# GEAR TECHNOLOGY

The Journal of Gear Manufacturing

## ALTERNATIVE GEAR MANUFACTURING
## IMTS 98 PRE–SHOW

July/August 1998

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EFFECT OF RATIO ON PLANETARY DRIVE LIFE
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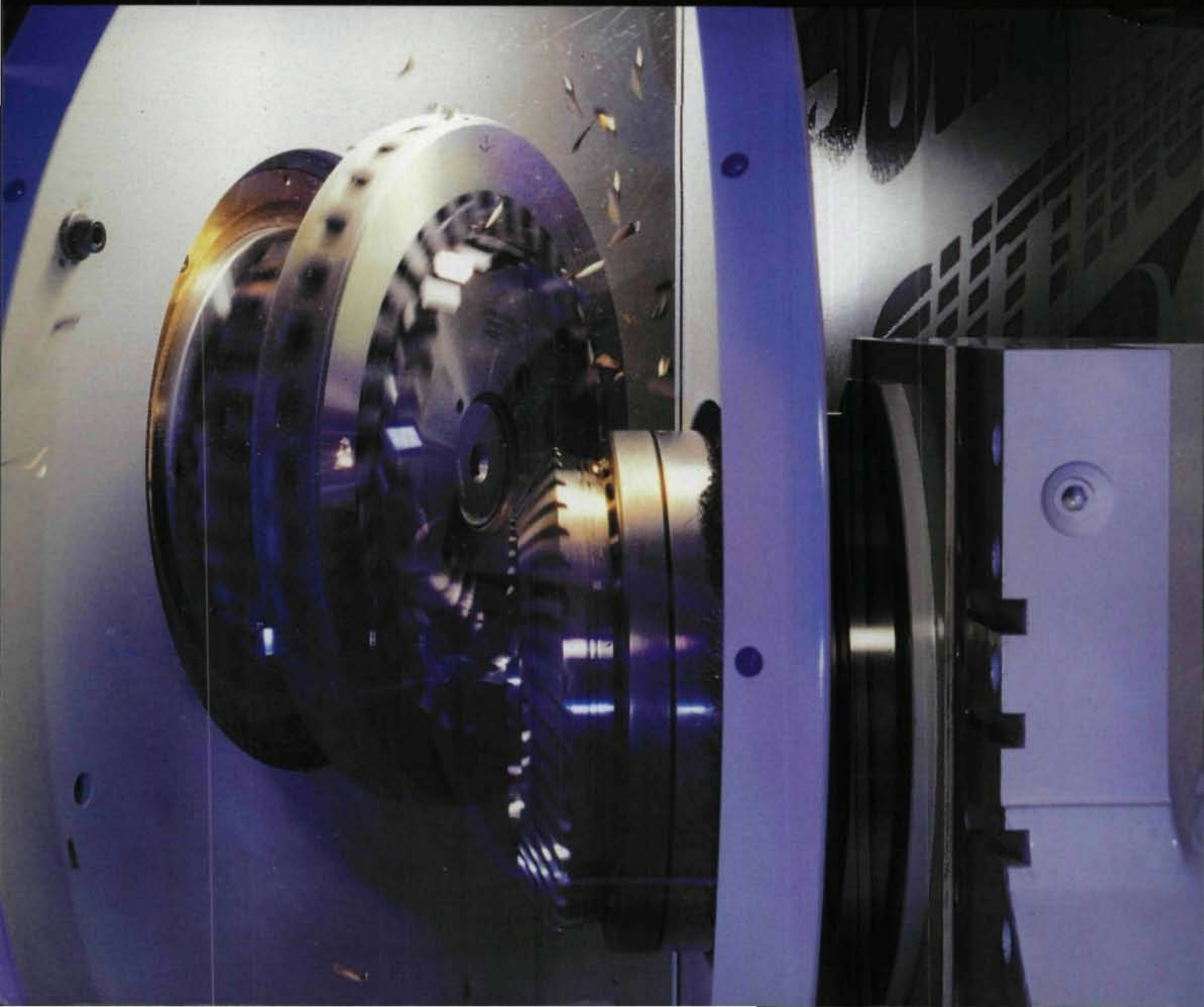

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## FEATURES

33



## SPECIAL SECTION



## DEPARTMENTS




60

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# GEAR TECHNOLOGY

The Journal of Gear Manufacturing

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CIRCLE 114

# POLITICS OF MANUFACTURING

In the approximately 15 years that I have been writing editorials for *Gear Technology*, I've purposely avoided certain topics. Sex, religion and my own used gear machinery business are among the subjects that have always been off limits. But with this issue, I'm going to break one of my long-standing taboos by talking politics.

It's not politics in the usual sense of partisan debate between Republican and Democrat. It's not about my stance on government regulation, health care reform or environmental legislation. This is politics on a more general level.

For a long time I've felt that Americans don't have enough exposure to or understanding of the importance of manufacturing and industry to the overall well-being of our country. Fifty years ago, people lived and worked around factories. People lived in towns where things were made. Today many of us live in suburbs and work in offices. The only time most of us interact with manufactured goods is when we buy them.

Part of the problem is image. The media has portrayed factory work as dirty, boring and dead-end. But the fact remains that industry is as important to our economy today as it was 50 years ago. Unfortunately, many Americans are too far removed from actual manufacturing to understand that much of our country's strength comes from our ability to create wealth out of raw materials.

The manufacturing perspective is even less well represented among our elected officials. Since *Congressional Quarterly* began tracking the previous occupations of members of Congress in the 1950s, lawyers have always been the biggest group. In today's Congress, they make up 42% of the total. Businessmen and bankers make up the next big chunk, with 40% of the total. But people with a manufacturing background are only a small, unidentified portion of this 40%. Most of the rest are from banking, finance and major corporations.

At some point we have to ask ourselves whether the right mix of people are making the rules, whether the right experiences, backgrounds and mindsets go into the decision-making processes that affect all of our lives. After that, we have to ask ourselves if there's anything we could or should be doing about it?

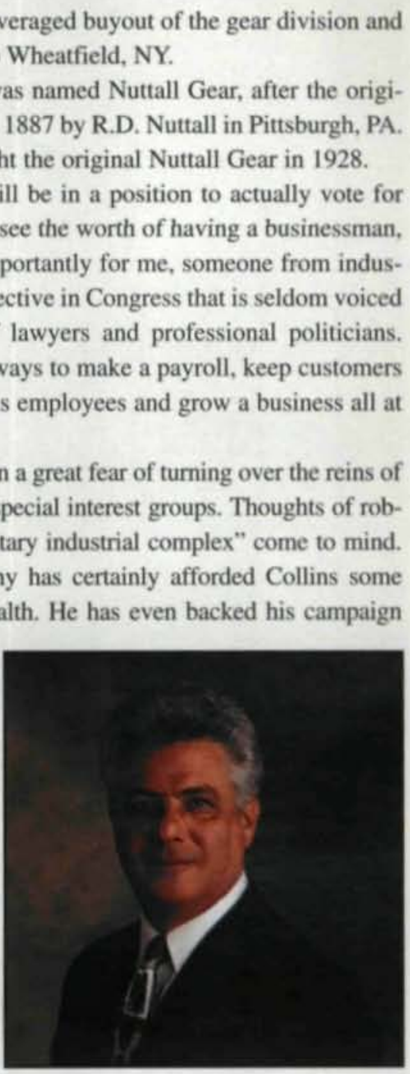
This brings us to politics on a more personal level. A young man that I've known for the last couple of years has decided to run for the U.S. House of Representatives in the upcoming November election from his district in the Niagara Falls area of New York. Chris Collins, who was president and majority owner of Nuttall Gear, recently sold his company and has decided that the best use of his experience and talent is to try to help influence the direction of our country and our society by running for Congress.

Collins began his career in the gear industry with Westinghouse Electric, where he worked his way up to manager of gear products for their Electric Motor & Gear Division in Cheektowaga, NY. He served in that post from 1979 until 1982, when he arranged the leveraged buyout of the gear division and moved the operations to Wheatfield, NY.

The new company was named Nuttall Gear, after the original company founded in 1887 by R.D. Nuttall in Pittsburgh, PA. Westinghouse had bought the original Nuttall Gear in 1928.

While few of you will be in a position to actually vote for Collins, I hope that you see the worth of having a businessman, a gearman, and most importantly for me, someone from industry, representing a perspective in Congress that is seldom voiced among a population of lawyers and professional politicians. Collins has had to find ways to make a payroll, keep customers happy, be sensitive to his employees and grow a business all at the same time.

There has always been a great fear of turning over the reins of government to wealthy special interest groups. Thoughts of robber barons and the "military industrial complex" come to mind. Selling his gear company has certainly afforded Collins some measure of personal wealth. He has even backed his campaign with some of his own money. But the mid-sized business represented by the 130-employee operation Collins left behind is a far cry from the mega-corporations so often the target of anti-business-in-Washington sentiment. The fact is, more Americans work for small and mid-size companies than for large ones. According to the 1992 U.S. Economic Census, more than 50% of the work force is employed by firms with fewer than 500 employees. The background and ideas Collins could bring to the table might provide some much needed balance to what has for a long time been a very lopsided Congress.



I can't speak to Collins's stance on specific issues. From my viewpoint, it doesn't much matter whether he is Republican or Democrat (Republican, for the record). But I can tell you that he has been very closely involved with subjects that are important to me personally and to the industry I am part of.

I also can't tell you what to do with your money. Political contributions are a very personal business. But the chance to have in Congress a friend of manufacturing in general and of the gear industry in particular might be an investment worth making.

Michael Goldstein,
Publisher & Editor-in-Chief

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CIRCLE 113

# Alternative Gear Manufacturing

Charles Cooper

The gear industry is awash in manufacturing technologies that promise to eliminate waste by producing gears in near-net shape, cut production and labor costs and permit gear designers greater freedom in materials. These methods can be broken down into the following categories: alternative ways to cut, alternative ways to form and new, exotic alternatives. Some are new, some are old and some are simply amazing.

### Alternative Ways to Cut

Traditional gear manufacturing involves cutters, hobs and other tools that quickly remove metal from the piece being worked. These are not, however, the only ways to cut metal. Stamping, fineblanking, lasers, electrical discharge machining and abrasive waterjet are all being used for gear production, each filling its own market niche.

***Stamping and Fineblanking.*** Stamping is a metalworking technique that has been compared to using a cookie-cutter. A cutting die is pressed down into the metal and pulled out again. When it comes up, the workpiece is ejected and the process begins again. Stamping is very fast, very efficient, but not terribly precise, with a great deal of clearance differences between workpieces common. Because of this, workpieces often require post-press grinding, shaving or other machining. Stamping is restricted by the thickness of the piece being worked and is used primarily for spur gears and other thin, flat forms.

Fineblanking shares certain similarities to both stamping and forging. The process takes metal from a sheet like stamping but differs from it in that it uses two dies and forms the workpiece by pressing it into the desired shape. In this way it is similar to forming techniques such as forging and powdered metal compaction. The metal is extruded into the die cavities to form the desired shape. Also unlike stamping, fineblanking offers the designer a limited three-dimensional capability and can thus be used to create bevels, multiple gear sets and other complex forms.

**Fig. 1 — A double gear fineblanked in one hit using a semipierce by MPI International, Inc.**

The double gear for an automotive seat shown in Figure 1 was made by MPI International, Inc. a Michigan-based fineblanking and stamping company. The part was traditionally manufactured by taking a stamped gear and welding a machined gear hub to it. This was expensive, the results inconsistent and, according to MPI, there were many rejects. Fineblanking's repeatability of the concentricity of the two gears as well as nearly distortion-free shaping was the answer. Tolerances were kept to .0005 inches and savings were realized on the elimination of rejects and the additional machining and welding required under the original design. The gear was strength tested prior to production and has successfully carried passengers in over 2 million vehicles.

"Fineblanking gives you a stronger gear than stamping or powdered metal," said Rick Eisele of MPI International. "In fact, many powdered metal gears are replaced by fineblanked gears. You get close to machined-gear quality with fineblanking." Stamped and fineblanked gears can be found in a myriad of applications including the automotive, appliance, office equipment, hydraulic and medical equipment industries.

***Lasers.*** While sometimes slower than traditional techniques, depending on the material, lasers can easily cut complex shapes such as gears with great precision and very little waste. This conservation comes from the ability of the CNC machines controlling the lasers to reuse cutting paths, getting as many gears from a single sheet of metal as possible. According to Matt Kalina, Director of Marketing for the LAI Companies, specialists in laser and abrasive waterjet technology, this fine nesting capability makes laser cutting one of the most economical ways to make certain types of gears. Also, the computer control means laser cutting is also low maintenance. The setup and first runs are always closely supervised, but the actual production runs don't need any real supervision due to the CNC programming.

The trade-off for this speed, precision and ease of use is that pieces cut with lasers have heat affected zones, areas where the metal is heated beyond a critical transformation point and recast. These zones are limited, however, to the edges of the cuts—minimizing, but not eliminating heat distortion and the need for further machining. Post production grinding and hobbing are common.

The type and thickness of the metal being cut is also at issue with lasers. "Lasers have trouble cutting metal more than 3/4" thick. To cut anything over that would require too much power," said Kalina. "They are also limited to non- or semi-reflective materials. Metals like aluminum and brass, that are highly reflective, are difficult to cut because the laser has trouble focusing its beam."

While lasers are, like stamping, traditionally limited to flat forms such as spur gears, newer five- and six-head CNC controlled machines are changing that. LAI has used them to cut more complex gear forms such as spiral bevels, worms and helical gears. "We've done a few jobs like these," said Kalina, "everyone was very happy with the results."

***Electric Discharge Machining.*** EDM uses electricity to melt or vaporize the material being cut. Depending on the application, the electrode can either be a wire (wire EDM) or a pre-shaped solid used as a vertical "sinker" EDM.

Like laser cutting, EDM causes heat affected zones in the workpiece that could require later machining. However, it also eliminates many of the other problems associated with traditional gear cutting methods. The metal can be pre-hardened and then EDM processed to eliminate the need for any further machining. Also, wall thickness, and cutting and clamping pressures are not considerations since the piece is being cut with electricity instead of steel.

According to James Spalding, CBC, Marketing Manager for Charmilles Technologies, "for gear manufacturers, the biggest advantage of EDM is unattended machining. A group of machines can be programmed and left to work."

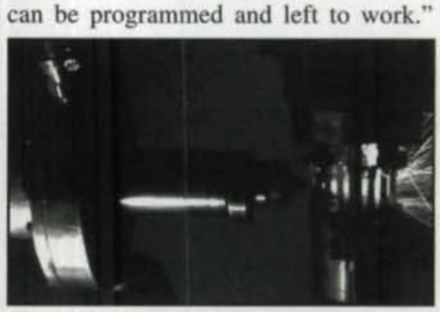
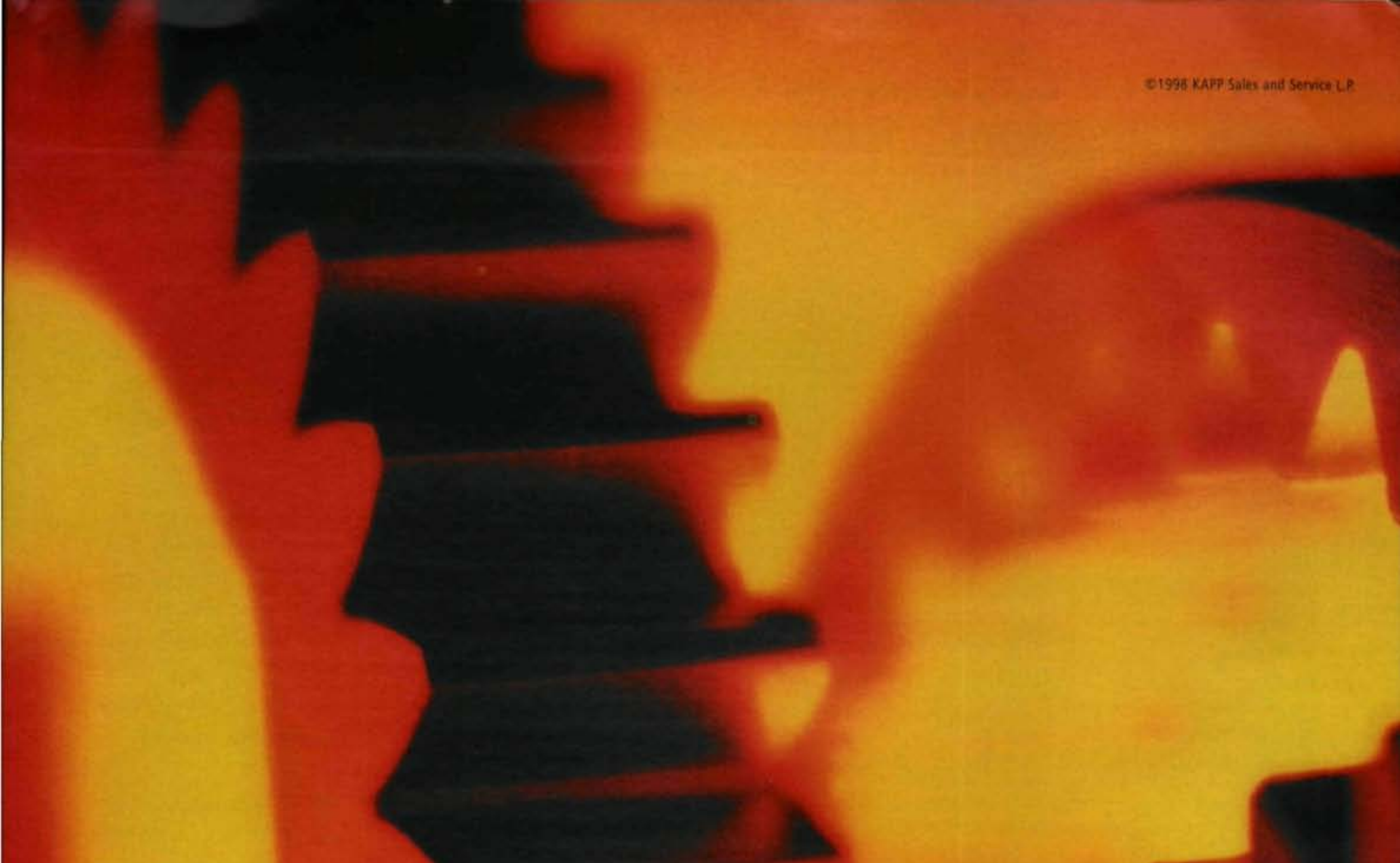


**Fig. 2 — An LAI laser cutter in action.**

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**CIRCLE 145**

**Fig. 3 — An LAI five-axis waterjet uses a 55,000-p.s.i. stream of water mixed with garnet abrasive to trim an aircraft screen panel made of titanium for Lockheed-Martin's new F-22 Fighter.**

This translates into a savings in terms of labor because a machinist does not have to be present during the entire production cycle. Additionally, because the gears produced are near-net shaped, costly post-production machining can also be avoided. EDM can provide pieces with tolerances up to AGMA class 10 right off the machine.

