GEAR TECHNOLOGY

The Journal of Gear Manufacturing

GEAR EXPO 97 SHOW ISSUE

September/October 1997

WHO'S SHOWING WHAT AT GEAR EXPO

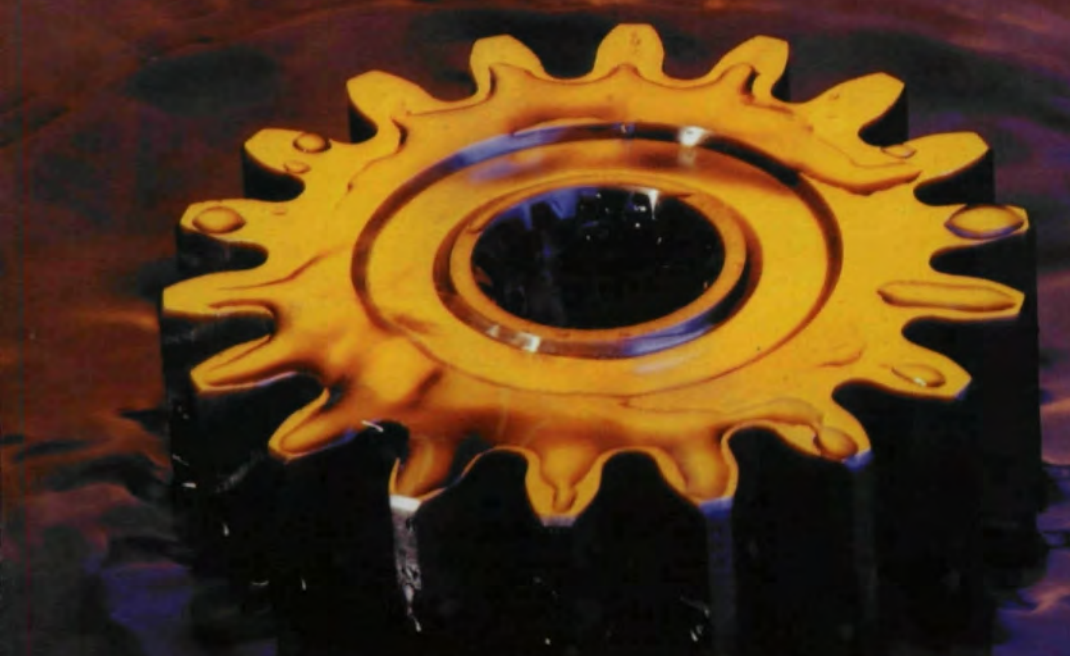
WORM GEAR MEASUREMENT

BRINGING GEAR MANUFACTURING IN HOUSE

DESIGNING GEARS WITH ASYMMETRICAL TEETH–PART II

THE GEOMETRY OF HELICAL MESH

Plus • The First Lady of Gearing • Detroit for Gear Lovers • Gears in Sneakers



THE GEAR INDUSTRY'S INFORMATION SOURCE

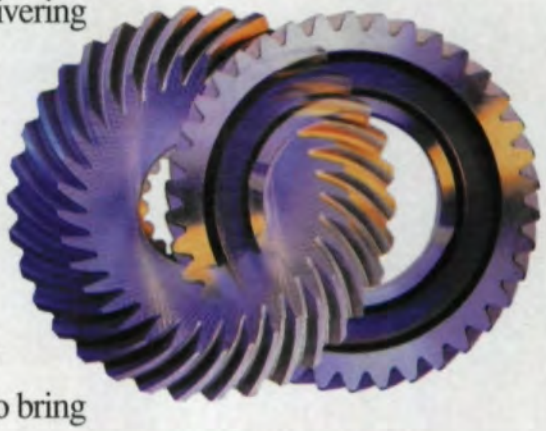
Gleason

PFAUTER

Going into the next millennium, gear manufacturers in every industry will need bold new machine and tooling solutions to gain the advantage in fierce competition worldwide.

They'll find it at Gleason/Pfauter.

What brings these two world leaders in bevel and cylindrical gear manufacturing together is a shared commitment to delivering new gearmaking technologies to the global marketplace... technologies that ultimately lead to a customer's ability to bring product to market faster, more economically, and with greater quality than ever before.



After all, if Gleason and Pfauter were that good operating independently, then imagine what they can do together…

Gleason/Pfauter. The dawn of a new era.

Gleason/PFAUTER

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

American Pfauter L.P., 1351 Windsor Rd., Loves Park, IL 61111
Phone: 815/282-3000 • Fax: 815/282-3075

Pfauter-Maag Cutting Tools L.P., 1351 Windsor Rd., Loves Park, IL 61111
Phone: 815/877-8900 • Fax: 815/877-0264

SEE US AT AGMA GEAR EXPO BOOTH #100 **CIRCLE 100**

STAR PRECISION HOBS...
BECAUSE NOT ALL GEARS ARE CREATED EQUAL

SEE US AT AGMA GEAR EXPO BOOTH #200

The only way to get top quality gears, is to machine them with precision hobs. At Star Cutter, we utilize the most advanced technology available to insure that each of our precision hobs will deliver the exact performance you need – cut after cut, day after day.

Take advantage of our experienced engineering department to design and develop the most economical hob to meet your individual special unique gear manufacturing requirements. These hobs are available with Gold Star titanium nitride, titanium carbo-nitride and other advanced Gold Star coatings.

If faster-running, quieter and more accurate gears are your objective, you can't do better than Star. Call, write or fax for more information.

Since 1927

Star®

STARCUT SALES, INC.
Subsidiary of Star Cutter Company

P.O. Box 376
Farmington, MI 48332-0376
248/474-8200 Fax 248/474-9518
CIRCLE 128

GEAR TECHNOLOGY

SEPTEMBER/OCTOBER 1997

The Journal of Gear Manufacturing

FEATURES

11

The First Lady of Gearing
How Kate Gleason made it in a man's world.....11

Worm Gear Measurement
How to inspect worms and worm gears for quality.....18

Bringing Gear Manufacturing In House
Should you do it?.....25

Thermal Effects on CMMs
How temperature can affect results.....41

Technical Focus
Structural Analysis of Asymmetrical Teeth–Part II
Reducing size and weight.....47

Gear Fundamentals
The Geometry of Helical Mesh
The basic math you need to know.....53

SHOW COVERAGE

What You Need to Know About Detroit.....29

Who's Showing What
The products, the services, the booth numbers.....32

DEPARTMENTS

72

Cover art courtesy of
Regal-Beloit Corporation
Beloit, WI

Publisher's Page
Looking to the Future.....7

Guest Editorial
David George, Chairman, AGMA.....9

Industry News
What's happening now.....28

Advertiser Index.....45

Literature Mart.....62

Technical Calendar.....64

New Products.....67

Classifieds.....70

Addendum.....72

GEAR TECHNOLOGY

The Journal of Gear Manufacturing

EDITORIAL

Publisher & Editor-in-Chief
Michael Goldstein

Associate Publisher & Managing Editor
Ed Mueller

Senior Editor Nancy Bartels

Associate Editor William R. Stott

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

ART

Art Director Jean Bartz

ADVERTISING

Advertising Manager
Patricia Flam

Ad Sales Coordinator
Elizabeth Melone

CIRCULATION

Circulation Coordinator
Daniel S. Wachula

RANDALL PUBLISHING STAFF

President Michael Goldstein

Vice President Richard Goldstein

Vice President/General Manager
Ed Mueller

Controller Patrick Nash

Accounting Laura Manion

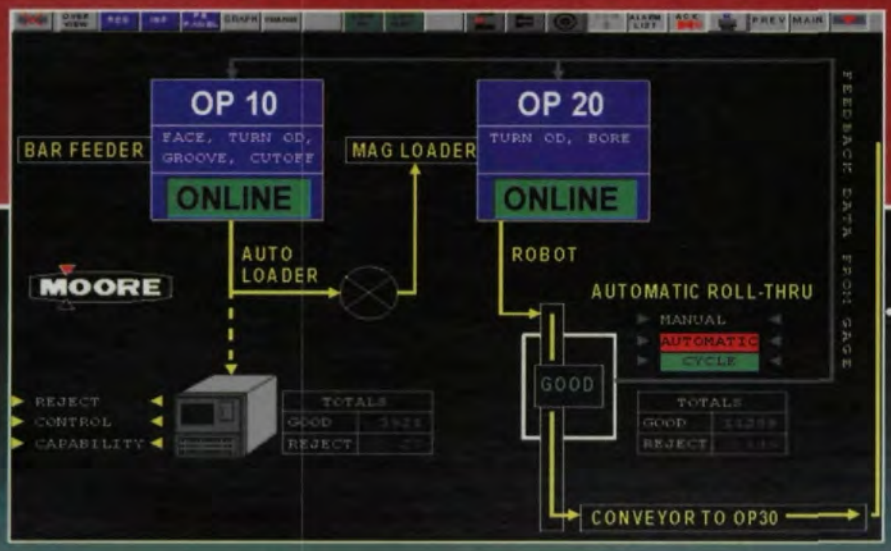
Art Consultant Marsha Goldstein

Phone: 847-437-6604
e-mail: people@geartechnology.com

BPA INTERNATIONAL®

VOL. 14, NO. 5

GEAR TECHNOLOGY, The Journal of Gear Manufacturing (ISSN 0743-6858) is published bimonthly by Randall Publishing, Inc., 1425 Lunt Avenue, P.O. Box 1426, Elk Grove Village, IL 60007, (847) 437-6604. Cover price $5.00 U.S. Periodical postage paid at Arlington Heights, IL, and at additional mailing office. Randall Publishing makes every effort to ensure that the processes described in GEAR TECHNOLOGY conform to sound engineering practice. Neither the authors nor the publisher can be held responsible for injuries sustained while following the procedures described. Postmaster: Send address changes to GEAR TECHNOLOGY, The Journal of Gear Manufacturing, 1425 Lunt Avenue, P.O. Box 1426, Elk Grove Village, IL, 60007.



Only MOORE can help you set up very affordable process measurement & control

MOORE windows-based real-time monitoring system is available for integrating gaging and production equipment.

MOORE OFFERS THE INDUSTRY'S WIDEST RANGE OF FUNCTIONAL GAGING SYSTEMS FOR GEAR PRODUCTION

For high volume gear inspection systems, you can't beat Moore. Here's why:

MOORE Experience
Moore has been designing and producing high quality, reliable gaging systems for more than 50 years.

MOORE Technical Back-up
Moore's U.S. operations provides over 1,000 employees and a 375,000 sq. ft. manufacturing facility, full engineering services, plus additional operations worldwide.

MOORE High-end Electronics
Moore's Gaging Division draws on the technical skills and experience of the Moore Products Co., Instruments and Controls Division, which produces state-of-the-art computer systems and software for process control.

MOORE's Size
Moore is large enough to handle major programs and specialized enough to assure you personal attention.


Automatic tight mesh inspection system


Semi-automatic tight mesh inspection


Universal center distance gear checker


Pitch diameter inspection gage


Modular gear blank fixture


Manual roll stand

Call Or Fax The Moore Gear Gaging Experts Now

Tel: 1-215-646-7400 Ext. 2352
Fax: 1-215-653-0347
Attn: Gage Division, Gear Team

Moore Products Co., Gaging Division
Sumneytown Pike, Spring House, PA 19477

MOORE®
"The Measurable Difference"

CIRCLE 106

Looking To The Future

Economic times are good right now in America and in the gear industry. We're in the seventh year of an up cycle. The tough shake-outs of the 1980s and early 90s are over. Orders are up. Backlogs are at comfortable levels. We're looking at what promises to be the biggest, most successful trade show in the industry's history coming up in Detroit in October. The most pressing question on the immediate horizon seems to be "How long can the good times go on?"

It's tempting to pause now and take a breath. After all, it seems we've all spent the last decade making adjustments, alterations and upgrades, just trying to stay even. It would be nice to relax. Unfortunately, we can't. In business, you're either moving ahead or falling behind. We owe it to ourselves and our companies to plan for the future—either good or bad.

Now, when Gear Expo 97 is on the horizon, is a good time to look long and hard at our total operations and evaluate how well prepared we are for tomorrow and the changes that will inevitably overtake us as we enter the next century.

Begin with an examination of your machinery. Many of you have already taken advantage of the strong economy to upgrade equipment, both hardware and software. If you haven't, there's never going to be a better time to begin. Mechanical machines still have their place in gear manufacturing, but companies that plan to compete into the next century probably ought to be integrating CNC into their production strategies. The quality, flexibility and productivity found in the machine purchased by Ann Arbor Machine (see story p. 25) can probably be had from most all of the major machinery manufacturers today.

If you have been upgrading, you have to ask yourself if you've done enough. Other hi-tech manufacturing approaches, such as CIM, CAD/CAM, just-in-time manufacturing, rapid prototyping and intranets, are areas to explore. They're not the whole story, and not all of them will fit into your manufacturing system, but they're worth the time to investigate. Can you honestly say no new products are on the market that could improve your productivity and your bottom line?

It's tempting to take the money and stand pat rather than risk being saddled with heavy debt when the business cycle takes an inevitable turn for the worse (and we've been waiting a long time for it), but that may not be the wisest choice.

Capital investment decisions are highly personal, and only you and your pocketbook can decide whether investing in new equipment now is the answer for your business, but, to my mind, unless you've made major upgrades in the last five years, you probably aren't planning on being in business through the next inevitable downturn in the economy.

Machines are not the only things necessary to keep your business growing. Investment in your people and their skills are just as important. A recent AGMA survey indicates that 59% of the society's membership said that their operating personnel needed more education and training opportunities. This tells me that the awareness of the "skills gap" in our industry is certainly there. What we are missing are enough creative solutions to closing it. AGMA programs can only do so much. What can you do or are you doing close to home, on your own factory floor, to make sure that current and future employees will have the training and education they need to keep you competitive?

As if keeping an eye on your investment in machines and people weren't enough when planning for your company's future, there's the "global marketplace" to consider. The term is a cliché, but it's also a reality. The question is whether it's a reality that has yet had an impact on your business.

Maybe it has and maybe it hasn't, but you owe it to yourself to find out which. Better to find out about that global market before it shows up on your doorstep.

Now is the time to explore the questions of whether you should be looking overseas for new opportunities or sticking closer to home to grow your business. If you're moving overseas, you should know that the emerging economies in Asia and Latin America will be both your potential customers and competitors. Now is the time to factor them into your plans for the next five to ten years.

Mergers and realignments among machine tool manufacturers and shifting philosophies of outsourcing vs. in-house manufacturing are also having and will continue to have a profound impact on the future of the industry. Your company will need to respond to these changes as well.

Planning for the future is always tricky. Our crystal balls are never as clear as we would like, and these days, it often seems the rules of the game change faster than our latest computers become obsolete. But now, on the upside of a business cycle, and next month, when leading industry experts showing the latest in goods and services will gather in Detroit, might be good times for you to begin a systematic look at your operation.

Times are good. The industry as a whole is not in "survival mode." There will never be a better time to step back and take a look at where your business is and where it could or should be going in the future.

The next move is yours.

Michael Goldstein
Publisher & Editor-in-Chief

The Gear Standards Challenge

David L. George

Who wants or needs technical details about gearing? Who cares about it? Three out of every four people who are reading this magazine make up at least 75% of those who have an interest in the subject. The members of AGMA, EUROTRANS, JGMA and JSIM have an interest. All the people attending Gear Expo in Detroit have an interest. Clearly, however, the people with the most pressing interest in our industry are our *customers,* the end users of gear products. The unfortunate reality, though, is that in many cases, these customers don't even know that's what they want.

What they do know is that they want products that will meet their needs and give them the greatest value available for their dollar, mark, yen, peso or whatever. And they want a way to tell whether the gears they're buying will meet those criteria. For us as sellers of gearing, the question becomes not whether we can design, manufacture or market a gear with 4, 5 or 20 years of life; but rather, "Is this the gear my customers want?" and "Can they look at what is being offered and identify what they will get?"

Our goal as engineers, manufacturers and marketers of gear technology is to make it as easy as possible for customers to answer those questions. One of the items that will make it easier for our customers and their customers is a common set of gear rating standards with global acceptance. These standards will allow customers to compare apples with apples, no matter where they are grown. They will lessen the confusion associated with the many different approaches to designing gear products today.

The gearing community has begun this difficult project through the International Standards Organization (ISO). Members of AGMA, EUROTRANS and JGMA have all had occasions to meet and begin development of universal standards. In 1993 the U.S. delegation represented by members of AGMA became the Sectretariat and leader in the endeavor.

This is an effort open to input from anyone in the gear industry. In fact, AGMA would welcome participation by you and/or other engineers in your organization. Participation is a win/win proposition. The standards-making bodies benefit from your expertise, and you gain the experience derived from networking with other global players, which is invaluable as a training or learning tool. You also get the vital opportunity to have your say about what these standards should be.

Unfortunately, time and manpower are always in short supply, and direct participation is not always possible. There are, however, other ways to contribute. Corporations, such as General Motors, Caterpillar, Cincinnati Gear, Gleason Corp. and Falk, have contributed significant time and dollars to the AGMA Foundation to help foster this effort. The Foundation was established to fund research, education and this ISO initiative.

If your company's customers are global or are buying globally, then you should consider being a part of this task, which will in part shape your future. Having input into new common standards gives your company a say about the new global rules for tapping gear markets. A call to Joe Franklin or Bill Bradley at AGMA can put your organization at the forefront of this endeavor.

In the July/August issue of *Gear Technology*, Mr. Eliot Buckingham stated that he sometimes feels the need for an American Gear *Users* Association. I agree with his focus. In fact, the AGMA and ANSI rules for "balance" on technical committees require that the user community be represented. By working toward one universal set of gear standards, we are heading toward making it easier to define what users can expect from the technology available.

The road ahead is a long one, but these associations working together toward common standards will increase our value to the users of gears and simplify OEM and user decision making.

Wouldn't you like to be a part of the process?

AGMA OFFERS GEAR TECHNOLOGISTS A CHANCE TO HAVE HANDS-ON INFLUENCE ON MANUFACTURING STANDARDS.

David L. George
is 1997 Chairman of AGMA. He is also the Director of Sales for the Falk Corporation, a Sundstrand Company.

In This Dog Eat Dog World...

...Productivity and efficiency are everything. You need hobs that perform with superior accuracy and efficiency. You need hobs you can rely on, day after day, to maintain maximum productivity. You need LMT-Fette hobs.

For almost a century, LMT-Fette hobs have provided a competitive advantage. Engineered to meet your specific manufacturing requirements, LMT-Fette hobs produce the highest quality gears at the fastest possible rate. And LMT-Fette hobs are so precise, efficient and free cutting, they reduce wear and tear on your machines, provide longer tool life and minimal down-time. In other words, they'll take a ***big bite*** out of operating costs!

LMT-Fette offers a wide variety of productivity-enhancing hobs, including:

Solid Carbide Hobs for Dry Machining
- Maximum Speed and Productivity
- Cleaner Shop, Parts and Environment

Heavy Duty Roughing and Finishing Hobs
- 2-3 Times Faster than Conventional Hobs
- Staggered Teeth for Smoother Operation

Indexable Carbide Insert Hobs
- Reduced Downtime by Exchanging Pre-set Segments on Machine
- Carbide Insert Grades to Match Gear Material
- No Resharpening

Skive Hobs for Hardened Gears
- Removes Distortion Faster than Grinding
- Use as Pre-grinding Hobs to Reduce Grinding Time

Gash Master Hobs with the Most Gashes Available
- Faster, More Productive Cycle Times

Gear Gashing Cutters
- Rough Machining of Large Gears
- With Bore or End Mill Style

Resharpening Services Available

Call your local authorized

LMT • FETTE

distributor!

Gear Expo

SEE US AT AGMA GEAR EXPO BOOTH #530

CIRCLE 104

LEITZ METALWORKING TECHNOLOGY GROUP

BÖHLERIT • FETTE • KIENINGER

3725-I N. 126TH ST., BROOKFIELD, WISCONSIN 53005 • PHONE: 800-225-0852 • FAX: 414-783-5043

The First Lady of Gearing

How William Gleason's oldest daughter, Kate, helped build a company while making a place for herself in a "man's world."

Nancy Bartels

In 1877, Irish immigrant William Gleason, owner of a machine tool business in Rochester, NY, suffered a terrible blow. Gleason's son Tom died. The loss was not merely a personal one. Tom had been his father's assistant, and the senior Gleason had no one to fill the gap and help him carry on his business.

Help came from a most unexpected quarter. Tom's little half-sister, Kate, age 11, overheard her father lamenting, "What am I going to do without Tom. If only his sister had been a boy!" To her, the solution seemed obvious: The next day she showed up at the shop, asking to be put to work.

Perhaps he was still too absorbed in his own grief to notice. Maybe he was concerned that he might hurt his daughter's feelings, or perhaps being married to a woman who claimed Susan B. Anthony for a close friend gave him a different perspective on a woman's "place." Whatever the reason, William Gleason did not do what any proper 19th century American father would have done. He didn't send Kate home. Instead he took her up on her offer and launched the unlikely career that would help make Gleason Corporation one of the foremost companies in gearing around the world.

At a time when women's suffrage was still forty years away, higher education was thought to endanger the delicate health of young females, and a woman's place was definitely in the home, Kate Gleason became her father's right hand "man," keeping the books, travelling around America and to Europe alone to sell machine tools and providing much of the public "face" of The Gleason Works.

Even by today's standards, Kate Gleason's accomplishments are impressive. By the standards of her own times, they are remarkable.

By 1880, when she was 14, she was The Gleason Works' bookkeeper. In 1884 she became the first woman to enter Cornell University's engineering program. She never did get her degree, however, because she had succeeded in making herself almost indispensable to her father. The firm was struggling, and he couldn't afford to pay the salary of the man he had hired to replace her. Before her freshman year was over, she had to return home, a loss that devastated her. But she rallied, and in 1888, aged 22, she made her first "road trip" to Ohio to sell machines.

By 1890 she was the Secretary-Treasurer of The Gleason Works and its chief sales representative, a position she held until 1913.

In 1914, she was the first woman to be elected to full membership in the American Society of Mechanical Engineers, and in 1916 she was one of the first women to be elected to the Rochester Chamber of Commerce and the first woman elected to the Rochester Engineering Society.

But the East Coast and the Midwest were not a broad enough field for Kate's ambitions for the company. In 1893, at 27, she made her first trip to Europe. She had been ill, and her doctor suggested she go to Atlantic City for a rest. She told him that wasn't possible because she had no customers there. Instead, she toured England, Scotland, France and Germany and came back with orders from some of the most prestigious companies in Europe.

It was a breakthrough trip for The Gleason Works, for America and for Kate personally. James Gleason, current Gleason CEO, credits his great aunt with laying the groundwork for Gleason's presence overseas. Today an average of two-thirds to three-fourths of Gleason's sales are made outside the U.S. In 1893, when automobiles were still impractical toys for the idle rich and America was not yet anyone's idea of a global industrial powerhouse, Kate Gleason's European trip marked one of the earliest attempts by an American manufacturer to establish overseas markets.

Gleason had already established herself as a witty, knowledgeable and spunky non-conformist and nobody's fool when it came to machine tools, but the trip abroad brought her even more self-confidence and a polish which would stand her in good stead the rest of her life.

Miss Gleason's Grand Tour

In those days it was not uncommon for well-brought-up young women to

make the "grand tour" to Europe. They went for "finishing," to see the art of Florence and Rome, the couturiers of Paris, "to take the waters" at spas in Bavaria and Switzerland and sometimes to find husbands. They travelled in the first-class cabins of the best ocean liners with cartloads of luggage and were always carefully chaperoned.

But Kate Gleason was no heroine from a Henry James novel. She travelled alone on the cattle steamer *Mongolian* out of Montreal, bringing with her only a working knowledge of French and German (which both got considerably better), one good black dress and a letter of introduction from Henry Sharpe of Brown & Sharpe. (The letter was so useful that Kate sent half her earnings from this trip to Sharpe, who returned it to her.)

There were 14 other passengers, all men, who, in spite of her unconventionality, were pleased to take turns walking the deck with her. In the interests of fairness and to avoid any ill feelings, a stopwatch was used to make sure no one got more than his allotted time with Miss Gleason.

It wasn't just the lack of choice that kept the men clamoring for her attention. The young Kate Gleason was a pretty girl of average height and very straight posture with bright blue eyes. She wore glasses, but turned this presumed fatal flaw to feminine beauty into another symbol of her individuality by carrying a lorgnette.

She was, by all accounts, widely read, a wonderful conversationalist and a witty raconteur. She could talk knowledgeably about everything from gear engineering to animal husbandry. She was energetic, enthusiastic and given to sly fun. Her sister Eleanor liked to tell of her habit of hiding whatever novel she was reading inside a leather prayer book cover, so she could cultivate an image of pious devotion while enjoying herself.

A man could do worse than spend time strolling the decks with the likes of Kate Gleason.

She never married, but one suspects that was more because she was having too much fun doing everything else than from lack of opportunity.

While Gleason had learned as early as 1888 that the negative of being a female in business could be turned to a positive (see sidebar), it wasn't until her trips to Europe in the 1890s that she learned to use that tool to its best advantage.

