing else, it's one more reminder that nothing stays the same forever. Change is the default mode of existence.

Another, far more important change took place recently in the automotive gearing business. Marcello Finateri, after nearly 50 years with Ford Motor Company, has retired. Since 1962, Marcello has been involved in the development of the differentials for all Ford cars and trucks sold in the U.S. market. He was instrumental in developing and maintaining Ford's strong engineering capability in differential gearing. Many of the hot cars we lusted after in our younger (and not so younger) days have had Marcello's design engineering fingerprints all over their drivetrains.

But Marcello has been much more than a brilliant engineer. He's never met a gear he didn't like, and his long hours and killer work weeks were as much a result of his passion for what he was doing as a function of his work ethic.

Marcello loved his work, and his passion for gears has been infectious. He has left a valuable legacy at Ford, not only in terms of his expertise built into important automotive designs, but also in the lives he's influenced. He has trained scores of other engineers and set an example by his tireless work habits, his boundless energy and, above all, his unfailing good humor. No matter how tense the situation or brutal the schedule, Marcello could come up with a joke or a smile.

The depths of the industry's affection for Marcello were demonstrated when more than 300 of his colleagues appeared at a retirement dinner honoring him. And those of us in attendance were only the tip of the iceberg. People in the gear industry around the world know, respect and admire Marcello Finateri.

Like much, if not most change, Marcello's retirement is a bittersweet affair. We're happy that he will enjoy a well-earned rest and that he can look back on a full, busy and eminently successful career. We send him off with our best wishes for an equally full and rewarding retirement.

But there's a certain sadness about the business as well. All of us who have worked with Marcello in one capacity or another will miss him. The industry won't be the same without him.

No one is indispensable, the sages and our own common sense tell us. But some people are irreplaceable.

Arrivederci, Marcello, vogliamo augurare ad un eccellente collega di godersi ora il meglio per gli anni a venire con lo stesso stile ed entusiasmo che ti ha contraddistinto nella tua carriera.

Michael Goldstein
Publisher and Editor-in-Chief

George Wyss & Dennis Richmond of
Reishauer Corporation

For this interview, we spoke with George Wyss, president, and Dennis Richmond, vice president of Reishauer Corporation about gear grinding and its place in gear manufacturing today.

GT: Where do you see Reishauer's place in the total gear industry?

DR: Reishauer is in a niche within a niche industry. Somewhere between 5% and 7% of those in the industry grind gears. That means 93% to 95% of them don't. That sets us apart, and we have to do things a little differently.

GT: Can you characterize the 7% you're talking about?

DR: For the most part, they are sub-contractors—people that supply to original equipment manufacturers. Some OEMs don't see gear grinding as a technology they want to invest in. They leave that up to shops that have decades of experience grinding gears. Most of our customers make complete gears—everything from cutting raw materials to heat treating.

GT: Which market segments represent most of your business?

DR: Roughly speaking, 70% of our business is gear grinding machines under 400 mm in capacity—that is, 16" or smaller; 10% is in gear grinders up to 800 mm. The remaining 20% is composed of gear honing and thread grinding machines. The gears show up in printing presses, machine tools, material handling, off-road truck and vehicle transmissions, industrial speed reducers and increasers and cars.

GT: You mentioned cars last. Is that the smallest segment?

George Wyss, president.

DR: In the U.S. it is. In Europe automotive represents approximately one-third of our business.

GT: Why such a small U.S. segment?

DR: The machines sold to the European automotive industry are primarily used for finishing manual transmission gears. We don't make many manual transmissions in this country.

GT: What about the Japanese automotive market?

GW: The Japanese car makers build transmissions differently. They are split into two sections connected by a set of transfer gears with approximately 50 teeth. Also the final drive gear creates quite a bit of noise. It's those gears that are being hard finished. More and more American car makers are also looking into hard gear finishing. They're changing their thinking, especially where noise is critical in the final drive gear set in a transmission. In the last five or six years, some U.S. auto makers have started grinding the final drive set. So, I wouldn't count grinding out of the U.S. automotive market.

GT: So you see grinding as something the American auto industry is beginning to pick up on?

GW: The problem is actually multi-fold. A few years ago when you bought a car, it came with a lot of noise, but you not only had transmission noise, you also had wind noise. Today, most of the wind noise is gone, but you hear the transmission. You have to do something with the transmission to make it more quiet.

GT: To meet customer demand?

GW: Yes, and the alternatives to grinding to control noise can be very costly.

GT: With the cutbacks in aerospace, what markets are taking their place?

DR: New markets such as motorcycle transmissions are a good example. Harley-Davidson is now grinding gears to reduce the drive-by noise generated by the engine and transmission in its motorcycles. Five years ago no one would ever believe that you could buy a Harley-Davidson with a ground gear transmission. Another example is wind power generation. In order to efficiently use wind and water for power generation, you have to have some way to generate electricity that uses very little energy or friction. The way you do that is with precision ground gears.

GW: During the Reagan build-up years, we sold a lot of machines worldwide, but right now the demand for ground gears in the aerospace and the aircraft industry is really diminished.

DR: There's a lot of excessive capacity out there. The machines that were sold in the 80s are now 10 to 15 years old and certainly capable of still generating the necessary quality, at least for the time being.

GW: I don't see defense aerospace coming back with all the efforts for worldwide peace. I also don't think the commercial aircraft industry will boom. There's increasing demand over the next few years, but airplanes get faster, bigger, and you use fewer of them.

DR: But if you look at the average age of an airplane in an airline's fleet, it's now nearing 20–25 years old. So I think there could be another cyclic demand for commercial aircraft, and that might coincide with the need to replace the grinding equipment.

From a maintenance standpoint, the machines are going to be 15 or 20 years old, and the new technology is so much better that I think when the demand does come back, it won't take as many machines to satisfy it because the new machines are so much more productive.

GT: How are Reishauer machines changing?

GW: I think it will be difficult in the future to come up with machines that are even faster or more productive than they are now, because if this could be accomplished, it actually reduces the demand for new machines. They will be more expensive to build, and fewer machines will be sold because they're more productive.

You can only raise the technology of the equipment to the level of the tool. That is the key factor. If you look at grinding wheels today, there's a limit on how fast you can grind. Once you've eliminated all the idle times in the process, you are down to the tool. What's the grinding capability or the specific removal rate of the wheel? I think we are almost at the limit unless grinding wheels are going to be a lot more productive in the future.

I think the ultimate goal is to produce a gear for the least cost. Tooling and equipment has to be affordable for the customer, but I think the investment plays a secondary role. You may have to invest more in order to produce something at reasonable cost. You have to look at the cost per piece.

DR: The point is, if someone hasn't invested in new gear grinding technology in the last six years, they're not current. There's something on the market that's a lot better, that will produce a gear faster—up to 200 to 300% faster, depending on the age of the technology that they are using now—and make a gear for a lower perishable tool cost.

GW: There's always a relation between investment and cost per piece. Today you can produce a gear at a quarter of the cost that you could with old equipment, but the price of the equipment hasn't quadrupled; it's probably only twice as much.

GT: What about grinding wheel technology? How has it changed?

DR: Ten years ago there was a lot of interest in CBN. Some companies established processes that specified CBN. Recently an article published by the University of Aachen concluded that there was no advantage in compressive stresses gained from using CBN. With the new shift grinding machine technology we introduced several years ago, there is no productivity advantage to the single-ribbed, plated, CBN single-index grinding machine over our generating process. In fact, we now set the industry standard as far as productivity for medium pitch gears 400 mm and smaller.

Seeded gel wheels are also being used successfully, and we haven't abandoned aluminum oxide. That's been a mainstay over the years. The wheel composition has changed a little, and we are starting to see more and more induced-porosity wheels. They've given us some huge productivity gains.

GW: The basic material has not changed, but the ratios of composition have.

DR: I think that in the past we went with the approach that one wheel fits all. Now each gear has to be looked at individually, and we have to choose the optimum process for each specific part.

GT: Are there any other important trends to take note of?

DR: Many manufacturers are investigating honing, especially for high-volume applications, because the machine tool is less expensive, but I think most honing machine manufacturers are still trying to perfect the process. In most cases the gear is driven by the hone-ring. The machine doesn't require an electronic generating module. Honing machines are less expensive than grinding machines because they have fewer axes. Commercially available control components make these machines more economical to build. I think honing will definitely have a future once you have the right tool. By right tool I mean the right hone-ring and the dressing tool married to a rigid machine.

But honing won't eliminate grinding. If you want to have constant quality and process stability without tight control of the gear prior to heat treat, you can only get it by grinding. Honing by itself is not the answer to all the problems, but a combination of grinding and honing may be. In order to have honing accepted, we have to change the way we think about how we make gears in this country.

GW: Especially in the automotive industry. Eliminating shaving is quite difficult. If you talk to some engineers, especially in automotive, and tell them they don't have to shave any more, they say, then I have to roll. On the contrary, you don't have to roll either. It is hard to finish-hone a gear if you shape or roll it. You want to hob a gear, harden it and hone it without removing more material than you have to. But I don't think honing will replace gear rolling. That is by far the fastest process there is.

GT: How have the needs of your customers changed?

GW: I think the key point is that the machine operator from the past—the guy who had the expertise to know exactly what he was doing on the machine—is no longer available today. Now customers are looking for a process that allows anybody to run the machine with little or no training. If something breaks down, the customer expects us to be right there to keep the equipment going.

DR: We had a customer in Milwaukee tell us he wants to takes a guy off of the street and train him to run a grinding cell worth more than a million dollars in four hours. This individual is supposed to be totally responsible for the machine, process, quality and productivity.

GW: That's what we are faced with today. That's the trend. It's not realistic, but a lot of people expect this. They're pushing the envelope to come up with the lowest training cost and highest efficiency in terms of dollars and time. Customers assume CNC will let you train quickly, but there's more to a gear grinder than to a CNC lathe or CNC conventional machines. ○

If you would like more information about Reishauer Corp. please circle Reader Service Number A-104.

Tell Us What You Think... If you found this article of interest and/or useful, please circle Reader Service **Number A-105.**

GEAR GRINDING 1995

Technology and trends show that grinding's future is not so rough.

William R. Stott

Gear grinding is one of the most expensive and least understood aspects of gear manufacturing. But with pressures for reduced noise, higher quality and greater efficiency, gear grinding appears to be on the rise.

OSHA regulations and customer demands are forcing gear manufacturers to examine ways to make noisy printing presses and rolling mills purr like kittens rather than roar like lions. And drivers want their sedans to roll along on puffy white clouds rather than on rough and noisy thunderheads.

"I never thought I'd see the day when we'd have rolling mills with ground gears, but here we are with rolling mills ground to helicopter tolerances," says Brian Cluff, vice president–technical sales for American Pfauter.

For a big, expensive operation like a rolling mill, having a gear failure can cost hundreds of thousands of dollars per day. Ground gears will run smoother for longer. If that saves a company money in the long run, it makes a lot of sense, Cluff says.

Other manufacturers who are looking more and more to grinding include makers of automobiles, trucks and motorcycles. Harley-Davidson, for example, began grinding gears on some of its 1995 models and is expected to expand grinding operations for 1996. With the average motorcycle buyer looking more like a middle-aged yuppie than a long-haired, tattooed, black-leather biker, the appeal of the loud bike is getting smaller.

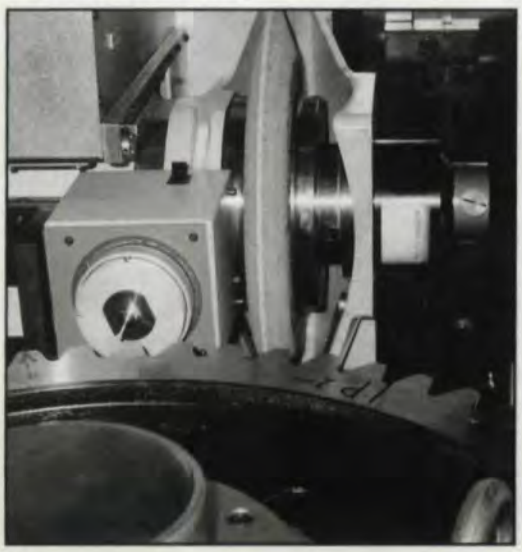


Photo courtesy of Höfler GmbH.

"Six months ago we didn't know we could grind from solid. In the next five years, we'll probably be able to grind anything from solid."

—Dave Matheson, Liebherr

On-machine measurement will continue to play a big role in grinding technology.

The demand for ground gears seems to be spreading faster in Europe than in the United States. For example, the spiral bevel gears in European truck axles are now being ground in large numbers, says Mark Smith, gear product manager for Ernst Winter & Son, manufacturers of gear grinding wheels.

In the United States, grinding of bevel and hypoid gears is almost unheard of outside the aircraft industry. But it's an area that's going to attract a lot of attention in the next few years, says Robert G. Hotchkiss, director of applications engineering for the Gleason Works. In car and truck manufacturing, grinding will become an environmentally friendly alternative to lapping, Hotchkiss says. In addition to reducing gear noise, manufacturers won't have to dispose of the gritty, messy lapping oils.

In addition to noise and environmental concerns, the demand for ground gears will be based on increased load-carrying capacity, says Matthew Babisz, president of Niagara Gear, a job shop specializing in ground gears. "When I bought this company 20 years ago, I concentrated on grinding. I could see the trend. People were looking for greater horsepower, higher speed and accuracy, and less noise."

With greater demand, manufacturers are looking for ways to increase the productivity of their grinding machines. One of the main improvements to machines over the past few years has been the development of more sophisticated computer controls.

The interfaces used on today's CNC machines are beginning to look more and more like the screens on our PCs at home and in the office. For example, the Oerlikon Opal 500 is run by a 486-66mHz PC with a Windows-NT control. The Pfauter-Kapp gear grinding machines also use a Windows environment. Programs for the

Reishauer RZ 820 machine can be prepared on a detached PC and downloaded to the machine. The Höfler machines can be equipped with a modem, which allows engineers in Germany to troubleshoot a machine without sending a service technician. When problems can't be solved over the phone, the technician will have a good idea of what needs fixing before he comes to the site.

By making the machines easier to use and capable of storing more setups and programs, the machine tool manufacturers have gone a long way toward making gear grinding machines more productive. "In the old days, you could spend a whole day or days setting up index plates and sine bars. Today, with a CNC machine, it takes 10 to 15 minutes for a preprogrammed part," says Don Kosal, sales engineer for National Broach.

In addition CNC controls improve the grinding process. "Burning of the gear is the greatest factor that inhibits reducing the costs of gear grinding," says Carl Eckberg, vice president for gear products, Bourn & Koch. "Our customers want to be able to produce more parts in less time for less money. They want to know how we can build machines to reduce the burning of the part and/or grinding cracks when feeds and speeds are increased." Advanced CNC controls allow machines to grind faster and deeper by varying the grinding cycle. "CNC can allow the machine to alternate grinding areas so that one area won't get too hot while another area is sitting cold," Eckberg says.

Also, CNC allows grinders to produce modifications to lead and profile that previously were either impossible or too time-consuming to be economically practical. "The introduction of CNC control technology has not only improved the efficiency, reliability and accuracy of gear grinding machines, but it has also opened the door to a wide variety of gear grinding process improvements," says Stephen Price, vice president of Höfler. Such improvements include workpiece management programs, automatic start and finish grinding, special relief modifications and on-machine gear inspection, Price says.

One area to watch in the coming years is on-machine measuring systems that automatically adjust the way the machine operates. Many machines already have some form of on-machine monitoring or sensing device to stop the machine or notify the user when the part being ground is no longer within specified tolerances. For example, on the Pfauter-Kapp machines, the user can input the profile tolerances and have the machine automatically dress the wheel or alert the user when the wheel needs to be changed. The advantage is especially noticeable for large parts, such as those the Pfauter-Kapp machines are used to grind. Rather than unloading a large, heavy gear and reloading it on a CMM, you can tell while the gear is being ground whether it is up to specifications.

"I never thought I'd see the day when we'd have rolling mills with ground gears, but here we are with rolling mills ground to helicopter tolerances." —Brian Cluff, American Pfauter

The Reishauer RZ 820 machine features a quality control module, which monitors the transient load oscillations that occur as the gear's teeth come in and out of contact with the grinding wheel. The machine evaluates and then counteracts any errors.

"Touch grinding" is one of the features touted by the manufacturers of the Niles gear grinder. An acoustic sensor detects typical or atypical grinding noise and can start or stop a specific action of the machine, depending upon what it detects. This is useful for aligning the workpiece to the grinding wheel and for automatic stock dividing. Niles grinders also have an optional remote diagnostic system with gear measurement on the machine.

Höfler's on-machine inspection equipment displays the results of lead, profile, spacing and modification inspections on a portable color screen. Results can also be printed out for quality control documentation, and data can be used for automatic machine corrections.

With machine speeds and feeds continually increasing, the pressure and placement of the lubricant nozzles have also come under close scrutiny. Theoretically, the more efficiently the hot chips are removed, the faster the machine can grind. Modern machines use high-pressure lubricant delivery systems with multiple nozzles. Some also have air jets to further direct the lubricant flow.

Coolant configurations will have to become more and more flexible as coolants and their setups become more and more customized to a particular application, says Dave Matheson of Liebherr.