***Abrasive Waterjet.*** Abrasive waterjet, introduced to manufacturing in the early 1980s, has evolved into a versatile method for cutting and drilling any material and continues its rapid growth as a viable option for making gears.

"The technology's key attributes—flexibility, quick setup and simple tooling—make it a good match for making prototypes and small runs of custom gears," said LAI's Matt Kalina. "However, waterjet's dual head capability, quick cycle time and ability to produce an excellent surface finish (125 r.m.s. typical) also distinguish it as a feasible alternative for medium to large production runs."

Here's how abrasive waterjet technology works: High pressure water (50,000-60,000 p.s.i.) runs through a jewelled orifice ranging from .005 to .013 inches in diameter and into a nozzle ranging in size from .015 to .05 inches in diameter. The water stream creates a vacuum, drawing finely ground abrasive (i.e. garnet) into the nozzle's mixing chamber and out to make contact with the work material.

For gear manufacturers, the main advantage is the ability to cut a ready to use part quickly and, depending on the level of precision, at a lower cost per unit than conventional machining. It is frequently the method of choice since it typically produces burr-free edges without heat affected zones, can easily handle heat-treated materials, and, unlike lasers, can cut through stacks of materials to create multiple parts at the same time, saving money and time.

LAI has used abrasive waterjets to cut lapping machine gears from the difficult to machine G-10 plastic resin composite material; cut titanium rack and pinion components for commerical jet pilot seats; process phenolics into machinery gear components and cut spring steel into gears with tightly spaced teeth. According to Kalina: "Since abrasive waterjet machines can achieve tolerances of +/-.001 inches, depending on the thickness of the material, they can produce desirable characteristics in gears that do not require a high degree of precision, especially large gears since huge waterjet gantries can accommodate massive work pieces."

**Alternative Ways to Form**

These methods use dies to mold the metal into the desired shape. Casting and forging are both press work techniques using heat and pressure to form the final workpiece. Both are also near-net shape methods that leave little scrap metal and require little or no subsequent machining.

***Casting.*** In its most basic form, casting is the process of pouring or injecting molten metal into a die, allowing it to cool, and then ejecting the finished or near-finished product. The major type of casting used in the gear industry today, for high strength and durability, is cold chamber casting.

Cold chamber casting begins with molten metal being ladled into the injection cylinder. A plunger pushes the metal into the closed die cavity where it is kept under pressure until it solidifies. The die is then opened, the piece is ejected and the plunger pushes the solidified slug from the cylinder.

One of the largest gear castings came out of Sivyer Steel of Bettendorf, Iowa. Their client, AmClyde, a manufacturer of mining and drilling platforms and machinery, needed a 62 foot diameter gear. It had to have a minimum ultimate tensile strength of 115,000 psi, a minimum 95,000 psi yield strength, minimum 14% elongation and minimum 30% reduction of area. Sivyer cast the gear in twenty segments, each 6 inches high by 6 inches wide by 117 inches long and weighing 1600 pounds using the cold chamber process. For the full story, read "A Huge Success" in the September/October 1995 edition of *Gear Technology*.

***Forging.*** Forging can create stronger parts than casting or any other manufacturing method. The forging process is usually performed hot with the metal preheated to a desired temperature and then placed under intense pressure until it deforms and fills the die cavity. This can be done on a traditional press or by using dies mounted on rollers in a method pioneered in the old Soviet Union. The resulting part is referred to as a forging.

Forgings are used primarily as components in critical mechanical systems where great strength and durability are required. According to the Presrite Corporation, tests showed that forged gears last almost twice as long as conventionally produced gears. This great strength comes from the grain fiber structure of the metal following the outside contour of the part being forged into the forging's final near-net-shape. At the end of the forging process, there is usually only a small amount of metal around the teeth that needs to be ground off. Once that is done, the gear is finished.

***Powdered Metal Forming.*** Compacting powdered metal into gears and other shapes is a materials innovation that uses powdered instead of molten or heated metals as in regular metal forming processes. The powder is usually a blend of metals which are compressed into a pair of dies at room temperature. This is usually followed by sintering, a process of heating the pressurized metal to just below the melting point of the base metal. Sintering binds the metal particles together, producing excellent tensile qualities which can be enhanced by further heat treatment.

Studies have been conducted comparing powdered metal gears to gears made by other processes. One such study, which can be found in the September/October 1995 edition of *Gear Technology* found that induction-hardened, sintered powder metal spur gears had slightly better dynamic tooth stress capacities than induction-hardened, melted steel spur gears but that for surface durability the steel gears were better. They also found that the steel gears, when they broke, would break suddenly, while the sintered gears would gradually weaken and break due to the porous nature of the material.

**Fig. 4 — An assortment of gears forged by the Presrite Corporation.**

Powdered metal compacting allows bevel, rack, face, spur, helical and compound gears to be made up to AGMA 8 standards with production rates of up to 1000 pieces per hour. Internal items like splines, keys and keyways can also be made to final shape with no post-press machining operations, eliminating scrap losses. Internal elements can be made simultaneously with the gear profile, again eliminating the need for subsequent machining and allowing an efficient use of dies and materials. All this makes powdered metal a popular alternative gear process with applications in the aerospace, automotive, home appliance and power and hand tool industries.

### Exotic Alternatives—Chemical Etching and Microgears

Using chemicals to etch out gears is new. Developed originally for making integrated circuits, this technology is now



being used at the Sandia National Laboratories in New Mexico to make experimental microengines, electric motors no bigger than a grain of sand.

The manufacturing process consists of laying down alternate layers of polycrystalline silicone (polysilicon) and silicone dioxide. Photolithography is used to set the patterns for the layers of the materials. Vias etched through the silicone dioxide provide anchor points between the mechanical layers and to the substrate. Finally, the silicone dioxide layers are etched away in a bath of hydrofluoric acid (HF), leaving a system consisting of one layer of polysilicon to provide electrical interconnection and one or more independent layers of polysilicon, which form mechanical elements such as gears.

Realizing that their electrostatically-powered microengines didn't produce enough power to actually do anything, the engineers working on the project went on to develop a microtransmission to provide their engine with a lower gear. So far, they have been able to put enough of these gears together to give their tiny motors 3,000,000 times the torque of the motor alone, theoretically enough power to move an object that weighs a pound.

The gears in the microtransmission assembly are similar to the gears on a ten speed bicycle with a smaller gear mounted concentrically onto a larger one. The transmission consists of a pair of these multi-level gears, the first with a gear reduction ratio of 3:1 and the second with a gear reduction ratio of 4:1 to give a total of 12:1. Twenty-nine such gears together give a remarkable gear reduction ratio of 2,985,984:1.

The first uses of these microengines and gears will be as safety devices on nuclear weapons as well as in the next generation of "smart" weapons, moving tiny reflectors to channel light through on-board fiber-optic networks and performing other high-precision tasks. Later applications could include implanted drug delivery systems, control systems for automobile airbags, adaptive optical

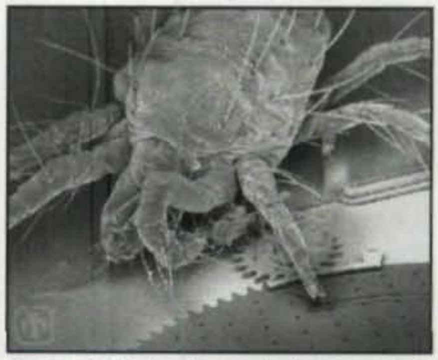

Fig. 5 — An electromicrograph showing a spider mite walking across microgears produced at Sandia National Laboratory.

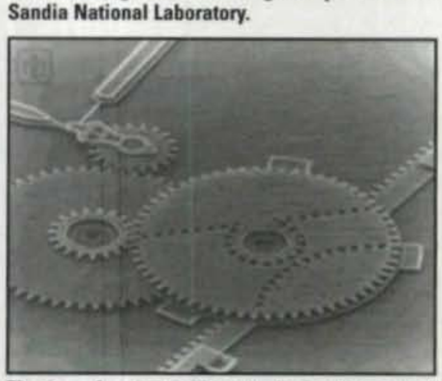

Fig. 6 — An electromicrograph showing part of the microtransmission built by Sandia National Laboratory.

technology, sensors for acceleration and rotation and as safety devices for conventional and civilian explosives. One major advantage will be ease of fabrication. According to project engineer Steve Rogers, companies will be able to download the basic transmission elements, and once they've done that, they can design as many as they need cheaply and easily.

Was the microtransmission able to move that one pound weight? According to Dr. J.J. Sniegowski, one of the inventors of the microtransmission, not yet. "The material isn't strong enough to take the strain and the gear teeth break," he said. " We are, however, experimenting with various methods to increase the strength."

Alternative gear processing is used to cut costs and waste and some techniques are better at it than others. Most promise to produce near-net shapes with little or no post production machining. With others some machining is necessary. Each, however, has its specific uses and produces gears with certain capabilities and applications and each has a place in the gear production marketplace.

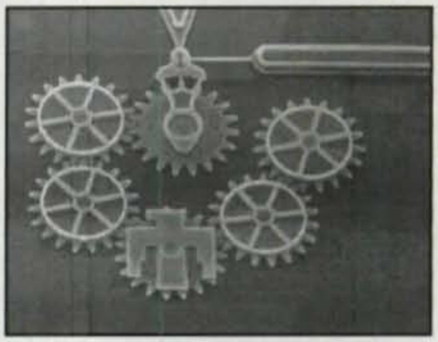

**Fig. 7 — An electromicrograph showing six microgears. Sandia National Laboratory.**

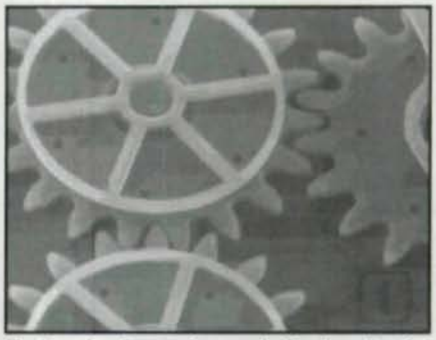

**Fig. 8 — An electromicrograph showing showing details of the gears in Figure 7. Sandia National Laboratory.**

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## INDUSTRY NEWS

### AGMA'S BANNER YEAR PUBLISHING STANDARDS

The Alexandria, VA based American Gear Manufacturers Association produced an extraordinary number of new technical standards, AGMA manuals and information sheets in 1997. "We're extremely pleased by the work, enthusiasm and care displayed by our committees," said William Bradley, Vice President of AGMA's Technical Division. "The members are very conscientious in sharing their professional knowledge and experience, and tenacious in solving problems."

The trend is expected to continue in 1998. AGMA anticipates releasing documents on enclosed drives, high-speed gear units, powder metallurgy gearing specifications, bevel gear rating, fine pitch gearing, materials for marine gearing, worm gear inspection, sound testing and flexible couplings.

### AMERICAN METAL TREATING ANNOUNCES MAJOR EXPANSION

American Metal Treating Company announced plans for a major expansion of their Cleveland, OH steel heat treating facility. The new building will add roughly 10,000 square feet of floor space at a cost of $400,000. The added capacity will allow American Metal Treating to induction harden gears measuring up to 16 feet in diameter and weighing up to 15 tons—a trend in the gear industry—and reduce lead times for their customers. "We have been operating close to capacity for several years now so the new machine hours will allow us to process parts faster," said Bruce Devney, V.P. Sales. "Customers are always looking for ways to shorten heat treating lead times."

### MITSUBISHI EDM APPOINTS REGIONAL SALES MANAGER

Mitsubishi EDM has appointed Stephen L. Bond as regional sales manager for their Southeast Technical Center located in Charlotte, NC. Bond will be responsible for managing four distributors covering 10 states and Puerto Rico.

"I'm thrilled with the opportunity to work for Mitsubishi EDM," said Bond. "I feel that my 15 years of experience in sales, service and installation will allow me to develop strong relationships with future Mitsubishi EDM owners."

### GLEASON CORPORATION REPORTS FIRST QUARTER RESULTS

Gleason Corporation (NTSE-GLE) reported an increase in earnings per share for the first quarter of 1998 to $0.59. This is a 14% increase over the first quarter of 1997. Net income increased 20% to $6.2 million and operating income (earnings before interest and taxes) increased 32% to $10.6 million over the same period.

At $95.4 million, first quarter sales were 58% higher than first quarter 1997. Excluding Pfauter, which the company purchased in July, 1997, sales were $60.6 million compared to $60.3 million a year ago.

Order levels for the first quarter totaled $95.8 million compared to $55.4 million in 1997. Orders were split 57% for machines and 43% for tooling and aftermarket products. Excluding the Pfauter operations, orders increased 10% over the first quarter of 1997.

**Tell Us What You Think . . .**
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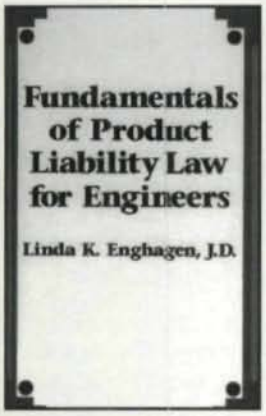
# Product Liability for Engineers

Robert B. Price, C.Mfg.E.




***Fundamentals of Product Liability Law for Engineers***

**By Linda K. Enghagen, J.D.**

**Industrial Press, N.Y., N.Y.**
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This textbook, written for college level engineering students, gives a basic grounding in the complexities of product liability law. It also provides useful information to those of us involved in the manufacturing of gears and gear systems in that the fundamental concepts apply to all types of manufacturers.

The book begins with some basic background information on the development of product liability law and then moves quickly into the two main subject areas: theories of liability and strategies for protection against lawsuits. In general, the book is clearly written and understandable in spite of the need to use a lot of legal phrases and words. There is a glossary that covers most of the legal terms used, an appendix listing numerous statistical facts regarding product liability lawsuits (dollar amounts and cases by state for instance) and a bibliography for those who might be inclined to pursue the subject further.

From the viewpoint of a gear manufacturer or, in my own case, from that of a consulting engineer, the primary focus is on cases that deal with manufactured products and how their failure brought on lawsuits rather than on the failure of a specific manufactured item such as a single gear, a series of gears or a gearbox. Nonetheless, the basic legal principles apply to the typical gear manufacturer, particularly a company manufacturing gears that go into someone else's products.

Much of the text in the first section is verbatim quotations from various lawsuits, which are used to illustrate the various types of liability and the differences between them. For instance, negligence vs. strict liability; express warranty vs. implied warranty; the difference in procedures between trial courts and appeals courts. One very interesting case is that of a table saw manufacturer sued by someone who cut his hand because the blade guard had been removed. The court ruled that since the particular operation could not be performed with the blade guard in place and since the user knew that a table saw was inherently a dangerous tool, particularly with the blade guard removed, the manufacturer was not liable for the injury.

The section dealing with how to avoid lawsuits is useful because it outlines various checklists that can be adopted by a company so that all the proper questions are asked and answered. This establishes a paper trail showing that the company adhered to reasonable and appropriate procedures in manufacturing and marketing a product or component of a product. There is also a list pertaining to a product liability loss assurance committee, which purports to set up procedures to prevent a lawsuit from occurring. Some of the items on the checklist suffer, however, from having been created by a lawyer. For instance, "What is the user population?" and "What are all possible hazards?" are two of the questions. Who among us would dare claim to be able to answer those questions in the absolute? I know of a case in which a manufacturer was sued when the owner of an oven opened the lower door of the oven and stood on it in order to reach something on a shelf above the oven. When the hinges broke, the owner sued. Her lawyer claimed that standing on an oven door was "a foreseeable use."

This book would be a good addition to the library of any conscientious gear manufacturing engineer. It provides an excellent grounding in the very complex vagaries of product liability law and suggests several methodologies to help establish some company procedures to protect both individuals and the company from lawsuits.

The author ends the book on a philosophical note with a discussion regarding ethics. The author goes on at some length about ethics in government and in the engineering profession. The author points out that since most engineers do not have a direct one-on-one relationship to their customers as do doctors, accountants and lawyers, the failure of a manufacturing engineer to "properly" make a gear does not always result in a direct one-on-one confrontation. If the gear is part of a lawnmower drive train and it keeps failing, users will be unhappy but not necessarily injured. If the gear is used to move a control rod drive mechanism into a nuclear reactor and it fails during an emergency scramming operation, a large number of people could be injured or killed. What we all do, in the final analysis, does matter. The last sentence of the book is good advice for all of us: "Do the right thing for the best of all possible reasons—to feel good about yourself." ○

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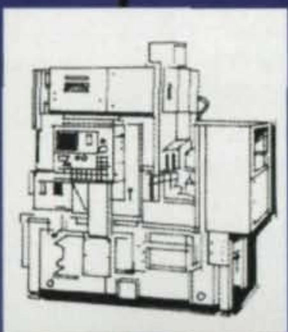

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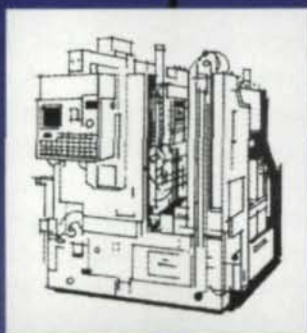

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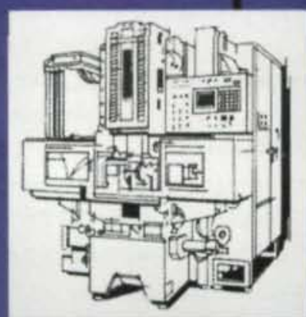

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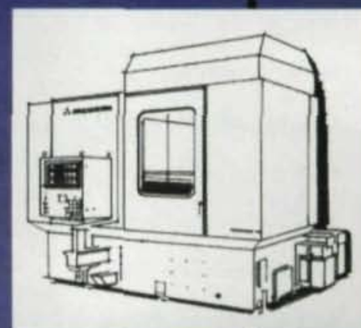

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**CIRCLE 109**

# Introduction to ISO 6336 What Gear Manufacturers Need to Know

**Don McVittie**

***This is the first of a series of articles introducing the new ISO 6336 gear rating standard and its methods of calculation. The opinions expressed herein are those of the author as an individual and not necessarily those of any organization of which he is a member.***

ISO 6336 *Calculation of Load Capacity of Spur and Helical Gears* was published in 1997 after 50 years of effort by an international committee of experts whose work spanned three generations of gear technology development. It was a difficult compromise between the existing national standards to get a single standard published which will be the basis for future work. Many of the compromises added complication to the 1987 edition of DIN 3990, which was the basic document.

