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*The Journal of Gear Manufacturing*

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NOVEMBER/DECEMBER 1996

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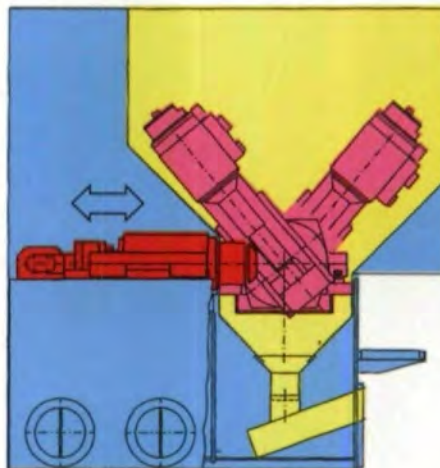
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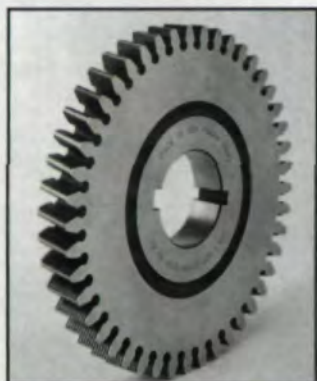


# GEAR TECHNOLOGY

NOVEMBER/DECEMBER 1996

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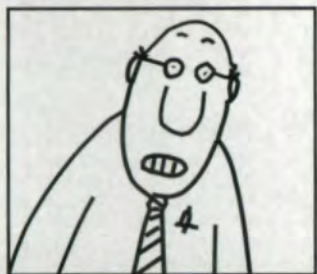
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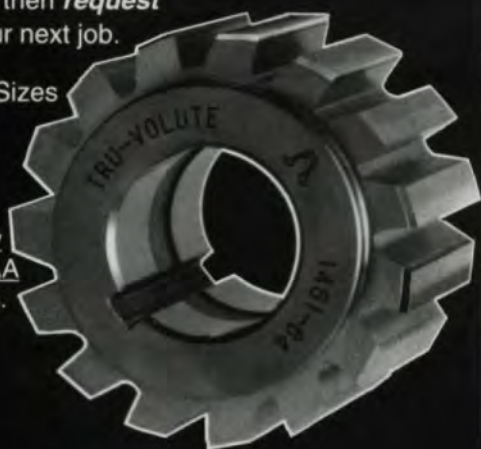
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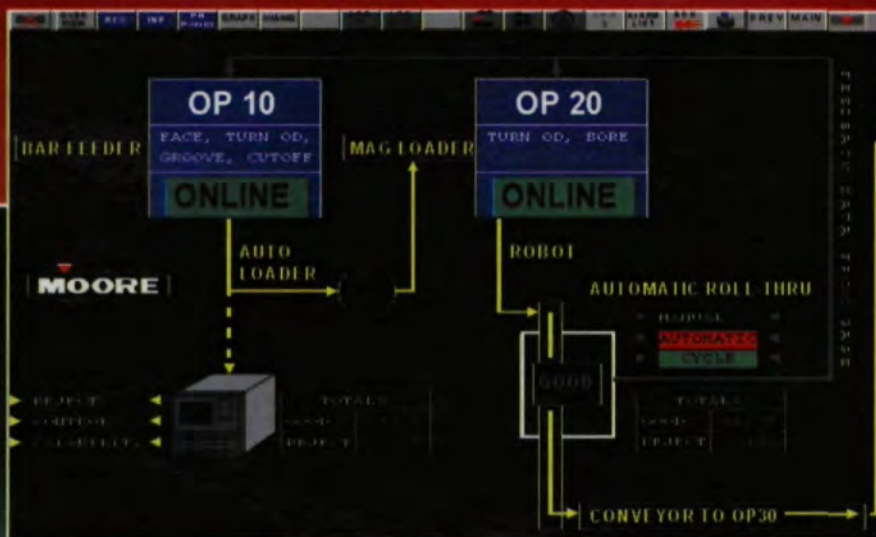


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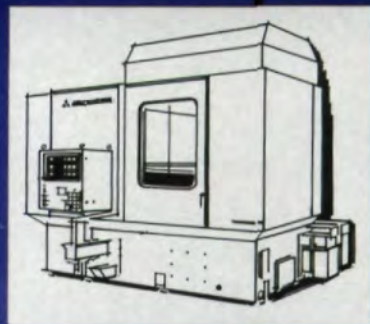
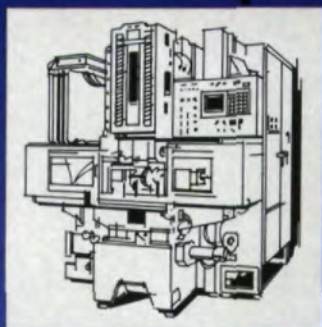
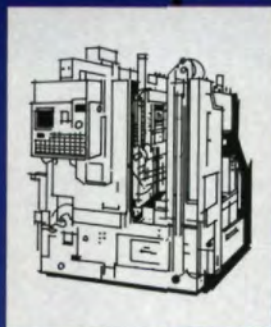
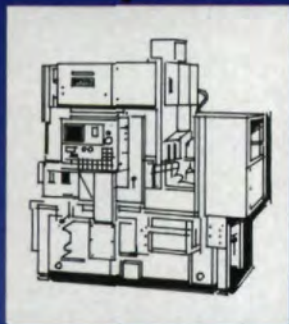
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# Two columns for the price of one . . .

Just back from IMTS and once again, I'm struck by the enormous vitality and strength of the manufacturing sector of the U.S. economy. It has made a phoenix-like rise from the grave dug for it by pundits in the '80s and has come back more robust and competitive than ever.

True, it's not our father's factory floor on display at the show, but in most ways it's a lot better than he ever dreamed it could be. It's a lot cleaner and there's a heightened awareness of safety and health issues. Production is faster, more organized and at the same time more flexible. The new applications and processes would amaze Dad (they amaze me). The companies have a real global reach now, and the faces to be seen are from every corner of the planet. Doesn't look much like a dying sector of the economy to me.

IMTS itself gets bigger and better every two years. It now takes up all three buildings at McCormick Place, and "doing" the entire show requires the training and stamina of a triathlete. To counter the inevitable information overload caused by a show this size, the addition of "pavilions," including the one for gear machinery, are especially welcome. It was a real treat to have most major industry players all conveniently located in the North Building, where valuable

time could be spent looking at machinery and talking to the experts rather than walking through miles of other booths.

The "hot" news at the Gear Generating Pavilion was the agreement in principal between Gleason and Pfauter (see our story on p. 16). The details of this agreement have yet to be worked out, but this is a story to watch over the next few months.

Industry trends continue much the same as they were at Gear Expo last November: Dry hobbing, faster speeds and feeds, more flexible manufacturing, and the growing presence of Windows-based software for all kinds of gear applications. The other good news is the reappearance of cheerful, smiling faces among the sales staffs. Business is very good for almost everyone, a welcome change from a few years ago, when popular wisdom had our industry on life support.

*Meanwhile, back at the office . . .* Our own newest ventures, The Gear Industry Home Page™, our electronic buyers guide for gear machinery, tooling and accessories, and *Gear Technology* online, are both off to a strong start. We have had over 3000 "hits," or page requests, originating everywhere from Malta to Malaysia in both August and September. Reports from advertisers on The Gear Industry Home Page™ are also positive.



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We've now introduced our direct response forms, which allow Internet explorers to request information online. Advertisers get specific information, such as names, addresses and job titles, about inquirers, much as they would from people who fill out "bingo card" forms in print magazines.

Like everyone else on the Internet, we're learning to use this new medium as we go along. Some important facts we've discovered so far are these.

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expense of printing) you incur to reach your customers. The print bill alone for even a simple one- or two-page brochure can run to thousands of dollars even before you mail it. The same information disseminated on the Internet costs the amount of time it takes to generate the copy and get it up on line. And you have no mailing costs at all.

2. The Internet is an infinitely flexible medium for spreading the word about your company. Changes to your information can be made in a matter of minutes, at little or no additional cost. You never have to store the extra copies of anything or throw away

hundreds of out-of-date (and expensive) versions of your literature.

3. The Internet can put you in touch with people you never dreamed would be interested in your product, ones you wouldn't necessarily find by renting a mailing list. The very public nature of this medium means that people from everywhere can check out your site with the ease of a few mouse clicks. True, you may attract some "tire kickers" this way, but you also can establish contacts with potential customers you never knew were there.

4. The people who use the Internet most right now are what marketers call "early adapters." They like new technology, and they're eager to use it. This attitude doesn't just apply to the Internet. They're just as interested in your newest products and services. They're the kind of potential buyers you want to attract.

As late as this summer, I was an Internet skeptic and let my staff talk me into this venture with some reluctance. Now that I've seen how the Internet works and the power it has to convey information about products and services quickly and inexpensively anywhere in the world, I've become a convert. The success of our own Internet ventures has convinced me that as time goes on, more and more of our business will be conducted in cyberspace. People and companies who establish their presence early and who learn how to market their companies and products on the Net will have an advantage over the competition.

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# Standard Issues

*Like making law and sausages, standards development is an important, but messy process.*

Nancy Bartels

**S**tandards are not unlike gears themselves: mundane, but complex, ubiquitous and absolutely vital. Standards are a *lingua franca*, providing a common language with reference points for evaluating product reliability and performance for manufacturers and users. The standards development process provides a scientific forum for discussion of product design, materials and applications, which can lead to product improvement. Standards can also be a powerful marketing tool for either penetrating

new markets or protecting established ones.

No wonder then that their development and publication is an important part of the work of major technical societies, including AGMA. AGMA's input into gear standards development here and overseas causes ripples that reach all the way to the floors of the tiniest gear shops.

Because of the globalization of manufacturing, interest in developing common international standards has grown. AGMA plays an important role in this development. In addition to developing

national standards, it serves as the secretariat for work on international gear standards. Working through ANSI, the American National Standards Institute, it is responsible for processing documents as they are developed. It also oversees and arranges the various committee meetings, organizes ballots, supervises editing, handles logistics, distributes reports of meetings, etc.

Fig. 1 shows the relationship of the various national standards bodies. In reality, the process of developing common standards is not nearly so tidy. Different company and national interests, various interpretations and understandings about what is important, differing personalities and agendas on the part of the delegates, all have to be factored into the equation.

## An Ever-Receding Horizon

In truth, developing all universal gear standards may not be possible, at least in the foreseeable future. For example, until U.S. gear buyers accept metric units, if they ever do, two sets of measurements will be used.

AGMA continues to develop its own standards for use in the U.S. Its goal is to harmonize its standards with those of ISO, but at the same time, parallel development continues. At present, AGMA has standards regarding some issues that ISO does not cover. ISO's 18 standards

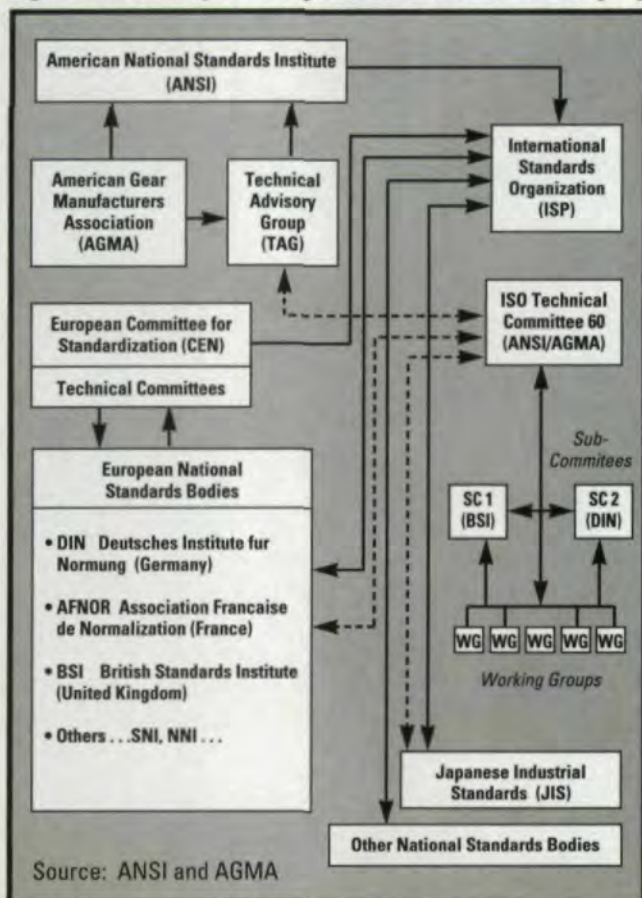
cover rating nomenclature, tooling and geometry, while AGMA's 58 standards also cover materials, enclosed drives, lubrication and other issues.

At the same time, AGMA closely evaluates ISO gear standards development and decides whether to incorporate its work into AGMA standards. It also sends delegates to ISO standards meetings to ensure that the U.S. has input into ISO standards development.

According to AGMA Technical Director, Bill Bradley, the goal of AGMA and ISO is to have good international standards that everyone can use. The approach to this goal is an incremental one. Standard by standard and meeting by meeting, AGMA and the other national standards-making organizations are working to bring their various standards closer and closer together.

## Consensus by Compromise

According to Bradley, some of the issues that make international standards development an exercise in the fine art of compromise are the varying formulas used for determining gear performance and design, differences in understanding what these formulas mean and how they are to be implemented, differing national and company interests and different cultural expectations.



Source: ANSI and AGMA

Fig. 1 — Framework for the development of international gear standards.



## CURRENT AGMA STANDARDS PROJECTS

STANDARD/INFO SHEET	AGMA COMMITTEE	DOCUMENT NAME
903-AXX	7c	Scoring Design Guide—Aerospace Gears
912-AXX	3a	Mechanisms of Gear Tooth Failures
913-AXX	3a	Profile Shift (Addendum Modification)
916-DXX	3b	Fine-Pitch, On-Center Face Gears
917-BXX	3b	Design Manual; Parallel Shaft Fine-Pitch Gearing
920-AXX	3c	Plastic Gearing Materials
921-AXX	7g	Guide for Wind Turbine Drives
922-CXX	6e	Load Classification & Service Factors; Flex Couplings
923-AXX	5c	Gear Material Grade Specifications
924-AXX	5c	Metallurgical Practice for Ind. Carburized Gearing
925-AXX	5a	Lubrication Effects on Distress (Scuffing, etc.)
926-BXX	7c	Procedure for Carburized Aerospace Gears
927-AXX	5a	Gear Tooth Load Distribution Calculations
928-AXX	4b	Inspection Data Electronic Interchange Protocol
929-AXX	5b	Calculation for Bevel Gear Topland Tooth . . . .
930-AXX	3d	Load Capacity of Powder Metal Gears
931-AXX	4c	Calibration Alignment
1002-BXX	4a	Gear Cutting Tools, Fine- and Coarse-Pitch Hobs
1006-AXX	3c	Tooth Proportions for Plastic Gears
1106-AXX	3c	Metric Tooth Proportions for Plastic Gears
2003-BXX	5b	Rating Pitting Resistance & Bending Strength, Bevels
2009-AXX	4b	Classification & Inspection of Bevel Gears
2011-AXX	6a1	Wormgear Tolerance & Inspection Methods
2113-AXX	4c	Measuring Machine Calibration—Alignment
6001-DXX	5e	Design of Components of Enclosed Drives
6007-AXX	3c	Test Methods for Plastic Gears
6008-AXX	3d	Powder Metallurgy Gears
6009-AXX	6c	Gearmotor, Shaft Mount & Screw Conveyor Drives
6010-FXX	6b	Spur, Helical, Herringbone & Bevel Enclosed Drives
6011-HXX	7b	Specification for High-Speed Helical Gear Units
6025-DXX	4d	Vibration Enclosed Helical & Spiral Bevel Drives
6030-DXX	6a2	Design of Industrial Double-Enveloping Wormgears
6033-BXX	7a	Standard Marine Gear Units, Materials
6110-FXX	6b	Spur, Helical, Herringbone & Bevel Enclosed Drives
9001-BXX	6e	Lubrication for Flexible Couplings
9004-AXX	6e	Flexible Coupling Mass Properties
9008-BXX	6e	Dimensions for Gear Coupling Flanges
9009-DXX	6e	Nomenclature for Flexible Couplings
9102-AXX	6e	Metric Bores & Keyways for Flexible Couplings

Take the case of developing a formula for applying load to gear teeth as an example. There are a number of ways to do this. Which way should go into the standard? Should two or three ways be put in and let the user decide which to use, or should one be specified? If so, which one? Or should a new formula that incorporates the best of all of them be developed?

All of these issues—and similar ones for every standard—have to be hammered out.

One of the most obvious cultural differences that must be worked around is the reluctance of the U.S. to adopt the metric system. ISO

wants—and needs to have—standards stated in metric. But it's not enough to convert measurements from one system to the other. ISO would prefer to have standards in "hard" metric; that is, developed in metric from the ground up. Such standards for gears are easier to work with if tooling is already set up in metric increments.

On the other hand, many U.S. companies are still oriented toward working in inches and feet, and it does not seem likely that the U.S. will abandon the old pound-inch measurement system any time soon. Given that fact, AGMA standards will

have to accommodate both measurement systems for some time to come.

Another important difference that affects the way standards development shakes out is the manufacturing orientation of AGMA and other U.S. standards. "Standards development should be a market-driven process. There should be a market need for a given standard before it's developed," says Bill Bradley. "Standards are no good unless they are usable in a contract."

AGMA's standards tend to reflect the "state of the market," lagging behind the "state of the art." Typically, they rely on simple empirical equa-

tions in contrast to others, such as the DIN standards, which tend to include more complex equations based on element-by-element lab testing of ideal gears. Advocates of the DIN methods point out the advantages of a strong theoretical basis, while AGMA's supporters stress ease of use and years of successful applications over a wide range of sizes and configurations. Finding a common ground between these positions is a slow process.

A factor which is of less importance to Europeans, but which is crucial to U.S. standards, is the issue of product liability. In the U.S., standards have to be very explicit about





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## GEAR STANDARDS

their applicability, the range of their application, etc. Language like "... is outside the scope of this standard," is frequently found in U.S. standards. The less litigious nature of European countries makes that language unnecessary in ISO standards.

### Corporate & National Interests

AGMA has long been encouraging manufacturers to get more involved in standards development by sending delegates to standards committee meetings. "They should be involved," says Bradley, "because they're the ones who know what the markets have been asking for. They have the field experience to say what's realistic."

But this involvement can impede compromise. Obviously, individual companies have specific interests they want protected. However, as time goes on, and American manufacturers become more globally oriented, the need for compromise becomes more apparent and looking beyond narrow self-interest becomes easier.

The same is true of various national interests. The way standards are written can, intentionally or not, favor practices in one country over those of another. Overcoming this national interest in the push for a common benefit is one more element that has to be accommodated in the process.

Perhaps surprisingly, this obstacle is not as big as it might be. "There's not as much nationalism or company protectionism as you might think," says Bradley. "People on the committees tend to think more about the technical aspects of the prob-

lem. We've all learned to develop a consensus."

### A Knowledge Bank

In the midst of all this jockeying for position and accommodating a variety of interests, one important function of gear standards making tends to get lost: that of providing a repository of gear knowledge. The professionals who serve on the standards committees bring a wealth of theoretical and practical experience to the table. In the process of hammering out the final form of the standards, much of this knowledge gets preserved and transmitted. If gear standards served no other function, this would be a vital one.

"The U.S. gear industry is old and is consolidating," says Bradley. "There are fewer good, experienced gear engineers, and we need all of them to work on standards in order to keep up their quality. If one waits for others to do the standards development, they will! For the U.S. to continue to be truly competitive, we must participate and take a leadership roll in developing industry standards."

### The 9000 Series Controversy

At present, the standards that are getting the most attention are the 9000 series of quality standards. AGMA does not have a comparable set of standards and has no official position on whether these standards should be adopted by individual companies. ISO 9000 series standards can be applied to the entire manufacturing process, but AGMA is interested only in gear standards. It does not write quality method standards.



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## GEAR STANDARDS

However, these standards have caused a good deal of controversy. Many people both in the U.S. and Europe feel that the ISO 9000 standards were never intended to be vehicles for third-party certification, but rather were meant to be used internally by companies for their own evaluation purposes. The development of a lucrative third-party certification industry, the concerns of smaller companies about the high cost of qualification, and the debates about the qualifications of registrars and consultants have led some to reconsider the entire ISO 9000 certification process.

The advent of the Big Three automakers' QS-9000 program has only complicated the issue. This program is not a product of the original ISO 9000 series, but a separate set of quality standards which is now being demanded by Ford, GM and Chrysler. The pros and cons of this program and its effect on the ISO 9000 series are the subject of still more debate.

### AGMA's Overall Goal

The development of common standards may seem glacially slow at times, but progress is definitely being made. At any given time, AGMA has between twenty and twenty-five active committees at work on one and sometimes two or more standards. (See the attached list of current AGMA projects.) In addition, some committees are working on information sheets, which contain material that is not included in standards, but is useful or needed to apply standards effectively.

AGMA's goal is to bring AGMA and ISO standards into harmonization as soon as the gear industry will accept a single standard, but progress is slow and tedious. It takes two to three years to revise or develop a standard, depending on how active a committee is. And committees are all made up of volunteer members.

### The Best of Times; The Worst of Times

Ironically, times like these, when business is good, can be one of the worst times for standards development. Some companies are too busy to let valuable employees have time away from the office to attend standards committee meetings. On the other hand, when business is poor, companies can't afford to let employees attend. Willingness and commitment on the part of both individuals and their employers are crucial to the success of the various standards committees.

International standards development may be a bit like making law and sausages—a messy process whose result is not necessarily to everyone's liking. But it is an important one. As business becomes more and more global, the push to harmonize standards, although it may come in fits and starts, will certainly continue. ⚙

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**NORTON TOOLROOM SCHOOLROOM**

The Norton Company offers this course in various cities around the country during the weeks of **Nov. 10 and 17**. The course is a one-day seminar focusing on how to select and use grinding wheels for optimum efficiency and results. It will cover grinding theory, bonded abrasive basics, wheel selection, dressing, superabrasives, mounting and truing and grinding wheel safety. Contact Norton at 508-795-5000 or fax 508-795-2688 for more information.

**EDUCATION SYSTEMS WORKSHOP, INC.**

Steel Mill Gearing Symposium, Sharon Station Square Hotel, Pittsburgh, PA. Held **Nov. 13-14**, this course will cover steel mill drive systems using the gear units as reference points. The use of gear standards, optimum gear tooth modification metallurgy and drive lubrication for all types and geared drive systems for steel mills will be discussed. The course should be of particular interest to maintenance personnel, operators, engineers, metallurgists and researchers, as well as manufacturers of drive components, mill builders, service personnel and consultants. Contact ESW at 219-865-1318 for more information.

**SME AUTOFACT '96**

Conference and exhibition will be held **Nov. 12-14** at Cobo Center, Detroit, MI. Autofact '96 is billed as the industry's premier conference and exposition for products and processes for design engineering in manufacturing. Exhibits and seminars on a variety of subjects of interest to design and process engineers and managers, including CAD/CAM, EDM, rapid prototyping, systems and communications and factory automation. Contact SME at 800-733-4763, 313-271-1500 or fax 313-271-2861 for more information, or check the SME web site, <http://www.sme.org>.

**AGMA GEAR SCHOOL**

This final session of the year will be held at Richard J. Daley College, Chicago, IL from **Nov. 18-22**. The course is designed for employees with at least six months' experience in setup or machine operation, and it covers setup, gear inspection, gear calculations and basic gearing principles. Call Susan Fentress at AGMA, 703-684-0211 or fax 703-684-0242 for more information.

**SPC AND METROLOGY FOR GEAR MANUFACTURING**

Two-day course in SPC will be held **Jan. 21-22, 1997**, and a one-day mini-course in Understanding Gear Metrology will take place on **Jan. 23, 1997**. Both courses will be held in Indianapolis, IN, and are sponsored by SME. For more information, contact Cherrie Bacon at SME Headquarters, 313-371-1500, x 358 or e-mail: [bacoche@sme.org](mailto:bacoche@sme.org). Information is also available on the SME web site, <http://www.sme.org>.

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# New Gear Developments at IMTS

The International Manufacturing Technology Show provided one of the biggest ever marketplaces for buying and selling gear-making equipment, with 121,601 attendees, making it the largest IMTS ever. The show took place September 4-11 at McCormick Place in Chicago, IL.

The gear industry made a strong presence at the show, with the introduction of the Gear Pavilion at IMTS. The new focus area allowed visitors to find most of the companies who sell gear manufacturing machinery all in one place.

Several key gear industry companies made announcements or introduced new machines that should have an impact on gear manufacturing for many years to come.

## Gleason to Acquire Pfauter Group

Gleason Corporation shocked the gear industry just before the show opened by announcing that it had reached an agreement in principal to acquire all assets of the Hermann Pfauter Group, based in Ludwigsburg, Germany.

The purchase will include Pfauter's gear machinery manufacturing operations in Germany, Italy and the United States as well as the company's 76% interest in Pfauter-Maag Cutting Tools, L.P., located in Loves Park, IL. The Pfauter Group employs about 1,050 worldwide and had combined sales of \$175 million in 1995.

According to Gleason and Pfauter management, the entire deal took place over the last few weeks before IMTS and was kept under tight wraps so an announcement could be made at the show.

"Pfauter has long been recognized as a leading supplier of cylindrical gear production equipment, as Gleason has for bevel gear production equipment. The combination of our two companies will create an excellent strategic fit that will expand our product line, substantially enhance our ability to provide our customers fast and effective solutions to their gear processing needs and offer significant benefits from combining technology, production capabilities and distribution channels," said James S. Gleason, chairman and president of Gleason Corporation.

## Mitsubishi Debuts 3-in-1 Gear Center

A unique machine that combines hobbing, deburring and rolling in one machining center was demonstrated for the first time at IMTS by Mitsubishi Machine Tools USA.

The GT06R is aimed directly at automotive manufacturers—it can produce one AGMA Class 10 gear every 10-15 seconds. One machine and one operator can produce gears that leave the machine ready for heat treating.

The machine has a maximum hob speed of 4,000 rpm and a maximum table speed of 750 rpm. It measures 13.2 feet by 11.5 feet. Also available is a GT06S model, which replaces the rolling function with a shaving function to finish the gears.

## Fellows Introduces Direct-Driven Shaper

The new FS180 Mark III CNC Hydrostroke gear shaper features six servo-driven axes of motion for higher-speed cutting cycles. In addition, the machine is being introduced at a lower price than that of the previous model.