Photo courtesy of Höfler GmbH.

Grinding is getting more user-friendly, with PC-like screens and easy-to-use controls, as shown by the Höfler interface at right.

In addition, "Gear manufacturers are just now beginning to understand the effect the right grinding fluid can have," says Carl Eckberg of Bourn & Koch. Advances in coolant materials will allow gear manufacturers to become more environmentally friendly. Despite the fact that synthetic and water-soluble lubricants are now available and being developed every day, 90% of all gear grinding is done with straight oil, says Kris Kumar, applications engineer with GE Superabrasives. Alternative materials will probably be used more and more, he says.

One of the areas where coolants are going to play a more important role is in grinding parts from solid, Matheson says. Many of the machine tool manufacturers have been experimenting with and touting their machines' abilities to grind through-hardened parts from solid, eliminating the hobbing or shaping process altogether.

Traditionally, it has been economically practical to grind from solid only the smallest, finest-pitch gears. Today that's changing. The Sigma Pool companies have been doing extensive tests on grinding from solid. An example is a 6DP, 29-tooth, 1½-inch gear ground from solid in 14 minutes. "Six months ago we didn't know we could grind from solid," Matheson says, "In the next five years, we'll probably be able to grind anything from solid."

American Pfauter's Brian Cluff agrees. CBN technology has allowed grinding from solid to eliminate processes and save money. Despite common notions, it can be done with aerospace alloy steels, and it can be done on gears larger than 20", Cluff says. "We can grind gears 1DP and coarser from solid. In some cases, there's no other way to make the gear except to grind it from solid." Internal gears are a natural, Cluff says. *That way, you don't have to have a dedicated* shaping machine with specialized internal tooling.

Other companies have also been experimenting with various methods for rapid stock removal. Höfler promotes its machines' ability to combine deep feed grinding with double flank grinding, which, according to the manufacturer, accomplishes in one grinding pass what would take three or four passes using conventional generating grinding.

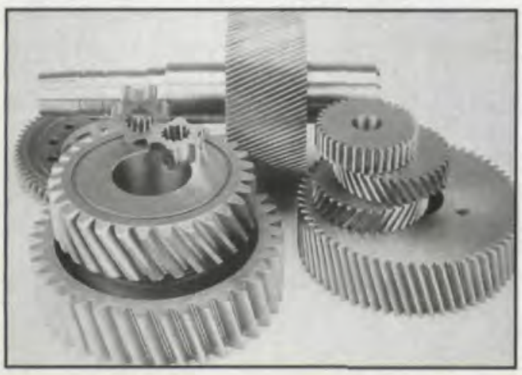


Photo courtesy of Gleason Works.

"Our customers want to be able to produce more parts in less time for less money. They want to know how we can build machines to reduce the burning of the part and/or grinding cracks when feeds and speeds are increased." —Carl Eckberg, Bourn & Koch

With concern over gear noise increasing, more and more gears are being ground.

Edgetek Machinery Co. is interested in applying a technology called high efficiency deep grinding to gearing. Edgetek produces a CNC grinding machine with a 35hp spindle that is capable of up to 40,000 sfpm using electroplated CBN wheels.

Wes Lee, president of Edgetek, says high efficiency deep grinding could provide 4–5 times the efficiency of creep-feed grinding with up to a 40% reduction in cycle times. Edgetek's technology is currently being used to produced splines, slots and other gear-like forms.

Although CBN technology has been around for about 15 years, it remains one of the least agreed-upon topics in gear manufacturing. Part of the problem is that every machine tool manufacturer has tried to carve out its own niche in the market. Certain grinding machines are geared toward using electroplated CBN wheels, while others try to take advantage of vitrified aluminum oxide wheels. Because competition is so fierce, it's no surprise that the manufacturers are reluctant to talk about their competitors' technologies.

There is no question that CBN is an outstanding material. Its metal cutting qualities have been well documented. It's hard—nearly as hard as diamond. Its structure is such that is stays sharper for longer than other materials. It sounds like a wonder-material. And for many applications, it is.

But there is a great deal of misconception about the best uses for CBN grinding. According to Brian Cluff of American Pfauter, the misconception is that CBN is cost-effective only for high-volume production. "Plated CBN grinding is cost-effective both for large and small lots," Cluff says. *"It's cost-effective for one gear."* Cluff points to a major gear job shop that produces very large, very expensive gears with CBN grinding.

On the other hand, Gary Rackley, president of Pro-Gear Co., which specializes in gear tooth grinding, says the misconception is that electroplated CBN wheels are the way to go for every application. Pro-Gear uses seeded gel wheels. And Matthew Babisz, president of Niagara gear, which also specializes in ground gears, says, "Electroplated CBN is good stuff, but it's very expensive. We use ceramic-type wheels."

Each manufacturer of gears has his own product mix and will have to choose his own optimum grinding technology. It is difficult to generalize about what is the state of the art in gear grinding when it is different for each application. You can buy an awful lot of vitrified-bond aluminum oxide wheels at $35 each before you can justify the $2,000 or more it might cost for an electroplated CBN wheel. But on the other hand, it may be important to finish a large, expensive part as quickly as possible, so the cost may be justified.

To make matters more confusing, a great deal of work has been done in recent years to improve the bonds used with aluminum oxide and other conventional materials. "The area that we're getting some of the biggest surprises in is in vitrified wheel technology," says Dave Matheson of Liebherr. "We've been able to increase aluminum oxide grinding cycle times to nearly as good as CBN cycle times by putting more air space in the grinding wheel. We've been able to put so much air space in the wheel that you could hold one up to your mouth and blow out a candle through it." The air space allows for less material buildup, which in turn allows for greater stock removal.

"There is a definite trend back to the basics," says Stephen Price of Höfler, "That is, back to dressable aluminum oxide and corundum."

Because of the advances in vitrified-bond technology, the movement in the industry also seems toward dressable CBN. The advantages of this technology are a more stable finish, a more consistent level of material removal and a more consistent level of heat generated, because the wheel is constantly being adjusted to present an accurate profile, says John Ferriola, product manager for Ernst Winter & Son. In addition, with dressable wheels, when a minor print change comes down, you don't have to order a new wheel. You can reprofile the one you have.

Most of the grinding machine manufacturers will tell you that their machines are capable of using dressable CBN technology. But capable doesn't necessarily mean practical. In fact, the use of dressable CBN is not very widespread. Vitrified-bond CBN is dressable, but only to a certain extent, says Ronald Halama, sales manager for WMW Machinery Co., which represents the Niles grinder in America. Because CBN is so hard, it must be dressed with diamond tools. Making major adjustments to a dressable CBN wheel causes great wear and tear on the dressing tool, and also results in throwing away large amounts of expensive CBN material, Halama says.

The Sigma Pool has researched the use of vitrified-bond CBN wheels. "We got more parts than with standard vitreous wheels, but it took longer to dress and it ate up the dressing wheel. The technology is not there yet," says Dave Matheson of Liebherr.

However, there are companies using dressable CBN grinding with great success, says Brian Cluff. Dressable CBN is applicable for a variety of industries, he says.

"Grinding has got to be economically viable from the viewpoint of cost per piece. It's hard to nail down the value of improved quality or reduced noise, so it's not easy to justify in every case." —Robert G. Hotchkiss, Gleason Works

Because there are so many different technologies involved in gear grinding, it's important for manufacturers to have a solid understanding of them all. Most of the machines on the market today are capable of using either electroplated or dressable wheels. In many cases, it's up to the gear manufacturer to decide what process is going to be most cost-effective for a given application.

The cost of gear grinding is one of the key factors that has prevented its widespread use, and it's not always easy to justify. "Grinding has got to be economically viable from the viewpoint of cost per piece," says Robert G. Hotchkiss of the Gleason Works. "It's hard to nail down the value of improved quality or reduced noise, so it's not easy to justify in every case."

In fact, a number of alternative technologies have been experimented with as replacements for hard finishing gears by grinding, but grinding's place seems secure. "I've been in the gear business for 40 years and in the grinding part of the business for 30 years," says Niagara Gear's Matthew Babisz. "I've seen them try just about everything—from carbide hobbing or skive hobbing to ausrolling to trying to control the heat treating process—and it just doesn't work. Grinding is still the best solution." ○

For more information about any of the companies mentioned in this article, please circle the appropriate Reader Service number below.

American Pfauter/Pfauter-Kapp..............A-106
Bourn & Koch..............A-107
Edgetek Machinery..............A-108
Ernst Winter & Son..............A-109
GE Superabrasives..............A-110
Gleason Works..............A-111
Höfler..............A-112
National Broach..............A-113
Niagara Gear..............A-114
Oerlikon/Liebherr/Sigma Pool..............A-115
Pro-Gear..............A-116
Reishauer..............A-117
WMW Machinery/Niles..............A-118

Tell Us What You Think... If you found this article of interest and/or useful, please circle Reader Service **Number A-119.**

The Shape of Things to Come

How AlliedSignal used stereolithography to save time and money on a helicopter gearbox prototype.

Nancy Bartels

Top: Distinctive square-hatch pattern of the QuickCast™ build style. Middle: Cutaway section of AlliedSignal's upgraded gearbox for the T55 engine. Bottom: Delphi Harrison Thermal Systems' SL masters for vacuum sand casting tools.

An engineer's responsibility for verifying a new design or product concept as manufacturable early in the development cycle is a tough challenge. What appears to work on a blueprint or in a three-dimensional CAD file on a computer screen may not work on the factory floor; and the downstream impact on the manufacturing process of an undetected design flaw can be enormous. Costs can run into the millions.

Increasingly, manufacturers are turning to stereolithography (SL) for rapid prototyping of new or re-engineered products to fully visualize, verify, iterate, optimize and test parts before making any commitment to hard production tooling. Developed by 3D Systems of Valencia, CA, the SL process enables transformation of a 3-D computer model directly into a tangible part using the combined technologies of computers, optical scanning, lasers and photochemistry. Complicated product concepts, assemblies and systems are easily verified and/or modified before costly production is ever undertaken. Parts that would take weeks to machine can now be produced in hours with stereolithography.

Stereolithography—How It Works

SL creates three-dimensional plastic parts directly from CAD/CAM data. A Stereolithography Apparatus (SLA) receives design data from the CAD file and "slices" it into thin cross sections. Next, an ultraviolet laser traces each successive cross section of the object onto the surface of a vat of photosensitive resin. The liquid plastic hardens only where touched by the laser beam. A new liquid layer is then spread over the solidified layer, and the next contour is drawn by the laser. The process repeats automatically and unattended until the part is complete.

Good for the Gear Business

While SL has been in widespread use in the aerospace, automotive, computer and consumer electronic industries on every product from complex propulsion systems to computer mice, gear manufacturers have been slow to test its mettle. That may change as the gear industry learns how hundreds of companies, both small and large, throughout the U.S., Europe and Asia report reductions in tooling costs, improvements in product quality and the ability to cut their product development time by half or more using SL.

An excellent example of how SL can make a critical difference in gear manufacturing is offered by AlliedSignal Engines (formerly Textron Lycoming) of Stratford, CT. Like many companies in the military sector, AlliedSignal, a leading manufacturer of military/commercial aerospace engines, sought ways to cope with fewer large government contracts and the business realities of doing more with less in a downsized economy. The company resolved to create new markets through technology infusion and the development of value-added components that would meet or exceed program objectives without running up costs.

Allied's Pilot Program

One of the first opportunities to exercise AlliedSignal's new competitive posture took place when the company led a pilot program to upgrade its T55 gas turbine engine, which powers the CH-47, twin-engine Chinook helicopter, the Army's workhorse transport. In order to infuse new life into this reliable, but aging helicopter engine, AlliedSignal offered a technology package to attract the interest of the Great Lakes Composite Consortium (GLCC).

Among the parts slated for improvement were several external engine components, such as gearboxes, accessories and oil lines. Priority was placed on weight reduction, maintainability, longer life cycle and lower cost. Due to the potential for high payback, special attention was paid to the top- and bottom-mounted gearboxes. A newer, more compact, top-mounted design was formulated to replace the existing gearbox.

To help secure additional contract funding, newer technologies, such as composites, and short cycle time methodologies were required. That meant the development team, consisting of Ted Westerman, composites development manager; Jennifer Finch-Johnson, components group development engineer; Frank Leech, gear development manager; George Milo, manager of components engineering, and others had to pursue visionary approaches to meet these objectives.

As a result, AlliedSignal was awarded a multi-year contract from GLCC and NAVAIR, which administers the U.S. Navy's naval air programs, to develop composite gearbox technology that could be directly transferable to larger components. AlliedSignal entered Phase One of a three-year program that would ultimately require the company to infuse new technology into the larger developmental V-22 Osprey tilt-rotor helicopter, as well as into the Chinook. A joint effort between Bell Textron and AlliedSignal, the U.S. Navy's V-22 represented a valuable opportunity to introduce lightweight components into both helicopters.

The initial plan called for newer, more advanced composite technology to be applied to highly loaded structural components, such as the accessory gearbox, which utilizes internally cored passageways and bearing liners. What's more, the new gearbox would have to be reliable to 25,000 hours, a quantum leap in performance from the standard 6,000 hours of useful life.

Given the time and weight constraints, AlliedSignal's skill in rapid prototyping would be essential. SL was selected as the most effective proof-of-concept tool to validate a new design on a small scale quickly and with confidence.

AlliedSignal reasoned that because so much development work had been done on the composite inlet housing unit for the T55 engine, SL technology would provide the additional confidence needed to build the entire T55 gearbox to scale (12" x 4") and to develop a top-mounted, high-speed, composite gearbox on the larger 3.5' scale needed for the V-22. Ideally, the development effort would benefit both the CH-47 and the V-22, giving the company a double-header of technology infusions. The design synergy to be gained would net tremendous cost reductions in tooling alone.

With AlliedSignal at the design helm, a three-dimensional solid model was built in the Unigraphics® CAD system. The file was then turned over to specialist Dan Domeracki, a development assembly technician, who built the gearbox prototype on AlliedSignal's Stereolithography Apparatus, the SLA-500 model. Kaman Aerospace of Bloomfield, CT, was selected to do the 2D braiding and Resin Transfer Molding (RTM), a process where dry reinforcement braiding is held in a closed mold. Low viscosity resin is then injected into the mold and cured to form the part.

Once Kaman was able to view the SL prototype, a real "eye-opener" occurred. The company now understood what they were up against with regards to the complex passageways, bearing bores and highly loaded areas. As a result, several important design changes were made.

Although AlliedSignal did not initially intend to cast metal, the team opted to use SL in 3D Systems' QuickCast™ build style because of its high level of accuracy. QuickCast replaces traditional wax patterns for investment casting with patterns created in a robust, durable material without tooling or loss of time. QuickCast builds highly precise, thin-walled parts down to 0.050".

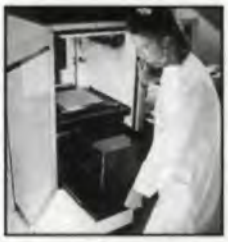
The outcome was better than imagined: two functional SLA prototypes of a top-mounted, high-speed gearbox that feature more than 30 moving parts, including seven different gears and six shafts. The planned engine gearbox will also incorporate other high technology components, such as composite bearing cages, composite sintered air oil separators and new corrosive resistant stainless steel bearings. SL enabled the team to do fit checks, implement assembly procedures, and, most important, provide a reliable visual aid for a perplexing concept.

But the best was yet to come. Feeling they were on a roll, the design team worked through the Christmas holidays to be ready for an Army review meeting. When they removed their one-of-a-kind gearbox from its protective air bag, the customers stood in "disbelief," says George Milo. "No one imagined we'd get the job done with such success. That made it worth giving up our Christmas holidays."

High-tech prototyping was a smart investment. AlliedSignal estimates that the use of stereolithography for rapid prototyping will net a 30% reduction in program cost and development time, the equivalent of $500,000. Better yet, the advantage of having an exact physical representation of the gearbox to present to their customer may have paved the way to secure multimillion-dollar, follow-on contracts—not bad for a little work over Christmas vacation. ⚙

For more information about 3D Systems, circle Reader Service Number A-121.

AlliedSignal's team knew it had to go beyond traditional design methods to meet the demanding new standards.



Top: 3D Systems' SLA-250 rapid prototyping system. Bottom: The SLA-500 gives high-throughput part building capability.

Tell Us What You Think... If you found this article of interest and/or useful, please circle Reader Service **Number A-122.**

Nancy Bartels
is Gear Technology*'s senior editor.*

New Names and Faces

Huddersfield, U.K.—**David Brown Group, PLC**, has announced the acquisition of the gear businesses remaining in David Brown family ownership. The companies are **David Brown, Australia, David Brown, South Africa, David Brown, Zimbabwe** and **Bostock & Bramley, U.K.** David Brown Group management says the reuniting of this group of complementary businesses will net several advantages, including the expansion of the Group's manufacturing capabilities and capacity, the broadening of the acquired companies' activities to take advantage of David Brown Group product developments, and the maximization of the David Brown name and reputation for engineering excellence.

Waterloo, IA—**Advance Heat Treat** announced plans to open a new 12,000 sq. ft. facility in Monroe, MI, which is expected to employ 25 people. The new facility offers five ion nitriding vessels to treat workpieces up to 160" in diameter and 360" in length, induction and duplex hardening capabilities, a 10- and 25-ton lifting capacity and a complete metallurgical lab. Also included in the $2.4 million facility is a synthetic media blasting system for steel, fiberglass, aluminum and polyurethane.