**Fig. 1 — Countries adopting ISO Standards.**

- All EC members—required by EC rules
  - France
  - Germany
  - United Kingdom
  - Benelux
- "Eastern Bloc"—required by national laws
- Japan

**Fig. 2a — New symbols.**

$\alpha$ = pressure angle
$\beta$ = helix angle
$\varepsilon$ = contact ratio
a = center distance
b = face width
z = number of teeth
u = gear ratio

**Fig. 2b — New symbols.**

K = General influence factor
Z = Pitting influence factor
Y = Bending influence factor
H = Subscript related to pitting
F = Subscript related to bending
$\gamma$ = Subscript for combined, axial + transverse

**Fig. 2c — New symbols.**

$K_{H\_}$ = Face load distribution factor for pitting
$\varepsilon_\alpha$ = Transverse contact ratio
$\varepsilon_\beta$ = Face contact (overlap ratio)
$\varepsilon_\gamma$ = Total contact ratio

What does this new standard mean to gear manufacturers around the world? How will it affect your gear-related business? The answers may depend—at least initially—on where you do business and where your customers do business.

ISO is a quasi-voluntary organization with indirect government support. While it doesn't have authority like the U.N., it is the result of an international agreement to support a combined effort by the world's national standards bodies to achieve a set of unified international technical standards. Those national standards organizations pay the administrative costs of ISO through annual dues and royalties on publications.

Most nations have a national standards administrative organization that receives most of its funding from the national budget and forms the national position with regards to technical standards. The U.S. is different in that the American National Standards Institute (ANSI) is supported without government funding by its publication revenues and the dues of its member companies and individuals. It is independently governed by its own volunteer board of directors, representing the members[1]. ANSI has appointed AGMA to represent it to ISO Technical Committee 60 (TC60) for gears.

Another difference between the U.S. and the rest of the world is the mechanism by which national standards are adopted. In most countries, if an ISO standard is adopted, the law requires that it be used as a national standard. This is particularly true in developing nations that don't have the resources to develop a variety of national standards but want the quality protection of producing, buying and selling a product to an agreed standard.

In most of the major gear making nations, a national gear rating standard already exists. Will these standards be replaced by ISO 6336?

The member countries of the European Economic Community (EEC) have adopted a system of *Euronorms* to standardize products within the EEC. The EEC rules suggest that ISO standards, if they exist, should be adopted as Euronorms. It may take a few years to translate and apply, but ISO 6336 is almost certain to be the Euronorm for gear capacity calculation (Fig. 1).

At the same time, the Japanese Standards Institute (JSI) is actively translating the ISO gear standards for adoption in Japan.

That leaves the U.S. as the largest gear making nation with no plans to adopt ISO 6336 in the near future. That seems strange, but the reason is in the ANSI standards approval process, which requires a national consensus ballot, with 75% approval, to adopt a proposed national standard. Under the present ANSI rules, the U.S. gear community would have to abandon the ANSI/AGMA 2001 standard—which is proven and most are happy with—to adopt ISO 6336. There is not a 75% majority agreement to do that today.

So what should you do as a gear specifier, gear user or gear maker? The answer depends on your place in the market.

If you are an importer or exporter of gears or gear products, you'll have to look to the market for guidance. The end user usually decides which standards will be used in his application, but that decision is greatly affected by the availability of product. If the end user is offered two products, made to two different standards, how will she choose? One would hope that an informed user would make an intelligent decision based on the merits of the case. That won't happen unless someone who knows both standards helps by making comparisons, since few end users have the resources to do it themselves.

If you are a gear manufacturer using gear inspection equipment to qualify your product to a customer's requirements, you'll have to look to your customer for guidance. As the new ISO 1328 quality standard is used on newer drawings, you'll have to get new software for your inspection machines as a minimum. (See the article in May/June 1998 by R.E. Smith for more information on ISO 1328.)[2]

If you specify gears for your own products or the products of others, you'll have to learn the ISO gear rating system sooner or later. You won't necessarily adopt it without a lot of thought about its suitability for your task and the reliability of the results, but in order to make intelligent choices and deal with the questions of customers and end users regarding "which standard," you'll have to know what is required of each system.

**Fig. 3a — New Meanings.**

- AGMA dynamic factor $K_v$
    - Includes effect of pitch error
    - Does not include effect of gear inertias
    - Does not include effect of tooth stiffness
    - Not load dependent
- ISO dynamic factor $K_v$
    - No influence of pitch error
    - Includes tooth stiffness and gear inertias
    - Load dependent

**Fig. 3b — New Meanings.**

- AGMA face load distribution factor $C_m$
    - Not load dependent
    - Analytical method withdrawn
- ISO face load distribution factor $K_{H\beta}$
    - Load dependent
    - Analytical method required for Methods B & C
- ISO has separate factors for bending and transverse load distribution

**Fig. 3c — New Meanings.**

- Application factor $K_A$
    - Similar to AGMA, except definition
    - Uses same values as AGMA

### Where Do I Begin?

It sounds like a big task, but it's fairly simple if we begin by looking at the fundamental differences and similarities between ISO 6336 and AGMA 2001. One of the best ways to learn the new system is to recalculate some of the gears you know well by the new system. I recommend that you begin by getting a good software package to calculate gear capacities by ISO 6336. AGMA is offering a good program for ISO calculation written by a volunteer committee of its members.[3]

The ISO standards use SI dimensions. If you are still uncomfortable with that, the AGMA program allows input in inch-pound units as an alternative, translating into SI for internal calculation with output in either system or both.

In addition to obtaining the software, you will probably want to become familiar with some of the conceptual differences between the standards.

First we'll have to learn some new symbols and some new meanings for familiar symbols (Figs 2a–2c). In general, the ISO symbols are highly organized, with only one meaning for

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**Fig. 4 — ISO 6336 Part I, Basic Principles**

- Order of calculation is important, because the influence factors are load dependent
  - $K_v$ with the force $F_tK_A$
  - $K_{H\beta}$ with the force $F_tK_AK_v$
  - $K_{H\alpha}$ with the force $F_tK_AK_vK_{H\beta}$
- You must iterate to get a rating value at a required safety factor

**Fig. 5 — Gear Capacity (Rating) Standards**

- ISO 6336 general standard, similar in scope to AGMA 2001
  - Part 1 — Definitions and common factors
  - Part 2 — Pitting capacity
  - Part 3 — Bending capacity
  - Part 5 — Materials and allowable stresses

**Where To Get Information on ISO Standards**

AGMA is responsible for distribution of ISO standards related to gears. The ISO 6336 standard comes packaged with the AGMA/ISO 6336 software for $995.

The software comes with a manual that explains how to use ISO 6336 and guides the user through the more than 80 inputs required to calculate using the standard's method B.

Contact:
The American Gear Manufacturers Association
501 King Street, Suite 201
Alexandria, VA 22314
Phone (703) 684-0211 • Fax (703) 684-0242

Additional information may be obtained at the AGMA and ISO Web sites:
*www.agma.org*
*www.iso.ch*

each major symbol or subscript. There are inconsistencies, however, and it will be worth your while to check meanings in the symbols table of the standard to be sure. AGMA publishes many useful editorial documents to help you find your way. I particularly recommend AGMA 900 F96 *Style Manual for the Preparation of Standards, Information Sheets and Editorial Manuals* as a starting point.

Here are some examples of new meanings: Both ISO 6336 and AGMA use an application factor to account for variable loading, a dynamic factor to account for the dynamic loads due to gear inaccuracy and a load distribution factor to account for the unequal distribution of load across the face width of the teeth (Figs. 3a–3c).

Since the ISO dynamic factor and the load distribution factors are load dependent, it is not possible to directly calculate the capacity of the gear set unless you know the load, which depends on those factors. ISO 6336 calculates a safety factor at a given load, based on allowable stress divided by applied stress rather than rated load or power. If you need to know the rated power at a given safety factor, it is necessary to iterate with variable load until the required safety factor is achieved. It's really best to have a good computer program to shorten the calculation time. The load dependency of the influence factors requires that they be applied in the correct order (Fig. 4).

Three basic rating methods are recognized, in order of decreasing accuracy:

- Method A—Full-scale testing or a verified, detailed mathematical model. This recognizes the validity of the development programs typical of the aircraft and vehicle industries, but no standard methods are specified.
- Method B—A detailed calculation method, standardized to allow comparison of a design to test or field data from similar designs. This is the core of the standard and the method programmed by the AGMA committee.
- Method C—Simplified methods which are sufficiently accurate for a restricted field of use or a narrow range of geometrical configurations.

The ISO standard is divided into four parts, covering common factors, pitting resistance, bending resistance and gear materials (Fig. 5). The general theory is very similar to AGMA 2001, using fundamental Hertzian surface stress for pitting and a simplified cantilever beam with stress concentration factors for bending, so you will be able to follow the general principles without trouble. The differences come in the greater detail of the ISO analysis, which require more design data, e.g. blank geometry, lubricant viscosity and tooth finish values as input information. We'll cover those topics in upcoming issues as we go through the sections of the standard in detail. ○

Next issue: Details of ISO 6336-1, General influence factors. Application Factor, Dynamic Factor, Load Distribution Factor and tooth stiffness.

1. Bartels, N. "Standard Issues," *Gear Technology*, Nov/Dec 1996.
2. Smith, R.E. "AGMA and ISO Accuracy Standards," *Gear Technology*, May/June 1998.
3. Stott, W.R. "Gear Teeth With Byte," *Gear Technology*, Jan/Feb 1998.

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CIRCLE 108

# Effects of Planetary Gear Ratio on Mean Service Life

M. Savage, K. L. Rubadeux & H. H. Coe

| Nomenclature |
|---|
| *Variables* |
| $a$ — gear addendum (mm, in) and bearing life adjustment factor |
| $C$ — dynamic capacity (kN, lbs) |
| $E$ — elastic modulus (MPa, psi) |
| $f$ — face width (mm, in) |
| $F$ — load (kN, lbs) |
| $K_f$ — stress concentration factor |
| $l$ — life (106 cycles and hours) |
| $n$ — gear ratio relative to the arm, number of planets |
| $n_a$ — actual transmission gear ratio |
| $N$ — number of gear teeth |
| $P_d$ — diametral pitch (1.0/inch) |
| $R$ — gear radius (mm, in) and reliability |
| $Y$ — Lewis Form Factor |
| $\phi$ — pressure angle (degrees, radians) |
| $\upsilon$ — Poisson's Ratio |
| $\rho$ — radius of curvature (mm, in) |
| $\sigma$ — bending stress (Pa, psi) |
| $\sigma_H$ — Hertzian contact stress (Pa, psi) |
| $\omega$ — angular velocity, speed (rpm) |
| $\omega_b$ — bearing load cycle speed (rpm) |
| $\Sigma$ — central angle between two adjacent planet center lines with the input shaft center (radians) |

| *Subscripts* | *Superscripts* |
|---|---|
| av — mean | b — Weibull slope exponent |
| d — dynamic | p — load-life exponent |
| o — output | |
| pl — planet | |
| r — ring gear | |
| s — sun gear | |
| 1 — pinion | |
| 2 — gear | |
| 10 — 90% reliability | |


### Abstract

Planetary gear transmissions are compact, high-power speed reducers that use parallel load paths. The range of possible reduction ratios is bounded from below and above by limits on the relative size of the planet gears. For a single-plane transmission, the planet gear has no size at a ratio of two. As the ratio increases, so does the size of the planets relative to the size of the sun and ring. Which ratio is best for a planetary reduction can be resolved by studying a series of optimal designs. In this series, each design is obtained by maximizing the service life for a planetary transmission with a fixed size, gear ratio, input speed, power and materials. The planetary gear reduction service life is modeled as a function of the two-parameter Weibull distributed service lives of the bearings and gears in the reduction. Planet bearing life strongly influences the optimal reduction lives, which point to an optimal planetary reduction ratio in the neighborhood of four to five.


### Introduction

Planetary gear transmissions offer the user a moderate gear reduction with a high power density. By carrying multiple planet gears on a rotating arm, load sharing is enabled among the planets. The symmetrical placement of the planets about the input sun gear provides radial load cancellation on the bearings that support the input sun and the output arm (Refs. 4 & 6). The fixed internal ring gear support also has no net radial load. With near-equal load sharing in medium-to-fine pitch gearing, a compact reduction results. Planetary reductions are often found in transportation power transmissions due to this weight and volumetric efficiency (Refs. 4 & 8).

Much of the published design literature for planetary gearing focuses on the kinematic proportioning of the unit to achieve one or more reductions through the use of clutches and brakes (Refs. 7 & 18).

Recent literature on planetary gears has focused on the dynamic loads in the transmission with measurements of load sharing and load variations in specific units (Refs. 3, 5, 8 & 10). Monitoring the dynamic loads in a planetary transmission has also been proposed as one method of determining the need for preventive maintenance in the transmission (Ref. 2).

While the reduction of dynamic loads in a planetary transmission is an important task, these studies do not indicate which ratio is best suited for a planetary transmission. Studies of rotating power in planetary transmissions have indicated that as the ratio is increased, the percent of rotating power in the unit decreases (Ref. 6). This suggests that the best ratio for a planetary reduction is the highest possible, which is reached with the largest planet gears. Addendum interference between the planets determines this limit. However, when one considers the size of a planetary reduction required to transmit a given power level at a given input speed, the loading on the gears and bearings in the reduction become an important factor, as do the component lives under load (Refs. 11 & 15).

Since aircraft and automotive transmissions can see service in excess of their nominal design lives, periodic maintenance is provided throughout their lives (Refs. 2 & 12). The service life of a transmission between maintenances is a design variable that one would like to maximize for a given size and power.

Programs have been written to optimize transmissions for service life (Refs. 9, 13 & 14). The service life of the transmission is modeled as a function of the service lives of the components that have a two-parameter Weibull distribution. The critical components for this calculation are the bearings and the gears in the transmission. A mean life of the transmission is determined from the mean lives of the critical components under load.

In this article, the influence of speed reduction magnitude on the service life of a planetary gear reduction is investigated for reductions with similar components. An optimal gear reduction for a planetary gear set is sought considering the size and capacities of the components. For a fixed power level and transmission size, the life is charted versus the reduction ratios for a fixed input speed and three, four and five planets.

**Planetary Constraints**

In comparing the lives of similar transmissions, one needs to specify the conditions of similarity. The planetary gear reductions considered in this work are single-plane reductions with input sun gears, fixed ring gears and multiple planet gears. The planet gears are placed symmetrically about the concentric input and output shafts as shown in Fig. 1. Each planet of a reduction is connected to the output arm through a single ball bearing at its center. Since the input sun gear and fixed ring gear mesh with all the planet gears, a single diametral pitch or module is used for all gears in a reduction, as is a single face width.

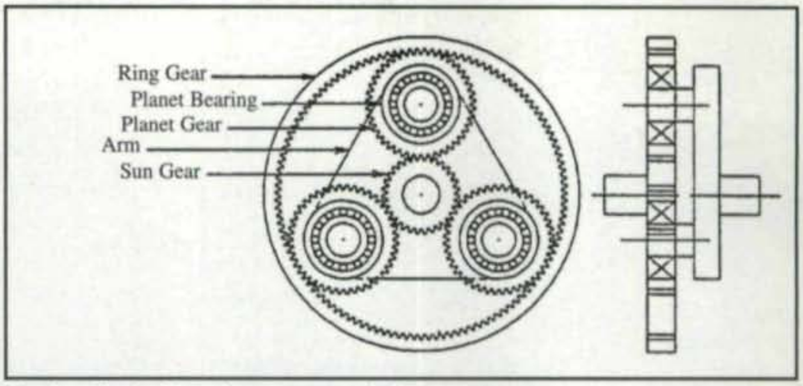

**Fig. 1 — Single-plane planetary transmission.**

No bearings are included on the input or output shaft since the internal loads in the planetary transmission are balanced on these shafts due to the symmetric placement of the planets. Bearings are needed on these shafts, but their placement and loading are based on external considerations.

All transmissions carry the same power and have the same outside diameter, which provides a radial ring thickness outside the ring gear teeth of 1.5 times the tooth height.

In this comparison, the input speed and torque are fixed as the ratio is varied. For each design, the planetary system life is maximized subject to the above constraints in addition to constraints on the stresses in the gear teeth and on assembly clearances. The parameters that define each design are the number of teeth on the sun gear, $N_s$, the face width of the gears, $f$, and the diametral pitch of the gears, $P_d$.

**Kinematics**

In a planetary gear train, the planetary gear ratio is the ratio of the speeds of the input and output shafts. To determine this ratio, one first needs to calculate the gear ratio of each gear mesh in terms of the number of teeth on each gear. The gear ratio of the sun gear mesh with the arm fixed is

$$n_1 = -\frac{N_{pl}}{N_s} \qquad (1)$$

and the gear ratio of the ring gear mesh with the arm fixed is

$$n_2 = \frac{N_r}{N_{pl}} \qquad (2)$$


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where the overall transmission gear ratio relative to the arm is

$$n = n_1 \bullet n_2 \quad (3)$$

and the speed of the output arm relative to the fixed ring is

$$\omega_o = \frac{\omega_o}{(1-n)} \quad (4)$$

So the planetary gear ratio is

$$n_a = 1 - n \quad (5)$$

And the speed of each planet gear is

$$\omega_{pl} = \omega_s \left(\frac{n - n_1}{n_1 (1-n)}\right) = \omega_s \left(\frac{1 - n_2}{1-n}\right) \quad (6)$$

The planet bearing load cycle speed is the speed of the planet with respect to the arm:

$$\omega_b = \omega_{pl} \left(\frac{n}{n - n_1}\right) \quad (7)$$

For each transmission studied, the planetary gear ratio, $n_a$, is fixed, and the number of teeth on the sun gear is an independent design parameter. Values that maximize the service life for a given transmission size are found for the number of teeth on the sun gear, the gear face width and the diametral pitch. This requires the number of teeth on the ring gear, $N_r$, and on each planet gear, $N_{pl}$, to be found in terms of $n_a$ and $N_s$.

The number of teeth on the ring gear is related to the number of teeth on the sun by the gear ratio relative to the arm, since the planets become idlers in this inversion.

$$N_r = -nN_s = (n_a - 1)\, N_s \quad (8)$$

Since the diameter of the ring gear is equal to the diameter of the sun gear plus twice the diameter of the planet gear, the number of teeth on each planet gear can be calculated by

$$N_{pl} = \frac{N_r - N_s}{2} = \frac{(n_a - 1 - 1)N_s}{2} = \frac{(n_a - 2)N_s}{2} \quad (9)$$

To keep the number of planet teeth positive, the transmission gear ratio, $n_a$, must have a value greater than 2. At 2, the planet gears have no size, and the planetary reduction ceases to exist.