The manufacturer claims the machine may reduce cutting cycle times by as much as 35% with speeds up to 2,000 strokes per minute. It handles pitch diameters up to 7" and face widths up to 1 1/4", which makes it appropriate for automotive transmission applications.

## Gleason Knowledge System Demonstrated



The Gleason Works introduced a new software system for its PHOENIX 125GH CNC hobbing machine. The software, installed on a personal computer, provides the machine operator with setup, startup, operational, troubleshooting and maintenance information.

The system combines the knowledge of Gleason's technical experts to include complete fault diagnostics with suggested remedies, a complete set of replacement parts drawings, animated tutorials to explain key concepts and complex procedures and training modules to help the user get accustomed to the machine interface and control panels.

## Bourn & Koch Redefines Small Footprint

The Model 25H hobbing machine demonstrated by Bourn & Koch Machine Tool Company is a 4-axis CNC hobber for 1" maximum diameter and 4" maximum face width gears.

The machine is almost a desktop model, occupying a 30" x 30" space on the floor. It includes auto hob shift, double cut and crowning capabilities and can use carbide or HSS hobs.

## Star Cutter Introduces Tool & Cutter Grinder

Elk Rapids Engineering, a subsidiary of Star Cutter Company, demonstrated its new UTG-300 CNC five-axis tool and cutter grinder, which includes Windows-format software for sharpening hobs, shaper cutters, broaches, end mills, taper fluted tools and Maag-style cutters.

## Pfauter-Maag Introduces Shaving Cutter Line

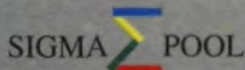


Pfauter-Maag Cutting Tools, L.P. announced that it has begun offering a complete line of shaving cutters, including standard, underpass, plunge and diagonal-type cutters in a range of sizes and accuracy capabilities.



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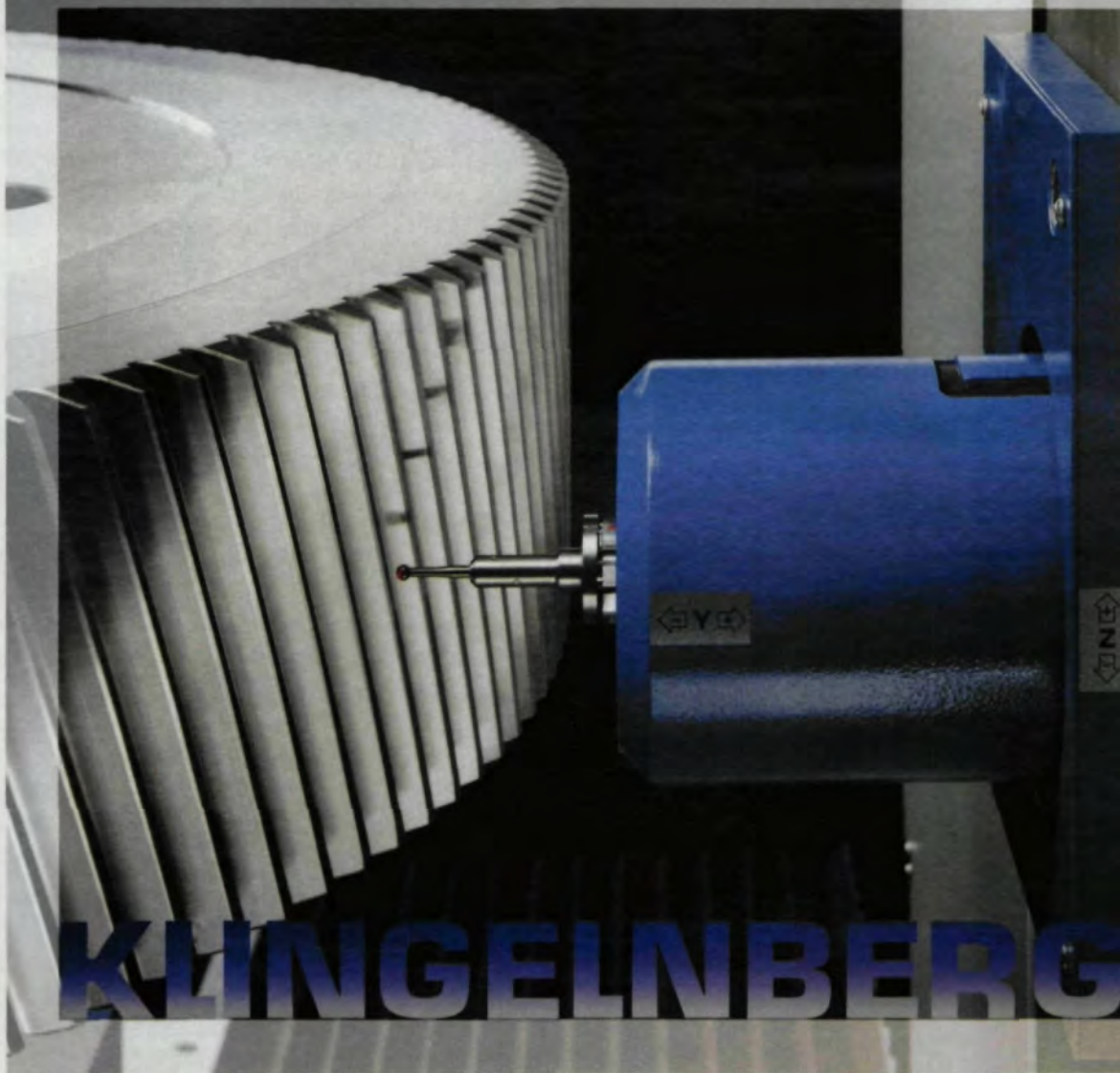
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# The Advantages of Ion Nitriding Gears

*This process can eliminate the need for expensive post-heat treatment operations.*

**Robert Lamont, Jr. & A. Bruce Craven**

**W**hen it comes to setting the standard for gear making, the auto industry often sets the pace. Thus when automakers went to grinding after hardening to assure precision, so did the machine shops that specialize in gearing. But in custom manufacturing of gears in small piece counts, post-heat treat grinding can grind away profits too.

One alternative that has yet to be fully exploited by the gearing industry is ion nitriding. General Motors' Allison Division has ion nitrided 4140 steel diesel engine gears, Ford has used the process for certain models, and perhaps a dozen commercial heat treaters around the United States provide ion nitriding services to machine shops. Here—from the perspective of a custom gear shop and a heat treater—are some of the advantages that ion nitriding offers gear makers.

## Advantages of Ion Nitriding

For any manufacturing operation, grinding adds not only time and labor, but also an element of risk. Grinding has become a routine part of gear making, primarily because the heat treating processes that harden load-bearing parts such as gear teeth also introduce thermal stresses that cause distortion. But unlike induction hardening, a commonly used surface hardening process in which gear teeth are hardened tooth-by-tooth or one at a time, ion nitriding introduces favorable compressive stresses.

Ion nitriding is performed in a precision-sealed vacuum furnace. After the air is evacuated (to less than 100 ppm of air), a small partial pressure of hydrogen and nitrogen gas is bled into the chamber, and the vacuum is maintained at about 5 torr (atmospheric pressure is 760 torr). Then, energizing the parts to a negative (approximately 500 volt) potential initiates an electrical plasma of gaseous ions. The positively charged ions are attracted to the part, subsequently reacting with the alloy elements of the steel part to form nitrides. The nitriding temperature is significantly lower than that of induction hardening or carburizing—specifically, 950°F. Moreover, with ion nitriding, there is no need for a liquid quench, eliminating another source of adverse stresses and distortion. Eliminating most heat treat-induced distortion is critical for any manufacturer, particularly smaller machine shops with limited equipment for secondary operations such as grinding and straightening.

## Practical Applications

How do these theoretical advantages translate into everyday practice? At Atch-Mont Gear, a good customer requested a Class 10 gear with hardened teeth. A Class 10 gear is not that hard to machine, but typical practice for a 4140 gear (either annealed or pre-heat treated) would have been to induction harden the *gear teeth only* for better wear characteristics. The distortion introduced by induction hardening or carburizing lowers the class number (or precision) because of the high process temperature (in excess of 1600°F) and subsequent quench. Lacking the ability to grind all types and sizes of gears, Atch-Mont's only option for returning the gear to the required precision appeared to be sending the piece out for tooth grinding. This was cost prohibitive.

Fortunately, Atch-Mont has had some customers who requested gas nitriding with ammonia, so the company was familiar with nitriding's low-distortion benefits. Solar Atmospheres, a commercial heat treater specializing in vacuum processing, suggested the piece would be a good candidate

Table 1 — Case Depth

Steel Grade	Typical	Practical Maximum
1045	.001" – .002"	.002"
4140	.010" – .012"	.025"
4340	.008" – .010"	.015"
A-2, D-2, H-13	.008" – .012"	.015"
400 Series S/S	.004" – .006"	.010"
300 Series S/S PH S/S (17-4, 17-7, etc.)	.003" – .004"	.005"



for ion nitriding. Atch-Mont told the customer it couldn't *guarantee* Class 10, but could ion nitride and lap the gear teeth if necessary. The results were successful.

#### **Ion Nitriding Worm and Pinion Shafts**

Worm and pinion shafts are also good candidates for ion nitriding. Parts that are usually made from 8620 steel and carburized, or from 0.4 carbon medium alloy carbon steel and induction hardened need to be rough machined with extra material on the journals. This allows for finish machining to overcome the distortion resulting from carburizing or induction hardening. With ion nitriding, this is not a requirement.

Worm gears—typically made from 8620, 4615 or 1045 steel—have a tendency to unravel when carburized or induction hardened (because of the higher temperature process), which means they have to be ground afterwards to make them straight and true with respect to the bore (or centerline). At Atch-Mont, engineers found that by making the gears of pre-heat treated 4140 steel and ion nitriding them, nearly the same hardness could be achieved. Herringbone gears will respond with the same positive results.

At Solar Atmospheres, gears in the 10–12" diameter range are commonly ion nitrided, and gears of up to 30" in diameter can be accommodated. Gear materials most commonly ion nitrided are the medium alloys—the 4000 and 5000 series steels and, occasionally, the 6000 series steels. Stainless steel, which is very hard to gas nitride without mechanical or chemical surface treatments prior to processing, can be ion nitrided, although not as easily as the medium alloys. (The high percentage of chromium and nickel develops very hard surface nitrides that saturate the metallurgical structure quickly, making the ultimate case depths shallower than the alloy steels.)

Ion nitriding introduces minimum growth on the order of .0001—.0002" per side and requires less processing time than gas nitriding. But the real advantage for a machine shop is the reduced number of machining steps coupled with the quick turnaround, which results in faster manufacture. It can also give manufacturers more material selection choices. The resultant benefits are moderate surface hardness gains with deep case depths in medium alloy steels, high surface hardness with shallow case depths in stainless steels and high surface hardness with modest case depths in tool steels.

#### **Masking**

With ion nitriding, workpieces may have to be masked to insure that surface hardening occurs only where it is supposed to. Sometimes this is

relatively easy; i.e., gears can be stacked, permitting nitriding of the teeth with just the topmost pieces requiring a mask to cover the face and bore. But even when individual pieces have to be masked with a stop-off paint—a time-consuming but effective process—Atch-Mont Gear feels it's well worth it to "get the gear we want."

Currently, ion nitriding is used for gears up to 30" or 36" in diameter. In fact, the authors believe it is technically feasible to produce ion nitrided gears that would compete with many carburized gear applications. Most ion nitriding heat treating shops do not have the equipment capability to handle the 30" or larger gears.

One of the factors contributing to the relative scarcity of ion nitriding is the high cost of the machinery required. As interest and demand increases, however, the large capital outlay is being overshadowed by the business potential, and companies like Solar Atmospheres are looking to this area for expansion.

It is this heavy investment in equipment, as well as a lack of education as to the potential of ion nitriding, that the authors believe have kept the process from taking off in the United States as it has in Germany and other European countries. In addition, equipment problems when ion nitriding was first introduced in this country created the image of an unreliable process that has stuck in the minds of some engineers. While this is no longer a valid objection, it is true that ion nitriding furnace operators must be carefully trained, as the process is more technically challenging than gas nitriding.

These factors need not concern custom gear makers or tool and die shops, however, since there are commercial heat treaters who have expertise in developing processes even for runs of one or two parts. With ion nitriding's ability to eliminate many secondary operations and to turn jobs around relatively quickly, it's a process worthy of the machinist's consideration. ☉



Fig. 1 — A load of gears before (left) and after ion nitriding.



Fig. 2 — Parts as loaded for ion nitriding on the furnace hearth plate.

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For more information about **Atch-Mont Gear Inc.**, circle 204.

For more information about **Solar Atmospheres, Inc.**, circle 205.

#### **Robert Lamont, Jr.**

is the former president of and a consultant for Atch-Mont Gear Inc. of Ivyland, PA.

#### **A. Bruce Craven**

is Vice President, Engineering, of Solar Atmospheres, Inc., Souderton, PA, a commercial vacuum heat treating company.



# Dry Hobbing Saves Automaker Money, Improves Gear Quality

*Dry hobbing delivers a breakthrough in productivity, economy, cycle times, tool life and part quality.*

David Arnesen

It takes confidence to be the first to invest in new manufacturing technology. But the payback can be significant. That has been the experience at the Ford Motor Company's Transmission & Chassis Division plant at Indianapolis, IN, which boasts the world's first production application of dry hobbing.

Beginning in July 1994, Ford began installing Liebherr LC 82 CNC hobbing machines to hob steering pinions (SAE

1045, 22 Rc). According to Ford manufacturing engineers, dry hobbing with carbide cutters has reduced machining costs by 44%, shortened cycle time by 48% and increased tool life by a factor of 6. So far.

## Goal No. 1: Improve Pinion Quality

The task at Ford's Indianapolis plant was to improve gear quality—surface finish and pitch diameter runout—and meet increased production demands. After determining that existing hobbing

machines using standard coated HSS hobs with coolant were incapable of meeting the plant's targets, the engineers investigated new technology.

After extensive research and subsequent testing at Ford, carbide hobbing without coolant showed the most promise in meeting quality goals and offered the additional potential of greatly extended tool life and lower maintenance costs. During test cutting of the steel pinions, the process demonstrated a Cpk of 3.0, and tool life was far longer than was achieved with any steel hob. The process testing was completed using carbide hobs on a Liebherr CNC hobbing machine specifically designed for carbide dry hobbing.

## More Speed, Greater Horsepower

To properly utilize the advantages of carbide, a hobbing machine must be capable of increased speeds and greater horsepower than is typical of conventional machines. The Liebherr machine table can achieve speeds up to 450 rpm; the hob head is equipped with a heavy duty drive that permits speeds up to 3,000 rpm with drive power to 18 kW (25 hp), several times that of the conventional hobbing machines at Ford.

The combination of carbide hobs with maximum diameter of 90 mm (3.6") and the new machines, which have cutter spindle speeds of 2,000 rpm, enabled hobbing at 850 sfpm, much greater than the capability of conventional production machines.

The higher cutting speed reduced machining times to approximately 22 seconds from 42 seconds previously with HSS. A workpiece load/unload mechanism built into the hobber and closely coordinated with workpiece



View of the pinion, hob and tailstock in the Liebherr LC 82. The workpiece load/unload mechanism built into the hobber, closely coordinated with workpiece clamping, reduced Ford's chip-to-chip time to about 4 seconds.



clamping reduced Ford's chip-to-chip time to about 4 seconds.

Because the pinions are held rigidly in place during machining by hydraulic gateways driven by cams, part movement or deflection is prevented, and the potential for runout, feed scalloping and chatter marks is reduced. The result is that surface finish improved to between .5 and .75 Ra from 1.1 to 1.5 Ra.

In the first year of production, Ford Indianapolis immediately achieved significant gains in tool life, more than offsetting the higher initial cost for carbide cutters. Because heat is the main factor affecting tool life, the engineers made several further changes to allow the cutter to run even cooler. These included different coatings, recently developed carbide materials and hob geometry.

To reduce heat build-up at the edge of the cutter and increase the shearing action, the rake angle was increased to 5°. The number of gashes was reduced to 12 from 15, allowing more room for chip evacuation.

#### Documented Benefits

Data from the Ford experience clearly points to the benefits of dry hobbing. According to Ford manufacturing engineers, tool life improved to 252,000 pinions per hob (14 regrinds) using dry carbide from 39,000 pinions per HSS hob (12 regrinds) on existing wet cutting machines. Machining cost fell by 44%. In addition, Ford found that the process is very stable, maintaining exceptional consistency well within the process capability specifications.

Increasing the cutting edge rake angle and changing the coating to TiAlN is now being tested, and Ford is now achieving up to 33,000 pinions per



Dry hobbing produces Ford steering pinions in 48% less time, at 44% less cost and improved gear quality.

regrind, with the potential of getting nearly 300,000 pinions per cutter.

The primary goal was to improve quality and production economy, but the plant also achieved a Ford 2000 environmental goal by eliminating the use of cutting oils and coolants. Operators like the rapid, coolant-free cycling. It's environmentally safer and cleaner with no cutting oils and mist.

A search for a better quality pinion at Ford Motor Company yielded a process

that not only produced a better surface finish, but reduced piece cost and cycle time. It also provided the additional advantage of coolant-free operation, saving costs and improving operator morale. ☉

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## TOS ČELÁKOVICE GEAR HOBGING AND SHAPING MACHINES



Gear Hobbing Machine, Model OFA 32 R

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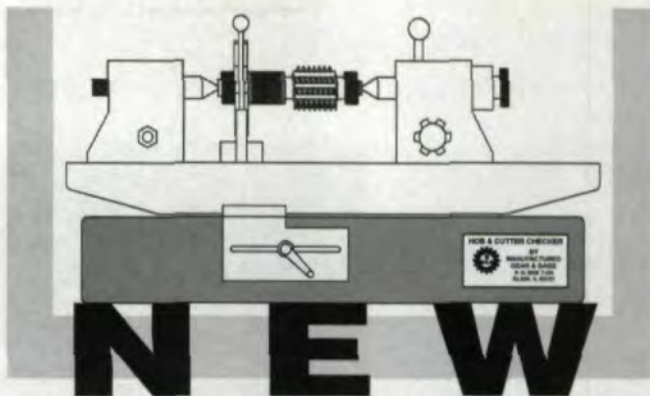
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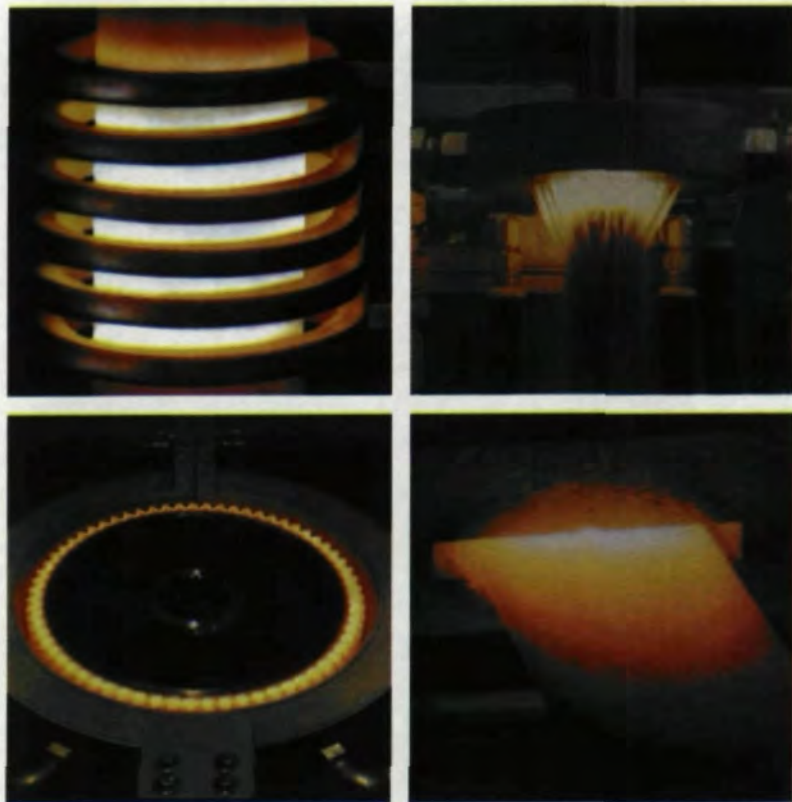
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# Chamfering and Deburring External Parallel Axis Gears

Basavaraj Nyamagoudar

**T**he chamfering and deburring operations on gear teeth have become more important as the automation of gear manufacturing lines in the automotive industry have steadily increased. Quieter gears require more accurate chamfers. This operation also translates into significant cost savings by avoiding costly rework operations. This article discusses the different types of chamfers on gear teeth and outlines manufacturing methods and guidelines to determine chamfer sizes and angles for the product and process engineer.

## Why Chamfers?

Chamfers are needed in gears:

- To prevent nick and bump damage along the active tooth surface after the shaving or finishing operation;
- To prevent burrs and sharp edges which cause gear noise;
- To prevent the break-off of burrs and sharp edges during torque transfer when the gears have been assembled in boxes or transfer cases;
- For cosmetic reasons.

In the last few years, gear manufacturers have intensified their efforts to prevent or reduce nick and bump damage. Handling systems have ratchet conveyors, which prevent the gears from touching each other. Special baskets are used to protect the gears from accidental damage during heat treatment process. Operator training has stressed the careful handling of gears at every stage of production. In spite of all these steps, the problem still persists. The number of gears rejected because of nicks can range from 10–60% of a batch. Nicks modify lead or involute characteristics, causing meshing defects.

Chamfers significantly reduce noise while the gears mesh and effectively protect all vulnerable zones in the gear tooth.

## Types of Chamfers

Four chamfers are shown in Fig. 1. Chamfer A is the tip chamfer along the lead produced by the

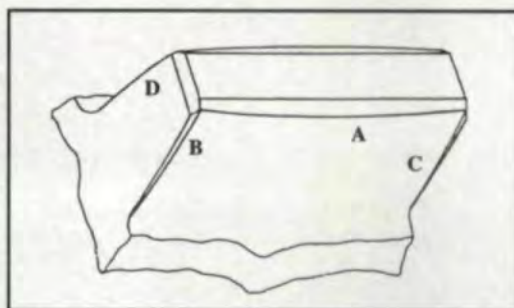


Fig. 1 — Types of chamfers on gear teeth.

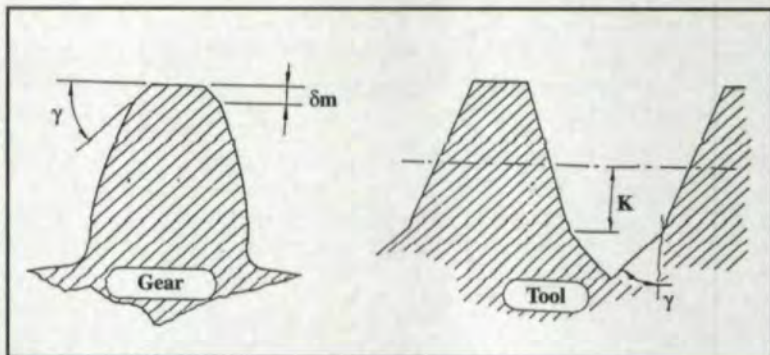


Fig. 2 — A) End of chamfer along lead; B) Basic rack of preshave tool.

preshave tool. B is the acute edge chamfer in cylindrical helical gears. C is the obtuse edge chamfer in cylindrical helical gears produced by cutting, grinding or rolling operations. D is the tip chamfer on end faces produced during the turning of blanks.

The tip chamfer along the lead is generally executed while cutting the gear with either a hob or a shaper cutter which has a modified tooth profile called semi-topping. The size of the chamfer depends on the gear's diametral pitch (the module). Generally it is

$$\delta_m = 0.10-0.15 \text{ mm}$$

$$\gamma = 30-40^\circ$$

See Fig. 2 for details.

It is difficult to maintain the size of the tip chamfer, since it is related to the tolerances of the outside diameters and gear tooth thickness. For example, gears with normal diametral pitches up

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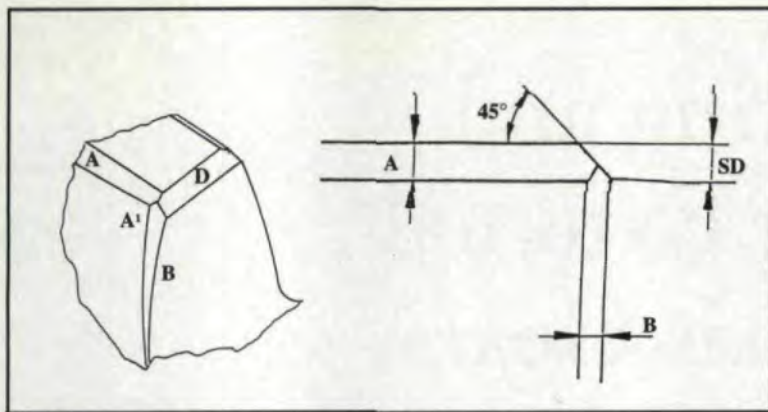


Fig. 3 — Gear tooth with edge chamfer and both tip chamfers.

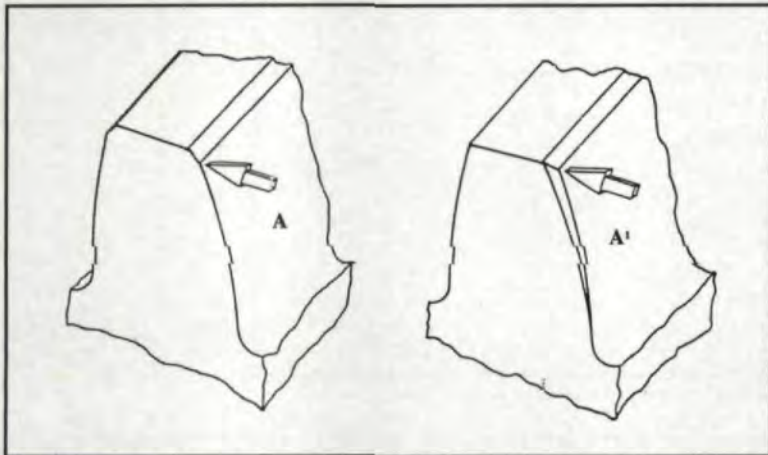


Fig. 4 — Gear tooth with tip chamfer and tip chamfer along lead and edge chamfer.

