GEAR TECHNOLOGY

The Journal of Gear Manufacturing

METROLOGY• THE COMPUTER IN YOUR WORKPLACE

January/February 1996

BEVEL GEAR METROLOGY
NEW NIST GEAR CALIBRATIONS
ERRORS WHEN MEASURING OVER PINS
GEAR INFORMATION ON THE INTERNET
PART SPECIFYING WITH A CD-ROM

PLUS • Interference in Shaper-Cut Gears
• Viewpoint with AGMA's Charles Brannen • The SERCOS Controller Standard

THE GEAR INDUSTRY'S INFORMATION SOURCE

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 for the best in gear hobs, shaper cutters, and form-relieved milling cutters.

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-cutting tools and form-relieved milling cutters.

Pfauter-Maag Cutting Tools
Limited Partnership

Telephone (815) 877-8900 • Fax (815) 877-0264
1351 Windsor Road, P.O. Box 2950, Loves Park, IL 61132-2950

CIRCLE 102 on READER SERVICE CARD

GEAR INSPECTION CHECK LIST

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

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

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

SEND FOR FREE TECH REPORT

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

M&M PRECISION SYSTEMS Corporation

"THE METROLOGY AND MOTION PEOPLE"

CIRCLE 103 on READER SERVICE CARD

GEAR TECHNOLOGY

JANUARY/FEBRUARY 1996 *The Journal of Gear Manufacturing*

FEATURES

Cover art by Tom Longtin, Fulcrum Design, Bennington, VT. Image produced on a Silicon Graphics workstation using Pixar's RenderMan software.

9

DEPARTMENTS

48

GEAR TECHNOLOGY
The Journal of Gear Manufacturing

"BPA International Publication Membership Applied for September 1994."

EDITORIAL

Publisher & Editor-in-Chief
Michael Goldstein

Associate Publisher & Managing Editor
James K. Spalding, CBC

Senior Editor Nancy Bartels

Associate Editor William R. Stott

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

ART

Art Director Jean Bartz

ADVERTISING

Advertising Manager
Patricia Flam

CIRCULATION

Circulation Coordinator
Deborah Donigian

RANDALL PUBLISHING STAFF

President Michael Goldstein

Vice President Richard Goldstein

Vice President/General Manager
James K. Spalding, CBC

Controller Patrick Nash

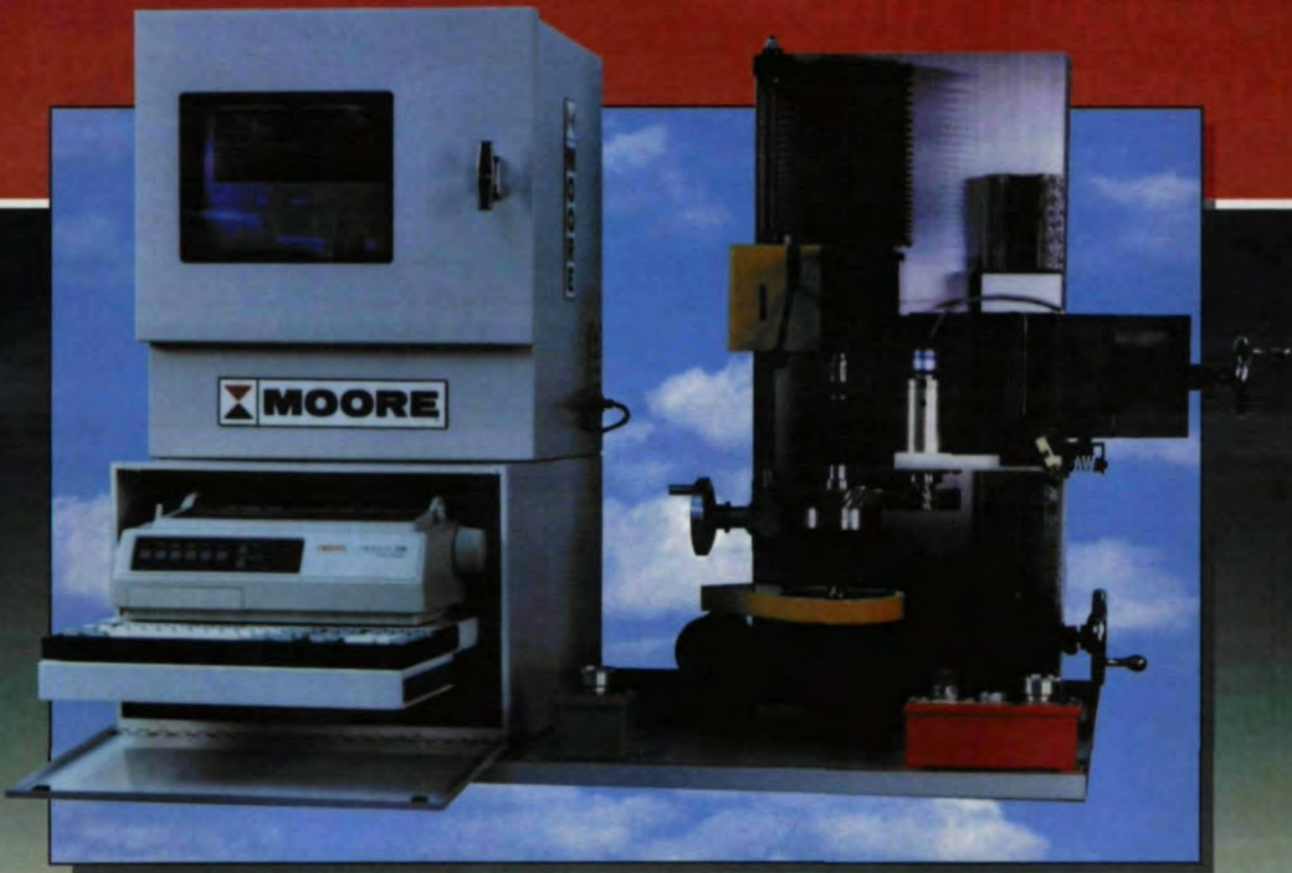
Accounting Laura Manion

Art Consultant Marsha Goldstein

VOL. 13, NO. 1

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

Only MOORE can give you such performance in a



UNIVERSAL TIGHT MESH GEAR INSPECTION SYSTEM

- *Checks and displays results for 7 center distance characteristics*
- *Adjustable for Gears 1"to 8" P.D.*
- *Computer analysis and digital filtering*
- *Numeric and strip chart outputs*
- *Quick changeover*

For more information on this and other MOORE gear measurement technology, use the attached Reader Service Card. For an immediate response, phone us at 215-646-7400 (Ext. 2167), or fax us at 215-653-0347.

INSPECTS:

- ***Functional tooth thickness***
- ***Total composite action***
- ***Pitch diameter runout***
- ***Sectional composite runout***
- ***Pitch diameter***
- ***Functional size***
- ***Sectional runout***

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

MOORE®

"The Measurable Difference"

CIRCLE 106 on READER SERVICE CARD

PLAN AHEAD

Indianapolis in 2001 and beyond is a good move for AGMA.

Indianapolis is a nice city. No. It's a great city for a convention. The facilities and the city are modern, clean and bright. The Convention Center is easy to get to by either car or plane, and its central location in the heart of town and the enclosed skyway system between it and major hotels put visitors close to amenities like restaurants, shopping and entertainment. The people are friendly and go out of their way to make visitors feel welcome.

My own very positive experience at Gear Expo '95 and the numerous comments I heard from other exhibitors and visitors convince me that AGMA could do no better than to make Indianapolis its permanent site for the Gear Expo. Located in the heart of gear manufacturing country, it's a day's drive for approximately 60% of the gear manufacturers in the U.S., making it a big draw for single-day visitors. Prices, both for the visitor and the exhibitor, are reasonable—far less than in most major metro areas, which attracts more exhibitors and, therefore, more visitors as well. And make no mistake: those attendance numbers are crucial to the continuing success of the Expo.

AGMA is unfortunately committed to Cobo Hall in Detroit in 1997 and to Nashville in 1999. While I and many others are less than thrilled with those choices, particularly downtown Detroit, which grows to resemble Batman's Gotham City more closely all the time, there's no reason to assume the Gear Expo will not do well at either place. AGMA may have to work harder to attract visitors to these somewhat less than optimum sites and to overcome poor decisions made years ago, but expositions in those locations can still be successful.

The good news/bad news story of Gear Expo is the fact that the show is now big enough to have to be very selective about its sites. Space and facilities that can accommodate the large machines being shown are not found in every city, and the ones that are available fill up early. The Gear Expo could not go back to Indianapolis before 2001, even if it weren't already committed elsewhere.

Fortunately AGMA seems to be moving quickly and is negotiating now for Indianapolis in 2001. The next logical move should be to work with Indianapolis to make the Convention Center the permanent site for the Expo. A fixed location popular with exhibitors and visitors alike and near the geographic and economic center of the gear industry could be the linchpin of the continuing growth and success of the Gear Expo.

The votes are in. The gear community has made it pretty clear that it would welcome an Indianapolis location. It is my hope that the AGMA planners make it happen.

Michael Goldstein
Publisher and Editor-in-Chief

The good news/bad news story is that Gear Expo is now big enough to have to be very selective about its sites.

Gear Expo '95
BEST EVER

Machines, tools, software, services, even a special fashion statement filled the Indianapolis show.

Gear Expo '95, held in Indianapolis, November 12–15, 1995, closed to rave reviews from both the attenders and the exhibitors. Traffic for the show was well up from 1993, with a total of about 4,000 visitors during the $3^1/_2$ day exhibition. One hundred thirty-two companies from all over the U.S. and as far away as India and The People's Republic of China displayed their wares.

"Between pre-registrations and actual visitors, we had more people in attendance by the close of the show on Sunday than we had at the entire show in 1993," said Joe Franklin, AGMA's executive director. He also indicated that the number of decision-makers in attendance was up, as was the number of international visitors.

Exhibitors and visitors agreed. "I was impressed with the number of people coming here with a real agenda in mind," said Ed Doepp of Lindberg Heat Treating. "They had real questions and legitimate interest in buying."

A wide variety of products and services from cutting tools and machines to heat treating, shot peening, inspection equipment and engineering consulting and training seminars were on display. New technologies and products for niche markets were highly visible.

Lambert AG, represented by TPS of Sussex, WI, and Parker Industries of Bohemia, NY, displayed three models of gear hobbers for plastic and composite fine pitch gears.

A steady stream of traffic flowed through the Indiana Convention Center during Gear Expo '95.

Among the machines on display at the JRM International booth was the Kesel milling macine. The only CNC rack miller in the world, this 3-axis machine features automatic leveling and 3100 mm capacity for both spurs and helicals up to 1.25 DP.

The Oerlikon Spiromat L22 CNC-controlled spiral bevel and hypoid gear lapping machine was in operation at the Liebherr America booth. This machine features a small footprint that uses 30% less floor space than the other lappers, FANUC controls, and updated software. Among its new features is the capacity to cause the gear rather than the pinion to be the driven spindle.

Redin Corporation unveiled its new Model 18 Wash and Grind machine. This machine eliminates parts handling by combining in one operation chamfer grinding, washing and blow drying parts. The machine deburrs, washes, dries and applies rust preventative at one location in a single operation.

The PBM pot broach machine was featured at the National Broach booth. This machine has a flexible modular design that offers from 5- to 50-ton capacity in the same floor space. It has automatic tool changing and load/unload features and is available with CNC controls. It is designed with cell and family-of-parts manufacturing needs in mind.

The Reishauer booth featured the new RZ 820 large capacity grinder with a hydraulic tailstock, shifting with closed collet, automatic balancing on the spindle, and 820 mm capacity, suitable for grinding long pinions up to 800 mm between centers.

Ash Gear & Supply was demonstrating an upgraded version of its gear calculation software program, GCP 2. The program calculates gear data for internal, external, spur, helical and worm gears, as well as racks and straight-sided splines.

Fellows displayed their new FS 180 Mark III CNC Hydrostroke Gear Shaper. This machine is designed for both high and low volume manufacture of the smaller gears found in automotive transmissions. Its new "gearless" technology features six servo-driven axes of motion for higher speeds than were previously possible. The machine also features a GE FANUC 15 MB computer control. The FS 180 has a capacity to 7" (180 mm) pitch diameter and will handle face widths to $1^1/_4$" or 32 mm.

Top: The "gearless" Fellows FS 180 Mark III Hydrostroke gear shaper in action. Bottom: The Lambert AG booth featured affordably priced mechanical hobbers for fine-pitch gears.

At work at the American Pfauter booth was the P100 hobbing machine, which the company bills as an "entirely new concept in hobbing." The P100 can handle both cutting with high-speed tools and cooling oil or dry cutting with super hard cutting materials. It features a small footprint and is designed with all components not directly involved in the cutting process located outside the working area for easy maintenance. It has anti-friction slideways of the linear axes for both maximum stiffness and accuracy, superior thermal stability and a Siemens 840 CNC control system.

Alpha 1 Induction Heat Treating Center introduced αAlphaform™, its new formable induction heating concentrator. This patent-applied-for material is a composite of insulated micro iron particles, space-age polymers and a thermal sensitive catalyst. The purpose of such concentrators is to decrease the amount of energy and/or cycle time needed to heat the part and to help control, aim, focus, shield and direct the magnetic field. Alpha 1 says that αAlphaform can save from 35 to 60% on energy and cycle times.