To prevent interference among gear teeth of adjacent planet gears, sufficient circumferential clearance must be provided. Requiring that the distance between the axes of two adjacent planets be greater than the outside diameter of the planet gear by twice the tooth addendum will accomplish this:

$$2 \bullet (R_s + R_{pl}) \bullet \sin\left(\frac{\Sigma}{2}\right) > 2 \bullet (R_{pl} + 2 \bullet a) \quad (10)$$

where $\Sigma$ is the central angle between two adjacent planet center lines and $a$ is the addendum of the planet gears.

One additional constraint is needed to allow the planets to be positioned symmetrically around the sun gear. The sum of the number of teeth on the sun and on the ring divided by the number of planets must produce an integer.

$$\frac{N_s + N_r}{n_{pl}} = I \quad (11)$$

**Tooth Strength**

The AGMA model for gear tooth bending uses the Lewis form factor and a stress concentration factor to determine the stress in the tooth for a load at the highest point of single tooth contact (Ref. 1). The bending stress model is

$$\sigma = \frac{F_d \bullet P_d \bullet K_f}{f \bullet Y} \quad (12)$$

where $F_d$ is the tangential dynamic load on the tooth, $K_f$ is the stress concentration factor and $Y$ is the Lewis form factor based on the geometry of the tooth. Since the Lewis form factor is a function of the tooth shape, it is dependent on the number of teeth on the gear, as is the stress concentration factor.

Large localized stresses occur in the fillets of gear teeth due to the change in the cross section of the tooth. Although the maximum stress is located closer to the root circle than predicted by Lewis' parabola, the distance between the two locations of maximum stress is relatively small, and the stress concentration factor accurately compares the maximum stress in the tooth to the Lewis stress (Ref. 1). This method of rapid calculation of bending stress for external gear teeth is extended to include the bending stress in the internal gear teeth of the ring gear (Ref. 17).

In addition to bending stresses, surface contact stresses can contribute to gear tooth failure. The Hertzian pressure model closely predicts these contact pressures:

$$\sigma_H = \left(\frac{F_d}{\pi \bullet f \bullet \cos\phi}\left(\frac{\frac{1}{\rho_1} + \frac{1}{\rho_2}}{\frac{1-\upsilon_1^2}{E_1} + \frac{1-\upsilon_2^2}{E_2}}\right)\right)^{1/2} \quad (13)$$

where $\phi$ is the normal pressure angle of the gear mesh, $\rho_1$ and $\rho_2$ are the radii of curvature of the pinion and gear tooth surface at the point of contact, $\nu_1$ and $\nu_2$ are the Poisson ratios and $E_1$ and $E_2$ are the moduli of the material elasticity for the two gears.

Contact pressure near the pitch point leads to gear tooth pitting, which limits the life of the gear tooth. Gear tip scoring is another type of failure that is affected by the contact pressure at the gear tooth tip. One model for gear tip scoring includes the pressure times velocity factor, where the sliding velocity at the gear tip is tangent to the tooth surfaces.

### Service Life

Surface pitting due to fatigue is the basis for the life model for the bearings, gears and transmission. Fatigue due to this mode of failure has no endurance limit, but has a service life described by a straight line on the log stress versus log cycle S-N curve. This life-to-load relationship can be written for a specific load, $F$, at which the 90% reliability life is $l_{10}$ and which is related to the component dynamic capacity, $C$, as:

$$l_{10} = a\left(\frac{C}{F}\right)^p \qquad (14)$$

Here the component dynamic capacity, $C$, is defined as the load that produces a life of one million cycles with a reliability of 90%, and $a$ is the life adjustment factor. The power, $p$, is the load-life exponent, which is determined experimentally.

Complementing this load-life relationship is the two-parameter Weibull distribution for the scatter in life. In this distribution, the reliability, $R$, is related to the life, $l$, as:

$$Ln\left(\frac{1}{R}\right) = Ln\left(\frac{1}{0.9}\right) \bullet \left(\frac{l}{l_{10}}\right)^b \qquad (15)$$

A meaningful estimation of service time is the mean time between overhauls. The mean life for a two-parameter Weibull distribution can be expressed in terms of the gamma function, $\Gamma$, as:

$$l_{av} = \frac{l_{10} \bullet 10^6 \bullet \Gamma\left(1 + \frac{1}{b}\right)}{60 \bullet \omega_o \bullet \left[Ln\left(\frac{1}{0.9}\right)\right]^{\frac{1}{b}}} \qquad (16)$$

including the conversion from million cycles to hours, where $\omega_o$ is the output speed in rpm.

If the repairs are component repairs, rather than full replacements, then the mean life between overhauls is based directly on the mean lives of the individual components. In this case, the transmission repair rate, which is the reciprocal of the mean life, is the sum of the individual component repair rates. Thus, the transmission mean service life is estimated as the reciprocal of the repair rate:

$$l_{av,s} = \frac{1}{\Sigma \frac{1}{l_{av,i}}} \qquad (17)$$

**Table 1 — Planetary Design Inequality Constraints**

| *Constraint* | *Value* | *Unit* | *Type* |
|---|---|---|---|
| Bending stress: sun-planet | 40,000.000 | psi | upper |
| Full load Hertz stress: sun-planet | 180,000.000 | psi | upper |
| Gear tip Hertz pressure: sun-planet | 180,000.000 | psi | upper |
| PV factor of sun-planet teeth | 50.000 | $10^6$ psi-ft/min | upper |
| Flash temp of sun-planet teeth | 200.000 | deg. F | upper |
| Sun involute interference | 0.001 | radians | lower |
| Sun face width to diameter | 0.750 | ratio | upper |
| Bending stress: planet-ring | 40,000.000 | psi | upper |
| Full load Hertz stress: planet-ring | 180,000.000 | psi | upper |
| Gear tip Hertz pressure: planet-ring | 180,000.000 | psi | upper |
| PV factor of planet-ring teeth | 50.000 | $10^6$ psi-ft/min | upper |
| Flash temp of planet-ring teeth | 200.000 | deg. F | upper |
| Involute interference: planet-ring | 0.001 | radians | lower |
| Planet circumference clearance | 0.100 | in | lower |
| Bearing diameter | 0.400 | in | lower |
| Diameter of ring gear | 12.000 | in | upper |
| Volume of transmission | 1,000.000 | $in^3$ | upper |

### Planetary Designs

In considering the effects of the gear ratio on the mean transmission life, the input speed and power were held constant. The input speed was 2,000 rpm for all transmissions, which carried a power of 51 hp with a fixed input torque of 1,600 lb-in. Each transmission has a maximum ring gear outside diameter of 12". The sun gear mesh and the ring gear mesh both had a normal pressure angle of 20° and the same diametral pitch. All gears were made of high strength steel with a surface material strength of 220 ksi. The Hertzian contact pressure was limited to less than 180 psi, and the tooth bending stresses were limited to less than 40 ksi. These limits include a total load design factor of 1.5 to adjust the nominal stress calculations of Eqs. 12 and 13 to code levels. The PV factor was limited to less than 50 million psi-ft/min, and the gear tooth flash temperature was limited to less than 200°F. The Weibull slope of the sun gear, the three planet gears and the ring gear was 2.5. The load-life factor of all five gears was 8.93. The planet bearings were 300 series, single-row ball bearings, with a Weibull slope of 1.1, a load-life factor of 3.0 and a life adjustment factor of 6.

| Table II — Design Service Lives | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Planet | Ratio | Tooth Numbers | | | Face Width | Pitch | Life | Pitch | Life |
| | $n_a$ | $N_s$ | $N_{pl}$ | $N_r$ | f in | $P_d$ $in^{-1}$ | $l_{av}$ hrs | $P_d$1 $in^{-1}$ | $l_{av}$1 hrs |
| 3 | 3.0 | 60 | 30 | 120 | 1.0 | 11 | 1040 | 10.68 | 1320 |
| | 3.5 | 48 | 36 | 120 | 1.0 | 11 | 2430 | 10.7 | 3000 |
| | 4.0 | 45 | 45 | 135 | 1.25 | 12 | 4720 | 11.95 | 4870 |
| | 4.5 | 40 | 50 | 140 | 1.5 | 13 | 3880 | 12.4 | 5500 |
| | 5.0 | 36 | 54 | 144 | 1.5 | 13 | 4940 | 12.7 | 5870 |
| | 5.5 | 36 | 63 | 162 | 1.5 | 15 | 4300 | 14.2 | 6230 |
| | 6.0 | 30 | 60 | 150 | 1.5 | 14 | 3600 | 13.2 | 5590 |
| | 6.5 | 24 | 54 | 132 | 1.5 | 12 | 3740 | 11.68 | 4560 |
| | 7.0 | 24 | 60 | 144 | 1.5 | 13 | 3870 | 12.7 | 4600 |
| | 7.5 | 24 | 66 | 156 | 1.5 | 14 | 3900 | 13.7 | 4580 |
| | 8.0 | 24 | 72 | 168 | 1.5 | 15 | 3810 | 14.7 | 4450 |
| 4 | 3.0 | 60 | 30 | 120 | 1.0 | 11 | 1850 | 10.68 | 2340 |
| | 3.5 | 40 | 30 | 100 | 1.0 | 10 | 1640 | 9.02 | 3680 |
| | 4.0 | 40 | 40 | 120 | 1.25 | 11 | 5880 | 10.7 | 7240 |
| | 4.5 | 40 | 50 | 140 | 1.5 | 13 | 6900 | 12.35 | 10100 |
| | 5.0 | 36 | 54 | 144 | 1.5 | 13 | 8780 | 12.68 | 10560 |
| 5 | 3.0 | 60 | 30 | 120 | 1.0 | 11 | 2890 | 10.68 | 3660 |
| | 3.5 | 40 | 30 | 100 | 1.0 | 10 | 2570 | 9.05 | 5600 |
| | 4.0 | 40 | 40 | 120 | 1.25 | 11 | 9180 | 11.7 | 11300 |


Fig. 2

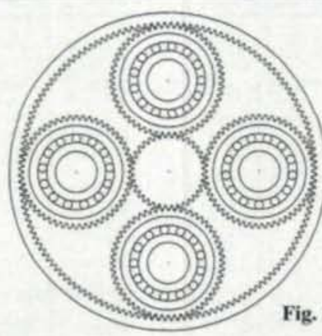
Fig. 3

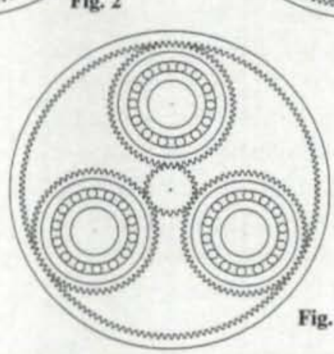
Fig. 5

**Fig. 2 — Planetary transmission with a reduction ratio of 3.0**

**Fig. 3 — Planetary transmission with a reduction ratio of 5.0**

**Fig. 4 — Planetary transmission with a reduction ratio of 7.0**

Table II lists the obtained designs with the numbers of teeth on the sun, planet and ring gears, the gear face width and the diametral pitch for each ratio. These teeth numbers are discrete values that produce the required planetary ratio and allow symmetric placement of the planets for radial load cancellation. After the diametral pitch, the mean service life of the transmission is listed for component replacement at repair. This life corresponds to the integer diametral pitch listed before it. It also corresponds to a somewhat smaller transmission as dictated by the integer pitch. The last two columns show larger lives, which vary more continuously, and the fractional diametral pitch required to obtain these lives by allowing the transmission to have the full 12" outside ring diameter. The table includes blocks of data for three-, four- and five-planet designs.

Even higher lives would be possible with fine pitch gearing, since the outside diameter limit includes the ring gear dedendum and the rim height outside the ring gear pitch diameter. Both distances are proportional to the tooth height. However, the diametral pitch is limited to 16 or less to maintain overload tooth bending strength.

The results show that as the gear ratio was increased, the size of the sun gear decreased, and the size of the planet gears increases. Figs. 2–4 show planetary transmission designs for speed reduction ratios of three, five and seven.

The effect of the gear ratio on the mean life of the transmission is plotted in Fig. 5. For the integer diametral pitch designs with three planets, the mean service life, plotted as a series of crosses, increased from 1,040 hours for a gear ratio of three to 4,940 hours for a gear ratio of five, and then decreased to 3,600 hours for a gear ratio of six, with a final life of 3,810 hours for a gear ratio of eight. Higher lives that varied more continuously were available with uneven pitches and are plotted as a life limit line above the found design lives. This line corresponds to the primed pitches and lives of Table II and is also jagged due to the discrete nature of the numbers of teeth.

Similar data are plotted with circles for integer pitch designs with four planets and with squares for designs with five planets. For the four-planet designs, the integer pitch design lives ranged from 1,850 hours for a gear ratio of three to a maximum of 8,780 hours for a gear ratio of five. And for the five-planet designs, the mean service lives varied from 2,890 hours for a gear ratio of three to 9,180 hours for a gear ratio of four. Similar life limit designs are plotted above these points for designs with the full 12" outside diameter and non-integer diametral pitches.

At low planetary ratios, the planet and planet bearing sizes were small. At a ratio of three, the smallest bearings for the optimal designs were selected, causing the low life designs for each number of planets. As the planetary ratio was increased, the size of the planets and the planet bearings increased, which increased the life of the transmissions. With more planets to share the load, the four- and five-planet designs had greater lives than the three-planet designs. However, circumferential planet interference limited the five-planet designs to a maximum ratio of four and the four-planet designs to a maximum ratio of five. At ratios above 5.5, the life of the three-planet designs dropped due to the increase in the output torque. Once again, the lower transmission life was attributable to lower planet bearing life. At a gear ratio of eight, the pitch diameter of the sun gear had decreased to 1.6" with a face width of 1.5". Larger ratios would have decreased this length-to-diameter ratio even further and would have increased the bending stress in the sun gear teeth above the 21 ksi present in the eight-to-one gear ratio design. So the table and graph were cut off at this gear ratio even though designs are possible at higher ratios with three planets.

## Conclusions

The effect of the gear ratio on the life of the transmission was examined. Of interest is the possibility of an optimal planetary gear reduction from a life standpoint. In this study the overall size of the transmission was held constant, its strengths were maintained and the ratio was varied for the three-, four- and five-planet arrangements. Each optimal design was defined by the number of teeth on the sun gear, the gear face width and the diametral pitch of the gears. For the comparison, the transmission input speed and power were held constant. The results show that as the gear ratio increased, the size of the sun gear decreased, and the size of the planet gears increased. At a ratio of three, the planet bearings were reduced in size relative to the transmission sufficiently to limit the transmission life. Five-planet designs had a maximum ratio of four with no planet interference, and four-planet designs could be obtained with ratios up to five. Above five and a half, the lives of the three planet designs fell off due to the higher output torques. The optimal design exists for a transmission with a gear ratio of approximately four to five. ○

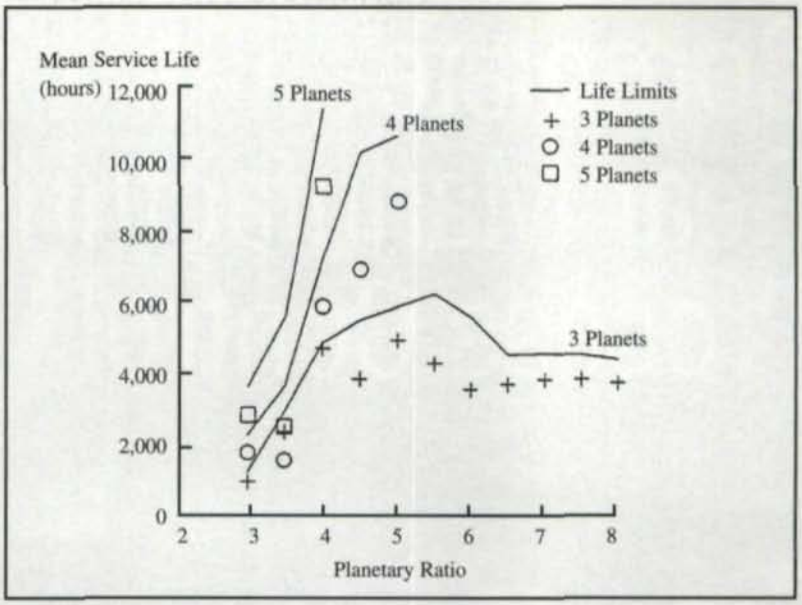


**Fig. 5 — Mean transmission service life versus speed reduction ratio with constant input speed and torque.**


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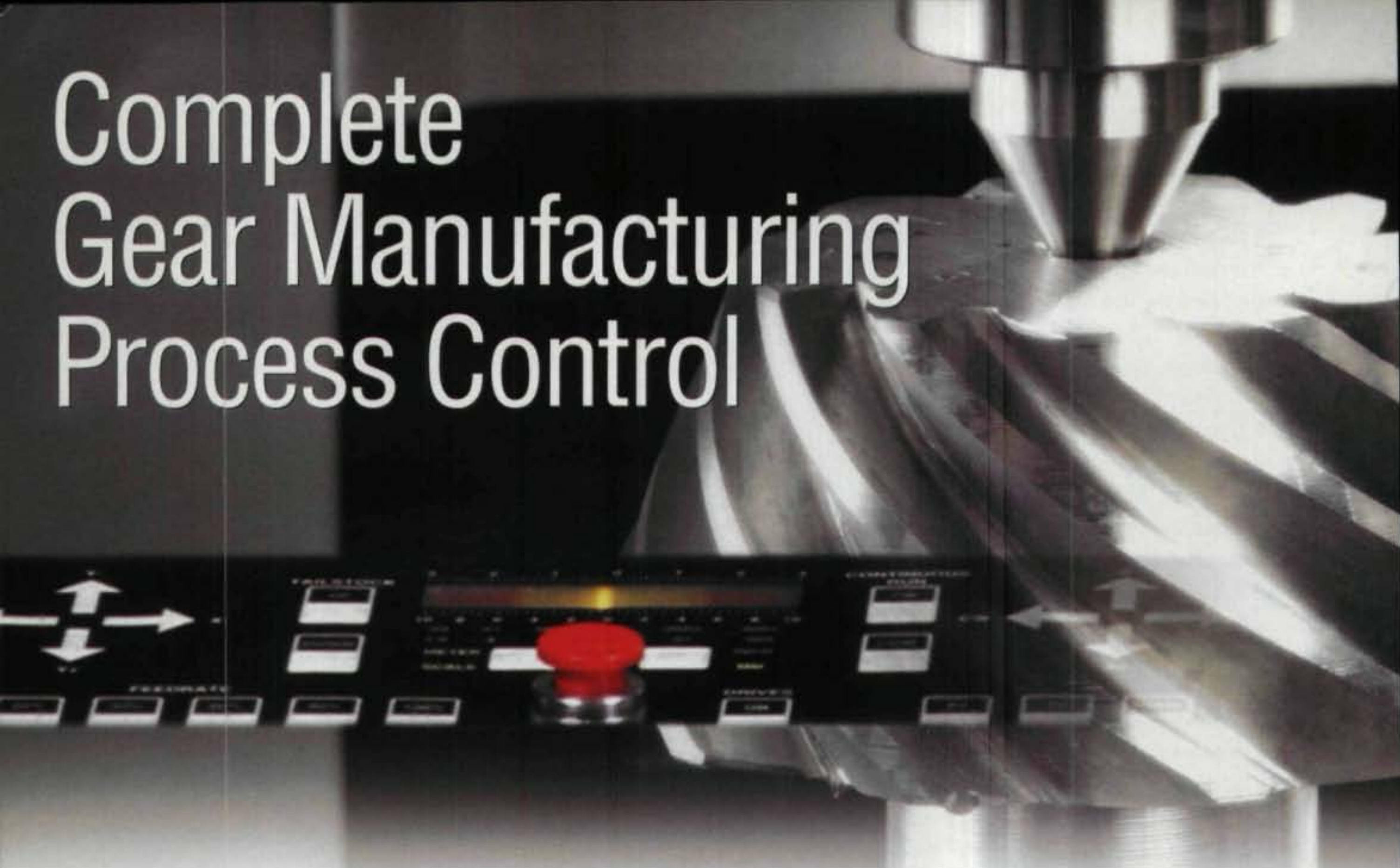

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# Plastic: The Not-So-Alternative Technology

William R. Stott

**"We're taking over,"** says Art Milano.

It's a bold statement from the engineering manager of Seitz Corporation, one of the largest manufacturers of injection molded plastic gears, but Milano has reason for his optimism. Plastic gears are big business—probably bigger than most gear industry "insiders" realize.