Family legend suggests that Gleason was not above showing up for work in overalls (nearly unthinkable in the 1890s), although she always denied this. What is true is that prior to her European trip, she never paid much attention to her clothes, wore her hair unfashionably short and was sometimes accused of smelling of horses (she loved to ride).

She told Helen Christine Bennett of *The American Magazine* in an interview that even her mother's friend, Susan B. Anthony, had suggested she do something about her appearance. "So I went in for extremely feminine attire," she told Miss Bennett. "I had my hair dressed and wore violets in my muff and had some soft, frivolous gowns made. This attention to dress repaid me well. Some of my customers spoke to me twenty years after about a certain dress or hat that I wore when I made a sale. I learned to value clothes, to love clothes and to use clothes."

The Paris Exposition

By 1900, when Gleason was representing the company at the Paris

Miss Gleason Pays A Sales Call

The following is from a letter Kate Gleason wrote to her brother on October 25, 1888.

❖ ❖ ❖ ❖ ❖ ❖

"Dear Jim,

I have just returned from a four days drumming trip down in Ohio and in the course of my travels I took an order for a large planer and saw the Cincinnati Centennial Exposition. You see, Father has been out of town so much lately that I thought it would be well for him to stay home... while I went after this order... I met Mr. Arthur Curtis on the train. I asked him not to tell you about my little trip for fear I wouldn't get the order, in which case I would rather you remained in dense ignorance.

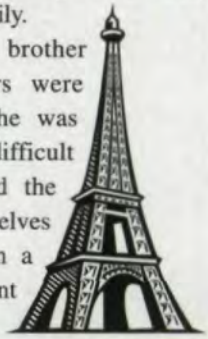
"You see, I had a good many quakings of my valiant spirit. The customer's name was Rudolph Schneible. That sounded as if he might be a Dutchman, and if he were an old Dutchman, the chances were he would not like to have a fascinating young woman like me after his order for machine tools and might put me out at the end of a shotgun. But fortunately for me, Mr. Schneible is young, only 23, and he has until lately attended a Jesuit college, is not used to girls, so I managed to make a 'crush' on him quite early in the morning. After I secured his order, I traveled around Dayton to call on all the firms I had ever heard of there, and in every case I was treated with 'the most distinguished consideration.' I had invitations to go for drives around the city and to the show in the evening, but I didn't accept any of them."

Exposition, this investment in "finishing" paid off. The display of Gleason planers was placed, along with the wares of some other unfortunate companies under the stairs in a dark corner. One Swedish company went so far as to ask their ambassador to intercede for a change of location to no avail.

Kate took a different tack. She went to see the exposition manager. She drew him out about the difficulty of his task and the strain of his enormous responsibility. She listened sympathetically and never once mentioned her own troubles. When the manager finally got around to asking about her company's exhibit and discovered its location, he personally arranged for her to have her choice of one of the best places in the hall.

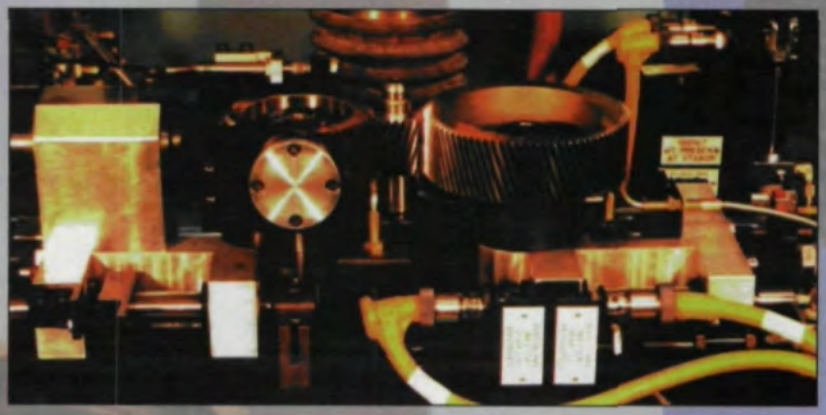
But Kate Gleason was not all frills, furbelows and feminine wiles. She could be very tough-minded and aggressive, and she understood the uses of publicity. In the Bennett interview she said, "Susan B. Anthony . . . had impressed one fact upon me while I was growing up. 'Any advertising is good,' she said. 'Get praise if possible, blame if you have to. But never stop being talked about.' I have come to believe that absolutely. In those early days I was a freak; I talked of gears when a woman was not supposed to know what a gear was. It did me much good. For, no matter how much men disapproved of me, they were at least interested in seeing me, one distinct advantage I had over the ordinary salesman."

Unfortunately, this was still a time when "decent" women only had their names in the papers three times—when they were born, married and died. Gleason, for all her intelligence, talent and success, was an anomaly—a woman in a man's world—a fact that was tough to swallow, even for her own family.



By 1913, her brother Andrew and others were complaining that she was "overbearing and difficult to work with," and the siblings found themselves on opposite sides in a number of important business decisions.

When it comes to double flank inspection,



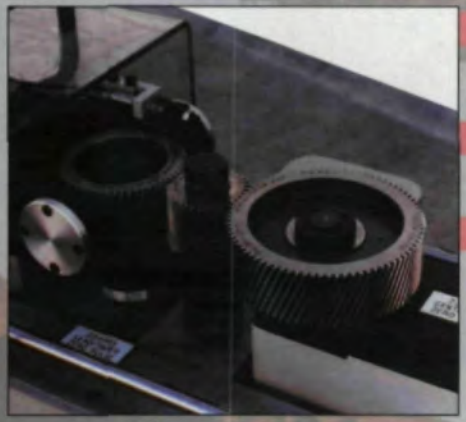
High Speed Automatic In-Line Inspection

put your trust in the people who invented the process.

Since 1936, ITW has been the leader in double flank inspection.

ITW Heartland offers both automatic and process inspection for internal and external gears, both spur and helical. For complete details, contact the gear inspection experts by phone, fax or e-mail.

Sales & Service Offices Worldwide.



Portable Computerized Process Inspection

ITW Heartland
A Division of Illinois Tool Works Company
1205 36th Avenue West
Alexandria, MN 56308
Phone:320-762-8782
Fax: 320-762-5260
E-Mail: itwgears@gctel.com

Gear Expo

SEE US AT AGMA GEAR EXPO BOOTH #314

CIRCLE 110

Visit our Web Site at: www.gctel.com/~itwgears/itwheart.htm

"A Wonderful Mechanic"?

Another part of the problem may have been Kate's growing reputation as "a wonderful mechanic," which was only partly deserved. While no doubt she was extremely knowledgeable about the Gleason product line, contrary to popular wisdom and the fact that she was admitted to ASME on the basis of her "contributions to gear design," she did not invent the Gleason gear planer.

The source of the story that she did may have been Henry Ford, who, it should be noted, regularly called history "bunk." He was in the habit of describing the planer as "the best machine ever invented by a woman." No matter how often Gleason tried to deny that she was the inventor (it was her father), the story stuck.

Still her travels and her forceful personality did make her the most well-known Gleason, which may have been another cause for discontent back in Rochester.

Ultimately, in 1913, Gleason resigned from the company and while that may have eased tensions within the family, it certainly didn't get her to conform. She simply went on to build another career.

Life After The Gleason Works

In 1914 she was the first woman to be appointed receiver by a bankruptcy court. She undertook the reorganization of the Ingle Machine Co. of East Rochester, NY. The company's stock was

A Letter to *The Times*

A letter from Kate Gleason to the *New York Times* dated May 18, 1910.

The New York Times
Editorial Dept.
New York City

❖ ❖ ❖ ❖ ❖ ❖

Gentlemen,

There was a paragraph about me in your paper of May 15th that I wish were all so—but it isn't. The paragraph is headed "Feminine Mechanical Genius" and credits me with designing our Bevel Gear Planer when the nearest I have come to designing it is in having a father and a brother smart enough to do it.

My place in the business is Secretary and Treasurer. You see, I have captured two jobs, but neither of them have anything at all to do with designing.

Is there any chance you can overtake that mistake with a correction? It will oblige me very much if you will try. About the most important training for the treasurer is not to take what does not belong to one, and it looks to me as though I would be falling down on my own job if I get credit for other people's work.

Yours truly,
Kate Gleason

worthless, and it was $140,000 in debt. In a year and a half, all the debts were paid, and when Gleason returned the company to its shareholders in 1917, it had earned one million dollars.

In 1917, when the president of the First National Bank of East Rochester went off to World War I, Kate Gleason was named acting president, the first woman in America to hold such a post. It was then that she realized the potential for suburban residential and industrial development, and during the next few years she helped to launch eight new businesses in the East Rochester area.

The largest of these was the Concrest community, a subdivision of one hundred low-cost, poured-concrete, six-room houses, along with a country club, golf course and park. With some success, Gleason tried to apply the techniques of standardization and mass production she had learned in gear manufacturing to home construction. The units sold for as little as $4,000 and could be purchased for a small down payment and $40 a month. Some of these buildings are still occupied.

This second career in building and real estate not only brought her considerable wealth in her own right, but to Berkeley, CA. In 1924, she was called in to advise the city on rebuilding after a disastrous fire there. She also built a number of homes in Sausalito, although much of the property was taken over to provide the northern approach to the Golden Gate Bridge. She also bought property in Beaufort, SC, and in Septmonts, France, where she helped the village rebuild after the war.

But Gleason's interests were not devoted exclusively to business. She was generous with her money and involved in a number of charities, many times anonymously. She contributed to a number of causes, from a Catholic orphanage in San Francisco to Johns Hopkins University, as well as libraries and schools. At the time of her death in 1933, she was in the middle of building an artists' and writers' colony on her South Carolina property.

Gleason's place in the history of American gearing is an ironic one. That she was one of the tough and courageous pioneers carving out a place for women in what was understood to be a "man's world" is without dispute; however, the accomplishment she is most often credited with, the invention of the gear planer, is the one she didn't achieve.

What she did do is often overlooked. Her real legacy is in being what Christopher Lindley in *Notable American Women* calls, "the invaluable middle link between her father's inventive genius and the business world . . . that helped to build her family's small machine-tool factory into the leading American producer of gear cutting machinery." ○

Thanks to Jan (Mrs. James) Gleason for her help with this article.

Tell Us What You Think . . .
If you found this article of interest and/or useful, please circle **201.**

Worm Gear Measurement

Cedric Barber

Several articles have appeared in this publication in recent years dealing with the principles and ways in which the inspection of gears can be carried out, but these have dealt chiefly with spur, helical and bevel gearing, whereas worm gearing, while sharing certain common features, also requires an emphasis in certain areas that causes it to stand apart. For example, while worm gears transmit motion between nonparallel shafts, as do bevel and hypoid gears, they usually incorporate much higher ratios and are used in applications for which bevels would not be considered, including drives for rotary and indexing tables in machine tools, where close tolerance of positioning and backlash elimination are critical, and in situations where accuracy of pitch and profile are necessary for uniform transmission at speed, such as elevators, turbine governor drives and speed increasers, where worm gears can operate at up to 24,000 rpm.

Most quality worm gear sets consist of a parallel worm having the thread flanks in the form of an involute helicoid developed from a base circle. The worm wheel is generated by a cutter, the shape and radius of which approximate the form and size of the mating worm with detail differences that may be unique to the manufacturer. This article deals specifically with this type of worm gear, although most of the following features and procedures are applicable to all-enveloping and concave worm gearing as well.

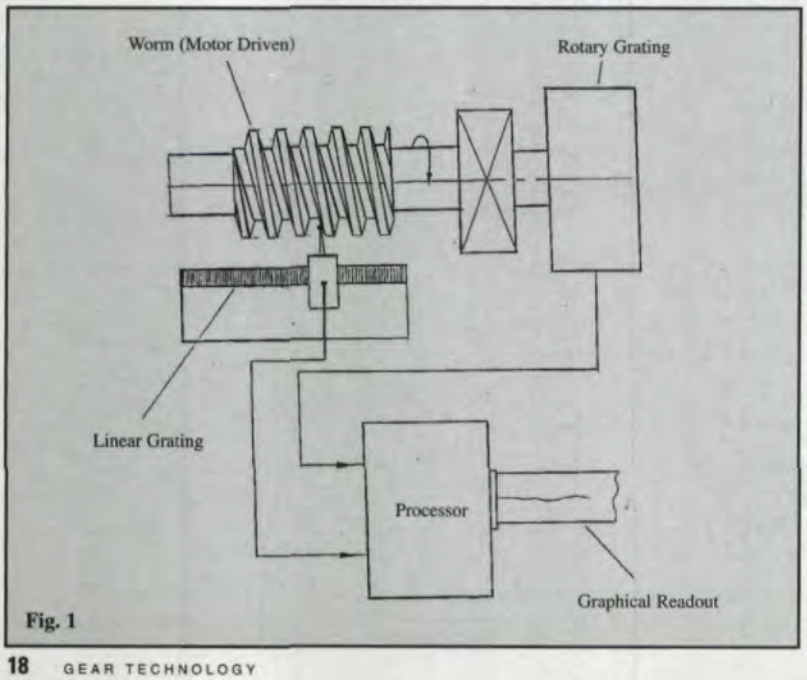


Fig. 1

Definition of Terms

The Worm Shaft. *Axial pitch deviation* is the difference between the design pitch and the actual measured pitch of a designated number of pitches measured at the same radial distance from the axis. (See also *lead deviation.*)

Cyclic error is an error that occurs during each revolution of the element under consideration.

Lead deviation is the difference between the design lead and the measured lead or helix. Since the lead should be equal to the axial pitch multiplied by the number of threads, this also provides a check on the axial pitch. (See also *cyclic error.*)

Profile deviation is the difference between the design profile and the actual measured profile. With an involute helicoid thread form, this setting is derived from the base diameter and the base lead angle.

Transverse pitch deviation is a measurement taken from one pitch to the next at the same radial distance, but at right angles to the axis, in a worm with a number of threads greater than one. This provides a check of the accuracy of the divide mechanism in the thread finishing process.

The Worm Wheel. *Adjacent pitch deviation* is the difference between the design pitch and the actual measured pitch of two adjacent pitches. The maximum adjacent pitch error will be that which occurs where the difference between the ideal and measured pitch is the greatest of the pitches tested around the circumference.

Cumulative pitch deviation is the difference between the design dimension and the actual measured dimension of any two teeth more than one pitch apart. The number of pitches to be covered is usually stipulated, and the error will be the algebraic sum of the adjacent pitch errors of all the intervening teeth taken over that number of teeth over which the maximum deviation occurs. This value will also take account of eccentricity, which of itself increases cumulative pitch error.

Profile error in a worm wheel tooth flank is imposed by the cutter with which the gear is generated. Since the shape of the profile changes at each position across the flank of the teeth, measurement is not practicable, and the correctness of

this depends almost totally on that of the cutter and the setting. Frequently a gear manufacturer will modify the profile in order to provide a facility for deflection and the ingress of lubricant, so the shape may intentionally vary from that of the worm.

Measurement

Worm shaft. The deviation in pitch and lead of a worm can be ascertained by mounting the component between centers in a test machine and then positioning a stylus touching a flank in the same horizontal plane as the axis. The probe is loaded and set to move parallel to the axis as the worm is rotated. The two movements are coordinated so that the probe follows the path of the true lead. Any inaccuracy in the lead will move the stylus, which causes the relative movement to be registered and recorded in the control system.

Fig. 1 shows diagrammatically the main components in a modern lead test machine where the rotary and linear gratings are coordinated through the processor or control system, which produces the results in the form of a graph and any error values in microns. The machine of this type used at Holroyd was designed and built in-house and is capable of measuring lead and, therefore, pitch to an accuracy of 1 micron. It is described in greater detail in the section dealing with single flank testing.

Transverse pitch deviation can be obtained by mounting the worm in a pitch testing machine, as shown in Fig. 2, with the stylus set to a position about half way down the flank, and the incremental divisions set to the number of threads in the worm. The stylus will then enter and, after contacting the worm flank, retract until the next flank is available. The stylus will register the position and possible deviation of the flanks, which is a function of the amount of the deflection of the stylus. The machine at Holroyd will measure pitch errors "on the fly," that is, while the component is rotating continuously, with the stylus being inserted and withdrawn automatically.

The profile can be checked as shown in Fig. 3, where a stylus is set to the root of the worm thread at a position offset from the axis at a radius equal to the base radius and at an angle equal to the base lead angle. When the worm is held rigid, it should be possible to draw the stylus along the flank, scribing a straight line. Any deviations that register on the dial gage indicator or meter are dimensional errors in the profile.

Worm Wheel. When confirming the adjacent and cumulative pitch errors in a worm wheel, it is necessary to mount the component on the spindle or table of a pitch test machine and ensure that it is concentric by reference to a location or diameter provided for that purpose. As mentioned earlier, the machine functions by rotating the wheel and a stylus mounted in a position level with the center line of the component. As shown in Fig. 4, the stylus enters the pitch space and retracts when touched by the flank of each tooth. In this way, the position of each flank is registered relative to the position of the next, and when the full circumference has been covered, a picture is available through a processor that shows a full picture of each tooth position. The charts in Fig. 5

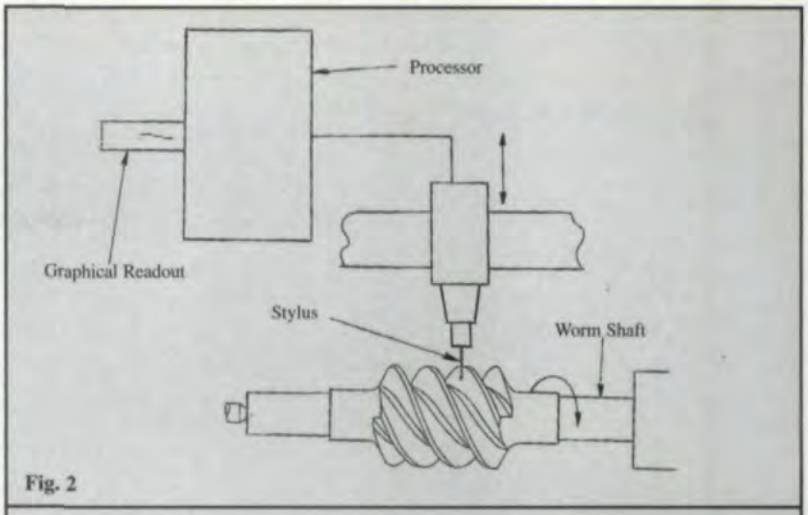


Fig. 2

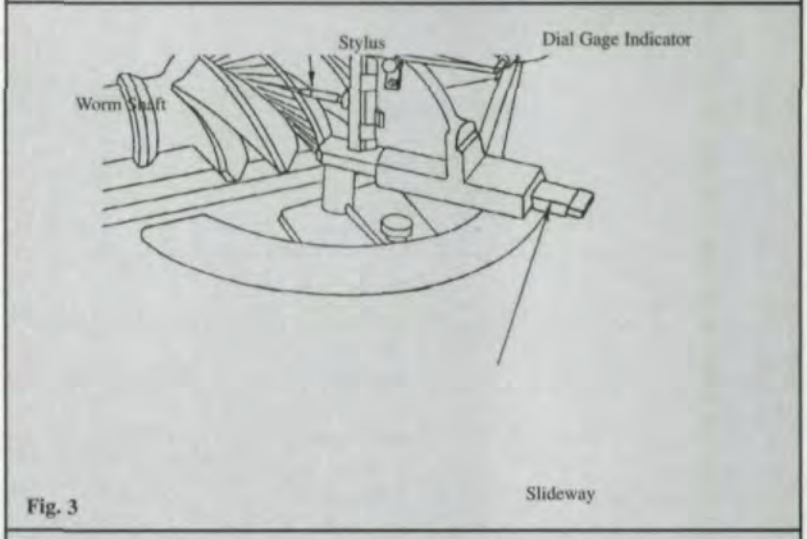


Fig. 3

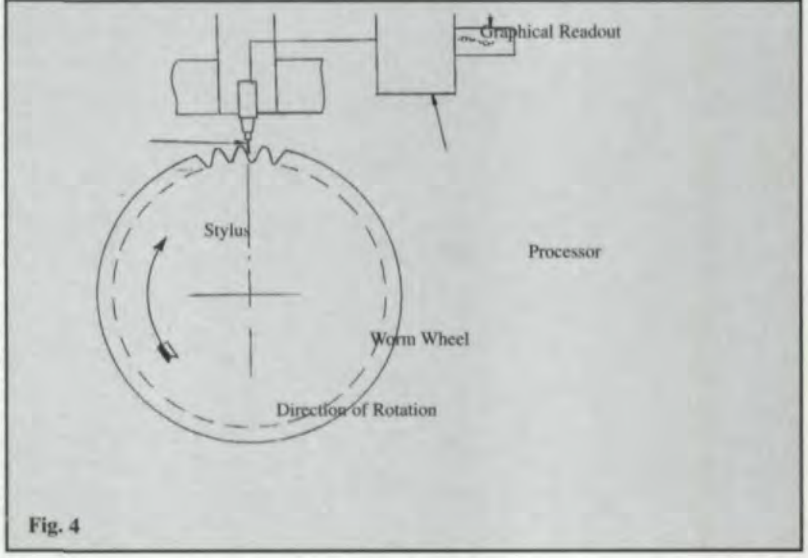
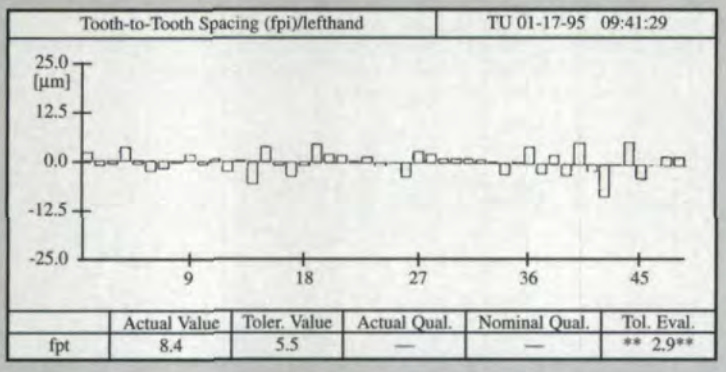


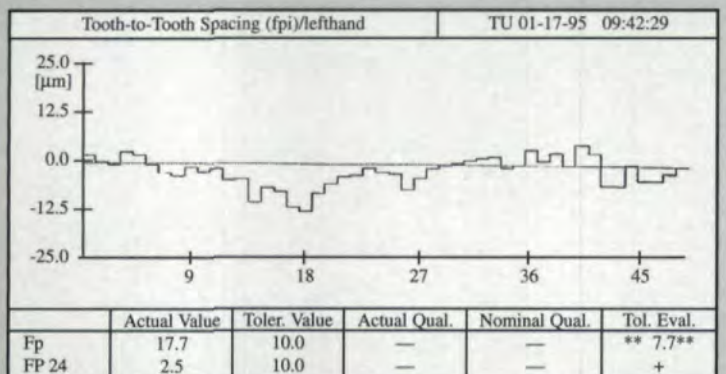
Fig. 4

Cedric Barber
is Technical Sales Manager, Worm Gears at Holroyd, Milnrow, Rochdale, England. He has over 40 years' experience in gearing and has written a number of articles on worm gears and related topics.



	Actual Value	Toler. Value	Actual Qual.	Nominal Qual.	Tol. Eval.
fpt	8.4	5.5	—	—	** 2.9**

Fig. 5a



	Actual Value	Toler. Value	Actual Qual.	Nominal Qual.	Tol. Eval.
Fp	17.7	10.0	—	—	** 7.7**
FP 24	2.5	10.0	—	—	+

Fig. 5b

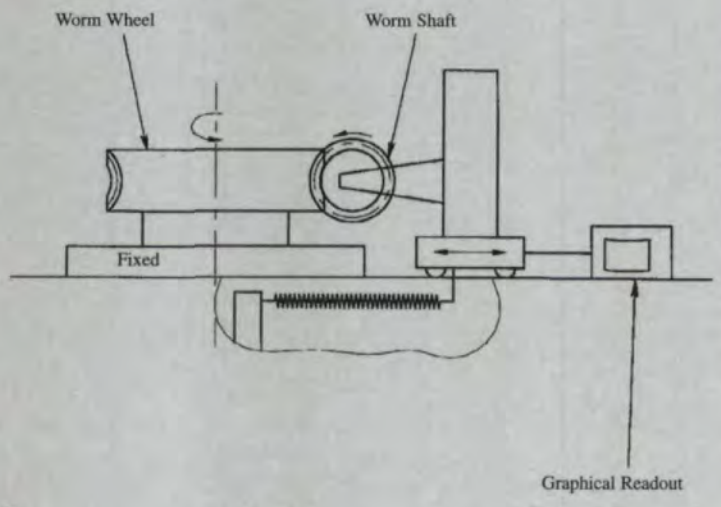


Fig. 6

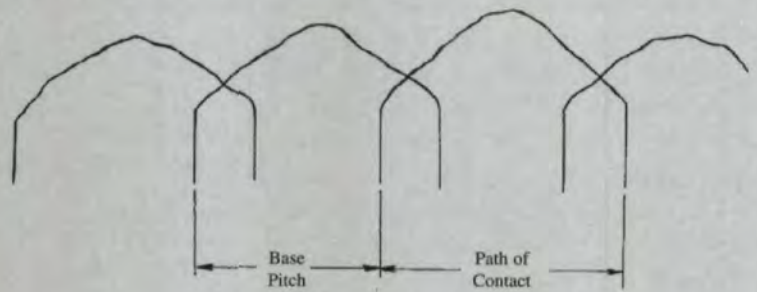


Fig. 7

illustrate an example taken from a 45-tooth worm wheel, 5a showing the tooth-to-tooth spacing errors and 5b the cumulative situation, which also demonstrates the eccentricity.