Lo-Tech Highlight

Perhaps the most interesting "low tech" item at the show was the centerpiece of a special unannounced event. Wendy Young, wife of Fred Young of Forest City Gear, auctioned off a special gear designer necktie at the Koepfer booth. This tie, the last one of a limited edition, featured a design of bevel gears on a dark blue background. The winner of the auction was Jim Gleason of The Gleason Works, and proceeds of the auction went to the AGMA Educational Foundation. Mr. Gleason was unavailable for comment about whether he would actually wear this piece of rare "gear art." ✪

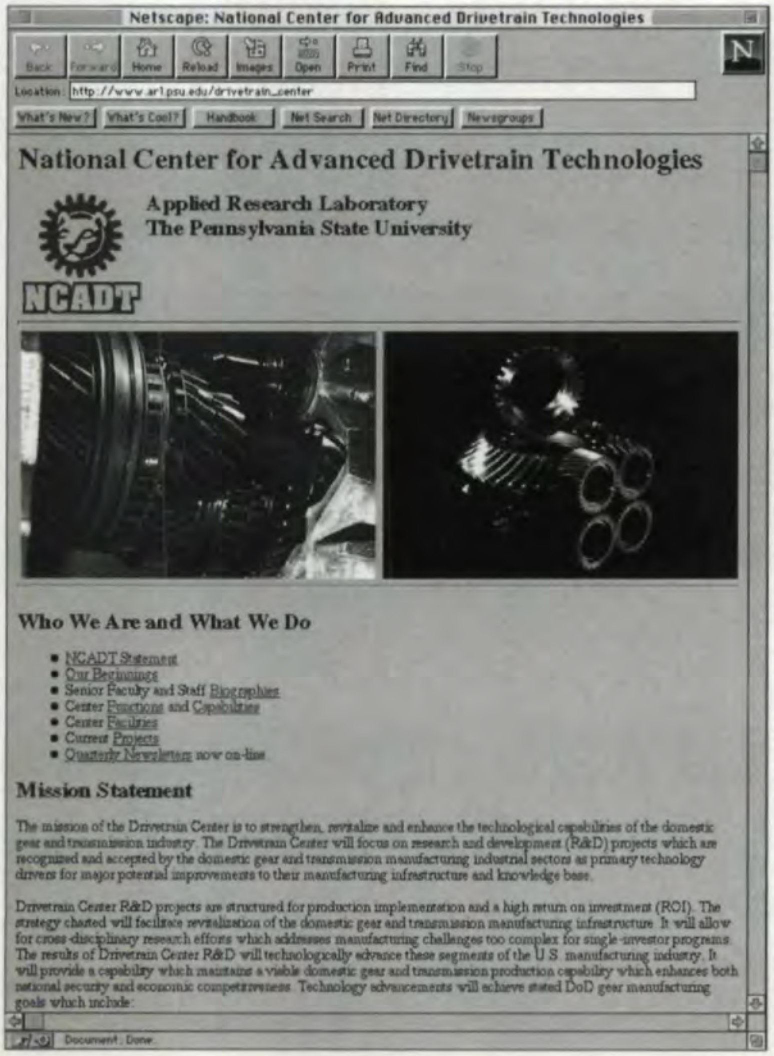
Tell Us What You Think...
If you found this article of interest and/or useful, please **circle 200.**

Watch This Space!

Nancy Bartels

The Internet. Big deal. Now that you've dialed up weird politics.com, http://www. Elvis sightings and alt.naughty bits, what's online that's useful? Anything that would make your job easier, answer important questions, solve tough design problems? Information about, say, gearing? Is there anything out there in cyberspace worth the expense and hassle of going after?

Yes. Behind the hype is a reality: the Internet can provide relatively cheap, very fast access to information that otherwise would be at least inconvenient, if not impossible to lay your hands on. For gear people, the amount is still small, but it's growing.



NCADT's home page.

Long before its more glitzy and bizarre aspects became media obsessions, engineers were using the Internet as a giant electronic library/phone line/coffee house/bulletin board for information exchange, and as more and more of the Internet superhighway is developed, gear information buried in large libraries or available only to the few who can spare the time and cash to go to a particular seminar could become available via computer almost instantaneously.

A Few Cautionary Remarks

The infobahn is not without its problems. First, it is at present a giant, chaotic system still under construction, with all the delays and hassles that implies. The technology is also still in its infancy, and the glitches are by no means out of the system. Depending on your equipment (and that on the other end), you will encounter your share of delays, roadblocks, blind corners and dead ends to be navigated. Patience may be your most important travel accessory on the information highway.

Second, in spite of what many true believers will tell you, traveling the Net is not always as easy as a few mouse clicks, but it's not gear engineering either. The learning curve will vary, depending a great deal on your comfort level with computers and on the hardware/software configuration of your machine.

Be prepared to spend some time (and money) getting yourself ready to travel cyberspace. A good Internet experience requires that you do some homework. But there's a thriving publishing sub-industry out there more than willing to provide you with guides on paper, disk and CD-ROM to ease your navigation.

Finally, don't assume that what you see on the Net today is all that will be there tomorrow. Even the most sophisticated web pages are not cast in stone. (Part of their beauty is the ease with which their content can be changed and updated.) The Web is growing exponentially. Just because you don't see a particular site today doesn't mean it won't be there tomorrow or next week or in six months. The distance between the promise and the reality of the Internet is shrinking daily.

WWW—Main Street, Cyberspace

If the Internet is a giant, virtual boom town, then the World Wide Web is its Main Street. It's where everybody goes to see and be seen, and this is a good first stop in your search for good gearing information.

Most web sites have the same basic configuration. The first thing you'll see is a "home page," which will have more or less elaborate graphic design and copy telling you where you are and what's available at this web site. Phone and fax numbers and addresses (both e-mail and USPS "snail mail") are also often on this page.

This opener will also contain a kind of table of contents—a list of other "pages" at the site. These key descriptors are either in colored type or underlined (depending on your computer system). They are the "hyperlinks" that will get you to other places on the web site.

Suppose you call up the home page of a technical society. Among the key words is "Membership." You click on that word and are taken immediately to a screen that gives you information about joining the society. Frequently a form appears, and, if you're willing to give your credit card number on-screen, you can join instantly.

The same principle operates for the other screens. You can look up information on (and order or register for) conferences, publications, special programs, etc. Sites may include complete lists of books, papers, video tapes and other materials available for purchase. Internet security is still a major concern, and most sites also have an 800 phone number, which may be a wiser course to take when ordering anything. On some sites, certain areas—usually bulletin boards for information exchange or options for downloading papers and/or software—are open to members only.

Some organizations will list key members, their qualifications or backgrounds, their e-mail addresses and direct phone/fax numbers, even their pictures. What you find at a particular site is limited only by the imagination and inclination of the site provider.

Cool Sites

Many of the traditional sources for gearing information have gone online. The **Society of Manufacturing Engineers (SME)** has a site much like the hypothetical one described above. Along with membership and conference information, the site contains a list, with brief descriptions, of 250 books, arranged by subject matter, that are available for purchase from the society. There's also a page for video tapes and courses. There's a bulletin board, accessible by members only, called SME ON-LINE. It provides employment information exchange and other discussion groups, plus manufacturing-specific software that can be downloaded right to your computer.

The **National Center for Advanced Drivetrain Technologies (NCADT)** at Penn State publishes its quarterly newsletter online. It provides e-mail addresses and qualifications and areas of expertise for key staff members. There's also information about the center, its functions and capabilities, current projects and its facilities.

The **American Society for Metals International (ASM)** has a web site, but its webmaster cautions that it is still very much "under construction." Work is in progress to link its successful members-only bulletin board to its web site. Along with membership information, the site has a guide to materials producers, a database of monthly magazines published by the society and members-only discussion groups and forums. ASM is experimenting with a number of other site possibilities, and this is one web address it might be well worth your while to watch carefully over the next months.

You can access the gear research information at **NASA's Lewis Research Center** from the Web. Information about the Center's Tech Briefs are online. So is information about opportunities for business and industry and technology transfer. You can get to the Lewis Tech Report Server and the general NASA Tech Report Server from this home page. This web site also has its own search engine, called Recon, which scans a very large data base of NASA research information.

ITTRI and **INFAC** can be accessed through the home page of the **Manufacturing Technologies Information Analysis Center (MTIAC)**. This is a Department of Defense-sponsored organization operated by IITRI to provide defense industry-related information. From here you can check on resources at universities and other government agencies. For example, the National Center for Excellence in Metalworking Technologies (NCEMT), the University of California at Berkeley Consortium on Deburring and Oak Ridge National Labs can all be called up from this home page.

The American Society of Mechanical Engineers (ASME) has a simple web site which outlines all its various programs. It also has a unique and useful e-mail feature. You can call up a simple form which allows you to e-mail questions to "Information Central." Fill in the blanks, click the "send" icon and your message is on its way.

AMT—The Association For Manufacturing Technology began its site in May of 1994 as a way to publicize IMTS'96. Information about the

The Gear Engineer's Internet Phone Book

Listed below are URLs (Uniform Resource Locators), a.k.a. addresses, for the Internet sites discussed in this article. This is by no means a comprehensive listing. New sites are added every day, and we did not cover every corner of the Net researching this story.

User Note: URLs are notoriously user-unfriendly. They must be keyed in *exactly*, or you won't get to the site you want. If you get a message to the effect that "We can't find this site," the first thing to check for is typos. And remember, all the dots, slashes and squiggly lines count.

AMT — http://www.tmn.com/amt/index.html

ASM — http://www.asm-intl.org

ASME — http://www.asme.org/asme/

IITRI-INFAC — http://www.dtic.dla.mil/iac/mtiac/MTIAC.HTML

Industry.Net — http://www.industry.net

Lycos — http://www.lycos.com

MRS — http://www.mrs.org/

NASA Lewis Research Center — http://www.lerc.nasa.gov

NCADT — http://www.arl.psu.edu/divisions/rcmp/drivetrain_center/drivetrain_center.html

NCMS — http://www.ncms.org

NIST — http://www.nist.gov/

SME — http://www.sme.org/

YAHOO — http://www.yahoo.com

show, including registration, is available online. In November, the general organization's web site opened at the same address. It contains information about the organization, membership and services. Like many other organizations, AMT is viewing its site as "experimental." Plans for future additions to the site will be dependent on the response to these initial offerings.

The **National Center for Manufacturing Sciences (NCMS)** has an elaborate site clearly divided between services for members and "guests." The best information, naturally, is available to members only, but as a guest, you can get a thorough tour of the organization's purposes and available services.

The **Materials Research Society (MRS)** is another group with a very rich site. It contains the usual information on membership, meetings, awards, publications, exhibits, etc., plus mechanisms to allow you to register for short courses. An FTP (computerese for "File Transfer Protocol," the software necessary to allow you to download information) site is under development. When this is done, it will allow members and others to share materials, information and software.

Commercial Sites

Research, government and technical societies are not the only people using the Net. There are thousands of commercial sites as well. As time goes on, more and more companies will be putting brochures, product lists and technical information about their products on the Web.

At present, one of the more interesting commercial sites is **Industry.Net**. It's a business-to-business directory that works very much like a controlled-circulation magazine. When you access the site, you're asked a number of questions about the type of business you're in and the kind of information you're looking for. Then, once you're "qualified," you have free access to over 4,000 companies with web pages on the Industry.Net Online Marketplace. These companies offer product descriptions, photos, manufacturer and supplier information, downloadable software and demos, catalogs, brochures and news items. Among the types of products offered are engineering software, PCs and workstations, industrial control products and design tools.

Industry.Net's home page.

Industry.Net also contains a search engine that allows you to type in the product you're looking for and get directions on where to find it. The company has recently cut a deal with NETCOM Online Communication Services to distribute its NetCruiser software free to Industry.Net customers. Call 412-967-3500 or e-mail info@industry.net for more information.

Lycos & Yahoo—The Library & The Phone Book

Two of the most useful sites currently on the Web for people searching out information on particular subjects are **Lycos** and **Yahoo**. Developed by Carnegie-Mellon University in Pittsburgh, Lycos is like a giant card catalog, providing a means of searching out specific information available on the Net and directions for finding it.

To do a Lycos search, you simply type the subject (say, "gear manufacturing") you're looking for in the box shown on your screen and let the computer go to work.

For the search on "gear manufacturing," Lycos scanned 8,545,325 unique URLs (internet addresses) in less than five minutes. It found 14,857 documents with either the word "gear" or "manufacturing" in them; 137 contained both.

Then it showed brief abstracts of the documents ten at a time and, almost more important, Internet addresses for them and their document size, which is an important consideration if you're considering downloading. The first ten called up were on subjects including gear metrology, ausrolling, face gearing, friction gears, gear grinding, gear patents and the home page of a machine tool manufacturing company.

Yahoo is more like the Yellow Pages. Developed by two college students—many cybermillionaires aren't yet old enough to shave—it is a series of menus. It divides the Web into categories to help you narrow your search. You start by clicking on "Engineering," and Yahoo begins calling up the addresses of Web sites that might contain the kind of information you're looking for.