Although estimates vary, the number of injection molded plastic gears manufactured in the United States **each year** probably numbers in the billions. Some people we talked to even suggested that plastic gears outnumber metal gears.

When you consider that a modern automobile incorporates up to 50 motorized devices—windshield wipers, seat adjusters, automatic windows, etc.—and that most of these devices use plastic gears, it becomes easy to see how the plastic gear industry has grown. When you consider some of the other industries that use a lot of plastic gears—computer printers, VCRs, home appliances, automated teller machines—numbers in the billions seem downright realistic.

So if you still manufacture gears the old-fashioned way—by cutting chips out of metal—should you be worried? Probably not, says Irving P. Laskin, an independent consultant who specializes in plastic and metal gear design. Plastic gears have found a niche in small, low-power gear trains, and while their use has become ubiquitous in certain applications, still others require the ultra high precision, load carrying ability or temperature resistance of machined metal.

In fact, although it's tempting for plastic and metal shops to view each other as competitors, some traditional metal-cutting machine shops have *benefited* from the increase in plastic gear business. Very often, these shops are called upon to make the molds or to make prototype gears out of metal because the turnaround time is generally much faster, says Laskin. Also, most injection molders don't have the knowledge or equipment to make metal parts themselves.

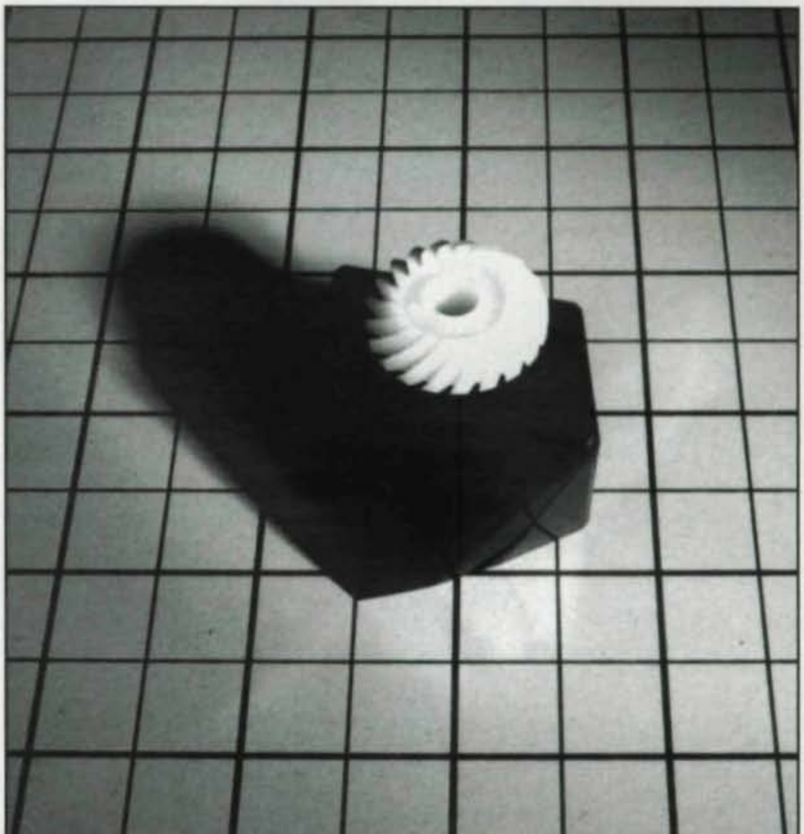


Photo by Charles Cooper

Lexmark implemented several spiral bevel gears in a recent printer drivetrain to increase the contact ratio and improve the smoothness of the gear train. The ever-increasing resolution of printers is demanding more and more accurate gear trains.

**Spiral Bevel Gear**

**Manufactured by: ABA-PGT, Inc., Manchester, CT.**

**Product: Lexmark printers.**

**Material: acetal and polyketone.**

**Laser Printer Gears**

**Manufactured By: GW Plastics, Bethel, VT**

**Product: Toner cartridge for Lexmark Optra line of laser printers**

**Material Used: Carilon® polymers from Shell Chemical**

This 40 mm gear is part of the photoconductor drum assembly used in the toner cartridge for Lexmark's Optra laser printer. The gear meshes with a mating gear in the printer itself. Requirements were toughness, quietness, wear resistance and creep resistance.

"In the past, it would have been unheard of to produce a 1400 dpi printer," says Alan B. Conrad, Industrial and Consumer Business Unit Manager for G.W. Plastics. "Gears are integral to that kind of technology."

This part was formerly manufactured out of lubricated acetal, but the Carilon polymer proved to be more stable (resulting in more consistent quality), more wear resistant and less expensive than the version of acetal previously used for this part.

Typical of injection molded plastic gears, this part enabled the designer to combine the gear with other parts without adding machining operations or assembly.

In addition, there has recently been a lot of cooperation between the traditional gear community and plastic gear manufacturers and material suppliers. One result of this cooperation is *ANSI/AGMA 1006, Tooth Proportions for Plastic Gears*, which was released along with *ANSI/AGMA 1106*, the metric equivalent, in 1997. AGMA's plastic gear committee is now working on an information sheet for plastic materials selection, says consultant Clifford Denny, committee chairman.

On the other hand, plastic gears were once unheard of for anything other than toys. "There was a time a long time ago when small, fine-pitch gears were all machined from metal," says Laskin. "The plastic gear industry hadn't developed yet." But today, plastic gears are in very serious applications such as medical tools, Laskin says.

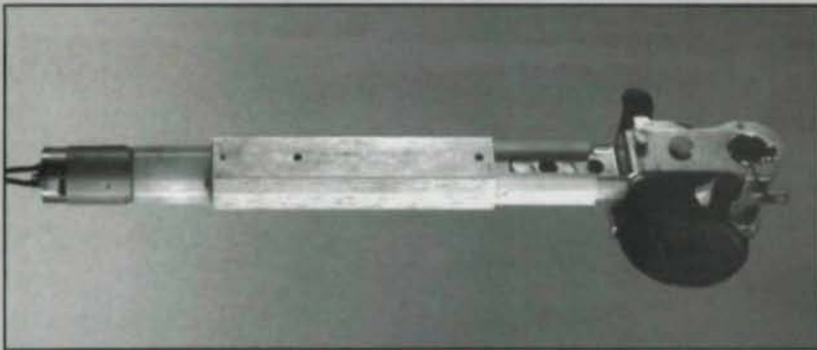
We're beginning to see plastic gears in applications with higher power and load demands. Fractional horsepower gearboxes are now commonly made out of plastic. Plastic gears capable of transmitting up to one 1 hp are achievable using today's technology. But plastic gear engineers now have their sights on 5 hp and greater applications in the not-too-distant future.

Some of the plastic gear manufacturers are currently working on gear trains in the 1-2 hp range, although most of them would not comment on any specifics for this article.

Another area where plastic injection molded gear manufacturers are looking is bigger parts. Injection molders have had difficulty creating parts larger than 2-3" in diameter. With larger spaces to fill, it becomes difficult to get an even flow of material into the mold. Traditionally, larger plastic gears have been machined just like metal gears, says Laskin. But injection molders continue to look at ways to increase their share of the market. "I'm entertaining doing an 8-pitch gear," says Milano.

The big chemical companies have added their considerable resources to the push. Ticona has a dedicated "Gear Team" for educating the industry about designing and implementing plastic gears. Ticona's gear team has developed P-GEAR, an automated gear testing system that collects data on fatigue life, wear, temperature, stiffness and other properties for gears molded with different materials. Similarly, Shell Chemical markets its Carilon and other lines of polymers specifically for gear manufacturing.

Better resins mean stronger gears. "The technology is getting better every year," says Seitz Corp.'s Milano. "We're not calling them actua-

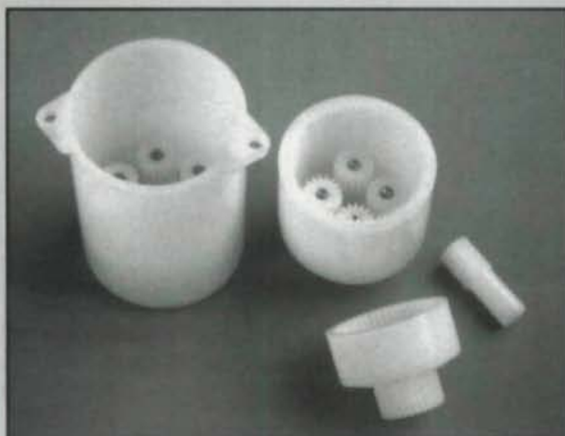


**Seat Belt Adjuster**

**Manufactured By: Epic Components Co., New Boston, MI.**

**Product: AlliedSignal Safety Restraint Systems seat belt height adjuster.**

**Material Used: Celcon® M90 acetal copolymer from Ticona.**

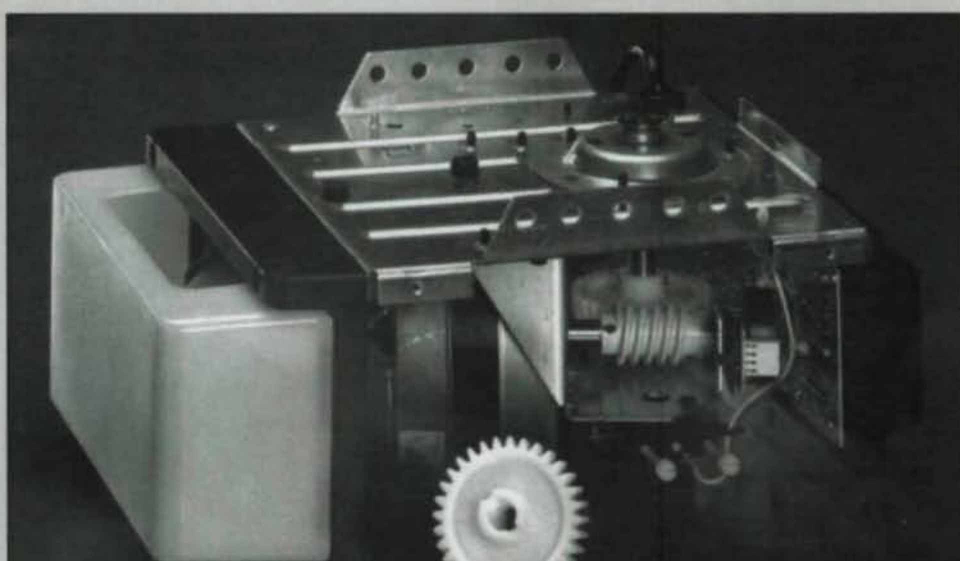


The coupled epicyclic gear system in this transmission is typical of the internal, cluster and split-power arrangements in today's plastic gear drives. Consisting of 14 injection molded acetal gears, the transmission is 1.44 inches in diameter and weighs 1.5 oz. It transmits 12 oz-in. of torque from a dc motor.

"A system of this type employs a number of internally- and externally-toothed gears to split the motion from the motor drive into multiple power paths, enabling the designer to pack a lot of gear ratio into a very small space," says Ticona gear specialist Dr. Zan P. Smith. "To do the job of the SRS transmission with conventional spur gears would require a gear set around five times larger."

The plastic worm for this garage door opener is mounted on a motor shaft and meshes with the gear to turn a vertical shaft that drives a belt or chain to move the garage door's operating arm along a track. The double-lead mesh keeps two sets of teeth in contact at all times to distribute the load and minimize friction and backlash.

The gear set replaces a glass-filled nylon worm and a steel gear from earlier models. The gears cost less than the previous materials, and the double-lead design eliminates the need for a brake.



**Garage Door Opener**

**Manufactured By: Chamberlain Group, Elmhurst, IL.**

**Product: Ceiling-mounted garage door opener.**

**Material Used: DuPont Minlon® 10B40 mineral-reinforced nylon (worm) and Delrin® 100 acetal resin (worm gear).**

**Electric Chainsaw Internal Gear**

**Manufactured by: Seitz Corporation, Torrington, CT.**

**Product: Pulan Electric Chainsaw**

This internal spur gear is a good example of the tendency today to use plastic for gears that have typically been made out of metal. It is part of a gear train driven by a 1.068 hp motor at 25,000 rpm. The maximum output torque is 137 in-lbs.

Seitz Corporation developed this gear using the latest AGMA PT-1 standardized tooth profile. However, the part required an extensive development program.

"Our experience told us that this internal spur gear would develop taper during the molding process," says Seitz Corp. engineering manager Art Milano. "A tapered tooth profile generates poor contact ratio, excess noise and most likely a weak gear. We knew we would develop this internal gear in phases to determine and compensate for the amount of taper we would encounter during production."

Seitz's development program includes three phases, Milano says. Phase One involves design, material selection and calculation of safety factors. During Phase Two, the company designs and builds prototypes, adjusting the mold until the parts measure up. Phase Three involves live testing of the gear in its application and making any necessary final adjustments to the mold.

tors any more. We're calling them plastic transmissions now."

But increasing the load and power capabilities of plastic gears are not the only areas where the technology is improving. Advances in resin technology and processing controls have allowed molders to hold tighter and tighter tolerances, says Alan B. Conrad, Industrial and Consumer Business Unit Manager for G.W. Plastics, Inc., Bethel VT. Injection molders today are capable of consistently producing gears as high as AGMA Class 9, Conrad says, and "some are asking for AGMA 10."

As buyers of plastic gears continue to seek better, stronger gears, and as manufacturers continue to aggressively explore new markets for their products, the plastic gear industry will continue growing at a rapid rate.

While most experts agree that we aren't likely to see plastic gears in automotive transmissions or plastic gears driving lift bridges anytime soon, the plastics suppliers, who want to sell more resin, and manufacturers, who want to sell more parts, are working together to push the envelope of plastic gear technology, and at least one advocate is hopeful that even some of these high-power, high-temperature industries might not be too far out of reach.

"I think we're going to see more appliance transmissions, lawnmower transmissions, even vehicles powered by plastic gears," says Milano. ○

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If you would like more information about **Seitz Corporation**, please circle **217.**

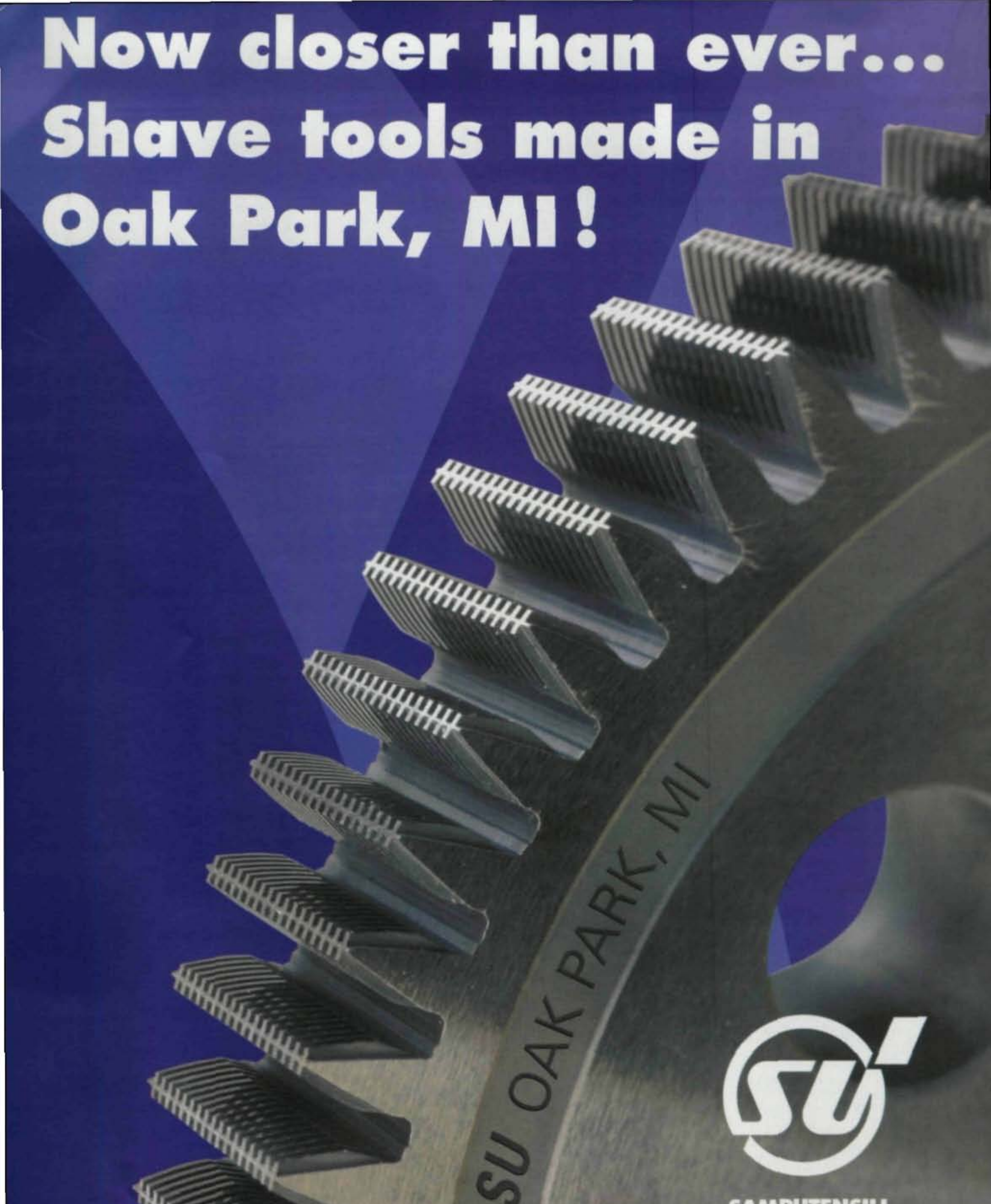
If you would like more information about **Shell Chemical Corporation**, please circle **218.**