To check the compatibility of the profile with that of the mating or master worm, it is usual to assemble the two at correct centers in a test rig, apply Prussian blue to the worm thread and adjust the wheel axially until a contact marking, which is a mirror image of the one apparent on the opposite side of the tooth, is obtained on the flanks.

Worm Shaft With Worm Wheel. Backlash can also be confirmed in this operation by placing a dial gage indicator at one point of the worm wheel with the stylus loaded and located touching a flank of the component. By preventing movement of the worm and attempting to rotate the worm wheel in each direction, the inspector is able to read the full rotational movement possible, which is the backlash.

The operations outlined can be carried out in the machine area and, if errors outside the specification are detected, and there is sufficient material remaining on the component, rectification may be practicable. Even then, these procedures can only give an indication that the gear will fulfill the designer's requirements, the ultimate proof being a dynamic test with the worm and worm wheel assembled in a test machine that simulates the eventual operating position.

One intermediate test, which has been performed frequently in the past and which does enable limited dynamic testing of the assembled gears, is the double flank composite or rolling test. The composite error is defined as one revealed by measurement of a dimension that is influenced by two or more of the classic errors of pitch, profile and radial or lateral runout. This test consists of mounting the worm and wheel at the correct center and height setting in a machine, which is shown diagrammatically in Fig. 6.

The assembly is composed of a fixed spindle upon which the worm wheel is placed. The worm is mounted between centers in a carriage that is spring-loaded to exert a pressure to close the centers and is also connected to a recording processor.

Once assembled, the carriage is released so that the worm is thrust into the worm wheel, resulting in a double flank contact. As the worm is rotated, it will move in or out of centers, these movements being recorded in the processor.

This test does identify variations in tooth thickness and the effect of errors, but does not facilitate the identification of these errors, for example, whether movement is caused by variable tooth

DON'T MESH WITH ANYTHING LESS

PRESRITE NEAR-NET GEARS ARE NEAR PERFECT

If you want the best gears money can buy, invest some time with Presrite. We've already invested millions to build a world-class gear forging plant. A dedicated facility equipped with a state-of-the-art gear lab, high-capacity presses, and the latest in sophisticated machinery.

The results are gear-making capabilities that are second to none. We hot-forge gears economically to near-net shapes. Because we can meet such tight tolerances, there's little or no hobbing required. The inherent strength of the forging is maintained while costly roughing and finishing operations can be eliminated.

See why customers around the world—in all types of industries—have come to rely on Presrite for high-quality forged gears. Contact us today for more information or a quote.

Presrite Corporation
3665 East 78th Street, Cleveland, Ohio 44105
Phone: (216) 441-5990 • Fax: (216) 441-2644

We're as NEAR as the NET! Visit our Web site at www.presrite.com.

CIRCLE 108

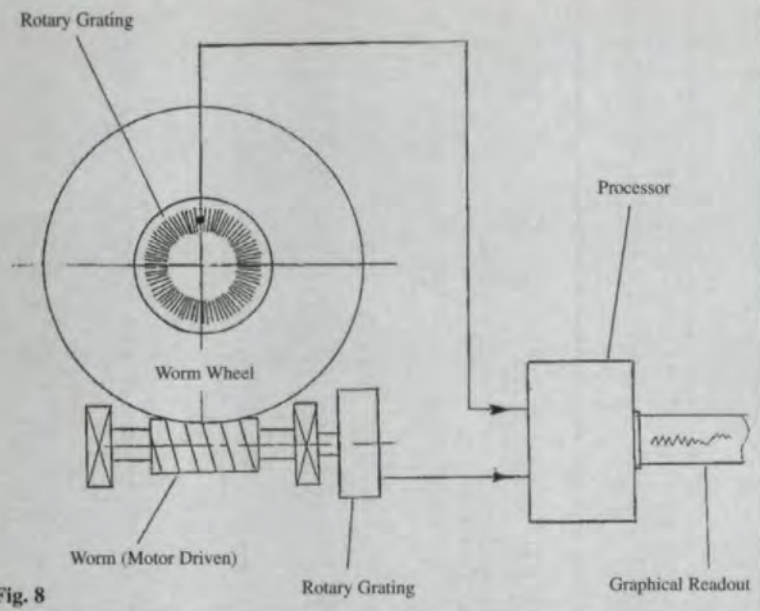


Fig. 8

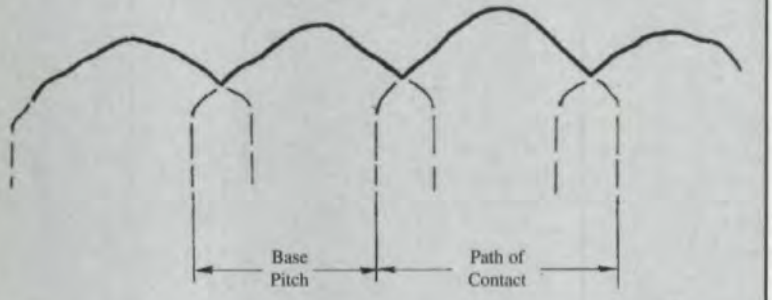


Fig. 9

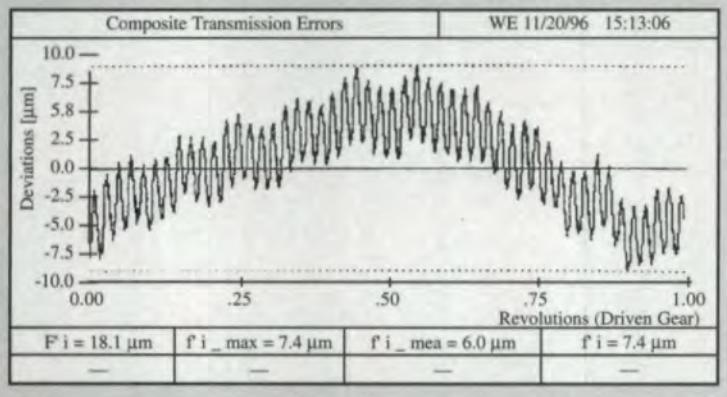


Fig. 10

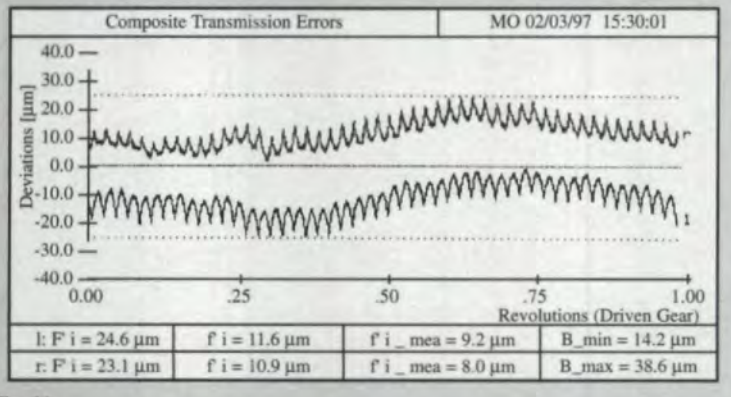


Fig. 11

thickness or an error of pitch. Also, it involves contacts on both sides of the teeth and threads, in which condition very few worm gear sets actually operate, and at closer than design centers, which of itself can introduce effective profile errors where, in fact, they may not truly exist.

Single Flank Testing

More detailed information can be obtained from the single flank or transmission method of testing, which operates from the principle that when a worm and worm wheel are assembled at correct centers, and the worm is rotated at constant speed, there is a slight change of speed of the worm wheel with each tooth engagement, as graphically illustrated in Fig. 7. This variation can be the result of pitch or profile errors in either the worm or worm wheel, cyclic errors in the worm or, accumulatively, eccentricity in the worm wheel, which shows as displacement of the base line.

Fig. 8 shows the principal features of a machine on which this test is carried out. With the worm shaft having center locations ground concentric to the bearing journals, the component is located between centers and is driven by a geared servomotor with a precision optical grating attached to the worm axis.

The mating worm wheel is secured onto a rotary table, which is supported by a hydrostatic bearing and also has a precision optical grating coupled to its axis.

When the worm is driven, the speed of the worm wheel would ideally be that of the worm divided by the actual ratio of the gears, but in practice there will be microvariations in speed due to pitch and profile errors in the waveform shown in Fig. 9. These are detected through the relative dispositions of the grating's registering signals through the central system, where errors to 1 micron can be identified.

The scale of these can be varied in order to increase or decrease the dimensional representation. An example, which is taken from a 50/1 ratio worm gear set, is shown in Fig. 10.

These values are in terms of linear measurement, but by knowing the pitch or reference diameter of the worm wheel along which contact takes place, they can be easily translated into angular measurement in seconds of arc by use of the formula $412 \cdot 5F/d_2$, where F is the error in microns and d_2 the pitch diameter of the worm wheel in millimeters.

It is necessary to perform the test with a small amount of backlash present so that no contact with the nondrive flanks can occur, which otherwise would lead to incorrect results. Particular care is necessary here with the dual lead or duplex type worm gearing, where backlash can largely be

adjusted out to ensure clearance is present. Having carried out a recording of values for one direction of rotation, the directions can be reversed, and the procedure repeated in order to obtain values for the opposing flanks.

This method of gear measurement provides significant benefits to both the gear manufacturer and the customer.

For the manufacturer, the pitch-to-pitch probe test confirms the position of each tooth relative to its partners, which serves as a check on the accuracy of the production machine, but, unlike with the worm, it is not practicable to check the tooth form other than by a contact mesh test with the mating or a master worm.

Since the single flank test takes place with the gears in mesh with several teeth partially in engagement, the effect of individual adjacent pitch errors may be negligible, and a more accurate assessment of the ultimate performance is possible.

The influence of deviations in profile can be identified and in certain circumstances reduced by modifying the profiles of the worm threads, this being a relatively simpler operation than recutting the worm wheel.

A long-term solution to this problem would be for a consideration of the methods of manufacture and accuracy of grinding the worm or of the hob or cutter employed in generating the teeth of the worm wheel.

It might also be practical to increase the number of teeth in the worm wheel to ensure that a greater proportion are in instantaneous engagement, since where a component contains a relatively small number, the deviation recorded for the profile may exceed the effect of pitch and concentricity errors.

For the user, the information derived provides information relative to the likely dynamic performance. The waveform can indicate the degree of uniformity of motion, which will have a considerable bearing on the likely noise level at speed, or it will confirm the positional accuracy to which adjacent and accumulative pitch errors can only give guidance.

For example, having this information and knowing the start/finish position of the worm wheel in the test, the builder of CNC indexing or rotary tables can enter these values in the controlling software as a means of self-correction.

A further benefit of this system is that when performing the test for both directions of rotation, the results of the second or reverse operation can be reproduced onto the results of the first, as demonstrated in Fig. 11. When the upper limit line of the first test is positioned to coincide with the lower limit line of the second, the distance according to the scale between any two points on the curves in a vertical axis is the backlash. If the curves were to overlap at any point, this would represent interference.

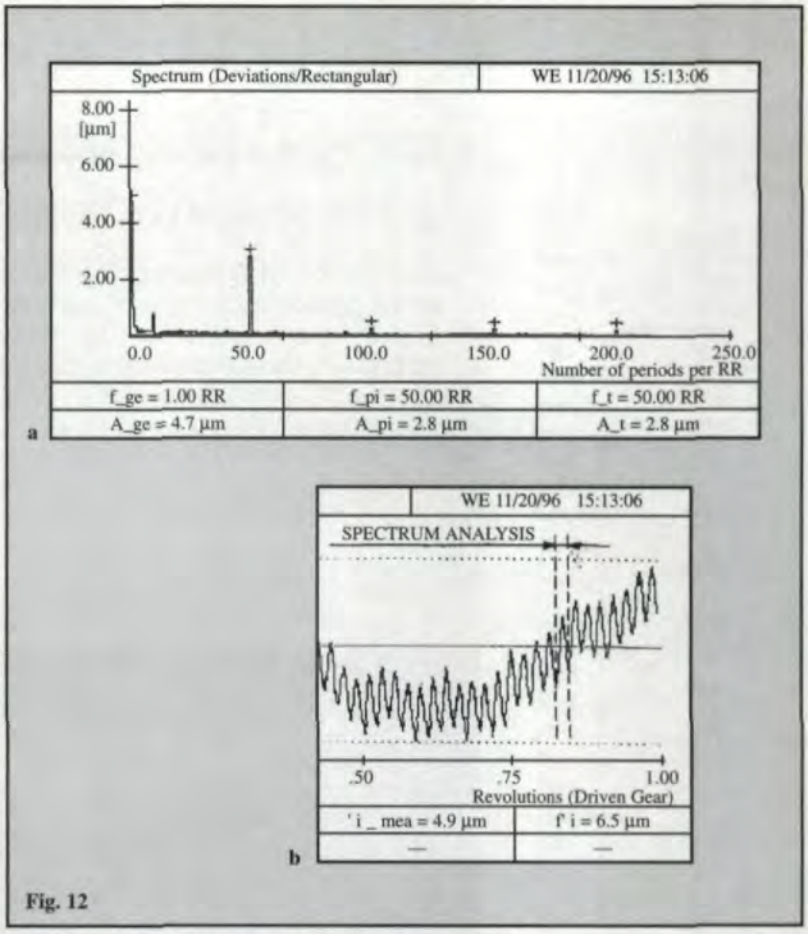


Fig. 12

In the example shown, the major cause of deviation of the curves is eccentricity, and it can be seen how this can influence backlash, a particularly important feature where the worm gears are required to operate in a situation when this has to be closely controlled or adjusted.

The facility also exists to carry out fast Fourier transformer spectrum analysis on the wave form, the results being quantified in Fig. 12a.

The baseline represents a number of periods of frequency over one revolution of the gear. The highest deviation occurs once per revolution, and in the case of this example, that will be the effect of the eccentricity. There is then a second major deviation at 50.00, which, with a 50-tooth worm wheel, represents each tooth engagement. Further smaller deviations occur at greater frequencies, representing a breakdown of the various characteristics of one "spark" or engagement, taken from the transmission test results, as shown Fig. 12b.

Information from this source can be invaluable when analyzing noise or vibration levels in a gear unit, for example, at high rotational speeds and in elevator machines. ○

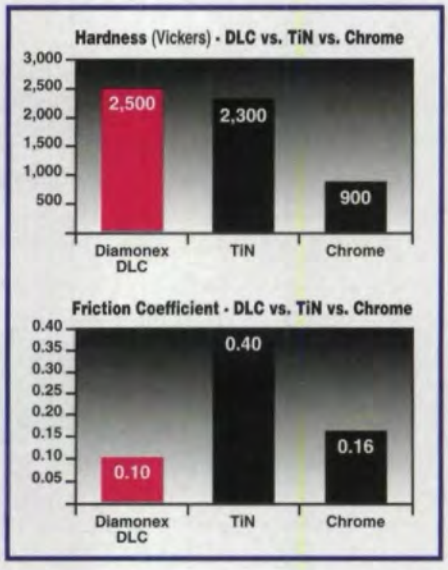
Diamonex® (DLC) Diamond-Like Carbon Coatings

Low Temperature CVD Plasma & Ion Beam Deposited Thin Film

Diamonex® DLC is a conformal, superhard and low friction coating of an amorphous form of carbon with diamond bonds. Amorphous carbon is a material whose properties resemble, but do not duplicate, those of natural Diamond.

DIAMOND-LIKE CARBON
amorphous diamond

- WEAR/ABRASION RESISTANT
- LOW FRICTION
- HIGH HARDNESS
- CORROSION RESISTANT
- GAS BARRIER
- CONFORMAL COATINGS



MATERIAL PROPERTIES

Hardness (Vickers)	1,000-3,000* (adjust.)
Friction Coefficient	< 0.1 (as-deposited)
Coating Thickness	.001 - 10µm
Max. Working Temp.	500 °C
Deposition Temp.	< 150 °C
Chemical Resistance	Inert
Electrical Resistivity	10^{6}-10^{12} (ohm-cm)
Coating Finish	Identical to substrate

Commercial/Industrial DLC Applications

- Aerospace
- Automotive
- Bearings
- Electronics
- Instrument
- Medical/Dental
- Metalworking
- Textile
- Tools/Dies/Molds
- Industrial Wear Parts

For additional information contact Joseph Rogers at: 610-366-2106, FAX a request to: 610-366-7144 or visit us at: www.diamonex.com

Diamonex®
PERFORMANCE PRODUCTS
A Unit of Monsanto Company

7331 William Ave.
Allentown, PA USA
18106

SEE US AT AGMA GEAR EXPO BOOTH #427

Special Machine Manufacturer Brings Gear Making In-House

Better turnaround, quality and efficiency, but this move's not for everyone.

Ray Mackowsky

When you have a multi-million-dollar transfer line sitting on the shop floor waiting for gears that might take up to two months to get, you have a costly bottleneck.

Ann Arbor Machine Co., a manufacturer of synchronous transfer lines, dial index tables, broach machines, plastic blow molding equipment and special EDM machines, located in Chelsea, MI, found itself in this situation.

Customer Deadlines Hindered By Lack of Gears

Ann Arbor Machine was jobbing out a million dollars worth of gears to a vendor over the course of a year. But turnaround was at times approaching two months. This severely limited the company's ability to complete multi-million-dollar metal-working equipment to meet its customers' deadlines.

To solve the problem, Ann Arbor Machine looked at various options. Would it make economic sense to buy a gear manufacturing company or to invest in gear hobbing equipment and make the gears in-house? With the majority of its gear needs being met with quantities of one to three and sizes from 1/2" to 8", could the investment be justified? Would either of these options bring the needed response time? And, if the work was brought in-house, would new or used equipment be the better investment?

New Hobbing Machine Purchased

After looking to buy a local gear manufacturer and finally abandoning this idea, Founder and Chairman Robert Betzig decided to bring the work in-house. He hired Bob Turke, who at one time had his own gear manufacturing company, to run the department. Turke purchased a new Gleason Phoenix 125GH six-axis, CNC gear hobbing machine, a number of used shaping and shaving machines and an M & M gear analyzer.

Turke said that Ann Arbor could have gone with a used hobbing machine. However, machines the company looked at couldn't match the gear-making versatility, precision or quality that the new machine offered.

For Ann Arbor, not only did it make economic sense to produce the gears in-house, but gear turnaround, at times, was cut to a matter of hours. "We felt that the cost per gear was about the same or a little lower than sending gears to a vendor. However, the most important thing for us was to get gears when we needed them and with consistent quality," Turke said.

How to Decide

Turke said that one way for a company to decide if it's worthwhile to bring gear production in-house is to look at the payback time. If a company can pay back its initial machine investment in three to five years, Turke believes that it would be a good investment. Also, by bringing gear production in-house, he feels that quality can go up because of more stringent controls and faster feedback if problems arise.

Turke added that three important parameters should be looked at before a company decides on in-house gear manufacturing: timing, quality and cost, in that order.

Timing relates to the needs of your company. What kind of turnarounds are you getting from your current vendor? Is the turnaround hampering manufacturing of other parts or products? Is it causing problems with customer deliveries?

Quality is important. If your vendor isn't giving you what's needed, your end product isn't satisfying your customers' needs, and you might lose them. Turke

To streamline gear production at Ann Arbor Machine Co., most gears have the same pitch and pressure angles. Gears manufactured are usually straight spur gears and some with internal splines.

believes in-house gear production can give you higher quality because you're watching over every step of the process.

Lastly, gear cost is significant. How much can you save by producing gears in-house; or, conversely, how much will it cost you to produce them compared to buying them somewhere else? If you have a very narrow selection of gears to make, it could be less expensive to produce them in-house. But if you need many different types of gears that require honing, grinding, shaving and various other operations in small lots, payback could be lengthy because of the specialized operator skills needed and the number of different machines required to produce the gears.

In the case of Ann Arbor Machine, gears produced in-house were not significantly less expensive than outsourced gears, but the control over the process and delivery times made the investment in in-house manufacturing worthwhile.

Pitfalls

Some of the pitfalls of bringing gear production in-house include the responsibility of dealing with various vendors that you might never have worked with

before, such as heat treaters. With in-house manufacturing, you also need the equipment to verify the quality from these vendors, adding another expense and additional demands on your time.

Also, competent gear manufacturing personnel are hard to get. You'll probably need an overall coordinator, the department head and at least one good production person, depending on your needs. So now you have more payroll and more personnel coordination.

New or Used?

Should you buy used equipment or new? Turke said that from a technology standpoint, new equipment's production speed will be greater, quality will be better (new machine rigidity, superior CNC controls, etc.) and gear setup time will be less because of the machine controls' ease of use. On the other hand, late-model used machines are sometimes available with no lead time for 1/2 to 1/3 the price of new and, depending on the application you have in mind, they may suit your purposes.

Turke explained that another reason for purchasing new equipment is the possibly positive impression it may make on potential customers. It might tip the balance in favor of your company and bring in work, as it has for Ann Arbor Machine. New equipment is also under warranty and training is provided by manufacturers. If you don't have trained personnel to fix used equipment, breakdowns can cause significant production problems.

Financing

The question of leasing equipment rather than buying it outright with cash or with bank or manufacturer/dealer financing is an option to be explored. Each choice has its attractions. Leasing allows you to use the equipment during crunch times or for particular projects and then return or upgrade it, but over the long haul, it can cost as much as buying the machine in the first place. Every company has different needs and expectations for in-house gear manufacturing, and this decision needs to be evaluated in the light of them.

Gears Designed for Ease of Manufacturing

There's more to manufacturing gears in-house than simply bringing in the machines to do the work. Through careful planning, Ann Arbor Machine optimized its production.

To streamline production at Ann Arbor, most gears have the same pitch and pressure angles. Production is usually limited to straight spur gears and some with internal splines. All gear cutting on

Close-up of gear being cut. All hobs are made of PM 45 high speed steel, TiN coated with AA tolerance. They have a single start and a class "AAA" line of action.

the new Gleason is done with 8" long hobs except for straight-sided splines, which are done with 3" hobs.

All hobs are made of PM 45 high speed steel, TiN coated with an AA tolerance. They have a single start and a class "AAA" line of action.

Gear blanks are machined in-house using 4150 pre-hardened steel with a Rockwell C of 34–38. All machining is done after heat treating.

To simplify workholding, custom gear blank arbors are made in-house and use slip-fit collars to fit the various blanks and allow fast changeover.

Turke said, "In six months' time, we've made about 2,000 gears, of which there are about 300 different types. We do up to eight part changes per day on the hobber. In fact, we're so confident of its precision and performance, we no longer do trial cuts. The first gear off, we use.

"Our quality from this machine has been so good that we've produced unbelievable tolerances. We've consistently manufactured AGMA class 10 gears and up to an AGMA class 14 gear on some elements with just a finish hob."

Bruce Colosimo, the machine's operator, said that he usually runs the hobber a bit slower than its capabilities to save wear and tear on the hob. If a gear can be cut in 30 seconds, he'll do it in three or four minutes, which, he said, is still faster than most other hobbing machines he has worked with.

Because of the simplicity of the machine's operator-friendly software and the Fanuc 32-bit, 15-megabyte controller, he can program a new gear in about five minutes. A standard storage capacity exists on the machine for up to 100 previously developed part programs. The part summary number is entered, and the gear manufacturing data is downloaded to the CNC. Summary data can be transferred to and from a 3.5" floppy disk.

The Fanuc controller allows automatic setup and control of axial feed, radial feed, hob position, hob speed and hob swivel angle setting. This gives Colosimo fast setup times. Plus, to change hobs, he simply presses two buttons to chuck and dechuck the tool. The hob is automatically aligned and the first part off is a good one. Hob changes take less than a minute.

The added efficiency of the new machine has also opened up other opportunities. According to Turke, "Since we have the production capability . . ., I can easily slot in outside work when I don't need the machine for our gears."

While producing gears in-house may not be the choice for every operation, the flexibility, production control and new business opportunities it can create make it an option worth exploring. ⚙

Ray Mackowsky
is a Michigan Regional Manager for the Gleason Corporation.

Tell Us What You Think . . .
If you found this article useful or informative, circle **205**.

For more information about Ann Arbor Machine, circle **206.**

For more information about Gleason, circle **207.**

Gleason Corporation Acquires The Pfauter Group

Gleason Corporation has announced that agreement has been reached on all terms to acquire for approximately $36 million in cash the Hermann Pfauter Group, including, among other operations, Hermann Pfauter GmbH & Co., a privately held leading producer of gear equipment based in Ludwigsburg, Germany; its 76% interest in Pfauter-Maag Cutting Tools, a leading cutting tool manufacturer based in Loves Park, IL; and Pfauter-Maag management's 24% ownership interest in that company. The acquisition includes all assets and liabilities, including the assumption of approximately $56 million in bank debt.