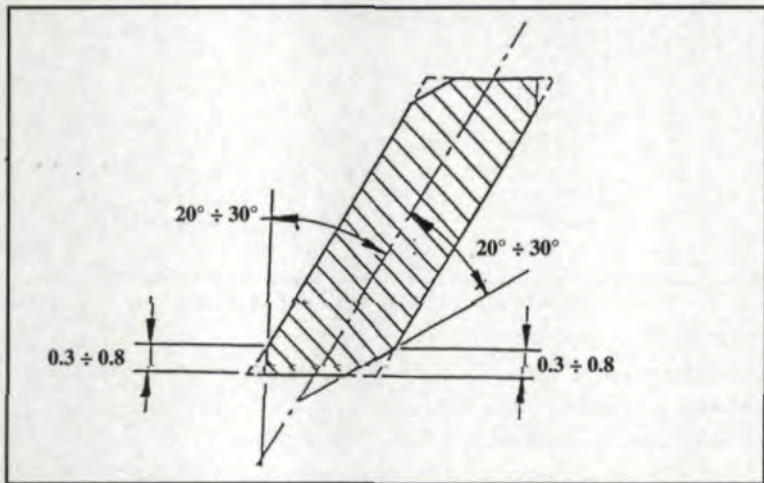


Fig. 5 — Chamfer angles must be set with exposed points as far away from the ends of the tooth as possible.

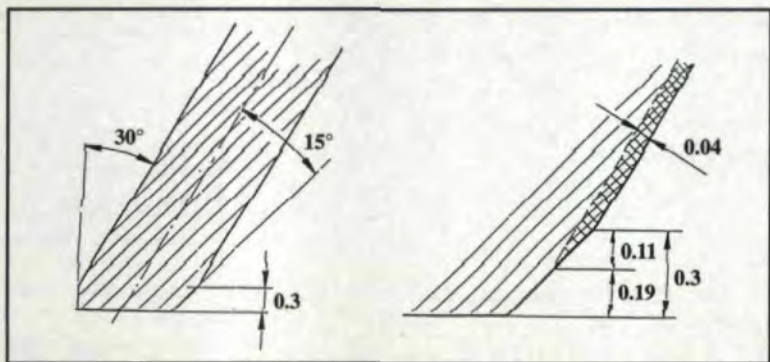


Fig. 6 — Shaving reduces the size of the chamfer to some extent.

to 8–10 (module 2.5–3.0) have an O.D. tolerance of roughly 0.008" (0.2 mm) and a variation of 0.004" per side (0.1 mm/side). The cutting tolerance on tooth thickness may be  $\pm 0.0008$ " (0.02 mm), which affects the cutting tool position. The chamfer will have the following variation:

$$\delta_m = \frac{(0.0008)}{\tan \alpha_n}$$

where  $\alpha_n$  = normal pressure angle

When  $\alpha_n = 14^\circ 30'$ ,  $\Delta\delta_m = 0.003$ " (0.077 mm).

When  $\alpha_n = 20^\circ$ ,  $\Delta\delta_m = 0.002$ " (0.055 mm).

This variation is close to 50% of the nominal value of the chamfer size. This becomes much more significant when we are dealing with gears with a normal diametral pitch (NDP) of more than 20 (or module less than 1.25). The tolerances of the O.D. and the tooth thickness exceed the chamfer's nominal value. It then becomes necessary to cut the gears with "topping" tools, which simultaneously cut the teeth and the O.D.

Sometimes when it is necessary to use as much active profile as possible because tip chamfers reduce the working diameter and the line of action, gear designs do not allow tip chamfers. In some rare instances, only a few tenths of a millimeter make up the meshing continuity. Such constraints must be resolved during the early stage of a transmission design, and the designer must make accommodations for tip chamfer.

The chamfer "D" on end faces is required for assembly purposes and for smoother meshing. The chamfer "D," which is put on the gear during turning, can actually cause more nicks than it prevents. Usually the project engineer requires an end tip chamfer without paying too much attention to its size. From Fig. 3, it can be seen that as chamfer "D" is increased, chamfers "A" and "B" provide less protection. Therefore, it should be made as small as possible and never larger than the value

$$S_d = 0.5(a + b)$$

Another reason favoring reduction of the end tip chamfer to a minimum is the presence of hobbing and shaping burrs in this area. These burrs are not removed by the usual deburring tools and may be difficult to remove if they are large. Smaller burrs usually disappear during heat treatment or shot peening. If the chamfer "D" is large and has a heavy burr, sometimes it is necessary to employ an additional deburring tool.

From Fig. 4, it is clear that in the absence of an edge chamfer, point A is more exposed to nicking. With an edge chamfer, the most exposed point, A', is shifted towards the inside and is therefore less prone to nicks. The tip chamfer is rendered



useless unless there is an edge chamfer. Edge chamfer dimensions do not have the constraints of tip chamfers, since they are made after the gear teeth are cut. Their dimensions are to some extent independent of gear tooth tolerances. Chamfer sizes range from 0.012" (0.3 mm) to 0.030" (0.8 mm). The angles need to be set so that the exposed points are as far away from the ends of the tooth as possible (see Fig. 5). As the helix angle increases, the chamfer angle (related to the tooth axis) decreases to less than 20°. For example, a 30° helix angle will lead to a 15° chamfer angle. There is some reduction in the chamfer size while shaving (Fig. 6). During this process, 0.0015" (0.04 mm) of stock is removed from each flank. If the original chamfer size was 0.012" (0.3 mm), the chamfer size after shaving would be

$$\delta_m = 0.3 - \frac{(0.04)\sin 45^\circ}{\sin 15^\circ} = 0.19 \text{ mm or } 0.0075''$$

Therefore, it is necessary to start with a larger size chamfer, maybe 0.024–0.030" (0.6–0.8 mm). The chamfer should be made without finishing with a step. Sometimes it is better to chamfer the root fillet even if this area is not susceptible to nicking. Fig. 7 shows the correct procedure for chamfering.

#### Production Methods

Edge chamfers can be produced by three different methods.

**A cutting operation.** There are two cutting methods. The machine may be designed to have a milling cutter and a gear train of CNC equipment to generate an involute. The milling cutter can be held steady with only one circular speed along its axis. In this case, the chamfer is uniform and parallel to the involute. This method produces a good chamfer, and there is no need for any additional deburring operations. On the other hand, milling is a costly operation, and it is difficult to chamfer gears lying adjacent to a shoulder using this technique. Cycle times are long in this method because of indexing, and tool life is poor.

A second way to cut a chamfer is to use a gear train or CNC equipment to index in conjunction with a cutter. The cutter has a reciprocating motion timed with the indexing motion. This type of operation usually produces the chamfer along a straight line. The advantage of this method is that no further deburring operation is required. Among the disadvantages is the fact that this method creates an uneven chamfer extending through the whole root. Sometimes burrs are left on the gear in the root area. Chamfering gears adjacent to a shoulder is also difficult with this method. Again, cycle times are long, and tool life is poor. This

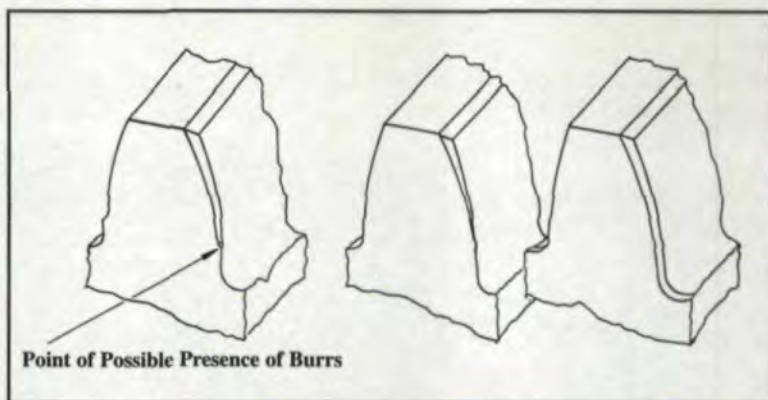


Fig. 7 — Correct chamfering procedure.

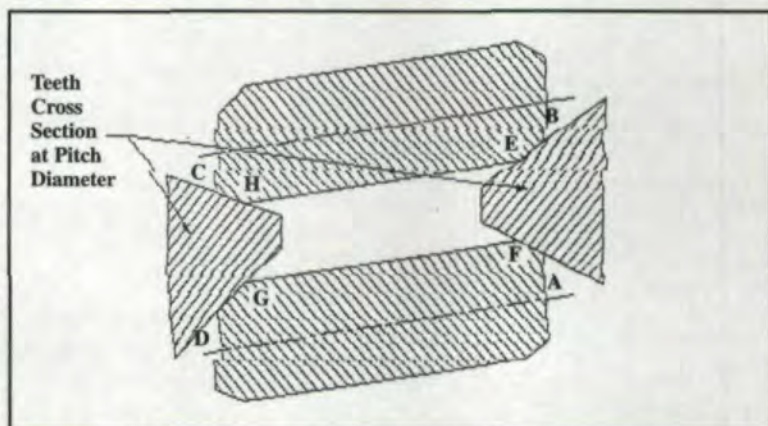


Fig. 8 — A cross section of gear and chamfering tool teeth in a rolling operation.

approach also requires a lot of operator assistance to maintain a good setup.

**A grinding operation.** In this method, a grinding wheel is used to produce the chamfers. The advantages are low cycle times and acceptable chamfers all around, but the grinding powder mixed with steel particles pollutes the atmosphere, creating Clean Air Act compliance problems and raising concerns about employee health and general environmental ethics. To counter the pollution effects, expensive filters and dust collectors are needed. Tiny burrs are created along the involute, and they need an extra cleaning operation like shot peen blast. A lot of operator assistance is required to maintain a good setup.

**A rolling operation using special chamfer tools.** This operation involves driving a chamfer tool in mesh with the gear under pressure. The pressure will plastically deform the material, producing the chamfer. Most of the material deformed plastically will flow out of the sides A, B, C and D (see Fig. 8). Tiny portions, about 0.0008" (0.02 mm), will rise up as tiny ridges inside the involutes E, F, G and H, and a very small portion will rise out of the tip chamfer (D) (Fig. 1) produced by a turning operation. Because of this, the operation must be followed by a finishing operation like shaving or grinding. It is not recommended for finished cut parts.



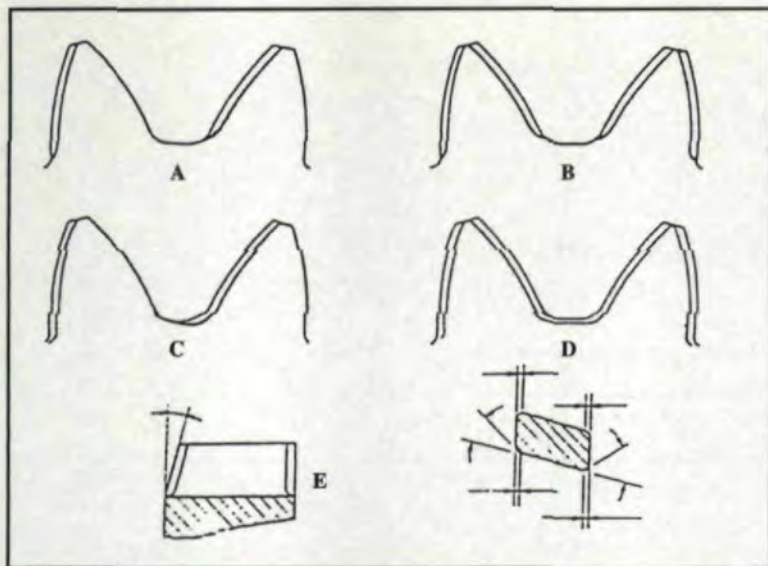


Fig. 9 — Types of edge chamfers.

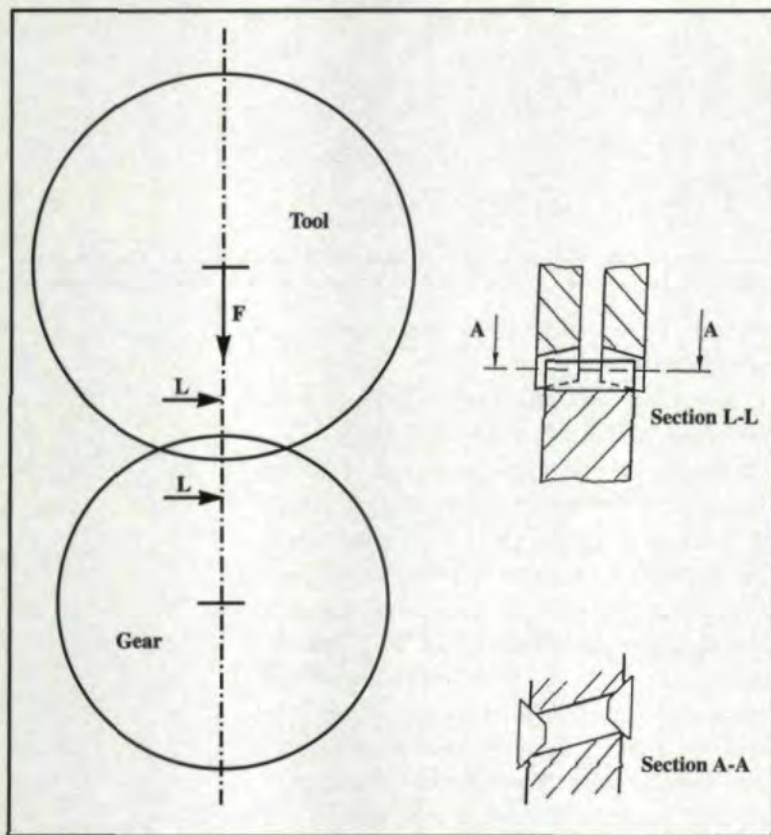


Fig. 10 — Schematic diagram of chamfer tool in mesh with gear.

The material raised along the surfaces A, B, C and D and the burrs produced during the cutting of the teeth are removed by a spring-loaded deburr tool. The chamfer and deburr operations must be carried out simultaneously to avoid pushing the burrs into the gear teeth after cutting. The chamfer tool will force the burrs out for a cleaner cut by the deburr tool. The material raised along the surface D can be minimized by designing the chamfer tool with an operating pressure angle that minimizes the sliding velocity toward the tip. A pair of burnishing tools can be added to the deburr tool group to remove the raised material along D.

The main advantage of this method is extremely long cutter life. It is quite common to chamfer more than 100,000 parts between resharping. The machine cut cycle time is only 3–4 seconds, while the floor-to-floor cycle time varies from 7–15 seconds for pinion gears. Constant sizes of chamfer parallel to the involute and chamfering the root are possible. This method can chamfer/deburr any adjacent shoulder both on the gear side and the groove side.

Some stress points should be considered when producing edge chamfers by rolling. The plastic deformations of the material should produce residual stresses along the involute surface chamfer that would locally increase the surface stress limit and reduce the stress concentration factor, thus enhancing the overall resistance of the chamfered gear. It is essential to chamfer not only the acute angle called for on most drawings, but also the obtuse angle. This gives better protection from nicks and bumps and ensures homogeneous behavior of both the flanks of the gear under load because of the residual stress.

For simplest applications, the tool used on chamfering and deburring machines consists of a set of chamfering tools and a set of skiving tools to deburr lateral surfaces. Because of the force between the tool's springs and the gear's width once it enters into the tools, the two deburring tools will spread open. Chamfering and deburring tools run free on their own quills and self-center themselves on the center line of the gear, thus assuring symmetrical chamfers and complete removal of burrs.

The tool group on a one-head machine in the simplest form consists of one set of chamfer bevel gears and one set of cutter discs mounted together as a gang. The workpiece drives the complete tool group, since it is in mesh with the chamfering tool.

The various types of chamfers that can be achieved on either spur or helical gears cover the whole range usually required for any cylindrical gears. Examples of feasible chamfers include a) chamfering only on one flank without the root; b) chamfering both flanks without the root; c) chamfering one flank and part of the root; d) chamfering the complete profile; e) chamfering inclined faces (see Fig. 9).

Each problem can be evaluated individually and tooling engineered to suit specific applications. Cluster gears can be chamfered and deburred with machines having multiheads with two working stations. To work different gears on the same machine, the tools can be designed to keep a constant center distance between the workpiece and the tool in order to reduce the changeover time.



## Chamfering Tools

Chamfering tools are engineered to generate the chamfer on the edges of the gear teeth. The chamfer is made by the rolling action of chamfering tools. In effect two bevel gears mate with the work gear only along the corner edges of its teeth. The force "F," provided by a pneumatic cylinder, represents the thrust necessary for rolling (see Fig. 10). Because of their bevel gear shape and balanced application (one pair of identical tools symmetrically coupled), opposed axial stresses are generated during rolling. As the tool group is free to move axially, it centers itself on the centerline of the gear width.

If the two tools are off center as in Fig. 11A, after the tool group is engaged, the gear will move axially until the forces are balanced. The final position is shown in Fig. 11B. This makes the chamfers symmetrical. These tools will work either spur or helical gears.

Fig. 12 describes a chamfering tool tooth. Besides being tapered, the teeth have an involute form enabling them to mesh with the gear and roll on its corners.

The angle of the tooth flanks of the chamfering tool depends on the gear helix angle and the angle of chamfers to be generated (Fig. 13).

$\beta 1$  and  $\beta 2$  = chamfer angle required by part print drawing.

$\beta$  = gear helix angle.

$\gamma 1$  and  $\gamma 2$  = flank angle on the chamfering tool teeth.

$\gamma 1 = \beta + \beta 1$ , and  $\gamma 2 = \beta 2 - \beta$ .

In order to have the chamfers correctly executed, the chamfering discs must be in such a position that the axes of the chamfer tools have the same helix angle as the gear (phasing along helix angle).

### Special Cases

When a shoulder or radius is present on the side face of the gear, the chamfering operation cannot be completed all along the profile. The chamfer must end at least 0.012" (0.3 mm) before a step or a radius begins. In cases where the gear has an angled side face, it is necessary to engineer tools with properly modified pressure angles.

### Chamfer Tool Resharpener

The chamfering tools are able to produce many thousands of pieces before resharpener. The chamfering tool teeth are not truly resharpener. Rather, the position of the chamfering disc is changed with respect to the gear so that afterward chamfers will be generated by a new area of the chamfer tool teeth that is not worn yet.

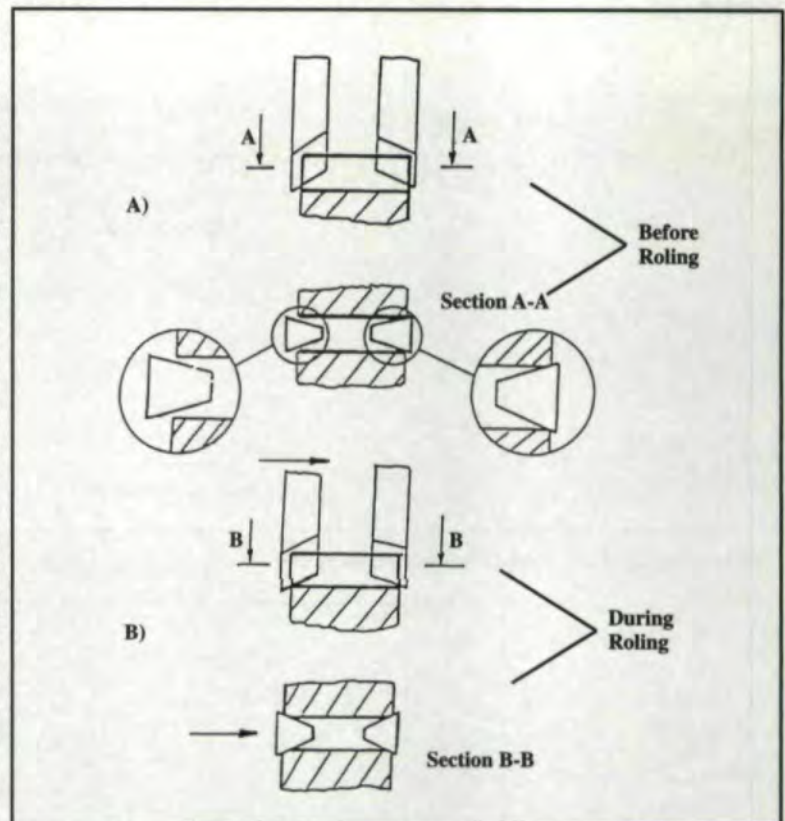


Fig. 11 — A) Nonsymmetrical chamfer tools; B) Symmetrical chamfer tools.

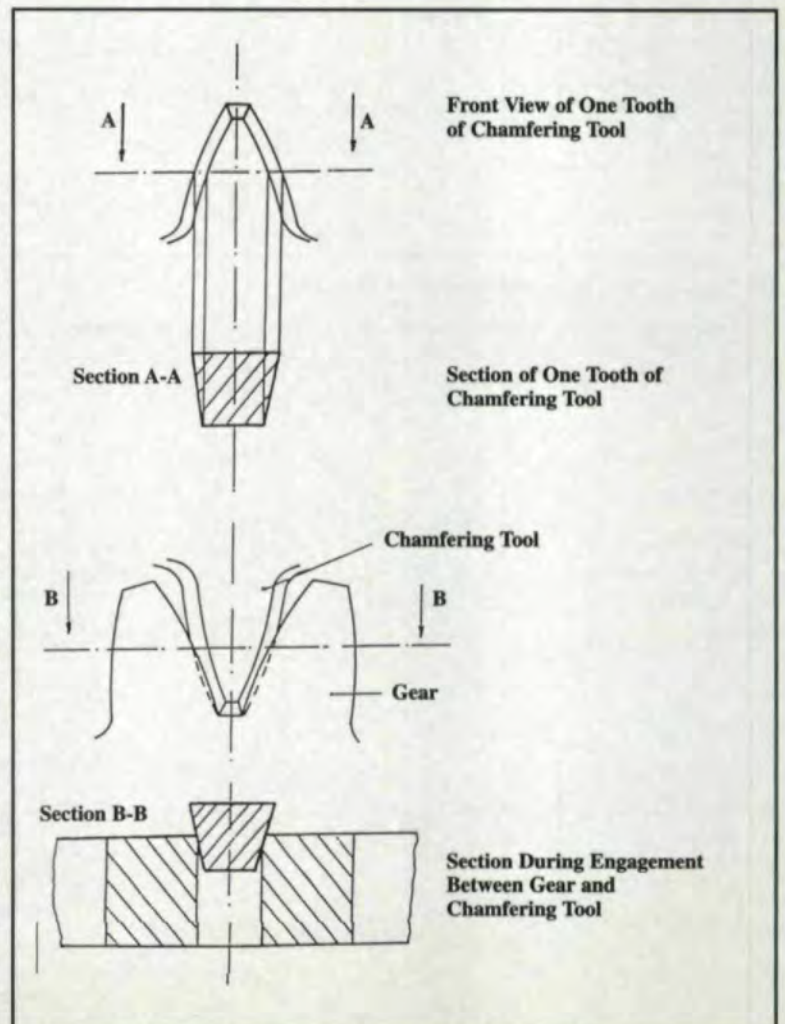


Fig. 12 — Gear tooth and chamfering tool tooth sections.



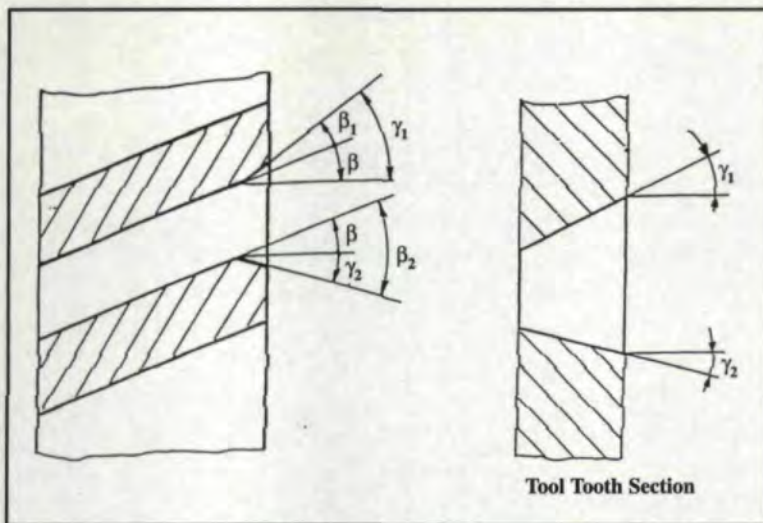


Fig. 13 — Section view of deburring tools in mesh with gear.

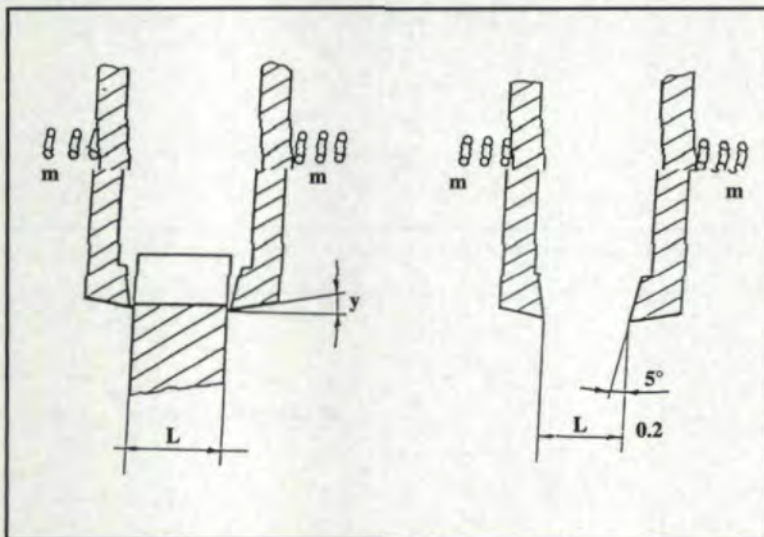


Fig. 14 — "R" type deburring tool in mesh with gear.