If you would like more information about **Ticona**, please circle **219.**

**Industry resources are coming together for a workshop titled *TOPTEC: Plastic Gears for Power Applications, Fractional to 5hp*, which is scheduled for August 26–27 in Dayton, Ohio. The event, cosponsored by AGMA and the Society of Automotive Engineers, will feature presentations on plastic gear applications, design, manufacturing and testing.**

**This is the first of what is intended to be an annual event. It will include presentations on innovative design concepts, software, materials selection, inspection and more. There will also be a "Power Gear Symposium" focusing on the future of the industry.**

**For more information, contact the SAE Dayton section at (412) 772-8524.**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# Exhibitors Prepare for the Biggest IMTS Ever

***It's big. More than 1,400 exhibitors* are expected to display the latest manufacturing technology available.**

**It's big. Organizers expect attendance to equal the IMTS 96 record of more than 120,000 visitors.**

**It's big. Exhibits will take up more than 1.4 million square feet of space.**

**So why would anyone in his right mind want to go to Chicago, fight the crowds and walk miles and miles through booth after booth of exhibits?**

**The answer is quite simple. Nowhere in the western hemisphere will you find a more complete collection of the manufacturers and suppliers of the latest in machine tools, cutting tools and services for industry.**

**This year's show will feature 10 pavilions focusing on areas of manufacturing technology. The pavilions include Abrasive Machining, EDM, Environmental Safety, Factory Automation, Gear Generation, Lasers, Metal Cutting, Metal Forming, Quality Assurance, and Tooling & Workholding.**

**In addition, SME will hold its Manufacturing '98 technical conference in conjunction with the show. The conference features over 70 one- and two-day courses and clinics on a variety of manufacturing topics.**

**Gear industry suppliers will be well represented at the show. For the second time, IMTS will feature a gear generation pavilion, where most of the gear machine and cutting tool manufacturers will have their booths. The following is a list of some of the booths that might be of interest to gear manufacturers.**

### Guide to the Booths

**A.G. Davis/AA Gage (Booth E1-2332)** will have on display their line of Hydragrip hydraulic expansion arbors and chucks for gear grinding, hobbing, shaping, honing and other manufacturing operations. They will also show their line of face gear couplings.

**Emuge Corporation (Booth E1-2352)** is a premier manufacturer of quality workholding and electronic control systems for gear manufacture. Emuge will feature a precision clamping product line that includes arbors, chucks, diaphragm chucks, spindles, draw bars and machine operation measuring systems configured to accomplish a broad range of turning, grinding, hobbing, milling, drilling, lapping, balancing, inspection and assembly operations. Emuge's mechanical, hydraulic and mechanical/hydraulic systems achieve an excellent runout accuracy—typically .00008 to .0002—and are renowned for reliability, functionality, clamping element interchangeability and ease of maintenance. Custom application services are offered. Emuge's Web site at *www.emugecorp.com* outlines details.

**Euro-Tech Corporation (Booth E1-2530)** will show the Frenco line of gages and workholding devices, Mytec hydraulic expansion arbors and chucks and the Euro-Tech Power Block III toolholder. Frenco's product range includes extremely long-wear go/no go gages, bevel gear testing gages, completely automatic spline and cluster shaft inspection systems and a full range of clamping arbors, chucks and nests for inspection and machining applications. Mytec rupture-proof arbors and chucks are ideally suited to precision applications. Mytec arbors and chucks provide normal runouts under .00012" for grinding, hobbing, shaving, shaping and inspection of gears. The Power Block III mounts directly to your bench or table to make tool changes easy and risk-free. Vertical and horizontal axis allows access to the bottom of the toolholder. Either axis may be outfitted with like or different receptacles to accommodate any standard or custom toolholder tapers, including HSK.


**Gleason Pfauter Hurth (Booth B1-7150)** will exhibit several new products for gear manufacturing. The new Power Dry Cutting process for bevel and hypoid gears will be demonstrated on the new Gleason 175HC Power Dry Cutting machine. The 175HC will demonstrate face milling and face hobbing on bevel gears. Gleason will also premier the new 600HTL Hypoid Turbo Lapping machine for hard finishing bevel and hypoid gears. The turbo lapping process (ultra high speed) is possible due to Gleason advances in machine dynamics and compound application technology. Gleason-Pfauter will exhibit for the first time the new (16") P400G profile grinder with integrated gear measuring and integrated CNC wheel dressing. Gleason-Hurth will demonstrate the capabilities of the

## SHOW FACTS

IMTS 98
MCCORMICK PLACE, CHICAGO, IL
SEPT. 9–16, 1998

- 1,400+ exhibitors will fill 1.4 million square feet of space.
- Attendance is expected to equal or exceed the record of more than 120,000 set at IMTS 96.
- Registration and exhibitor information is available online at *www.imts.org* or by calling AMT—The Association for Manufacturing Technology at (800) 828-7469.
- SME's Manufacturing '98 technical conference will be held in conjunction with IMTS. More than 70 technical courses and clinics. Visit *www.sme.org* or call SME at (800) 733-4763 for more information.

ZH125 CNC spheric honing machine for hard finishing cylindrical gears using an internal abrasive honing tool. The machine will be shown with automation. Gleason and Pfauter will also exhibit, for the first time, a new joint engineering and manufacturing cooperation in machine design with a new gear manufacturing machine to be unveiled at IMTS.

**Gold Star Coatings (Booth E1-2701)** will feature a variety of thin film coatings.

**H.B. Carbide Co. (Booth E1-2700)** is a manufacturer of carbide pre-forms.

**Holroyd (Booth C2-5575)** will show, for the first time anywhere in the world, the TG150E thread grinder. This is a 'sister' version of the TG350E launched two years ago as the first in a planned new generation of machines. The TG150E has been specifically designed for grinding smaller components, with profiles up to 70 mm wide and less than 300 mm in diameter (the TG350E has a maximum 350 mm capacity and 110 mm profile width). An important feature of the new machine is integrated 3D component profile measurement with automatic machine compensation to all axes. Also on display will be a range of worm gears, screw compressor rotors and other helical products manufactured by Holroyd's subcontract facility.

**Kapp Sales & Service L.P. (Booth B1-6981)** represents the Kapp and Niles product lines of internal and external grinding machines featuring stock dividing, on-board measuring, dressable wheels and CBN wheels for the manufacture of internal and external spur and helical gears, ball screw tracks, worms, compressor rotors, rotary pistons (root type), pump spindles (IMO type), pump rotors (gerotor type), vane pump rotors, constant velocity tracks (CVT and the like) and more.

**Liebherr America (Booth B1-7170)**, North American representative of Sigma Pool partners Klingelnberg, Lorenz and Oerlikon, will demonstrate new gear machinery. Liebherr will demonstrate high-speed dry hobbing with the new LC 82 CNC hobbing machine, which was developed for dry cutting with carbide and cermet tools. The LC 82 has a 3,000-rpm motor hob head and a 450-rpm table, permitting cutting speeds up to 2,000 feet/minute. Klingelnberg will demonstrate the compact Hoefler ZP 260 CNC gear inspection center designed for the shop floor. The ZP 260 takes up less than 16 square feet of floor space, but measures workpieces up to 40" diameter and 40" between centers. Oerlikon will exhibit the C28 bevel gear machine for high-volume dry machining.

**M&M Precision Systems Corporation (Booth B1-7149)** manufactures CNC gear manufacturing process control systems utilizing 1D, 3D and laser probe technologies. M&M's Metrology Systems group also provides CNC systems for measuring threads, turbine blades, helical rotors, scroll compressor components and a variety of other complex forms. In addition, M&M supplies a complete line of functional gaging products including double flank roll testers, D.O.P. gages, variable indicators, master gears and spline gages. M&M's Motion Systems group carries a complete line of linear and rotary components and subassemblies and brings almost 50 years of experience in the design and manufacture of standard and custom positioning systems.

**Mahr Corporation (Booth D2-4437)** will present metrology products for measuring gears as well as surface texture, form and length on a variety of parts. The Extramess 2000 is a new analog/digital inductive comparator accurate to .000012". The M1 and M2 are the first of a new series of surface texture measurement instruments designed for the shop floor. The Optimar 100 is a new bench-top calibration system for dial indicators, dial comparators, dial test indicators, incremental probes and LVDTs.

**Mitsubishi Machine Tools (Booth A1-8242)** will demonstrate its line of gear hobbers, shapers, shavers and grinders. Mitsubishi's gear shapers and hobbers have sophisticated cutting mechanisms for high productivity shaping and hobbing of gears up to one meter in diameter. Their gear shavers can handle gears up to 450 mm diameter.

**Mitsui Machine Technology Inc. (Booth A1-8733)** represents Ikegai Corporation with their full line of CNC machining centers, including gear hobbing, boring, milling, turning, grinding and combination machines. MMT also will show the O-M Ltd. line of vertical CNC lathes and the Howa Machinery Co. line of vertical CNC machining centers.

**National Broach (Booth B1-7490)** introduces three new gear machines at IMTS 98. The NBV 5-8 is a low-cost broaching machine that was specially designed for small part broaching applications. The Red Ring Shavemaster 400 will be on display to show how you can produce high quality gears at an efficient cost. In addition, National Broach will demonstrate their CLP-35 CNC gear checking machine as well as their complete line of quality Red Ring brand tools including broach, shave cutter, hob, hone, roll form racks and master gears.

**Pfauter-Maag Cutting Tools (Booth B1-7150)** is a world leader in the manufacturing of hobs, shaper cutters, shaving cutters, form cutters, CBN grinding wheels, thin film coating, bevel gear tools and heat treat service. Their products are sold throughout the U.S., Mexico, Canada, Asia, Europe and South America. Pfauter-Maag features tools made of premium high speed steel as well as carbide.

**Radyne (Booth C2-5364)** will exhibit its Power Integrated ScanMaster line of solid state induction heating systems. The ScanMaster incorporates a 250 kW/10kHz IGBT solid state induction power source and Windows-based PC control. The scanner drive uses an AC brushless servo motor, providing some of the fastest scan speeds with the highest degree of positioning accuracy in the industry. Also featured will be the Dual Position Power Integrated Pop-Up Fixture with its integral 160 kW/30kHz IGBT solid state induction power source. This design incorporates three positions, allowing one position to load, a second to heat, and a third to quench. In addition, Radyne will provide a hands-on demonstration of its Apex QA Quality Assurance Monitoring System. Finally, a pre-show press release suggests that "a few other surprises may be awaiting you at the Radyne booth."

**Reishauer Corporation (Booth B1-7164)** is demonstrating the RZ820, the biggest machine in the Reishauer product line. It is capable of efficiently grinding large, heavy duty gears to a very high quality level. This machine replaces all previous ZB, RZ701 and RZ801 machines. The RZ820 has improved software for increased productivity and improved positioning accuracy of the shift axis, which greatly reduces idle times. Hydraulic tailstock and on-machine fine balancing of the grinding wheel are two new features that enhance throughput.

**Richardon (Booth B1-7164)** will display the R200 CNC high production hobbers. The Richardon machine comes with a modern 6-axis control coupled with the mechanical stiffness of all cast iron and all vee way construction. It has been configured to handle high helical jobs (-45° to +60°) that are difficult to cut on competitive machines. As standard the R200 CNC can be used to mill or hob gears, and its compact design is intended to please equipment engineers.

**S.L. Munson & Company (Booth B2-6555)** will be displaying products from Dr. Kaiser Precision Diamond Products Company and DWII Super Abrasives. They will display a complete line of rotary diamond dressers for all gear dressing applications; a new single- and double-side dresser design including an integral rotary root relieving tool for Reishauer SPA and Fässler DSA system dressing units; wear parts produced with polycrystalline diamond surfaces lapped to extremely close tolerances; CNC profiling dressers; and rotary diamond dressers for plunge form applications. DWH products include examples of vitrified CBN and vitrified diamond wheels for precision grinding applications.



**Schunk Inc. (Booth E1-2471)** manufactures and sells a wide range of tooling products, including hydraulic chucks, hydraulic arbors, lathe chucks, chuck jaws, FUNDO–a new hydraulic dowel pin, and TRIBOS–a revolutionary new tool-holding system. Schunk also manufactures grippers for factory automation.

**Star Cutter Co. (Booth B1-7182)** will display Elk Rapids Engineering CNC sharpening machines as well as its full line of cutting tools, including hobs, milling cutters, pressure coolant & non-pressure coolant drills & reamers, solid carbide tooling and PCD tooling.

**SU America (Booth B2-6657)** will feature a CNC gear grinding machine, which the company says is accurate, flexible and affordable. It is a form grinder that can use ceramic and/or conventional grinding wheels. It can grind internal gears as well as externals and splines, and it has the latest-generation numerical controls. SU's entire line of gear cutting tools, including carbide hobs, will also be on display. ○

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## TECHNICAL CALENDAR

**July 13–17. ASM Principles of Failure Analysis.** Materials Park, OH. This seminar is designed for people new to failure analysis or those who want a state-of-the-art update. It is also designed for technicians and those interested in understanding how knowledge of failure analysis can lead to better productivity. The areas covered are procedures for analysis, failure mechanisms and failure in product forms and components. Also offered Nov. 2–6. For more information call 440-338-5151.

**Aug. 10–14. Heat Treatment of Steel.** Materials Park, OH. This is a comprehensive course that covers practical heat treating of carbon, alloy, stainless and tool steels. It also covers atmosphere control, quenching, temperature control and equipment types. The course is designed for shop floor workers, technicians and engineers. Also offered Nov. 9–13. For more information call 440-338-5151.

**Aug. 24–28. AGMA Hob Sharpening Workshop.** Richard J. Daley College, Chicago, IL. An intermediate-level hob-sharpening course offering classroom and hands-on instruction in set-up, grinding and wheel dressing, inspection, and sharpening of helical flute hobs. For more information or to register, log on to *www.agma.org* or call 703-684-0211.

**Sept. 9–16. IMTS 98.** McCormick Place, Chicago, IL. Billed as "the largest concentration of the world's newest manufacturing technology ever seen in America," IMTS promises 1.3 million square feet of display space devoted to machine tools, automation, tooling, controls, computers, software, systems and processes. Ten "Shows Within the Show" will be featured. These are pavilions dedicated to Abrasive Machining, Sawing & Finishing; EDM; Environmental Safety & Plant Management; Factory Automation; Gear Generation; Lasers; Metal Cutting; Metal Forming & Fabrication; Quality Assurance and Tooling and Workholding Systems.

The Society of Manufacturing Engineers will also hold its Manufacturing 98 conference in conjunction with the show. For IMTS information or registration, log on to *www.imts.org*. For SME conference information, log on to *www.sme.org*.

**Sept. 14–18. AGMA Training School For Gear Manufacturing.** Richard J. Daley College, Chicago, IL. This Training School provides five days of classroom and hands-on training in basic gearing, efficient machine set-up techniques, accurate gear inspection, and gear calculation. To register or for more information log on to *www.agma.org* or call 703-684-0211.

**Sept. 21–25. AGMA Advanced Inspection Course.** Richard J. Daley College, Chicago, IL. The advanced gear inspection and troubleshooting workshop is designed to cover analytical and functional inspection; set-up, qualifying and operation of manual lead, involute and spacing checking machines; and troubleshooting lead and involute errors. For more information or to register, log on to *www.agma.org* or call 703-684-0211.

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If you found this article of interest and/or useful, please circle **221**.

# ADVERTISER INDEX

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







# What the Internet Means To Your Gear Business

Michael Goldstein, Editor-in-Chief

Let's face it. The Internet is still, to many of us, exciting, confusing, terrifying and frustrating by turns. The buzzwords change so fast that even the most high tech companies have a hard time keeping up. Cyberspace. Firewall. Java. E-commerce. The list goes on.

It's easy to get overwhelmed by the stories we hear about the Internet. Web sites cost a fortune, they say. Nobody makes any money on them, you'll hear. Meanwhile, everyone is telling you to get connected. But why? What's it supposed to do for you and your gear-related business?

While there are no easy answers, it's becoming more and more clear that the time is **now** for getting involved or starting to get involved with this medium. The technology is developing at rocket speeds, with innovations being announced daily. The sooner you get involved, the sooner you can begin to learn how to use the Internet to make you and your company more effective, productive and profitable. The longer you wait, the steeper your learning curve will be.

### What *IS* the Internet?

Simply put, the Internet is a global network of computers that can communicate with one another. Its has infinite potential, and it's expanding rapidly every day. The two most important parts of the Internet are e-mail and the World Wide Web.

I believe your model for finding your company's place, if any, on the Internet should be the cat rather than the python. A python swallows its food whole. A cat eats its dinner a few mouthfuls at a time, goes away, and comes back for more. That's the way I think most of you should be approaching the challenge of getting your company Internet-ready.

### The Cat Model: Taking the First Bite

Before you take the plunge and establish your own Internet presence, it might pay to do some exploring as a visitor. You won't have to commit any more money than it takes to buy a computer with a modem and an account that gets you Internet access. The account can be a generic account through a local internet service provider (ISP) or an account with an online service such as America Online. In either case, this gets you e-mail, which is the most valuable part of the Internet today.

Being without e-mail today is like being without a fax machine. If you haven't had a customer ask you to "e-mail the files, the drawings and the photos," you certainly will. Even if you never use another part of the Internet, integrating e-mail into your operations, because of its efficiency and cost-effectiveness, is a must today.

With e-mail, you can transfer as much material as you like, as far as you like, for the cost of a local phone call and a little time. And you're not limited to just text messages. With e-mail, you can send virtually any kind of computer file, including photos, CAD files, spreadsheets and more.

Think of all the uses this technology could have for your business. Are there situations where field service technicians could benefit from seeing manuals or drawings immediately delivered to them by e-mail? Could your company benefit by receiving pictures of a broken gear—taken with one of these new digital cameras—from a field engineer in a customer's plant?