Gopher and WAIS

In all the hype surrounding the World Wide Web, it's easy to lose site of the fact that it's not the only thing on the Internet. There are other information sources on the Net that can be just as useful. **Gopher** and **WAIS** are ways of organizing the vast quantities of information spread all over cyberspace. Gopher, named for the mascot at the University of Minnesota, where it was developed, is like the table of contents of a book. You look through the various menus listed to see if there's anything of interest in a particular area. WAIS (pronounced "ways") stands for "Wide Area Information Server." It's like a book's index. Even if a subject didn't seem of sufficient importance to rate a place in the table of contents, it might be included in the index. As with Lycos, you type in the name of the subject that interests you, and WAIS pulls up menus that contain possible locations to check.

The amazing (and a little scary) thing about Gopher and WAIS is that a few mouse clicks will suddenly bring you to a menu item like "Library-Oxford University" or "Search all Gophers in South America." Some Gopher sites are also cross-linked to the Web. For example, we first found the NIST (National Institute of Standards and Technology) site in Gopherspace, but it can also be accessed through the World Wide Web.

The Local Coffee Shop

Chat lines and bulletin boards are another part of the Internet. If the Web is Main Street, Cyberspace, and Gopher is a virtual public library, then BBSs, or bulletin boards, and chat lines ("Usenet" newsgroups in Net-language) are like public kiosks or coffee shops. You post a notice or go in and hang around and see what happens.

BBSs and chat lines are usually segregated by topic. How you find the topic you're searching for will depend on the format your particular Internet service provider uses. "Netiquette" suggests that in a chat room (where you can enter a "live" conversation in real time), you "lurk" for awhile, listening to the ongoing conversation before butting in. After you get a feel for the particular discussion and culture of the group, you just jump in.

One thing to keep in mind: On serious bulletin boards and chat lines among experts and professionals, you're expected to bring something to the party. Legitimate questions—even from "newbies" or first time users—are welcomed, but you can get some pretty testy responses to general questions that suggest you've been either too lazy to do your homework or are clueless about the subject. "Hey, I need all the information you have about spur gears," is not the way to win friends and influence people in this part of cyberspace.

If you cannot find a chat line or BBS about the subject that interests you (we struck out on gearing subjects during a cursory search one afternoon), you can always set one up yourself. Again depending on your service provider, you may have access to a process whereby you can open a discussion group on a new subject. You post a notice that says, for example "I want to exchange information on the subject of gear design with other engineers." Then you wait to see if anyone responds.

Honeywell's home page accessed through Industry.Net.

We're Not in Kansas Anymore

The Internet is a whole new ball game in terms of accessing information. The medium is also maturing. Cyberspace is not populated entirely by dateless seventeen-year-old propeller heads and cranks broadcasting accounts of their abduction by space aliens. Serious research tools are where the Internet began, and now the software is available to help those of us without advanced degrees in programming to access them. Businesses have also discovered the Internet and are in hot pursuit of ways to use it.

Some gear information is available in cyberspace now, and more will be coming. True, it's still easier in many cases to just grab the phone and call for information, but given the confluence of more user-friendly technology and the demand for more and more information from everywhere faster and faster, an Internet connection may become an important item in your engineer's tool box in the future. Even if you don't feel it's time for you to hit an entry ramp to the information highway yet, you're going to want to be scanning the traffic out there. "Cyber" is definitely a space worth watching. ○

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

The Next Generation of Gear Specialists

Beyond AGMA's Gear School

AGMA has an excellent Training School for Gear Manufacturing. It's a great product providing a great service to the gear industry. Thus far we've educated 117 employees from 71 companies; students range from new hires with no experience to company presidents. Essentially every class since December, 1992, has been sold out.

But what happens next?

Based on my conversations with members and on formal surveys, the biggest problem we have today and the most frequently asked question is, "Where can I get a reliable source of qualified employees?" The AGMA Foundation recently completed a study (funded by the Gleason Foundation) of the needs of the gear industry in the future and found, not too surprisingly, that education and training were near the top of the list of concerns.

There are a number of good programs currently available that cover specific manufacturing and design issues. Most of us use the courses offered by machine tool builders. AGMA has other educational programs, such as the Fall Technical Meeting. Ohio State University and SME, among others, offer short courses that help us all. Our own Gear School has begun offering advanced courses such as our Hob Sharpening Workshop.

These are good for the professional development of our current staffs, but what about the in-depth training of new employees? What about recruiting new people to the field? Corporate-funded, in-house training is beyond the reach of all but the largest of our businesses, and the lack of skilled personnel entering the gear industry is no longer news, but a fact of life.

What to do?

I'm excited to report that the Director of Manufacturing Technology, Mr. Prem Sud, and Dean of Skills and Manufacturing Programs, Dr. Shirley Knazze, of Daley College in Chicago have been working on the problem and have presented a concept to me, which, if accepted by the industry, could help us find the employees we need well into the future. And this educational program can be readily "cloned" into any community in which our members operate.

The program would be open to any student entering Daley College and especially to current employees of gear companies. Students would take two courses each semester (the time can be extended if students take one course per semester). At the end of this training, the student/employee would receive an Advanced Certificate from Daley College. He or she would then have three options: transfer to the Illinois Institute of Technology's Bachelor of Manufacturing Technology Program, continue at Daley College for an additional year to receive an Associate's Degree or enter or return to full-time work.

Full-time Daley College students would take these courses in the context of their regular college curriculum. If your company sponsored students, it would be expected to develop a cooperative work/study program that would allow them to attend classes while continuing to work essentially full-time.

What will students learn in the program? The curriculum is a mix of basic college courses such as English and math, supplemented by formal education (and some hands-on labs) in manufacturing. The selections allow for flexibility, so the courses can be tailored to meet the needs of the student and of his or her employer.

The program is affordable. The preliminary estimate of the full two-year program is in the range of $2,500.

What do you have in the end? The Daley College curriculum has the multiple objectives of 1) providing a strong education in mechanical and gear manufacturing skills, 2) helping enhance the skills of current employees and 3) developing long-term employees to cover attrition and growth in the future.

From my viewpoint, this is clearly a win-win arrangement: Employees become educated in both hands-on and college instruction and finish the program as qualified technologists. Employers strengthen their workforce base and gain access to a constant stream of motivated, educated future employees, and our community and society benefit because we are teaching practical, usable skills that lead to a real job at the end. It's good for our industry, our companies and for the individuals who might otherwise be stuck in low-wage, low-advancement positions.

I'd be interested in your views. Please contact Mr. Prem Sud at Daley College (312) 838-7836 or me at (708) 543-9570 if you'd like to be part of this new program. ○

Charles A. Brannen
is the president of AGMA and the vice president of Overton Gear and Tool Corporation, Addison, IL.

Based on an article, "How to Find Good Employees," which appeared in the AGMA News Digest, *July/August 1995.*

Tell Us What You Think...
If you found this article of interest and/or useful, please circle **202**.

The Next Step in Bevel Gear Metrology

Hermann J. Stadtfeld

In recent years, gear inspection requirements have changed considerably, but inspection methods have barely kept pace. The gap is especially noticeable in bevel gears, whose geometry has always made testing them a complicated, expensive and time-consuming process. Present roll test methods for determining flank form and quality of gear sets are hardly applicable to bevel gears at all, and the time, expense and sophistication required for coordinate measurement has limited its use to gear development, with only sampling occurring during production.

The Gleason Works has developed an innovative bevel and cylindrical gear tester which addresses these issues. The Phoenix® 500 HCT allows a performance-related forecast of the quality of a gear set and delivers data for tooth geometry corrections. The first of these new machines were delivered in December.

New Test Concept for Gears

The Phoenix® 500 HCT (Hypoid Cylindrical Tester) was developed to determine the behavior of a gear set under load and at realistic speed before mounting it in the vehicle. The machine features a state-of-the-art combination of digital tooth contact imaging, high-speed single flank testing and 3-D, structure-borne noise analysis. Its mechanical construction is based on the 6-axis Phoenix® free-form concept (Fig. 1).

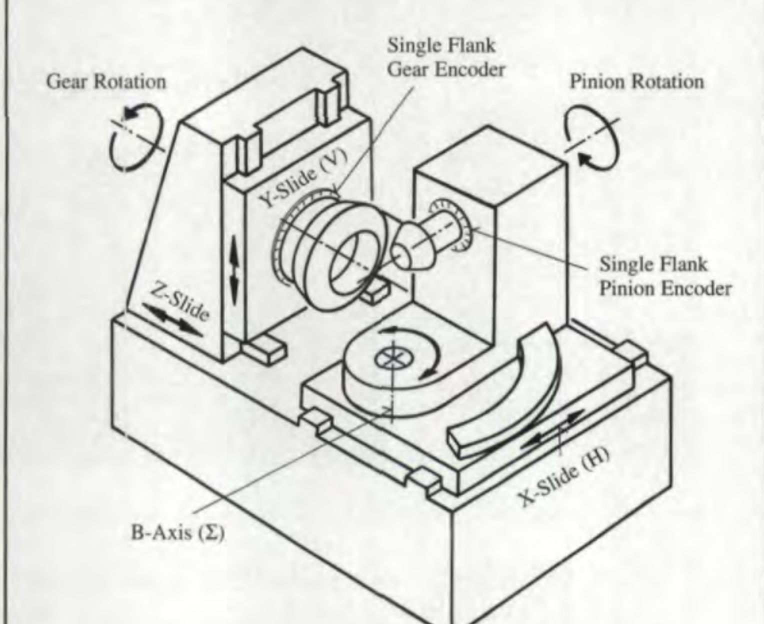


Fig. 1 — Location of the main component of the universal HCT concept.

Extensive analysis has shown that in roll testing, the quality of the results greatly depends on the precision of the setup (Refs. 1, 3). Solid-wall, ribbed cast iron machine frame and spindle housings, preloaded roller bearings on slide ways and optimally located linear scales and angular encoders were used to ensure the highest precision and stiffness. Hypoid offset (Y or "V"), pinion cone (X or "H") and gear cone (Z or "G"), as well as the shaft angle (B or "α") can be changed. A shaft angle adjustment between zero and 90° enables the HCT-testing of cylindrical as well as bevel gears. All axes can be adjusted during testing. Together with a gear torque of 72 ft/lbs. or 100 Nm (144 ft/lbs. or 200 Nm optional) and pinion speeds up to 3,000 rpm, this enables simulation of critically noisy situations in the vehicle.

During actual operation of a transmission, the gear axes are translated and the shaft angle is deflected. Optimization of the pinion cone in such a deflected position can be accomplished while under torque loading. The result is a pinion mounting distance for the load-free, undeflected state. During the pinion cone search under load with adjusted (deflected) X, Y and α settings, the backlash is kept constant. Because pinion speeds of up to 3,000 rpm require adequate lubrication during cycles, a flow of oil is periodically directed on the gear mesh. Four-quadrant operation ensures realistic test cycles simulating drive conditions. Drive and coast sides can be tested in the same direction of rotation, with positive or negative brake torque. Conventional testing using forward and reverse rotation is also possible.

In the 500 HCT tester, the chucking cylinders are not attached to the rear of the spindles by rotary joints, which would cause vibration, but are integrated in the spindles between the bearings. A newly developed lightweight construction concept delivers a low-vibration spindle with minimum inertia. All setup work, such as installing and fastening the draw rod, can be done conveniently from the machine's work area. The linear Z-axis, which moves the gear axially, has a spring-loaded, ball-screw nut, which prevents damage to the spindle in case of top-on-top interference during the Z-slide advance for meshing. When the spindle nut is displaced by such an interference, a proximity switch is tripped, initiating withdrawal of the Z-axis slide, rotation of the pinion and a repeated mesh attempt. This mechanism is also used to set backlash by advancing the Z-axis to a metal-to-metal position, followed by a defined withdrawal of the gear slide. All slides are fitted with direct linear measuring systems, so that the effective position of the Z-axis slide is always known, even when the ball-screw nut is displaced. The fact that the gear slide is loaded against a spring also enables composite testing. A single revolution of the gear with double-flank contact is sufficient to determine the face runout of the gear, shaft runout of the pinion and an optimized gear mounting position (with guaranteed minimum backlash). If face runout and shaft runout exceed predetermined tolerances, the gear set will be rejected right at the beginning of the test, and the cause attributed to pinion or gear will be displayed on the screen.

For designation of the machine axes Y, X, Z and B, the traditional gear testing axis nomenclature, V, H, G and α, has been chosen as the best compromise between Gleason's traditional designations (E, P, G and α) and the common worldwide designations (V, H and ?).

All tests and measurements on the 500 HCT tester can be performed on cylindrical gears as well as on bevel gears. This means that parallel-axis gears for applications where deflection and noise are critical can be tested for tooth contact pattern, structure-borne noise and transmission error, just as bevel gears can.