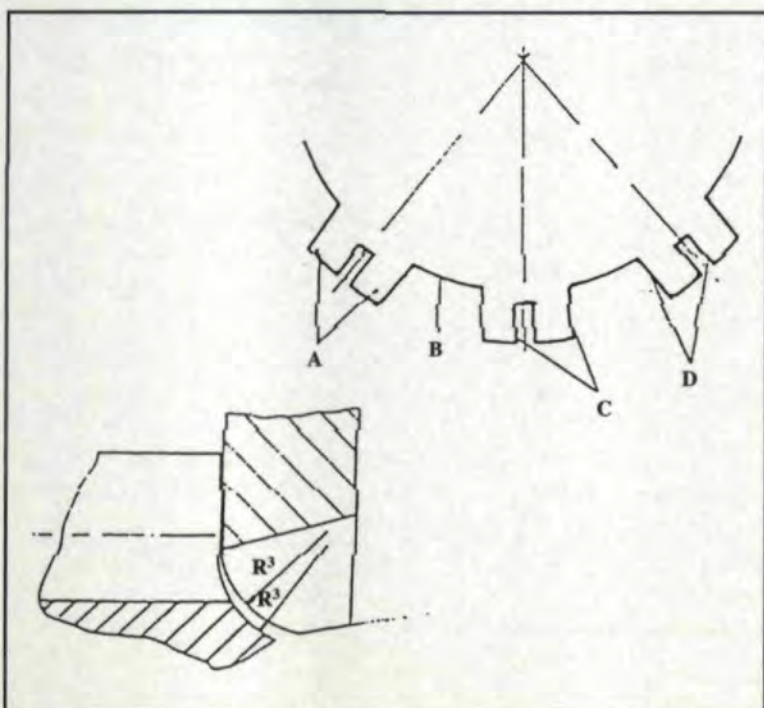


Fig. 15 — Cross sectional view of deburring tool.

Each chamfering disc can be utilized three or four times. When the chamfers no longer have a constant size from one gear tooth to another when the rolling stress rises, or when each single chamfer is no longer uniform along the profile, it is time to grind the chamfering discs in such a way that a new rolling area will contact with the edges of the gear teeth.

### Deburr Tools

Deburring tools are large diameter discs whose external rims are ground to the rake angles necessary for cutting action. The distance between the two discs is not constant because they can move axially either under the action of the springs ("m" shown in Fig. 14) or as a consequence of the self-centering with the gear to be deburred.

In the rest position, the spring pressure on the deburring discs brings their separation distance to a minimal value, which is about 0.008" (0.2 mm) less than the minimum gear width. If the distance between the discs were fixed, the discs themselves would hit the outside diameter of the workpiece, chipping it when discs are plunge-fed towards the workpiece. To avoid this, the cutting edge of each disc is provided with a tapered lead-in whose size is large enough to avoid hitting the outside diameter of the gear to be deburred. The first contact must occur between the lead-in surface and the workpiece outside diameter.

The deburring discs are rotated by the workpiece itself, and the burrs are removed through a true skiving action on the gear lateral faces. Generally 100,000 pieces or more in some cases can be deburred before resharpening the tool. The tool life between resharpenings depends upon a number of factors. They are

- The hardness and machinability of workpiece material;
- The thickness of burrs and the size of the requested chamfer;
- The length of the deburred area (workpiece whole depth);
- The presence of steps, radii or shoulders, which may interfere with the tool cutting edge;
- The correct resharpening and assembly of the tool group.

### Special Cases

For gears with shoulders or radii, special types of deburring tools are designed for a correct action of the deburring discs in order to avoid the interference. To deburr a gear with a radius (see Fig. 15), a special type of deburring tool known as an "R" type tool is used. Due to the spring loading action, the burrs are uniformly and cleanly skived off the surface by the tool following the profile of the gear. The same tool also performs the debur-



ring of the straight portion. The radius form protuberances A are alternated with the cutting edges B, which work the straight portion of surface S like a standard deburring tool. Protuberances A remove burrs from the radii by means of the true cutting action of the cutting edges C or D according to the direction of rotation. Portion B skives the straight faces as far as .008" (0.2 mm) to 0.012" (0.3 mm) above radius R<sup>3</sup>.

When the surface to be deburred is tapered, specially tapered deburring tools with many inclined slots are used to generate an adequate number of sharp cutting edges. During helical gear cutting with either a hob or with a shaper cutter, burrs are usually left on the acute edge (where the tool comes out of the gear). The relative traverse movement between the deburring tool and the gear must push the burr toward the tooth and not toward the space.

### Deburring Tool Sharpening

Wear can be removed by grinding either surface E or surface H (see Fig. 16A). Stock size removed must be 0.008" (0.2 mm) or its multiples in the direction of the disc's axis. The disc thickness reduction is compensated for by shifting the spacers.

With no gear between the tools, the discs are in the conditions shown in Fig. 16B. The springs push the disc and the spacer against the shoulder flange. When the gear enters the discs, it forces the discs apart, thus moving the tool from the shoulder flange and creating a gap approximately 0.004" (0.1 mm) between flange and spacers (see Fig. 17). After resharpening the gap will not be the same. In order to return to the initial conditions, a space 0.008" (0.2 mm) thick will have to be shifted from position 1 to position 2 as shown in Fig. 18. After every resharpening, it is necessary to check the lead in chamfer size so that it lies outside of the gear when the tool contacts the gear. ☉

*Presented at SME's 1st International Advanced Gear Processing & Manufacturing Conference, June 3-5, 1996. Reprinted with permission.*

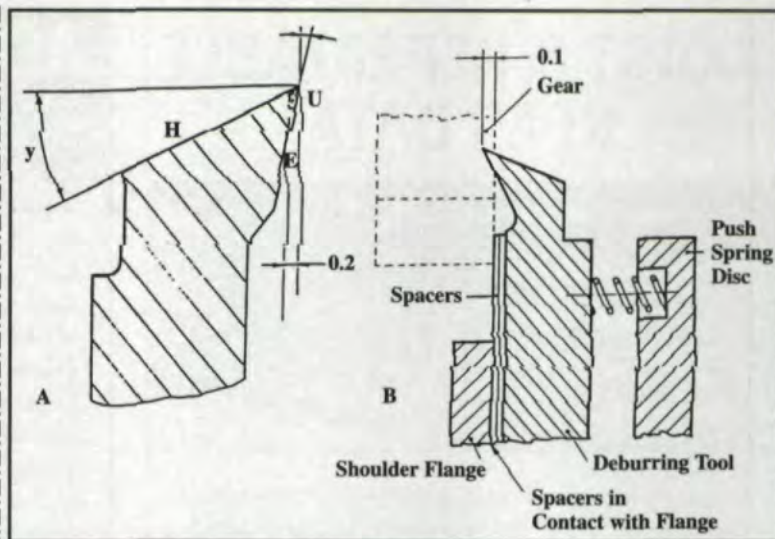


Fig. 16 — Principle of deburring tool operation.

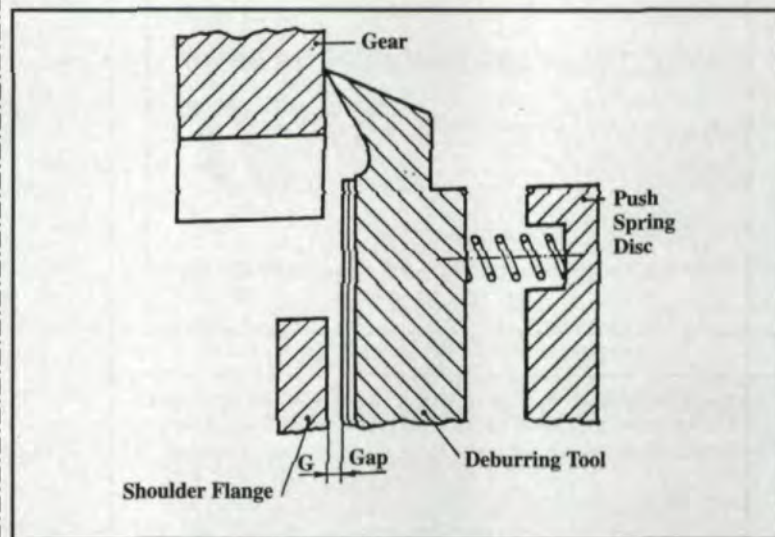


Fig. 17 — Cross sectional view of deburring tool with spacers and springs.

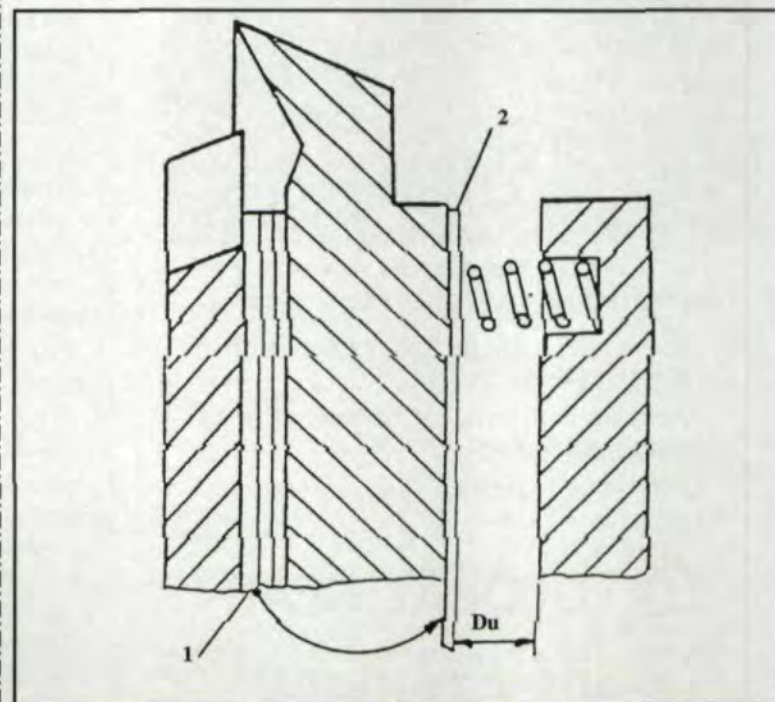


Fig. 18 — Position shift after resharpening.

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TPI Powder Metallurgy  
Trogetec Inc.  
Trojan Gear Inc.  
Vic Machine Tools Corp.  
Viking Air Tools  
Wedin Intl. Inc.  
Winzler Gear  
Worcester Gear Works  
Xtek Inc.  
Yieh Chen Co. Ltd.

**Gears—Spiral Bevel**

A. W. Sadler Machine  
ABA-PGT Inc.  
Advance Gear &  
Machine Corp.  
Aero Gear Co.  
Akron Gear &  
Engineering  
Alpha Gear Drives, Inc.  
**Amarillo Gear Co.**  
Arrow Gear Co.  
**Asco Sintering Co.**  
Ashot Ashkelon  
Industries  
**ATA Gears Inc.**  
Bengal Industries Inc.  
Boeing Precision Gear  
Bonfiglioli UK  
Boston Gear  
Carbon City Products  
Case Corp.  
**Caterpillar Industrial  
Products Inc.**  
Chicago Gear-D. O.  
James  
Ciateq A.C.  
CMD (UK) Ltd.  
Curtis Machine Co. Inc.  
Dana Corp.  
Designatronics  
Electrex Ltd. (India)  
Engranes Industriales  
Rivera  
Engratec de Mexico  
Engrecon S.A.  
Fairfield Mfg. Co.  
Falk Corporation  
Flender Corporation  
Flender-Graffenstaden  
Foote-Jones/Illinois Gear  
Gear Group International  
The Gear Works Seattle  
Gears & Drive Systems  
**The Gleason Works**  
HICO  
Hua Yang Machine Co.  
Intech Corp.  
Keystone Powdered  
Metal Co.  
Krupp Engineering Inc.  
Labeco  
Merger Corp.  
**Midwest Gear & Tool**  
Milford Gear Works  
Moore Gear  
Manufacturing Co.  
Nanchang Gear Works  
New Venture Gear Inc.  
Philadelphia Gear  
Corporation  
Philadelphia Gear — GSD  
PIC Design  
Power Eng. & Mfg. Ltd.  
Precision Gear Co.  
**Presrite Corp.**  
The Purdy Corp.  
Robotronix  
Rockwell Intl.  
Sinter Metals Inc.  
Southern Gear &  
Machine  
Thomson Micron, L.L.C.  
Von Ruden Mfg.  
Wedin Intl. Inc.  
Westech Gear

**Gears—Spur**

A. W. Sadler Machine  
ABA-PGT Inc.  
Accu-Prompt Inc.  
Aero Gear Co.  
The Adams Company  
Advance Gear &  
Machine Corp.  
Aerocom Industries Inc.  
Akron Gear & Engineering

Albro Gear & Instrument  
Alliance Gear Inc.  
Alpha Gear Drives, Inc.  
American Machine  
Works  
Ancon Gear & Inst.  
Anderson-Cook Inc.  
Aplus Engineering Inc.  
Arrow Gear Co.  
**Asco Sintering Co.**  
Ashot Ashkelon  
Industries  
Ashot U.S.A. Inc.  
Axicon Technologies  
Bengal Industries Inc.  
Bilgram Gear Co.  
Boeing Precision Gear  
Bonfiglioli UK  
Boston Gear  
Bourn & Koch Machine  
Tool  
Boxx Gear Mfg.  
Buckeye Gear Co.  
Bucyrus-Erie Co.  
Calicut Eng. Works Ltd.  
Capstan Atlantic  
Carbon City Products  
**Caterpillar Industrial  
Products Inc.**  
Chardam Gear Co.  
Charles A. Templeton  
Mach. Inc.  
Charles Bond Co.  
Chicago Gear Works  
Chicago Gear-D. O.  
James  
Ciateq A.C.  
Cincinnati Gear  
Clarke Gear Co., Inc.  
Cloyes Gear & Products  
CMD (UK) Ltd.  
Columbia Gear Corp.  
Commercial Gear &  
Sprocket  
Cornell Forge Co.  
Cunningham Industries  
Curtis Machine Co. Inc.  
Cyclo Transmission Ltd.  
Dabko Industries Inc.  
Dana Corp.  
Davis Tool &  
Engineering  
Dayton Gear & Tool  
Dearborn Gear & Tool  
Designatronics  
Dynamic Tool Grinding  
Service  
Eaton Corp.  
Electrex Ltd. (India)  
EMCO Gears  
Engranes Industriales  
Rivera  
Engratec de Mexico  
Engrecon S.A.  
**Equitable Engineering**  
Fairfield Mfg. Co.  
Fairlane Gear Inc.  
Falk Corp.  
Federal Gear Corp.  
**Fellows Corp.**  
Flender Corporation  
Flender-Graffenstaden  
Foote-Jones/Illinois Gear  
**Forest City Gear Co.**  
Franke Gear Works Inc.  
Fuller Company  
Gear Group International  
Gear Motions  
Gear Systems Inc.  
The Gear Works Seattle  
GEARCOA  
Gears & Drive Systems  
Gears for Industry Inc.  
Geartronics Industries  
General Electric

Generated Gear &  
Machine  
**The Gleason Works**  
GW Plastics  
Hand Screw Machine  
Harder Precision  
Components  
Harnischfeger  
Highway Machine Co.  
Howard's Machine Shop  
Hua Yang Machine Co.  
Inso Corp.  
Intech Corp.  
Invincible Gear Co.  
Invo Spline Inc.  
KA-Wood Gear &  
Machine  
Keller Machine Co.  
Keystone Powdered  
Metal Co.  
Krupp Engineering Inc.  
L + H Welding &  
Machine  
Lamont Gear  
Lawler Gear Corp.  
M.J.H. Gear & Tool Co.  
**Merit Gear Corp.**  
Micron Instrument Corp.  
Mid-State Machine Co.  
Midwest Gear  
**Midwest Gear & Tool**  
Milford Gear Works  
Mobile Pulley & Machine  
Works  
Modified Gear & Spline  
Molon Gear & Shaft  
Moore Gear Manufacturing  
Moore Machine & Gear  
Mostar Gear & Machine  
Murray Brothers Mfg.  
Nanchang Gear Works  
**National Broach &  
Machine Co.**  
New Venture Gear Inc.  
Niagara Gear Corp.  
Nordberg-Lokomo Oy  
O'Neill Gear  
Omni Gear & Machine  
**Ontario Drive & Gear**  
Patterson Gear & Machine  
Pennsylvania Pressed Metal  
**Perry Technology**  
Philadelphia Gear Corp.  
Philadelphia Gear — GSD  
PIC Design  
Power Eng. & Mfg. Ltd.  
Precision Gear Co.  
Precision Gear Inc.  
Precision Gears Inc.  
**Presrite Corp.**  
**Process Industries**  
Progressive Engineering  
The Purdy Corp.  
Qualicast Corp.  
R.L. Wagner & Assoc.  
RD Industries  
Reef Gear Mfg.  
Riley Gear Corp.  
Riverside Spline & Gear  
Robotronix  
Rockwell Intl.  
Schafer Gear Works Inc.  
Schwartz Precision Gear  
SDMG  
Sepac Electric Clutch &  
Brake  
Southern Gear & Machine  
St. Marys Carbon Co.  
Thomson Micron, L.L.C.  
Tifco Gage & Gear  
TPI Powder Metallurgy  
Trogetec Inc.  
Trojan Gear Inc.  
U.S.E.M.  
Vic Machine Tools Corp.



Von Ruden Mfg.  
Waldemar Design & Machine  
Wedin Intl. Inc.  
Westech Gear  
Windsor Gear Co.  
Winzler Gear  
Wohlert Corp.  
Worcester Gear Works  
Xtek Inc.  
Yieh Chen Co. Ltd.

**Gears—Straight Bevel**

A. W. Sadler Machine Co.  
Accu-Prompt Inc.  
The Adams Company  
Advance Gear & Machine  
Aero Gear Co.  
Akron Gear & Engineering  
Alliance Gear Inc.  
Alpha Gear Drives, Inc.  
American Machine Works  
Arrow Gear Co.  
Asco Sintering Co.  
Ashot Ashkelon Indust.  
Ashot U.S.A. Inc.  
Bengal Industries Inc.  
Bilgram Gear Co.  
Bonfiglioli UK  
Boston Gear  
Boxx Gear Mfg.  
Calicut Eng. Works Ltd.  
Capstan Atlantic  
Carbon City Products  
Case Corp.  
Caterpillar Industrial Products Inc.  
Chardam Gear Co.  
Charles A. Templeton Mach. Inc.  
Charles Bond Co.  
Chicago Gear Works  
Chicago Gear-D. O. James  
Ciateq A.C.  
Clarke Gear Co., Inc.  
CMD (UK) Ltd.  
Commercial Gear & Sprocket  
Cornell Forge Co.  
Curtis Machine Co. Inc.  
Dabko Industries Inc.  
Dayton Gear & Tool Designatronics  
Engranes Industriales Rivera  
Engratec de Mexico  
Engrecon S.A.  
Fairfield Mfg. Co.  
Falk Corp.  
Federal Gear Corp.  
Foote-Jones/Illinois Gear Group International  
Gear Motions  
The Gear Works Seattle  
Gears & Drive Systems  
Gears for Industry Inc.  
GEARCOA  
Geartronics Industries  
Generated Gear & Machine  
The Gleason Works  
GW Plastics  
Hua Yang Machine Co.  
Intech Corp.  
Keystone Powdered Metal Co.  
Krupp Engineering Inc.  
Labeco  
Lamont Gear  
Lawler Gear Corp.  
M.J.H. Gear & Tool  
Merger Corp.  
Midwest Gear & Tool

Milford Gear Works  
Moore Gear  
Manufacturing Co.  
Moore Machine & Gear  
Nanchang Gear Works  
New Venture Gear Inc.  
**Perry Technology**  
Philadelphia Gear Corporation  
Philadelphia Gear — GSD  
PIC Design  
Power Eng. & Mfg.  
Precision Gear Co.  
**Prestite Corp.**  
**Process Industries**  
Progressive Engineering  
Robotronix  
Rockwell Intl.  
St. Marys Carbon  
Sinter Metals Inc.  
Southern Gear & Machine  
Thomson Micron, L.L.C.  
TPI Powder Metallurgy  
Von Ruden Mfg.  
Waldemar Design & Machine  
Wedin Intl. Inc.  
Westech Gear  
Windsor Gear Co.  
Winzler Gear  
Worcester Gear Works  
Xtek Inc.  
Yieh Chen Co. Ltd.

**Gears—Worm**

A. W. Sadler Machine  
ABA-PGT Inc.  
Accu-Prompt Inc.  
The Adams Company  
Advance Gear & Machine  
Akron Gear & Engineering  
Alliance Gear Inc.  
Alpha Gear Drives, Inc.  
American Machine Works  
Anderson-Cook Inc.  
Aplus Engineering Inc.  
Bengal Industries Inc.  
Bilgram Gear Co.  
Bonfiglioli UK  
Boston Gear  
Bourn & Koch Machine Tool  
Boxx Gear Mfg.  
Buckeye Gear Co.  
Calicut Eng. Works Ltd.  
Charles A. Templeton Mach. Inc.  
Charles Bond Co.  
Chicago Gear Works  
Chicago Gear-D. O. James  
Ciateq A.C.  
Cincinnati Gear  
Clarke Gear Co., Inc.  
CMD (UK) Ltd.  
Commercial Gear & Sprocket  
Cone Drive Operations  
Dayton Gear & Tool  
Delroyd Worm Gear  
Designatronics  
EMCO Gears  
Engranes Industriales Rivera  
Engratec de Mexico  
**Equitable Engineering**  
Fairlane Gear Inc.  
Falk Corp.  
Federal Gear Corp.  
**Fellows Corp.**  
Flender Corporation  
Foote-Jones/Illinois Gear  
**Forest City Gear Co.**  
Franke Gear Works Inc.  
Gear Group International

Gear Motions  
Gear Systems Inc.  
The Gear Works Seattle  
GEARCOA  
Gears & Drive Systems  
Gears for Industry Inc.  
Geartronics Industries  
General Electric  
Generated Gear & Machine  
GW Plastics  
Harder Precision Components  
Harnischfeger  
**Holroyd Machine Tool**  
Hua Yang Machine Co.  
Inso Corp.  
Intech Corp.  
Invincible Gear Co.  
KA-Wood Gear & Machine  
Lamont Gear  
Lawler Gear Corp.  
M.J.H. Gear & Tool Co.  
Merger Corp.  
Mid-State Machine Co.  
Milford Gear Works  
Moore Gear Mfg.  
Moore Machine & Gear  
Mostar Gear & Machine  
O'Neill Gear  
Omni Gear & Machine  
Patterson Gear & Machine  
Pennsylvania Gear  
**Perry Technology**  
Philadelphia Gear Corporation  
Philadelphia Gear — GSD  
PIC Design  
Power Eng. & Mfg. Ltd.  
Precision Gear Co.  
Precision Gear Inc.  
Precision Gears Inc.  
**Process Industries**  
Progressive Engineering  
Riley Gear Corp.  
Riverside Spline & Gear  
Robotronix  
Schafer Gear Works Inc.  
Schwartz Precision Gear  
SDMG  
Southern Gear & Machine  
Tifco Gage & Gear  
Trojan Gear Inc.  
U.S.E.M.  
Vic Machine Tools Corp.  
Wedin Intl. Inc.  
Westech Gear  
Windsor Gear Co.  
Worcester Gear Works  
Yieh Chen Co. Ltd.

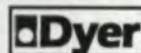
**Gears—Other**

Anderson International Corp. — Pinions  
Clarke Gear Co., Inc. — Face Gears  
CMD (UK) Ltd. — Planetary Gears  
Commerical Gear & Sprocket — Ratchets, Jaw Clutches, Large Diameter Gears  
Cone Drive Operations — Double-Enveloping Worm Gears  
Fairfield Mfg. Co. — Axle Shafts  
Federal Gear Corp. — Gearbox Repair & Reconditioning  
Flender-Graffenstaden — High-Speed & Epicyclic Gears  
Franke Gear Works Inc. — Double-Enveloping Worm & Gear Sets

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CIRCLE 198

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Peoria, Illinois 61629-4375  
Telephone 309-675-5451



CIRCLE 197



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Derlikon, max. ring gear dia. 25"

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**ATA GEARS, INC.**

1340 Depot St. Cleveland, Ohio  
Tel: 216-331-2231 Fax: 216-356-0289

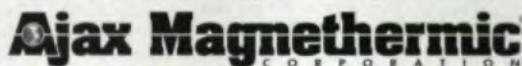
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P.O. Box 120, FIN-33101, Tampere, Finland  
Tel: 358-31-2870111 Fax: 358-31-2870249

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Automation • Complete Factory Cells  
Heat Treating Development



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**GEARCOA** — Evolvid Gears  
 Geartronics Industries — Generated Pinion Rods  
 Hand Screw Machine — Serrations for Strapping  
 Kaman Aerospace Corp. — Helicopter Gearboxes  
 Keller Machine Co. — Custom Gears & Sprockets  
 Lovejoy Inc. — Gear Couplings  
 Michigan Automatic Turning — Spline Rolling  
 Micron Instrument Corp. — Gearheads  
 Milford Gear Works — Pulleys, Serrations, Ratchets  
**National Broach & Machine** — Prototypes  
**Parker Industries Inc.** — Custom Gears  
 Philadelphia Gear Corporation — Epicyclic  
**Presrite Corp.** — Forged Tooth Gears  
 The Purdy Corp. — Zerol Bevel Gears, Curvic Couplings  
 Spline Gauges Ltd. — Oil Test Gears  
 Sussex Gear Company Inc. — Linear Actuators  
 Thomson Micron, L.L.C. — Planetary Gearheads  
 Wedin Intl. Inc. — Ground Gears  
 Westech Gear — Specials  
 Xtek Inc. — Couplings, Gear Assemblies  
 Yieh Chen Co. Ltd. — Gear Pumps

**Spines**  
 A. W. Sadler Machine ABA-PGT Inc.  
 Accu-Prompt Inc.  
 The Adams Company  
 Advance Gear & Machine Corp.  
 Aerocom Industries Inc.  
 Akron Gear & Engineering  
 American Machine Works  
 Ancon Gear & Inst.  
 Anderson-Cook Inc.  
 Aplus Engineering Inc.  
 Arrow Gear Co.  
**Asco Sintering Co.**  
 Ashot Ashkelon Indust.  
 Bilgram Gear Co.  
 Boeing Precision Gear  
 Boston Gear  
 Bourn & Koch Machine Tool  
 Boxx Gear Mfg.  
 Buckeye Gear Co.  
 Bucyrus-Erie Co.  
 Calicut Eng. Works Ltd.  
 Capstan Atlantic  
 Carbon City Products  
**Caterpillar Industrial Products Inc.**  
 Chardam Gear Co.