The acquisition will move Gleason into the number one worldwide position in overall gear production equipment and related technology.

The Pfauter acquisition is a major step forward in Gleason's strategic plan, begun in the early 1990s, to complement its acknowledged leadership in bevel gearing by building its presence in the cylindrical gearing market. In 1995, Gleason acquired another German machine and tooling manufacturer, Hurth Maschinen und Werkzeuge GmbH of Munich.

The Pfauter Group, founded in 1900, with operations in Germany, Italy and the U.S., manufactures the world's most comprehensive line of gear cutting machinery for the production of cylindrical gears. Pfauter employs more than 1,000 people and generated 1996 sales of approximately $175 million and earnings before special charges, inter-est, taxes, depreciation and amortization of approximately $17 million. Gleason said it expects to retain the Pfauter trade name and key members of Pfauter management in their existing positions.

The acquisition will be funded through syndicated bank financing led by Chase Manhattan Bank. Regulatory approvals in Germany and the U.S. have been granted.

McCarthy Wins E. P. Connell Award

Dave McCarthy, P. E., was presented the E. P. Connell Award at the annual AGMA meeting in Tucson, AZ, this spring. McCarthy is the Vice President, Engineering, of the Dorris Company, Inc. and Chairman of the Gear Rating Committee of AGMA. The award is a memorial to Edward P. Connell, presented to candidates who bring about important advancements in the gear industry.

Oak Ridge Offers New Metrology Service

The Metrology Center of the Dept. of Energy's Oak Ridge Centers for Manufacturing Technology (ORCMT) is now offering lead master calibration service. Using the lead master and the involute master, manufacturers can test in-house gear measuring devices for performance accuracy. The center uses a Leitz Precision Measuring Machine to do the testing.

Superabrasives technologists train at North Central Technical College.

The service is the second in a series offered through an alliance between AGMA, NIST, ASME, ORCMT and Pennsylvania State University. ORCMT anticipates expanding its services with the calibration of index, pin and other gear masters.

Industrial Diamond Assn. Launches New Training Program

The Industrial Diamond Association of America has completed the first session of its new Superabrasives Technologist Certification Program at North Central Technical College in Mansfield, OH. Twelve students, including technical college faculty, field sales people and machine operators, graduated from the week-long course devoted to precision metalworking with diamond and cubic boron nitride tooling. At the end of the course, each student received certification and a designation as "technologist" for his or her work.

The course was developed as an outgrowth of the Partnership for Manufacturing Productivity, an educational program originally developed by GE Superabrasives. The Partnership is now a division of the Industrial Diamond Association.

More information about the course is available from the association headquarters at 704-684-1986.

THE GEAR LOVER'S GUIDE TO DETROIT

When travelling about in search of gears and other adventures, wise explorers bring along as much important information as they can. In the interest of keeping our readers as well-informed as possible, we bring you the following collection of Important Facts About Motor City.

COBO HALL FACTS

The "new," refurbished Cobo Conference/Exhibition Center is one of the largest convention facilities in the U.S. It now spans more than 17 acres of downtown Detroit and has more than 700,000 sq. ft. of exhibition space. There are 85 separate meeting rooms, which are linked to the exhibition halls by 26 escalators. The hall is named for the late Albert E. Cobo, Detroit mayor from 1950–1957. It is also the site of the Michigan Sports hall of fame and of one of Detroit's most recognizable figures, a statue of Joe Louis, which graces the facility's main entrance.

Photo by Vito Palmisano

Cobo Hall at night.

DETROIT BASICS

DOB: July 24, 1701

POPULATION: 3,935,734 (metro area)

LAND AREA: 136.6 sq. mi. (218.5 sq. k) – city
2,026.1 sq. mi. (3,241.7 sq. k) – metro

Altitude 581 feet (177 m) measured at the Detroit River

CLIMATE
Average High/Lows for October in degrees F/degrees C: 63/17 – 41/5

LOCATION
Distance in mi/kilos from

Atlanta	732/1177	New Orleans	1070/1724
Baltimore	514/827	New York	765/1224
Boston	509/814	Philadelphia	514/822
Calcutta	7705/12840	Pittsburgh	296/476
Chicago	275/440	St. Louis	541/866
Cincinnati	270/432	San Francisco	2399/3859
Dallas	1158/1864	Seattle	2327/3744
Denver	1283/2064	Sydney	9547/15361
Indianapolis	282/451	Tokyo	6574/10511
London	3675/5913		
Los Angeles	2288/3681		
Mars	35000000/56800000 (at its nearest)		

SHOW BASICS

Who? Everyone with an interest in gears and gear manufacturing.
What? AGMA's Gear Expo 97, "A Decade of Performance."
Where? Cobo Hall, Detroit, MI.
When? October 19–22, 1997.
Why? To see the only international trade show devoted exclusively to the gear industry.
How? Contact AGMA headquarters 703-684-0211.

For more information, see Show Central, *Gear Technology*'s electronic look at Gear Expo 97 (*http://www.geartechnology.com*).

Photo by Bill Publiano

Detroit People Mover.

GETTING AROUND

On a more practical note, Cobo Hall is adjacent to a vast parking garage and a People Mover station, which links it to all the other stations on the 2.9-mile track of the transit system.

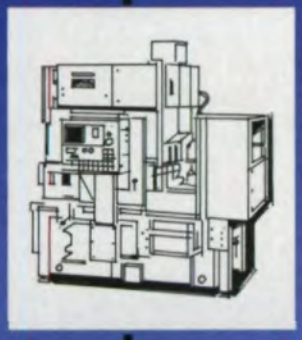
The People Mover is one of the most convenient ways to travel around the central business district of Detroit. It is an elevated, computerized rail transit system stopping at 13 stations throughout downtown Detroit and providing access to the city's major office buildings, hotels, restaurants and shopping districts, as well as to Cobo Hall. Rides cost 50 cents. Exact change or a purchased token is required. The system operates on Mon.–Thurs. from 7 a.m.–11 p.m.; Fri., 7 a.m.–midnight; Sat., 9 a.m.–midnight; and Sun., noon–8 p.m.

THE REST OF THE STORY

There's a whole lot more to Detroit than gears, or even cars. For the lowdown on everything from the professional athletic teams to the Detroit Zoo, (not to mention the sights and night life across the river in Windsor, Ontario), contact Michelle Fusco at the Metropolitan Detroit Convention & Visitors Bureau, 313-259-4333; fax 313-259-7583; e-mail *MFUSCO@visitdetroit.com*; or check out the bureau's World Wide Web site at *www.visitdetroit.com*. ○

Tell Us What You Think . . .
If you found this article of interest and/or useful, please circle **210.**

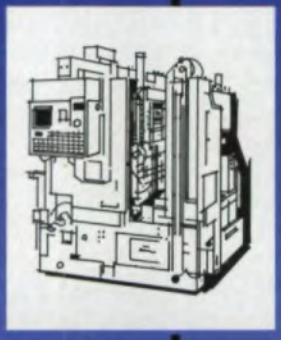
Our family of gear machines shares a name– and a whole lot more.



SHAPING

SD15CNC SC63CNC
SC25CNC SC100CNC
SC40CNC

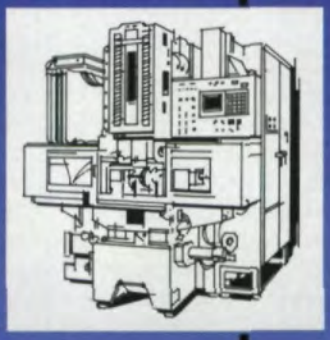
Sophisticated cutting mechanisms give you high productivity for gear shaping needs up to 1 meter diameter.



HOBBING

GD10CNC GC63CNC
GD20CNC GC100CNC
GC25CNC GB-H18CNC
GC40CNC

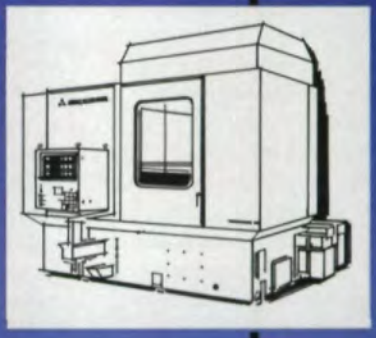
Get high precision gears —up to 1 meter—with our gear hobbers—fast.



SHAVING

FB30CNC FA45CNC

Cut gears up to 450 mm fast, with simple set up and conversational programming on our gear shavers.



GRINDING

ZG400CNC ZG1000CNC

Our highly precise grinders give you gears that meet the highest world-class standards.

The most complete family of gear cutting machines share Mitsubishi machine construction, Mitsubishi software, and common controls. For the fastest CNC learning curves and the highest quality gears, contact your Mitsubishi representative today.

Gear Expo

SEE US AT AGMA GEAR EXPO BOOTH #354

This is . . . **MITSUBISHI MACHINE TOOLS**

MHI Machine Tool U.S.A., Inc.
907 W. Irving Park Road • Itasca, IL 60143-2023
Phone: (630) 860-4222 • FAX: (630) 860-4233

CIRCLE 109

Who's Who and What's What At Gear Expo '97

Below are listed the Gear Technology *advertisers exhibiting at Gear Expo 97. Booth numbers are correct as of July 25, 1997.*

Accu-Cut Diamond Tool Co., Inc. – Booth 728. Company staff will be on hand at Accu-Cut's booth to discuss the new finish requirements and bearing ratios for super-finishing the I.D.s of gears. On display will be the new Accubore Model VXG2 machine for finishing precision bores in a two-tool pass operation. Other diamond bore sizing tools for a variety of gear applications will also be on display.

Amarillo Gear Co. – Booth 523. Amarillo Gear Company will exhibit a variety of spiral bevel gears from its large range of parts. Catalogs of the company's product line of spiral bevel gears, right angle pump drives and right angle cooling tower fan drives will also be available in the booth.

American Gear Manufacturers Association – Booth 400. AGMA, the sponsor of Gear Expo 97, is an association of companies, consultants and academicians with direct interest in the design, manufacture and application of gears and flexible couplings. AGMA is member-driven and conducts programs for and provides services to the gear industry and its customers. AGMA's 380 members include gear manufacturers and suppliers to the industry from around the world. AGMA is accredited by ANSI to write all U.S. standards on gearing and is also the ISO Secretariat for TC 60, the committee that develops all international gearing standards.

American Metal Treating Co. – Booth 518. American Metal Treating Company will feature samples of gear induction hardening patterns at Gear Expo 97. The company's induction hardening experts will be at their booth to demonstrate their techniques. They will also be available to answer questions regarding your distortion and tooth wear problems and to discuss your heat treating requirements.

American Pfauter, L.P. – Booth 100. American Pfauter is a manufacturing unit of the Pfauter Group, the leading manufacturer of standard and custom machines and tools for rough and finish machining of gears. APL offers a comprehensive gear cutting machine program for gear hobbing, shaping, milling and grinding applications for cylindrical gears. APL will showcase its new, compact P200G CNC grinding machine at its booth. The P200G offers all the benefits of Pfauter's larger machines at an affordable price.

American Wera – Booth 348. American Wera, Inc., now representing Präwema, a German gear honing machinery producer, will feature these machines at its booth. Präwema *Synchro-Fine* high performance gear honing machines feature electronically synchronized technology. Another Präwema machine line, the hypocycloidal *Synchro-Form*, performs a step-lock milling process for sliding sleeves (back-angled shifter locks) that saves time and expense compared to the traditional method, which includes turning, broaching and other steps made unnecessary by the *Synchro-Form*.

ATA Gears Ltd. – Booth 509. ATA Gears has over 60 years' experience in the production of spiral bevel gears and custom-designed gear units. The company makes lapped, hard cut or ground spiral bevel gears to AGMA quality number 14 and up to 47" and custom-made right angle gears to 5000 hp. Company experts will be on hand to discuss your gearing needs.

A/W Systems Company – Booth 121. A/W Systems has a full line of spiral gear rough and finish cutters and bodies. The company will be displaying a complete array of gear cutting tools: stick blades and bodies, straight bevel blades, rack cutters, diamond dressing tools, spiral gear cutting blades, keyseat cutters, hard turning (CBN) tools and bore and height gages. All products are manufactured in the U.S.

Barit International Corporation – Booth 155. Barit is a supplier of spur and helical gear tooling. Its manufacturing and off-the-shelf inventory includes: gear and worm gear hobs; parallel and involute spline hobs; disc, deep C-bore and shank type shaper cutters; keyway, round spline, hexagon, square surface and special form broaches and shaving rolls. Hobs and shaper cutters are available in a 1 DP and finer range. They are all precision ground, made to AGMA standards, TiN coated and available for immediate delivery. Staff will be on hand at the Barit booth to discuss your tooling needs.

Basic Incorporated Group – Booth 160. Basic is an importer and distributor of machine tools manufactured in the Far East. The company offers 50 models of gear hobbers, shapers, honers, shavers, grinders, gear cutter grinders, bevel gear generators, rack shapers, worm millers, gear testers and more. Manual, automatic and CNC gear machines are available. Machines are stocked in Los Angeles for prompt delivery, and service technicians are quartered in both Chicago and Los Angeles. Basic bills itself as one of the few sources available for new "manual" gear machines.

Bourn & Koch Machine Tool Co. – Booth 361. Bourn & Koch will be exhibiting its newest standard model hobbing machine, the 100HCNC. The hobber is a 4-axis CNC machine capable of cutting 10 NDP, AGMA Class 10 up to 5.0" in diameter. The 100H has a small footprint and incorporates the latest technologies.

Colonial Saw – Booth 738. Colonial Saw will exhibit a new NC hob grinder for straight and helical gashes, high-speed steel and carbide. The UTMA model LC35-NC3 is a 3-axis NC tool grinder that can sharpen end mills, milling cutters and shaper cutters as well as hobs. The company says the LC35-NC3 combines accuracy, ease of setup and flexibility at an affordable price.

Colonial Tool Group Inc. – Booth 642. Colonial Tool will be showing a wide variety of precision high speed spindles for many machining applications and a selection of broach tools, broaching systems and spline rolling racks. Colonial will customize tools to match customers' applications. Technologists will be on hand to discuss Colonial services, including turnkey machine setups and in-house design, manufacturing and heat treating for individual customer applications.

Commercial Steel Treating Corporation – Booth 535. Staff will be on hand to discuss a wide range of heat treating services, including carbonitriding, carburizing, gas nitriding and salt bath

nitriding. According to the company, salt bath nitriding (ferritic nitrocarburizing) in particular, extends the wear, corrosion and fatigue properties with minimal distortion.

Crown Gear B.V. – Booth 442. Visitors to Crown Gear's booth will be introduced to the revolutionary Cylkro® gear technology used for the development of the Cylkro angular transmission and the Cylkro tooth coupling. Technical features of the Cylkro angular transmission, a cylindrical pinion with an involute profile mating with a Cylkro face gear, are axial freedom of the pinion, freedom of choice (0°–110°) of the shaft angle, and the options of either straight or helical teeth with or without axis offset and the possibility of meshing multiple pinions with one or more Cylkro gears.

Diamonex – Booth 427. A unit of Monsanto's Advanced Performance Materials Group, Diamonex is the largest commercial manufacturer/developer of products and vacuum technologies based on diamond and related superhard materials. It also provides coating services and process/product development and engineering. Its coatings for gear components have the following characteristics: DLC coating thickness range 0.000001"–0.00010"; microhardness 5–35 GPa (500–3,500 Vickers); friction coefficient ≤0.1; deposition process temperature <150°C; film surface roughness—conformal, identical to substrate.

D.I.G.I.T. – Booth 334. This builder of custom-designed gages will be demonstrating its products. D.I.G.I.T. gages provide repeatable exact gear measurements, including pitch diameter of internal or external spline, helical or spur gears with either odd or even numbers of teeth. The gages will operate in any environment, be it the shop floor or the testing lab.

Dura-Bar – Booth 543. Dura-Bar is an industry leader, supplying continuous cast iron bars to industry. The company says its special process eliminates scrap resulting from shrinkage, porosity and tool-wearing inclusions that frequently occur in static-cast iron. Bars are available in gray and ductile iron, in round bars from 5/8" to 20" in diameter and also in machined gear blanks. Staff will be on hand to discuss your continuous cast iron needs.

Emuge Corporation – Booth 601. Emuge is a manufacturer of quality workholding and electronic control systems for gear manufacture. The precision clamping product line 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–.0002–and offer reliability, functionality, clamping element interchangeability and ease of maintenance. Staff will be present to discuss custom applications.

Euro-Tech Corp. – Booth 731. Euro-Tech will be exhibiting the following new items at its booth: The Frenco "URM-K" profiled shaft inspection machine designed for fast, accurate inspection of profiled shafts; the Frenco "dynamic gage," which offers three-second inspection of size and form/profile on internal or external splines; the Frenco "VPE," a new DOP/DBP bench gear tester with a movable Z-axis to measure spur and helical gear size, crown and taper; the complete line of Mytec hydraulic expansion arbors, chucks and quick change tooling for gear manufacturing; and the Kostyrka line of compensating face washers for hob holding applications.

Fässler Corp. – Booth 244. Fässler Corp. suggests that when you want to reduce the cost of gear production by eliminating shaving and grinding, the Fässler K-300 5-axis CNC gear honing machine is the answer. It will be on display at the Fässler booth, along with the HS-100 hard broaching machine, which the company recommends as an alternative method for processing splined bore parts.

The Gleason Works – Booth 100. At Gear Expo 97, The Gleason Works will display a complete line of bevel and cylindrical gear cutting machines in its new 120' x 30' booth. Also shown will be profile grinding and honing machines manufactured by The Gleason Works, Gleason-Hurth and Pfauter. An extensive line of workholding products and Pfauter-Maag cutting tools for the gear industry will be displayed. Show attendees will see the latest in gear manufacturing machines, processes and equipment.

Global Gear – Booth 408. Global Gear is a manufacturer of quality precision helical and spur gears. The company will have examples of its product on hand, as well as technicians to discuss your product engineering, tool design and EDI needs. You are invited to stop at the booth to see how Global can help your company meet the demands of a rapidly changing gear market.

Great Gear Corp. of Taiwan – Booth 715. On display will be a wide variety of gears, including spur, helical, internal, external, worm, bevel, plastic and herringbone. Aerospace gear shafts in titanium alloy or AISI 9310 up to AGMA class 14 will be shown. Gearboxes and gearheads for AC/DC/stepper motors will also be shown. Great Gear can also do crown and skive hobbing for noise reduction and misalignment compensation and sintering.

Ikegai America Corp – Booth 126. Ikegai will be displaying its SX-15 CNC gear hobber and the SAN-20 CNC hob sharpener. The SX-15 uses a 2,000 rpm spindle along with a 220 rpm table and comes with a hob quick-change system, which eliminates hob centering at regrinding. The machine is also equipped with a Fanuc 5-axis CNC. Its maximum workpiece diameter is 150 mm; maximum gear module is M4 (6) and maximum hob diameter times length is 120 x 180 (120 x 250) mm. The SAN-20, 4-axis CNC hob sharpener is fully automatic and can grind spiral as well as straight gear hobs. The Y-axis cross-slide travel is NC-controlled, allowing fast and simple changes between CBN and standard grinding wheels. Spindle speed is 3,000 rpm. Maximum hob diameter is 220 mm; maximum hob length is 270 mm and maximum hob pitch is DP 1.6/M 16.

ITW Heartland – Booth 314. ITW Heartland has been designing and manufacturing gear inspection systems for over 60 years. The company also manufactures high-speed, high-production burnishing machines. On display at the Heartland booth will be a dimension-over-pins unit, a computerized gear roller, gear rolling inspection units and video demonstrations of high-speed gear inspection and burnishing machines. Visitors are also encouraged to visit the company's Web site at *www.gctel.com/~itwgearsitwheart.htm*.

Kapp GmbH – Booth 144. Kapp GmbH, along with affiliated companies, Niles, Kapp Sales & Service and Kapp Tech, will display machine modules demonstrating external and internal gear and profile hard finishing. In addition, CBN grinding wheels from Kapp Tech, product photos and specifications from Niles and new Kapp technologies will be introduced. Kapp and Niles machines are capable of hard finishing gears and profiles using four technology concepts: form grinding with CBN profile grinding wheels; form grinding with dressable grinding wheels; form generation with dressable or non-dressable wheels; and coroning. Coroning is a unique, efficient, hard gear finishing process using non-dressable CBN coroning rings.

Koepfer America, L.L.C. – Booth 256. The new Koepfer Model 160 will be on display at the company's booth. The 160 is an 8-axis CNC high speed hobbing machine designed for either dry or wet hobbing. The cutter and work spindles have a maximum speed of 5,000 rpm and 1,000 rpm, respectively. This machine also incorporates a 45° slant bed to aid chip flow, as well as a high speed load/unload system to quickly change (2–3 seconds) parts. Also on display will be a CNC hob sharpener and various cutting tools.

SHOW COVERAGE

Lambert/Wahli/Parker – Booth 132. Lambert and Wahli CNC hobbers will be on display. These machines are suitable for pitches of 12 DP and finer. There will also be information about a Wahli machine for very fine pitch work and a Lambert worm and thread miller. With hob speeds up to 4000 rpm, these CNC machines are excellent for use with carbide and HSS hobs. A selection of high quality carbide and HSS hobs and shaper cutters will also be on display, together with spline gages and master gears from the Parker Industries group.

Lemur Enterprises – Booth 129. Staff will be on hand to demonstrate the GeCCo© v. 1.1 (Gear Cutter Configurer) software that calculates machine settings for spiral and straight bevel gears cut on Gleason machines in-house on the customer's own computer. Information will also be available on the new visual drive train design program which enables the user to build any drivetrain and then automatically perform the mathematical analysis to check the workability of the design.

Liebherr-America – Booth 648. Liebherr will be demonstrating three new machines at Gear Expo. The LC 83 is Liebherr's high speed, high precision dry gear hobbing machine, which has a 3,000 rpm hob head and a 450 rpm table drive, which permits cutting speeds up to 2,000 feet/min. The Höfler ZP 260 is a new, compact CNC gear inspection center for the shop floor. It is suitable for measuring work pieces up to 40" in diameter and 4" between centers. It has full three-axis measuring to 4 millionths' resolution, a collision-protected 3-D multi-axis probe and a wide range of software. Oerlikon will also demonstrate a new bevel gear machine.

LMT-Fette – Booth 530. On display at this booth will be solid carbide hobs for dry machining, heavy duty roughing and finishing hobs, indexable carbide insert hobs, skive hobs for hardened gears, Gash-Master hobs with most gashes available and gear gashing cutters. Technical staff will also be on hand to discuss visitors' specific applications.

M & M Precision Systems – Booth 230. M & M provides a complete line of computerized analytical and functional gaging systems, including gear inspection systems with capacities up to 95" in diameter. M & M's exclusive GearNet™ server automatically shares data for SPC, remote analysis and archiving. The company's gear inspection systems feature certification to .001 mm, traceable to NIST and .00002 mm probe resolution. New models are 20% faster for greater part throughput.

Mahr Corporation – Booth 655. Visitors will want to see Mahr's DFI 890 series, double-flank gear roll testers, which provide accept/reject test results to ISO, AGMA and DIN standards and which have Windows® 95-compatible WinGear® test and evaluation software. Mahr, an ISO 9001-certified supplier, provides a comprehensive gear product line including hand-held gear measuring tools; PC-controlled double-flank roll testers, PRIMAR universal CNC analytical gear and form testers and surface finish test equipment for gear tooth profiles.

Manufactured Gear & Gage – Booth 721. MG&G will introduce a computer-driven version of its hob & cutter measuring instrument. This version, which the company describes as versatile, accurate and economical, has options for 6" ITW and 10" Barber Colman index plates.

Mitsubishi Machine Tool – Booth 354. Mitsubishi will exhibit the newest addition to its family of gear machines—the ST25CNC. This new gear shaper combines a high speed, high precision spindle with a patented synchronized control that eliminates the need for helical guides. Helical gears can be handled by simply setting the helix angle on the CNC control. The company says this machine is ideal for short run prototype work because angle adjustments are easily made, and the gears are shaped quickly.

Now you can turn your surface grinder into a spur gear and spline grinder.

Normac's revolutionary spur gear and spline grinding package retrofits to your current surface grinder turning it into a profit making center at a fraction of the cost of a gear grinding machine.

The package includes:
The Formaster CNC Grinding Wheel Profiler, with diamond disc rotary attachment and constant preload, for dressing wheels up to 2" (50 mm) wide. A Lehmann precision indexing head. Siemens 810M control with brushless servo motor system (not shown). External spur and spline software that automatically generates part programs on a personal computer with MS-DOS.

See the spur gear and spline package at Gear Expo '97 - Booth #630

Normac, Inc.
Precision Grinding Machines

PO Box 245 / 720 East Baseline Road / Northville, MI 48167 USA
Tel: +1.248.349.2644 / Fax: +1.248.349.1440
E-mail: info@normac.com / Web: www.normac.com

SHOW COVERAGE

S. L. Munson & Company – Booth 645. The S. L. Munson booth will be featuring Dr. Kaiser precision diamond products for gear dressing. Dr. Kaiser produces direct plated and sintered construction in a full range of modules and pressure angles. Applications available for most dressing systems including Reishauer, Fässler, Gleason, Hoglund, Normac, G11, Liebherr, Csepel & Niles.