Laboratory and Production Floor Use

The 500 HCT measuring and testing machine is not only a high-precision measurement tool for the laboratory, but also a 100% inspection tool for the production environment or for quality control. It is incorrect to assume that a production test can be less precise and should be without advanced measurement and analysis features. Today's quality standards demand a full-featured production testing machine that brings lab testing abilities to the shop floor. The laboratory investigation can establish the combination of criteria to be fulfilled by an individual gear set in order to pass acceptance in the vehicle. This can include requirements related to tooth contact, structure-borne noise emission or single flank variations. It is not

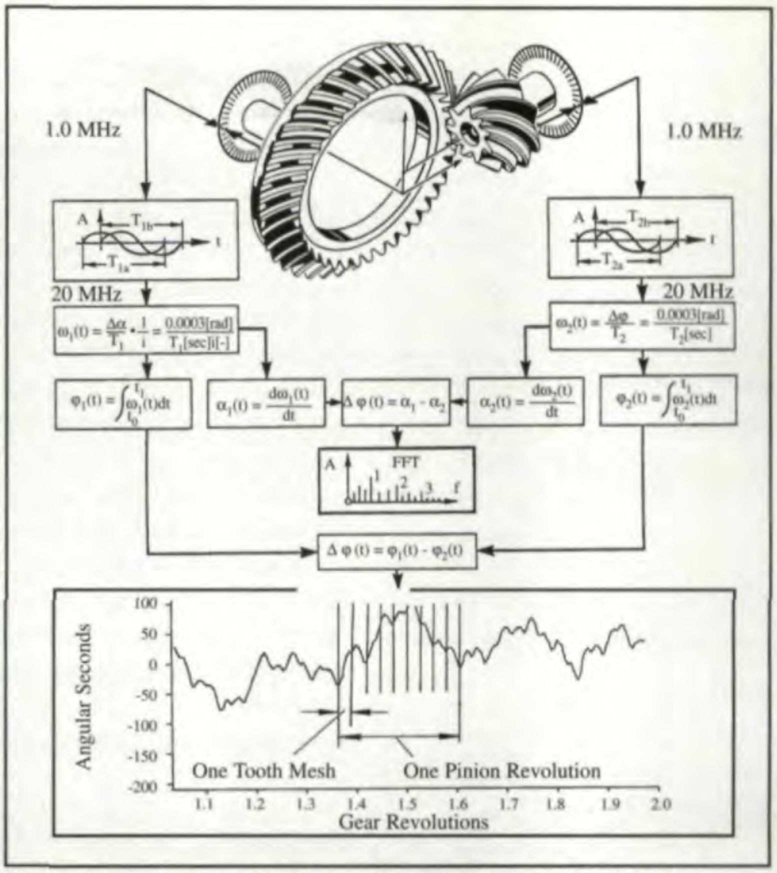


Fig. 2 — Measurement and structure of data processing for single flank tests.

necessarily evident beforehand if criteria for all three test types can be established or if it is mandatory to do so.

It is quite possible, for instance, that the analysis of vibrations a gear set transmits to the spindle housing of the testing machine does not reveal a correlation with the noise in the vehicle. The noise levels of a "quiet" gear set may well be higher on the testing machine than those of a "loud" gear. In this case, the single flank test or a combination of single flank test and structure-borne noise analysis will provide a criterion for testing.

Automatic test cycles are not required in the laboratory, and digital image detection of the tooth contact pattern is only necessary in certain cases. For optimum use in the laboratory, the 500 HCT has an operator panel that pivots 90° and houses two color monitors, all hardware controls and an electronic handwheel. While tests and experiments are carried out, the gear set and panel both can be conveniently viewed from one position. The handwheel can be switched to move an axis or to rotate the pinion. Thus, the simple and practical handling of the old mechanical testers is being realized for the first time in a CNC tester. This ease of use means an enormous increase in effectiveness. In production testing, the electronic handwheel can be used for setup. In automatic operation, the panel may be pivoted back to be flush with the machine front.

Dr. Hermann J. Stadtfeld

is the director of research and development at the Gleason Works, Rochester, NY.

All options and features described below are equally important in both laboratory and production use. Specific software and electronic hardware components for single flank testing and structure-borne noise analysis will be discussed later (Ref. 2).

High-Speed Single Flank Analysis

Circular Heidenhain ERA angular encoders with 18,000 lines are integrated into the spindle units of the Phoenix 500 HCT behind the front end plates. Their location between the gear/pinion and the front spindle bearing is optimal, based on Abbe's principle. The integration of the encoders into the spindle housing and the use of a positive pressurized atmosphere protects them against damage and contamination. All wires are located inside the spindle housings to prevent interference in the work area and accidental damage. Behind the circular front cover, the encoder reading head is positioned at an angle to eliminate all linear relative vibrations between the head and the encoder disk, thus preventing corruption of measurement results. Both spindles (pinion and gear) are constructed identically.

The new generation angular encoders do not transmit a current signal as conventional encoders do. Instead they send a voltage signal to the digitizing unit (called "IVB" instead of "EXE," as in older systems). This allows twice the conventional data transmission rate between the reading head and IVB of 1 MHz (Fig. 2, top), with full-time resolution corresponding to a spindle speed of 3,333 rpm. The transmission speed between IVB and the counter board is 20 MHz, allowing measurement with a time resolution of 50 ns.

3-D Structure-Borne Noise Analysis

Behind the front spindle covers, accelerometers capable of measuring vibration components in three dimensions are mounted next to the reader heads of the angular encoders. Therefore, three independent signals are available from both pinion and gear housing for structure-borne noise analysis. Conventional testing machines analyze structure-born noise by measuring only the radial vibration near the front gear bearings. However, the front bearings of a tester, similar to the bearings of a gear in a gearbox, transmit both radial and axial vibrations from the rotating gear set to the housing. The Phoenix 500 HCT was designed to capture all components of structure-borne noise in order to parallel reality as closely as possible. Since the pinion as well as the gear can induce and transmit vibrations, both spindles are equipped with 3-D accelerometers.

As shown in Fig. 3 (top right), the axial pinion vibrations are measured in the direction of the X axis. The vibration signals in the Y and Z direction can be added as vectors to obtain the radial component ($S_{radial} = [S_y^2 + S_z^2]^{1/2}$). Regardless of the direction in which the largest radial signal S_{radial} occurs, it is automatically found with a simple calculation. This is important, since the orientation of the maximum radial vibration differs slightly between designs and even between individual gear sets. The slightest variation can cause a fixed sensor operating in only one dimension to become insensitive to even significant vibrations in other directions. The sensor on the gear side measures the axial vibrations in the direction of the Z axis. The radial vibrations are calculated from the equation given above.

Digital Image Recognition of Tooth Contact Pattern

Even with CNC testers, unattended testing has been possible only under very limited conditions. Only when both the position and form of the tooth contact pattern were assumed to be always acceptable, and documentation of the pattern in production testing was not required, has a fully automatic test been possible. Again setting a new standard, the Phoenix 500 HCT employs two video cameras for the automatic recognition of the contact pattern on both the drive and the coast sides.

The cameras are mounted inside the chamber and can be pivoted in two directions. During setup, manual pivoting of the cameras ensures that the gear segment investigated coincides with the

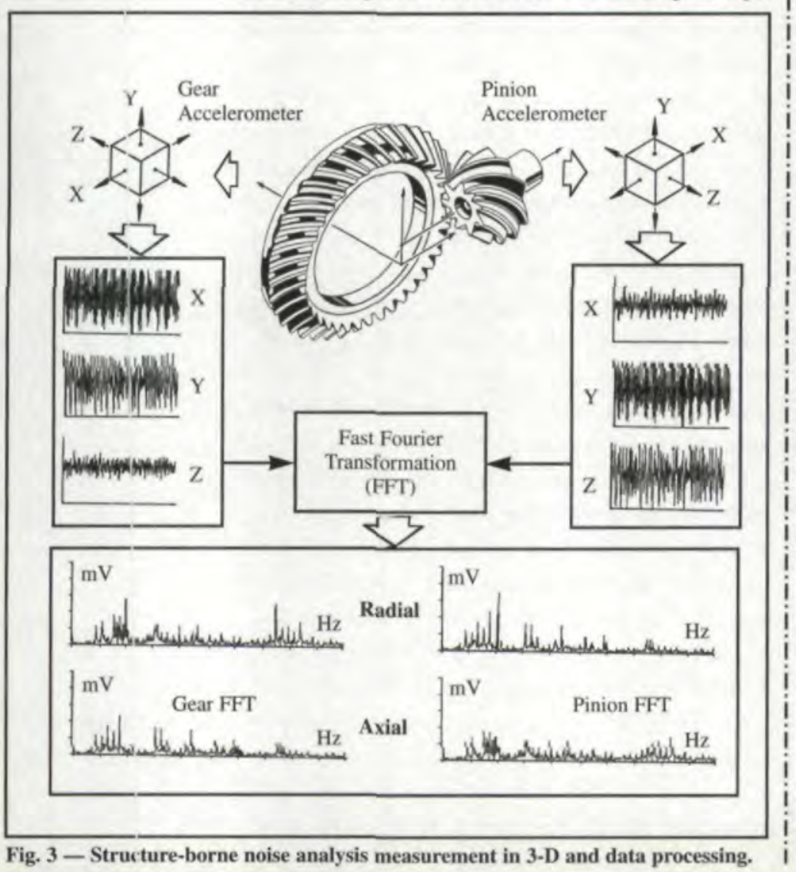


Fig. 3 — Structure-borne noise analysis measurement in 3-D and data processing.

center screen portion; thus, the distance and position of the measured object to the camera are exactly reproducible without the use of special measuring equipment. The video cameras send their data to an image processor board (Fig. 4), which delivers a data file with binary information, allowing 256 different shades of gray per pixel. The problem of oil mist obscuring the view of the cameras has been solved by a unit that removes the oil, leaving no dirty compound mist behind, and applies marking compound with a rotational brush to the teeth. To save time, this is done while the gears are rolling together.

Image data computation redefines the 2-D video image of the picture of a gear segment into 3-D information. To quickly and precisely locate the position of a tooth and its outlines, a virtual tooth was previously generated. This virtual tooth is transformed in the machine coordinate system and rotated until it matches with the video image. Subsequently the picture pixels within the tooth contact pattern are mapped to tooth surface coordinates. The contact information of all teeth investigated is superimposed on one tooth, resulting in only one contact pattern image each for the drive and coast sides in which the influence of light reflections and camera viewing angle is largely eliminated.

Tooth contact patterns obtained by video in this way can be displayed in color on the screen of the HCT tester and archived. In the automatic test run, the contact pattern information obtained is compared to information for a master gear. The patterns are stored together with the acoustic and geometrical test results and can be used for documentation of statistical quality control.

Modular Design of the Test Cycles and Special Options

In designing the HCT operating software, great effort was made to develop a completely universal, modular program structure, which allows for maximum flexibility for the individual user in determining appropriate test cycles. The script function in Fig. 5 lists a subset of the basic features required in a test cycle. These and many more basic features have been made into standalone routines or script functions. They can be called up in random order and as often as desired. The script functions or "modules" take the necessary data directly from the test summary to which each is interfaced. The summary is a set of test data containing all information on the gear design to be tested as well as on the specific cycle. The order of operations comprising a cycle is determined by the script commands; all data is taken from the summary.

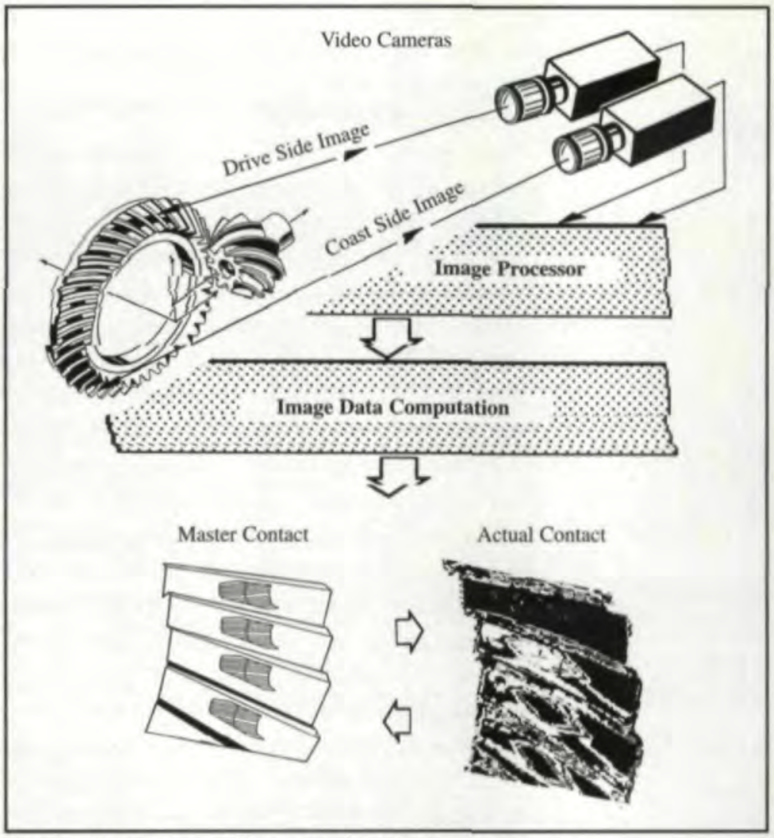


Fig. 4 — Contact recognition system by video image processing.