### A World of Information

But e-mail is just the beginning. The World Wide Web is the next step. A network of Web sites on the bigger Internet, the World Wide Web is a great tool for

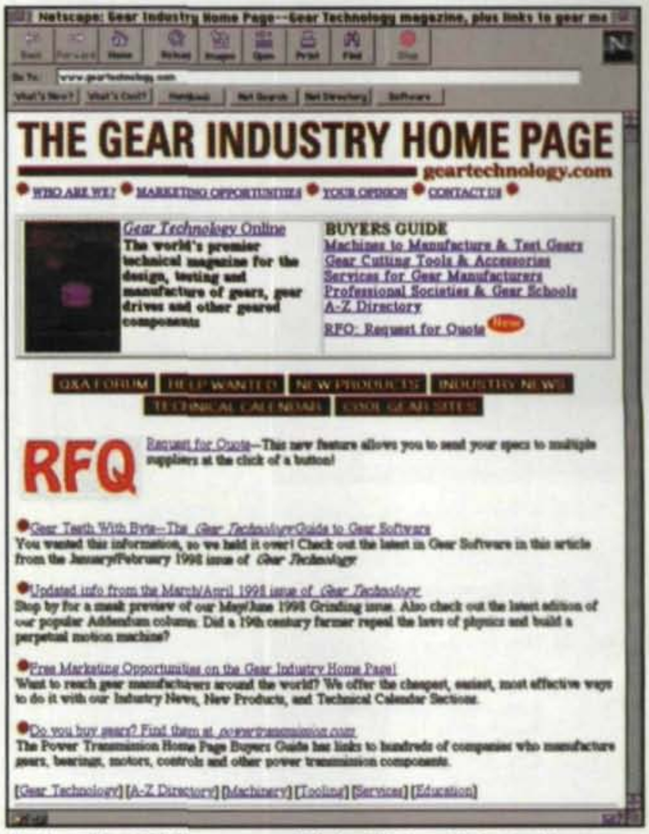



Fig. 1 — Most Web pages are filled with *hyperlinks* to other pages.

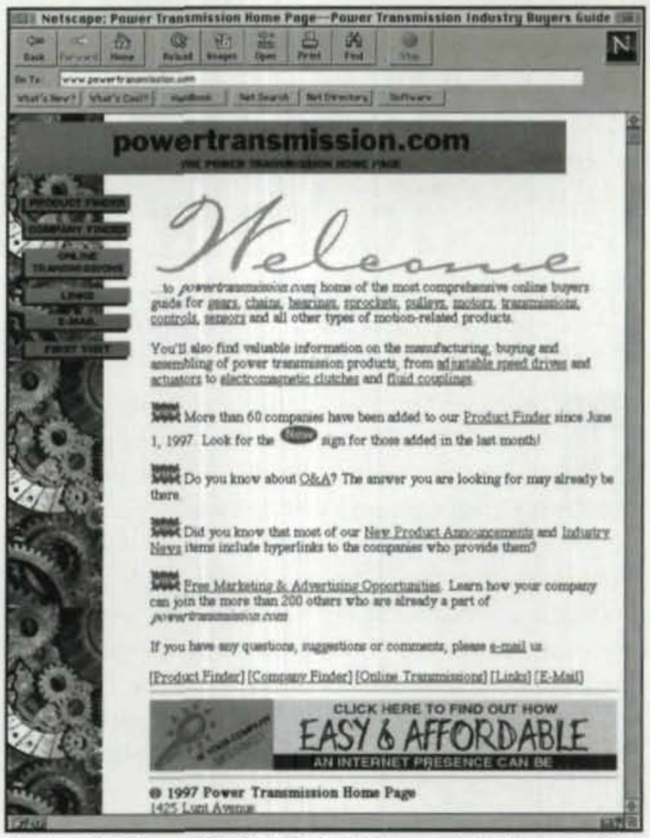



**Fig. 2 — Clicking on "Product Finder" takes you to the buyers guide.**

finding information. Anyone who's unfamiliar with it should spend some time just seeing what's out there and finding out how the Internet works. You may be amazed at the amount and variety of material that's already available—even on a subject as limited in scope as gear manufacturing. As you search, you'll find Web sites belonging to individuals, businesses, churches, libraries, schools, government agencies, museums, clubs, and anyone else you can think of—even a lot of your competitors.

Each Web site contains all sorts of information that the owner hopes will be of interest to at least part of the Internet audience. A Web site can contain sound, graphics, schedules, stock lists, novels, jokes, pictures, inventory, places to leave messages, songs, late-breaking news, anything the site developer can imagine.

Each of these Web sites is connected to other Web sites through a little piece of programming called a hyperlink, which is usually hidden behind one or two words on your computer screen or behind a button or graphic image. Clicking on these hyperlinks transports you instantly to another site on the Internet.

A hyperlink lets you follow your nose in researching an idea without being bound by rigid, linear thought patterns or by the limits of geography. It lets you click on the picture of *Gear Technology* to be transported right to *GT*'s online version (Fig. 1). By clicking on the words "Machines to Manufacture & Test Gears," you bring up the page that helps you find new gear-making equipment.

Similarly, clicking on the button labeled "PRODUCT FINDER" (Fig. 2) will take you to the ***powertransmission.com*** page with buyers guide listings of types of power transmission components. Clicking on the word "gears" will take you directly to the page that will help you find manufacturers of different types of gears. Each page links to several others. Sometimes the page you link to links back to the previous one. Sometimes it takes you off in an entirely different direction.

But all this variety and interconnectivity on the Internet creates a problem. How do you start to find the information you need? The Internet has been described as a giant library where all the books have been pulled off the shelves and dumped on the floor. The solution to all this clutter is a kind of mega-index called the search engine.

The search engine helps you sort through the mess to find what you're looking for by providing a list of hyperlinks based on the criteria you provide. There are several engines on the Web, and they all work more or less the same—though the results for individual searches will vary widely depending on the engine you use. Excite!, AltaVista and Lycos are three of the major ones. Yahoo, one of the biggest Internet directories, allows you to perform searches on its categories or submit a search to one of the engines.

But even with a search engine, you may find that you have thousands of potential sites to go through before finding one you want to visit. Recently we typed "spiral bevel gears" into the Alta Vista search engine and were shocked to find more than 19,000 hyperlinks to Web sites that supposedly relate to this topic (Fig. 3).

Most of you don't have time to look at 19,000 Web pages to find a supplier. But fortunately, as you explore, you're likely to find more focused information sources as well. For example, the first listing that appeared when I typed in "spiral bevel gears" was a link to the ***powertransmission.com*** page with more than 75 of the top spiral bevel gear manufacturers and hyperlinks to *their* Web pages (Fig. 4).

***The Power Transmission Home Page™*** is just one example of industrial resources on the Web. Most professional organizations (such as AGMA, SME and ASME) and research centers also have Web sites devoted to the topic of their interest.

**The Next Bite: Taking the Plunge**

Up to this point, we have been discussing the Internet from the point of view of a visitor, someone just looking around, using the Internet for research or entertainment. But the question remains: What does all this have to do with my gear business? Is having my own Web site worth the hassle or is it a giant techno-pig in a poke?

As you explore the Internet and get comfortable with it as a user, you'll also begin to see the value of establishing a presence of your own. You'll begin to see how you might be able to use tools like the search engines and directories to harness the power of the hyperlink and bring potential customers to **your** electronic door.

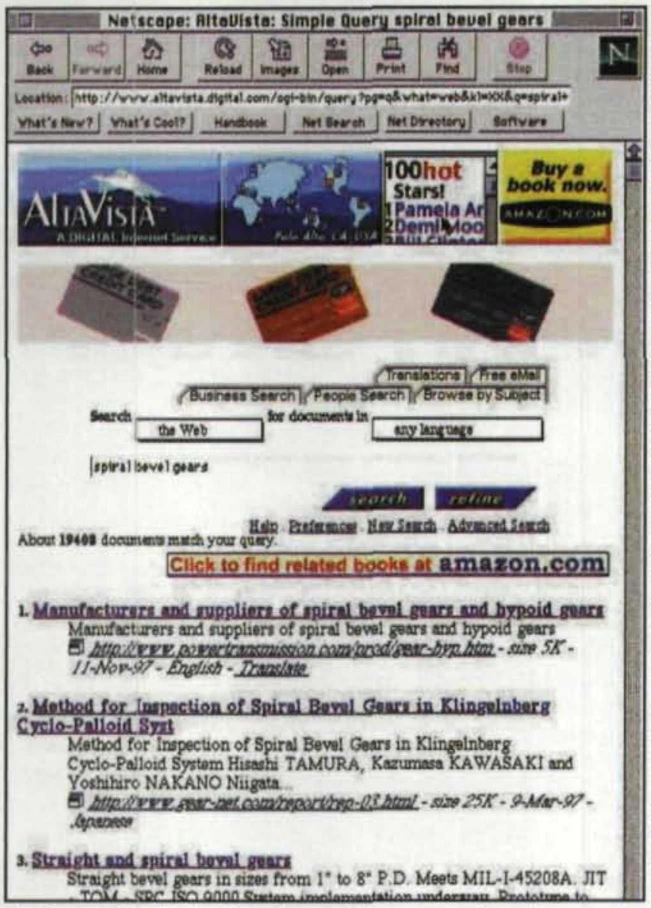



**Fig. 3 — Typing "spiral bevel gears" into a search engine reveals 19,000 listings.**


**Fig. 4 — Directories provide a more focused alternative.**

One of the main reasons for having your own Internet presence is that you can make available all sorts of information about your company and its products and services, including

- Your product literature (including descriptions in words and pictures).
- New products.
- Information on a new service you've just started.
- Photos of your shop.
- The new gear machines you just purchased.
- Open manufacturing time.
- Your distributor list.
- Your employee directory.
- Your plant locations.
- Your business hours.
- Anything else you think your customers or potential customers might want to know about your business.

What's more, this information becomes available 24 hours a day, 365 days a year, and it's accessible from anywhere on the globe.

Another benefit of your own Internet presence is that it can help project a corporate image. The shop with 10-20 people and the latest equipment can differentiate itself from a larger shop with good, older equipment set up for longer runs.

The amount of information and services that can be accessed through your Web site, its design and its ease of use all contribute to the impression you give to current and potential customers. Looking like the leader in your field always makes it easier to become the leader.

**Learn Today While It's Still Manageable**

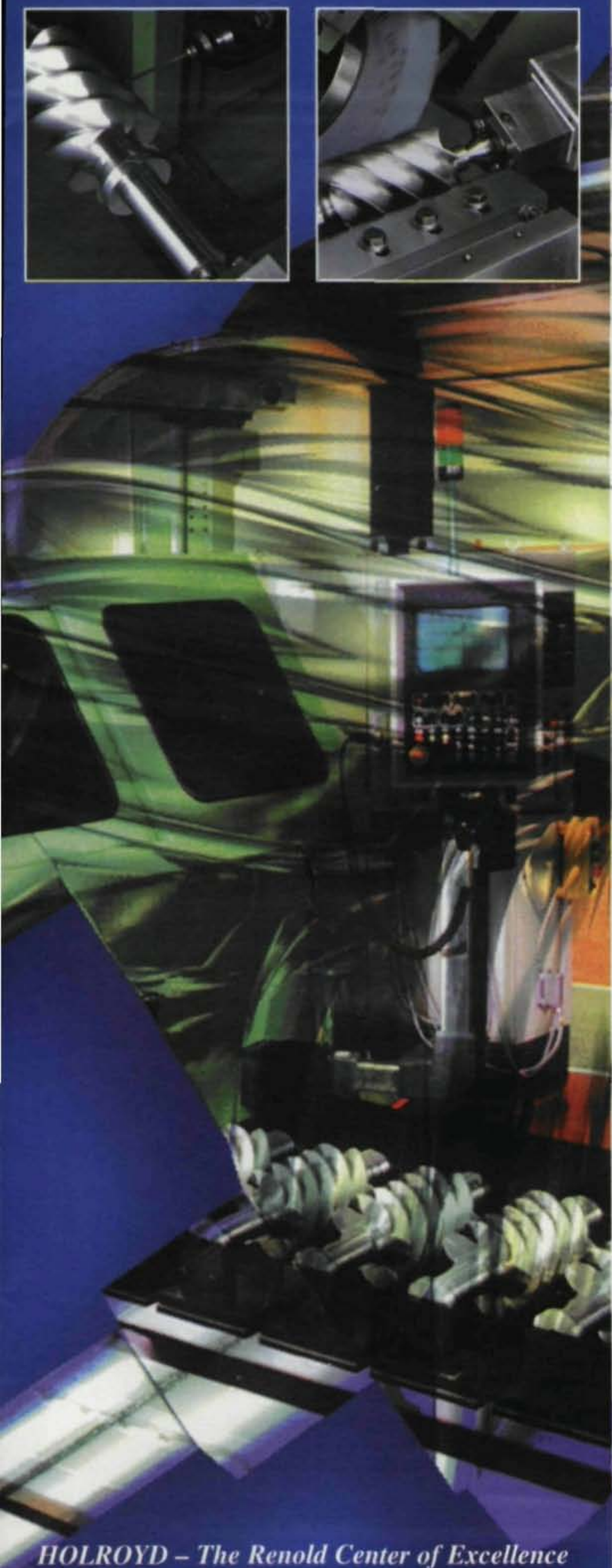
A modest Internet presence now is a great learning lab. It gives you a chance to experiment, a chance to learn what works and what doesn't and a chance to clarify your message.

This is part of the philosophy behind the way we set up ***The Gear Industry Home Page™*** and ***The Power Transmission Home Page™***. We wanted to make it as easy as possible for the companies in our industry (both the suppliers to gear manufacturers on ***geartechnology.com*** and the gear manufacturers themselves on ***powertransmission.com***) to get involved with the Internet in order for them to inexpensively see its marketing and sales potential. By giving our pages away for free for six months and not charging our advertisers extra for any changes to their pages, a company with no Internet experience can get online, tinker with its message and see what works and what doesn't.

For example, if your company is not getting the responses you hoped for, if the "wrong" people are contacting you, maybe it's because your message isn't clear. If you keep getting queries for products or services you don't provide, ask yourself what makes people think you do provide them. What in your message gives them that idea? It may not be the Internet that's the problem, but your message.

One of the beauties of a Web site is that it's cheap and easy to tinker with your message or even tailor-make it to a particular audience.

Another value of the Internet is that it allows your message to reach potential customers you don't even know about. Customers looking for suppliers of


HOLROYD – The Renold Center of Excellence

products and services are turning to the Internet to find what they need. If you're not there, they can't find you.

**The Next Bite: Marketing**

Unlike the ball diamond in *Field of Dreams*, just building a Web site doesn't mean that people will come to it—at least not necessarily the people you want—potential customers. Marketing your presence on the Internet becomes your next mission.

Some of the obvious ways of getting the word out are putting your Web address in your advertising and brochures, on your business cards and your company letterhead—in short, anywhere your company name appears.

But perhaps the best way to get traffic to your Web site is to get other Web sites to hyperlink to yours. Registering your Web site with the search engines is one of the best ways to start. By doing this, you tell the search engine to catalog your page and all the words on it so that when a visitor types in "spiral bevel gears," your page is among the 19,000.

Another popular and effective way to help direct people to your Web site is through the use of some of the industry-specific Internet directories mentioned earlier. By being among the 75 companies listed on ***powertransmission.com*** as well as the 19,000 listed by the search engine, you greatly increase your chances of being found. People might not know your company exists. But they might be looking for the products you manufacture or the services you provide.

The directories usually do more than just provide hyperlinks. They often do a lot of the marketing work for you. They register with the search engines, advertise and exhibit at trade shows. They also provide content, including feature articles, industry news and calendars of events, intended to attract visitors.

UNLIKE THE BALL DIAMOND IN *FIELD OF DREAMS*, JUST BUILDING A WEB SITE DOESN'T MEAN THAT PEOPLE WILL COME TO IT.

In the beginning, it may be to your advantage to get yourself listed in a number of relevant directories. The more hyperlinks you have, the more powerful your Web site becomes, because not everyone is going to look for you in the same place or in the same way. Some hyperlinks will prove to be more useful than others. As you begin to track the effectiveness of each one in bringing you the right kind of Web site visitors, you can rethink which ones you want to continue to use.

The cost for listings or pages in commercial directories can be anywhere from a few hundred to several thousand dollars a year. The amount, however, is not necessarily a good indicator of their effectiveness. Unfortunately, you won't know which directories are best until you experiment a bit. The fees are just part of the cost of learning to market your company on the Internet.

**So Is the Internet Hype or Reality?**

While there is still a lot of hype about the Internet and the uncertainty about the role it will play in the future, some things about it are becoming clear:

- The Internet is here to stay. It's not going away. It's not the 8-track tape deck of the 90s. You will have to take it into account in your business plans for the coming decades.
- E-mail alone is worth the price of admission. E-mail is the next fax machine. You don't need to wait to find out if this is good idea. It is!
- If you don't have a Web site already, you should start making plans to integrate the Internet into your future marketing strategy. If you haven't even thought of getting online yet, you are already falling behind.
- Start the learning curve today while it's still early. Give your employees the tools to learn how to begin using this new medium to market your company and to use it as a tool to find what you need.
- Remember that the Internet is fast becoming the method of choice by which more and more young people get their information, and it will figure in the way they conduct business, possibly even your business. These people already use the technology and have integrated it into the way they do research and communicate. They will be the decision makers, the managers and business owners who will be your customers, employees and competitors in a few short years.

Ignoring the Internet is not going to make it go away. True, you can probably do business just as you have in the past—that is, without the Internet—quite well for the next few years. But sooner or later, you're going to have to be part of the Internet revolution or be left behind. Better to develop your expertise like a cat—in small bites that leave you time and money for the rest of your business—rather than like a python, having to digest a lump of technology whole while running as fast as you can to catch up with everybody else.

*The information in this article was extracted from a speech originally presented at the AGMA annual meeting held in March 1998 in Puerto Rico.*

**Tell Us What You Think . . .**
If you found this article of interest and/or useful, please circle **222**.

**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.**

## Welduction to Feature Flexscan

Welduction Corporation will feature its Flexscan induction hardening machine at this year's IMTS. The Flexscan is a turnkey induction heat treat machine capable of handling parts up to 13" long that comes complete with controls, tooling and start-up and immediate delivery for under $100,000. It features a built-in solid state power supply available in 25 kW/30 kHz, 15 kW/200 kHz, 30 kW/200 kHz or 35 kW/10 kHz sizes; standard Durant controls; quench cooling system and operator interface with heat potentiometer. The user-friendly keyboard provides quick set-up, changeover and diagnostics capability. For further information contact Welduction Corporation at 800-798-3042, fax-248-442-9353, by e-mail at *weldn@welduction.com* or visit their Web site at *www.welduction.com.*

**Circle 300**

## Low PVD Coatings

RME, Inc., will showcase their line of low temperature PVD coatings for power tools and wear parts at IMTS 98. These thin, hard films protect cutting edges and reduce wear. Customers benefit from JIT delivery and reduced inventories of cutting tools through increased wear resistance. For more information contact RME at 800-875-6697 or by fax at 800-875-6814.