Charles A. Templeton Mach. Inc.  
 Chicago Gear Works  
 Chicago Gear-D. O. James  
 Ciateq A.C.  
 Cincinnati Gear  
 Clarke Gear Co., Inc.  
 Cloyes Gear & Products  
 CMD (UK) Ltd.  
 Columbia Gear Corp.  
 Commercial Gear & Sprocket  
 Curtis Machine Co. Inc.  
 Dabko Industries Inc.  
 Dayton Gear & Tool  
 Dearborn Gear & Tool  
 Deco-Technologies  
 Eaton Corp.  
 Elmass North America  
 EMCO Gears  
 Engranos Industriales Rivera  
 Engratec de Mexico  
 Engrecon S.A.  
**Equitable Engineering**  
 Fairfield Mfg. Co.  
 Fairlane Gear Inc.  
 Federal Gear Corp.  
 Foote-Jones/Illinois Gear  
**Forest City Gear Co.**  
 Franke Gear Works Inc.  
 Gear Motions  
 Gear Systems Inc.  
 The Gear Works Seattle  
**GEARCOA**  
 Gears for Industry Inc.  
 Geartronics Industries  
 Generated Gear & Machine  
**Global Gear**  
 Hand Screw Machine  
 Harder Precision  
 Components  
 Harnischfeger  
 Highway Machine Co.  
 Howard's Machine Shop  
 Hua Yang Machine Co.  
 Invo Spline Inc.  
 KA-Wood Gear & Machine  
 Keystone Powdered Metal Co.  
 Krupp Engineering Inc.  
 L + H Welding & Machine  
 Lamont Gear  
 Lawler Gear Corp.  
 Linamar  
 Lovejoy Inc.  
 M.J.H. Gear & Tool Co.  
**Mattoon Precision Mfg.**  
 Michigan Automatic Turning  
 Mid-State Machine Co.  
 Midwest Gear  
**Midwest Gear & Tool**  
 Milford Gear Works  
 Modified Gear & Spline  
 Moore Gear Manufacturing Co.  
 Moore Machine & Gear  
 Nanchang Gear Works  
**National Broach & Machine Co.**  
 New Venture Gear Inc.  
 Niagara Gear Corp.  
 O'Neill Gear  
 Omni Gear & Machine  
**Ontario Drive & Gear**  
 Patterson Gear & Mach.  
**Perry Technology**  
 Philadelphia Gear Corporation

Philadelphia Gear — GSD  
 Power Eng. & Mfg. Ltd.  
 Precision Gear Co.  
 Precision Gear Inc.  
 Precision Gears Inc.  
**Process Industries**  
 Progressive Engineering  
 The Purdy Corp.  
 R.L. Wagner & Assoc.  
 Reef Gear Mfg.  
 Rhinestahl Corp.  
 Riley Gear Corp.  
 Riverside Spline & Gear  
 Robotronix  
 Rockwell Intl.  
 Schafer Gear Works Inc.  
 SDMG  
 Sepac Electric Clutch & Brake  
 Sinter Metals Inc.  
 Southern Gear & Machine  
 St. Marys Carbon Co.  
 Tifco Gage & Gear  
 TPI Powder Metallurgy  
 Trojon Gear Inc.  
 Viking Air Tools  
 Von Ruden Mfg.  
 Wedin Intl. Inc.  
 Westech Gear  
 Windsor Gear Co.  
 Worcester Gear Works  
 Xtek Inc.  
 Yieh Chen Co. Ltd.

**Sprockets**  
 Aero Gear Co.  
 Buckeye Gear Co.  
 Cloyes Gear & Products, Inc.  
 Commercial Gear & Sprocket  
 Dabco Industries  
 Foote-Jones/Illinois Gear  
 KA-Wood Gear & Machine  
 Keller Machine Co.  
 Milford Gear Works  
 Pennsylvania Gear  
 Precision Gear Co.  
 Schwartz Precision Gear  
 SDMG  
 Wohler Corp.

**GEAR MANUFACTURING MACHINES**

**Broaching Machines**  
 Best Engineering Co.  
 Colonial Tool Group  
 Detroit Broach Co.  
 Elmass North America  
**General Broach & Engineering**  
 Jack Dustman & Assoc.  
 Miller Industrial Services Inc.  
**National Broach & Machine Co.**  
 The Ohio Broach & Machine Co.  
 Sales Consultants  
 Ty Miles Inc.

**Chamfering Machines**  
 American Sykes Co.  
 American Wera Inc.  
**Ataka Engineering Co. Basic Incorporated Group**  
 Best Engineering Co.  
 Eltech Inc.  
 GMI  
**The Gleason Works**  
 Jack Dustman & Assoc.

Redin Corp.  
 Schenck Turner  
 SU America  
 V&R Associates  
**WMW Machinery Company**

**Deburring Machines**  
 American Sykes Co.  
**Basic Incorporated Group**  
 Best Engineering Co.  
 Bourn & Koch Machine Tool  
 Eltech Inc.  
 GMI  
**The Gleason Works**  
 Harper Surface Finishing Systems  
**Holroyd Machine Tools**  
 Jack Dustman & Assoc.  
 Progressive Technologies  
 Redin Corp.  
 Schenck Turner  
 SU America  
 V&R Associates

**EDM Machines**  
 Agie USA, Ltd.  
**Basic Incorporated Group**  
 Bluegrass Precision Machinery  
 Charmilles Technologies  
 Current EDM, Inc.  
 Easco-Sparcatron  
 EDM Solutions  
 Engemaq U.S.A.  
 Hansvedt Industries Inc.  
 Hitachi EDM Products  
 KKG International/  
 Sodick EDM  
 LeBlond Makino  
 Machine Tool Co.  
 Mitsubishi EDM/MC  
 Machinery  
 Okamoto Corp., EDM  
 Division  
 Raycon Corp.  
 Sales Consultants  
 Vic Machine Tools  
 Victek Machinery Inc.  
 Xermac, Inc.

**Generating Machines**  
 American Pfauter L.P.  
**Ataka Engineering Co., Basic Incorporated Group**  
 Bourn & Koch Machine Tool  
**The Gleason Works**  
 Koepfer America L.P.  
**Liebherr-America National Broach & Machine Co.**  
 Trogetec Inc.  
 V&R Associates  
 Vic Machine Tools  
**WMW Machinery Company**

**Grinding Machines**  
 American Pfauter L.P.  
**Basic Incorporated Group**  
 Bluegrass Precision Machinery  
 Bourn & Koch Machine Tool  
 The Daniluk Corp.  
 Eltech Corp.  
**The Gleason Works**  
 GMI

Hermes Machine Tool  
 Höfler Maschinenbau GmbH  
 Hoglund Technology  
**Holroyd Machine Tools**  
 Lapmaster Intl.  
**Liebherr-America**  
 Meccanica Nova Corp.  
 Miller Industrial Services Inc.  
**Mitsubishi Machine Tool**  
**National Broach & Machine Co.**  
 Normac Inc.  
 Okamoto Corp EDM  
 Division  
 Reishauer Corp.  
 Sales Consultants  
 SU America  
 Sunnen Products Co.  
 USACH Technologies  
 V&R Associates  
**WMW Machinery Company**

**Heat Treating Equipment**  
 Abar Ipsen Industries  
**Ajax Magnethermic**  
 Bluegrass Precision Machinery  
 Can-Eng Furnaces Ltd.  
 Contour Hardening Inc.  
 Custom Electric Mfg.  
**Inductoheat Inc.**  
 K.H. Huppert Co.  
 Metaplas Ionon  
 MIFCO/McEnglevan  
 Industrial Furnace  
 Pacific Industrial Furnace  
 Pillar Industries  
 Quench Press  
 Specialties Inc.  
 Surface Combustion  
 Therm Alliance Co.  
 Tocco Inc.  
 Walnil Company

**Hobbing Machines**  
 Ace World Company  
**American Pfauter L.P. Basic Incorporated Group**  
 Best Engineering Co.  
 Bourn & Koch Machine Tool  
 Fayscott Co.  
**Fellows Corp.**  
**The Gleason Works**  
 Ikegai America Corp.  
 Koepfer America L.P.  
**Liebherr-America Mitsubishi Machine Tool**  
**National Broach & Machine Co.**  
 Sales Consultants  
 V&R Associates  
 Vic Machine Tools  
**WMW Machinery Company**

**Honing Machines**  
 American Pfauter L.P.  
**Basic Incorporated Group**  
 Bluegrass Precision Machinery  
 Engis Corp.  
**The Gleason Works**  
 Miller Industrial Services Inc.  
**National Broach & Machine Co.**

Reishauer Corp.  
 Sunnen Products Co.

**Inspection Machines**  
 Alpha Precision Inc.  
**American Pfauter L.P.**  
 American Sykes Co.  
**Basic Incorporated Group**  
 Best Engineering Co.  
 Bluegrass Precision Machinery  
 Bourn & Koch Machine Tool  
**D.I.G.I.T. Fellows Corp.**  
 FGT Gage & Systems  
**The Gleason Works**  
**ITW Heartland**  
 Kokusai Inc.  
**Liebherr-America M&M Precision Systems**  
 Mahr Corp.  
**Manufactured Gear & Gage**  
**Moore Products Co. National Broach & Machine Co.**  
 NewAge Industries Inc.  
 Ono Sokki Technology  
 Precision Gage Co.  
**Profile Engineering**  
 Progressive Tech.  
**Roto-Technology Inc.**  
 Spline Gauges Ltd.  
 SU America  
**United Tool Supply**  
 V&R Associates

**Keyseating Machines**  
**Basic Incorporated Group**  
 Elmass North America  
 Mitts & Merrill L.P.

**Lapping Machines**  
**Basic Incorporated Group**  
 Bluegrass Precision Machinery  
 Engis Corp.  
**The Gleason Works**  
 Lapmaster Intl.  
**Liebherr-America**  
 Miller Industrial Services Inc.

**Measuring Machines**  
 Alpha Precision Inc.  
**American Pfauter L.P.**  
 American Sykes Co.  
**Basic Incorporated Group**  
 Best Engineering Co.  
 Bluegrass Precision Machinery  
 Brown & Sharpe Mfg.  
**Fellows Corp.**  
**The Gleason Works**  
**Holroyd Machine Tools**  
 Krautkramer Branson  
**M&M Precision Systems**  
 Mahr Corp.  
**Moore Products Co. National Broach & Machine Co.**  
 Ono Sokki Technology  
 Precision Gage Co.  
**Profile Engineering**  
**Roto-Technology Inc.**  
 Spline Gauges Ltd.  
**United Tool Supply**



**Shaping Machines**  
**American Pfauter L.P. Basic Incorporated Group**  
 Bluegrass Precision Machinery  
 Bourn & Koch Machine Tool  
 Elmass North America Engranes Industriales Rivera  
**Fellows Corp.**  
 Liebherr-America  
 Mitsubishi Machine Tool  
**National Broach & Machine Co.**  
 V&R Associates  
 WMW Machinery Co.

**Shaving Machines**  
**American Pfauter L.P. Basic Incorporated Group**  
 Bluegrass Precision Machinery  
 Elmass North America  
**The Gleason Works**  
 GMI  
 Mitsubishi Machine Tool  
**National Broach & Machine Co.**

**Spline Rolling Machines**  
 GMI  
 Micromatic Textron  
**National Broach & Machine Co.**

**Testing Machines**  
 American Stress Technologies  
 American Sykes Co.  
**Basic Incorporated Group**  
 D.I.G.I.T.  
 Eltech Inc.  
**The Gleason Works**  
**Holroyd Machine Tools**  
 Jack Dustman & Assoc.  
 Krautkramer Branson  
 Liebherr-America  
**M&M Precision Systems**  
 Mahr Corp.  
**Manufactured Gear & Gage**  
**Moore Products Co.**  
**National Broach & Machine Co.**  
 NewAge Industries Inc.  
 Ono Sokki Technology  
**Parker Industries Inc.**  
 Precision Gage Co.  
**Profile Engineering**

**Turning Machines**  
**Basic Incorporated Group**  
 Bluegrass Precision Machinery  
 The Daniluk Corp.  
**Fellows Corp.**  
 Hermes Machine Tool  
 Miller Industrial Services Inc.  
**Mitsubishi Machine Tool**  
 Sales Consultants  
 Vic Machine Tools  
 WMW Machinery

**Worm Milling Machines**  
**American Pfauter L.P. Basic Incorporated Group**  
 Bourn & Koch Machine Tool  
 Koepter America L. P.  
**WMW Machinery Company**

**Gear Manufacturing Machines—Other**  
 American Wera Inc. — Polygon Cutting Machines (Profiling)  
**Ataka Engineering Co., Ltd. — Cutter Sharpening Machines**  
 Bazell Technologies — Coolant Filtration Equipment  
 Eltech Corp. — Worm Grinding Machines  
 Finishing Equipment Inc. — Cleaning Machines  
 Hoglund Technology Corp. — Computerized Wheel Dressers  
**Ikegai America Corp. — Hob Sharpeners**  
**Liebherr-America — Hob Sharpening, Worm Grinding Manufacturing Technology Inc. — Inertia/Friction Welders**  
 Mahr Corp. — Hand-held Gear & Spline Inspection Tools  
 NewAge Industries Inc. — Hardness Testers, Auto Traverse  
 Progressive Technologies — Surface Treatment  
 Raycon Corp. — Laser Welders  
 Reishauer Corp. — Thread & Worm Grinding Machines  
 Sala/BLM Corp. — Sawing Machines  
**United Tool Supply — Gages**  
 Walmlil Company — Parts Washers

**GEAR MATERIALS**

**Gear Blanks**  
 Accurate Specialties  
 Akron Gear & Eng. American Machine Works  
 Ancon Gear & Inst.  
 Bengal Industries Inc.  
 Boeing Precision Gear  
 Capstan Atlantic  
 Clarke Gear Co., Inc.  
**Clifford-Jacobs Forging**  
 Cornell Forge Co.  
 Dabko Industries Inc.  
 Dayton Gear & Tool  
 Designatronics  
 Dura-Bar  
 Elmass North America  
 EMCO Gears  
 Engratec de Mexico  
 Fairlane Gear Inc.  
 Fuller Company  
 Gear Motions

The Gear Works Seattle  
 Generated Gear & Machine  
 Harder Precision Components  
 Howard's Machine Shop  
 Intech Corp.  
 Krupp Engineering  
 Linamar  
 Mattoon Precision Mfg.  
 Mid-State Machine Co.  
 Milford Gear Works  
 Mobile Pulley & Machine Works  
 Moore Machine & Gear  
 PIC Design  
**Presrite Corp. Process Industries**  
 Qualicast Corp.  
 RD Industries  
 Reef Gear Mfg.  
 Riverside Spline & Gear  
 Robotronix  
 Schmid Tool & Eng.  
 Teledyne Portland Forge  
 Tifco Gage & Gear  
 Trogetec Inc.  
 Van Becelaere Machine  
 Viking Air Tools  
 Wells Manufacturing  
 Wohler Corp.

**Plastics**  
 A & E Gears BV  
 American Machine Works  
 Bengal Industries Inc.  
 Dayton Gear & Tool  
 The Gear Works Seattle  
 Hoechst Celanese Corp.  
 Howard's Machine Shop  
 Intech Corp.  
 Trogetec Inc.

**Powder Metals**  
 Alpha Sintered Metals  
**Asco Sintering Co.**  
 Capstan Atlantic  
 Carbon City Products  
 Cloyes Gear & Products  
 The Gear Works Seattle  
 Interlake  
 Metal Powder Industries Federation  
 TPI Powder Metallurgy  
 TPS Inc.

**Steels**  
 Ace World Company  
 American Machine Works  
 Crucible Service Centers  
 Dayton Gear & Tool  
 Elmass North America  
 The Gear Works Seattle  
 Impact Strategies  
 Krupp Engineering  
 Latrobe Steel Co.  
 Moore Machine & Gear  
 RD Industries  
 Trogetec Inc.

**Other**  
 Crucible Service Centers — High-Speed Steels for Cutting Tools  
 Dura-Bar — Cast Iron, Continuous Cast Iron  
 Intech Corp. — Plastic-Metal Composite  
 Teledyne Portland Forge — Precision Closed-Die Forgings

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CIRCLE 199



Trogetec Inc. — Laser Stampings  
Wells Manufacturing — Iron

**GEAR SERVICES**

**Consulting**

Advance Gear & Machine Corp.  
**American Pfauter L.P.**  
Aplus Engineering Inc.  
Applied Mechaniques  
Aston Metallurgical Services  
Axicon Technologies  
Best Engineering Co.  
C-Dot Engineering  
Chicago Gear Works  
Ciateq A.C.  
Dabko Industries Inc.  
Dayton Gear & Tool Drive Systems Technology  
Dynamic Metal Treating  
Engranes Industriales Rivera  
Fairfield Mfg. Co.  
Gary P. Mowers, P.C.  
**The Gleason Works**  
Guy Crader Consulting  
GW Plastics  
Hy-Mech Systems Inc.  
I.S.P.J.A.E.  
Impact Strategies  
Intech Corp.  
Jack Dustman & Assoc.  
James Reid Gear Services  
Management & Engineering Tech.  
**Manufactured Gear & Gage**  
McGinty Gear  
Milburn Engineering  
Milford Gear Works  
Moore Machine & Gear  
NCADT  
NASA Lewis Research Center  
**Ontario Drive & Gear Pfauter Maag Tools, L.P.**  
Power Eng. & Mfg. Ltd.  
Precision Engineering Services  
**Profile Engineering**  
Reilly Engineering Inc.  
Sales Consultants  
SBR Consulting  
Society of Manufacturing Engineers  
Spline Gauges Ltd.  
Sussex Gear Company  
Swiglo Metallurgical Consulting  
Trogetec Inc.  
Ty Miles Inc.  
U.S. Tech Corp.  
**Van Gerpen-Reece Eng.**  
Wedin Intl. Inc.  
Wes-Tex Gear Inc.  
Westech Gear  
Winzler Gear

**Cryogenics**

Boeing Precision Gear  
Fairfield Mfg. Co.  
Robotronix

**Fault Analysis**

Akron Gear & Engineering  
Applied Mechaniques  
Ashot Ashkelon Indust.  
Aston Metallurgical Services

Brown & Sharpe Mfg.  
Ciateq A.C.  
Dayton Gear & Tool Drive Systems Technology  
Gary P. Mowers, P.C.  
Geartech  
Hy-Mech Systems Inc.  
I.S.P.J.A.E.  
Milburn Engineering  
Modern Industries Inc.  
National Metrology  
Philadelphia Gear — GSD  
Power Eng. & Mfg. Ltd.  
Reilly Engineering Inc.  
Robotronix  
Technimet Corp.  
Trogetec Inc.  
Wes-Tex Gear Inc.  
Westech Gear  
Xtek Inc.

**Gear Design**

A. W. Sadler Machine  
ABA-PGT Inc.  
Advance Gear & Machine Corp.  
Akron Gear & Engineering  
Aplus Engineering Inc.  
Applied Mechaniques  
Ashot Ashkelon Indust.  
Ashot U.S.A. Inc.  
Axicon Technologies  
BestMetal Corp.  
C-Dot Engineering  
**Caterpillar Industrial Products Inc.**  
Ciateq A.C.  
Cincinnati Gear  
CMD (UK) Ltd.  
Columbia Gear Corp.  
Cone Drive Operations  
Contour Hardening Inc.  
Cunningham Industries  
Dayton Gear & Tool  
Deco-Technologies  
DMS Inc.  
Drive Systems Technology  
Dynamic Tool Grinding Service  
EMCO Gears  
Engranes Industriales Rivera  
Engratec de Mexico  
**Equitable Engineering**  
Fairfield Mfg. Co.  
Fairlane Gear Inc.  
Gary P. Mowers, P.C.  
The Gear Works Seattle  
Gearesearch Assoc.  
General Electric  
Generated Gear & Machine  
**The Gleason Works**  
Guy Crader Consulting  
GW Plastics  
Harder Precision Components  
Highway Machine Co.  
**Holroyd Machine Tools**  
Hy-Mech Systems Inc.  
I.S.P.J.A.E.  
Inscop Corp.  
ITW Spiroid  
Labeco  
McGinty Gear  
Milburn Engineering  
Milford Gear Works  
Moore Machine & Gear  
O'Neill Gear

Westech Gear  
Winzler Gear  
Wohlert Corp.  
Xtek Inc.  
**Gear Engineering**  
A. W. Sadler Machine  
ABA-PGT Inc.  
Advance Gear & Machine Corp.  
Akron Gear & Engineering  
**American Pfauter L.P.**  
Aplus Engineering Inc.  
Applied Mechaniques  
Ashot Ashkelon Indust.  
Ashot U.S.A. Inc.  
Axicon Technologies  
BestMetal Corp.  
Brown & Sharpe Mfg.  
C-Dot Engineering  
Ciateq A.C.  
Cincinnati Gear  
CMD (UK) Ltd.  
Columbia Gear Corp.  
Cone Drive Operations  
Consulting & Design Service  
Contour Hardening Inc.  
Dabko Industries Inc.  
Dayton Gear & Tool Designatronics  
DMS Inc.  
Drive Systems Technology  
Dynamic Tool Grinding Service  
EMCO Gears  
Engranes Industriales Rivera  
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Federal Gear Corp.  
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Gearesearch Assoc.  
The Gear Works Seattle  
Gears & Drive Systems  
Geartech  
General Electric  
**The Gleason Works**  
Guy Crader Consulting  
GW Plastics  
Harder Precision Components  
Highway Machine Co.  
**Holroyd Machine Tools**  
Hy-Mech Systems Inc.  
I.S.P.J.A.E.  
Inscop Corp.  
Intech Corp.  
Labeco  
**M&M Precision Systems**  
Milburn Engineering  
Milford Gear Works

Qualicast Corp.  
RD Industries  
Reef Gear Mfg.  
Reilly Engineering Inc.  
Robotronix  
SBR Consulting  
Society of Manufacturing Engineers  
*Southern Gear & Machine*  
Southern Sales & Engineering  
Spline Gauges Ltd.  
Sussex Gear Company  
Trogetec Inc.  
Universal Technical Systems  
**Van Gerpen-Reece Eng.**  
Von Ruden Mfg.  
Wedin Intl. Inc.  
Westech Gear  
Winzler Gear  
Wohlert Corp.  
Xtek Inc.

**Gear Engineering**

A. W. Sadler Machine  
ABA-PGT Inc.  
Advance Gear & Machine Corp.  
Akron Gear & Engineering  
**American Pfauter L.P.**  
Aplus Engineering Inc.  
Applied Mechaniques  
Ashot Ashkelon Indust.  
Ashot U.S.A. Inc.  
Axicon Technologies  
BestMetal Corp.  
Brown & Sharpe Mfg.  
C-Dot Engineering  
Ciateq A.C.  
Cincinnati Gear  
CMD (UK) Ltd.  
Columbia Gear Corp.  
Cone Drive Operations  
Consulting & Design Service  
Contour Hardening Inc.  
Dabko Industries Inc.  
Dayton Gear & Tool Designatronics  
DMS Inc.  
Drive Systems Technology  
Dynamic Tool Grinding Service  
EMCO Gears  
Engranes Industriales Rivera  
**Equitable Engineering**  
Fairfield Mfg. Co.  
Fairlane Gear Inc.  
Federal Gear Corp.  
Gary P. Mowers, P.C.  
The Gear Works Seattle  
Gearesearch Assoc.  
The Gear Works Seattle  
Gears & Drive Systems  
Geartech  
General Electric  
**The Gleason Works**  
Guy Crader Consulting  
GW Plastics  
Harder Precision Components  
Highway Machine Co.  
**Holroyd Machine Tools**  
Hy-Mech Systems Inc.  
I.S.P.J.A.E.  
Inscop Corp.  
Intech Corp.  
Labeco  
**M&M Precision Systems**  
Milburn Engineering  
Milford Gear Works

Modern Industries Inc.  
Moore Machine & Gear  
NCADT  
Nordberg-Lokomo Oy  
O'Neill Gear  
**Ontario Drive & Gear**  
Patterson Gear & Machine  
*Philadelphia Gear — GSD*  
Power Eng. & Mfg. Ltd.  
Precision Engineering Services  
**Process Industries**  
**Profile Engineering**  
Qualicast Corp.  
Reef Gear Mfg.  
Reilly Engineering Inc.  
Riley Gear Corp.  
Robotronix  
SBR Consulting  
Society of Manufacturing Engineers  
Southern Sales & Engineering  
Southern Gear & Machine  
Spline Gauges Ltd.  
Sussex Gear Company  
Trogetec Inc.  
Universal Technical Systems  
**Van Gerpen-Reece Eng.**  
Wedin Intl. Inc.  
Wes-Tex Gear Inc.  
Westech Gear  
Winzler Gear  
Wohlert Corp.  
Xtek Inc.

**Grinding**

Advance Gear & Machine Corp.  
Aerocom Industries Inc.  
Akron Gear & Engineering  
**American Pfauter L.P.**  
Aplus Engineering Inc.  
Ashot Ashkelon Indust.  
Ashot U.S.A. Inc.  
Axicon Technologies  
Boeing Precision Gear  
Brighton Industries  
**Caterpillar Industrial Products Inc.**  
Chardam Gear Co.  
Chicago Gear Works  
Cincinnati Gear  
CMD (UK) Ltd.  
Columbia Gear Corp.  
Dayton Gear & Tool  
Disston Precision Inc.  
Engranes Industriales Rivera  
**Equitable Engineering**  
Fairfield Mfg. Co.  
Fairlane Gear Inc.  
*Federal Gear Corp.*  
Flender Corporation  
Franke Gear Works  
Gary P. Mowers, P.C.  
Gear Motions  
The Gear Works Seattle  
GEARCOA  
Gears & Drive Systems  
Generated Gear & Machine  
**The Gleason Works**  
Höfler Maschinenbau GmbH  
Inscop Corp.  
Lawler Gear Corp.  
Meccanica Nova Corp.  
**Merit Gear Corp.**  
Midwest Gear  
Modern Industries Inc.

Modified Gear & Spline  
Multi-Arc Inc.  
**National Broach & Machine Co.**  
NCADT  
Niagara Gear Corp.  
Nordberg-Lokomo Oy  
Patterson Gear & Machine  
Philadelphia Gear — GSD  
Power Eng. & Mfg. Ltd.  
Precision Gear Co.  
Precision Gear Inc.  
**Pro-Gear Co. Inc.**  
**Process Industries**  
The Purdy Corp.  
Qualicast Corp.  
RD Industries  
Reef Gear Mfg.  
Riley Gear Corp.  
Riverside Spline & Gear  
Robotronix  
Southern Gear & Machine  
SU America  
Tifco Gage & Gear  
USACH Technologies  
Viking Air Tools  
Wedin Intl. Inc.  
Westech Gear  
Xtek Inc.