National Broach & Machine Co. – Booth 600. Three newly developed broach machines, all of which can be operated at floor level for optimum efficiency, will be on display at this booth. Visitors will also be able to see the new Red Ring Shavemaster gear shaving machine with 8-axis CNC control, the Red Ring/Kashifuji KA-400 CNC hobbing machine, and the Red Ring gear inspection analyzer for parallel-axis and spiral bevel gear checking. Also on display will be the latest in gear finishing tool for Spiralglide broaching, new material and coatings for hobs, shave cutters, roll form racks and hones.

Normac Incorporated – Booth 630. Normac will be showing a variety of its gear grinder and related supplies. The company's CNC threaded wheel trueing system includes the Wheel Profiling Center, software for calculating the required form and a special dresser unit to replace the existing dresser on the grinding machine. Sales engineers will be on hand to discuss customers' grinding applications.

Nye Lubricants, Inc. – Booth 330. The new line of synthetic gear oils by Nye Lubricants is backed by 150 years of specialty lubricant experience. This new line is for applications where *extended lubricant life and wide temperature serviceability is* required. These oils have a very high load carrying capability and are compatible with most seals, plastics and painted surfaces. Engineers will be available to answer questions about the SGO340 series of oils and other gear lubricant products. Information will also be available on the Nye "Lube Seminar" and on ways to improve gear performance and reduce friction and wear through better lubrication.

Perry Technology Corporation – Booth 117. Perry Technology invites show visitors to talk to their "Gear & Spline Experts" and to see a demonstration of a helical shaping operation. The Perry booth will also display a wide selection of geared and splined components and photos of the company's state-of-the-art manufacturing facility and equipment. Three generations' worth of gear experts will be on hand to answer questions.

Pfauter-Maag Cutting Tools, L.P. – 100. This leading international supplier of carbide and high speed steel gear hobs, shaper cutters, shaving cutters, form cutters, CBN grinding wheels, thin film coatings and heat treating services will be showing a variety of products at its booth. On display will be cutters, shapers and hobs for nearly every application, including carbide Wafer® hobs, Wafer® hobs, conventional hobs, Optigash® hobs, form relief milling cutters, shaper cutters, throwaway Wafer® shaper cutters and CBN wheels.

Presrite Corporation – Booth 660. Presrite is a leading provider of high-tech, high-strength forgings. The company will be displaying its line of forged near-net and net-shape gears. Staff will be on hand to discuss customers' special applications.

Profile Engineering – Booth 525. Profile Engineering, Inc., will demonstrate the PC-4 Composite Gear Analyzer® with the latest available data acquisition and computer analyzing software for double-flank composite gear measuring instruments. The PC-4 CGA® is designed with an anti-friction, flexible, mounted trunnion that allows for checking pressures down to zero, which is important on fine pitch, plastic or powdered metal gears. Staff will be on hand at the booth to answer visitors' questions about gear measuring.

Reishauer – Booth 156. Reishauer will be demonstrating its RZS CNC Gear Grinding Machine. The company describes it as designed to grind small to medium sized parts. It is best suited for use where a wide variety of hardened parallel axis gears exist and flexibility and productivity is of particular importance. The company says the machine offers high precision and process stability, high efficiency and superior productivity, ease of operation and durability and high reliability.

Roto-Technology, Inc. – Booth 500. Roto-Technology will be exhibiting the "Century," the newest version of the RC-400-Roto-Check, which is Windows 95-compatible. The company will also be emphasizing fine pitch gear testing by showing the RC-400-6" CNC automatic gear tester, which can inspect tiny parts, including injection molded and powdered metal parts with diametral pitches up to 100. This is accomplished by having the fifth axis rotate the probe. The modular designed system uses a Pentium® computer and has a 3-year warranty.

Saikuni Manufacturing Co., Ltd. – Booth 250. Saikuni will be displaying two machines: the NCG-125 spiral cutter sharpening machine with fully automatic cycles and an automatic cutter position device, power clamping and the ability to sharpen Coniflex, helical pinion and Revacycle cutters; and the NR-8LL rack milling machine with 3 axes and computer controls for heavy stock removal and large feeds.

Schunk Inc. – Booth 631. Schunk Inc. will be displaying its line of ultra high precision hydraulic expansion tooling with T.I.R. better than .00012". This tooling is available in both chuck and arbor styles with a large inventory of standard sizes. Also on display will be a new machinable plastic expansion arbor with 300% higher expansion rate than steel. You are invited to stop by the booth to talk to Schunk technicians and to pick up the company's latest catalog.

Star Cutter Co. – Booth 200. Star Cutter will feature broach sharpening, showing its CNC broach sharpening machine, Model UTG-1200. In addition, booth visitors will see hobs, shaper cutters, milling cutters, thin coatings (TiN, CrN, Ti[C,N] and [TiAl]N), solid carbide tooling, pressure coolant drills and reamers, PCD and PCBN tooling and grinding wheels and diamond gear dressers.

SU America – Booth 214. Samputensili will introduce a new CNC gear grinding machine, which the company says is accurate, flexible and affordable. It is a form grinder which can use ceramic and/or conventional grinding wheels. It can grind internal gears as well as externals and splines and has the latest generation numerical controls. SU's entire line of gear cutting tools, including carbide hobs, will also be on display. During the show, a seminar on gear grinding will also be held off site at no charge. To apply, contact SU's offices at 810-548-7177.

Toolink Engineering – Booth 113. Toolink Engineering is the North American distributor of Königdorn hydraulic arbors, chucks and other specialized workholding devices manufactured by König MTM of Wertheim, Germany. See product examples and talk with Toolink engineers about your turning, milling, grinding, balancing, drilling, measuring or inspection applications.

Walker Forge, Inc. – Booth 537. Staff will be on hand at the Walker booth to discuss all your advanced forging needs. Walker has capabilities in near net gear manufacturing, advanced die design, engineering and heat treating. Walker has been manufacturing carbo and ally steel forgings since 1950. ✪

Tell Us What You Think . . .
If you found this article of interest and/or useful, please circle **209**.

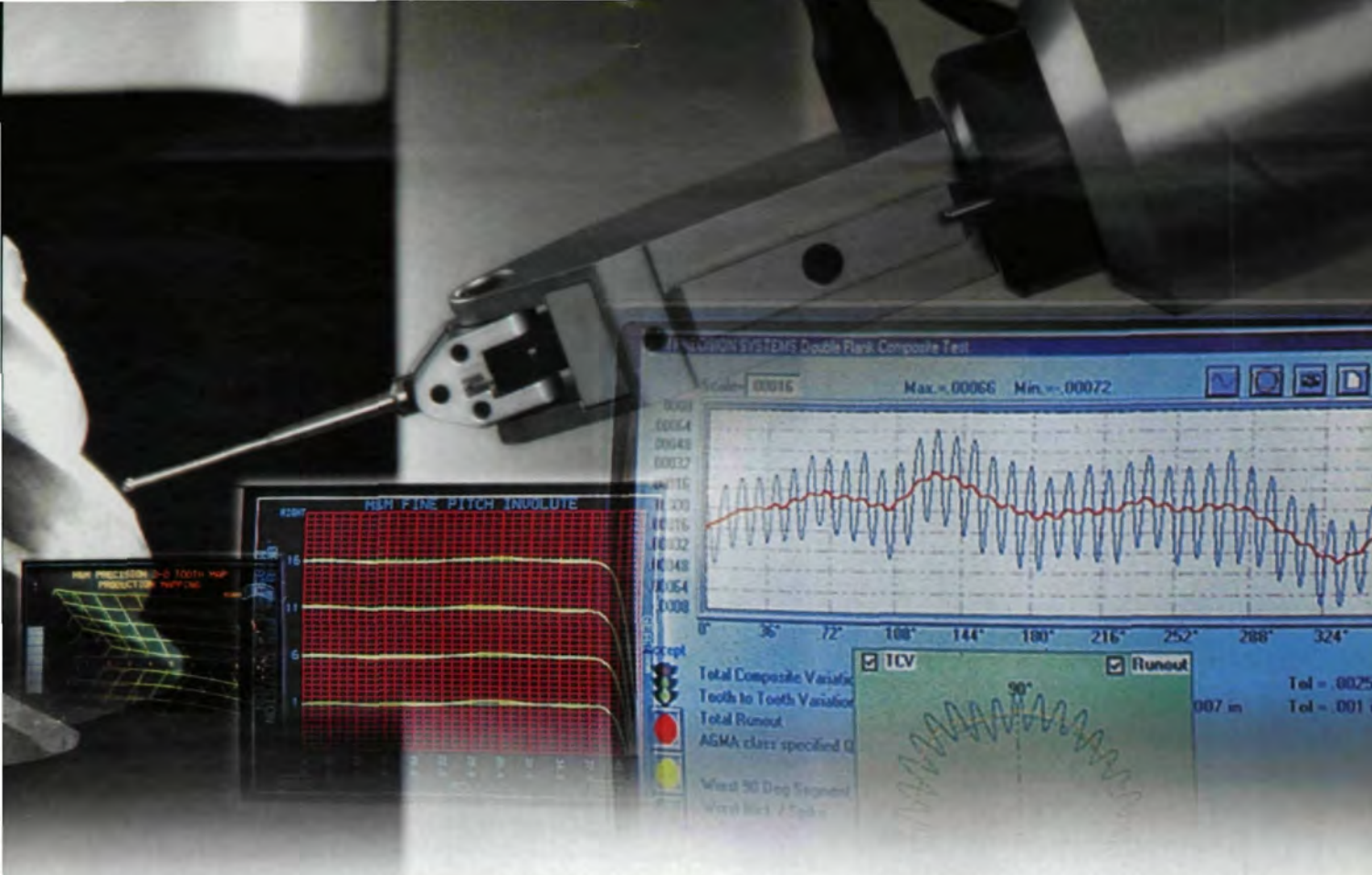
Complete Gear Manufacturing Process Control

From your single source for computerized analytical and functional gaging systems

- GearNet™ server automatically shares data for SPC, remote analysis and archiving.
- Simple, familiar interface ideal for manufacturing cell operators.
- Unmatched software selection, including bevel gear machine correction package.
- Pentium® based technology.
- Complete training and applications support with every system.

3500 Series CNC Gear Manufacturing Process Control Systems offer full four-axis flexibility and unsurpassed accuracy. Certification to .001mm traceable to NIST and probe resolution to .00002mm. You get greater productivity, too, with up to 20% faster throughput and capacities to 95″ in diameter.

200 Series Systems provide all the performance and durability of the larger systems, but in a compact size that's perfect for high production parts up to 10″ in diameter.



GRS-2 Double-Flank Gear Roller System combines proven performance with easy-to-use PC compatible software to make inspection accurate and simple. Total composite, tooth-to-tooth and runout tests determine if parts conform to specification. Computer analysis lets users specify AGMA or DIN standards, then determine the class of gear achieved.

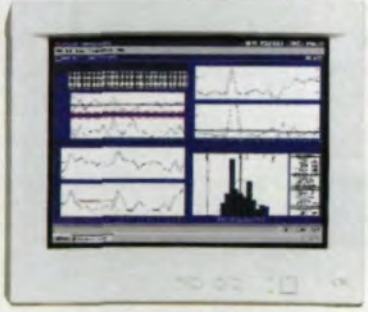
Dimensions Over Pins Gage measures actual tooth thickness at the pitch diameter. A unique constant-pressure gaging head assures repeatability and accuracy over the full range of the gaging system—while greater throughput allows you to inspect more parts and reduce production costs.

Other M&M Precision Systems inspection products:

- Master Gears
- Spline Gages
- Variable Spline Indicators
- Fixture Gages
- Arbors

Free brochure Call 937/859-8273 or fax 937/859-4452.

Visit us in booth 230 at Gear Expo '97



M&M PRECISION SYSTEMS CORPORATION

"THE METROLOGY & MOTION PEOPLE"®

SEE US AT AGMA GEAR EXPO BOOTH #230 **CIRCLE 140**

Thermal Effects on CMMs

Understanding their causes can improve your precision measurement equipment efficiency.

David Genest

The trend toward moving coordinate measuring machines to the shop floor to become an integral part of the manufacturing operation brings real time process control within the reach of many companies. Putting measuring machines on the shop floor, however, subjects them to harsh environmental conditions. Like any measuring system, CMMs are sensitive to any ambient condition that deviates from the "perfect" conditions of the metrology lab.

Of all the conditions on the shop floor that affect CMM repeatability, temperature has the most dramatic effect. That's because, according to international standards established in 1931, objects only have their correct size at 20°C. This is a matter of politics, not physics, and this standard was chosen by international agreement to ensure that measurements made in one country would agree with those made in another. It stands to reason then that for the highest measurement accuracy, the workpiece and CMM should be at that temperature. At temperatures other than 20°C, thermal expansion of the workpiece and CMM causes errors that can be difficult to correct.

Are there ways to minimize the effects of temperature on measurement? That depends upon a number of factors including workpiece tolerances, degree of acceptable total measurement error and how much of that total can be budgeted for thermal effects, and how much temperature control is necessary to keep thermal effects at an acceptable level. However, by understanding the concepts of *differential* expansion, temperature gradients and temperature variation, the problem and challenge of thermal effects become more manageable.

Differential Expansion

A coordinate measuring machine compares the distance between the locations of probe hits on a workpiece with corresponding distances on scales attached to each axis of the CMM. The corresponding length on the scale is determined by means of an encoder which counts the lines on the scale as the machine moves the probe from one hit position to another.

If the dimensions of a workpiece, or for that matter, the stated accuracy of the CMM, are correct only when they are at 20° C, how is it possible to accurately measure dimensions at any other temperature? The answer is that corrections in the measurement data have to be made that take into account both the effects of the temperature differences between the part and the ideal 20° C environment and between the part and the CMM.

Temperature compensation is a means of correcting measurement errors caused by temperature effects. Compensation can be either manual or automatic, depending on computing power and the software being used. With automatic systems, software-based adjustments are made to measurements according to sensed temperature fluctuations in key locations of the CMM's structure and the air surrounding the machine. Some advanced systems also include probes to detect part temperature variations with an additional compensation value factored into the machine and ambient conditions. With manual compensation, prior to taking measurements, the machine operator takes readings of the temperature of the

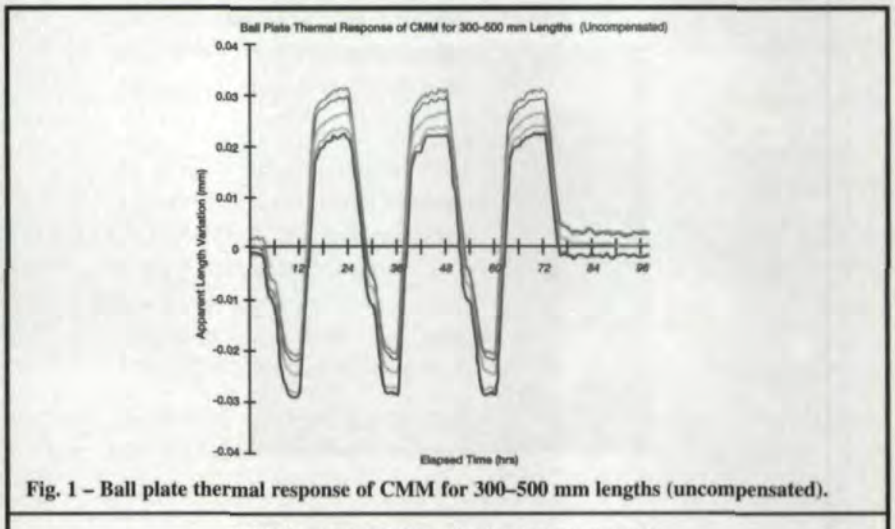


Fig. 1 – Ball plate thermal response of CMM for 300–500 mm lengths (uncompensated).

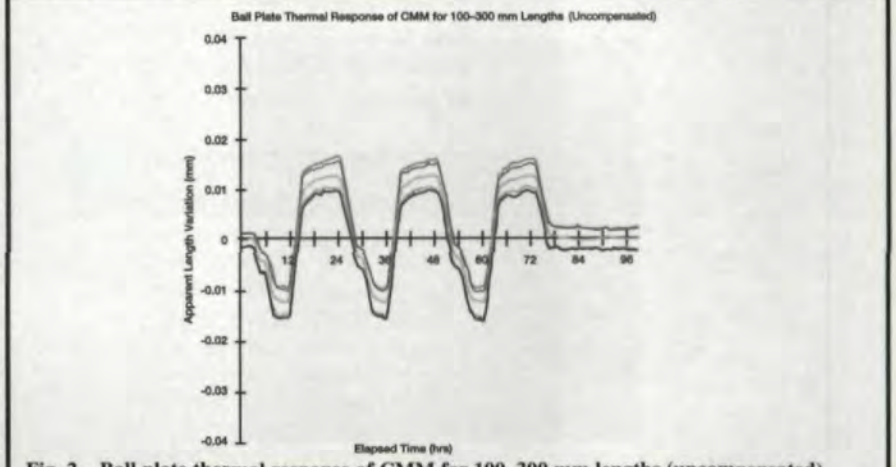


Fig. 2 – Ball plate thermal response of CMM for 100–300 mm lengths (uncompensated).

CMM's axes, the workpiece and the surrounding air and enters them into the software program for compensation.

Compensation does not allow the same degree of accuracy as in a controlled environment. The uncertainty of measurement increases as the temperature deviates from 20° C.

Nearly all materials expand when their temperatures increase. The amount of expansion, called the coefficient of thermal expansion, varies for each material, but tends to be the same for similar families of materials. This is called Nominal Differential Expansion (NDE). For example, in the case of a coordinate measuring machine, if the workpiece is steel and the scale is steel, they theoretically expand at the same rate, canceling out any measuring error. If the workpiece is aluminum, however, it expands faster than the steel scale. This uncertainty between the CMM scale and the workpiece is called Uncertainty of Nominal Differential Expansion (UNDE).

Differential expansion can be somewhat compensated for by subtracting scale expansion from workpiece expansion to determine the magnitude of the error. In effect, this is what temperature compensation software routines do. However, values for the coefficients of expansion are general, not exact. Actual rates of expansion that occur in practice and the value found in textbooks can vary as much as ± 10%. These variations are caused by workpiece geometry, exposed surface area, cross sectional area and variations in the microstructure as a result of processing.

The best current method for assessing the influence of the thermal environment on dimensional measurement is specified by ANSI/ASME Standard B89.6.2, "Temperature and Humidity Environments for Dimensional Inspection." It combines the calculation of the NDE of the CMM and the workpiece with the consequence of the UNDE and an observed temperature variation error (TVE). TVE is determined through a "drift test" where the measurement of a single object is repeated over an extended period with the center of the object plotted with respect to time.

Thermal Gradients

Other causes of measurement uncertainty are the effects of thermal gradients. Any change of temperature in the room where the CMM is located changes the dimensions of the machine structure. The same happens with the workpiece. Changes in temperature immediately surrounding the machine are called thermal gradients, and they cause different expansions in different parts of the machine and the workpiece.

Rapid temperature changes in the same direction for a long period of time cause the most errors. Large, rapid changes often occur on a shop floor because of ambient temperature differences between morning and afternoon. These large, rapid changes cause thin sections of the machine or workpiece to change temperature more quickly than thick parts, creating bending.

If air temperature cycles rapidly, due to air conditioning, for example, there is less time for heat to flow into the machine or workpiece before it has to flow out again. Gradients are close to the surface, and machine bending is minimized.

The goal in any CMM operation is to eliminate the effect of thermal gradients

GRIND

SAMPUTENSILI

THE SU FORM GEAR GRINDER, TYPE RI370 CNC

is specifically designed to offer the highest flexibility.Thanks to its on board wheel dressing capability it is also extremely simple to produce any desired profile without wheel changes. Further you can also inspect the work on the machine.

If you need to grind a worm, an internal gear, a shoulder gear or a spline, please contact us and we'll be happy to assist you with an application study.

AT SU YOU CAN CHOOSE THE FINISH!

HERE WE ARE!

In response to a large demand, SU is now offering shaving cutters made in the USA. From Michigan, you can receive your quality tools built to your specifications. Our staff is available to design the most suited tools for your application. *And of course... **no engineering charge!***

We also continue to offer the fastest and most economical regrind service.

The highest quality is assured.

See us at AGMA Gear Expo booth #214

SHAVE

MEMBER OF AGMA

CIRCLE 107

For detailed information please contact:

SAMPUTENSILI

SU America, inc.
8775 Capital Ave.
Oak Park, MI 48237
Ph: 248/548-7177 Fax: 248/548-4443
E-mail: usasu@concentric.net

The "Stimulated Response" Test For Measurement Uncertainty

The conflict resulting from the movement of coordinate measuring machines to the shop floor and thermally induced measurement errors has led to a variety of claimed solutions using mathematical compensation techniques, thermally insensitive machine components and localized temperature control methods. The best current method for assessing the influence of temperature on dimensional measurement is specified by the ANSI/ASME Standard B89.6.2.

However, extensive laboratory testing at Brown & Sharpe and shop floor experience with customers indicates that this method can be enhanced to provide more realistic estimates of shop floor accuracy degradation that results from thermal influences. First, the drift test evaluates the response of a CMM to its current environment, but does not provide a sensible way to make quantitative predictions about instrument behavior in an unknown, loosely specified environment like that found in most shops. Also, during an actual drift test, a real environment is unlikely to exhibit the full range of thermal behavior allowed by a specification, only the overall temperature range and a few rates of change. It is not easy for the ultimate user of the CMM to verify how well the machine will perform under a specified range of thermal conditions. Second, the thermal response of a CMM measuring a workpiece is highly dependent on both the workpiece thermal characteristics and the specific geometric quantity being measured.

To better address these concerns, Brown & Sharpe is proposing a new testing method call the "stimulated response" test. To stimulate thermal effects in the CMM and workpiece, the test uses a specific environmental temperature profile as a function of time to get typical shop floor results. By standardizing this profile, it is possible to compare the results from many different machines using different compensation techniques to handle temperature effects. The second feature of the test is the use of a simple artifact as a substitute workpiece, and to specify the measurement sequence to be used. This eliminates the ambiguity of the results from real workpieces and allows sensible comparative studies. The third feature is a single method of analyzing and presenting measurement data that graphically gives a realistic estimate of dimensional measurement uncertainty due to poor thermal environment.

A common test methodology like this provides a means for quantitative comparison of new technical approaches to control thermal effects, including studies into new structural materials, use of self-compensating structures and composites and thermal compensation mathematics. A well-designed, easily understood test will reduce confusion among CMM users and can serve as a vehicle to clarify the practical consequences of thermal effects.

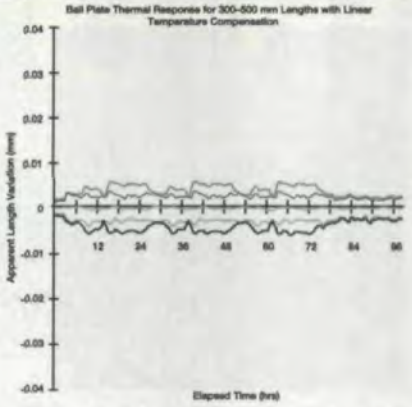


Fig. 3 – Ball plate thermal response for 300–500 mm lengths with linear temperature compensation.

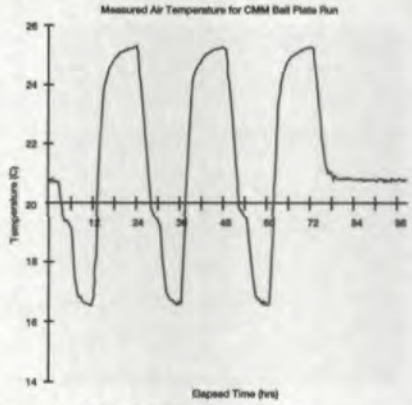


Fig. 4 – Measured air temperature for CMM ball plate run.

on measuring performance. One way to accomplish this is to provide constant air turnover in the room housing the CMM. The effect of thermal gradients can be virtually eliminated in rooms where the air flow rate completely changes the room air every minute. Another good idea is to allow the part to "soak" at the machine's ambient temperature so that its temperature is close to that of the machine. Both of these techniques help minimize UNDE and improve measurement accuracy.

Temperature Compensation

The uncertainties of thermal effects make complete, accurate compensation virtually impossible. Coordinate measuring machine manufacturers conduct tests that show how well a particular machine can compensate for changes in ambient temperature. However, due to there being an infinite variety of thermal conditions that can be encountered on the shop floor, not all types of tests give a complete picture of the true effects of temperature changes. Brown & Sharpe has undertaken the development of a standard thermal effects test that should prove to be an accurate and easily comparable method that can show how coordinate measuring machines respond to changes in workplace temperature. (See sidebar.)