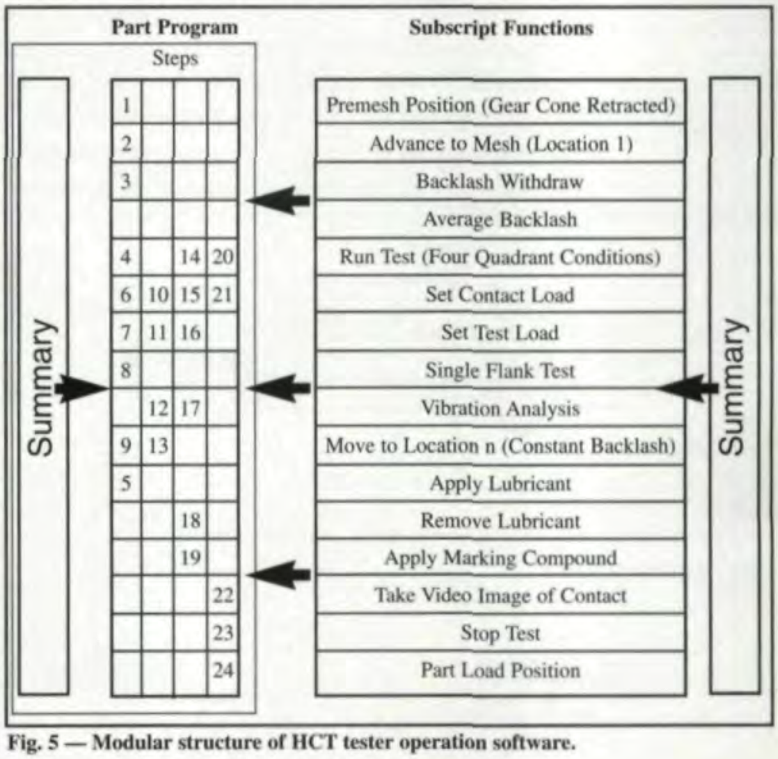


Fig. 5 — Modular structure of HCT tester operation software.

To minimize testing time, either all measurement tests at a given axis position or the same tests at all axis positions can be grouped together to organize the cycle. It is possible, for instance, to perform a single flank test, a noise analysis and a contact pattern recognition for the drive and coast sides in axis position #1 and to make the same test in position #2. This allows termination of the cycle in the first acceptable axis position.

Closed Loop Between Vehicle and Tester

The running vibration of the gear set provides an excitation to the vehicle as a total acoustic system. The various components of suspension and body amplify or attenuate the amplitude of the excitation. As the vehicle speed changes, these vibrations excite certain vehicle resonances, which in turn transmit these structure-borne vibrations to airborne vibrations, i.e., sound. The rise and fall of these excited resonances are the perceived sound in the vehicle as it passes through a resonant "noise period." The amplitude and duration of these noise periods are functions of the entire vehicle system, although changes to the excitation source (gear set) can cause improvement overall. The acoustic noise amplitudes transmitted by the vehicle can sometimes be dramatically different from the characteristics of the gear set alone, but the relationship remains just a function between the gear set and the ear of the driver (Ref. 4).

In order to establish correction guidelines or to quantify the transmission function of structure-borne noise and deduce a quality criterion from it, a mobile "sound analysis system" is being developed as an additional tool for use with the Phoenix 500 HCT. A laptop computer equipped for measuring structure-borne or airborne noise is carried in the vehicle during the road test. One or two accelerometers, each emitting up to three orthogonal signals, are mounted near the gear and pinion bearings. A microphone is installed at the ear height of the driver, and its signal is fed to the computer, together with the accelerometer signals (Fig. 6, top). Operation information from the vehicle, such as speed, torque, load and ratio, if available, can also be input to the portable computer. During the road test, the driver hits a push button at the very moment he objects to a noise. This may occur several times in differing driving situations. Pressing the button adds a time-related mark to the recorded information.

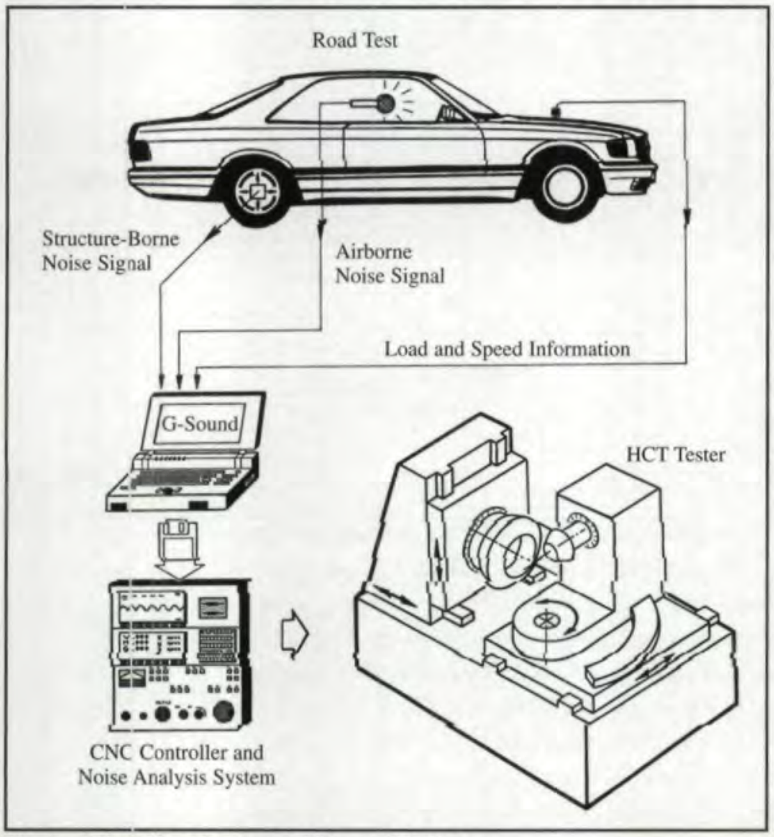


Fig. 6 — Closed loop between vehicle and HCT tester.

All results are transmitted by diskette to the analyzing computer of the HCT tester (Fig. 6, bottom). Subsequently, the same gear set is analyzed in the tester, using the same speed and torque as existed when the test driver indicated objectionable noise. Axis deformations will be simulated in V, H, G and α directions by using a strategy of search that leads to the most significant vibration results. The levels of the previously known critical frequency bands will then be transmitted as numerical values into a file for statistical evaluation and will be labeled with the grade the test driver had given. From at least four different gear sets and test drives, a valuation scheme can be established by the statistical program for use in 100% production testing. Use of more than 20 gear sets will provide a degree of certainty, depending on user-manipulated tolerances, which has never been reached by past methods.

In laboratory operation, results of just one test drive will be sufficient to calculate corrective values for production. From the objectionable frequencies, the levels of the first three harmonics of the tooth mesh frequency and their sidebands for calculation of fourth-order flank modifications, as well as the simulated axis deformations for initial correction of the tooth contact pattern location, will be used as a trigger for correction.

Conclusion and Outlook

The Phoenix 500 HCT tester represents the next step in the testing and measurement of gears. In the seventies, many gear manufacturers started to use single flank testing and structure-borne noise analysis. It was assumed that gear sets showing small amplitudes above the tooth mesh frequency and its multiples would run quietly. In too many cases, reality was different. The premature conclusion that dynamic measuring methods are unsuitable to indicate vehicle noise resulted in the continued practice of roll testing gear sets on manual testers and of relying on the auditory opinion of the operator. The operator was told what to pay attention to in critical cases. This information was often a feedback from the vehicle concerned.

What was realized there, under simple conditions, was an admittedly subjective, but quite

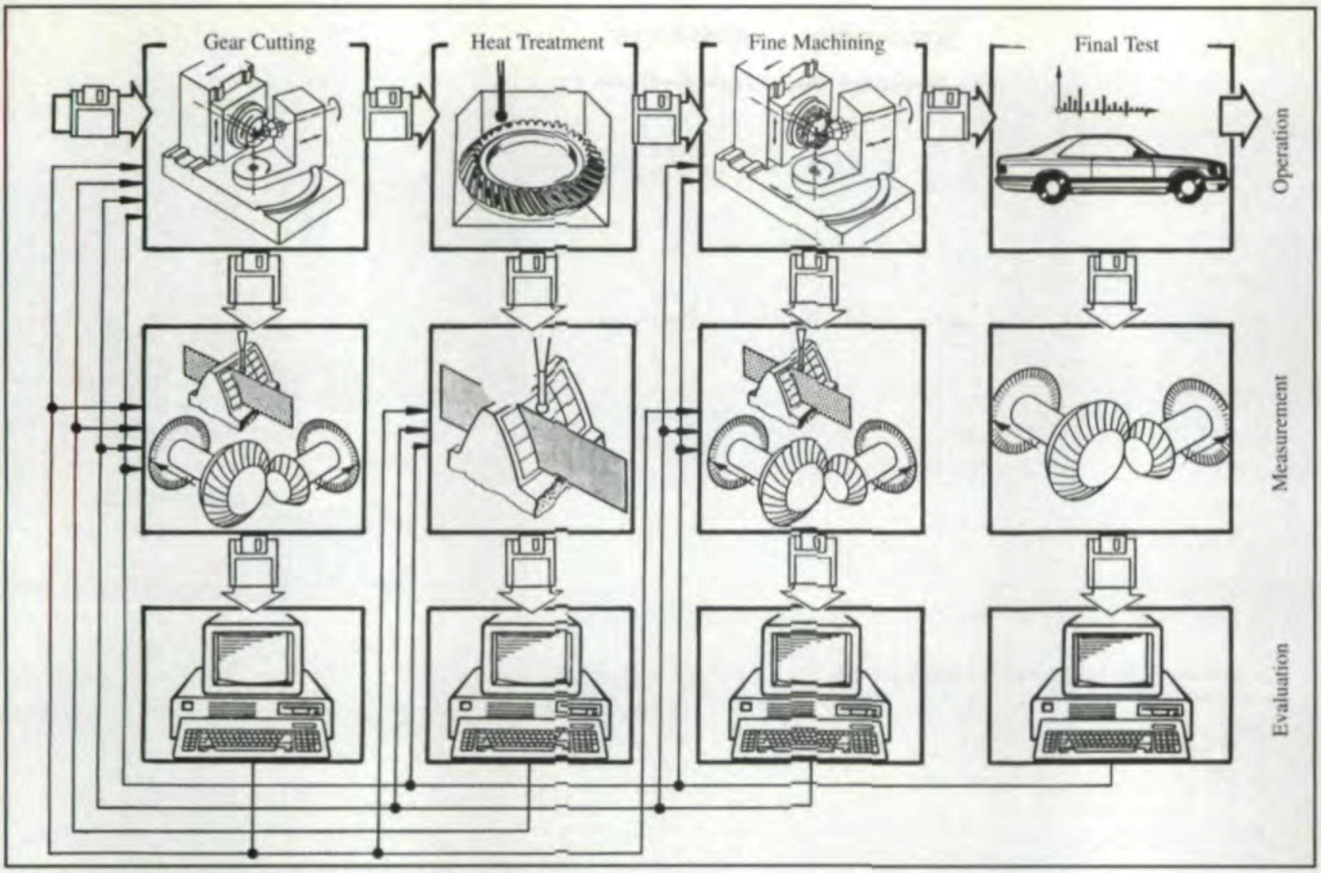


Fig. 7 — GLAB development system for bevel and hypoid gears.

sophisticated acoustic measurement. The operator at the manual testing machine took many factors into account, including different harmonic vibrations, their side bands, changes from drive to coast and whining noises during speed-up or slow-down. All these factors generally resulted from feedback from the vehicle test. After the test, the experienced operator checked the tooth contact pattern for acceptable appearance. The classical single flank test of the seventies could by no means be substituted for the abundance of information an experienced operator could absorb and evaluate during a test cycle of only a few seconds. Far more sensitive instrumentation and sophisticated evaluation techniques, as are offered in the Phoenix, are necessary to cover and quantify all the important relevant phenomena. The chief advantage of the new system, however, lies in achieving objective results to be compared against exact, consistent criteria.

Feedback from the gearbox, which in the best case is obtained when mounted in the final product, is indispensable, even when the objective measurement using the 500 HCT is made. Optimal gear development and production testing will be possible with the 500 HCT in the future (Ref.5). The chart in Fig. 7 shows the HCT's important function along with coordinate measurement. The duplication of basic geometry and the detection of heat treatment distortion is the task of coordinate measurement. All tasks related to the "fine tuning" of the tooth form (with respect to running performance and geometry) are the domain of the new tester. From the test results, changes of the tooth contact pattern position as well as higher order flank form corrections may be calculated as necessary to correct mesh interferences. ○

Bibliography

1. Gaiser, U. *Analyse des Abwälzverhaltens von bogenverzahnten Kegelrädern mit Hilfe der Einflankenwälzprüfung und deren Zusammenhänge mit der Geräuschentstehung*. Diplomarbeit FH Esslingen U. Mercedes-Benz, Stuttgart, 1989.

2. Legler, T. *Noise Tests and Production Control of Bearings with Data Base for Statistical Quality Control*. Company Publication, CMS GmbH, Ettlingen, Germany, 1991.