**Heat Treating**

Ajax Magnethermic  
**American Metal Treating**  
**American Pfauter L.P.**  
Aplus Engineering Inc.  
*Applied Process Inc.*  
Ashot Ashkelon Indust.  
Ashot U.S.A. Inc.  
Axicon Technologies  
Boeing Precision Gear  
Bucyrus - Erie Co.  
**Caterpillar Industrial Products Inc.**  
Cincinnati Gear  
Contour Hardening Inc.  
Dayton Gear & Tool  
Detroit Flame Hardening  
Disston Precision Inc.  
Dynamic Metal Treating  
Euclid Heat Treating  
Fairfield Mfg. Co.  
**Fellows Corp.**  
Foote-Jones/Illinois Gear  
FPM Heat Treating  
Gary P. Mowers, P.C.  
GEARCOA  
**The Gleason Works**  
Harder Precision Components  
Impact Strategies  
**Inductoheat Inc.**  
Linamar  
Lindberg Heat Treating  
**Merit Gear Corp.**  
Metlab  
Modern Industries Inc.  
Molon Gear & Shaft  
**National Broach & Machine Co.**  
Nordberg-Lokomo Oy  
Patterson Gear & Machine  
Paulo Products Co.  
**Pfauter-Maag Cutting Tools, L. P.**  
Philadelphia Gear — GSD  
Pillar Industries  
Progressive Engineering  
Qualicast Corp.  
RD Industries  
Robotronix  
Tocco Inc.  
U. S. Axle Inc.

Wells Manufacturing  
Westech Gear  
Wohlert Corp.  
Xtek Inc.

**Inspection**

A. W. Sadler Machine  
ABA-PGT Inc.  
*Ace World Company*  
Advance Gear & Machine Corp.  
Aerocom Industries Inc.  
Akron Gear & Engineering  
Alpha Precision Inc.  
**American Pfauter L.P.**  
American Stress Technologies  
American Sykes Co.  
Aplus Engineering Inc.  
Ashot Ashkelon Indust.  
Ashot U.S.A. Inc.  
Axicon Technologies  
Best Engineering Inc.  
Boeing Precision Gear  
Bourn & Koch Machine Tool  
Brighton Industries  
Brown & Sharpe Mfg.  
Cincinnati Gear  
Columbia Gear Corp.  
**D.I.G.I.T.**  
Dayton Gear & Tool  
Disston Precision Inc.  
Dynamic Metal Treating  
Engranes Industriales Rivera  
**Equitable Engineering**  
Euro-Tech Corporation  
Fairfield Mfg. Co.  
Fairlane Gear Inc.  
**Forest City Gear Co.**  
Fuller Company  
Gary P. Mowers, P.C.  
GEARCOA  
Gear Motions  
The Gear Works Seattle  
Gears & Drive Systems  
**The Gleason Works**  
Harder Precision Components  
Highway Machine Co.  
Interstate Tool Corp.  
Invo Spline Inc.  
Jack Dustman & Assoc.  
Krautkramer Branson  
Lawler Gear Corp.  
**M&M Precision Systems**  
Mahr Corp.  
**Manufactured Gear & Gage**  
**Merit Gear Corp.**  
Midwest Gear  
Modern Industries Inc.  
Moore Machine & Gear  
National Metrology  
**National Broach & Machine Co.**  
NCADT  
Niagara Gear Corp.  
Patterson Gear & Machine  
**Perry Technology Corp.**  
Philadelphia Gear — GSD  
Power Eng. & Mfg. Ltd.  
Precision Gage Co.  
Precision Gear Inc.  
Precision Gears Inc.  
**Process Industries**  
**Profile Engineering**  
The Purdy Corp.  
Qualicast Corp.  
RD Industries  
Reef Gear Mfg.  
Riley Gear Corp.



Riverside Spline & Gear  
**Roto-Technology Inc.**  
 Schafer Gear Works  
 Scott Machine Tool Co.  
 Southern Gear &  
 Machine  
 Spline Gauges Ltd.  
 Tifco Gage & Gear  
 Trogetec Inc.  
 UBM Corp.  
 Ultron Incorporated  
 Viking Air Tools  
 Wedin Intl. Inc.  
 Westech Gear  
 Winzeler Gear

**Shot Peening**

Ashot Ashkelon Indust.  
 Ashot U.S.A. Inc.  
 Boeing Precision Gear  
 Cincinnati Gear  
 Columbia Gear Corp.  
 Dayton Gear & Tool  
 Fairfield Mfg. Co.  
 Harder Precision  
 Components  
 Patterson Gear &  
 Machine  
 Progressive Technologies  
 RD Industries

**Tool Coating**

**American Pfauter L.P.**  
 Balzers Tool Coating  
 Best Engineering Co.  
 Diamond Black Tech  
 Dynamic Metal Treating  
 Eltech Inc.  
 General Magnaplate  
 LMT-Fette Inc.  
 Multi-Arc Inc.  
 Reid Tool Service Inc.  
 Richter Precision Inc.  
**Star Cutter Co.**  
 Wohler Corp.

**Other Services**

**American Metal**  
 Treating — Induction  
**Hardening**  
 Ascent Drafting Service  
 — Drafting Services  
 ASM International —  
 Training, Education,  
 Books  
 Aston Metallurgical  
 Services —  
 Metallurgical Testing  
 Becker Gearmasters  
 Inc. — Machine  
 Calibration  
 Capital Associates  
 International —  
 Machinery Leasing &  
 Financing  
**Clifford-Jacobs Forging**  
**Co. — Forging**  
 Detroit Flame  
 Hardening — Flame  
 Hardening  
 Elmass North America  
 Inc. — Broaching &  
 Keyseating Services  
 Eltech Inc. — Hob  
 Sharpening  
 Fairlane Gear Inc. —  
 Noise Evaluation  
 General Magnaplate  
 Corp. — Protective  
 Coatings  
 Hane Industrial Training  
 — Gear School  
**Holroyd Machine Tools**  
 — Complete  
**Manufacture**

Hy-Mech Systems Inc.  
 — Training Seminars,  
 Gear & Hydraulic  
 Product Design  
 Impact Strategies Inc. —  
 Engineering/Market-  
 ing/Consulting for the  
 Metalworking & Heat  
 Treating Industries  
 Intech Corp. —  
 Durability  
 Calculations  
 International Financial  
 Services —  
 Machinery &  
 Equipment Financing  
 James Reid Gear  
 Services —  
 Productivity &  
 Quality Improvement  
**Koro Sharpening**  
**Service — HSS &**  
**Carbide Hob**  
**Sharpening**  
 McGinty Gear — Spline  
 Design  
 Metlab — Carburizing,  
 Nitriding  
 Mikrofinish — Wear  
 Enhancement  
 Mitts & Merrill, L.P. —  
 Keyway Machining  
 Modern Industries Inc.  
 — Metallurgical  
 Evaluation  
 Modified Gear & Spline  
 — Crown Grinding  
 Morrison Knudsen —  
 Engineering Consultants  
 National Metrology —  
 Machinery  
 Calibration  
 NCADT — Condition-  
 Based Maintenance  
 Paulo Products Co. —  
 Metallurgical Support  
 & Services  
 Precision Engineering  
 Services —  
 Probabilistic Error  
 Analysis  
 Progressive Tool Co. —  
 Wire EDM  
 Spline Gauges Ltd. —  
 Plotting & Analysis of  
 Gear Stresses  
 Stearns Financial —  
 Machinery Financing  
 Sussex Gear Company  
 Inc. — Gearbox &  
 Actuator Design  
 Technimet Corp. —  
 Materials Selection &  
 Testing  
 Tri-Wire Inc. — Wire  
 EDM  
 Trogetec — Custom  
 Design & Software

**GEAR SOFTWARE**

**Custom**

Ace World Company  
**American Pfauter L.P.**  
 American Sykes Co.  
 Aplus Engineering Inc.  
 C-Dot Engineering  
 Ciateq A.C.  
 Gearsearch Assoc.  
 Gearsoft Design  
 Hoglund Technology  
 I.S.P.J.A.E.  
**Mahr Corp.**  
 Metal Powder Industries  
 Federation

Metrscope Corp.  
**Moore Products Co.**  
 NASA Lewis Research  
 Center  
 PC Enterprises  
 R.H. Software  
**Roto-Technology Inc.**  
 Scott Machine Tool Co.  
**Software Engineering**  
**Service**  
 Trogetec Inc.  
 Universal Technical  
 Systems  
 User Solutions Inc.  
**Van Gerpen-Reece Eng.**

**Gear Design**

ABA-PGT Inc.  
 Accu-Prompt Inc.  
 American Gear Mfgs.  
 Assn.  
 Bluegrass Precision  
 Machinery  
 C-Dot Engineering  
 Ciateq A.C.  
 Dabko Industries Inc.  
 Designatronics  
 Fairfield Mfg. Co.  
 Gearsearch Assoc.  
 Gearsoft Design  
 Geartech  
**The Gleason Works**  
 I.S.P.J.A.E.  
 NASA Lewis Research  
 PC Enterprises  
**Software Engineering**  
**Service**  
 Trogetec Inc.  
 Universal Technical  
 Systems  
**Van Gerpen-Reece Eng.**

**Gear Inspection**

Alpha Precision Inc.  
 American Machinery &  
 Engineering  
 American Stress  
 Technologies  
**American Pfauter L.P.**  
 American Sykes Co.  
 Bourn & Koch Machine  
 Tool  
 Brighton Industries  
 Brown & Sharpe Mfg.  
 Euro-Tech Corporation  
 Gearsearch Assoc.  
**The Gleason Works**  
 Krautkramer Branson  
**M&M Precision**  
**Systems**  
 Metrscope Corp.  
**Moore Products Co.**  
 NCADT  
 PC Enterprises  
 Precision Gage Co.  
 R.H. Software  
**Roto-Technology Inc.**  
 Scott Machine Tool Co.  
**Software Engineering**  
**Service**  
 Trogetec Inc.  
 Universal Technical  
 Systems

**Shop Management**

**American Pfauter L.P.**  
 JobBOSS Software Inc.  
 Metrscope Corp.  
 R.H. Software  
 Scott Machine Tool Co.  
 U.S. Tech Corp.  
 User Solutions Inc.

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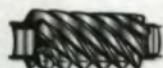


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# COMPANY INDEX

Welcome to the 1996 *Gear Technology* Buyers Guide Company Index. This year we have more listings than ever to give you even better coverage of the industry.

Use this index to locate the complete contact information for each company listed in the Products and Services Directory. *Gear Technology* advertisers are shown in boldface type. To find the pages on which their ads appear, see the Advertisers Index on page 32.

While *Gear Technology* has made every effort to ensure that company names and addresses are correct, we cannot be held responsible for errors of fact or omission.

If your company is not listed, and you would like to be included in 1997, call 847-437-6604, fax 847-437-6618 or e-mail us at [people@geartechnology.com](mailto:people@geartechnology.com), and we will add you to our mailing list.

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Northbrook, IL 60062  
847-272-8128  
Fax: 847-272-8210

Basic Incorporated Group  
Basic Machine Tools Div.  
P. O. Box 36276  
Los Angeles, CA 90036  
213-933-7191  
Fax: 213-933-7487  
E-mail: patrik@loop.com

Bates Technologies Inc.  
P. O. Box 213  
9059 Technology Dr.  
Fishers, IN 46038-0213  
317-841-8805  
Fax: 317-841-9443

Bazell Technologies  
5066 Commercial Circle  
Concord, CA 94520  
510-603-0900  
Fax: 510-603-0901

Becker Gearmeisters Inc.  
245 Hallock Rd.  
Stony Brook, NY 11790-3022  
800-423-2537  
Fax: 516-751-0205

Bengal Industries Inc.  
11346 53rd St.  
Clearwater, FL 34620  
813-572-4249  
Fax: 813-573-2428

Best Engineering Co.  
P. O. Box 510797  
2385 S. 162nd St.

New Berlin, WI 53151-0797  
414-784-2200  
Fax: 414-784-2541

BestMetal Corp.  
925 Dieckman St.  
Woodstock, IL 60098  
815-337-8800  
Fax: 815-337-8803

Bilgram Gear Co.  
Eight Union Hill Rd.  
W. Conshohocken, PA 19428  
610-828-7200  
Fax: 610-828-9428

Bluco Corp.  
509 Weston Ridge Drive  
Naperville, IL 60563  
800-535-0135  
E-mail: bluco@concentric.net

Bluegrass Precision Machinery  
442 Three Springs Rd.  
Bowling Green, KY 42104  
502-842-7201  
Fax: 502-842-7242

Boeing Precision Gear  
6006 W. 73rd St.  
Bedford, Park, IL 60638-6106  
708-728-2000  
Fax: 708-728-2009

Bonfiglioli UK  
Unit 5 Grosvenor Grange  
Woolston, Warrington, Cheshire  
WA1 4SF United Kingdom  
44 (925) 852664  
Fax: 44 (925) 852668

Boston Gear  
14 Hayward St.  
Quincy, MA 02171  
617-328-3300  
Fax: 617-479-6238  
E-mail: boston.gear@industry.net

Bourn & Koch Machine Tool  
2500 Kishwaukee St.  
Rockford, IL 61111  
815-965-4013 x320  
Fax: 815-965-0019

Boxx Gear Mfg.  
1314 Central Pkwy. SW  
Decatur, AL 356012  
205-355-4611  
Fax: 205-355-4661

Brighton Industries Corp.  
15 Essex Rd.  
Paramus, NJ 07010  
201-368-3933  
Fax: 201-368-8743

Brown & Sharpe Mfg. Co.  
200 Frenchtown Rd.  
North Kingstown, RI 02852  
401-886-2369  
Fax: 401-886-2970

Buckeye Gear Co.  
5130 Richmond Rd.  
Bedford Heights, OH 44146  
216-292-6424  
Fax: 216-292-6454  
E-mail: skidmore@earthlink.net

Bucyrus-Erie Co.  
1100 Milwaukee Ave.  
S. Milwaukee, WI 53172-0500  
414-768-4361  
Fax: 414-768-4750

**C**

C-Dot Engineering  
14900 Robinwood  
Plymouth, MI 48170-2660  
313-420-2075  
Fax: 313-420-1279

Calicut Eng. Works Ltd.  
P. O. Box 9119  
26A Camac St.  
Calcutta 700016  
India  
(91) 33-2475693  
Fax: (91) 33-2476072

Can-Eng Furnaces Ltd.  
P.O. Box 235  
Niagara Falls, NY 14302  
905-356-1327  
Fax: 905-356-1817

Capital Associates International  
4598 Valleyview Dr. Ste. 5200  
West Bloomfield, MI 48323  
810-855-0855  
Fax: 810-855-0972

Capstan Atlantic  
10 Cushing Dr.  
Wrentham, MA 02093  
508-384-3100  
Fax: 508-384-3196

Carbon City Products  
Metal Powder Products Div.  
150 Ford Rd.  
St. Marys, PA 15857  
814-834-2886  
Fax: 814-834-9091

Case Corp.  
700 State St.  
Racine, WI 53404  
414-636-0266  
Fax: 414-636-7132

Caterpillar Industrial Products Inc.  
100 N. E. Adams St.  
Peoria, IL 61629-4375  
309-675-5451  
Fax: 309-675-6457

Chardam Gear Co.  
40810 Brentwood  
Sterling Heights, MI 48310  
810-795-8900  
Fax: 810-795-8908

Charles A. Templeton Mach. Inc.  
P. O. Box 2566  
2727 N. Golder  
Odessa, TX 79760  
915-332-2932  
Fax: 915-332-0412

Charles Bond Co.  
1035 Louis Dr.  
Warminster, PA 18974  
800-922-0125  
Fax: 215-957-7999

Charmilles Technologies Corp.  
560 Bond St.  
Lincolnshire, IL 60069-4224  
847-913-5300  
Fax: 847-913-5340

Chicago Gear-D.O. James  
2823 W. Fulton St.  
Chicago, IL 60612  
312-638-0508  
Fax: 312-638-7161

Chicago Gear Works  
1805 S. 55th Ave.  
Cicero, IL 60650  
708-863-2700  
Fax: 708-863-2749

Chowgule Matrix Hobs Ltd.  
26A Industrial Estate  
Patancheru 502 319  
DT. Medak A.P.  
India  
(91) 8453-2305  
Fax: (91) 8453-2096

Ciateq, A. C.  
Mechanical Transmissions Div.  
Retablo 150  
Queretaro 76150  
Mexico  
(52) 421-6808  
Fax: (52) 421-69963  
E-mail: rodlop@ciateq.mx

Cincinnati Gear  
5657 Wooster Pike  
Cincinnati, OH 45227  
513-271-7700  
Fax: 513-271-0049

Cincinnati Milacron  
4701 Marburg Ave.  
Cincinnati, OH 45209  
513-841-8100  
Fax: 513-841-8991

CJT/Koolcarb  
1040 W. Fullerton Ave.  
Addison, IL 60101  
630-543-7144

Clarke Gear Co. Inc.  
8058 Lankershim Blvd.  
N. Hollywood, CA 91605  
818-768-0690  
Fax: 818-767-5577

Clifford-Jacobs Forging Co.  
2410 N. Fifth St.  
Champaign, IL 61824-0830  
217-352-5172  
Fax: 217-352-4629

Clipper Diamond Tool Co.  
47-16 Austell Place  
Long Island City, NY 11101  
718-392-3671  
Fax: 718-392-4124

Cloyes Gear & Products Inc.  
P. O. Box 528  
615 W. Walnut  
Paris, AK 72855  
501-963-2105  
Fax: 501-963-2163

CMD (UK) Ltd.  
Royd House Birds Royd Lane  
Brighouse, W. Yorkshire  
HD6 1LQ United Kingdom  
(44) 01484-401617  
Fax: (44) 011484-401618

Colonial Tool Group Inc.  
5505 Concord  
Detroit, MI 48211  
313-965-8680  
Fax: 519-253-5911

Colorado School of Mines  
ASPPRC  
Golden, CO 80401  
303-273-3265  
Fax: 303-273-3795



D

Columbia Gear Corp.  
P. O. Box 1000  
530 County Road 50  
Avon, MN 56310  
320-356-7301  
Fax: 320-356-2131

Commercial Gear & Sprocket  
618 Washington St.  
E. Walpole, MA 02032  
800-491-1073  
Fax: 508-668-1073

Comtorage Corp.  
58 NS Industrial Drive  
Slatersville, RI 02876  
401-765-0900  
Fax: 401-765-2846

Cone Drive Operations  
Div. of Textron Inc.  
P.O. Box 272  
240 E. 12th Street  
Traverse City, MI 49685-0272  
616-946-8410  
Fax: 616-946-0235

Consulting & Design Service  
17033 E. Aloe  
Fountain Hills, AZ 85268  
602-837-8283  
Fax: 602-837-8211

Contour Hardening Inc.  
7898 Zionsville Rd.  
Indianapolis, IN 46268  
317-876-1530  
Fax: 317-879-2484

Cornell Forge Co.  
6666 W. 66th St.  
Chicago, IL 60638  
312-767-4242  
Fax: 312-767-9443

Crucible Service Centers  
5639 W. Genesee St.  
Camillus, NY 13031-0991  
315-487-0800  
Fax: 315-487-4028

Cunningham Industries  
102 Lincoln Ave.  
Stamford, CT 06902  
203-324-2942  
Fax: 203-324-6039

Current EDM Inc.  
2577 Leghorn St.  
Mountain View, CA 94043  
415-966-9676  
Fax: 415-966-1881

Curtis Machine Co. Inc.  
P.O. Box 700  
2500 E. Trail St.  
Dodge City, KS 67801-0700  
316-227-7164  
Fax: 316-227-2971  
E-mail: curtis@midusa.net

Custom Electric Mfg.  
48973 West Rd.  
Wixom, MI 48393  
810-305-7700  
Fax: 810-305-7705

Cyclo Tansmissions, Ltd.  
Gearbox Division  
at Post-Pat Khal  
Tal/Dist. Satara  
Maharashtra 415011 India  
91-6262-31939/3  
91-6262-30185

D. A. Stuart Co.  
Metalworking Div.  
7575 Plaza Court  
Willowbrook, IL 60521  
630-655-4595  
Fax: 630-655-1088

**D.I.G.I.T.**  
**219H S. Pioneer Blvd.**  
**P.O. Box 367**  
**Springboro, OH 45066**  
**513-746-3800**  
**Fax: 513-746-5103**

Dabko Industries Inc.  
P. O. Box 9217  
61 E. Main St.  
Forestville, CT 06010  
800-437-3398  
Fax: 203-583-6902

Dana Corp.  
2424 W. State  
Fort Wayne, IN 46801  
219-481-3437  
Fax: 219-481-3115

The Daniluk Corp.  
8200 S.W. 29th  
Oklahoma City, OK 73179  
405-745-6644  
Fax: 405-745-6646

Davis Tool & Engineering  
19250 Plymouth Rd.  
Detroit, MI 48228  
313-835-6000  
Fax: 313-837-7220

Dayton Gear & Tool  
500 Fame Rd.  
Dayton, OH 45449  
513-866-4327  
Fax: 513-866-0408  
E-mail: dgear@rcinet.com

Dearborn Gear & Tool Co.  
4300 Cabot  
Detroit, MI 48210  
313-581-3111  
Fax: 313-581-3115

Deco-Technologies  
1360 E. Big Beaver  
Troy, MI 48083  
810-524-9800  
Fax: 810-524-9804

Delroyd Worm Gear  
Division of IMO  
121 First Ave.  
Trenton, NJ 08650  
800-432-0121  
Fax: 609-890-6800

Designatronics  
Stock Drive Products/Sterling Inst. Div.  
P. O. Box 5416  
2101 Jericho Trnkp.  
New Hyde Park, NY 11042-5416  
516-328-3300  
Fax: 516-326-8827  
E-mail: support@sdp-si.com

Detroit Broach Co.  
431 S. Buncombe Rd.  
Greer, SC 29651  
864-879-7641  
Fax: 864-879-7693

Detroit Flame Hardening  
17644 Mt. Elliott

Detroit, MI 48212  
313-891-2936  
Fax: 313-891-3150

Diamond Black Technologies, Inc.  
100 Somerset Drive  
Conover, NC 28613  
704-327-7442  
Fax: 704-322-4636

Dianamic Abrasive  
2566 Industrial Row  
Troy, MI 48084  
810-280-1185  
Fax: 810-280-2733  
E-mail: dianamicab@aol.com

Disston Precision Inc.  
6795 State Road  
Philadelphia, PA 19135  
215-338-1200  
Fax: 215-338-7060

DMS Inc.  
554 W. Wood  
Palatine, IL 60067  
847-359-7882  
Fax: 847-359-8481

Drewco Corp.  
3745 Nicholson Road  
Franksville, WI 53126  
414-886-5050  
Fax: 414-886-5872

Drive Systems Technology  
24 Marlborough Lane  
Glen Mills, PA 19342-1519  
610-358-0785  
Fax: 610-358-2776

Dura-Bar  
2100 W. Lake Shore Dr.  
Woodstock, IL 60193  
815-338-7800  
Fax: 815-338-1549

**Dyer Company**  
**P.O. Box 4966**  
**1500 McGovernville Road**  
**Lancaster, PA 17604-4966**  
**800-631-3333**  
**Fax: 717-569-6721**  
**E-mail: dyer@dyergage.com**

Dynamic Metal Treating Inc.  
7784 Ronda Drive  
Canton Twp., MI 48187  
313-459-8022  
Fax: 313-459-7863

Dynamic Tool Grinding Service  
872 Ridge Avenue  
Lombard, IL 60148  
630-620-5044  
Fax: 630-620-0177

E

Easco-Sparcatron  
Division of Liquid Drive Corp.  
10799 Plaza Dr.  
Whitmore Lake, MI 48189  
313-449-4443  
Fax: 313-449-4447

Eaton Corp.  
Highway 29 South  
Kings Mountain, NC 28086  
704-937-7411  
Fax: 704-937-4354

EDM Solutions  
2010 E. Touhy Ave.  
Elk Grove Village, IL 60007  
847-981-3361  
Fax: 847-981-0158

Educational Systems Workshops, Inc.  
P.O. Box 472  
Dyer, IN 46311  
219-865-1318  
Fax: 219-865-2775

Electrex Ltd. (India)  
Power Tools Div.  
21 D1 Peenya Industrial Area II Phase  
Bangalore 560058  
India  
(91) 80-8394477  
Fax: (91) 80-8392854

Elmass North America Inc.  
N114 W19320 Clinton Dr.  
Germantown, WI 53022  
414-255-5644  
Fax: 414-255-6509

Eltech Inc.  
9841 York Alpha Dr.  
North Royalton, OH 44133  
216-582-8195  
Fax: 216-582-8226

EMCO Gears  
4329 N. Kedzie  
Chicago, IL 60618  
312-539-1315  
Fax: 312-539-8792  
E-mail: 102050.1033@compuserve.com

Engemaq U.S.A.  
Montville Business Center  
20 Chapin Rd., Unit 1002A  
Pine Brook, NJ 07058  
201-808-2665  
Fax: 201-808-5258

Engis Corp.  
105 W. Hintz Rd.  
Wheeling, IL 60090  
847-808-9400  
Fax: 847-808-9430

Engranes Industriales Rivera  
EIRSA, de C.V.  
Apartado Postal 75-094  
Mexico City D.F. 07750  
Mexico  
(52) 5-587-8266  
Fax: (52) 5-368-3432

Engratec de Mexico  
Poniente 128 #425  
Nueva Vallejo 07750 D.F.  
Mexico  
(52) 567-73-43  
Fax: (52) 567-32-06

Engrecon S.A.  
Rod Mal. Rondon KM 42.4  
P.O. Box 031  
4 Santana de Parnaiba  
Sao Paulo 06500-970  
Brazil  
(55) 11-424-1777  
Fax: (55) 11-424-1627

**Equitable Engineering**  
**1840 Austin**  
**Troy, MI 48099**  
**810-689-9700**  
**Fax: 810-689-0281**



**Ernst Winter & Son Inc.**  
P.O. Box 1006  
100 Wilhelm Winter St.  
Travelers Rest, SC 29690  
864-834-4145  
Fax: 864-834-3730

**Esgard, Inc.**  
P.O. Drawer 2698  
Lafayette, LA 70502  
318-234-6327  
Fax: 318-234-0113

**Etna Products Inc.**  
P.O. Box 630  
16824 Park Circle Dr.  
Chagrin Falls, OH 44022  
216-543-9845  
Fax: 216-543-1789