The effects of temperature will always have a role in metrology. Although there are ways to control those effects, whether by special temperature compensation methods or enclosures that reduce temperature gradients, there is currently no way to avoid them completely. Understanding how temperature-induced errors are caused, however, can help minimize their influence on precision measurement.

Acknowledgement: *Reprinted from Vol. 4, Issue 2 of* mfg., *Brown & Sharpe's publication of precision manufacturing.*

David Genest
is Director of Marketing & Corporate Communications for Brown & Sharpe.

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.

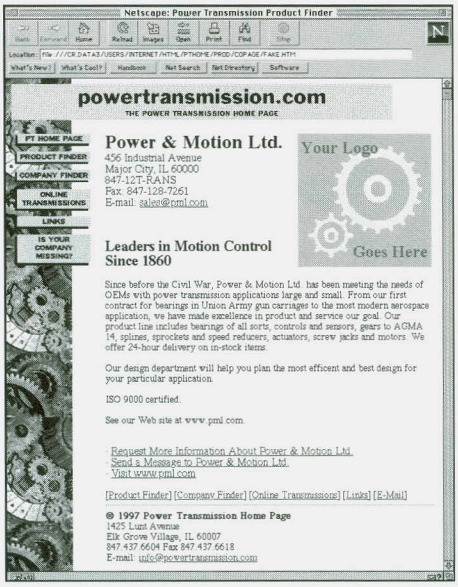
Advertiser	Page No.	Reader Service No.
AGMA	36, 61	125, 166
Ajax Magnathermic	63	117
Allied Gear Co.	70	193
Amarillo Gear	27	183
American Metal Treating Co.	70	174
American Wera	14	197
ATA Gears Ltd.	42	139
Ataka Engineering	69	148
A/W Systems	16	105
Barit International	36	175
Basic Incorporated Group (Wolf)	51	111
Bourn & Koch Machine Tool Co.	48	154
Chamfermatic, Inc.	45	171
Colonial Saw Co.	68	142
Colonial Tool Group	62, 63	184, 185, 186
Crown Gear B.V.	45	167
Diamonex Diamond Films	24	144
D.I.G.I.T.	63, 65	156, 157
Dr. Kaiser (S. L. Munson)	13	103
Dura-Bar	59, 62	158, 187
Emuge Corp.	4	130
Euro-Tech	40	147
Fässler A.G.	34, 63	135,190
Forest City Gear	IBC	138
Gardner Environmental	26, 62	141,189
Gleason/Pfauter	IFC, 1	100
Global Gear	50	136
Great Gear Corp., Taiwan	48	195
Holroyd	66	121
Ikegai America	58	124
ITW Heartland	15	110
Kapp Tech	52	145
Koepfer America, L.L.C.	14	116
Koro Sharpening Service	70	192
LeCount Inc.	55	112
Lemur Enterprises	30	198
LMT-Fette	10, 62	104,188
Lorenz (Liebherr/Sigma-Pool)	8	126
M & M Precision Systems, Inc.	38-9	140
Mahr Corp.	12, 63	122,194
Manufactured Gear & Gage	37,62	164,169
Midwest Gear & Tool	64	113
Midwest Gear Corp.	70	173
Mitsubishi	31	109
Moore Products	5, 63	106, 162
National Broach & Machine	6, 62	114,160
Niagara Gear	62, 67	152, 151
Normac, Inc.	35, 63	120,191
Nye Lubricants	50	170
Parker Industries	55, 64	168,127
Perry Technology	12	146
Pfauter-Maag Cutting Tools	BOC, 70	102,177
Presrite Corp.	21	108
Profile Engineering	17	133
Pro-Gear Co., Inc.	70	180
Purdy Corp.	37	150
Reishauer Corp.	49	165
Roto-Technology, Inc.	40	161
Schunk, Inc.	65	153
Shin-Shin Enterprise Corp.	61	172
Speed Grip Chuck, Inc.	30	159
Starcut Sales	2	128
SU America	43	107
United Tool Supply	69	155
Walker Forge	49	149

WHO'S BEEN HIT 20,000 TIMES

AND IS STILL READY FOR MORE?

The 200 companies on

powertransmission.com™



Call Ed Mueller at 847-437-6604
to find out how your company can get hit for free.

http://www.powertransmission.com

We've got the Internet presence you want.

SEE US AT AGMA GEAR EXPO BOOTH #418

Structural Analysis of Asymmetrical Teeth: Reduction of Size and Weight

G. Di Francesco & S. Marini

Abstract

The present article contains a preliminary description of studies carried out by the authors with a view toward developing asymmetrical gear teeth. Then a comparison between numerous symmetrical and asymmetrical tooth stress fields under the same modular conditions follows. This leads to the formulation of a rule for similar modules governing variations of stress fields, depending on the pressure angle of the non-active side. Finally a procedure allowing for calculations of percentage reductions of asymmetrical tooth modules with respect to corresponding symmetrical teeth, maximum ideal stress being equal, is proposed. Then the consequent reductions in size and weight of asymmetrical teeth are assessed.

Introduction

In a paper read at the 24th Annual Italian Association for Stress Analysis (AIAS) Convention (Ref. 1), a geometrical formula for a new type of tooth was presented; this formula is characterised by the fact that the two sides of the tooth have different forms.

The teeth proposed have an asymmetrical form. The two sides of each tooth are characterized by profiles with different pressure angles. These teeth prove useful in mechanisms where the forces employed during rotation in one direction are greater than those engaged in rotation in the opposite one.

The difference of form is obtained by adopting different reference pressure angles ($\alpha_{01} \neq \alpha_{02}$) for the two sides of a tooth.

At a later stage (Ref. 2), in order to compare this new form with the traditional one, a structural analysis using finite elements was carried out; in this study, given the complexity of asymmetrical profiles, it became necessary to devise a specific and totally automatic finite element mesh program. This permitted numerous structural checks covering a broad spectrum of cases and a heterogeneous selection of tooth contours.

All other factors being equal and comparing the results for teeth having different α_{02} values, it appears evident that structural strength increases with the increase of the aforementioned angles.

This implies that in the presence of equal maximum ideal stresses at the root of the teeth, it is possible to create asymmetrically toothed wheels of smaller dimensions with a decrease in weight and bulk, not only of the gear wheels themselves, but also of their boxes and housings.

SYMBOLS

The following symbols, based on those recommended by ISO/R 701 (UNI 6773) for notations pertaining to gears, shall be used in the present paper:

m_0	reference module
m_{0a}	reference module in asymmetrical tooth
G_a	weight of asymmetrical tooth
G_0	weight of symmetrical tooth
α_{01}, α_{02}	reference pressure angle of the grip side, during rotation in preferential and non-preferential directions.
$\sigma_{i\,max}$	maximum ideal stress in symmetrical tooth
σ_{imaxa}	maximum ideal stress in asymmetrical tooth
$\Delta\alpha_0$	$\alpha_{01} - \alpha_{02}$

In Ref. 2 variations of stress fields regarding α_{02} were calculated. The maximum ideal stress, σ_{imax}, corresponding to the mesh's uppermost element, was taken into account; then the value for σ_{imax} under the same load and using the same module was compared.

The Law of Stress Field Variation for Similar Modules

Keeping in mind the conclusions of the aforementioned studies, the present work aimed at carrying out automated structural analyses of numerous asymmetrical tooth profiles. Then a comparison between these and corresponding symmetrical teeth, having similar modules, was carried out.

The outcome of this thorough investigation confirmed the hypothesis that increases in α_{02} led to a diminution in σ_{imax} values; inversely, diminishing α_{02} led to increases in σ_{imax} values.

The diminution of σ_{imax}, with $\alpha_{02} > \alpha_{01}$ is essentially due to an increase in the section close to the internal root contact area. On the basis of this, it is interesting to seek a generally applicable mathematical relationship between $\Delta\sigma_{imax}$ % and $\Delta\alpha_0$, where $\Delta\sigma_{imax}\% = (\sigma_{imaxa} - \sigma_{imax})100/\sigma_{imax}$.

From the results obtained by carrying out numerous comparisons, it emerged that highly accurate variations of $\Delta\sigma_{imax}$ % related to $\Delta\alpha_0$ are obtained by applying the following formula:

$$\Delta\sigma_{imax}\% = \psi\Delta\alpha_0 - \zeta\Delta\alpha_0^2 \quad (1)$$

where ψ and ζ are two coefficients obtained by interpolating the numerous results obtained for external spur gears.

The relationship described in Eq. 1 is general; it permits us, without carrying

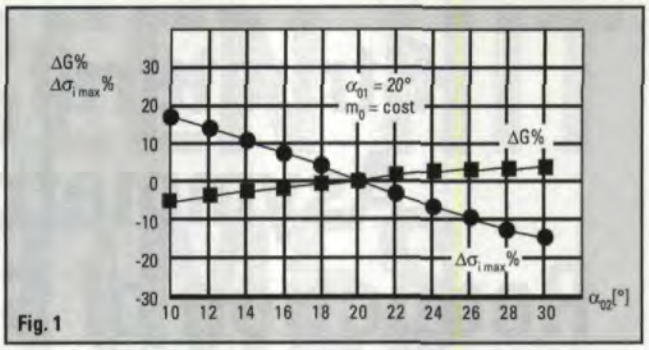


Fig. 1

out structural analyses, to establish readily stress field variations for every kind of asymmetrical tooth in relation to a corresponding symmetrical one.

Establishment of Reduced Modules in the Presence of Identical Maximum Ideal Stress

On the basis of the results thus obtained, it has been noted that, in the presence of identical modules, the diminution of maximum ideal stress in a tooth having $\alpha_{02} > \alpha_{01}$ is greater in terms of percent than the corresponding increase in weight.

Fig. 1 illustrates trends in the presence of identical modules and of α_{01} for $\Delta\sigma_{imax}$ % and for $\Delta G\% = [(G_a - G_0)/G_0]100$ where $\alpha_{02} = \Delta\alpha_0 + \alpha_{01}$.

When $\alpha_{02} = 30°$ (that is for $\Delta\alpha_0 = \alpha_{02} - \alpha_{01} = 10°$), $\Delta\sigma_{imax}$ % = –15.2 over an increase in $\Delta G\%$ weight = 2.54; therefore only a slight increase in weight is required to obtain a considerable reduction of the stress field at the tooth root.

On the basis of Fig. 1 we could see that maximum ideal stress being equal for both the symmetrical and asymmetrical teeth, it was possible to create asymmetrical $\alpha_{02} > \alpha_{01}$ teeth far lighter than traditional ones.

It was therefore important to study the possibility of obtaining, at identical maximum ideal stress rates, asymmetrical teeth smaller (smaller module) and lighter than corresponding symmetrical ones.

The possibility of quickly and precisely calculating smaller m_{0a} modules having $\alpha_{02} > \alpha_{01}$ tooth and maximum ideal stress equal to that of a conventionally profiled tooth, was then tested under the same load conditions, that is, applying the same quantity of force.

This second state was devoted to seeking a calculation system capable of establishing m_{0a} modules having $\alpha_{02} > \alpha_{01}$ in the presence of identical maximum ideal stress and identical load.

On the basis of the numerous cases studied, it appeared possible to calculate with a high degree of accuracy asymmetrical tooth m_{0a} modules. This was done by departing from the conventional tooth m_0 module value. This m_0 module value is reduced according to the relationship described in Ref. 1 by a percentage value equal to the reduction of the $\Delta\sigma_{imax}$ % value. It is, therefore, possible to apply, with a high degree of accuracy, the following relational formula:

$$\Delta m_0\% = \Delta\sigma_{imax}\ \%$$

where

$\Delta m_0\% = (m_{0a} - m_0)\ 100/m_0$.

As $\Delta\sigma_{imax}$ % can be unequivocally established on the basis of a chosen $\Delta\alpha_0$ value, it is thus possible to

calculate, according to the relationship obtained, the value for m_{0a}, when the m_0 reference module is known.

The calculation methodology developed required the introduction of an index, definable as the I_a "asymmetry index," which can be calculated on the basis of the following simple relational equation:

$$I_a = \psi\Delta\alpha_0 - \zeta\Delta\alpha_0^2 \quad (2)$$

The I_a index allows for ready calculation of reduced m_{oa} asymmetrical $\alpha_{02} > \alpha_{01}$ tooth modules, departing from the conventional tooth m_0 module:

$$m_{0a} = m_0 (1 + I_a / 100) \quad (3)$$

where I_a is derived from Eq. 2.

Eq. 3 was also tested by carrying out numerous comparisons between traditional and asymmetrical teeth. For every pair of teeth—one symmetrical and one asymmetrical tooth based on Eq. 3—the maximum ideal stress values, calculated using automated structural analysis, were compared. The difference between these maximum ideal stress values always stood at about 1% and never topped 2%.

Summing up, at the present stage of development, in order to calculate the size of an asymmetrical tooth, one may proceed as follows. It is possible to begin from the size of a traditional symmetrical tooth. Using the usual calculation procedures, the m_0 module is estimated. Then one must choose a value for $\alpha_{02} > \alpha_{01}$ compatible with the final geometrical characteristics desired.

By applying Eq. 3, it is possible to calculate the m_{0a} module value for the asymmetrical tooth.

The above applies in the presence of equal force loads being brought to bear upon the symmetrical and asymmetrical teeth.

At this point it may be of interest to verify the degree of weight reduction applicable on the basis of the reduced module obtained by applying $\alpha_{02} > \alpha_{01}$.

In the graphs in Fig. 2 the values for $\Delta G\%$ related to α_{02}, for identical α_{01} values, and for maximum ideal stress at a constant within the ranges described above (±2%), this in the following two cases: α_{01} = 17°30' and α_{01} = 20°.

In the case of α_{01} = 17°30', for α_{02} = 30° (that is $\Delta\alpha_0$ = 12°30'), the weight

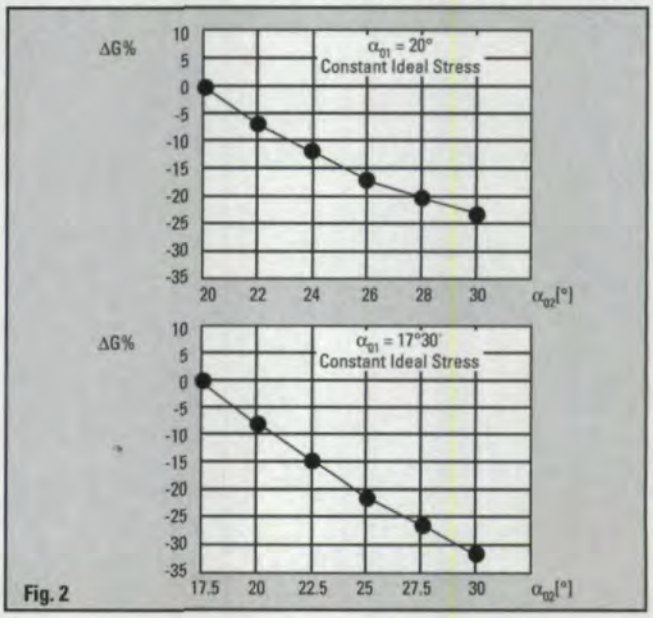


Fig. 2

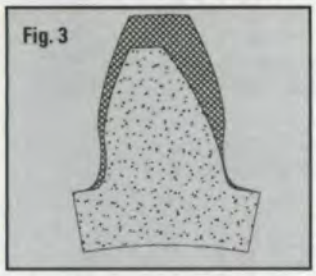


Fig. 3

reduction obtained is over 30%; in this particular case the $\sigma_{imax\ a}$ value was 1% lower than that for the symmetrical tooth.

In Fig. 3, a traditional and an asymmetrical tooth in identical maximum ideal stress condition are shown. For both $\alpha_{01} = 17°30'$, the number of teeth is 20; furthermore $m_0 = 2$ mm, $m_{0a} = 1.63$ mm.

It emerges from this figure that, in the presence of identical maximum ideal stress, it is more economical to use asymmetrical rather than traditional symmetrical teeth.

Conclusions

In the light of these considerations it appears evident that, in cases where weight reduction is the primary need, the application of $\alpha_{02} > \alpha_{01}$ teeth leads to noteworthy results and shows the undeniable benefits of adopting teeth with non-conventional profiles.

At this stage the structural analysis and the entire study might stop here, were it not for the fact that the reduction of the module (adopted to achieve the same state of stress in the presence of identical load) involves a corresponding reduction of the diameter of the gear wheel, a reduction which, under conditions of identical normal force, leads to a reduction of the transmitted torque. The two gears, conventional and asymmetrical, while equivalent from a structural point of view, are not from the point of view of the transmitted torques. It is interesting to note how the reduction of the transmitted torque, which, as is known, is equal in terms of percent to the reduction of the tooth module, is also lighter in weight. It is therefore possible to create teeth having $\alpha_{02} > \alpha_{01}$ and smaller modules, capable of transmitting the same torque as traditional teeth, although their size is smaller. With this in mind the authors are carrying out a specific study for the calculation of m_{0a} modules having the same transmitted torques. ✪

References:

1. Di Francesco, G. and S. Marini: "Ruote Dentate Caratterizzate da Denti a Profilo Asimmetrico." XXIV Convegno AIAS, Parma, 1995.
2. G. Di Francesco, S. Marini: "Structural Analysis of Tooth Having an Asymmetrical Winding Profile." International Conference on Material Engineering, Gallipoli, 1996.
3. Di Francesco, G. et al. "Calculation of the Maximum Bending Stress at the Tooth Root Through an Analytic and Graphic Identification of the Resisting Sections, and Comparison of Their Respective Stress Values." ICED '90 (International Conference on Engineering Design), Dubrovnik, 1990.
4. Di Francesco, G. "Analisi delle Sollecitazioni su Denti di Ruote per Unità Idrostatiche ad Ingranaggi. Espressione Analitica Delle Tensioni al Piede dei Denti." Il Progettista Industriale, *Tecniche Nuove*, Gennaio-Febbraio, 1985.
5. Castellani, G. and V. Parenti Castelli. "Rating Gear Strength." *Transactions*, ASME, April, 1981.
6. Dudley, D. W. *Gear Handbook*. McGraw-Hill, New York, 1962.
7. Henriot, G. *Traité Théorique et Pratique des Engrenages*. Dunod, Paris, 1975.

Dr. G. Di Francesco
is on the faculty of the Dept. of Mechanical and Industrial Engineering of the University of Rome.

Prof. S. Marini
is also on the mechanical engineering faculty at the University of Rome.

Tell Us What You Think ...
If you found this article of interest and/or useful, please circle **212.**

Brain Time

Machines, Tools and Technologies from

KAPP, KAPP TECH and NILES

Efficient Solutions for Hard Gear and Profile Finishing

Visit Us At The AGMA GEAR EXPO 97
Booth 144

KAPP Sales & Service L.P.

2870 Wilderness Place Boulder, Colorado USA Phone (303) 938-9737 FAX (303) 447-1131

CIRCLE 145

The Geometry of Helical Mesh

William C. Smith

Introduction

In 1961 I presented a paper, "Calculating Conjugate Helical Forms," at the semi-annual meeting of the American Gear Manufacturers Association (AGMA). Since that time, thousands of hobs, shaper cutters and other meshing parts have been designed on the basis of the equations presented in that paper. This article presents the math of that paper without the formality of its development and goes on to discuss its practical application.

Most gearing texts quickly get through the fundamental law of gear tooth action and start concentrating on the involute. While involute geometry is undeniably the most important aspect of modern gearing, it will be useful to examine the general geometry of parts in mesh with each other in order to understand the generating process for involute gears, straight-sided splines, impeller rotors, sprockets and any other toothed form that runs with a mate or that is hobbed, shaped, ground or shaved. The math presented here is applicable to any toothed form, internal or external, meshing on either parallel axes or crossed axes. This article intends to explore:

1. How to calculate a mating form to mesh with any known form.
2. How to overcome calculation problems in computer-generated forms.
3. How the fundamental law of gear tooth action applies to crossed-axis gearing.
4. How to calculate the path of contact in three dimensions.
5. Why generated forms may have unwanted "fill-in" and "round-over."
6. How to use mesh math to solve common design and manufacturing problems.

The math in this article may be used directly without having an understanding of underlying concepts. However, it is based on a theorem and its corollary, both of which are so simple in concept that they can be understood without vigorous proof:

Theorem A. To assure conjugate action between a helical form and a rack, the surfaces of these forms should come into contact along a single line when placed in stationary mesh.

Corollary. If each of two helical forms in stationary mesh with each other makes line contact with the opposite surfaces of an infinitesimally thin rack form inserted between them, the helical forms will have conjugate action with each other.

The term "line" is used in the gearing sense—actually a curve in space, single-valued in x, y and z. Only in involute gearing does this curve resolve to a straight line. The term "conjugate" means meshing with on-going contact at a constant velocity ratio. Using this theorem reduces a dynamic analysis to a static one.

Understanding Theorem A Without Heavy Math

Consider a helical gear in stationary mesh with a rack. (This could be any rack and gear, but, for simplicity, make it an involute rack and gear.)

Mentally mark a reference axial position where a transverse cross section of the gear contains the gear tooth and rack tooth in contact at the pitch point. (The common contact line for Theorem A is a segment of the involute generatrix passing through this point. The generatrix is the straight line that unwinds from the base helix like a taut string and generates the involute tooth surface.)

Now rotate the gear through a small angle, driving the rack with it. Move the transverse cross section axially to a new reference position where the same gear tooth and rack tooth are again in contact at the pitch point.

Obviously, everything about this new configuration in the vicinity of the pitch point is indistinguishable from the previous configuration, which indicates that as the gear rotates, the shape of the contact line remains unchanged, but traverses along the rack elements as the mesh advances.

Therefore, without ever rotating the gear, we know that conjugate action would occur with the rack if we did rotate it.

By using the corollary to Theorem A, we can determine the form of a second gear meshing conjugately with a given gear without considering any rotational aspect.

TABLE I — GLOSSARY

Angle Between Axes — For two gears in mesh, this is the algebraic sum of the two helix angles.

Array — The collection of coordinate points that describe a form.

Helix Angle — The angle between the gear axis and any rack element. The helix angle has the same sign as the lead. The rack element that contacts the gear at the pitch point is tangent to the helix of the gear at its pitch radius.

Lead — The axial advance in tracing any helix of a gear tooth through 360°. By convention a left-hand lead is negative.

Line-Arc Geometry — A form made up of a series of arcs and/or lines all connected end to end.

Normal — As an adjective: being at right angles. As a noun: a straight line perpendicular to a surface.

Normal Circular Pitch — The normal distance from a rack element on one rack tooth to a similar element on the adjacent rack tooth.

Pitch Point — The tangent point viewed in the transverse plane of the gear where a circle on the gear (Gear Pitch Circle) rolls without slipping along a line on the rack (Rack Pitch Line).

Rack Element — For a rack constrained to move in a horizontal plane, any straight horizontal line on the rack surface.

Slope — The tangent of the slope angle.

Slope Angle — The angle from the positive X axis to a line that is tangent to a form at a given point.

Spur Part — A gear or other toothed part that has a helix angle of zero.

TABLE II — SYMBOLS

Known part lead	L	Left hand is negative
Mating part lead	L'	Left hand is negative
Known part number of teeth	N	
Mating part number of teeth	N'	
Known part pitch radius	R	
Mating part pitch radius	R'	
Known part helix angle	α	Left hand is negative
Mating part helix angle	β	Left hand is negative
Multiplier 1	IK	-1 if either part is internal, else +1
Multiplier 2	IM	-1 if mating part is internal, else +1
Angle between axes	Σ	
Center distance	C	
Normal circular pitch	P	
Input coordinates	xt, yt	Known form defined in transverse plane
Slope at xt,yt	st	
Output coordinates	xr'', yr''	Rack form
	xt', yt'	Mating form in its transverse plane
	za', ya'	Mating form in its axial plane
	xc'', yc'', zc''	Path of contact in rack axis system
	xc, yc, zc	Path of contact in known part axis system
	xc', yc', zc'	Path of contact in mating part axis system

TABLE III — STANDARD EQUATIONS

$P = \pi/\text{Normal Diametral Pitch}$ ..... (1)

$R = P \cdot N/(2 \cdot \pi \cdot \cos\alpha)$ ..... (2)

$R' = P \cdot N'/(2 \cdot \pi \cdot \cos\beta)$ ..... (3)

$L' = (2 \cdot \pi \cdot R \cdot N'/N) \cdot \cos\alpha/\sin\beta$ ..... (4)

$L' = IK \cdot (2 \cdot \pi \cdot R \cdot N'/N)/(\sin\Sigma - (2 \cdot \pi \cdot R/L) \cdot \cos\Sigma)$ ..... (4.1)

$\alpha = \arctan(2 \cdot \pi \cdot R/L)$ ..... (5)

$\beta = \arctan(2 \cdot \pi \cdot R'/L')$ ..... (6)

$\Sigma = \alpha + \beta \cdot IK$ ..... (7)

$C = IM \cdot (R + IK \cdot R')$ ..... (8)

Note 1: Equation 8 is for a standard center distance. However, the pitch cylinders of two gears in mesh at crossed axes may be tangent to each other, intersect or not meet at all, so C can vary from this calculation.

Note 2: R' in Equation 3 is not used in the mathematical form development equations, and since β and C are usually determined by external requirements, R' is mainly an informational quantity.