3. Weck, M & Plewnia, C. *Messtechnische Untersuchungen zum Laufverhalten von Kegelradgetrieben unter Betriebsbedingungen*. Bericht Zahnrad-und Getriebeuntersuchunger, RWTH, Aachen, 1990.

4. Smith, R. E. "Identification of Gear Noise with Single Flank Composite Measurement." AGMA Fall Technical Meeting, San Francisco, CA, October, 1984.

5. Stadtfeld, H. J. *The G-LAB Expert System, A Third Dimension in Developing Bevel Gears*. Company Publication, The Gleason Works, Rochester, NY, 1994.

Tell Us What You Think...
If you found this article of interest and/or useful, please circle **203**.

For more information about the product described in this article, please circle **204**.

Introducing... WinSpect™
Gear Inspection Product Platform

New Concept...

The future product platform for gear inspection is here! The *Winspect* platform is a revolutionary development available only from *American Sykes.* By using advanced PC electronics and software, this proprietary product platform finally gives gear producers the edge... an easy way to collect and manage gear inspection data from a variety of peripheral gear inspection instruments offered by American Sykes or other producers!

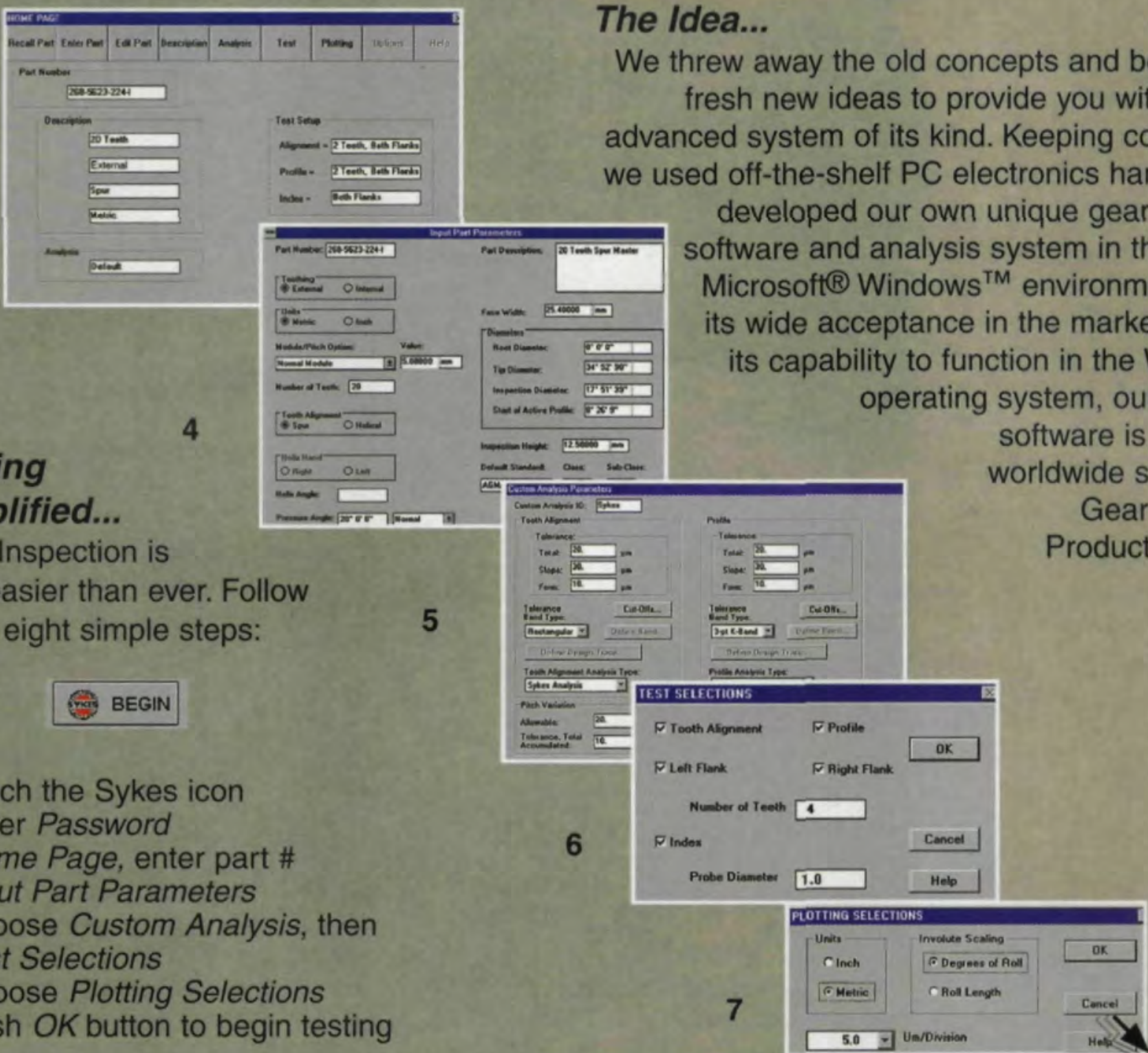
1

2

The Idea...

We threw away the old concepts and began using fresh new ideas to provide you with the most advanced system of its kind. Keeping cost in mind, we used off-the-shelf PC electronics hardware and developed our own unique gear inspection software and analysis system in the powerful Microsoft® Windows™ environment. Due to its wide acceptance in the marketplace and its capability to function in the Windows™ operating system, our *WinSpect* software is setting the worldwide standard for Gear Inspection Product Platforms.

3 4 5 6 7



Testing Simplified...

Gear Inspection is now easier than ever. Follow these eight simple steps:

☞ BEGIN

1. Touch the Sykes icon
2. Enter *Password*
3. *Home Page,* enter part #
4. *Input Part Parameters*
5. Choose *Custom Analysis,* then
6. *Test Selections*
7. Choose *Plotting Selections*
8. Push *OK* button to begin testing

American Sykes Company

INVOLUTE ARTIFACT CALIBRATION BEGINS AT Y-12

Rebuilding a Metrology Infrastructure

The American Society of Mechanical Engineers (ASME) announced at Gear Expo '95 that a national service for the calibration of involute artifacts is now available at the Department of Energy's Y-12 Plant in Oak Ridge, TN.

The service is part of a national program for gear metrology that is backed by a $3 million grant from the Department of Defense's Technology Reinvestment Program (TRP) and $4.8 million in matching funds, mostly from the Department of Energy and the Department of Commerce. The program is a result of a collaboration among ASME, Y-12, the National Institute of Standards and Technology (NIST), AGMA and Penn State University.

The service is the program's first step in reestablishing a national infrastructure for gear metrology that has been sorely missed by many in the industry. In 1986, the National Bureau of Standards (NIST's predecessor) stopped calibrating gear artifacts because the agency's equipment was becoming outdated and unreliable.

With no official calibration service for almost a decade, U.S. gear manufacturers have had no affordable, reliable way to prove that their measurements were accurate. One time-consuming and expensive option has been to send artifacts overseas to the German or British national laboratories for calibration. The other option has been to have artifacts calibrated by a private service in the United States whose measurements are traceable either to one of the overseas laboratories or to the 1986 or earlier measurements performed at the National Bureau of Standards.

Who needs Artifacts?

Artifacts are used by gear manufacturers to calibrate their gear measuring equipment. Often, a statement of the level of uncertainty in those measurements must accompany orders, especially when the customer is a government agency or has ISO 9000 or other strict quality documentation requirements. In addition, the measurements must be traceable to a nationally or internationally recognized standard.

Traceability means that an artifact or end product has been compared, either directly or indirectly, with an artifact whose measurement uncertainty is known. When an involute artifact is calibrated by NIST or Y-12, the owner is provided a chart showing how the artifact differs from a theoretically perfect involute, along with a level of uncertainty for those measurements. If that artifact is then used as a master to create additional artifacts, the manufacturer will have to add the uncertainty of his own equipment and methods to that of the original artifact.

Fellows Corporation, Springfield, VT, is generally recognized as the premier U.S. manufacturer of gear artifacts. In addition, Fellows offers an artifact calibration service. However, all of the artifacts the company has manufactured since 1986 and all of those it has calibrated since 1986 are traceable to the measurements made at the national laboratory almost 10 years ago.

"Our most important need was to have one source nationally that everyone is traceable to. Everybody is asking us to be traceable to NIST, but all we can do is be traceable to our last check at NBS," says Gerry Gagnier, quality control manager for Fellows.

According to Gagnier, gear artifacts should be recalibrated at least every 5 years, under the best of conditions. When calibration service companies have to rely on old measurements of their master artifacts, questions are raised in the minds of their customers. What if the master artifact has been dropped? What if it got scratched or dented? A lot can happen in 10 years.

These concerns are important to companies like M & M Precision Systems, manufacturers of dedicated gear measuring equipment. M & M buys gear artifacts to ship with its machines so that the end user can calibrate the machines. According to Mark Cowan, quality control manager for M & M, master artifacts should be recalibrated on a yearly basis. But with no national laboratory capable of performing these calibrations, this was practically impossible.

Building a Team

The lack of a national calibration service left a lot of people feeling—well, uncertain—about the measurement uncertainty levels being attributed to gears made in the United States. "If you can't measure it, you don't know if you've made it," says Bill Rasnick, development engineer at Y-12.

Gear industry concerns about the lack of a calibration service were first voiced to NIST at a 1992 workshop on precision tolerance manufacturing. This concern led NIST to invite gear industry participants to a workshop focusing on gear metrology in 1993. Here, the initial plans for the national gear metrology program were born. The partnership between NIST, Y-12, ASME, AGMA and Penn State University was formed. In September 1994, funding from the $3 million TRP grant began.

The steering force behind the project is ASME. The project is headed by Howard Clark, director of research for ASME's Center for Research and Technology. In addition, ASME's Committee on Gear Metrology, which is headed by AGMA's Bill Bradley, acts as an advisory body for the program.

The first priority of the gear metrology program was to reestablish a calibration service for gear artifacts. Because the national laboratory at NIST did not have the facilities for an ongoing gear calibration service, the Y-12 plant was selected as the best location for the Center for Gear Metrology. Y-12, which began as a nuclear weapons manufacturing plant, has one of the best environmentally controlled laboratories in the world, along with the right equipment to perform measurements on complex forms.

"Because of Y-12's experience and expertise in metrology, they are going to be the point of delivery for the gear artifact calibration service," says Howard Harary, a NIST physicist who manages NIST activities in the program.

Although Y-12 would normally be considered one step removed from NIST in the traceability chain, the uncertainty statement that accompanies calibrations done at Y-12 was prepared jointly by NIST and the staff at Y-12. Therefore, the actual level of uncertainty for these calibrations is not necessarily higher at Y-12 than it would be at NIST.

With the involute calibration service under way, the next step will be lead and index calibration services, which should be available in 1996 or 1997, Harary says. Eventually, the lab at Y-12 will perform other types of gear measurement as well, including bevel and spiral bevel gears.

Another objective of the national gear metrology program is to develop and implement gear metrology training and education programs. The TRP partners plan to have training programs in place at the gear metrology center in Oak Ridge by April 1997. Penn State will have university courses in gear metrology by October 1997.

The program partners also are working to establish new and improved gear metrology standards. AGMA's Calibration, Handbook, Inspection and Wormgearing committees are actively working on metrology standards, according to the July/August AGMA *News Digest*.

The Involute Calibration Service

The Y-12 Plant began performing involute calibrations of Fellows 4.5" base circle involute masters in October 1995. The statement of uncertainty says, in effect, that the measurements will be within .9 microns, or about 36 millionths of an inch, 95% of the time, says Bill Rasnick of Y-12. The service for a "standard" calibration costs around $2600 and takes about six weeks.

The National Metrology Center at Y-12 is capable of performing calibrations for involute masters other than the Fellows 4.5", but prices and lead times will vary.

The level of uncertainty for calibrations performed at Y-12 is "essentially equivalent" to calibrations performed by overseas laboratories, Rasnick says.

Because of government regulations, the calibration service is not allowed to compete with U.S. private industry. Therefore, when an artifact comes in for calibration, the owner has to sign a document stating that the services are unavailable elsewhere. Because of this, many will have to rely on calibration through private companies, unless they require a level of precision that only the lab at Y-12 can provide.

"We're hoping that the net effect of the calibration service will be an increase in our business," says Gerry Gagnier of Fellows. "We are now going to have a more up-to-date calibration that our customers can rely on." In addition, Fellows offers calibration of the same artifact for about $600, with a higher level of uncertainty, Gagnier says.

M & M Precision Systems also sees the calibration service as a potential boon to business. "It will allow us to ultimately obtain lower measurement uncertainty for our machines," says Mark Cowan.

The organizers of the national gear metrology program hope that enough interest is generated in the industry for the program to continue after the TRP grant runs out in 1997. "We are trying to set up a service that will be self-supporting," says ASME's Howard Clark.

Anyone interested in sending an involute artifact to Y-12 for calibration can call the Department of Energy's Technology Transfer hotline at 1-800-356-4USA.