**Euclid Heat Treating Co.**  
1408 E. 222nd St.  
Cleveland, OH 44117  
216-481-8444  
Fax: 216-481-3473

**Euro-Tech Corporation**  
14665 W. Lisbon Rd.  
Brookfield, WI 53005  
414-781-6777  
Fax: 414-781-2822

**F**

**Fairfield Mfg. Co.**  
P. O. Box 7940  
U. S. 52 South  
Lafayette, IN 47903-7940  
317-474-3474  
Fax: 317-477-7342  
E-mail: fairfld@aol.com

**Fairlane Gear Inc.**  
8182 Canton Center Rd.  
Canton, MI 48187  
313-459-2440  
Fax: 313-459-2941

**Falk Corp.**  
P.O. Box 492  
Milwaukee, WI 53201-0492  
800-545-5215  
Fax: 414-937-4359

**Fayscott Co.**  
225 Spring St.  
Dexter, ME 04930  
207-924-7331  
Fax: 207-924-5510

**Federal Gear Corp.**  
38134 Western Pkwy. Unit #1  
Willoughby, OH 44094  
216-946-4327  
Fax: 216-946-8018

**Fellows Corp.**  
**Precision Dr.**  
Springfield, VT 05156  
802-886-8333  
Fax: 802-886-8561

**FGT Gage & Systems Inc.**  
2624 S. 162nd St.  
New Berlin, WI 53151  
414-827-0558  
Fax: 414-782-3210

**Finishing Equipment Inc.**  
3640 Kennebec Dr.  
St. Paul, MN 55122  
612-452-1860  
Fax: 612-452-9851

**Fiske Brothers Refining Co.**  
Lubriplate Div.  
129 Lockwood St.  
Newark, NJ 07105  
800-733-4755  
Fax: 201-465-5736

**Flender Corporation**  
P.O. Box 1449  
950 Tollgate Road  
Elgin, IL 60123  
847-931-1990  
Fax: 847-931-0711

**Flender-Graffenstaden**  
1589 Aztec Ln.  
Mount Pleasant, SC 29464  
803-856-0108  
Fax: 803-856-0104

**Footo-Jones/Illinois Gear**  
2102 N. Natchez Ave.  
Chicago, IL 60635  
773-622-8000  
Fax: 773-622-8176

**Forest City Gear Co., Inc.**  
P. O. Box 80  
11715 Main St.  
Roscoe, IL 61073-0080  
815-623-2168  
Fax: 815-623-6620  
E-mail: fyoung@firecraker.com

**FPM Heat Treating**  
1501 S. Lively Blvd.  
Elk Grove Village, IL 60007  
847-228-2525  
Fax: 847-228-5912

**Franke Gear Works Inc.**  
4401 N. Ravenswood Ave.  
Chicago, IL 60640  
800-311-8425  
Fax: 800-311-8426

**Fuji Univance Corp.**  
38505 Country Club Dr., Ste. 204  
Farmington Hills, MI 48331  
810-489-5641  
Fax: 810-489-5642

**Fuller Company**  
South 10th & Mill St.  
Allentown, PA 18103  
610-770-7400  
Fax: 610-770-7429

**G**

**Gary P. Mowers, P.C.**  
2797 E. Rude St.  
Weedport, NY 13166  
315-834-8823  
Fax: 315-834-8824

**Gear Group International**  
1825 I St. N.W.  
Washington, DC 20006  
202-429-2734  
Fax: 703-522-7153

**Gear Motions**  
1750 Milton Ave.  
Syracuse, NY 13209  
315-488-0100  
Fax: 315-488-0196

**Gear Research Institute**  
1801 Maple Ave.  
Evanston, IL 60201-3135  
847-491-5900  
Fax: 847-491-5986  
E-mail: dbreen@nwu.edu

**Gear Systems Div.**  
Leeson Electric Corp.  
23400 Apollo Ct.  
Lake Villa, IL 60046  
847-356-1606  
Fax: 847-356-1631

**The Gear Works Seattle**  
500 S. Portland St.  
Seattle, WA 98108  
206-762-3333  
Fax: 206-762-3704

**GEARCOA**  
14300 Lorain Ave.  
Cleveland, OH 44111  
216-671-5400  
Fax: 216-671-5825

**Gearsearch Inc.**  
750 Indian Wells Rd.  
Banning, CA 92220-5308  
909-845-5822  
E-mail: 73743.1322@compuserve.com

**Gears & Drive Systems Inc.**  
P.O. Box 109  
1364 Welsh Rd.  
Spring House, PA 19477-0109  
215-540-0820  
Fax: 215-540-0360

**Gears for Industry Inc.**  
1925 S. Moorland Rd.  
New Berlin, WI 53151  
414-797-9960  
Fax: 414-797-9245

**Gearsoft Design**  
8/26 Huxtable Ave.  
Lane Cove NSW 2066  
Australia  
(61) 2-4111282  
Fax: (61) 2-4111282

**Geartech**  
100 Bushbuck Rd.  
Townsend, MT 59644  
406-266-4620  
Fax: 406-266-4625

**Geartronics Industries**  
P.O. Box 376  
100 Chelmsford Road  
North Billerica, MA 01862  
617-933-1400  
Fax: 508-667-3130

**General Broach & Engineering**  
50325 Patricia  
Chesterfield, MI 48051  
810-598-7594  
Fax: 810-949-8007

**General Electric Marine Products Div.**  
1100 Western Ave.  
Lynn, MA 01910  
617-594-7298  
Fax: 617-594-2464

**General Magnaplate Corp.**  
1331 U.S. Route 1  
Linden, NJ 07036  
908-862-6200  
Fax: 908-862-6110  
E-mail: info@magnaplate.com

**Generated Gear & Machine**  
25418 Ryan Rd.  
Warren, MI 48091  
810-756-6470  
Fax: 810-756-8517

**The Gleason Works**  
1000 University Ave.  
Rochester, NY 14692  
716-473-1000  
Fax: 716-461-4348

**Global Gear**  
**Div. of Dynagear Inc.**  
2500 Curtiss St.  
Downers Grove, IL 60515  
630-969-1008  
Fax: 630-969-3970

**GMI**  
6708 Ivandale Rd.  
Independence, OH 44134  
216-642-0230  
Fax: 216-642-0231

**Guy Crader Consulting**  
P.O. Box 126  
Lake Ariel, PA 18436-0126  
717-689-7452  
Fax: 717-689-7452  
E-mail: gcrader@aol.com

**GW Plastics**  
P.O. Box 56  
113 Pleasant St.  
Bethel, VT 05032  
802-234-9941  
Fax: 802-234-9940

**H**

**Hand Screw Machine**  
17703 Pennsylvania Ave.  
Maple Heights, OH 44137  
216-475-0220

**Hane Industrial Training**  
120 S. 7th St.  
Terre Haute, IN 47807  
812-232-0753  
Fax: 812-232-3978

**Hangsterfer's Labs Inc.**  
P.O. Box 128  
Mantua, NJ 08051  
609-468-0216  
Fax: 609-468-0200

**Hansvedt EDM**  
P.O. Box 6099  
803 Kettering Park  
Urbana, IL 61801  
217-384-5900  
Fax: 217-384-0091

**Harder Precision Components**  
P.O. Box 1405  
1123 Seminole St.  
Clearwater, FL 34615  
813-442-4212  
Fax: 813-447-4463  
E-mail: jkatopis@citicom.com

**Harnischfeger**  
P&H Mining Div.  
4400 W. National  
Milwaukee, WI 53201  
414-671-7684  
Fax: 414-671-7309

**Harper Surface Finishing Systems**  
70 Gracey Ave.  
Meriden, CT 06450  
203-630-0550  
Fax: 203-630-0346



Hermes Machine Tool Co., Inc.  
Five Gardner Rd.  
Fairfield, NJ 07004  
201-227-9150  
Fax: 201-227-9364  
E-mail: hermes@newmach.com

HICO  
18000 Studebaker Rd. #550  
Cerritos, CA 90703  
310-809-5050  
Fax: 310-809-5251

Highway Machine Co.  
RR1 Box 208A  
Princeton, IN 47670  
812-385-3639  
Fax: 812-385-5232

Hindustan Motors Ltd.  
Passenger Car Division  
Old Palasia P.O. Box 16/5  
Indore, M.P., India 452001  
91-07292-55241-42  
Fax: 91-07292-56134

Hitachi EDM Products  
1555 Barclay Blvd.  
Buffalo Grove, IL 60089  
847-808-0098  
Fax: 847-808-0233

Hoechst Celanese Corp.  
Technical Polymers Div.  
90 Morris Ave.  
Summit, NJ 07901  
800-833-4882  
Fax: 908-598-4330

Höfler GmbH  
Industriestr 19  
Ettlingen 76275  
Germany  
(49) 7243-599-0  
Fax: (49) 7243-599-165

Hoglund Technology Corp.  
1050 Route 22 West  
Lebanon, NJ 08833  
908-236-7794  
Fax: 908-236-6826

**Holroyd Machine Tools**  
**Harbour Lane North**  
**Milnrow, Rochdale OL16 3LQ**  
**UNITED KINGDOM**  
**(44) 1706-526590**  
**Fax: (44) 1706-353350**

Houghton International Inc.  
P.O. Box 930  
Madison & Van Buren Ave.  
Valley Forge, PA 19482  
610-666-4000  
Fax: 610-666-1376

Howard's Machine Shop  
2230 S. Main St.  
Carthage, MO 64836  
417-358-7143  
Fax: 417-358-3130

Hua Yong Machine Co., Ltd.  
No. 5 Torng Lih Rd.  
Hsiao Kang Kaohsiung  
Tawain, ROC  
(886) 7-8125710  
Fax: (886) 7-8318728

Hy-Mech Systems Inc.  
3641 E. Long Lake Rd.  
Traverse City, MI 49684  
616-946-7781

I.S.P.J.A.E.  
Facultad de Ing. Mecanica  
Calle 116 S/N Cujae  
Marianao 15 Ciudad Habana  
Cuba  
(537) 202267  
Fax: (537) 332429  
E-mail: mecanica@cujae.cu

**Ikegai America Corp.**  
**2246 N. Palmer #108**  
**Schaumburg, IL 60173**  
**847-397-3970**  
**Fax: 847-397-7535**

Impact Strategies  
P.O. Box 5317  
Clinton, NJ 08809  
908-730-9163  
Fax: 908-730-8334

**Inductoheat Inc.**  
**32251 N. Avis Dr.**  
**Madison Hts., MI 48071**  
**810-585-9393**  
**Fax: 810-585-0429**  
**E-mail: moorhous@inductoheat.com**

InSCO Corp.  
P.O. Box 489  
412 Main Street  
Groton, MA 01450  
508-448-6368  
Fax: 508-448-5155

Intech Corp.  
250 Herbert Ave.  
Closter, NJ 07624  
201-767-8066  
Fax: 201-767-7797

Interlake Hoeganaes  
River Rd. & Taylors Ln.  
Riverton, NJ 08077  
609-829-2220  
Fax: 609-786-2574

International Financial Services  
Nine Village Circle, Ste. #450  
Westlake, TX 76034  
817-488-3230  
Fax: 817-488-3345

Interstate Tool Corp.  
4538 W. 130th  
Cleveland, OH 44135  
216-671-1077  
Fax: 216-671-5431

Invincible Gear Co.  
11970 Mayfield  
Livonia, MI 48150  
313-421-4620  
Fax: 313-421-6132

Invo Spline Inc.  
P.O. Box 70  
2357 E. Nine Mile  
Warren, MI 48090  
810-757-8840  
Fax: 810-757-8849

**ITW Heartland**  
**3501 S. Broadway**  
**Alexandria, MN 56308**  
**320-762-8782**  
**Fax: 320-762-5260**

ITW Spiroid  
3700 W. Lake Ave.  
Glenview, IL 60025  
847-657-5074  
Fax: 847-657-5098

Jack Dustman & Assoc.  
P.O. Box 55585  
3600 Washington Blvd.  
Indianapolis, IN 46205  
317-925-3537  
Fax: 317-925-3383

James Reid Gear Services  
102 N. Williams Street  
Westmont, IL 60559  
708-963-9620  
Fax: 708-963-9632

JobBOSS Software Inc.  
7701 York Ave. S.  
Minneapolis, MN 55435  
612-831-7182  
Fax: 612-831-2811  
E-mail: answers@jobboss.com

JRM International Inc.  
1214 Shappert Dr.  
Rockford, IL 61115  
815-282-9330  
Fax: 815-282-9150

K

K.H. Huppert Co.  
16850 S. State St.  
South Holland, IL 60473  
708-339-2020  
Fax: 708-339-2225

KA-Wood Gear & Machine  
32500 Industrial Dr.  
Madison Heights, MI 48071  
810-585-8870  
Fax: 810-585-3011

Kaman Aerospace Corp.  
P.O. Box 2  
Old Windsor Road  
Bloomfield, CT 06002-0002  
203-242-4461  
Fax: 203-243-7975

Keller Machine Co.  
315 N. Leavitt St.  
Chicago, IL 60612  
312-421-5285  
Fax: 312-421-4102

Keystone Powdered Metal Co.  
P.O. Box 313, 1935 State St.  
St. Marys, PA 15857-0313  
814-781-1591  
Fax: 814-781-7648

KGK International/Sodick EDM  
901 Deerfield Parkway  
Buffalo Grove, IL 60089  
847-465-4432  
Fax: 847-465-0181

Kluber Lubrication North America, L.P.  
54 Wentworth Ave.  
Londonderry, NH 03053  
603-434-7704  
Fax: 603-434-8046

Koepfer America L. P.  
635 Schneider Dr.  
S. Elgin, IL 60177  
847-931-4121  
Fax: 847-931-4192

Kokusai Inc.  
6009 W. 71st St.  
Indianapolis, IN 46278  
317-293-6038  
Fax: 317-293-6514

Koolant Coolers Inc.  
2625 Emerald Dr.  
Kalamazoo, MI 49001  
616-349-6800  
Fax: 616-349-8951

**Koro Sharpening Service**  
**9530 85th Avenue N.**  
**Maple Grove, MN 55369**  
**612-425-5247**

Krautkramer Branson  
50 Industrial Park Rd.  
Lewistown, PA 17044  
717-242-0327  
Fax: 717-242-2606  
E-mail: kb-ltn.mhs@compuserve.com

Kromhard Twist Drill Co.  
1097 Sweitzer Ave.  
Akron, OH 44301-1382  
330-535-7129  
Fax: 330-535-3729

Krupp Engineering Inc.  
8121 Gregory Rd.  
Dexter, MI 48130  
313-426-2604  
Fax: 313-426-2450

L

L + H Welding & Machine Co.  
P.O. Box 219  
913 L + J Court  
Gillette, WY 82716  
307-682-7238  
Fax: 307-686-1646

Labeco  
156 E. Harrison St.  
Mooreville, IN 46158  
317-831-2990  
Fax: 317-831-2978

Lamont Gear  
1850 Gravers Rd.  
Norristown, PA 19401  
610-277-7350  
Fax: 610-277-3787

Lapmaster Intl.  
6400 W. Oakton St.  
Morton Grove, IL 60053  
847-967-2975  
Fax: 847-967-3903

Latrobe Steel Co.  
Division of The Timken Co.  
P.O. Box 31  
Latrobe, PA 15650-0031  
412-537-7711  
Fax: 412-532-6316

Lawler Gear Corp.  
1320 SE Hamblen Rd.  
Lee's Summit, MO 64081  
816-525-0002  
Fax: 816-525-1113

LeBlond Makino Machine Tool Co.  
7680 Innovation Way  
Mason, OH 45040  
513-573-7330  
Fax: 513-573-7360

**LeCount Inc.**  
**P.O. Box 950**  
**12 DeWitt Dr.**  
**White River Jct., VT 05001**  
**802-296-2200**  
**Fax: 802-296-6843**  
**E-mail: lecount@sover.net**



**Liebherr-America Inc.**  
**1465 Woodland Dr.**  
**Saline, MI 48176**  
**313-429-7225**  
**Fax: 313-429-2294**

Linamar  
 30555 Southfield Rd., Ste. 250  
 Southfield, MI 48076  
 810-642-0800  
 Fax: 810-642-7815

Lindberg Heat Treating  
 1975 N. Ruby St.  
 Melrose Park, IL 60160  
 708-344-4080  
 Fax: 708-344-4010

LMT-Fette, Inc.  
 3725-I No. 126 St.  
 Brookfield, WI 53005  
 414-783-7606  
 Fax: 414-783-5043

Lovejoy Inc.  
 2655 Wisconsin Ave.  
 Downers Grove, IL 60515  
 630-852-0500  
 Fax: 630-852-2120

**M**

M.E. Cunningham  
 P.O. Box 307  
 Ingomar, PA 15127  
 412-366-3048  
 Fax: 412-369-9199

M.J. Gallagher & Assoc.  
 P.O. Box 281  
 Spring Grove, IL 60081-0281  
 815-675-2648  
 Fax: 815-675-2648

M.J.H. Gear & Tool Co., Inc.  
 442 W. 49th St.  
 New York, NY 10019  
 212-246-3800  
 Fax: 212-265-4053

**M&M Precision Systems**  
**300 Progress Rd.**  
**West Carrollton, OH 45449**  
**513-859-8273**  
**Fax: 513-859-4452**

Mahr Corporation  
 11435 Williamson Road  
 Cincinnati, OH 45241  
 513-489-6116  
 Fax: 513-489-6302

McGinty Gear  
 11050 E. McKeese Rd.  
 Suttons Bay, MI 49682  
 616-271-4153  
 Fax: 616-271-4177

Management & Engineering Tech.  
 161 Copperfield Dr.  
 Dayton, OH 45415  
 513-832-1583  
 Fax: 513-832-0858  
 E-mail: 74214.415@compuserve.com

**Manufactured Gear & Gage**  
**P.O. Box 7155**  
**Elgin, IL 60121**  
**630-377-2496**  
**Fax: 630-377-2546**

Manufacturing Technology Inc.  
 1702 W. Washington

South Bend, IN 46628  
 219-233-9490  
 Fax: 219-233-9489

Mattoon Precision Mfg. Inc.  
 1221 Old State Rd.  
 Mattoon, IL 61938  
 217-235-6000  
 Fax: 217-235-6010

Mecatool USA, Ltd.  
 165 Hansen Ct. #111E  
 Wood Dale, IL 60118  
 630-595-9696  
 Fax: 630-595-9101

Meccanica Nova Corp.  
 24371 Catherine Industrial Ste. 235  
 Novi, MI 48375  
 810-449-4000  
 Fax: 810-449-4004  
 E-mail: ncnova@aol.com

Meister Grinding Tech. Corp.  
 1200 Millbury St. Unit 7F/7G  
 Worcester, MA 01607  
 508-753-0808  
 Fax: 508-753-4404

Merger Corp.  
 978 Southampton Rd.  
 Westfield, MA 01085-1364  
 413-568-6181  
 Fax: 413-568-6839

**Merit Gear Corp.**  
**P.O. Box 486**  
**810 Hudson St.**  
**Antigo, WI 54409**  
**800-756-3748**  
**Fax: 715-623-2290**

Metal Powder Industries Fed.  
 105 College Rd. East  
 Princeton, NJ 08540-6652  
 609-452-7700  
 Fax: 609-987-8523  
 E-mail: info@mpif.org

Metaplas Ionon  
 14301-C South Lakes Drive  
 Charlotte, NC 28273  
 704-587-4554  
 Fax: 704-587-4560

Metlab  
 1000 E. Mermaid Ln.  
 Wyndmoor, PA 19038  
 215-233-2600  
 Fax: 215-233-5653

Metscope Corp.  
 355 Woodruff Rd., Ste. 405  
 Greenville, SC 29607  
 803-754-0090  
 Fax: 803-234-4852

Michigan Automatic Turning  
 P.O. Box 297  
 Brighton, MI 48116  
 810-227-3520  
 Fax: 810-227-1014

Micromatic Textron  
 345 E. 48th St.  
 Holland, MI 49423  
 616-392-1461  
 Fax: 616-392-1710

Mid-State Machine Co.  
 2960 Corriher Grainge Rd.  
 Mount Ulla, NC 28125  
 704-636-7029  
 Fax: 704-637-3484

Midwest Gear  
 2182 E. Aurora Rd.  
 Twinsburg, OH 44087  
 216-425-4419  
 Fax: 216-425-8600

**Midwest Gear & Tool**  
**26069 Groesbeck**  
**Warren, MI 48089**  
**810-776-7580**  
**Fax: 810-776-2322**

MIFCO/McEnglevan Industrial Furnace  
 P.O. Box 31  
 700 Griggs St.  
 Danville, IL 61834  
 217-446-0941  
 Fax: 217-446-4535  
 E-mail: mifco@ix.netcom.com

Mikrofinish  
 1275 Bloomfield Ave.  
 Fairfield, NJ 07004  
 201-227-8777  
 Fax: 201-227-7953

Milburn Engineering Inc.  
 12024 7th N.W.  
 Seattle, WA 98177  
 206-365-2818  
 Fax: 206-361-6221

Milford Gear Works  
 241 Research Dr.  
 Milford, CT 06460  
 203-783-9595  
 Fax: 203-783-9595

Miller Industrial Services Inc.  
 9415 W. Forest Home Ave.  
 Hales Corners, WI 53130  
 414-425-7766  
 Fax: 414-425-7090

Mississippi State Univ.  
 Mech. Eng. Dept.  
 210 Carpenter Bldg.  
 Mississippi State, MS 39762  
 601-325-7313  
 Fax: 601-325-7223  
 E-mail: jones@meng.msstate.edu

Mitsubishi EDM/MC Machinery  
 1500 Michael Dr. Ste. C  
 Wood Dale, IL 60191  
 630-860-4210  
 Fax: 630-860-2572

**Mitsubishi Machine Tool**  
**907 W. Irving Park Rd.**  
**Itasca, IL 60143**  
**630-860-4222**  
**Fax: 630-860-4233**

Mitts & Merrill L.P.  
 P.O. Box 691  
 615 Chippewa Road  
 Harvard, IL 60033  
 815-943-3303  
 Fax: 815-943-3366

Mobile Pulley & Machine Works  
 P.O. Box 1947  
 905 S. Ann St.  
 Mobile, AL 36633-1947  
 334-432-7631  
 Fax: 334-432-8364  
 E-mail: 75357.1513@compuserve.com

Modern Industries Inc.  
 613 West 11th Street  
 P.O. Box 399  
 Erie, PA 16512  
 814-455-8061  
 Fax: 814-453-4382

Modified Gear & Spine  
 18300 Mt. Elliott  
 Detroit, MI 48234  
 313-893-3511  
 Fax: 313-893-6110

Molon Gear & Shaft  
 335 E. Illinois St.  
 Palatine, IL 60067  
 847-705-0608  
 Fax: 847-705-8349

Moore Gear Mfg. Co.  
 P.O. Box 49  
 Two Hawthorne Dr.  
 Hermann, MO 65041  
 573-486-5415  
 Fax: 573-486-3487

Moore Machine & Gear, Inc.  
 10920 N. St. Joseph Ave.  
 Evansville, IN 47720  
 812-963-3074

**Moore Products Co.**  
**Gage Division**  
**One Sunnyside Pike**  
**Spring House, PA 19477-0900**  
**215-646-7400 x2352**  
**Fax: 215-653-0347**

Morrison Knudsen  
 1500 W. 3rd St.  
 Cleveland, OH 44113  
 216-523-5600

Mostar Gear & Machine Inc.  
 714 S. Jefferson  
 Washington, MO 63090-2710  
 314-390-3909  
 Fax: 314-390-3966

Multi-Arc Inc.  
 200 Roundhill Dr.  
 Rockaway, NJ 07866  
 201-625-3400  
 Fax: 201-625-2244

Murray Brothers Mfg. Co.  
 7711 W. 99th St.  
 Hickory Hills, IL 60457  
 708-430-8111  
 Fax: 708-430-8222

**N**

N. E. Wisconsin Technical College  
 1601 University Dr.  
 Marinette, WI 54143  
 715-735-9361  
 Fax: 715-735-0171

Nanchang Gear Works  
 Engineering Administration Office  
 Nanchang, Jiangxi 330044  
 PRC 0086  
 791-3805885-254  
 Fax: 791-3805757

NASA Lewis Research Center  
 21000 Brookpark Rd.  
 Cleveland, OH 44135  
 216-433-3915  
 Fax: 216-433-3954

**National Broach & Machine Co.**  
**17500 Twenty-Three Mile Rd.**  
**Macomb, MI 48044-1103**  
**810-263-0142**  
**Fax: 810-263-4571**



National Metrology  
P.O. Box 686  
11 Stagecoach Ln.  
Sunapee, NH 03782  
603-763-5881  
Fax: 603-763-3058

NCADT  
P.O. Box 30  
State College, PA 16804-0030  
814-865-8207  
Fax: 814-863-1183  
E-mail: gij1@psu.edu

New Venture Gear Inc.  
1650 Research Dr. Ste. 325  
Troy, MI 48083  
810-680-4900  
Fax: 810-680-6566

NewAge Industries Inc.  
2300 Maryland Rd.  
Willow Grove, PA 19090  
215-657-6040  
Fax: 215-657-1697

Niagara Gear Corp.  
941 Military Rd.  
Buffalo, NY 14217  
716-874-3131  
Fax: 716-874-9003

Nordbert-Lokomo Oy  
Parkano Works  
Vanhantalantie 3  
Fin-39700 Parkano  
Finland  
358-204-80-144  
Fax: 358-204-80-145

Normac Inc.  
P.O. Box 69  
Airport Road Industrial Park  
Arden, NC 28704  
704-684-1002  
Fax: 704-684-1384  
E-mail: info@normac.com

Nuttall Gear Corp.  
P.O. Box 1032  
2221 Niagara Falls Blvd.  
Niagara Falls, NY 14302  
716-731-5180  
Fax: 716-731-9329

Nye Lubricants Inc.  
12 Howland Rd.  
Fairhaven, MA 02719  
508-996-6721  
Fax: 508-997-5285

**O**

Oberlin Filter Co.  
404 Pilot Ct.  
Waukesha, WI 53188  
414-547-4900  
Fax: 414-547-0683

The Ohio Broach & Machine Co.  
35264 Topps Ind. Pkwy.  
Willoughby, OH 44094  
216-946-1040  
Fax: 216-946-0725

Okamoto Corp., EDM Division  
1500 Busch Parkway  
Buffalo Grove, IL 60089  
847-520-7700  
Fax: 847-520-7980

Omni Gear & Machine  
90 Bissel St.