The facility is expected to operate 24 hours a day, seven days a week.

South Bend, IN—**Ingersoll-Rand Co.** has reached agreement to buy its competitor, **Clark Equipment Co.**, for $1.5 billion. Ingersoll's original offer was rebuffed by Clark, but the sweetened terms of the announced deal won the unanimous approval of both companies' boards.

Providence, RI—**Madison Cutting Tools, Inc.** has moved to an expanded production facility in Pawtucket, RI. The new facility offers 34,000 sq. ft. of manufacturing floor space. The company's mailing address, phone and fax numbers remain the same.

Avon, MN—**Columbia Gear Corporation**, a custom gearing design and manufacturing company, has achieved ISO-9002 certification for its manufacturing and assembly operations. The company, a subsidiary of Vesper Corporation, was audited by Det Norske Veritas (DNV), an independent auditing firm. Columbia is a supplier of custom spur and helical gearing and related services.

Promotions . . . Rodney W. Howard has been named sales engineering manager and limited partner with William C. Perrin, president of **Perrin Precision Tool, Inc.**, Denver, NC . . . **Master Chemical Corporation** of Perrysburg, OH, has named **Paul E. Laura** operations manager responsible for the company's domestic and European fluids division . . . **Wayne H. Gross** has been named managing director of the **International Gas Turbine Institute of ASME International**, where he will oversee and help develop a wide range of technical and continuing education programs, expositions and conferences in support of gas turbine technology.

INFAC REPORTS ON RECENT HOBBING AND HEAT TREATING EXPERIMENTS

Chicago—Results of recent studies on residual stress in gear hobbing, hobbing without lubricants and heat treating were reported by representatives of INFAC (Instrumented Factory for Gears) at an industry briefing in March of this year.

The results of four experiments on residual stress in gear hobbing indicated the following: conventional hobbing generates lower residual stress than climb hobbing; lower speed/feed means lower residual stresses; stresses in the roots of the gear teeth are generally higher than those in the flanks; and the leading side of the gear tooth flank always has higher stress than the trailing side of the gear tooth flank.

Dry hobbing studies involving residual stress depth profile analysis showed that the profile was independent of speed, but dependent upon feed rate and hardness of the materials.

Heat treating is another important research subject at INFAC. A major statistically designed experiment determined the effects on part quality of the heating cycle, the carbon diffusion cycle, the location of parts within the carburization furnace and of incoming residual stress in parts after carburizing. Results showed an unexpected trend toward less distortion in index and runout for parts with higher incoming stresses. Other conclusions are that the ramp heating cycle produced less error in index and runout in gears after carburizing; the boost heating cycle caused slightly higher tensile residual stresses in the carburized areas; and the furnace location had no effect on residual stresses, but did influence distortion.

In another, preliminary heat treating study, the possibility is being explored that dew probes may be used in place of oxygen probes for atmosphere control in carburizing furnaces.

Another important focus for INFAC has been the use of alternative processing methods to reduce pollution. In an experiment using paints and non-cyanide based plating for selective hardening, several alternative stop-off methods performed well enough for aerospace applications.

In another experiment, the Barkhausen Effect, a magnetic effect, was studied for possible use in gear manufacturing inspection, especially case depth measurement and grinding burns detection. Results indicated that it may have use in case depth measurement, but testing still needs to be done in the detection of grinding burns.

For more information about these experiments, circle Reader Service Number A-102.

Tell Us What You Think... If you found this article of interest and/or useful, please circle Reader Service **Number A-103.**

How to Avoid Errors When Measuring Step Gears

Think of a cookie cutter and a broomstick...

Heinz Röhr

There are problems in dimensional measurement that should be simple to solve with standard measuring procedures, but aren't. In such cases, using accepted practices may result in errors of hundreds of microns without any warning that something is wrong.

One such problem is the accurate measurement of the dimensions of the three-dimensional track, or the motion surface, around a cylindrical cam, or step gear (Fig. 1). Step gears are used to index a number of different devices such as tool changers, transfer line mechanisms and parts handling systems—virtually any apparatus that must accurately locate workpieces or tools for subsequent operations.

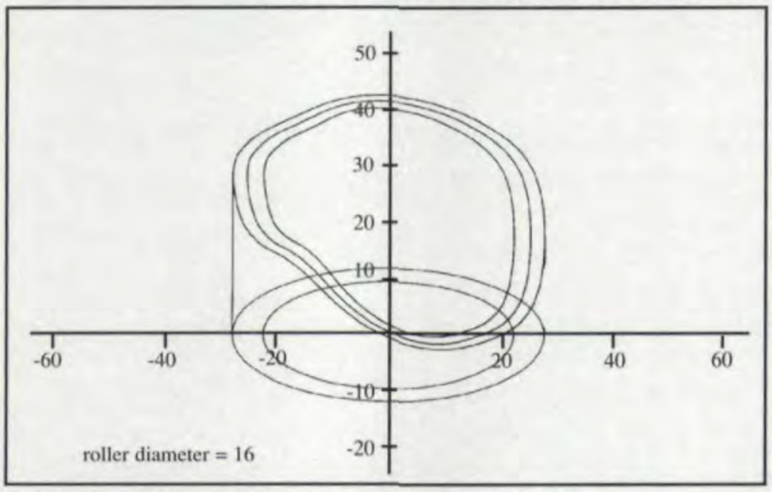


Fig. 1 — Three-dimensional track or cylindrical motion surface.

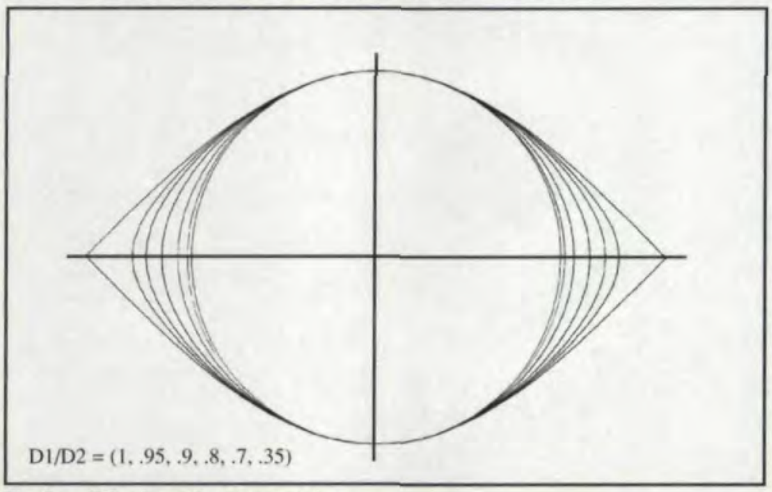


Fig. 2 — Effective roller cross section.

The three-dimensional track forces a cylindrical roller to move parallel to the axis of the cylinder. The relationship between the track and the roller is critical to the operation of the step gear. The challenge is to correctly measure the dimensions of the track with a coordinate measuring machine to determine the axis position of the roller as it moves on the track around the circumference of the cylinder. The position of the roller axis is important since it determines where indexing will begin and end for each "stop."

The standard procedure to determine the position of the roller axis is to measure two parallel lines at the top and bottom of the track around the cylinder at a predefined distance from its axis. This circular measurement is "unwrapped," and a track radius correction is made to compensate for the radius of the roller in order to determine the roller's "center" position.

The error in this procedure is hidden in the roller radius correction. To find the error, it is important to understand the contact characteristics of the roller as it travels the length of the track.

Typically, the roller is tapered so that it fits snugly into the tapered open side of the track. As the track "rises" during the rotation of the cylinder, the curve of the track around the cylinder presents changing surface characteristics to the static surface of the roller. Due to the taper of the track, the slope increases on the inside of the track, causing the line of contact of the roller to shift off axis. When the track descends, the line of contact on the roller swings back past perfect alignment with the cylinder axis to the mirror image of what it was on the ascent curve. The point of contact between the track and roller scribes an oval rather than a perfect circle.

Traditionally, to find the contact point of the roller/surface at a specific radius from the center of the cylinder, the roller and track would be mated and then "cut" with a phantom coaxial cylinder having a diameter sufficient to intersect the roller at that specific radius from the center. This results in two plotted curves on the coaxial cylinder which may be "unwrapped" into a plane. One is a line created by the circumference of the coaxial cylinder, which traces the full path of the track. The second is a point on the axis of the roller where the coaxial cylinder cuts through the cylindrical roller.

The oval shape of the unwrapped, curved intersection plane of the roller is determined by the proportion of the roller and cutting diameters (Fig. 2). As an example, if a broomstick is cut with a circular cookie cutter, the cut end may appear to be a perfect circle. Because the cookie cutter is round, however, it creates an arc-shaped cut through the broom handle which will appear ovoid when viewed off-axis. The shape of the oval depends on the size of the broom handle and/or the size of the cookie cutter. In the case of a step gear, the contact points on both unwrapped curves represent the contact characteristics of the roller on the track at a specific radius. The center point on the oval represents the roller axis.

When using a coordinate measuring machine to find the roller axis position for all measured points along the track, follow standard procedures to create an unwrapped plane using the phantom coaxial cylinder approach. The resulting oval's orientation on that plane must then be mathematically determined. The path of the axis center point on the oval, not a circular cross section of the roller, gives the true position of the roller axis.

The difference in resultant accuracy between using the ovoid shape of the roller and the circular shape of the roller averages 200 microns. Slope characteristics as well as the relative diameters of the coaxial cylinder (the cookie cutter) and the roller (the broom handle) will affect the total error. Maximum discrepancies will appear at the area of maximum slope and at the inner diameter of the motion surface (Fig. 3).

Between the inner and outer radius of the track, the "oval effect" is different. Larger deviations belong to the inner radius where measurements are rarely carried out because of the limitations imposed by the radius of the CMM probe. Conversely, measurements are not carried out at the outside edge because of varying chamfer, which only adds to the problem. The rotating roller may contact the track only at or near one edge. This lack of full length support caused by faulty manufacturing procedures results in high surface pressure and possible catastrophic part failure.

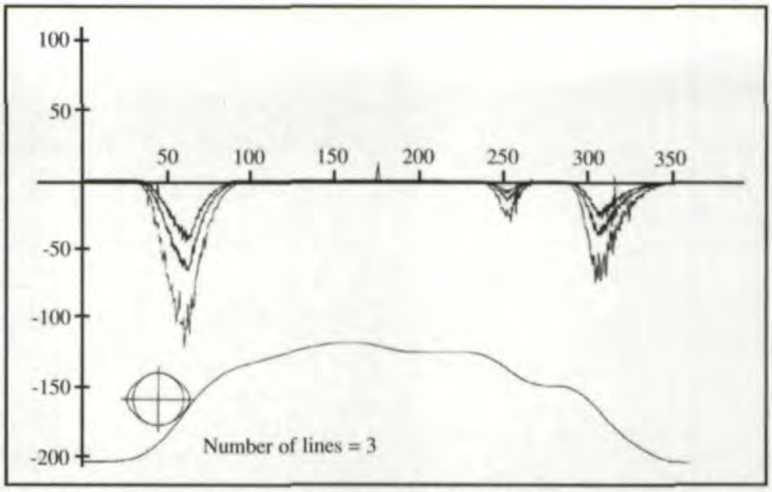


Fig. 3 — Difference between exact solution and simplification.

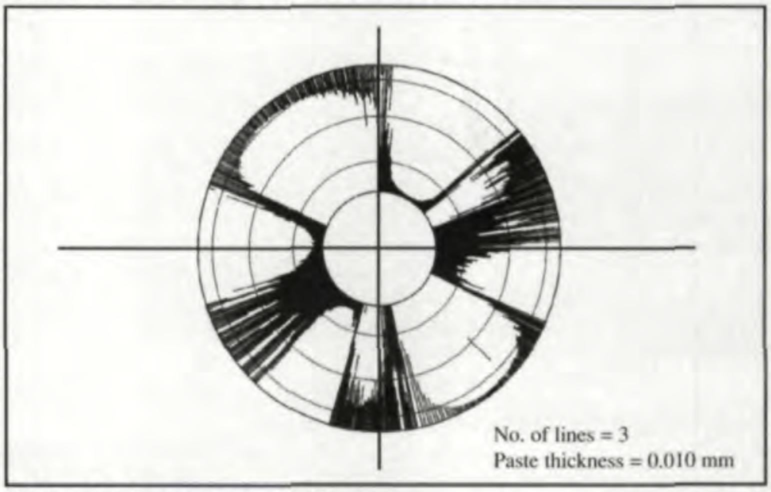


Fig. 4 — Bearing pattern for cylinder curve.

The mathematical relationship between the track and the roller is a complex one. The advantage of using a CMM in this type of measurement is that it can express that complex relationship in terms of *X*, *Y*, and *Z* coordinates, which makes the measurement easier to perform. Special software packages such as the STEPGR option for QUINDOS® metrology software from Leitz take the problems out of step gear measurement, making the radius correction automatically and assuring the correct calculation of the roller position. A bearing pattern can also be generated using this software package if more than one line is measured (Fig. 4). The bearing pattern shows the distribution of areas with high pressure as well as a displacement of the whole shape. ○

For more information about Leitz or Brown Sharpe, please circle the Reader Servivce Number A-123.

Tell Us What You Think... If you found this article of interest and/or useful, please circle Reader Service **Number A-124.**

Heinz Röhr
is with Leitz Messtechnik GmbHA, a Brown & Sharpe Company.

New Concepts in CNC Gear Shaping

When is a gear shaper not a gear shaper?

Klaus Felten
Michael Johnston

In today's economy, when purchasing a new state-of-the-art gear shaper means a significant capital investment, common sense alone dictates that you develop strategies to get the most for your money. One of the best ways to do this is to take advantage of the sophistication of the machine to make it more than just a single-purpose tool.

With the right machine adjustments, cutting tools and auxiliary attachments, a modern gear shaper can produce a variety of parts beyond a simple circular gear. It can make variants of square external profiles, splines, spur couplings with straight-sided teeth, face gears with non-parallel axes, sector steering gears and racks, parts for hydraulic motors and pumps and elliptical gears. It can also perform more than one operation in a single setup.

Following are six examples of the kinds of applications a modern gear shaper can do.

External Gear Machined in One Setup

The task is to machine an external gear with face width bigger than the stroking length of a given machine and specific runout conditions. This is done with a gear shaper with a sliding cutter head and special SSM software.

Requirements

- Cutter head slide machine with high accuracy
- Special back-off cam
- Special software
- Dialogue programming
- Special cutter holder

Possible Applications

- Production of extended stroking length
- Shaping parts with limited runout, dependent on pre-set stroking length
- Shaping of parts without runout
- Optimizing shaping conditions

Machine Data

- According to customer requirements

Conveyor Units (Gate Parts)

Pump Gear for Conveying of Granulates

The task here is to shape all outer contours; no teeth. The required surface finish is Rz = 16μm = 400 μinch (finish shaping).

The Specific CNC Programs Used

- Main Program: Positioning data and signals for tool changer
  Cutting data with number of cuts
  Stroking speed and radial infeed
- Sub-Program: Track data, turning direction

Machine Data

- Two-cut operation (roughing/finishing)
- Cutting speed – 25 m/min
- Total cycle time – 113 min
- Peripheral length – 800 mm

Cutting Tool

Two disc-type cutters, ASP 60 (different diameter, positioned on one cutter holder), one for concave and one for the convex section.

Hydromotor

The task is shaping of internal and external non-circular gears. Three major steps are necessary to produce the a.m. components.

1. Calculation of the generating curves
2. Calculation of the geometry of the gear
3. Calculation according to the collision diagram

Machine Requirements

- Highly precise rotation axes C and D
- Highly precise X-axis with extremely low backlash for forward and backward movement
- High-speed CNC control and dialogue programming as well as software for manufacturing non-circular gears

The complex geometry of the internal involute gear requires that the cutting tool will be mounted eccentrically and that a special back-off cam is available.

Pedal Arm for Bicycle Polygon Internal Profile

The task here is to cut a tapered internal square.

Machine Data

- Special back-off cam for taper cutting
- Face Width: 14.5 mm
- Number of Cuts: 2
- Feed Method: Generating
- Cycle Time: 1.05 min

Cutting Tool

- Shank-type cutter, polygon, TiN-coated

Dr. Klaus Felten
is director of research and development for Liebherr/Lorenz, Ettlingen, Germany.

Michael Johnston
is product manager for Liebherr America, Saline, MI.

Steering Segment and Steering Rack

The task is to shape a steering gear with three teeth. The thickness of the center tooth is different and will be varied by moving the X-axis during shaping. A steering rack with two teeth (three spaces) must also be shaped.

Machine Data

- Number of cuts – 2-3
- Feed method – Plunging without generating motion
- Machining method – Generating of axes C and D and interpolation of X-axis
- Cycle time –
  1. Steering segment – 0.7 min., column inclination for taper cutting 4", special back-off cam for the steering segment
  2. Steering rack – 1.5 min

Cutting Tool

1. Disc-type cutter with segments, 36/12 teeth for the steering rack
2. Disc-type cutter with 35 teeth for the steering segment (shaft)

Both made of ASP 30 material + TiN.