Note 3: The lead of a spur gear is infinite. For computer purposes, the lead of a spur gear may be entered as zero, which the computer program can use as a code to actually make $1/L$ equal to zero. By the same token, the solution for $1/L'$ instead of L' (Equation 4) is usually made when calculating by computer. This avoids operations with infinity, which result in computer error.

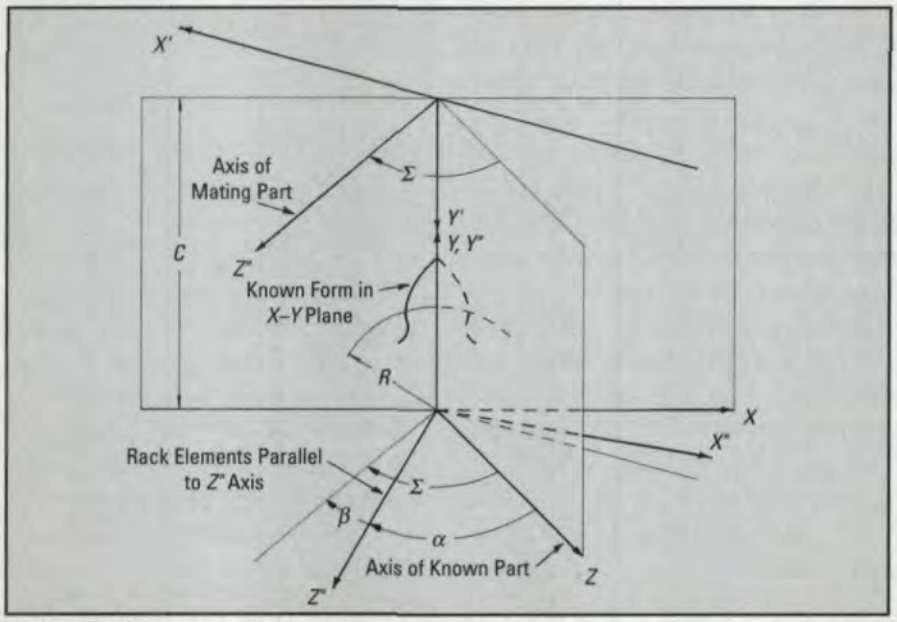


Fig. 1 — The three coordinate axis systems.

Part I—The Math of Mesh

Parallel-axis gearing and crossed-axis gearing differ in that two helical forms in mesh on crossed axes make only point contact, while two forms in mesh on parallel axes make line contact. This math is applicable in both cases, including spur forms.

For the purposes of this article, the form of the known part is assumed to be in its transverse plane (plane of rotation). We choose the transverse plane because it will accommodate all gears from spurs to worms. A spur form cannot be defined in the axial plane.

The form is expressed as a series of coordinate points with associated slope (xt, yt, st). All of these xt, yt points taken together are referred to as the xt, yt array. In practice, of course, the form may begin by being defined (by line-arc geometry for example) in some other cutting plane and cranked along the helix by some utility computer program to the transverse plane in point-slope format. It is a fairly simple procedure to pick both points and slopes from forms defined by line-arc geometry. To keep our definitions straight, note that the known part form is the input form, and the mating part form is the output form.

Fig. 1 shows the three coordinate systems used in this math. X, Y, Z is the system for the known part where Z is the part axis, and the X-Y plane is the transverse plane of the known part. X', Y', Z' is the system for the mating part where Z' is the axis of the mating part. The rack occupies the X'', Y'', Z'' system where Z'' is parallel to the rack elements. Note the glossary of terms in Table I, the symbol definitions in Table II and the standard equations in Table III. The standard equations provide a means for deriving various parameters from other known parameters. The helix angle of the known part is α; that of the mating part is β, and Σ is the angle between the axis of the known part and the axis of the mating part. In Fig. 1, α and β are both illustrated as positive angles, which for this case means both the known part and the mating part have right hand leads and helix angles. The center distance between the known part and the mating part is C. The number of teeth in the known part is N, and N' is the number

of teeth in the mating part. The lead of the known part is L, and L' is the lead of the mating part. Two unit multipliers, IK and IM, provide required sign changes when either of the parts is internal. The pitch radius of the known part, R, may have any value that lies within the framework of the standard equations and that is large enough to keep Equation 11 from becoming the square root of a negative number. It is often chosen so that the pressure angle of the mating part stays above some minimum value. The sign convention of the axis systems allow the output form geometry to be fed back directly as input form geometry.

$$\phi = \arctan(1/st) \quad (9)$$

$$v = xt \bullet \sin\phi + yt \bullet \cos\phi \quad (10)$$

$$q = \sqrt{R \bullet R - v \bullet v} \quad (11)$$

$$x2 = v \bullet \sin\phi \pm q \bullet \cos\phi \quad (12)$$

$$y2 = v \bullet \cos\phi \mp q \bullet \sin\phi \quad (13)$$

$$\Theta = \arctan(x2/y2) \quad (14)$$

$$xk = xt \bullet \cos\Theta - yt \bullet \sin\Theta \quad (15)$$

$$yk = xt \bullet \sin\Theta + yt \bullet \cos\Theta \quad (16)$$

$$zk = .5 \bullet L \bullet \Theta/\pi \quad (17)$$

$$xr = xk + R \bullet \Theta \quad (18)$$

$$yr = yk \quad (19)$$

$$xr'' = xr \bullet \cos\alpha \quad (20)$$

$$yr'' = yr \quad (21)$$

In the X-Y plane, $x2$, $y2$ is a point where the normal to the form at the point xt, yt intersects the pitch circle. Since any line that intersects a circle has two intersection points, $x2$, $y2$ has two possible positions as determined by the ± sign. Both of these positions are valid, but only one applies to the application at hand. In most cases, the non-applicable root applies if you change the space into a tooth and the tooth into a space.

In Part II we will discuss selection of roots and root tracking.

In the known part axis system (X, Y, Z), xk, yk, zk is a point where the known form contacts the rack form when placed in stationary mesh in accordance with Theorem A.

Point xr, yr is on the rack as seen in the X–Y plane.

Point xr'', yr'' is on the rack in the rack's own X''–Y'' plane. The xr'', yr'' array defines the complete rack form.

$$ym' = C \bullet IM - yr \quad (22)$$

$$xm' = (IK \bullet R \bullet N'/N - ym' \bullet \cos\beta/\cos\alpha)/\tan(\phi - \Theta) \quad (23)$$

$zm' = IK \bullet (-xr'' - xm' \bullet \cos\beta)/\sin\beta$ ....(24)

$\tau = \arctan(xm'/ym') - (xm' \bullet \cos\beta/\cos\alpha + xr) \bullet IK \bullet N/(R \bullet N')$ ....(25)

$za' = IK \bullet \tau \bullet .5 \bullet L'/\pi$ ....(26)

$ya' = \sqrt{xm' \bullet xm' + ym' \bullet ym'}$ ....(27)

$xt' = IK \bullet ya' \bullet \sin\tau$ ....(28)

$yt' = IK \bullet ya' \bullet \cos\tau$ ....(29)

The transverse pressure angle of the known part at the point of contact with the rack is $(\phi - \Theta)$. Point xm', ym', zm' is in the mating part axis system (X', Y', Z'), where the mating form contacts the rack form when placed in stationary mesh in accordance with the corollary to The-orem A. This same point cranked along the helix to the transverse plane of the mating part is xt', yt'. Cranked along the helix to the axial plane of the mating part, it is za', ya'. This math works even when the mating part is a spur form. In this case, calculations for ya', xt' and yt' are valid, but za' in Equation 26 goes to infinity. For this reason, the xt', yt' array should be considered the primary definition of the output form.

Note that Equations 17 and 24 are included for three-dimensional completeness but, along with Equation 26, are not required in the math for the final output form. Avoiding these three equations will remove most possibilities of dealing with division by zero in the computer.

For computer applications, Equations 14 and 25 should use an expanded arctan routine [ATAN2(x2, y2), for example], so that the resultant angle will lie within the full range of ± 180° instead of the usual ± 90°.

Part II—Solving Calculation Difficulties

Point $x2$, $y2$ always has two possible positions corresponding to the ± condition in Equations 12 and 13. (Note that when "+" is used in (12), "-" is used in (13) and vice versa.) Experience has shown that there is not an easy way to pre-select which sign to use in choosing one of these positions, so we calculate both of them and compare them with our model for the application at hand.

In order to apply root tracking logic, the array of points xt, yt must be in consecutive order from the shoulder on one side of the form to the shoulder on the other side. Use the following algorithm to select the correct root:

1. Select the first point xt, yt with slope st. Set IFIRST=1.

2. If Equation 11 becomes the square root of a negative number, there is no output point corresponding to this input point, so go to Step 6. Otherwise, calculate both positions of the point $x2$, $y2$ and both positions of the point xr, yr.

If IFIRST equals 0, go to Step 4.

Otherwise, calculate the distance, DIST1, from xt, yt to the first position of $x2$, $y2$. Calculate the distance, DIST2, from xt, yt to the second position of $x2$, $y2$. Distance calculation is the simple "square root of the sum of the squares" used to find the hypotenuse of a right triangle.

3. If DIST1 is less than DIST2, then choose the first position of $x2$, $y2$ and xr, yr as the correct values. Go to Step 5.

Otherwise DIST2 is less than DIST1, so choose the second position of *x2, y2* and *xr, yr* as the correct values. Go to Step 5.

4. Calculate the distance, DIST1, from XRSAV, YRSAV to the first position of *xr, yr*. Calculate the distance, DIST2, from XRSAV, YRSAV to the second position of *xr, yr*. Go to Step 3.

5. Save the chosen position of point *xr, yr* as XRSAV, YRSAV. Calculate and save *xt', yt'* in a point array. If all points in the *xt, yt* array have been processed, go to Step 7. Set IFIRST=0.

6. Select the next point *xt, yt* with slope *st*. Go to Step 2.

7. Exit algorithm.

This tracking logic works best when the output points *xt', yt'* are spaced closely together (about .001"). Because output spacing is seldom the same as input spacing, sometimes the spacing of the input points *xt, yt* will need to be decreased in order to achieve satisfactory output spacing. Also, whenever the input tooth form has a sudden change in slope, such as the corner of a tooth where the outside radius intersects the tooth flank, that corner point should be entered several times with the same *xt, yt* values, but with slope (*st*) values ranging from the slope of the curve at the outside radius to the slope at the flank. This is because a single input point can generate a series of different output points. A similar situation occurs when replacing the corner point with a very small corner radius.

After the output form has been calculated, it invariably needs further enhancement to be useful. Some of the calculated output coordinate points may need to be thrown out because they form a closed loop or zigzag. Part V goes into the significance of these discarded points.

Although it is possible to graphically display the output directly as a series of points and to manually unselect the extraneous points, it is much easier to use a curve fitting utility program to fit the points into line-arc geometry. Then another utility program can trace through this geometry and eliminate the loops and zigzags. Fig. 2 shows a known form which is to be processed to calculate its mating form. This is the tooth space of an ordinary 20-tooth pinion. The mating form is a single tooth of a 75-tooth gear.

Fig. 3 shows the mating form directly after curve fitting and again after elimination of loops and zigzags.

A zigzag occurs whenever the generation goes through a brief reversal before continuing on. The zigzag is usually not visible except at high magnification and would not ordinarily affect the display or usage of the form. However, if line-arc geometry containing a zigzag is presented to a computer program for further processing or to an NC machine, it will be perceived as an error condition. Fig. 4 shows a highly magnified section of a form containing a zigzag and again with the zigzag removed. Removal is accomplished by finding the intersection point after the reverse leg of the zigzag is discarded and joining the form at that point.

For purposes of sending the output geometry back through the system as input geometry (an operation known as "playback"), it is possible to derive from the mesh equations the slope *st'* corresponding to each point *xt', yt'* of the mating part. However, in practice this is avoided simply by picking new points and slopes from the line-arc geometry provided by the aforementioned curve fitting utility program.

Part III—The Fundamental Law of Gear Tooth Action Applied to Crossed-Axis Gearing

The pitch cylinders of two gears in mesh at crossed axes may be tangent to each other, intersect or not meet at all. This statement has two implications. First, it implies that each pitch circle has its own pitch point. Secondly, it implies that the pitch circles of parts in mesh at crossed axes do not change when the center distance changes. Both of these implications are true, which leads to a restatement of the law of gear tooth action when applied to crossed-axis gearing:

"In order for two meshing parts to have conjugate action, the common normal at any point of contact must pass through the *line whose end view in the transverse plane is a* pitch point."

The italicized words extend the standard law into a more universal law. When the pitch cylinders are non-tangent, the common normal must therefore pass through both lines whose end views are pitch points. Visualizing this in three dimensions will be somewhat easier after considering the path of contact equations in Part IV.

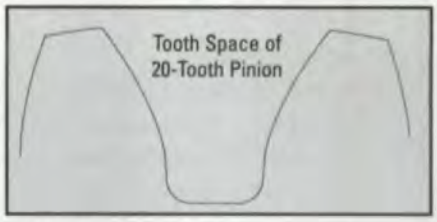


Fig. 2 — Input form.

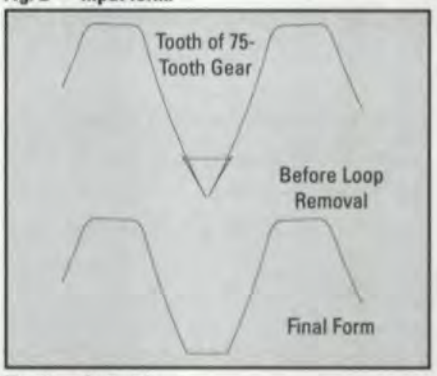


Fig. 3 — Output form.

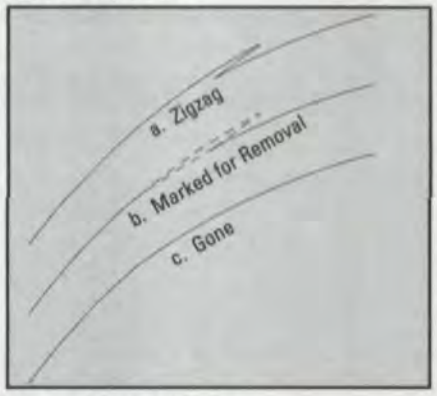


Fig. 4 — Zigzag, 250x size.

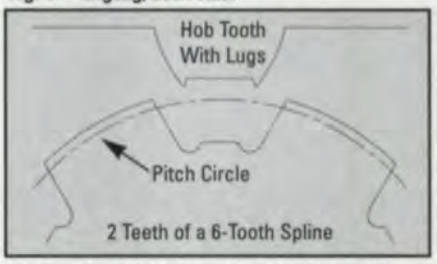


Fig. 5 — Straight-sided spline and hob tooth.

When the pitch cylinders are tangent to each other, which is the more common case, both of the pitch points are coincident. Although the math of Part I does not require direct application of this extended law to define the mating form, nevertheless, an understanding of this geometry will help in visualizing the contact of parts running at non-standard conditions.

Two further points should be noted:

1) For parallel-axis gearing, the pitch circles of mating gears must always be tangent to each other, which means that

the pitch circles must change when the center distance changes.

2) For involute gearing, a change in center distance does not require a change in the tooth form. For any other meshing pair, a new mating form must be calculated for any center distance change, regardless of whether the parts are designed to run with tangent pitch cylinders or non-tangent pitch cylinders.

Part IV—The Path of Contact

An important part of mesh math is the calculation of how the mating parts contact each other. This can tell us not only where contact occurs in each coordinate axis system, but the limits of contact.

When the pairs mesh on parallel axes, the path of contact does not have the same meaning as it does for crossed axes, so Equations 33–52 will not apply. Instead of single point contact, simultaneous contact occurs all across the face of the meshing parts in parallel-axis gearing, so we usually only define the path of contact in the transverse plane. Equations 15 and 16 give the contact point xk, yk in the transverse plane of the known part, which, for parallel axes, is also the transverse plane of the mating part. The following equations give the contact point in the rack's X''-Y'' plane (which is the part's normal plane):

$$xc'' = xk/\cos\alpha \quad (30)$$

$$yc'' = yk \quad (31)$$

$$zc'' = 0 \quad (32)$$

For crossed-axis gearing, previous equations have established where each of the two forms contact the same rack element, but not at a coincident point. We know that part rotation will cause a contact point to move along the rack element, so it is a simple solution to find the amount of rotation, δ, defined in the transverse plane of the known part, which will bring the two points into coincidence:

$$zk'' = zk \cdot \cos\alpha - xk \cdot \sin\alpha \quad (33)$$

$$zm'' = zm' \cdot \cos\beta - xm' \cdot IK \cdot \sin\beta \quad (34)$$

$$\delta = 2 \cdot \pi \cdot (zm'' - zk'')/[L \cdot \cos\alpha + IK \cdot (N/N') \cdot L' \cdot \cos\beta] \quad (35)$$

$$xc'' = xr'' + R \cdot \delta \cdot \cos\alpha \quad (36)$$

$$yc'' = yr'' \quad (37)$$

$$zc'' = zk'' + .5 \cdot \delta \cdot L \cdot \cos\alpha/\pi \quad (38)$$

The distance on the rack element between the contact point with the known part and the contact point with the mating part when both parts are in stationary mesh in accordance with the corollary to Theorem A is $(zm'' - zk'')$.

Point xc'', yc'', zc'' is in the rack axis system (X'', Y'', Z'') where the known part contacts the mating part after the rotational adjustment. The xc'', yc'', zc'' array of points describes the path of contact of the mating pair. Further, since zc'' is usually zero (see next paragraph), the contact path usually occupies only the X''–Y'' plane. This is very convenient for displaying the active mesh of a mating pair on a computer screen.

When meshing at crossed axes with tangent pitch cylinders, the term zc'' is always zero for any form, involute or otherwise. When the cylinders are non-tangent, the center distance becomes greater or less than standard, and zc'' becomes a nonzero constant for involute forms (plus on one side of the tooth and minus on the other). For non-involute forms, zc'' becomes a variable. The actual value of zc'' depends on the amount of deviation from the standard center distance and other factors. Geometrically, this deviation allows the common normal to intersect both lines whose end views are pitch points, a required condition explained in Part III. For a pair of non-involute parts meshing at a non-standard

Continuous Quality. Sound Performance.

There's only one way to ensure that the gears you produce will always deliver superior and quiet performance. Make sure they're bred from quality stock.

Dura-Bar® continuous-cast gray and ductile iron performs like free-machining steel with an important added bonus – quieter operation.

Like steel, Dura-Bar can be austempered, through-hardened, flame-hardened, or induction-hardened for added wear resistance. But the superior vibration-dampening characteristics of Dura-Bar make for quieter running gears. And Dura-Bar is 10% lighter than steel.

Dura-Bar round bars are available in diameters ranging from 5/8" to 20" and lengths of 6-20'. So you won't need to make major changes in your machining equipment. And our extensive inventory means Dura-Bar is available now – when you need it.

When it's quality material, quiet performance, and quick delivery that count, look to continuous-cast Dura-Bar for your gear production needs.

DURA-BAR®

1-800-227-6455 • 815-338-1549 (FAX) • 2100 West Lake Shore Drive, Woodstock, IL 60098-7497

center distance, each pitch point moves axially during the mesh, although their end views do not change.

There are two special cases where one of the forms is helical and the other spur. In these cases either Equation 17 or Equation 24 goes to infinity.

Case 1. Known part is spur. Do not use Equations 17 or 33 or 35–38.

$$\delta = -\Theta \quad (39)$$

$$xc'' = xk \quad (40)$$

$$yc'' = yr'' \quad (41)$$

$$zc'' = zm'' + IK \bullet \Theta \bullet R \bullet \cos\beta/\sin\beta \quad (42)$$

Case 2. Mating part is spur. Do not use Equations 24 or 34–38.

$$\delta = -(xr'' + xm')/(R \bullet \cos\alpha) \quad (43)$$

$$xc'' = -xm' \quad (44)$$

$$yc'' = yr'' \quad (45)$$

$$zc'' = zk'' - .5 \bullet L \bullet (xr'' + xm')/(\pi \bullet R) \quad (46)$$

Finally, Equations 47–49 convert the contact point xc'', yc'', zc'' to the known part axis system, and Equations 50–52 convert it to the mating part axis system.

$$xc = xc'' \bullet \cos\alpha - zc'' \bullet \sin\alpha \quad (47)$$

$$yc = yr'' \quad (48)$$

$$zc = xc'' \bullet \sin\alpha + zc'' \bullet \cos\alpha \quad (49)$$

$$xc' = -xc'' \bullet \cos\beta - zc'' \bullet IK \bullet \sin\beta \quad (50)$$

$$yc' = ym' \quad (51)$$

$$zc' = -xc'' \bullet IK \bullet \sin\beta + zc'' \bullet \cos\beta \quad (52)$$

Part V—Fill-In and Round-Over

Two common problems with generated forms are "fill-in" and "round-over." Fill-in occurs when you ask for a small root fillet, but because of spatial interference (those points we had to throw out back in Part II), the generating too produces a sweeping trochoidal fillet instead. This can be avoided by reducing the pitch radius so that the pitch circle passes through the root fillet, because the least amount of relative motion occurs at the pitch point. This, however, often leads to the problem of round-over. Round-over is required whenever the desired tooth form has a section where the normal to the surface does not intersect the pitch circle. It is not possible to generate a form at a point where the normal does not intersect the pitch circle (because Equation 11 becomes the square root of a negative number), so the solution must be either to increase the pitch circle or to change the curve of the tooth form (rounding over), allowing generation to occur.

The hobbing of a straight-sided spline provides a perfect example of both these problems. When the pressure angle is low (as in the case of straight-sided splines), the pitch circle must be large enough to avoid round-over, but the farther the pitch circle is from the spline tooth root, the more fill-in occurs. Often a compromise is made where the manufacturing form tolerance is used to allow incipient round-over near the tip of the spline, and lugs are added to the tip of the hob to push the fillet into a groove. Fig. 5 shows a spline form and the hob tooth that generates it.

Part VI—Using the Math of Mesh

The design of parts that mesh with each other, such as seam rollers and impeller rotors, can be optimized rapidly by generating mating forms at varying center distances and viewing the mesh graphically.

Contact limits can be calculated to find the required width of parts meshing at crossed axes. These limits also can define the generating length of a hob. Contact points and contact limits can be calculated for gear shaving cutters, which routinely mesh on crossed axes at non-standard center distances.

In addition to the obvious use of the math to calculate mating forms, it may also be used to determine the amount of error that occurs when non-involute forms mesh at changed center distances. The most common example of this is a hob designed to cut an impeller form, sprocket or a straight-sided spline. As the hob is sharpened, it runs at a closer and closer center distance than it was designed for. By running the hob form through the mesh math with a reduced center distance, the actual part form may be determined. This can be compared with the desired part form (usually by graphical overlay).

Even involute hobs are not totally free of this problem. Hobs are invariably manufactured with straight sides rather than the curvature required by the involute. When they are sharpened, they deviate even further from the theoretical curvature. This error will never be discernible except in very coarse pitch hobs or multiple start hobs because the involute curvature is so slight on single thread involute worms with a small lead/diameter ratio.

Another application is determining the range of teeth a non-involute hob or shaper cutter can cut. Chain sprockets, timing belt sprockets and pre-shaved involute gears are examples of parts which have hobs or shaper cutters designed for a particular number of teeth. Mesh math can determine the form that these tools will produce when they cut a different number of teeth. Then a graphic overlay with the theoretical form will quickly determine whether the form error is great enough to warrant a new hob or shaper cutter design.

Yet another use of mesh math is to determine how close a generated form will be to the desired form. As a case in point, consider a toothed ratchet form with a sharp root fillet which is to be produced by hobbing or shaping. The ratchet tooth form is fed into the mesh math, and the hob or shaper cutter tooth is output. Depending on several factors, there will probably be some unavoidable loss of form, which will result in having fill-in at the ratchet tooth root fillet. Because the mesh math is reversible, the hob or shaper cutter geometry form data can be fed directly back through the system to determine the actual ratchet tooth form. This often points to the simple solution of choosing a smaller pitch radius, or it can lead to a redesign of the hob as a "mutilated tooth" hob or an "alternate gash" hob.

The concepts of the mathematics of mesh are simple, but they require care in their application. Nevertheless, a minimally experienced computer programmer should be able to make productive use of these equations. ○

William C. Smith

was employed as Principal Engineer/Scientist at Barber-Colman Company for many years and is now self-employed as a consultant and owner of Software Engineering Service, Rockford, IL. He has authored several articles on gear manufacturing and many computer programs in the area of gear cutting tool design and manufacture.

LITERATURE MART

PRECISION GROUND GEARS

Niagara Gear's new brochure on precision ground spur, helical and pump gears details complete capabilities to meet demanding, close tolerance requirements, with the fast turnaround typically associated with conventional gear manufacturing. For a brochure, or for information, contact Niagara Gear Corporation, 941 Military Road, Buffalo, NY 14217. Phone: 716-874-3131, Fax: 716-874-9003.