Joliet, IL 60432  
815-723-4327  
Fax: 815-723-9207

O'Neill Gear  
9207 Ivanhoe St.  
Schiller Park, IL 60176  
847-678-0676  
Fax: 847-678-0784

Ono Sokki Technology Inc.  
2171 Executive Dr. #400  
Addison, IL 60101  
630-627-9700  
Fax: 630-627-0004

**Ontario Drive & Gear**  
220 Bleams Rd.  
New Hamburg Ontario N0B 2G0  
Canada  
519-662-2840  
Fax: 519-662-2421  
E-mail: donna@odg.com

**P**

P.F. Markey Inc.  
2880 Universal Dr.  
Saginaw, MI 48603  
800-792-3811  
Fax: 517-793-9511

Pacific Industrial Furnace Co.  
26000 Capitol Ave.  
Redford, MI 48239-2499  
313-937-4130  
Fax: 313-937-1677

**Parker Industries Inc.**  
1650 Sycamore Ave.  
Bohemia, NY 11716  
516-567-1000  
Fax: 516-567-1355

Patterson Gear & Machine  
P.O. Box 7240  
5876 Sandy Hollow Road  
Rockford, IL 61126-7240  
815-874-4327  
Fax: 815-874-7448

Paul W. Marino Gages Inc.  
21300 MacArthur Blvd.  
Warren, MI 48089  
810-759-2400  
Fax: 810-759-2423

Paulo Products Co.  
5711 W. Park Ave.  
St. Louis, MO 63110  
314-647-7500  
Fax: 314-647-7534

PC Enterprises  
115 Yonder Lane  
Sedona, AZ 86336  
800-437-2368  
Fax: 520-282-6104

Pennsylvania Gear Corp.  
One Cabot Blvd. East  
Langhorne, PA 19047-1801  
215-945-6000  
Fax: 215-945-2052

**Perry Technology**  
P.O. Box 21  
29 Industrial Park Road  
New Hartford, CT 06057  
860-738-2525  
Fax: 860-738-2455

**Pfauter-Maag Cutting Tools**  
P.O. Box 2950  
Loves Park, IL 61132-2950  
815-877-8900  
Fax: 815-877-0264

Philadelphia Gear Corporation  
181 S. Gulph Rd.  
King of Prussia, PA 19406  
610-265-3000  
Fax: 610-337-5637

Philadelphia Gear Corp.  
Gear Services Div.  
4631 Winfield  
Houston, TX 77039  
713-449-2200  
Fax: 713-449-2294

PIC Design  
P.O. Box 1004  
86 Benson Rd.  
Middlebury, CT 06762-1004  
203-758-8272  
Fax: 203-758-8271  
E-mail: info@pic-design.com

Pillar Industries  
N92 W15800 Megal Dr.  
Menomonee Falls, WI 53051  
800-558-7733  
Fax: 414-255-0359

Pitch Templates Inc.  
1718 Sheffield Dr.  
Blue Bell, PA 19422  
610-279-0443  
Fax: 610-275-9877

Ply-Mar Tool Co.  
1718 Sheffield Dr.  
Blue Bell, PA 19422  
610-279-0443  
Fax: 610-275-9877

Power Eng. & Mfg. Ltd.  
P.O. Box 4055  
2635 WCF&N Dr.  
Waterloo, IA 50704-4055  
319-232-2311  
Fax: 319-232-6100

Precision Engineering Services  
388 Palmer Ln.  
Pleasantville, NY 10570  
914-769-3196  
Fax: 914-769-3196

Precision Gage Co.  
6939 W. 59th St.  
Chicago, IL 60638  
773-586-2121  
Fax: 773-586-2159

Precision Gear Co.  
1900 Midway Dr.  
Twinsburg, OH 44087  
216-487-0888  
Fax: 216-487-0618

Precision Gear Inc.  
48-09 108th St.  
Corona, NY 11368  
718-592-7100  
Fax: 718-592-2525

Precision Gears Inc.  
N13 W24705 Bluemound Rd.  
Pewaukee, WI 53072  
414-542-4261  
Fax: 414-542-1592

**Presrite Corp.**  
3665 E. 78th St.

Cleveland, OH 44105  
216-441-5990  
Fax: 216-441-2644  
E-mail: info@presrite.com

**Pro-Gear Co. Inc.**  
23 Dick Rd.  
Depew, NY 14043  
716-684-3811  
Fax: 716-684-7717

**Process Industries**  
3860 N. River Rd.  
Schiller Park, IL 60176  
847-671-1631  
Fax: 847-671-6840

**Profile Engineering**  
100 River St.  
Springfield, VT 05156  
802-885-9176  
Fax: 802-885-6559

Progressive Engineering Co.  
2010 E. Main St.  
Richmond, VA 23223  
800-868-5457  
Fax: 804-780-2230

Progressive Technologies  
4201 Patterson S.E.  
Grand Rapids, MI 49546  
616-957-0871  
Fax: 616-957-3484  
E-mail: ptisales@ptihome.com

Progressive Tool Co.  
1624 Blackhawk St.  
Waterloo, IA 50704  
319-234-6619  
Fax: 319-234-7828

Purdue at Indianapolis  
799 W. Michigan St.  
Indianapolis, IN 46202  
317-274-7377  
Fax: 317-274-4567

The Purdy Corp.  
586 Hilliard St.  
Manchester, CT 06040  
860-649-0000  
Fax: 860-645-6293

**Q**

Qualicast Corp.  
P.O. Box 122  
Broomall, PA 19008  
610-356-7464  
Fax: 610-353-7829

Quench Press Specialists Inc.  
4159 Church St.  
Roebuck, SC 29376  
864-576-3502  
Fax: 864-576-3513

**R**

R.H. Software  
Four Reddick Rd.  
Asheville, NC 28815  
704-298-1008  
Fax: 704-298-6030

R.L. Wagner & Assoc.  
695 Cavalcade Circle  
Naperville, IL 60540  
630-961-9200  
Fax: 630-961-9917  
E-mail: rlw695@aol.com



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# 18 Things You Should Know About SPC for Gears

Dr. Hans Bajarria

**S**tatistical Process Control (SPC) and statistical methods in general are useful techniques for identifying and solving complex gear manufacturing consistency and performance problems. Complex problems are those that exist in spite of our best efforts and the application of state-of-the-art engineering knowledge.

Statistical methods approach these problems *results-backward* as opposed to *knowledge-forward*. For example, the knowledge-forward approach would seek consistencies in gear profile, lead, runout, etc., with the assumption that consistencies improve performance. The results-backward approach, on the other hand, will analyze the situations starting from assembly performance. It will then relate performance variation to specific gear characteristics.

In other words, we use our gear expertise in a knowledge-forward approach. When this fails to solve a problem, we should use the results-backward approach. Once critical gear characteristics are determined, we can begin attempting to achieve consistency.

Let us begin by describing six SPC fundamentals and six statistical applications for gear design and manufacturing. These will lead us to an effective sequence for applying statistical methods.

## Six Fundamentals of SPC

SPC is only a subset of statistical methods helpful in analyzing complex problems. These methods can be a useful set of tools for carrying out investigations of our manufacturing processes. SPC can chart the output of any process to examine whether the process condition is stable, has an excessive variation or is off-target. Furthermore, SPC can offer clues to strategies for correcting

these conditions. Additional statistical tools can help us establish relationships between problematic process conditions and suspect variables.

**1. Multivariate ( $T^2$ ) Charts** are useful in understanding and controlling correlated performance characteristics. The performance characteristics of assemblies, such as noise, durability, ease of maneuverability, etc., are likely to be correlated. That means, for example, that trying to reduce the noise may result in losing maneuverability, or improvement of maneuverability may result in a reduced durability, and so on. The problems associated with correlated characteristics can only be defined with the use of a multivariate chart (see Fig. 1).

**2. Multivariate ( $T^2$ ) Charts** are also useful in understanding and controlling input gear characteristics. Gear characteristics are most likely to be correlative because they are generated simultaneously. In practical terms, we can state that when characteristics are correlated, each individual characteristic can be within specification, and yet jointly they constitute a statistical instability.

**3. Multi-vari Charts** are useful in analyzing size as well as shape problems. For example, four teeth on a gear measured by conventional means may all individually be within specification, and yet differences among them may be the root cause of a problem. A proper way to define a problem that takes into account characteristics of each tooth individually as well as differences among the four teeth is a multi-vari chart (See Fig. 2).

Multi-vari and multivariate charts are different. Multi-vari charts analyze variations within a given characteristic, whereas multivariate charts analyze

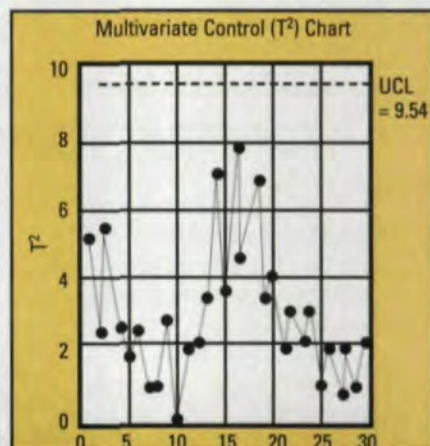


Fig. 1 — This  $T^2$  chart combines 3 characteristics—tip, form and high point—in a single entity.

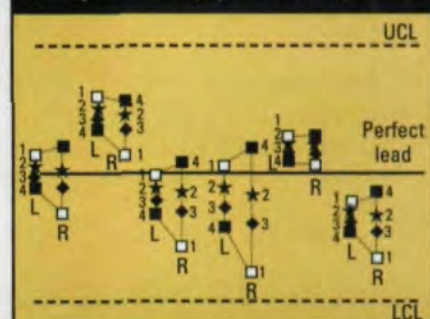
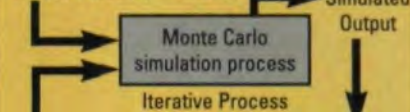


Fig. 2 — A multi-vari chart showing lead variation on 4 left and 4 right teeth simultaneously.

Equation Derived From Multiple Regression Analysis

Gear Performance Output

$$= 36.96 + 0.39 (A) - 0.55 (B)$$



Random Variables: Gear Characteristic A  
Gear Characteristic B

Fig. 3 — A Monte Carlo simulation.

## Dr. Hans Bajarria

is the president of Multiface, Inc., an SPC consulting firm in Garden City, MI. He has presented a number of seminars on SPC for gears for SME.



relation and variation between two or more characteristics.

4. **Multivariate Analysis** is useful in analyzing process instabilities and relating them to process variables. An instability is characterized by an abnormal condition on a control chart. To understand the source of unstable behavior, we generally analyze process variables. If process variables are stable, then we look for the explanation elsewhere. Multivariate analysis captures the

missed opportunities in analyzing process variables that we have prematurely concluded to be noncontributory. For example, (A) incoming material condition, (B) workpiece speed and (C) tool feed may all appear to be within normal range when analyzing an instability visible on a control chart. Conventional wisdom leads us to look elsewhere for the root cause. A multivariate chart will offer additional help by analyzing  $T^2_{AB}$ ,  $T^2_{AC}$ ,  $T^2_{BC}$  and  $T^2_{ABC}$ . If this aid is not

utilized, it is possible that the instability may remain a mystery.

5. **Multiple Regression Analysis** is useful in establishing relationships between gear performance characteristics and gear characteristics. Neither worst-case tolerancing nor statistical tolerancing alone are sufficient to fully understand how gear characteristics affect the performance of assemblies containing gears. Such understanding can only be developed through probabilistic relationships based on actual data rather than any theoretical considerations. Multiple regression analysis helps develop this relationship.

6. **Monte Carlo Simulations** are computer-based, iterative statistical procedures wherein we determine targets and ranges of critical gear characteristics to match targets and ranges of performance. The inputs to the simulation processes are probabilistic equations and targets and ranges of gear characteristics. The output from the simulation processes are the target and range of performance (see Fig. 3).

**Six Applications for SPC in Gear Manufacturing**

1. Acceptable as well as unacceptable production of gears can best be characterized by using SPC. Gear characteristics that fall within specifications are not in themselves indications of the quality of the processes that produced them. For example, an acceptable gear profile is judged by a specified envelope. However, the process that created the envelope is a multivariate process; that is, three characteristics that make up the gear profile—tip, form and high point—are produced simultaneously. A correct judgment about the process condition responsible for these characteristics can only be made with a  $T^2$  chart. Any decisions regarding process actions based on specifications tend to produce either overreactions or underreactions. While gear metrology is very advanced, it does not go far enough in integrating SPC for process actions.

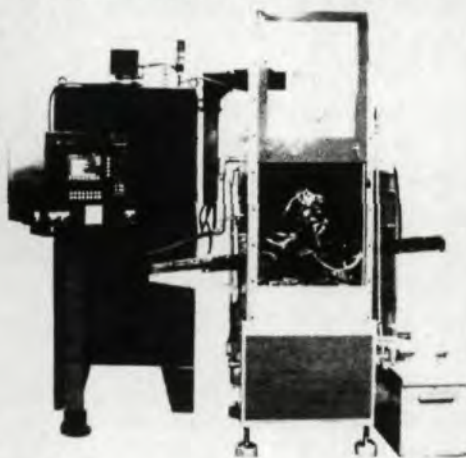
2. Effects of design and production of gear characteristics on gear performance can best be characterized by using SPC. Gear characteristics are simultaneously

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generated and therefore, we must judge their acceptability together, rather than discretely. The issue of joint acceptability does not get enough coverage either in standards or at gear design and manufacturing conferences.

3. Output performance characteristics of assemblies containing gears, such as durability, noise, ease of transmission under quickly changing inputs and smoothness of transmission, are correlated to one another. Knowledge of these correlations is critical to the SPC of assemblies. These correlations can be quantified using statistical methods.

4. Suspect gear characteristics that contribute to poor performance of assemblies are most likely correlated to one another. Knowledge of these correlations is critical to the SPC of gear manufacturing processes. These correlations can be quantified by using statistical methods.

5. Manufacturing precision of gear characteristics is uneconomical until statistical relationships between gear characteristics and assembly performance are first established. In one example, a lead variation was found to be almost 95% out of specification, and yet assemblies containing the gears with such excessive variation only suffered 5% reject rate. If we rush to solve the lead variation problem at great expense, there is no guarantee that the 5% assembly reject rate will go down. How a 95% out of spec gear characteristic can cause only a 5% assembly fallout can be explained only through statistical relationships.

6. Without the use of statistical methods, it is almost impossible to separate the effects of machining and heat treating on manufacturing variation. Without such clear separation, fully resolving variation problems is impossible.

**Recommended Sequence for Deploying**

**SPC & Statistical Methods**

1. Establish a statistical relationship between assembly performance and gear characteristics. Then select eight assemblies with acceptable performance and eight assemblies with borderline or unacceptable performance. It may not be easy to find 16 assemblies if you are in the

prototype stage. In that case, select the following alternate route to generating 16 assemblies. Take two assemblies. Any gear assemblies will have a minimum of four parts. By swapping these four parts between two assemblies, you can generate 16 assemblies for purposes of statistical analysis. Use multiple regression to analyze the data and generate an equation between performance characteristics and gear characteristics.

2. Use Monte Carlo simulations to establish targets and ranges of gear characteristics to match performance targets and ranges.

3. Investigate whether any correlations exist among critical gear characteristics. Use correlation analysis.

4. If correlations are high, use a multivariate ( $T^2$ ) chart to monitor the output.

5. If correlations are low, use either average and range (X-R) charts (Fig. 4) or

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individuals and moving range ( $\bar{X}$ -MR) charts (Fig. 5) for monitoring each individual gear characteristic. To select either set of charts, first determine whether a process output is homogeneous or heterogeneous. Do this by taking a group of five consecutive pieces and examining its range. If the range is one-half of the specification range or lower, the process output is homogeneous. Otherwise it is heterogeneous. If the process is homogeneous, use X-MR charts for monitoring

process output. If the process is heterogeneous, use  $\bar{X}$ -R charts.

6. Because differences among teeth are contributing factors to ultimate gear performance, a multi-vari chart must accompany all the other charts to understand and control tooth-to-tooth variation within a gear.

The above described sequence is an investigative use of SPC. If any problems are uncovered as a result of this exercise, we can begin the solution

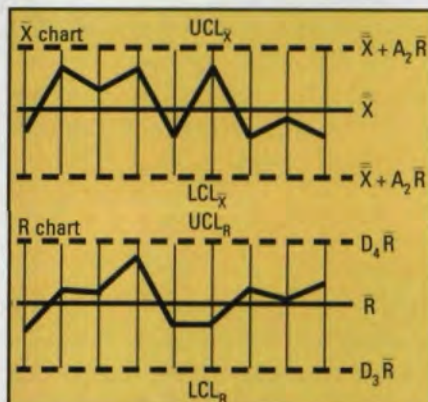


Fig. 4 — Data in the form of an X-R chart.

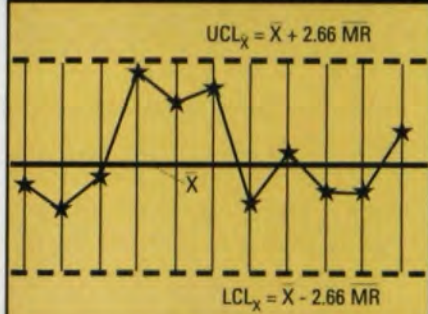


Fig. 5 — Data in the form of individuals (X).

process. If no problems are uncovered, we may choose to use SPC from this point on in the process for monitoring output. Inappropriate variations can then serve as a warning of incipient problem conditions.

Statistical tools may come to the rescue when you are confronted with puzzling gear problems. SPC, a results-backward approach, is a complement to the more traditional knowledge-forward approaches to gear problem solving. Once you develop expertise in the use of these methods, you will find they also accelerate and improve the productivity of your knowledge-forward approaches as well. ⚙️

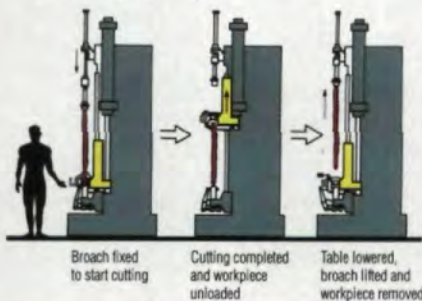
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# PRODUCT NEWS

Welcome to our Product News page. Here we 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.



## Vertical Honing Machine

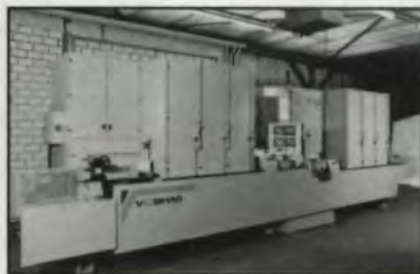
Sunnen's new CK-21 computerized vertical honing machine is designed for precision honing of 3/4" (19 mm) to 8" (203 mm) bores in applications such as small engine blocks, air compressor cylinders, valve bodies and aircraft cylinders. The unit features a micro-processor based control system that enables the operator to control all aspects of the production cycle. The machine has a 3 hp (2.2 kW) spindle motor, and its new hone heads are designed for use with superabrasives. It has a real-time graphic display, will hold the geometry of the bore to within 2 tenths (6 microns), depending on the application, and allows for two different spindle speeds and multiple feed rates during a single honing cycle.

Circle 325

## Digital AC Servomotors

Indramat introduces its line of rugged, low cost, MKD digital AC servomotors. The line offers peak motor power up to 12 kW, with peak torques ranging from 4 to 102 Nm (35 to 9000 lb-in) and speeds up to 9,000 rpm. They are available in five frame sizes and are available with an option integral multi-turn absolute resolver feedback, eliminating the need for axis homing routines. They are rated IP65, making them ideal for use in harsh environments in packaging, material handling, converting and printing.

Circle 326



## Deburring Machines

Feintool Equipment Corp. is marketing the complete line of Vobhag deburring machines, which come equipped with optional PC-based process controls to compensate for brush or fleece wear automatically. All models let users fine-tune speeds of both head and brushes to "debug" the deburring process without hardware changes. The units all use linear guides to position the Rotex head to ensure the rigidity necessary for high-force fleece deburring. The control area and work zone are sealed and separate from one another for operator safety and to guard against drive contamination.

Circle 327



## Vibration Monitor

Schenck Trebel introduces the Vibrocontrol 920, a single channel monitor, which the company says is flexible, dependable and provides maximum protection for motors, fans, pumps and other equipment critical to operations. It accepts virtually any type pickup, including velocity sensors and 2-, 3- or 4-wire accelerometers. A program provides password protection and allows pre-programming of limits for

warning devices. The VC920 features a 4-20 mA output for system integration with a PLC and a buffered output for instant vibration analysis. It accepts all power supplies (115/230 V A/C, 24 V DC) and is easily mounted on rails or within a cabinet enclosure.

Circle 328



## Brinell Hardness Tester

NewAge Industries, Inc., announces the HB3000 Series Brinell hardness tester with motorized dead-weight load application and automatic readout options to reduce sources of error in Brinell testing. The basic tester operates in any Brinell range from 62.5 to 3000 kg loads and with 2.5, 5 or 10 mm ball indentors. The capacity is 9" vertical and 4.5" throat depth. The BOSS Automatic Readout Option uses a hand-held scanning head that views the Brinell impression. The software measures the impression at many angles to derive the Brinell hardness and impression diameters. Outputs include histograms, X-Bar & R charts and RS 232 output to a printer, computer or data gathering system.

Circle 329



**Small Size Broaching Tools**

National Broach's SPIRALGLIDE broaching tooling is now available in smaller diameters. It is now available in sizes from 3/4" to 12". According to the manufacturer, the SPIRALGLIDE series offers a unique configuration which provides constant tooth engagement with the workpiece, giving longer tool life, more pieces per sharpening, the ability to accommodate shorter lengths

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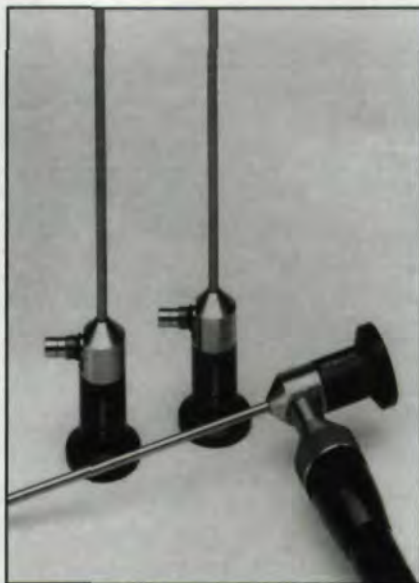
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Circle 332

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# Gears on Film

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

**O**n our unceasing attempt to further educate our readers—and find new and creative ways to waste time at work—the Addendum staff has spent many long hours (and many dollars on popcorn) to bring you our latest research on gears in film.

We'll be assigning ratings (1 gear = pretty awful; 4 gears = terrific) to the movies based on the following qualities: impressiveness of the gears, relevance to the plot, prominence in the film, star quality and dramatic interpretation.

*Modern Times (1936)*. Our nominee in the Classic Gear Movie category is Charlie Chaplin's last film without dialogue (or almost without it anyway), and may be one of his finest. In it Chaplin plays a hapless victim of modern factory life, while a very young Paulette Goddard plays his love interest, known only as "The Gamin."

The plot, which might have been co-written by Charles Dickens, Victor Hugo, Scott Adams and the Monty Python gang, is a darkly comedic look at the Depression-era struggles of ordinary people trying to survive in an industrialized society.

We're sorry to say that the gears play metaphorical villains, but they're nasty in the grand tradition of movie bad guys. If not quite as evil as Olivier's Richard III or as funny as Alan Rickman's Sheriff of Nottingham, they make worthy symbolic opponents, and they're considerably more obvious as symbols than Charles Foster Kane's Rosebud. They're also very sexy, as gears go, and they film wonderfully in black-and-white.

Our only quibble is that in a couple of crucial scenes, some of the gears are

running backwards. But then maybe it's not fair to expect someone to be both a directorial genius and a gear engineer. Rating: ○○○○.

*The Rock (1996)*. An action/adventure flick with Nicolas Cage as an FBI biochemical weapons specialist and Sean Connery as the only man ever to have escaped from Alcatraz.

The gears—or in this case, gear segments—come into play after terrorists steal some chemical weapons and take over "The Rock." Connery, Cage and a small band of Navy SEALs must sneak into Alcatraz, disarm the weapons and save San Francisco from total destruction.

At a crucial point in the plot, Connery must roll underneath a series of giant pendulums with gear teeth on their bottoms while avoiding spouts of flame shooting up from the floor. We're not entirely sure what this contraption is supposed to be. The gear teeth don't

appear to mesh with anything, and we don't know why flames are shooting up from the floor, but it's really cool and scary-looking. Rating: ○○○○.

## The Metaphysics of Gears

To answer the question, what is a real gear, we have consulted no less an authority than Eliot K. Buckingham. Mr. Buckingham comes down on the side of the stationary objects. He says, "... to my mind, a single gear is a piece of metal with projections on it. A gear is designed to be operated with another gear or gears. You do not design a single gear ...

"If a gear has to be moving to be a gear, what are all those things in planetaries, and often differentials, that don't move, but are absolutely necessary to proper performance, and have all the appearance of being gears, with teeth and all?"

He approaches the "Biggest Gear in the World Question" using the same logic: "Actually, the largest gear in the world is a cog railroad, since the rail is a rack, which is a segment of a gear of infinite diameter."

Since no discussion of either philosophy or movies is complete without a dissenting point of view, Addendum is waiting for yours. If you have nominations for our Gear Movie Hall of Fame or another philosophical viewpoint on the ontology of gears, let us know. We have a new referee's whistle we'd love to try out. ○



**The Addendometer:** If you've read this far on the page and enjoyed it, please circle 225.



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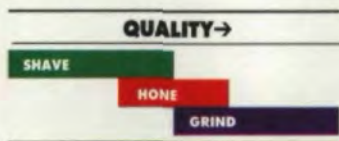
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In some cases, a Hob/Heat Treat/ Hone sequence can eliminate a previously-required shaving operation while improving quality. Depending on stock removal and quality requirements, honing can potentially replace grinding, with significant cost savings per gear.



Honing can also be added to enhance shaving or grinding to meet today's stricter quality and noise requirements. We can help you analyze your current methods to determine if honing can be productively applied.

Whether the solution involves hobbing, shaving, grinding or honing...or any combination...we have the proven technology, and we back it with Gleason's worldwide training and service support.

Call 1-800-643-2770 or your Gleason regional sales manager. The answer is "Yes."