Variable Valve Timing Unit

The task is to cut the cam shaft part. This involves finish-shaping of two position-oriented helical gears, each with a block tooth, in one setup. The complete unit consists of three parts:

1. *The Chain Wheel*
   internal helical gear* — shaped
   chain wheel for sprocket chain — hobbed

2. *Shaft Cam*
   internal* and external* gear — shaped (see picture)

3. *Flange Case*
   external* gear

* Each of these gears had a block tooth and was shaped with the same cutter.

Number of Teeth

- Internal – 20, external – 29

Machine Data

- Number of cuts – 2
- Feed method – plunging without generating motion
- Cycle time – 3.35 min

Cutting Tool

- Solid wafer, ASP 30 + TiN, 14 teeth

Positioning of the cutter and the size of the gears are controlled and monitored by the machine by an electronic measurement device via tool data stored in the cutter adapter (E-Prom).

For more information about Liebherr's products and services mentioned in this article, please circle Reader Service Number A-125.

Tell Us What You Think... If you found this article of interest and/or useful, please circle Reader Service **Number A-126.**

ADVERTISER INDEX

For more information about a product or service advertised in this issue of *Gear Technology*, circle the appropriate number on the Reader Response Card and put the card in the mail, or fax it to 708-437-6618.

Advertiser	Reader Service No.	Page No.	Advertiser	Reader Service No.	Page No.
A/W Systems, Inc.	11	11	M & M Precision Systems, Master Gears/Spline Gages Div.	21	44
American Gear Manufacturers Association	14	38	M & M Precision Systems	5	2
American Metal Treating Company	44	47	Midwest Gear	17	41
American Pfauter, L.P.	1	1	Niagara Gear	9	8
American Sykes Co.	3	4	Parker Industries, Inc.	47,16	18,40
Basic Incorporated Group	12	25	Pfauter-Maag Cutting Tools, L.P.	2,41	IFC,47
Bourn & Koch Machine Tool Co.	38	41	Pro-Gear Company, Inc.	40	47
Diagrind	23	44	Process Industries, Inc.	48,20	18,44
Diamond Black Technologies, Inc.	10	10	Roto-Technology	42	47
Fairlane Gear, Inc.	13	38	Russell, Holbrook & Henderson	39	46
Forest City Gear	46	IBC	Simon International	22	44
Gleason Works	6	BC	Software Engineering Service	43	47
GMI	7	6	Starcut Sales, Inc.	37	19
Höfler		37	Wendt Dunnington	4	4
ITW Heartland	15	40	Winter, Ernst & Son	19	43
Liebherr	8	5			

A Basic Guide to Deburring and Chamfering Gears

Choose the right tools and techniques for the best, most cost-effective results.

Bruce Horst

In today's industrial marketplace, deburring and chamfering are no longer just a matter of cosmetics. The faster speeds at which transmissions run today demand that gear teeth mesh as smoothly and accurately as possible to prevent premature failure. The demand for quieter gears also requires tighter tolerances. New heat treating practices and other secondary gear operations have placed their own sets of demands on manufacturers. Companies that can deburr or chamfer to these newer, more stringent specifications—and still keep costs in line—find themselves with a leg up on their competition.

Wheels or Brushes?

The choice of grinding wheels or power brushes for deburring depends on a number of factors: the type of gear, the material used, the part print requirements, the gear configuration and the customer's specifications, tooling costs and production requirements. In general we prefer to use brushes for deburring because:

1. They create less grit and dust and cause fewer cleanup problems than grinding wheels.
2. They normally give better tool life.
3. They do not require a precision setup.

However, keep in mind that while a power brush can deburr and provide a radius on the tooth, it cannot cut a chamfer. If specs call for a specific chamfer, a grinding wheel must be used.

Fig. 1 — Deburring a helical pinion gear with power brushes.

The particular material of the gear in question also plays an important role in choosing a wheel or a brush. Certain materials, such as plastic or nylon, are "gummy," that is, quite soft. If burrs are removed from such material by grinding, the process often simply rolls the burr into the tooth flank. The grinding wheel also has a tendency to load up, significantly shortening its usable life. Such materials are prime candidates for brush deburring, as are "green" gears.

Which Brush Should You Use?

When selecting the proper brush for a particular application, first keep in mind the type of gear tooth to be deburred. The type of gear will determine how to set up the brush. The severity of the burr will determine the type of brush to use. In general, the more severe the burr, the more aggressive the brush should be. Fig. 1 illustrates a helical pinion with a straight spline on one end. In this case, two standard three-inch-diameter wire brushes attack the gear from different directions, eliminating all burrs in that area. Fig. 2 illustrates a spur gear with a three-inch, nylon-impregnated, 180-grit brush following a grinding wheel. The brush is positioned on top of the gear teeth in such a way as to perform an action similar to surface grinding, which allows both sides of the gear tooth profile to be worked.

Choosing the Right Grinding Wheel

The diametral pitch must be considered when selecting the proper grinding wheel. The wheel must be as wide as possible, but less than the width of the gear tooth root. If it is not, the grinding wheel will ride down the gear tooth flank and begin grinding the adjacent tooth flank, missing the tooth root. Use the finest grit possible, given the particular gear being ground. This will give the best grinding wheel life.

How smoothly the grinding wheel enters the gear teeth also affects grinding wheel life. The size of the chamfer required can be controlled by grinding wheel grit size, speed of the work spindle and air balance control. An increase in tool life can be expected on wet grinding applications.

Helpful Gear Deburring Hints

The closeness of the hub diameter of the tool to the gear tooth root diameter has always been a problem in gear grinding. The hub diameter tends to interfere with the grinding wheel before it reaches the gear tooth root diameter because the grinding wheel will hit the hub first and not grind the root diameter. This causes an interrupted, unacceptable chamfer.

Using power brushes can solve this problem. Brushes will remove most burrs, but, as stated before, they will not provide a chamfer. Brushes do, however, provide a radius, which offers additional strength to the gear teeth. The brush is positioned to miss the hub diameter and deburr the entire gear tooth profile.

If hub interference is a problem, and a chamfer is absolutely necessary, the only alternative is to use single gear tooth flank deburring. This is a much slower, significantly more expensive process. You will probably want to consult with your deburring supplier before proceeding.

When deburring with brushes, the brush should reverse rotation on the gear teeth whenever possible to ensure that both sides of the tooth have been worked. This not only provides a uniform corner break, but also keeps the brush ends sharp. Using a light spray on brushes offers an increase in brush life and working ability.

In some cases, brushing is integrated into the grinding process. This is sometimes necessary when grinding green gears. Green gears tend to roll the burr when grinding, and adding a brush station eliminates any feather edges left. In this method, both the grinding wheel and the brush work at the same time.

Exit Burrs

Excessive shaper or hob cutter exit burrs on gear teeth are another perennial problem. As the cutting tool gets dull, the number of exit burrs increases. A simple rule is, if the burr cannot be flicked off with a fingernail, the grinding wheel or power brush will have difficulty providing a uniform chamfer or radius. The reason is, the wheel or brush will tend to follow this excess material. A simple skive unit eliminates this problem without much additional cycle time. The skive unit uses power brushes, grinding wheels or high-speed cutters. The skive unit removes the excessive burr, and the brush or grinding wheel provides the uniform radius or chamfer. (See Fig. 3.)

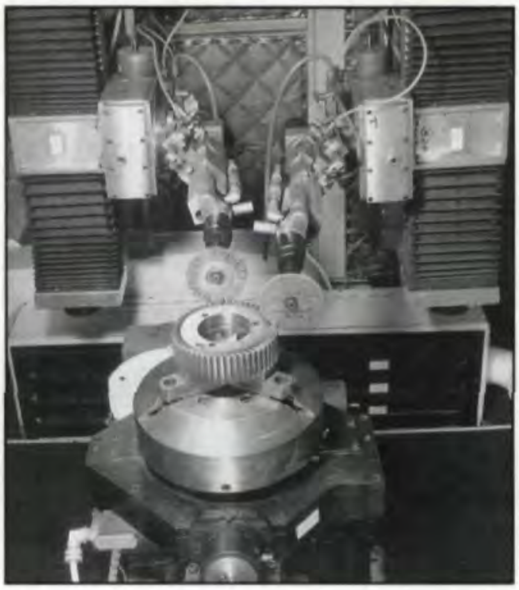


Fig. 2 — Deburring a spur gear with a brush followed by a grinding wheel.

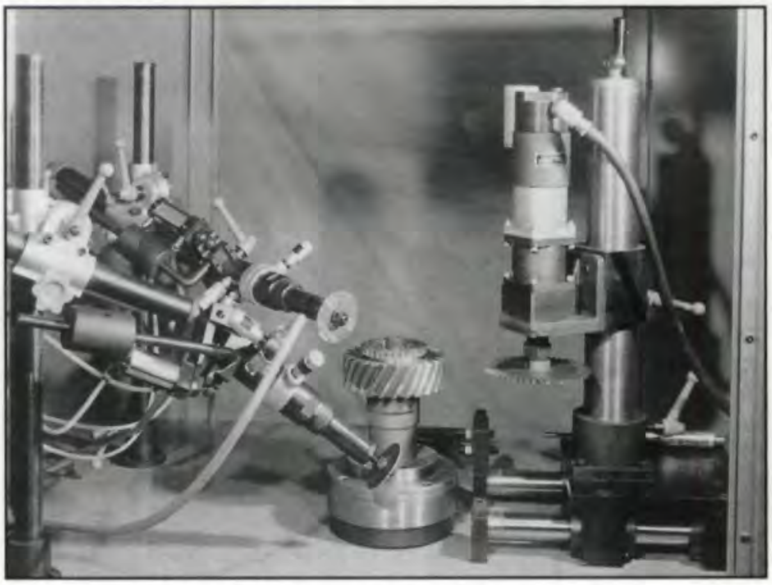


Fig. 3 — Removing exit burrs with a skiving unit and a grinding wheel.

The process works like this: The workstation with the skive unit is started first. After the skived area rotates at least 45°, another workstation with either a grinding wheel or a brush mounted on it begins to work the skived area. As many workstations as required are energized accordingly. Thus at some point in time all stations are working simultaneously, cutting down on the overall cycle time.

Deburring Spur Gears

When using a grinding wheel on external spur gears, the grinding wheel approach angle is normally 45°. Using the selector switch, the machine is placed in the manual mode so the machine will not run during setup. Then, the grinding head is adjusted to the 45° approach angle as shown in Fig. 4.

The grinding head pivot assembly should be positioned at a 45° angle, with the grinding wheel point of contact angle also at 45°. If this is not done, the chamfer will change on the gear teeth as the grinding wheel wears down. By following the prop-

Bruce Horst
is president/CEO of Redin Corporation, Rockford, IL.

er positioning, grinding wheel life will drastically improve and chamfer consistency will also improve.

Align the grinding wheel to the center of the gear (see Fig. 5). The grinding wheel can be operated from either the right- or left-hand side of the gear. Remember that the gear rotation must be away from the grinding wheel. In some cases, positioning the grinding heads will allow deburring of both sides of the gear simultaneously while rotating 180°. This will increase production.

Extreme concentricity of the gear is not required,

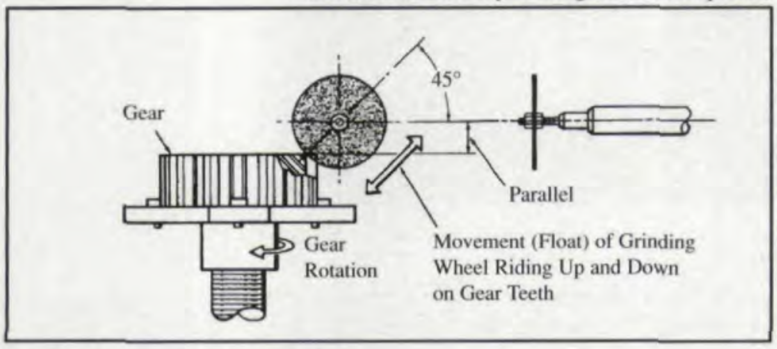


Fig. 4 — Alignment of grinding wheel.

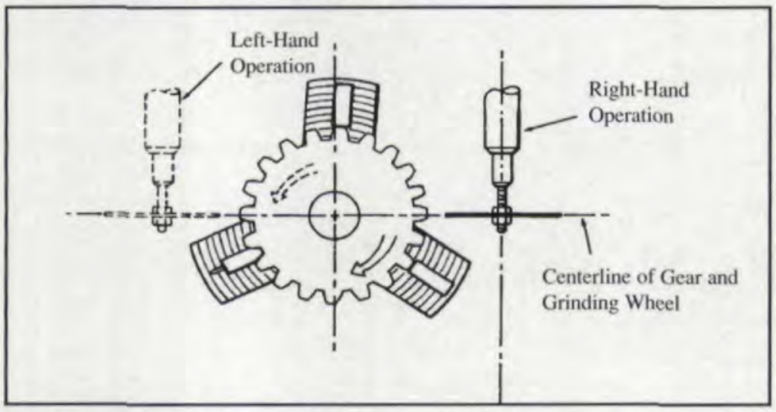


Fig. 5 — Aligning the grinding wheel to the center of the gear.

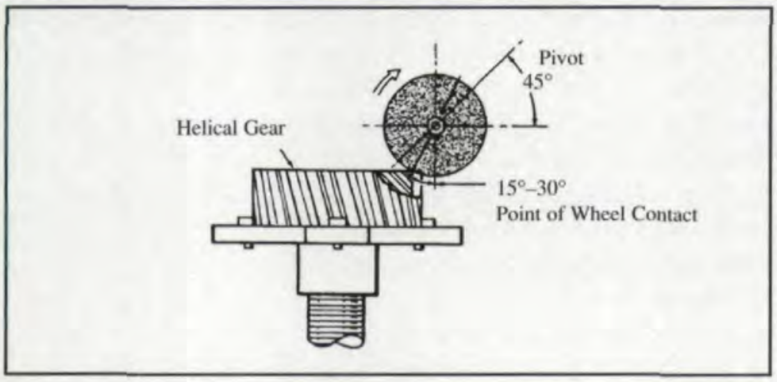


Fig. 6 — Helical gear wheel contact.

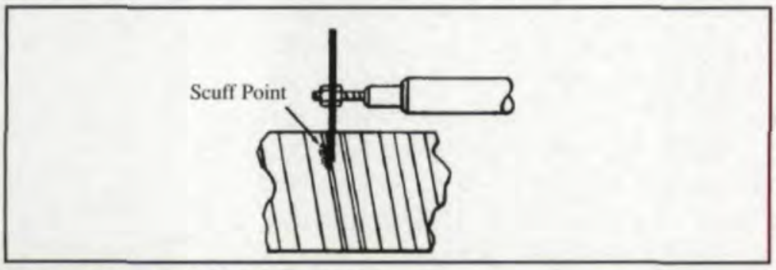


Fig. 7 — Example of wheel set too deeply.

because the grinding or brushing head "floats." The head assembly is mounted on a fulcrum, and a column of air provides the counterweight.

After the valve is energized and the grinding or brushing head enters the workpiece, the air pressure is reduced. This allows freedom of the head. The head can be easily lifted by hand, depending on the amount of air still supplied (normally 25 psi). In this way anything rotated under the head raises or lowers the unit. So up to a certain range, the floating head follows whatever profile is under it. For additional ranges, we've added special cams. These cams are integrated into the grinding or brushing heads, allowing irregularly shaped parts to be deburred.

Deburring Helical Gears

Helical gears up to a maximum helix angle of approximately 30° can be deburred. A rather flat chamfer can be expected. Setup for these models is similar to that for spur gears. The point of contact of the wheel on helical gears must be reduced to prevent scuffing one side of the gear flank (see Figs. 6–7).

When grinding helical gears, the grinding wheel angle must match the helix angle of the gear tooth being chamfered (see Fig. 8). If the angle is too flat, the grinding wheel will ride over the top of the gear tooth and will not properly chamfer the corner of the gear tooth flank. If the grinding wheel angle is too steep, it will drop off the gear tooth and scuff the adjacent gear tooth flank. The rotation of the gear must be such that the wheel grinds up the acute angle and down the obtuse angle. This procedure will produce a uniform gear tooth chamfer. The proper procedure used to top- and bottom-grind a helical gear simultaneously is to reverse the direction of the work spindle. This can be completed in one automatic cycle. If the gear teeth specifications are not stringent, both top and bottom grinding can be accomplished simultaneously, increasing gear production. If customer specs allow it, power brushes can be used.

Deburring Spiral Bevel Gears

The alignment of the grinding wheel to spiral bevel gears is similar to other gears with the following exceptions:

- Instead of aligning the grinding wheel with the centerline of the gear, it should be positioned on the gear tooth root that is closest to being parallel to the grinding wheel (see Fig. 9, View A).
- The pivot angle "Z" should be approximately 15° from the gear face being chamfered (see Fig. 9, View B).

On spiral bevel gears, both the heel and toe can be deburred simultaneously using two grinding heads (see Fig. 9, View C).

Deburring Straight Bevel Gears

The alignment of the grinding wheel for deburring straight bevel gears is similar to that of external spur gears (see Fig. 10).