Tell Us What You Think...
For more information about the national gear metrology program, please **circle 205.**

If you found this article of interest and/or useful, please **circle 206.**

"BECAUSE OF Y-12'S EXPERIENCE AND EXPERTISE IN METROLOGY, THEY ARE GOING TO BE THE POINT OF DELIVERY FOR THE GEAR ARTIFACT CALIBRATION SERVICE," SAYS HOWARD HARARY, NIST PHYSICIST.

WILLIAM R. STOTT

GMI
CLEVELAND, OH USA

The SERCOS Interface Standard

Standardized digital interfaces drive ahead.

Scott Hibbard

Today motion control systems are migrating from analog to digital technology at an ever-increasing rate because digital drives provide performance equal to or exceeding that of analog drives, plus information to run your machine more effectively and manage your quality program and your business. Most of this data is simply not available from analog drives.

The Interfacing Problem

For the past 30 years, the motion control industry has relied on a de facto ± 10V interface standard between analog controls and drives, where 10V equals full speed of the drive, and + or - determines the direction of motor rotation. Although it was fine for analog systems, this interface is totally inadequate for new, more complex digital technologies. The digital servo drive technology incorporates low-cost, high-performance digital signal processors (DSPs) to provide capabilities well beyond those of analog drives. However, in order to fully exploit the potential of digital drives, a well-defined digital interface must also be specified.

Some early digital drives did interface to a digital motion controller via an analog signal, but resolution was sacrificed, and noise sensitivity was a serious problem. Proprietary, vendor-specific digital interfaces have existed since the 1980s. However, they restrict the user to a single source for both drives and control and often limit flexibility for future expansion and use of newer technologies. Thus, the user's ability to select components based on application need is limited, and a substantial support burden is created when attempting to maintain non-complementary equipment from a number of suppliers.

SERCOS IS TO THE MACHINE CONTROL WHAT THE CLIENT-SERVER IS TO OFFICE AUTOMATION.

Enter The SERCOS Interface Standard

The SERCOS (acronym for SErial Real time COmmunications System) interface standard was initiated by a group of European machine builders, control builders and drive manufacturers who were concerned about the impending problems of multiple digital interfaces. They foresaw the benefits of a digital interface standard that would allow many manufacturers' drives and controls to communicate. Since its inception, the interface has been endorsed by other European and American manufacturers.

The SERCOS interface will allow any manufacturer's SERCOS-compatible digital NC to talk to any other SERCOS-compatible digital servo drive, digital spindle drive or digital I/O over a well-defined fiber-optic link.

With an open-architecture interface, the machine builder or user has the flexibility to configure multi-vendor control systems, choosing the best controls, servo drives, spindle drives and digital I/O for the

This column will answer your questions about gear machinery controls and electrical systems. Send your questions to Mission: Controls, P. O. Box 1426, Elk Grove, IL 60009, or fax them to 708-437-6618.

Scott Hibbard
is vice president, Machine Tool Industry Group, Indramat Division, The Rexroth Corporation, Hoffman Estates, IL.

operation. Controls and drives can be independently selected based on the required performance criteria. No compromises need be made by being locked into purchasing all digital systems components from only one manufacturer. SERCOS provides the user with options, both at initial purchase and for future expansion.

General Motors Corporation has recognized the benefits provided by such an open interface standard. In May 1995, two GM groups issued a joint letter to suppliers which states, "General Motors Powertrain and General Motors Europe are working together to develop common standards for powertrain equipment. [We] have jointly agreed that an open digital CNC and drive system interface is required for future equipment purchases . . . the only existing standard that complies is the defined SERCOS interface. Therefore, products utilizing a SERCOS interface are required by October 1, 1995, to meet current power train requirements."

About the Interface

The interface is not a product to be purchased. Rather it is a set of standard specifications that may be incorporated into any company's products. Each control or drive maintains its own functions and features.

SERCOS interface compatibility provides additional capabilities because the controls and drives comply with a standard medium for transmission, topology, connection techniques, signal levels, message structure, timing and data formats.

The SERCOS interface allows manufacturers to use any product-specific features on their machines, as long as the controls or drives are SERCOS interface-compatible.

The interface unlocks the door to great expansion potential as new manufacturing challenges unfold. In addition to allowing widespread use of today's digital technology, it allows communication with digital drives that may be developed in the future.

Interface Features

With the SERCOS interface, one fiber-optic ring is used to exchange data between NC controls and drives. The fiber optics provide inherent noise immunity and eliminate the immense requirements for conduit, wiring and terminations normally required with an analog interface between the CNC and the drives.

Standardized message formats are used for entry and display of operating data and parameters. In addition, the interface allows extensive real time servo and machine diagnostics and performance data to be monitored. For example, the Indramat DDS intelligent digital servo drive has a built-in digital oscilloscope capability, allowing it to capture a snapshot of drive performance which can be transmitted over the SERCOS interface to a CNC or higher level plant control for analysis.

Precise timing and synchronization of commands and interpolation for multiple drives is achieved with the interface. All operating data (command values, feedback values, etc.) are simultaneously updated between the drives in each cycle.

The specification provides two groups of parameters. The first set of 32,000 parameters is predefined for CNCs and drives, although no control system must use all of them. A second set of 32,000 freely definable parameters is allotted, providing the flexibility for manufacturers to include unique capabilities in their products, yet still conform to the specification. It also leaves room to accommodate future developments.

But What About Drawbacks?

Concerns about SERCOS have appeared in the trade media. One misconception is the number of drives allowed on a ring. A system with eight drives has been described as an example to illustrate timing. Certain writers have seized on this as a limitation, where, in fact, SERCOS can support up to 254 devices per fiber optic ring, with multiple rings available.

Another misconception is that SERCOS, as a serial interface, is too slow. SERCOS can support tightly synchronized multi-axis motion, as proven by existing applications in the machine tool, converting and packaging industries. Manufacturers offering the SERCOS interface generally find that this objection is raised by other manufacturers who have a history of investment in central control. It is important to note that SERCOS was developed in response to the emergence of intelligent digital drives. Intelligent drives perform many of the tasks that were handled by the machine control in previous generation systems.

A parallel can be drawn to the emergence of personal computers in the 1980s. At first, mainframe computer suppliers were very resistant to using PCs for anything more than terminal emulators, ignoring the potential to download mainframe tasks to PCs. In time, they realized that the PC could perform many of the mainframe's tasks, allowing the mainframe to handle additional tasks, to be downsized or perhaps to become nothing more than another PC acting as a client-server. This fact didn't bode well for those with an investment in "big iron" mainframes, but opened up a host of new opportunities for smaller server manufacturers.

THE INTERFACE IS NOT A PRODUCT; IT IS A SET OF STANDARD SPECIFICATIONS THAT MAY BE INCORPORATED INTO ANY COMPANY'S PRODUCTS.

Intelligent digital drives and SERCOS offer much the same situation. Similar to the PC used as a terminal emulator, an intelligent digital drive can be used to just close current or velocity loops, as did the previous generation of drives. Their speed and synchronization capabilities, plus their noise immune characteristics, offer an advantage over the ±10V analog interface. The potential of the intelligent digital drive is not realized, however, until its power is used to perform axis-specific tasks. In addition to position loop closure, SERCOS allows the intelligent drive to capture registration marks, perform homing sequences, provide cam table functionality, switch performance parameters in real time, capture actual motor temperature and motor parameters, provide backlash compensation, leadscrew error compensation, adaptive positioning and torque monitoring, thereby tending to lower the complexity and motion control overhead of the machine control.

The use of SERCOS allows the migration to true PC-based NC designs and easier programming methods. SERCOS-based controls differ from their analog-interface forefathers. Thus, the SERCOS standard is to machine control what the client-server is to office automation.

SERCOS also offers easy adaptation to different applications. A control that is tightly coupled with its interfaces is less adaptable to different applications and less able to take advantage of technological innovations in drives, feedbacks or sensors. The use of SERCOS with intelligent digital drives improves system flexibility, as one identical drive can handle multiple prime movers, such as permanent magnet servomotors, high horsepower induction servomotors (vector drives) and linear motors.

The SERCOS Interface—A Reality In The Marketplace

SERCOS is an internationally accepted standard. Thousands of systems have been shipped by manufacturers in Europe and North America on applications including high-speed transfer lines, multi-axis dial machines and stand-alone milling, drilling, turning and grinding machines. Multi-axis applications such as packaging machines, converting and printing machines, material handling systems, robots, woodworking machines and assembly and test machines are providing worldwide manufacturing with the benefits of the SERCOS interface.

Currently over 25 drives and controls suppliers offer SERCOS-compliant products worldwide. In North America, a number of suppliers support SERCOS N.A., a SERCOS promotional alliance based in Lincolnshire, IL. Current SERCOS N.A. members include Lutze, Inc., Indramat Division of Mannesmann Rexroth Corp., Motion Engineering, Inc., Pacific Scientific Motion Technology Division and Automation Intelligence, Inc., a Pacific Scientific Company. For more information, contact SERCOS N.A. at 1-800-5-SERCOS or the author, Scott Hibbard, at 708-645-3600. ○

Tell Us What You Think...
If you found this article of interest and/or useful, please **circle 207.**

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.

New Views

A different way to spec and shop for parts

Nancy Bartels

Information is the name of the game in the 90s. We need more of it; we need it faster; and we need it in infinitely manipulatable and user-friendly form. In many cases, getting it that way is still something of a Holy Grail, somewhere off on the distant horizon. But thanks to computer technology, bit by byte, we're getting there.

The latest fixture of our design and engineering offices that may succumb to the lure of the electronic is the fat industrial products catalog. Many major suppliers are now making parts catalogs, information sheets and brochures available on PC-compatible disks or CD-ROMs. Why stop everything to thumb through 500 closely printed pages of specs when you can call the whole thing up on your screen with the click of a mouse or a couple of key strokes?

The "Killer App"

By far the most elaborate of these new catalogs is the Mechanical Library from Autodesk®. It's a two-volume CD-ROM set of parts and materials specifications that works in conjunction with the company's AutoCAD® system and with other major CAD software.

A typical pair of PartSpec screens for a gear set. Parts drawings can be imported directly into other AutoCAD drawings.

The library comes in two parts: PartSpec™, which contains information about over 250,000 parts from 29 leading U.S. vendors, and MaterialSpec™, which contains over 100,000 data sheets on over 25,000 materials from more than 300 worldwide vendors. The system runs on either Windows™ or DOS and uses industry-standard file formats, including .DWG, .DBF, ASCII and .GIF.

PartSpec includes parts information about machine components, including gears, fluid-based power components and electrical components, plus a library of commonly used ANSI-standard fasteners. Among the companies represented are Boston Gear, Jergens, Inc., Parker Hannifin, Smalley Steel Ring, Square D, Timken and Wolverine Tool. MaterialSpec includes information on plastics, ceramics, metals and composites compiled by Information Indexing, Inc. (Infodex), a leading supplier of materials information in the U.S.

But the library is more than just a parts and materials list. PartSpec has been designed to enable the user to specify a part from a vendor, call up information about it, view drawings and photos and import the drawings into an AutoCAD drawing file as a fully compatible .DWG block. Vendor-supplied attribute data, such as names and part numbers tagged to each part, are embedded in the drawing and can be used for generating parts lists or bills of materials. Pull-down menus in both volumes allow the user to call up vendor information for easy ordering.

The volumes are also designed to be updated periodically to keep the material as current as possible.

System Requirements

The system does require some fairly significant computing power to run. You will need DOS 5.1 or Windows 3.1 or later and a 386/486/Pentium® IBM or 100% compatible PC with a math coprocessor. A minimum of 2 MB of hard disk space, a permanent swap file of 65 MB and at least 8 MB of RAM are recommended. Your system must also have a CD-ROM drive. Autodesk recommends at least a dual-speed drive. A quad-speed drive will, naturally, make data access that much faster. You will also need a VGA video display and a mouse. Running PartSpec on DOS also requires AutoCAD Release 12 or 13 for DOS.

The Price Tag

This ultimate catalog system doesn't come cheap. Each volume can be purchased separately for $295. The complete set goes for $495. (Both are available at introductory prices of $199 per volume and $350 per set until May of this year.) Autodesk is marketing the library rather like a magazine subscription. The prices include one 6-month update. Subscribers also will be offered renewal discounts, another page taken from publishers' marketing books, according to Chris Hock, Product Marketing Manager for Autodesk Data Publishing.

Still the ease and convenience of the system may make it worth the price. The savings in time alone are significant. When you add up the number of hours spent searching catalogs, comparing prices and specs from different suppliers, drawing parts, checking for and correcting mistakes, and all the other roadblocks to getting a product ready for production, the ROI could come with the first project.

Test Drive

The Mechanical Library sounds pretty impressive on paper, but we wondered how it would work in real life. To find out, we gave a set to Wayne Avers, a manufacturing engineer with Bley Engineering in Elk Grove Village, IL, a company specializing in component parts, subassemblies, machines and reverse engineering.

Wayne played with the system for several weeks, using it on a 90 MHz Pentium machine with 32 MB of RAM, a quad-speed CD-ROM drive and AutoCAD Release 13. He quickly became a convert.

He liked the ease with which both volumes in the library ran. He also was impressed by the completeness of the information in MaterialSpec. The system contained the same information in both the DOS and Windows versions, although Wayne admits the Windows graphics are "cooler."