**Circle 301**

## Overbeck New Internal Grindier

The new model IC-400 will be on exhibit at IMTS 98. The new IC-400 is equipped with newly developed slide units with a large support width of pre-tensioned roller bearings leading to maximum rigidity. In connection with rigid grinding spindles, this permits the use of CBN and diamond tools. All axis drives are equipped with highly dynamic Siemens Digital servo drives. The Overbeck Internal Grinding Machine Model IR-400 for bore and radius is based on the Model IC-400 but in addition is equipped with a radius swiveling plate mounted under the workhead (B-azis) with a swivel range of 95 degrees toward the rear and 15 degrees toward the front, for radius grinding with a cylindrical wheel. For more information contact Overbeck at 516-273-3030 or by fax at 516-273-3037.

**Circle 302**

## National Broach to Introduce Machines

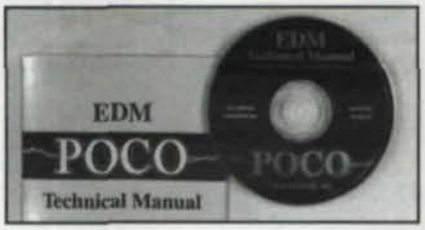
National Broach will showcase a low-cost broaching machine (NBV 5-8) as well as the latest in CNC gear shaving (Shavemaster 400) and gear checking (CLP-35) technology at this year's IMTS. The NBV 5-8) was designed for small-part broaching applications, the Shavemaster 400 is designed to produce the highest quality gears at an economical price while the CLP-35 represents the latest in quality control technology from National Broach. For more information contact National Broach at 810-263-0100 or by fax at 810-263-4571.

**Circle 303**

## Waterlink/Sanborn Fluid Recovery

In the area of coolant and oil purification, Waterlink/Sanborn Technologies will be exhibiting the portable Puritan System at IMTS 98. The Puritan is one of Sanborn's integrated fluid recovery systems, providing portable recycling of up to 1500 GPD of contaminated coolant or oil. The system achieves single-pass purification through an integrated combination of filtration, high-speed disc centrifugation and pasteurization. The system is guaranteed to remove solids to one micron, tramp oils to less than one quarter of one percent and biological contaminants to like-new fluid levels. Along with the Puritan, the company will also be demonstrating the Turbo Separator Model T10-3 coolant clarification system. It will remove solids and tramp oil and is ideal for high solids applications such as grinding and milling.

**Circle 304**




## POCO Tech Manual on CD-ROM

Poco Graphite, Inc., a manufacturer of graphite electrode materials, will be displaying its EDM Technical Manual on compact disc at IMTS 98. The CD-ROM allows users to compare expected performance data of two grades of Poco graphite on a selected workmetal using the same machine setup. Metal removal rate, end wear, corner wear and surface finish data is available for each material. An EDM calculator section computes duty cycle, metal removal rates, frequency and wear percentages as well as peak current for 12 typical geometries via the manual's area formula feature. For more information, contact Poco Graphite at 800-433-5547, by fax at 940-393-8362, by e-mail at *sales@poco.com* or on the Web at *www.poco.com.*

**Circle 305**

## Mitsubishi EDM Adds Larger Wire Machine to the FX Series

Mitsubishi EDM has introduced a new submerged wire EDM machine that handles a larger range of workpiece sizes and offers flexibility in machining operations. The FX30 Submerged Wire EDM handles workpieces weighing up to 4,000 pounds and measuring up to 51" x 31.5" x 13.5". The machining range in the X,Y,Z axes is 29.5" x 19.68" x 13.77". Like other Mitsubishi FX machines, the FX30 incorporates exclusive Mitsubishi features that provide for superior surface finish and cutting conditions including the Anti-Electrolysis Power Supply, the PM2 Power Control, Corner Master and Econo-Cut. For more information contact Mitsubishi EDM at 630-860-4210 or by fax at 630-860-2572.

**Circle 306**



## Grob "C" Series Cold Rolling

Three different spline profiles formed in a single part program is only one of the unique features of the new Grob series "C" cold rolling machines. Grob has taken advantage of the latest synchronizing capabilities in CNC technology to eliminate all the mechanical connections previously required to ensure the rolling tools contacted the workpiece at the correct position. This savings in machine parts leads to significant savings in terms of machine cost and size. The result is a less expensive machine that can be packaged as a self-contained unit. The machine design also eliminates the need for a separate sound enclosure, greatly reducing floor space requirements. The additional "Y" axis provides three different vertical positions in which to place the rolling tools in contact with the workpiece. This feature allows up to three rolling tools with different profiles and different numbers of splines to be used within a single part program. For more information contact Ian Dempster at 810-227-3977.

**Circle 307**

**Send your new product releases to:**
***Gear Technology***
**1401 Lunt Avenue,**
**Elk Grove Village, IL 60007**
**Fax: 847-437-6618.**

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ADVERTISING SECTION

# WEBFINDER MART

**Companies listed below offer product information and design assistance on the world wide web. Reach them through home pages listed below.**

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From our manufacturing facility or on-the-shelf inventory, we supply top quality tools at competitive prices.

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**On Hand Inventory:** We stock a full range of hobs and shaper cutters. All hobs and cutters are precision ground and TiN coated.

www.barit.com

## ARROW GEAR COMPANY

Arrow Gear's Web site features information on our world-class precision gear operation. Arrow is fully equipped for the design and manufacture of spur and spiral bevel gears up to AGMA quality 13, and complete aerospace and commercial gearboxes. The site highlights our history, capabilities, and integration of the most advanced technologies. Our products are used worldwide by the most demanding manufacturers of aerospace and commercial applications.

www.arrowgear.com

## RUSSELL, HOLBROOK & HENDERSON

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Precision gear tools from **STOCK**. Visit the Russell, Holbrook & Henderson, Inc. home page for a list of current inventory, request quotation and order our **FREE** catalog.

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## KAPP TECH/ KAPP SALES & SERVICE

Kapp Sales and Service/Kapp Tech can serve all your gear and profile grinding needs under one roof. In our Boulder, Colorado facility we offer sales, process support, and service for both Kapp and Niles gear and profile grinding machines, as well as providing CBN grinding wheel sales, engineering, manufacturing, and customer service.

Please visit our Web site for more information on the Kapp family of products and services.

www.kapp-usa.com

## NISSEI CORP. OF AMERICA

Do you have a requirement for small gears? Are you interested in an on-time supplier that will hold and manage inventory to your needs? Nissei specializes in OEM quantities and quickly develops samples. Resources include in-house gear engineering, CNC blanking, CNC gear cutting, heat treatment, CNC inspection, FPI and Cpk quality documentation and compartmented packaging for shipping protection. Please browse our Web site for more about Nissei.

www.powertransmission.com/prod/copage/nissei.htm

## LECOUNT INC.

LeCount expanding mandrels are designed for gripping on the inside diameter of parts to be inspected. Once a part is loaded on the mandrel, the unit is loaded between centers and you are ready for inspection. Simple, fast and accurate! Our mandrels are distributed throughout Europe, Japan, South Korea and the United States. If you are interested in obtaining a brochure or the name of a representative in your area, please visit our Web site for further information.

www.sover.net/~lecount

## THE POWER TRANSMISSION HOME PAGE

Does your company buy gears? How about actuators, bearings, belt drives, brakes, clutches, controls, couplings, gear drives, hydraulic power, linear motion, motors, sensors or transducers? ***The Power Transmission Home Page™*** is the most comprehensive online buyers guide for power transmission components, with links to hundreds of manufacturers and distributors. Log on today to find the parts you need—FAST!

www.powertransmission.com

## THE GEAR INDUSTRY HOME PAGE

Stop by to see the newly redesigned ***Gear Industry Home Page™***. Now it's even easier to find the machinery, cutting tools, services and information you need to design, manufacture, inspect and specify gears. Check out our frequently updated New Products, Industry News, Technical Calendar, Help Wanted and Q&A sections. Sign up for *Gear Technology* online. Browse our index of articles from past issues. Explore the world of gear manufacturing from your desktop.

www.geartechnology.com

## CARBON CITY PRODUCTS

Visit our Web site to learn more about how Carbon City Products, an operating unit of Metal Powder Products Company, designs and manufactures high-strength P/M components for transmissions, engines, compressors and hydraulic applications. CCP specializes in gears, including spur, helical, bevel, and other types. Also, cams, sprockets, brake assemblies and pressure-sealed parts. From our Web site, you can sign up for Free P/M Design Seminars.

www.carboncity.com

## ENGINEERED HEAT TREAT, INC.

Founded in 1959, we provide heat treating services to the aircraft, automotive, construction, military and tooling industries. Parts 1"–130" are processed in salt baths, computer controlled endothermic atmosphere and vacuum furnaces. Quality approved by NADCAP, MIL-6875 and AMS 2750. Processes include Carburizing, Hardening, Martempering, Normalizing, Nitriding, Vacuum, Carbonitrid-ing, Deep Freezing, Annealing, Straightening, Tempering, Neutral Salt Baths, Grit Blasting and complete Lab services.

www.ehtinc.com

## RUSH GEARS INC. HOME PAGE

Rush Gears Inc. Home Page is the primary information source offering emergency breakdown service for made-to-order gears. At our site you will find information on our rush services, gear gages, metric gears, 8 materials, and a wide range of gear types and related tooth products. Request our FREE catalog featuring over 30,000 pre-engineered standard gear designs. Also, check out our customer and applications and industries lists.

www.rushgears.com

## GLOBE GEAR CO. HOME PAGE

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CIRCLE 154

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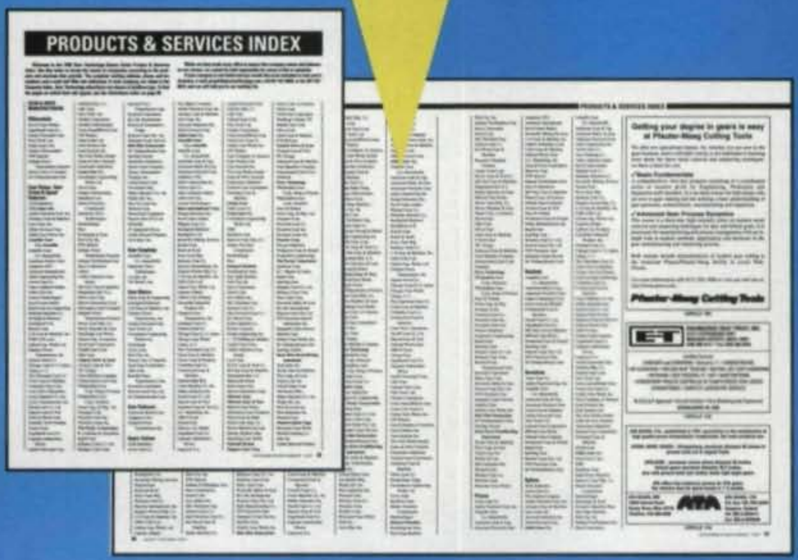
# FILL OUT THE FORM!

**If you provide a product or service to the gear industry**

**(the people who design, manufacture, test or buy gears),**

**turn to page 32 and get a free listing in**

**THE 1999 GEAR INDUSTRY BUYERS GUIDE**



# The Music of the Gears

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

It should be obvious by now that gears are more than just mechanical components. We have brought you movies with gears and Shakespeare with gears, jewelry made out of gears and so on. Now we, the humble staff at Addendum, are proud to present gears in the world of music.

"Music?" we hear you cry. "Sure, there are gears in a music box, but beyond that what else could a musician, or a musically-inclined engineer for that matter, hope to do with gears? Play them like drums? Bang them together like cymbals?" No. Gears form the motifs behind some of the most intriguing music and musical staging in the past thirty years.

In 1967, the British band Cream came out with the album "Disraeli Gears," which was their first big step toward mega-stardom because they, as one reviewer put it, "stopped covering American Blues musicians and started writing their own psychedelic blues-based hybrids" including "Sunshine of your love" and "Tales of Brave Ulysses." While the album was a step forward for the band, the only gear reference came from the album title.


**Ed Wellersby**
*Assembly line worker who puts the bugs in new automobiles*

In the mid-1980s, "Spam Town" (a.k.a. Austin, Minnesota—the home of Hormel) gave rise to another union of gears and music, this time in the form of the Gear Daddies, a group led by guitarist Martin Zellar. Famous, at least in and around the Minneapolis music scene for their gritty girls, booze, and getting-out-of-this-small-town songs, the Gear Daddies produced solid, country-tinged rock and roll until their break-up in 1992 with only three albums to their credit. Their songs spoke to the unfulfilled dreams of everyone who works, sweats, and quietly lives a life of unrequited love and broken dreams in this mechanistic society. Gear manufacturers everywhere should recognize this lifestyle. In spite of their local, and later regional, successes, the Gear Daddies couldn't break out of the shadow of their harder-edged peers such as Soul Asylum and the Replacements.

By 1993 the idea of gears in music had definitely been taken down a rough road with a new genre in rock called "Grindcore/Industrial-influnced/Death Metal." Los Angeles was the center and Turning of the Gears was the band. Founded on the notion of doing something brutal and original, Turning of the Gears (whose very name implies the relentlessness of a mechanical grinder) was a quick success in spite of numerous personnel problems (the band lost their lead singer and two bass players in three years). They have just released their second CD.

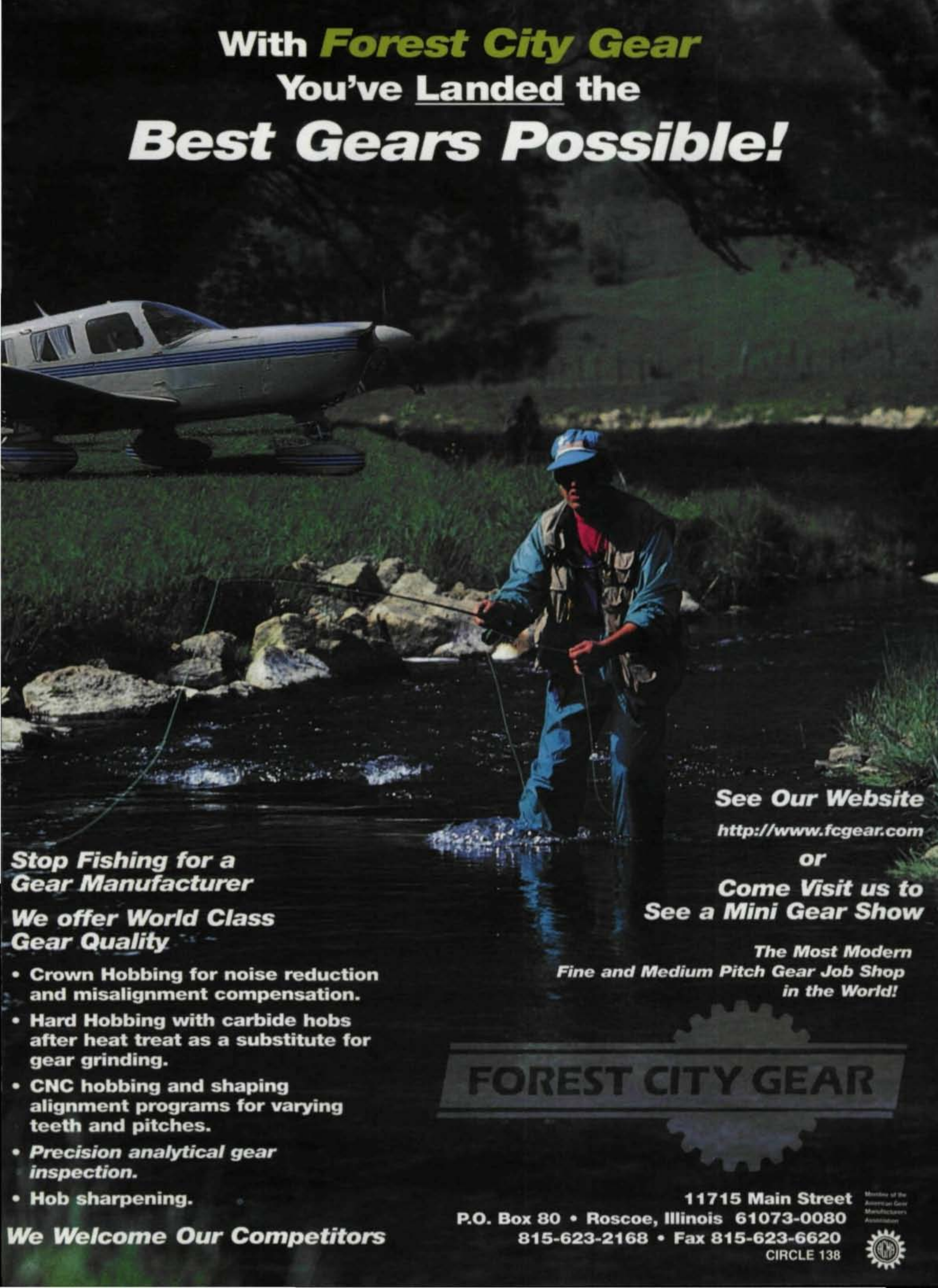
Now, it's not all ugliness and pain when you think of gears in music, though that seems to be the trend in "industrial rock." No, gears also appear in gentler pieces as well, and the 1997 San Francisco Opera production of Les Contes D'Hoffman (The Story of Hoffman) by Jacques Offenbach is a prime example.

The story is simple enough. Hoffmann is waiting for a lady (Stella) in a tavern, and while he waits, he entertains the other patrons with stories of the three loves of his life: Olympia, Antonia and Giulietta. These three represent three aspects of love: mindlessness (Olympia), purity (Antonia) and carnal love (Giulietta). What will be of particular concern to cultured Addendum readers everywhere is the character Olympia and the way the San Francisco Opera's Lighting Designer, Thomas Munn, handled her scenes.

Olympia is simply a wind-up mechanical doll, run on fine gears and clock-workings, made real to Hoffmann only when he dons a pair of rose-colored glasses given to him by one of Olympia's makers. When he wears the glasses, the stage is flooded in pink light and Olympia is as real as any other woman in Hoffmann's world. However, when he removes the glasses the light becomes harsh and white, and projected upon the stage and background are the shadows of huge, moving gears that never once allow you to forget who and what Olympia is. This addition of the gears to Olympia's already mechanical movements played a pivotal role in the success of the first act and is one of the things audience members walk away talking about.

Gears in music. They tinkle out a sweet melody for us from music boxes, give personality to bands obsessed with the darker side of our industrial, technological culture, and make the opera a memorable experience as they help Hoffmann tell his tale of love never shared. So what's next? Gears as fine art and sculpture? You bet! Stay tuned.

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