Deburring Square Slots or Splines

Deburring square slots and splines, (either I.D. or O.D.) can be accomplished as illustrated in Fig. 11. With the grinding wheel positioned behind the centerline, one side of the slot and half of the root is deburred, and with another grinding wheel positioned ahead of the centerline, the other side of the slot and the other half of the root is deburred. This operation can be accomplished simultaneously.

The Cell Concept & Deburring

Deburring fits nicely into operations where manufacturing cells are popular. Careful planning can eliminate entire operations, saving both time and money. We recently eliminated a customer's wash station by integrating the cleaning process with the gear deburring, thus reducing production times. Using a wet machine will also drastically increase grinding wheel tool life.

In another case, we are working with a customer to integrate a deburring machine into his present work cell, which manufactures splined pinion gears. Doing so will eliminate the need to handle the parts and move them to a separate deburring station. The longest cycle time in the cell is three minutes. The cycle time of our deburring machine is two minutes, thereby giving the customer "free" deburring.

Sample Gear Deburring

Customer sample gear deburring tests prior to machine quotations are a good idea. They allow us to present the customer with all the information he or she needs to make informed decisions. A computer printout showing tooling used, expected tool life, cycle time, etc., is returned with the samples. This procedure eliminates unnecessary problems that may occur during a machine runoff. Choosing the proper machinery for quality, long life, versatility, ease of changeover, room for expansion at a reasonable price is our goal.

This kind of cooperative effort between customers and suppliers can make deburring operations efficient, accurate and cost-effective, all necessary ingredients for success in today's demanding gear production market. ⭘

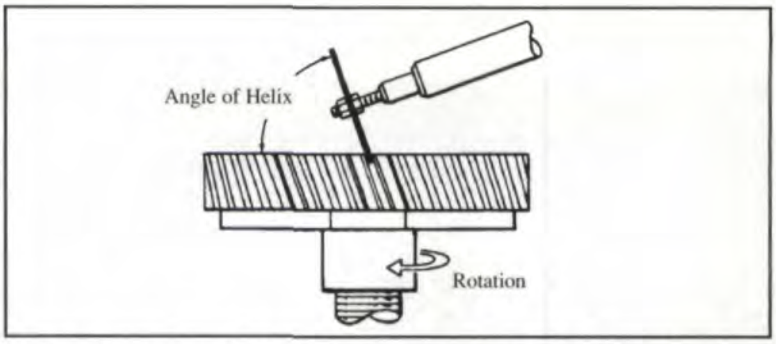


Fig. 8 — The grinding wheel angle must match the helix angle of the gear tooth.

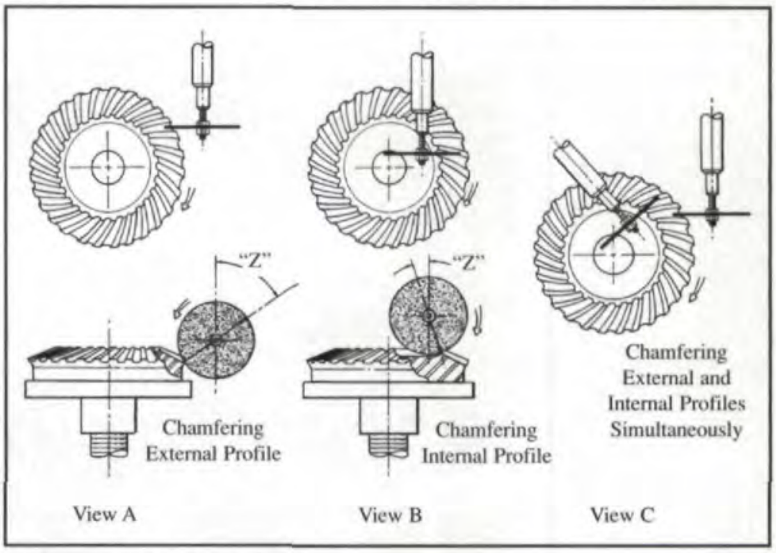


Fig. 9 — Spiral bevel gear setup.

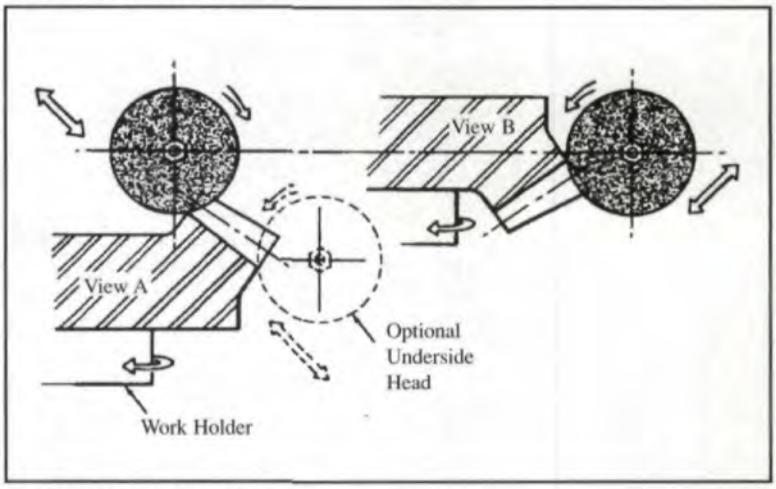


Fig. 10 — Straight bevel gear setup.

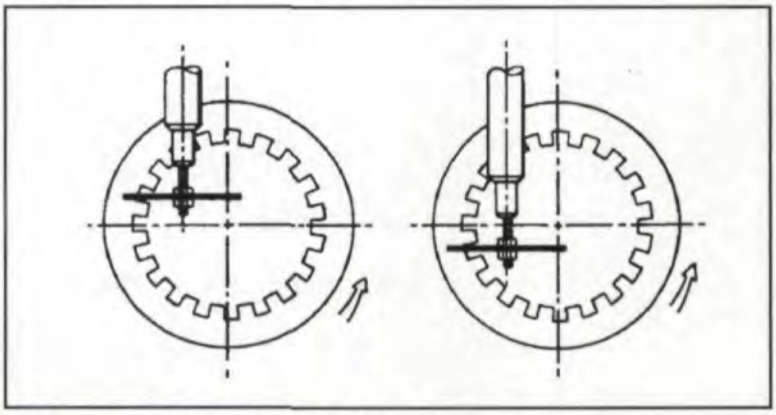


Fig. 11 — Setup for deburring square slots or splines.

Hotter, Faster, Harder Cutting

Whisker-reinforced ceramic inserts perform even under hostile conditions.

Keith H. Smith

Fig. 1 — A selection of popular ceramic inserts including composite and whisker-reinforced materials.

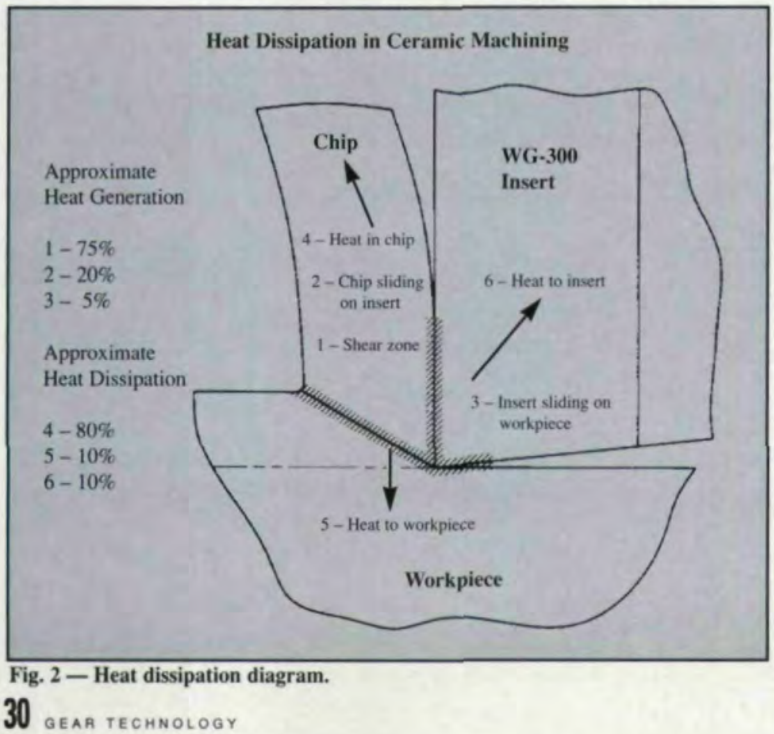


Fig. 2 — Heat dissipation diagram.

What Is Whisker-Reinforced Ceramic?

Whisker-reinforced ceramic as applied to cutting tool inserts comprises a matrix of aluminum oxide into which approximately 50% by volume of high-purity silicon carbide "whiskers" are randomly dispersed. The "whiskers" are, in fact, single crystals having dimensions of approximately 0.6 microns in diameter x 10–80 microns in length. These "whiskers" have a tensile strength on the order of 1,000,000 psi (690 MPa). The composite material that is the best known and most widely applied using this technology is designated WG-300 and manufactured by the Greenleaf Corporation of Saegertown, PA.

When reinforced with silicon carbide whiskers, the aluminum-oxide-based composite exhibits a number of highly desirable properties not found in any other material; namely, very high hot hardness (as high as 1400°C has been measured), exceptional resistance to thermal shock, high abrasion wear resistance, excellent resistance to mechanical shock, chemical inertness and high hardness (94.5 Ra). These properties enable cutting tools to perform reliably and repeatedly in what are regarded as very hostile situations.

For example, nickel-base alloys such as Inconel can be readily machined at speeds as high as 2,000 S.F.M., which is 8 to 10 times the highest speed achieved with tungsten carbide tools. Hardened materials up to 62 Rc can be machined, often as a substitute for grinding. It has been shown that in bearing surface applications, a machined surface will often outwear a ground surface. This is probably due to the elimination of abrasive particles on the surface of the parts.

In the gear industry, there are applications in the facing of hardened gears where the cutting tool is required to pass across the intermittent surface of the gear teeth. Provided that speed is maintained and the feed rate kept within reasonable boundaries, this type of operation can be achieved with a very high rate of reliability, often at speeds as high as 300 to 500 S.F.M.

Whisker-reinforced ceramics owe their performance very largely to their ability to withstand very high cutting temperatures without sacrificing strength and hardness. Cutting tools are, therefore, programmed to achieve a temperature of approximately 1200°C ahead of the tool in the shear zone. In this way, the velocity of the tool generates sufficient heat to plasticize the material immediately ahead of it, facilitating its removal. Therefore, whisker-reinforced ceramics cannot be used to form gear teeth because the short interrupted cuts required for that process will not generate the required heat.

In the hardness range of 43–62 Rc, in continuous engagement operating in turning, boring and grooving, whiskered ceramics offer an alternative technique that can dramatically reduce floor-to-floor times and increase quality and profitability.

A nomogram has been developed that will indicate the approximate surface speed needed to generate the desirable 1000–1200°C temperature ahead of the tool at a given hardness. If speeds *lower* than the recommended speed are mandated, then a corresponding decrease in feed rate from the recommended will be necessary to maintain the required heat.

To use the nomogram, go to the centered horizontal bar and locate the material hardness. Go directly vertically to the upper curve to find the starting speed and then vertically to the lower curve to find a starting feed rate.

In addition to whisker-reinforced ceramics, there are other materials available in the ceramic family that will perform very well on hard ferrous materials. One of these is a material designated GEM-6, which is a composite of titanium carbide and aluminum oxide with special additives. While lower in strength than WG-300 whiskered materials, GEM-6 is extremely wear-resistant and lower in cost and can be expected to perform well in interrupted operations.

It should be mentioned that coolants are recommended for use with whiskered materials because of extreme resistance to thermal shock, whereas the opposite can be said about composite inserts, which are mostly run dry.

The same starting speeds and feeds chart can be used for composite materials. ⭘

For more information about Greenleaf Corporation, please circle Reader Service No. A-129.

Tell Us What You Think... If you found this article of interest and/or useful, please circle Reader Service **Number A-130.**

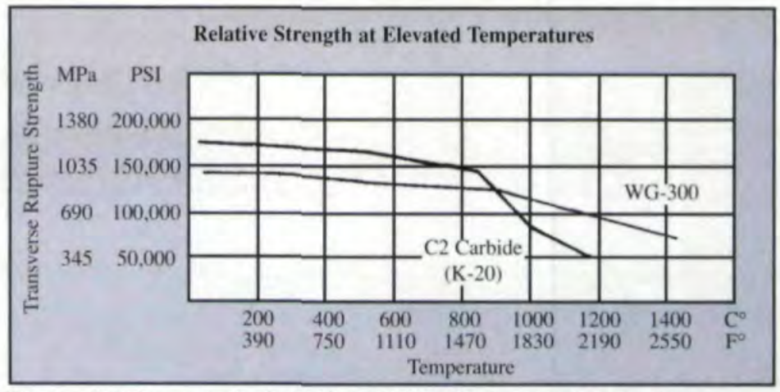


Fig. 3 — Relative strength of carbides and WG-300 at elevated temperatures.

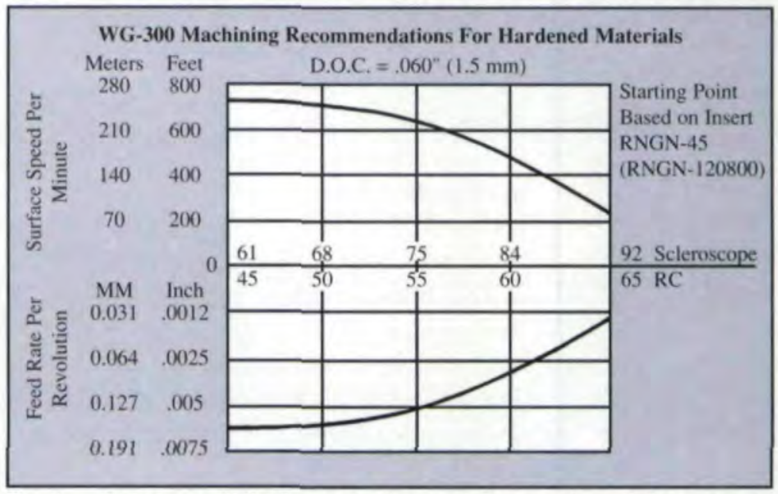


Fig. 4 — Nomogram indicating approximate surface speed needed to generate 1000°–1200°C at a given hardness.

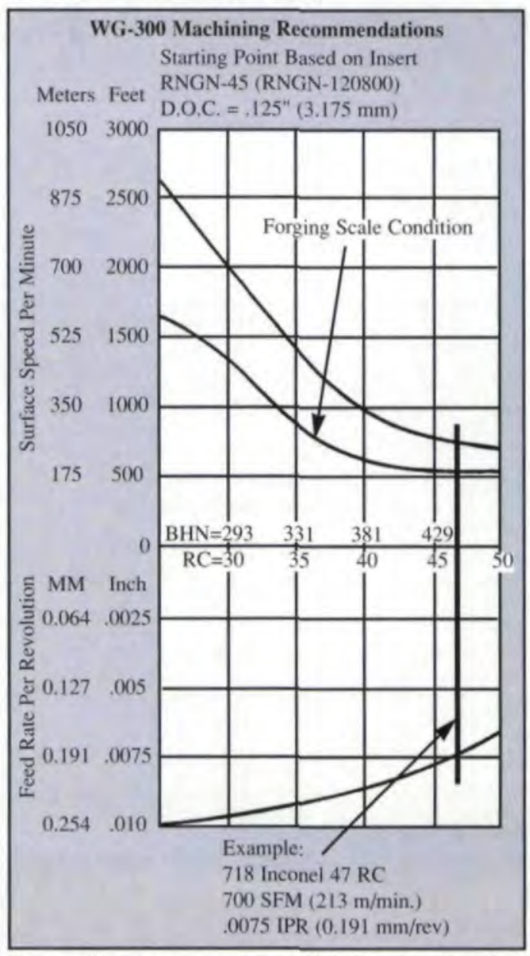


Fig. 5 — Sample nomogram for nickel alloy aircraft engines.

Keith H. Smith

is manager of international sales at Greenleaf Corporation, Saegertown, PA.

GEAR FUNDAMENTALS

Gear Grinding Comes of Age

What you need to know about wheels and abrasives now.

Phillip Plainte

In the quest for ever more exacting and compact commercial gears, precision abrasives are playing a key production role—a role that can shorten cycle time, reduce machining costs and meet growing market demand for such requirements as light weights, high loads, high speed and quiet operation. Used in conjunction with high-quality grinding machines, abrasives can deliver a level of accuracy unmatched by other manufacturing techniques, cost-effectively meeting AGMA gear quality levels in the 12 to 15 range. Thanks to advances in grinding and abrasive technology, machining has become one of the most viable means to grind fast, strong and quiet gears.

The Evolution of Grinding

Traditional gear grinding was a slow, expensive process that required complex machines and highly skilled operators, a process considered appropriate for only the closest-tolerance applications, such as aerospace. Engineers would develop performance-enhancing tooth geometry changes using prototype ground gears, then purchase tooling for shaving production. Now such changes are made on the gear grinder and do not require shaving tooling. Similarly, manufacturers now rough-hob gear blanks, heat treat them, then grind them to specification on new CNC or computer-controlled gear grinders. Shaving is no longer required for production either.