CIRCLE READER SERVICE #152

HIGH-SPEED SPINDLES

Spindle stiffness, accuracy and tooling are critical in machining. Have the spindle designed for your application. Design analysis to ensure maximum life and precision. Patented designs support our name: "Rigidity at speed." Our 60 years of spindle manufacturing give you world class results.

Colonial Tool Group Inc.
Detroit, MI
313-965-8680
519-253-5911

CIRCLE READER SERVICE #184

BROACHES & SPLINE RACKS

CNC manufacturing and innovative designs ensure the highest quality broach tools and spline rolling racks consistently and on time! We customize all our tools to your application. Complete in-house heat treatment allows ultimate control. Turnkey machine setups/ broaches/spline rolling racks and precision machine spindles. HELICAL BROACHES TOO!

CIRCLE READER SERVICE #185

DURA-BAR

Continuous cast iron from Dura-Bar performs like free-machining steel but with 10% less weight. And Dura-Bar's superior vibration-dampening characteristics make for quieter running gears. Available in diameters from 5/8"–20" and lengths of 6'–20'. Contact Dura-Bar at 800-227-6455.

CIRCLE READER SERVICE #187

BROACHING MACHINES & TOOLS

This sixteen-page brochure covers National Broach's complete line of Red Ring vertical, pot, blind spline and surface broach machines, along with CNC broach sharpening systems. National Broach also offers a comprehensive range of broach tools, accessories and services. For more information and a free brochure, contact the National Broach & Machine Company at (810) 263-0100.

CIRCLE READER SERVICE #160

LMT-FETTE

LMT-Fette hobs give you the competitive edge you need to succeed in the gear cutting industry. At LMT-Fette we custom design our hobs to specifically meet your individual manufacturing needs. We believe in working with you side by side to ensure total optimization in your hobbing process. For a hob that's a cut above the rest, LMT-Fette is sure to have a hob perfect for you.

CIRCLE READER SERVICE #188

NEW GAGE-O-MATIC

Manufactured Gear & Gage, now in its 10th year of producing its highly accurate, easy-to-use gear measuring instruments, will introduce an improved Gage-O-Matic™ Gear Measuring Instrument at AGMA Gear Expo. The unit eliminates the mechanical handle, significantly improving accuracy, repeatability and reliability. It includes updated computer interfacing and a rock-solid base.

Phone (630) 377-2496
Fax (630) 377-2546.

CIRCLE READER SERVICE #169

OIL MIST/SMOKE/DUST COLLECTOR

The GA-1400 Oil Mist/Smoke/ Dust Collector is designed for direct source capture of various nuisance or hazardous airborne contaminants. Can be used anywhere CNC machining, metal turning, wet drilling, grinding or welding are performed. Gardner Environmental Products, 1201 West Lake Street, Horicon, WI 53032. For more information or literature, call (800) 558-8890 or fax (414) 485-4370.

CIRCLE READER SERVICE #189

LITERATURE MART

GEAR HONING MACHINES

-Direct honing after hobbing and heat treating.

Hard Broaching Machines

-Removal of heat treat distortion from splines, keyways, or internal diameters.

Diamond Wheel Dressing Devices

-Dressing of rack profiles into gear grinding worm wheels.

Diamond Tooling

-Gears, profiling wheels, broaches.

For more information:
Phone: 414-255-0695
Fax: 414-255-9676

CIRCLE READER SERVICE #190

INDUCTION FIXTURES

The LR-PAK data sheet describes induction lift rotate fixtures useful for heat treating parts such as transmission O.D. races, I.D. cams, hubs, spindles, C.V. joints and gears. LR-PAKs are completely assembled and interconnected.

Ajax Magnethermic Corp.
1745 Overland Avenue
Warren, OH 44482
800-547-1527
Fax: 330-372-8608

CIRCLE READER SERVICE #117

EXACT GEAR MEASUREMENTS

Whatever your requirements, D.I.G.I.T. can custom-design a measuring system to accurately determine exact pitch diameter of internal or external splines, helical gears or spur gears. All gauges come with custom-designed measuring probes and mandrels and easy to follow programming instructions. Call 513-746-3800 or fax 513-746-5103 for our brochure.

Member AGMA

CIRCLE READER SERVICE #156

CYBERSPACE IS CALLING

A Company Page in The Gear Industry Home Page Internet Buyers Guide lets you sell your products or services to gear industry CEOs, engineers and managers around the world. This is the best Internet deal around. Call 847-437-6604 for a FREE brochure or send e-mail to *people@geartechnology.com*.

CIRCLE READER SERVICE #275

GEAR GRINDING PACKAGE

Do you want to turn your surface grinder into a gear/spline grinder? Retrofit it with a Normac gear grinding package. The package consists of a Normac CNC grinding wheel profiler, Lehmann CNC indexing head and custom Normac profile grinding software for external spur gears and splines.

CIRCLE READER SERVICE #191

DOUBLE FLANK GEAR ROLL TESTERS

New color brochure offers descriptions and specifications of Mahr DF1 Series gear measurement instruments and WinGear®, Windows®-based test and evaluation software. System provides automatic, push-button measurements and test analysis to DIN, ISO and AGMA standards. Mahr Corporation, 11435 Williamson Rd., Cincinnati, OH 45241. Phone: 1-800-969-1331. Fax: 513-489-2020.

CIRCLE READER SERVICE #194

GEAR CHECKER

Moore Products' Universal Center Distance Gear Checker permits easy monitoring of tight-mesh gear characteristics. Adjustable system promotes quick changeover; one gage inspects all parts. Advanced software permits quantitative analysis, provides process control and statistical analysis reports. Produces wide range of results including runout, sectional runout, average and maximum tooth-to-tooth action and more.

CIRCLE READER SERVICE #162

COLD-FORMING SPLINE ROLLING RACKS

The best tool life gives you lowest cost per piece. Colonial Tool Group Inc. has been manufacturing cold-forming racks for over 30 years. Our library allows us to design and build your tools right the first time. The complete manufacturing process is done in-house, including engineering and heat treat.

Colonial Tool Group Inc.
Detroit, MI
(313) 965-8680
Fax: (519) 253-5911

CIRCLE READER SERVICE #186

TECHNICAL CALENDAR

AGMA GEAR SCHOOL

The AGMA Training School for Gear Manufacturing is held at Daley College, Chicago, IL. This one-week course is designed for employees with a least six months' experience in setup or machine operation, and it covers setup, gear inspection, gear calculations and basic gearing principles. The curriculum includes both classroom and hands-on training in hobbing, shaping and inspection. The remaining sessions for 1997 will be held Sept. 22–26 and Nov. 17–21.

For more information, contact Susan Fentress at AGMA. Phone 703-684-0211, fax 703-684-0242, Send e-mail to *agma@clark.net* or log on to *www.agma.org*.

OTHER EVENTS OF INTEREST

Sept. 4–5. Metalworking Software Expo '97. Chicago Marriott O'Hare, Chicago, IL. This exhibition will display the latest software and hardware for job shops involved in production machined parts, screw machine parts, dies and molds, fabricated parts and assemblies, stampings, castings, die castings, forgings, fasteners, springs, metal finishing and heat treating. Software applications include CAD/CAM and engineering systems, integrated management systems, office automation, data collection, CNC machine control systems, quality management systems and special application software. Contact Michelle Jenkins at Gardner Management Services, 1-800-950-8977 or fax 513-527-8950.

GEAR NOISE COURSES

Sept. 9–11. Gear Noise Short Course (Basic). Ohio State University. This course will cover how gear design parameters and manufacturing errors affect noise. Principles of gear transmission error, methods of predicting such errors, gear system dynamics, gear rattle and advanced signal processing. The course is designed for engineers and technicians in the automotive, transportation, machine tool, process machinery, aircraft, appliance, general manufacturing and gear manufacturing industries. Appropriate for gear designers with little knowledge of noise analysis and noise specialists with no prior knowledge of gears.

Sept. 16–17. Gear Noise Short Course (Advanced). This two-day session is for those who have previously completed the basic gear noise course. It will include workshops and lectures on advanced topics: i.e., computer modeling, transmission error prediction, general system dynamics, bearing and casing dynamics, acoustic radiation, advanced signal processing, etc.

For registration information about both courses, call Martha Leming at 614-292-2226 or e-mail her at *leming.1@osu.edu*.

Sept. 14–18. 17th ASM Heat Treating Society Conference & Exposition. This event will cover every aspect of heat treating—equipment, processes, microstructures, properties, control of distortion, quality and cleaning. In addition to the programs and presentations, some 250 exhibitors will demonstrate products and answer questions regarding equipment, processes, supplies and services. Call 800-ASM-4HTS (216-338-5151 x5900 outside U.S.), fax

216-338-4634, e-mail *Mem-Serv@po.asm-intl.org* or log on to *www.asm-intl.org/event97/*.

Sept. 15–18. MechanCAD. Ramada Congress Hotel, Chicago, IL. Billed as the PC-Based Mechanical Design Conference, this symposium offers a series of seminars, classes and demo sessions designed to provide training for drafters, designers and engineers using PC-based mechanical design software. Covers a variety of subjects including data exchange, virtual and rapid prototyping, engineering drawing and document management systems, collaboration on intranets and the Internet, finite element analysis, product data management and more. For more information, call 800-789-2223, fax 972-385-9003 or log on to *www.mechancad.com*.

Sept. 22–24. Technology 2007 Convention & Exposition. Hynes Convention Center, Boston, MA. Sponsored by NASA, *NASA Tech Briefs* and The Technology Utilization Foundation, this convention is for engineers, scientists, managers, developers and entrepreneurs who need to stay on the cutting edge of technology development and/or who are looking for commercial partners. For more information, call 212-490-3999 or check the convention Web site at *www.nasatech.com/t2006*.

Sept. 30–Oct. 2. Wisconsin Manufacturing & Tool Expo. Wisconsin State Fair Grounds, West Allis, WI. This show will be of interest to companies who market metal cutting and forming equipment, tooling accessories, CAD/CAM, quality control, and manufacturing software and systems. Call 414-367-5500 or fax 414-367-9956 for more information.

Oct. 1–3. Bevel Gear Course. University Center for Continuing Education, UW-Milwaukee, Milwaukee, WI. Three-day seminar covering bevel gear design, application and use is aimed at the gear user, designer and beginning-to-intermediate gear technologist. Emphasis is on the proper selection, design, application, qc, assembly, installation and maintenance of bevel gear systems. For more information, call Valerie Jordan, 414-228-3167, send an e-mail message to *vjordan@csd.uwm.edu* or log on to *www.uwm.edu/Dept/CCEE*.

SME CONFERENCES

Oct. 21. Plastic Gearing Clinic. Detroit Crowne Plaza Hotel, Detroit, MI. One-day seminar on designing gears with plastics.

October 22–23. Gear Metrology Clinic. Detroit Crowne Plaza Hotel, Detroit, MI. Both of these conferences are sponsored by the SME. For more information, call Susan Hunt at SME headquarters, 313-271-1500 x352, fax 313-271-2661, e-mail *huntsus@sme.org* or log on to *www.sme.org*.

Nov. 9–11. AGMA Fall Technical Meeting. San Diego, CA. Presentations on a variety of gear subjects by experts from around the world. For more information, contact AGMA at 703-684-0211, fax 703-684-0242, e-mail *agma@clark.net* or log on to *www.agma.org*.

Tell Us What You Think . . .
If you found this article of interest and/or useful, please circle **215.**

The World rotates with Holroyd Screw Technology

- TG350E CNC Thread Grinding Machine
- Advanced Thread Milling Centres
- Complete Tool Profile Management
- Advanced Measurement Systems
- Tool Design Software
- Conturo-Automatic Deburring Centre
- Sub-Contract Rotor and Worm Gear Manufacturing Facility

HOLROYD

Intl. Headquarters:Harbour Lane North,
Milnrow, Rochdale OL16 3LQ. England
Telephone: (44) 01706 526590
Telex: 635772 Holryd G Fax: (44) 01706 353350

USA Office: RLH Associates, Inc., P.O. Box 807.3302 Hwy. 74 West Unit C, Monroe, NC 28111
Telephone: (704) 282-4895 Fax: (704) 289-9147

HOLROYD – The Renold Centre of Excellence

Certificate Number FM 32540
BS EN ISO 9001:1994

CIRCLE 121

PRODUCT NEWS

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

New Surface Measuring Instruments from Zeiss

Carl Zeiss IMT Corp. has introduced the TSK Surfcom 130A and Surfcom 480A surface measuring instruments for use in production. The 130A is a portable and compact high-precision roughness measuring system for evaluation and display of surface parameters. It has a straightness accuracy of 0.3 µm over 30 mm and a traverse range of 30 mm. It is operated with a touch-screen keyboard on a 6.5" color LCD display. The Surfcom 480A adds a control unit to the 130A, allowing for automatic or joystick operation.

Circle 300

NewAge Lab BOSS® Brinell Scanner

NewAge Industries, Inc., announces the redesign of the Lab BOSS Brinell Scanning System. Software for the benchtop Lab BOSS is now available in Windows® 3.x, Windows 95 and Windows NT-based software and has improved capability for setting up new files and parameters, storing data and calibration routines. Hardware has also been improved, with a smaller footprint scan head and a snap-on attachment that makes the base of the scan head wider for testing when the test specimen configuration permits. For use in a factory environment, the Lab BOSS has a mobile enclosure that can seal the computer while still providing good visibility and operability.

Circle 301

New Digital Linear Gage

Ono Sokki Technology, Inc. introduces the DG-525 digital linear gage for measuring dimensions, thickness, curvature, eccentricity, displacement, height, depth, flatness, variation, runout, roundness, distortion and deflections. It can also be used for load and pressure inspection applications. The company says it performs accurate measurement to 0.0005 mm (0.00002") throughout its full 25 mm measuring range. The indicator features one-revolution TIR to obtain simultaneous maximum, minimum and range values with only one sweep. It also offers an adjustable measuring force for taking accurate measurements on fragile or compressible materials. The DG-525 has an output speed of approximately 1.6 ms/data and is compatible with every major SPC data acquisition system.

Circle 302

New Magnifiers, Comparators & Microscopes

GEI International introduces a range of precision 7x and 10x measuring magnifiers and comparators with interchangeable glass measuring reticles for the accurate inspection and measurement of dimensions as small as 0.005". Five styles of reticles are supplied for a wide variety of applications, including measuring inches, millimeters, angles, hole sizes, radii, etc. The magnifiers incorporate a four-element achromatic color-corrected lens system and an adjustable helicoid focusing ring.

The company also has introduced a precision 20x microscope specifically designed for Brinell hardness testing. The Model MNS-0300 is designed to measure the impression made by a ball bearing in a surface for Brinell hardness measurements, and it may also be used for general shop applications requiring close inspection and precise measurements. It measures 6.3" high and 1.38" in diameter, with a field-of-view of 7.2 mm.

Circle 303

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

Tell Us What You Think...
If you found this article of interest and/or useful, please **circle 216.**

Unite-A-Matic™

TRUE DIMENSION GEAR INSPECTION

Provides actual over ball/pin measurment of any helical or spur gear or spline without the need of costly setting masters.

Provides vital S.P.C. information.

CAPACITY:
9" O.D.
8" I.D.

Gage Division

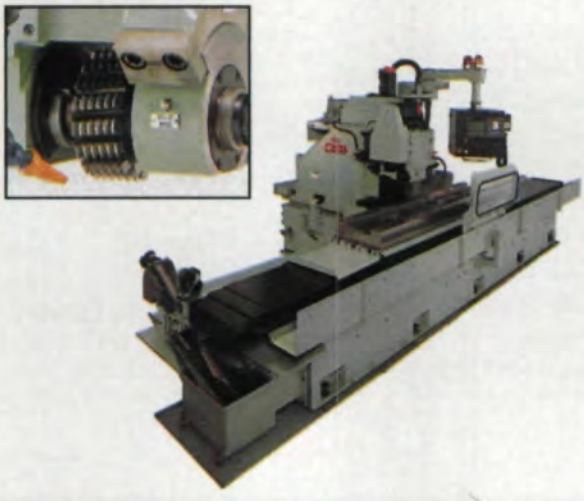
United Tool Supply

851 OHIO PIKE • CINCINNATI, OHIO 45245 • (513) 752-6000 • FAX (513) 752-5599

CIRCLE 155

Saikuni

Ataka Group • Ataka Machinery Co., Ltd. • Ataka Engineering Co., Ltd.
Phone (81)-52-772-0690 • Fax (81)-52-772-0692
e-mail: ataka@mxb.meshnet.or.jp



Rack Milling Machine NR-8LL

3-Axis CNC Controlled Machine

- This machine can cut the works under large stock removal and large feeds with automatic cutting cycle by pre-setting the cutting data.

SEE BOTH MACHINES AT GEAR EXPO '97 (DETROIT)

Spiral Cutter Sharpening Machine NCG-125/205

Advanced, Fully Automatic, Multi-Purpose, 5-Axis CNC Grinding Machine

- Full automatic cycle with automatic cutter positioning device
- Power clamping for easy load/unload
- Easy setup minimizes downtime
- Also sharpens coniflex, helical pinion and revacycle cutters

SEE US AT AGMA GEAR EXPO BOOTH #250 CIRCLE 148

CLASSIFIEDS

SERVICE

GEAR TOOTH GRINDING

Spur • Helical
• Herringbone (with groove)
Capacity up to 63" O.D.,
1 D.P., 16" face

AGMA Certification Inspection

Delivery to Meet Your Requirements

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

Direct your inquiries to
Ron Humphrey, General Manager

CIRCLE 173

GEAR TOOTH GRINDING SERVICES

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

PRO-GEAR COMPANY, INC.

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

CIRCLE 180

PFAUTER-MAAG CUTTING TOOLS LIMITED PARTNERSHIP

PICK UP AND DELIVERY IN MANY AREAS

- **HOB SHARPENING**
- **SHAVING CUTTER GRINDING**
- **TiN, TiCN, & TiALN COATING SERVICES**
- **CUSTOM HEAT TREAT SERVICE**

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

CIRCLE 177

HEAT TREATING

Contour Induction Hardening Specialists

Spur, helical and bevel gears

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

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

CIRCLE 174

SERVICE

ALLIED GEAR COMPANY

Manufacturers of Cut Tooth Gears and Sprockets

Spur and helical gears to 80" O.D. and 1 1/4 DP.
Bevel gears to 36" O.D. and 1 1/2 DP.
Internal gears to 36" P.D. and 3 DP.
Worm gears to 48" O.D. and 2 DP.
Sprockets to 80" O.D. and 2 1/2" pitch.
Spline shafts to 120" long.
Crown shaving to 24" O.D.
Gear tooth grinding to 24" O.D. and 2 D.P.
Thread grinding to 14" O.D. and 40" long.
Internal and external cylindrical grinding.

Call for our brochure
Phone 773-287-8742 • Fax 773-287-4720

CIRCLE 193

HOB SHARPENING (612) 425-5247

HSS & Carbide up to 5" Dia.
Straight Gash,
Sharpened & Inspected
Per AGMA STANDARDS
Quick Turnaround

KORO SHARPENING SERVICE
9530 - 85TH AVENUE NO. • MAPLE GROVE, MN 55369

CIRCLE 192

Rates—Line Classified: $35 per line, 8 lines per inch, $270 minimum. Classified Display (3" min.): **1X**—$585, **3X**—$545, **6X**—$515. Additional per inch: **1X**—$195, **3X**—$185, **6X**—$175. *Gear Technology* will set type to advertiser's layout or design a classified ad at no extra charge. **Payment:** Full payment must accompany classified ads. Send check or Visa/MasterCard/American Express number and expiration date to *Gear Technology*, P.O. Box 1426, Elk Grove Village, IL 60009. **Agency Commission:** No agency commission on classified ads. **Materials Deadline:** *Ads must be received by the 20th of the month, two months prior to publication.* **Acceptance:** *Publisher reserves the right to accept* or reject classified advertisements at his discretion.

SOFTWARE

HELP WANTED

Gears in Sneakers

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

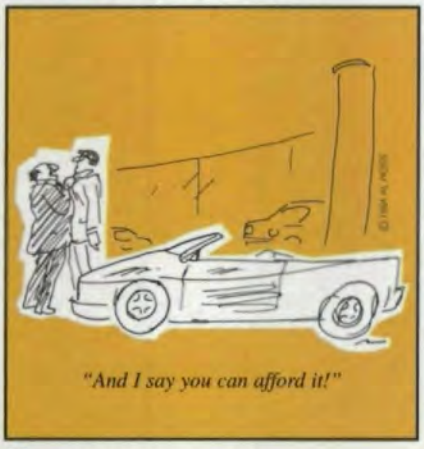
Move over, Michael Jordan. While the Addendum staff is as proud as any other Chicagoans of our unbeata-Bulls, we confess to a soft spot in our hearts for the hometown's *other* championship basketball team: The Chicago American Gears.

That's right, the Gears.

The Chicago American Gears played in the National Basketball League during the late 1940s. They were led by star center George Mikan and player-coach Bobby McDermott to their only championship in 1947. The story of the Gears is told in *The Dynasty That Never Was*, a book by Richard F. Triptow, who played for the Gears for three seasons.

How Does a Team Get Named The Gears?

The team was founded, owned and, for a while, coached by Maurice A. White, owner of the American Gear and Manufacturing Company in Chicago. This was in the early days when the National Basketball League, one of the precursors of the modern NBA, was struggling to make its transition from an industrial league to a professional one with teams like the Oshkosh All-Stars, the Indianapolis Kautskys and the Rochester Royals. When you think about it, wouldn't you rather cheer for the Gears than the Kautskys?



"And I say you can afford it!"

The Gears existed as a team from 1944, when White obtained the franchise, until 1947. Their short three-year tenure was filled with controversy, drama and even a little bit of success.

White was a bit of a basketball rebel right from the start. He was used to being in charge and applied his own particular style of management to his team. For example, in order to keep the fans interested and the game fast-paced, he reportedly offered his players an incentive program that included bonuses of $5 for each field goal and $2 for each free throw.

But the team didn't really take off until 1946, when White decided to spend what was then a small fortune to sign college basketball's greatest star, DePaul University's George Mikan, to a five-year, $60,000 deal.

Then as now, professional athletics was about big money and big egos. When White abruptly cut four of the Gears players, including Joe Mikan, the star center's brother, George quit the Gears, filed a lawsuit against the team and sat out for six weeks of the season.

Without Mikan, things looked dismal for the Gears. But during Mikan's holdout, White acquired player-coach Bobby McDermott, who was in his own right one of the game's biggest stars. After Mikan's and the team's lawyers worked things out, Mikan returned to finish out the season. With the added help of McDermott, the Gears went on to win 17 of their last 23 games to make the playoffs.

The Gears charged through the playoffs, defeating Indianapolis in the first round, Oshkosh in the second round and Rochester in the final round to gain the NBL title.

But White wasn't content with a championship. Based on the success of his team and the status of his two stars, he tried to leverage his way into a position as league president. When this attempt failed, he set out to form his own professional basketball league, with the Gears as the centerpiece team and himself as league president.

Unfortunately for White and the Chicago American Gears, the new Professional Basketball League of America folded just one month into the 1947-48 season. Miffed at White's audacity, the NBL refused to accept the Gears back as a team. A special draft was held and each player went to another team.

Today, the Gears are a scarcely remembered footnote in basketball history. But the Addendum staff can't help wondering if it isn't time for a revival. Somewhere out there, there must be another Maurice White, the owner of a successful gear manufacturing company who's willing to buy an NBA franchise. We can almost see the brightly colored Gears logo. Sign us up for season tickets. We'll be in the front row.

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

Between A Rock And A Cold Place?

Warm Up To Forest City Gear

And Find World Class Quality!

- Crown Hobbing for noise reduction and misalignment compensation.
- Hard Hobbing with carbide hobs after heat treat as a substitute for gear grinding.
- CNC hobbing and shaping alignment programs for varying teeth and pitches.
- *Precision analytical gear inspection.*
- Hob sharpening.

Hornby Creek, Wisconsin

FOREST CITY GEAR

11715 Main Street
P.O. Box 80
Roscoe, Illinois 61073-0080
815-623-2168
Fax 815-623-6620

Member of the American Gear Manufacturers Association

CIRCLE 138

The Most Modern Fine and Medium Pitch Gear Job Shop in the World!

Come Visit Us and See OUR Gear Show

We Welcome Our Competitors

Catch us on the web at www.fcgear.com

Pfauter-Maag Cutting Tools. Where the world goes for quality.

Manufacturers everywhere need new cutting tool technology that can produce parts faster, more accurately and less expensively than ever before. That's why more companies worldwide turn to Pfauter-Maag Cutting Tools.

At Pfauter-Maag Cutting Tools, we have people and plant resources unavailable anywhere else in the world. We can find the absolute best tooling approach for your application and help put it to use more productively than you might have believed possible.

So turn to Pfauter-Maag Cutting Tools for the best in gear hobs, shaper cutters, shaving cutters, form-relieved milling cutters and CBN grinding wheels.

Pfauter-Maag Cutting Tools
A Gleason Company

Telephone (815) 877-8900 • Fax (815) 877-0264
1351 Windsor Road, P.O. Box 2950, Loves Park, IL 61132-2950
Web Site: http://www.pmct.com • E-Mail: Sales@pmct.com

CIRCLE 102