Benefits of Ground vs. Cut Gears

As an alternative to cut gear sets, ground gears offer many benefits. These include:

- Uniform profile on all teeth of a specific gear and on all gears of the same design;
- Increased load capacity;
- Higher quality (up to AGMA class 15); and
- Elimination of the need for matched sets.

Grinding corrects spacing errors caused by prior machining and heat treatment. This improves gear set strength by allowing greater overlap ratios and evenly distributed tooth-to-tooth loading. Root radius grinding also improves the bending strength of gear and pinion teeth.

Noise reduction is achieved through the improved overlap ratio and tooth contact control. Tooth flank curvature in both profile and lengthwise direction may be accurately controlled to produce the low gear set motion errors required for quiet operation.

While conventional cut/hardened/lapped gear sets are not interchangeable, grinding produces more consistent tooth geometry, introducing the possibility of interchangeable gear members of a given design.

Finishing Techniques

Gears can be finished before or after hardening. When finishing is done before, distortion caused by heat treatment reduces the accuracy of the part. Machining adjustments can compensate for some of the anticipated distortion, but heat treating variables make highly accurate adjustments hard to achieve.

Grinding Methods: Spur and Helical Gears

Spur and helical gears are ground by three basic methods: single index generation, continuous generation or form grinding.

With the index generating method, the disc-shaped grinding wheel generates a single tooth slot by feeding the wheel through the slot in a series of passes. Each pass is preceded by a small radial infeed. The wheel grinds a single flank on one tooth or both flanks of adjacent teeth, then indexes to the next tooth space.

Continuous generating uses a grinding wheel in the form of a threaded worm or hob. As in the single index procedure, the grinding wheel is fed in the direction of the axis of rotation of the gear for a number of passes.

During form grinding, a shaped abrasive wheel passes between two teeth, grinding the entire surface of the adjacent tooth flanks. The gear is then indexed to the next tooth space.

Form grinding and index generating grinding are suitable for producing batch quantities of gears with diametral pitches generally coarser than 3 or as fine as 15. The continuous involute generating method is appropriate for large volume production and jobbing of gears up to 3 diametral pitch.

New Methods for Bevel and Hypoid Gears

New CNC equipment has changed the way bevel gears are made as well, replacing the traditional cut/harden/lap approach with cut/harden/grind for Formate® gear sets. When straight cup grinding on the machine, gear or pinion slots are generated by a relative motion between the wheel and the workpiece. This motion causes the wheel to function as a single tooth of an imaginary generating gear that mates with the workpiece. When the wheel axis rotates about the cradle axis, the generating gear tooth rolls with the workpiece to produce the desired tooth flank surface.

Generating Grinding Machines for Spur and Helical Gears

Depending on the type of wheel used, generating grinding machines fall into three categories: threaded, saucer or conical. Threaded wheel machines—made by Reishauer and Gleason (the new Gleason TAG 400)—are fast, high-precision units designed to accommodate external spur or helical gears up to 30" in diameter with helix angles up to 45°. For helical gears, pitch and helix angle determine the maximum face width.

Threaded wheel grinders are capable of producing tooth profile, spacing and lead within .00020", with excellent surface finish. Though CBN wheels have been successfully used in some thread worm applications, good results can generally be achieved with a good grinding oil and a vitrified aluminum oxide wheel.

Maag manufactures saucer wheel grinders; Niles and Höfler machines are designed for extremely large gears. These types of machines are suitable for grinding external spur and helical gears. Depending on the model, capacities range up to 142" in diameter. The diametral pitch varies from 6 DP to 25 DP on the smallest machine and from 1 DP to 9 DP on the largest.

Saucer wheel grinding supports topological modification, a technique that allows for the machining of an infinite variety of tooth forms. The tradeoff, however, is a slower cycle time. With saucer-type grinding, wheels may be set parallel to each other or at an angle of up to 100°. Vitrified aluminum oxide wheels are most commonly used. Grinding is done without coolants or oils, and dressing, done through wheel compensation, is accomplished with single-point diamonds.

Conical grinders have not been manufactured in great numbers since World War II. Large numbers of them, however, are still being used in the USA. Made by Reishauer, Höfler, Niles, Liebherr, Pfauter-Kapp and Gleason, these machines are typically designed to grind only external spur and helical gears.

Form Grinding Machines for Spur and Helical Gears

Form grinders are manufactured by Kapp, Leibherr, Okamoto, Gleason, National Broach and Orion (USA). These machines grind external and internal spur and helical gears up to 36" in diameter, with diametral pitch capacities from 64 to 2.

More flexible than their generating counterparts, computer-controlled form grinders lessen the hazards of surface tempering and require less setup time. Limited only by the type of forms that can be ground on the wheel, they're also more accurate, carrying out exact repetitions of the selected optimum grinding cycle. Wheel truing, profiling and dressing—also software controlled—can be done with diamond disks, single-point diamonds or diamond preformed dressing rolls.

Form grinding is most cost-effective when wheel wear and downtime are minimized. If production volumes justify it, the best ways to achieve those ends include the use of diamond dressing rolls, no-wear/no-dress plated CBN wheels and creep-feed grinding processes, which reduce wheel wear.

Grinding Machines for Bevel and Hypoid Gears

Bevel and hypoid gear grinders use cup-shaped wheels. Straight wheels are used to generate pinion or gear members. The Gleason flared cup process may be used to finish Formate gears. The Phoenix grinder implements this motion

Fig. 1 — Seeded gel threaded and cup-type grinding wheels used for grinding final drive helical and hypoid bevel gears.

Phillip Plainte
is a product engineer with Norton Company, Worcester, MA.

with coordinated X-, Y-, Z-, B- and A-axis movements which are similar to generating motions.

Breakthrough Bonds and Abrasives

Though grinding equipment is expensive, advances in grinding wheel technology enable faster speeds and feeds, which shorten cycle time and reduce costs. Such advances include the development of CBN, Seeded Gel (SG®) and TARGA™ abrasive wheels.

Cubic Boron Nitride (CBN)

The hardness of CBN (4700 Knoop scale) is second only to diamond. Classified as a superabrasive, CBN wears more slowly than conventional abrasives. It also conducts heat away from the ground surface, reducing thermal damage.

In recent years, manufacturers of precision gears (AGMA classes 12 to 14) have adopted CBN finishing for military and aircraft applications.

Though the initial cost of CBN is much higher than that of conventional abrasives, CBN finishing has been found to cut production time, improve quality and reduce manufacturing costs by as much as 80%.

Seeded Gel (SG) Aluminum Oxide

SG abrasives are manufactured by a sintering process that results in abrasive grits consisting of thousands of submicron-size aluminum oxide crystals. During dressing or self-sharpening, the grains shed these very small particles. The results are higher sharpness and lower total wear than for conventional abrasives. Due to more uniform microstructure and increased chemical purity, SG is also harder (2100, Knoop scale) than conventional aluminum oxide.

Since SG grains fracture by shedding submicron particles, wear flats do not develop at the working surface of the grinding wheel. Instead, sharp, relieved cutting edges are produced. As a result, seeded gel abrasives are sharper than conventional aluminum oxide.

Because of the increased hardness and the structure of the SG grains, SG generally wears longer than conventional aluminum oxide. As small particles break away from the grain due to grinding forces, only small portions of the total grain volume are lost.

SG functions best when aggressive metal removal rates are required and/or where the wheel wear conditions are severe. SG may also be the best abrasive choice for hard-to-grind materials, such as Waspalloy or other stainless steel alloys typically used in aerospace applications.

The recommended abrasive for flared cup grinding on Gleason machines, SG may offer improved performance over conventional abrasives for generated pinions and gears as well.

In use, self-sharpening SG has been found to increase the number of parts ground between dressings and to reduce wheel dressing by up to 80%. When tested, SG wheels finished 40 automotive gears per dress vs. 12 gears with conventional aluminum oxide wheels.

TARGA Abrasives—
The Next Generation of SG

TG abrasives, which perform in a more focused environment, feature a grain that is processed into elongated shapes with an aspect ratio dependent on both the type of abrasive product and the grinding application. The shape of TARGA abrasives establishes slightly more porosity than is shown in the typical specifications, a fact even more evident in higher structure TARGA wheels.

TARGA users find lower power draw produces higher unit forces per grain in higher structure wheels. TARGA users will gain benefits from the grain shape which lends itself to naturally increased porosity. This porosity increases unit pressure on the grain, which yields lower power draw with the benefit of achieving near superabrasive results in applications of creep-feed grinding of aerospace alloys.

Like SG wheels, TARGA abrasives are considered an alternative to the more costly vitrified

Important Grinding Wheel Characteristics

Wheels are classified according to a standard marking system (see Fig.2) that specifies the following characteristics: abrasive type; grain or grit size; grade; structure; bond; wheel type; and bond type.

Manufacturers' abrasive type, the first element in the marking system, specifies the class of a given abrasive. Norton, for example, offers several classes of aluminum oxide which differ in purity, crystal structure and friability.

Grain or grit size indicates the degree to which abrasive grains are rough or fine. In this system, the abrasive size increases as the grit size becomes finer. Wheel grade or hardness refers to the bond strength, or the force required to break the grain from the wheel. In this case, alphabetic letters are used to designate grades from soft to hard.

The structure of a grinding wheel refers to the spacing of the abrasive grains in the bond matrix. Grinding wheel structures from dense to open (low to high porosity) are indicated by increasing structure number.

The bond system is normally a function of the selected abrasive type, bond grade and structure; not an end-user variable. Wheel manufacturers have their own designations for bond systems, and must therefore be consulted for bond system recommendations and information.

bonded CBN wheels for most gear grinding applications using conventional grinding equipment.

SG Dressing Characteristics

SG abrasive is harder than conventional aluminum oxide (2150 Knoop hardness versus 1850 Knoop hardness). Consequently, SG may wear low-quality diamond dressing tools faster than conventional abrasives. SG may contribute to the erosion of the bond matrix of some diamond rolls. Modifications to the diamond roll bond matrix of some diamond rolls can prevent this, as well as modify dressing practices. When purchasing diamond rolls, specify that SG wheels are being utilized.

On the positive side, SG likes to be dressed less for better performance, which increases the life of the dressing tool. For effective dressing with SG, consider the following points:

• Use "A" or "B" quality natural diamonds

• Reduce dresser infeed rates. The rule of thumb is to cut infeed depth by 50%, though more is not uncommon.

Effective Dressing—SG and Conventional Abrasives: Single Point Diamond and Diamond Rolls

The dressing rate used has a significant impact on cutting ability, part accuracy and finish. Finely dressed wheels will hold their form, producing good finish and accuracy. However, they may load too quickly and cause burn or chatter. By increasing dresser rates and using a rapid traverse rate, a more open wheel with sharper cutting action will be gained.

The rate at which the single point diamond travels across the wheel face is known as dress lead. Dress lead is the distance the diamond travels for every rotation of the wheel—much the same as the thread on a screw.

Typical lead values are:

• Form grinding .0005–.001" per rev.

• General-purpose grinding .002–.003" per rev.

• Fast cutting/heavy stock .004–.005" per rev.

To determine the rate of diamond traverse for a desired lead, multiply the lead in inches by the RPM of the wheel. For example:

4000 RPM x .002"/rev. = 8 IPM dress rate.

Typical diamond infeed on roughing operations is .0005–.001" per pass. Finish operations require .0001–.0005" per pass.

A very fine finish can be obtained by making the final diamond pass with no infeed.

Diamond roll dressing is implemented for one or more of the following reasons: intricate form profiles; consistent accuracy of size and form; control of grinding wheel sharpness; control of workpiece surface finish; and production economics.

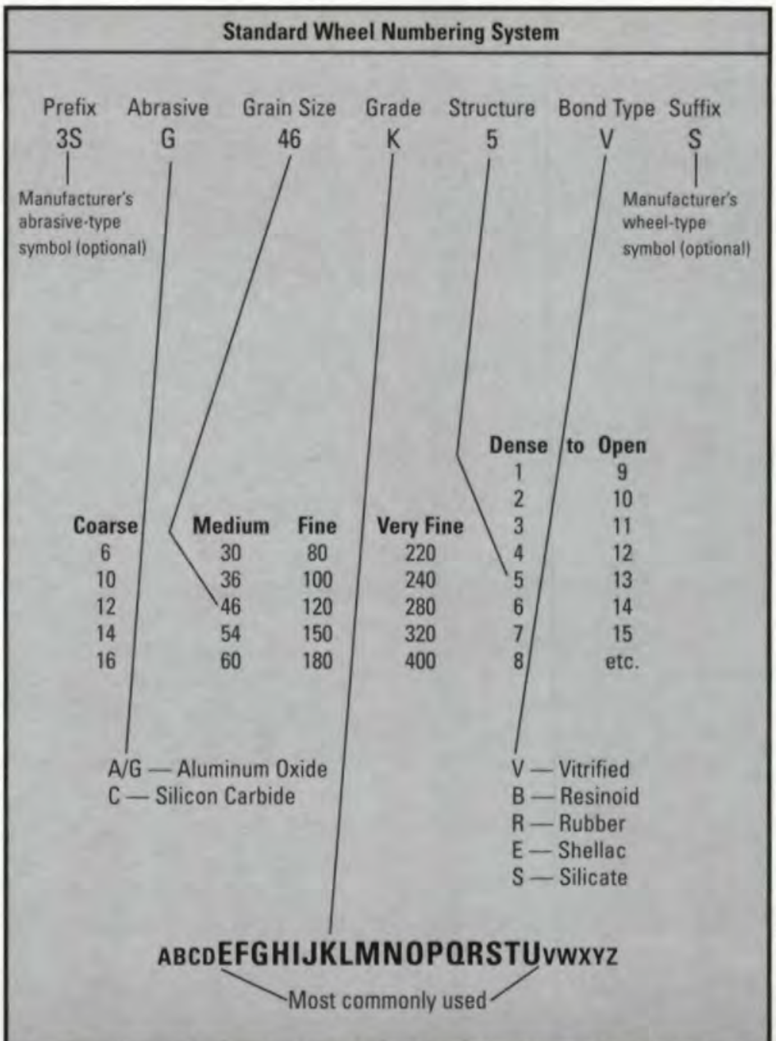


Fig. 2 — The marking system used by most manufacturers to identify important grinding wheel characteristics.

Courtesy of The Gleason Works.

Recommendations for speed ratio, rotation and materials are as follows:

• Maintain a speed ratio between .5 and .8;

• Maintain unidirectional rotation at the point of contact for most gear grinding;

• Use reverse-plated rather than bonded diamond rolls for superior durability and maximum diamond exposure.

To maximize the cost-effectiveness and efficiency of rotary diamond dressing devices, select a drive motor unit that complements the efficiency and accuracy of the diamond roll. Keep the following points in mind when making the selection:

• Older hydraulic motors, which generate a great deal of heat, may seriously affect the accuracy of axial run-out of the diamond roll as well as axial positioning.

• Air drives cause problems when running the dressing rolls at close to synchronous speed with the grinding wheel. At 0.8 to 0.9 ratio, the dresser has to act more like a brake to keep the dresser from rotating at wheel speed.

• Choose electrical drive motors that prevent the dresser from rotating at wheel speed and main-

Table I

Recommended Wheels—Threaded Generating Grinding Machines

Results:	
Good	38A 120/180 HIJ VBE
Better	3SG 80/120 IVS G12USP
Best	3TG 120/3 GB VCFIII

Recommended Wheels—Saucer Generate Grinders

Results:	
Good	32A 46/80 K/L UBE or 38A 80/5 H/J VBE
Better	3SG 80 G12 VSP
Best	3TG 120/3 GB VCFIII

Recommended Wheels—Bevel and Hypoid Machines

Results:	
Good	38A 60/80 J VBE
Better	55G 60/80 I/J VS
Best	5TG 120/2 I/J VH

Recommended Wheels—Niles and Höfler Machines (large gears)

Results:	
Good	32A 60/5 G25-H16 VCFIII
Better	3GP 54 GVSP
Best	5TG 120/2 GB-HB VCFIII

Recommended Aluminum Oxide Wheels—Form Gear Grinders

Results:	
Good	32A 60-80/S G-J VBE-VBEP
Better	3SG 100 G-I VS-VSP
Best	3TG 120/4 GB VCFIII

Recommended CBN Wheels—Form Gear Grinders

CB 180-220 plated/nickel bond or CB 180 MNV x222 C1/8 vitrified bond

Recommended Wheels—Form Grinding From a Solid

Results:	
Good	SG 54-80 J-L VS
Better	SG 54-80 J-L VH
Best	5TG 120/ J-L VH

tain a fixed set value of dresser RPM (2 kw or 2.65 hp minimum is recommended). Mechanical isolation is also imperative to eliminate vibrations from couplings and the drive motor itself to the roll.

Making the Right Choices

Grinding wheel selection directly influences at least four major performance factors:

1. Quality of the ground part, including flank form repeatability, tooth spacing, surface damage caused by burning and surface texture;

2. Floor-to-floor time, including wheel dressing/conditioning time and grinding time;

3. Abrasive tooling costs;

4. Flexibility to change the wheel profile for current and new jobs.

For these reasons, it is important to understand wheel and abrasive properties that are most critical to grinding performance and to seek further information from wheel and/or abrasive manufacturers in the event of any questions.

Apart from standard aluminum oxide wheels, there are two choices, each with its positive attributes:

SG and TARGA

- Higher metal removal rate capability than conventional abrasives, but lower than superabrasives.
- Increased sharpness to reduce tendency for burning.
- Longer lasting and better form holding capability than conventional aluminum oxide.
- Flexible, but very repeatable profile shapes.
- Self-sharpens properly with relatively high grinding forces.

Plated CBN

- Wheel dressing not required; reduces cycle time and saves expense of dressing tool.
- High metal removal rates because of hardness and toughness of CBN.
- Low tendency for burning—coolant application is easily optimized because wheel size and shape does not change through dressing.
- Thermal transfer properties of wheel materials (CBN, nickel bond, steel core) reduce tendency to burn.
- Compressive residual stresses left in workpiece surface layer increase strength.

In Conclusion

CBN abrasives offer excellent thermoconductivity and a cooler grinding process that helps to reduce tensile stresses and increase compressive stresses. As mentioned in related articles (including Wilfried König's "CBN Gear Grinding—A Way to Higher Load Capacity?" *Gear Technology*, Nov/Dec, 1993), the performance characteristics of CBN abrasives are the subject of much debate. This is particularly true in light of recent developments related to SG and TG abrasives. Like CBN, SG and TG abrasives have been proven to reduce tensile stresses and increase compressive stresses as well.

Recently, some manufacturers have found that the new abrasives have provided the required level of compressive stresses to enhance the performance level of their gears.

As this article is written, new technologies in abrasives and gear manufacturing equipment are being developed. These developments will provide gear manufacturers with more options, more choices and improved ways to produce higher quality gears with greater efficiency. ○

***Acknowledgment**: Background information for this article was contributed by Eric G. Mundt, senior research engineer at Gleason Works.*

For more information about Norton Company Abrasives, circle Reader Service Number A-131.

Tell Us What You Think... If you found this article of interest and/or useful, please circle Reader Service **Number A-132.**

Dry Gear Hobbing

How modern machine controls, drives and motors play a part in this emerging new technology.

E. Peter Kovar

Question:

We are contemplating purchasing a hobbing machine with dry hobbing capabilities. What do we need to know about the special system requirements for this technology?

Answer:

If you are cutting small gears in high-volume production, you should consider the dry hobbing option. Dry hobbing offers many advantages and very few disadvantages over conventional hobbing. Currently only certain sized gears justify the cost of cutting with this method. The decision is based on the pitch rating of the gears, which influences the cost of the tools. Dry cutting technology is generally used for smaller automotive sized gears. Larger pitch gears are not manufactured in sufficient quantities to justify the use of carbide hobs.

As additional dry hobbing machines of various sizes are introduced by the manufacturers and the cost of the tools goes down, the dry hobbing method will gain wider acceptance in the industry. (See *Gear Technology*, November/December 1994, "Gear Hobbing Without Coolant," for a basic introduction to this technology.)

There are two points that I would like to make regarding this new technology. The first one is that although the advance in CNC technology was not the only catalyst in the development of the dry hobbing technique, it is one of the keys to the functionality of this technology. Dry hobbing would not have been possible without the recent developments in CNC systems and motors. The second point is that dry hobbing is very fast, so fast that the CNC cannot correct inherent machinery problems (as it can in slower traditional methods). Therefore the dry hobbing machine needs to be very well designed.

Hand in hand with electronics, two other forces accelerated the development of dry hobbing technology. One was the introduction of better carbide tool materials. Significant increases in tool life have been achieved over the last few years. Further advances in carbide and ceramic tool technology, along with reductions in the cost of these tools, will increase the appeal of dry hobbing even more.

The second accelerating factor was the total redesign of the dry cutting machines themselves for accuracy, thermal stability and fast chip removal. The machines also needed to be built to more exacting tolerances. Machines cutting at these ultra-fast speeds need to be more accurate.

The integration of the hob and table kinematics of these fast machines tests the limits of modern CNC controls. Currently, CNC systems can correct kinematic errors in the magnitude of 160 Hz, depending on the inertia ratio between the servo motors and the machine elements to be controlled. The critical area is the angular link between the tool and the workpiece (the mechanical element in the hob head and the table). Errors in the kinematics of the machine cannot always be compensated for by the controls at such high speeds. These errors need to be eliminated in the design of the machines themselves.

Why Bother?

Dramatic new concepts are usually met with resistance. The poet Alexander Pope said, "Be not the first by whom the new are tried . . . " Most of us tend to agree, especially when the new involves big capital expenditures and the abandonment of old, comfortable ways of doing things. However, dry hobbing technology has been proven in tests to be faster, less expensive and more environmentally friendly than conventional hobbing for many high speed applications and, therefore, should be given serious consideration by gear application engineers.

The dry hobbing process was developed primarily for economic reasons. New cutting tool technologies using

***Gear Technology's* newest column will answer your questions about gear machinery controls and electrical systems. Send your questions about CNC, software and machinery electrical systems to Mission: Controls, P. O. Box 1426, Elk Grove, IL 60009 or fax them to 708-437-6618.**

E. Peter Kovar
is the vice president of U.S. Tech Corporation, Chicago, IL, and a recognized authority on CNC applications.

high-speed carbide cutters and ceramic tools, along with the higher speeds of modern machines, made the dry cutting process possible. One dry hobbing machine can replace two to six conventional machines, depending upon the hardness of the steel being cut.

One tremendous side benefit of this technology is environmental friendliness. Not only are coolant purchases and disposal costs eliminated, but there is also the added benefit of cleaner air on the production floor. Some of the chief proponents of this technology are the operators themselves, who can work in a cleaner environment when dry cutting. Shop personnel, floors and equipment are not covered with coolant at the end of the day. There is also a reduced fire hazard since flammable oils are no longer needed. Bacteria and corrosion from water-soluble coolants are also eliminated. A final benefit of dry hobbing is the simplification of the process, as parts do not require washing.

Ceramic or Carbide?

The cost-effectiveness of ceramic hobs is still subject to debate, especially since currently no domestic manufacturer makes these hobs. Most of the testing and research being done by the domestic automotive industry is now focused on carbide hobs (although Fiat-Italy, and ZF in Europe are testing ceramic hob capabilities). At the moment, ceramic hobs are very expensive, more sensitive to correct setup and calibration than carbide hobs and difficult to sharpen. However, new coatings are being tested that may significantly increase their performance.

What's Involved?

Dry hobbing is much more complicated than simply "turning off the coolant." In addition to the cutting tool, three design factors must be considered. The machine itself needs to carry away hot chips efficiently so the geometry of the workpiece is not affected. Also, the machine's chip chute must not inhibit the chips. The chute design is therefore much steeper than that of a conventional machine (see Fig. 1).

The machine design must ensure thermal stability, since there is no coolant in the machine bed to carry away the generated heat. Dry hobbing machines are designed with special internal ribbing for thermal stability. They are generally quite heavy and incorporate special steep walls around the table. The machines also include an integrated chip conveyor to keep the heat of the chips from accumulating in the machine and to maximize the speed at which the chips are removed from the machine for disposal. In some cases, the manufacturers of the machines are using special vibration panels underneath the workpiece to accelerate chip removal. Finally, the machine must be capable of high cutting speeds. The machine's CNC-controlled, integrated automation must support the shorter machining cycles of these machines.

The feeds and speeds of the machine, along with the number of starts in the cutting tool, need to be optimized to obtain a chip thickness that can carry the heat away from the part. The machine must be capable of a minimum hob speed of 3,000 rpm and a table speed of at least 500 rpm. Engineers carefully select the appropriate motor sizes for these machines in order to ensure that sufficient torque is available to cut the proper chip depth efficiently. As new carbide compounds are developed, the hob and table speeds will be pushed even higher.

Machines for dry hobbing need to incorporate modern, preferably digitally controlled motors capable of supporting the dynamics in this high-speed application. The speed of the application also puts a demand on the synchronization of the hob and table rotations controlled by the CNC.

Without today's electronic technology, dry hobbing methods would not be cost-competitive. The machines and controls must be capable of achieving at least a 3,000 rpm hob speed for long periods of time without overheating. The selection of the controls and motor capacity is critical.

Another area controlled by the CNC in the past is temperature compensation. The thermostability of the conventional machine was not a critical area of concern for machine designers. Most gear machine manufacturers were able to compensate for inherent machine temperature instability with special coolant routing or by using the CNC to perform electronic compensation, although neither method was very reliable. Dry cutting requires that the machines have an inherent thermostability, and, therefore, the machine does not need electronic compensation devices.

Most of the heat generated in the dry hobbing process (as much as 80%) is carried away with the chips. Gears generally come out of the machine in the temperature range of 105–115°F. Machines that heat gears only to 115° generally do not require thermal compensation devices.

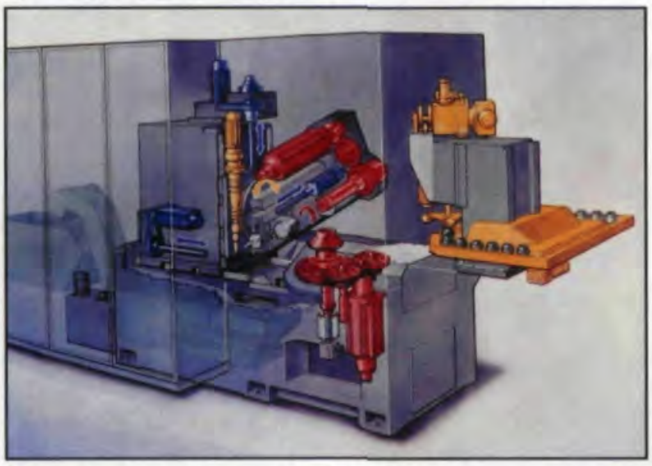


Fig. 1 — Concept hobbing machine for dry hobbing. Courtesy of Liebherr America. Used with permission.

Conclusion

Modern controls, drives and motors have set the pace for technological advances and a better environment. Dry hobbing technology is a giant step toward lowering the total long term costs of gear manufacturing and oil disposal. ✪

Tell Us What You Think... If you found this article of interest and/or useful, please circle Reader Service **Number A-133.**

Drivetrain Research

An Idea Whose Time is Overdue

The popular perception today is that technological advancement is an engine running almost out of control. New products and processes are developing faster than we can keep up with them, as anyone who has had a new computer system crash into obsolescence practically before it's out of the box can tell you. But that's not the case everywhere. Transmission technology, for example.

The drivetrain, perhaps because it doesn't lend itself to exciting film footage or glitzy electronic presentation, has been neglected.

Yes, some exceptions do exist. Thanks in part to research done during the military buildup of the 80s, the main propulsion gears of the U.S. Navy's surface and undersea fleet are now hardened and ground rather than shaved and *then* hardened. The Advanced Rotorcraft Transmission (ATR) program brought some developments which were integrated into the Comanche main transmission at Sikorsky, and McDonnell Douglas Helicopter Systems continues some of its ATR research.

But the fact is that the performance capabilities of rotorcraft have been steadily and significantly upgraded while the basic power transmissions remain relatively unchanged. I wonder whether we are not now approaching the "ragged edge"—a time when power transmissions are unable to cope adequately with the newly enhanced performance capabilities of the rest of the rotorcraft.

In one sense transmission technology has been the victim of its own success. Transmissions designed in the previous decades had such a large safety factor built into them that no major changes were believed necessary to carry the increased load and enhanced performance specifications. It was easy to neglect them because they grabbed attention only when they failed. By building better-than-required transmissions, designers and manufacturers have, unfortunately, deflected all the limelight away from transmissions—leaving themselves in the dark!

The problem now is, just at the moment when that ragged edge is on the horizon, political and economic times have changed. If no major innovations were evident when the defense budget, which funded much of the research, was "fat," what is to happen during the current and future "lean" years?

Safety issues aside, neglect in this area will cost us dearly. For example, we face vigorous and renewed overseas competition from a very determined and unified European helicopter industry. United States rotorcraft manufacturers will have to square off against the "Eurocopter" consortium on every potential sale in Europe and elsewhere. McDonnell Douglas recently won a significant contract against the "Eurocopter" with its pending sale of Apaches to the Netherlands. On the other hand, the government of Abu Dhabi has just ordered a dozen Eurocopters.

Aerospace is not the only place where the technological status quo could hurt us badly. The respite presently enjoyed by the automotive and off-highway vehicle sector because of the soaring yen rate cannot last forever. When the yen comes back, say to the 110 to the dollar level, can the Big Three or Caterpillar compete head-on with the Toyotas and the Komatsus? Higher power density drivetrains that are quieter and more reliable could be important to success in such a head-on competition.

Rest assured, someone is working on developing lighter, quieter and more reliable transmissions right now. It's just that they're not working on them in the U.S.

Unlike consumer electronics, power train development is not an area we can leave to someone else. The implications for both our defense and civilian economy are too important. Much more than national pride is at stake. There is also an economic imperative. Jobs, both civilian and military, defense preparedness and user safety are all under the gun if the status quo continues.

The good news is we're not starting from quite ground zero. Several university-based centers, using government funds, are doing research in this technology sector. The National Center for Advanced Drivetrain Technologies here at Penn State, the Instrumented Factory (INFAC) for gear manufacturing at the IIT Research Institute (IITRI) and the Gear Center at Ohio State University all have programs in place.

But these are only the beginning. More work needs to be done. Industry needs to aggressively interact with these research institutions to reap the most benefits from their work. And we need to remind our legislators that in the rush to downsize the military, we don't throw the baby out with the bath water.

The drivetrain industry is capable of overcoming years of neglect. It has the potential to be the best and most advanced in the world. But if we want to be leaders and not followers, *now* is the time to act.

Dr. Suren B. Rao
is the director of the National Center for Advanced Drivetrain Technologies at Penn State University.

For more information about NCADT, please circle Reader Service No. A-134.

Tell Us What You Think... If you found this article of interest and/or useful, please circle Reader Service **Number A-135.**

Hot Dates...

JULY 10–AUGUST 25

ASM International Education Seminars. **July 10–14**, Metallurgy for the Non-Metallurgist; **July 17–20**, Fracture Mechanics & Damage Tolerance; **July 18–20,** Tool Steel & Its Heat Treatment; **August 21–25**, Fundamentals & Applications of Powder Metallurgy; Mechanical Testing of Metals. All seminars held at ASM Headquarters, Materials Park, OH. Call 216-338-5151 or fax 216-338-4634.

SEPTEMBER 7–9

National Screw Machine Products Association Metalworking Software Expo '95. Chicago Marriott O'Hare. Showcasing the latest in software and computer technology serving the metalworking job shop industry. For more information, contact Gardner Management Services, 1-800-950-8977 or fax 513-527-8950.

SEPTEMBER 11–14

ASM 2nd International Conference on Heat-Resistant Materials. Focus on the development, performance and end-use of heat-resistant materials. Contact ASM at 216-338-5151, x 703 or fax 216-338-4634.

SEPTEMBER 11–15

AGMA Training School for Gear Manufacturing. Daley College, Chicago, IL. Contact AGMA at 703-684-0211 or fax 703-684-0242.

SEPTEMBER 12–14

Ohio State University, "Gear Noise Seminar." Covers measurement, sources, transmission error, rattle, reduction techniques and more. Contact Susie Young, 614-292-5860.

OCTOBER 16–18

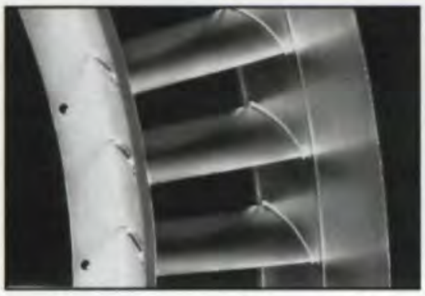
AGMA Fall Technical Meeting. Charleston, SC. Presentations on gear manufacturing and research subjects. For more information, contact AGMA at 703-684-0211 or fax 703-684-0242.

NOVEMBER 12–15

AGMA Gear Expo '95. Indiana Convention Center, Indianapolis, IN. The one trade show devoted exclusively to the gear and gear-related products and services industry. See the latest machines, products and processes. For more information, contact AGMA at 703-684-0211 or fax 703-684-0242.

To announce an important technical meeting, exposition or seminar, please send notification to Gear Technology Tech Calendar, P. O. Box 1426, Elk Grove Village, IL 60009. Notices should arrive in our offices six weeks prior to the date of the issue in which you wish it to appear. Items are used on a space-available basis.

Welcome to our Product News page. Here we will feature new products of interest to the gear and gear products markets. To get more information on these items, please circle the Reader Service Number shown.



High-Lubricity Alloy Coating

Microfin Corp. introduces a new plating process with outstanding lubricity, wear resistance and hardness. Lubralloy®, a chemically deposited alloy process, is said to be far superior to electro-deposited coatings, producing uniform, smooth and wear-resistant deposits on complex shapes. It works with aluminum, titanium, stainless steel, high-nickel alloys and copper, as well as most basic materials.

Circle Reader Service No. A-27

Honing System for Increased Production Capacity

Sunnen Products Co. announces the new ECA-3500 automated honing system, which provides consistent bore size and finish without the labor costs of a dedicated operator. Consisting of the company's EC-3500 standard honing machine and the ECA-7500 standard automation package, the system will increase production capacity, double the speed of existing honing machines and reduce load/unload times.

Circle Reader Service No. A-28

Tetrabond Coatings Available in Small Lots

Multi-Arc Inc. has initiated small lot production of its amorphous diamond coating, Tetrabond. These amorphous carbon-based coatings have diamond-like properties and can be deposited at temperatures below 150°C.

Circle Reader Service No. A-29

Adjustable Pitch Diameter Inspection Gage

Moore Products Co. offers a new adjustable pitch diameter inspection gage for measuring the over-ball or over-pin characteristics of gears and splines either in the gear lab or on the production floor. Standard equipment includes the pitch diameter inspection gage, one set of ball/pin anvils, a part-holding stand, the digital readout, the Data Gage 873 measuring system for automatic calculation of tooth thickness and dimensions over balls and pins and a workbench with storage drawer. Options include center assembly, printer and interface with a LAN (local area network).

Circle Reader Service No. A-30

Factory Gage Management Software

Allen-Bradley's DataMyte Business Unit has announced the release of EnGage!® factory gage management system for PC applications. Designed to accommodate factory auditing certification requirements, EnGage! software incorporates a fully functional tracking and recall system with calibration entry and storage, integrated import/export capability, help screens and integrated word processing features. It produces recall, inventory, cost and calibration worksheets, reports on gages due for calibration, event histories and overdue/out-of-tolerance gage listings and performs certification of calibration reports.

Circle Reader Service No. A-31

Targa-VH Bond Abrasive Products

Norton Company introduces a new product line of advanced ceramic abrasives, the Targa-VH line. The products deliver increased wheel life, aggressive cutting and improved form holding capabilities in demanding jobs such as cylindrical and plunge centerless grinding. Available in two concentrations (50%

and 30%) for both difficult-to-grind materials, small contact areas and heavy stock removal and easy-to-grind materials, large contact areas and light stock removal respectively. Available in a variety of grit sizes and wheel dimensions.

Circle Reader Service No. A-32

Economy Wastewater Evaporators

Landa, a manufacturer of water cleaning systems, introduces a line of economy wastewater evaporators. The all-electric Hot Box evaporators are designed for handling low volumes of wastewater from mop water to machine coolant rinse water. Available in two models, the Hot Box can evaporate waste streams in either batch process or continuous flow at up to 7 gallons per hour.

Circle Reader Service No. A-33

Hydraulic Clamping Device for Hobbers

Albert Schrem announces its Polyma-Adjusta No. DAKK 92 hydraulic-mechanical clamping device for gear hobbers and skiving machines. The device has a controlled axial clamping pressure and a floating clamping surface. A bevel spring between the arbor and the clamping device prevents radial movement of the part and at the same time retracts the piston to the zero position when unclamping. Also offers easy runout adjustment system.

Circle Reader Service No. A-34

Send your new product releases to:
Gear Technology
1401 Lunt Avenue
Elk Grove Village, IL 60007
Fax: 708-437-6618

CLASSIFIEDS

SERVICE

GEAR TOOTH GRINDING SERVICES

- Cost effective gear tooth grinding specialists
- Gear manufacturers are our only customers
- Prototype and production quantities
- Capacity to 27.5" P.D., 3.5 D. P.
- Able to match delivery to your requirements
- All service to AGMA standards with Certified Gear Inspection Equipment

PRO-GEAR COMPANY, INC.

23 Dick Road Depew, NY 14043
Phone (716) 684-3811
Fax (716) 684-7717

CIRCLE A-40 on READER REPLY CARD

PFAUTER-MAAG CUTTING TOOLS LIMITED PARTNERSHIP

- HOB SHARPENING
- SHAVING CUTTER GRINDING
- T.I.N. COATING SERVICE
- CUSTOM HEAT TREAT SERVICE

PFAUTER-MAAG CUTTING TOOLS
1351 Windsor Road, P.O. Box 2950
Loves Park, IL 61132-2950
Phone (815) 877-8900
Fax (815) 877-0264

CIRCLE A-41 on READER REPLY CARD

GEAR INSPECTION UPGRADE

If you are not using the latest IBM compatible "user-friendly" ROTO-SMART package for your gear testers, composite testers, lead testers, redliners, and other inspection systems, you need us!

With this service, which meets AGMA standards, you will have the latest in gear technology.

We can also supply a new RC-400 Gear Inspection System.

Call 1-800-875-ROTO
or Fax us at (513) 865-0656

ROTO-TECHNOLOGY, INC.
351 Fame Road, Dayton, OH

CIRCLE A-42 on READER REPLY CARD

FOR SALE

Established Precision Gear Mfg. Facility
Specializing in Transmission and Engine Gearing
$6 Million + Sales in Strong Growth Market
Send Inquiries to: **Box AA**
Gear Technology
P.O. Box 1426
Elk Grove Village, IL 60009

HELP WANTED

MANUFACTURER'S REP.
GEAR SALES ENGINEER
AUTOMOTIVE—AEROSPACE
ENGINE—TRANSMISSION
PROTOTYPE—PRODUCTION
SHAVED—GROUND—HONED
FAIRLANE GEAR P.O. BOX 709
PLYMOUTH, MI 48170

MANUFACTURING MANAGER: $80,000
ENGINEERING MANAGER: Fine Pitch. $70,000
PRODUCTION MANAGER: $70,000/Car
PRODUCTION CONTROL MANAGER: $60,000
Contact: Ann Hunsucker Godwin, Excel Assoc.
PO Box 520, Cordova, TN 38088 or call 501-735-6352 or FAX 501-735-6860.

To advertise on the Classified page call (708) 437-6604 for details.

SOFTWARE

GEAR SOFTWARE

GEARPACK

Announcing Version 4.00 of our popular Gearpack software. Now a single source for geometry, mesh graphics and strength of spur and helical gears.

Check out our other software for gear shaping, hobbing, grinding, gear tooling and setup. Many of your competitors did.

ASK FOR A DEMO DISK

SOFTWARE ENGINEERING SERVICE
2801 Ridge Avenue
Rockford, Illinois 61103
Fax/Phone (815) 963-1760

CIRCLE A-43 on READER REPLY CARD

HEAT TREATING

Contour Induction Hardening Specialists

Spur, helical and bevel gears

Our gear hardening equipment includes 3 NATCO submerged process machines and 4 AJAX CNC-controlled gear scanning machines. We can also tool to meet any production need. Write for a free brochure.

American Metal Treating Company
1043 East 62nd Street
Cleveland, OH 44103
(216) 431-4492
Fax: (216) 431-1508

CIRCLE A-44 on READER REPLY CARD

Rates: Line Classified—$30 per line. 8 lines per inch. $240 minimum. Classified Display (3" min.): **1X**—$525, **3X**—$495, **6X**—$465. Additional per inch: **1X**—$175, **3X**—$165, **6X**—$155. *Gear Technology* will set type to advertiser's layout or design a classified ad at no extra charge.

Payment: Full payment must accompany classified ads. Send check or Visa/MasterCard/American Express number and expiration date to: *Gear Technology*, P.O. Box 1426, Elk Grove Village, IL 60009. **Agency Commission:** No agency commission on classifieds. **Materials Deadline**: Ads must be received by the 25th of the month, two months prior to publication. **Acceptance:** Publisher reserves the right to accept or reject classified advertisements at his discretion.

Gears in Congress & Other Odd Places

Gear Technology's bimonthly aberration — gear trivia, humor, weirdness and oddments for the edification and amusement of our readers. Contributions are welcome.

Mr. Gear Goes to Washington

As the authority on gears of all sizes, shapes and political persuasions, *Gear Technology* tracks down information about the most important gears in the world. In this issue, a history lesson. **John Henry Gear** was a U.S. Senator from Iowa from 1895–1900.

Gear was born April 7, 1825, in Ithaca, NY, the son of an Episcopal clergyman. In 1843, he moved to Burlington, IA, where he began a successful career as a wholesale grocer. He also became heavily involved in the railroad business. He was the founding president of the Burlington, Cedar Rapids and Minnesota Railroad.

Gear's public career began when he was elected mayor of Burlington in 1863. In 1871 he was elected to the Iowa General Assembly, where he served three terms. In 1873 he was elected Speaker of the House after a two-week debate. After two terms as Speaker of the Iowa House, **Gear** was elected governor of Iowa, where he served from 1878 to 1881.

From there, **Gear** moved on to Washington, serving in the House of Representatives from 1887 until 1891. After a brief stint as assistant secretary to the Treasury in 1892 and 1893, he was re-elected to the House.

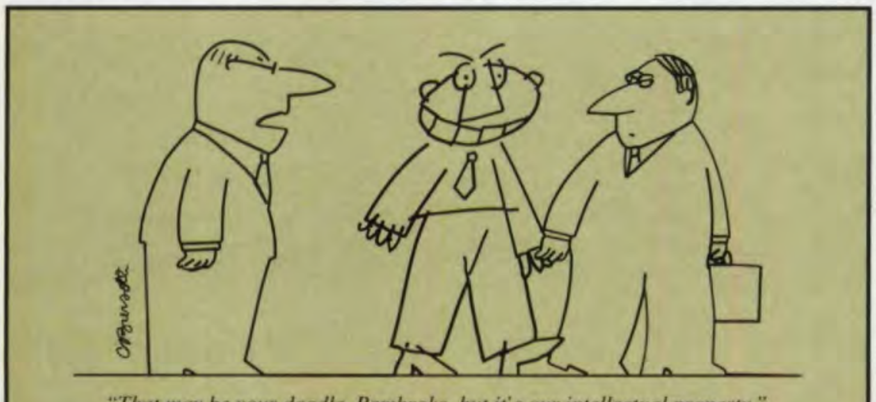
Finally, **Gear** served the United States Senate from 1895 until 1900, where he was chairman of the Committee on Pacific Railroads. Although he was re-elected for a second term, he died July 14, 1900, before the term began.

Gears Online

With all the hoopla surrounding the Internet these days, it's no surprise that new web sites are opening every day. *Gear Technology* is pleased to announce that there is now a home page called GEARS. But before the hoopla gets out of hand at your office, let us warn you: it's not what you think.

The Global Entomology Agricultural Research Server (GEARS) is a new web site devoted to—you guessed it—bugs. The server is provided by the USDA-ARS laboratory and includes the largest online collection of bee- and pollination-related information available. You can browse the art gallery of fascinating insect photographs, learn about the latest beekeeping techniques or listen to live recordings of bugs in their native environments.

You can log on to GEARS at *http://gears.tucson.ars.ag.gov/*, but if you leave a question on their bulletin board about the involute modification on your latest gear design, don't expect an answer any time soon.



"That may be your doodle, Pembroke, but it's our intellectual property."

Answers to Last Month's Puzzle

Use the chart below to help determine the probabilities for the next Wacky Widgets gearmotor. Assuming shelf A holds one spur and one helical gear, and shelf B holds two spur and one helical gear, the 6 lines represent the six different combinations of gears that are possible. S=Spur and H=Helical.

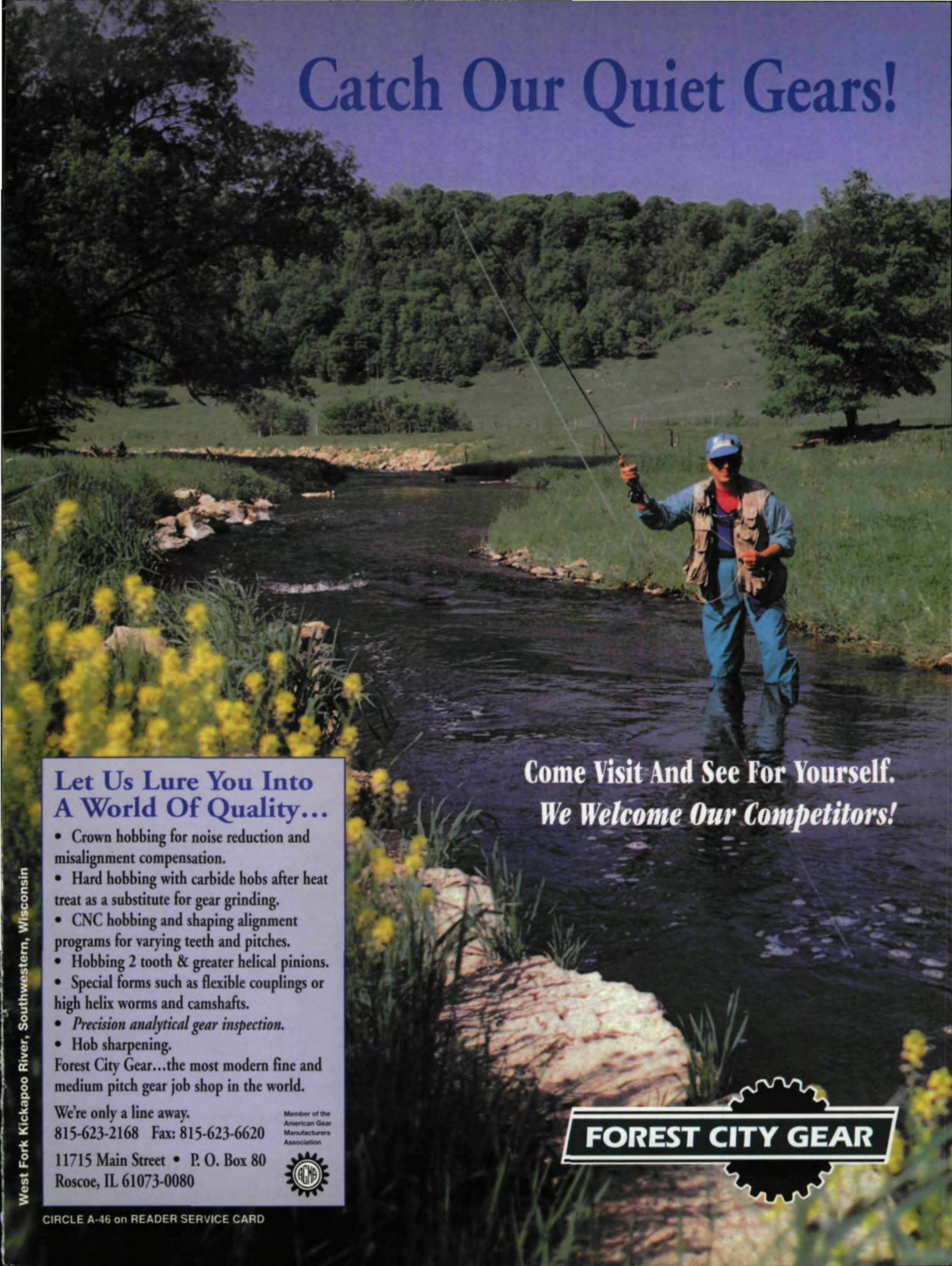
	Shelf A	Shelf B
1.	S	S1
2.	S	S2
3.	S	H
4.	H	S1
5.	H	S2
6.	H	H

Thus we can see that the chances of one spur and one helical gear are 3 in 6, or 50% (lines 3,4 and 5), and the chances of two spur gears are 2 in 6, or $33^1/3$% (lines 1 and 2). The chances of the foreman throwing up are zero. **After all, he is a trained professional (don't try this at home).**

Patriotic Gears

In celebration of U.S. Independence day, patriotic gear manufacturers can take heart in the fact that gears are doing their part to protect the nation.

There are approximately 576,000 gears in service as components of the U.S. Army's fleet of 7,775 helicopters, according to INFAC, the Instrumented Factory for Gears, a research organization sponsored by the U.S. Army Aviation and Troop Command at the IIT Research Institute in Chicago.



West Fork Kickapoo River, Southwestern, Wisconsin

THE WHOLE TOOTH... AND NOTHING BUT THE TOOTH.

Spur and Helical Gear Manufacturing Technology

If you hob and/or grind precision gears, Gleason machines can give you faster production response, higher quality assurance, lower tooling costs, and more parts per hour per machine. For starters, there's our high-rigidity CNC hobbers.

High-Volume Hobbing... in Small Quantities

Now you can combine high speed and high accuracy, with today's need for fast changeover and versatility. All in one affordable, highly-rigid CNC hobber that you can run wet or dry. Use of multi-gash hobs let you reduce cutting cycle times. And tool-free hob change (in seconds) gives you high-uptime batch run capability.

PHOENIX 125GH 6-Axis CNC Hobber

TAG 400 8-Axis CNC Gear Grinder

Completely Automatic Dressing and Grinding

Gleason's CNC Spur and Helical Gear Grinder provides completely automatic dressing and grinding cycles, to maximize production rates, wheel life, and gear quality while eliminating dressing guesswork. Utilizing the threaded-wheel generating process, you get continuously variable wheel speeds from 0-2500 rpm for process flexibility. 8-axis CNC lets you minimize initial setup and subsequent changeover time.

We also offer a 5-axis CNC chamfering/deburring machine and a CNC honing machine, as well as our 130-year leadership in machines for bevel/hypoid gears. Backed with worldwide support. Call 1-800-643-2770 or your Gleason regional sales manager.

The Gleason Works, 1000 University Ave., Rochester, NY 14692-2970
(716) 473-1000 FAX: (716) 461-4348

Gleason

CIRCLE A-6 on READER SERVICE CARD