The feature that sold him on the system was the ability of PartSpec to import parts drawings directly into an AutoCAD drawing. The way it works is this: The operator pulls down menus which open a particular catalog. Then a menu pops up which allows him or her to put in the required parts specifications. If such a part is in the catalog, a picture of it will show up on the screen. Then another couple of mouse clicks import the drawing into the larger AutoCAD drawing.

"It makes it easer to design more accurately and faster because you don't have to draw in parts," says Wayne. "You know from importing the drawing whether a part will work with the rest of the system. That ability gives you, as a designer, the freedom to be wrong. If one part doesn't work, it's no big deal to put in another."

He also points out that it takes only a couple of mouse clicks to move from one catalog to another.

The only downside is that on parts that require a lot of detailed specification, such as gears, the system is sometimes slow in loading the pictures onto the screen. It should be noted, however, that on the day we watched Wayne working with the system, "slow" was a matter of 30 seconds to a minute, rather than instantaneously.

Perhaps the most telling of Wayne's comments in praise of the system was this: "If I could find it on the CD-ROM, I would use that part rather than take the trouble to look for another one in a traditional catalog."

However, it's only fair to point out that we did not test the system on a machine using a different CAD system. Furthermore, according to Autodesk, while the library does run independently of the CAD system in place, the import feature does not work on systems other than AutoCAD. The company hopes in later versions to make the system more flexible.

The Supplier's Point of View

Wayne's comments are encouraging words for Autodesk and the suppliers whose catalogs are part of the library, but what about the rest of us? How does a company get to be part of this new marketing tool?

Autodesk has big plans for its library and welcomes companies wanting to get their catalogs on the system. It has a full-time staff of five that works with companies to adapt their material to the Materials Library format. The cost of getting a space on the CD-ROM depends on the amount of information to be included.

Future Goals

Autodesk does not plan to stop with the Mechanical Library as it is now. It may break down the PartSpec CD into smaller sections with more companies supplying particular types of products on a single volume. Plans are also in the works for plant/process/power and construction/architecture/engineering volumes.

The paper catalog as we know it is not quite on the endangered species list yet. However, as more companies discover the ease and cost-effectiveness of producing catalogs on disk or CD-ROM, as customers discover the ease of using them and as marketing tools like the Mechanical Library gain acceptance, the old paper catalog may find its highest and best use as a doorstop while the speccing of parts and materials goes on in cyberspace. O

Tell Us What You Think...
For more information about Autodesk Mechanical Library, please **circle 208.**

If you found this article of interest and/or useful, please **circle 209.**

Nancy Bartels
is Gear Technology*'s Senior Editor.*

Avoiding Interference In Shaper-Cut Gears

Harlan W. Van Gerpen & C. Kent Reece

In the process of developing gear trains, it occasionally occurs that the tip of one gear will drag in the fillet of the mating gear. The first reaction may be to assume that the outside diameter of the gear is too large. This article is intended to show that although the gear dimensions follow AGMA guidelines, if the gear is cut with a shaper, the cutting process may not provide sufficient relief in the fillet area and be the cause of the interference.

In 1982, J. Colbourne presented an ASME paper entitled "Gear Tooth Interference," which described the possibility of this type of interference and gave a mathematical analysis showing that it could exist. He also suggested that there probably would not be interference if the minimum root clearance was .25 m (module) (.25/dp). This condition is too restrictive when designing gears for maximum strength or high contact ratio. Frequently the inner bore of a gear also limits the depth of the root. The Colbourne paper also describes the mathematics of the relationship of a shaper cutter and a gear that can be used to predict interference. This article extends the discussion by showing that a very important criterion is the number of teeth, or diameter, of the shaper cutter.

In the design of custom gears, it is the usual procedure to incorporate the dimensions of the cutter in the design. When designing gears for high contact ratio or high pressure angle requirement, the AGMA standards no longer apply. The actual point of contact of the mating gear must be studied to prevent interference, primarily at the point where the involute and fillet join.

Since hobbing is the most desirable method of cutting gear teeth, a basic rack, usually the rack of a hob already available, will be assumed for the design process. However, when the gear goes into production, it may be cut with a shaper cutter for various reasons. When this happens, even though the gears may be operating on a standard center distance, it is possible that the tip of the mating gear will drag in the fillet of the small gear. This condition results in noise and high stresses and is evidenced by a shiny area near where the fillet and involute join. This article discusses possible reasons for this and illustrates the phenomenon with computer graphics. The writers do not know of any empirical equation that will predict this condition.

The basic design rule to prevent interference in the fillet applies to all gears. These rules specify that the tip of a mating gear involute profile must make contact between the tangent points on the line tangent to the two base circles. A basic rack represents a gear with an infinite number of teeth, and a hob with this profile and the usual standard proportions will provide "run out" clearance in the fillet area for gears with finite numbers of teeth. An interference exception would be a mating gear tooth with a very large chamfer, which could still bottom out in the root. This should always be checked. If the outside diameter of the mating gear exceeds the above criteria, it may drag in the fillet.

When it is decided to cut the gear with a shaper cutter, it is not too difficult to design the shaper cutter profile to generate the required involute curve. The process is similar to designing a mating gear. The outside diameter of the shaper cutter is calculated to give the same root diameter, and the assumption is that the fillet will be recessed enough to prevent interference.

It is difficult to predict if a design will lead to dragging in the fillet. To better understand what is going on, we need to study the generating path of the cutter. A computer program has been developed to graphically represent a point-by-point

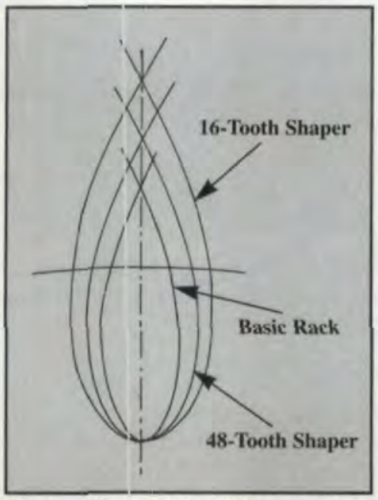


Fig. 1 — Trochoids for different cutters generating an 18-tooth gear.

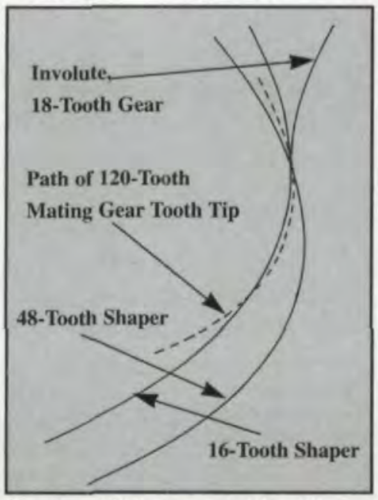


Fig. 2 — Fillets generated by different sized shapers.

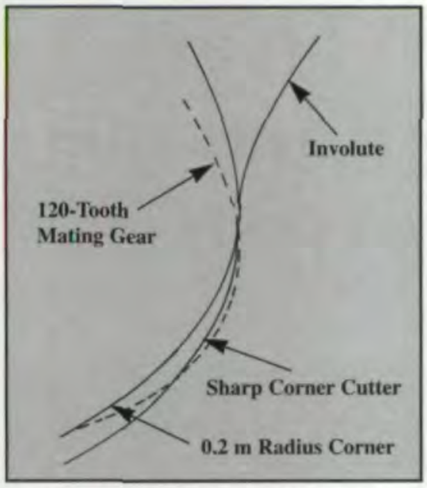


Fig. 3 — Effect of radius added to corner of shaper tooth compared to sharp corner.

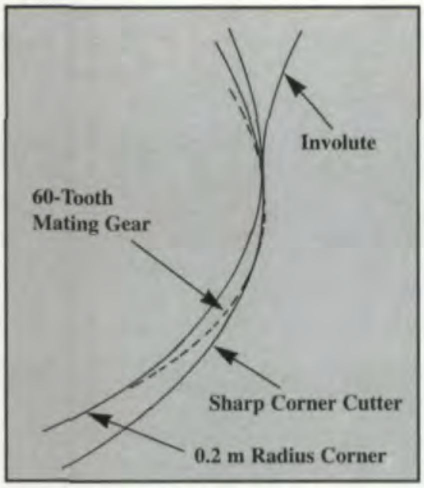


Fig. 4 — Effect of radius added to corner of shaper tooth compared to sharp corner when mating gear has 60 instead of 120 teeth.

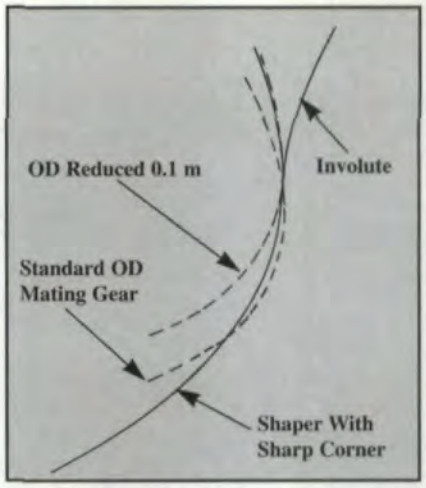


Fig. 5 — Effect of reducing the diameter of the mating gear by 0.1 m.

path of the cutter for comparison with a point-by-point plot of the path of the tip of the mating gear. An overlap in the fillet area indicates interference.

The trochoidal path of the tip of a basic rack (hob) will be quite narrow, depending upon how deep it goes below the generating pitch circle. For shaper cutters and mating gears, the trochoids will be wider, assuming the same depth below the generating pitch circle. The fewer the number of teeth in the mating gear or the shaper cutter, the wider the trochoid (Fig. 1). Also, the greater the addendum of the cutter, the wider the trochoid. Since the trochoid of a shaper cutter will be wider than that of a hob, the expectation is that there will be more clearance in the fillet area when using a shaper cutter.

However, the orientation (centerline) of the trochoid will not be the same for a shaper and hob. The shaper tooth is thinner than a hob tooth at the tip; therefore, the centerline of the trochoid for the shaper tooth tip that cuts the fillet is further from the center of the tooth of the gear, and this feature thickens the gear tooth in the fillet area (Fig. 2). The smaller the number of teeth in the shaper, the thinner the tooth tip and the thicker the gear tooth fillet profile. The higher the pressure angle of the cutter, the thinner the tooth is at the tip and, again, the thicker the shaper-generated tooth is in the fillet area. For emphasis, the plots in all figures have been expanded horizontally four times.

To demonstrate the effect of a radius on the tip of the shaper cutter, Fig. 3 shows that the overlap (interference) of the path of the mating gear is significantly greater than for a fillet generated by a sharp-cornered cutter. Most shaving cutters have some form of tip modification, frequently a sloped surface, which may be the best choice for least interference.

Fig. 4 illustrates the effect of the size of the mating gear. By reducing the number of teeth from 120 in Fig. 3 to 60 in Fig. 4, the interference shown in Fig. 3 becomes borderline when fillet-cut with a shaper with sharp corners at the tip. Significant interference exists when the tip of the cutter has a radius.

Fig. 5 shows the result when the outside diameter of the mating gear is reduced by 0.1 m. This minor change in outside diameter results in a trochoid for the mating gear that is a little shorter and narrower. It no longer interferes with a fillet generated with a sharp-cornered shaper; however, it may for a cutter with a radius.

To summarize, the following conditions may create a condition for interference in the fillet of a gear cut with a shaper cutter.

1. A gear set with a large ratio. In this situation, the large gear may travel a considerable distance below the base circle with a trochoid loop that is narrow and nearly straight toward the center of the gear. It will tend to intersect the fillet of the shaper-cut small gear that does not have a sufficiently recessed fillet.

2. A gear cut with a shaper cutter with a small number of teeth, a large tip radius and a short addendum. All these parameters contribute to a thicker fillet in a small gear.

When recycling shaper cutters, sometimes only a small shaper is available. In such cases, the possibility of interference should be investigated. ○

Reference:

1. Colbourne, J. R. "Gear Tooth Interference," ASME Paper 82-DET-128. Presented at the Design & Production Engineering Conference, Washington, D.C., Sept., 1982.

Harlan W. Van Gerpen & C. Kent Reece

are partners in Van Gerpen-Reece Engineering & Consulting in Cedar Falls, IA. They provide gear consulting and software services.

Measurement Error Induced by Measuring over Pins Instead of Balls

Richard D. Keiper

The purpose of this article is to clarify some terms and methods used in measuring the size of gears. There is also an explanation given of the error induced and how to correct for it in certain cases when the measurement is made using pins instead of balls.

Different Methods of Measuring Gears

Gear size can be specified in many ways. One way is to express the size of a gear in terms of tooth thickness—transverse circular tooth thickness, normal circular tooth thickness, transverse chordal tooth thickness or normal chordal tooth thickness. Another way is to express size in terms of what might be seen on a tight mesh rolling checker—functional tooth thickness, center distance, pitch radius or pitch diameter. Another way is to express size in terms of an over-ball or over-pin dimension. This last method is the most widely accepted way of specifying the size of a gear because it is the quickest and easiest way of measuring size.

Measuring Using Balls and Pins

Actually the terms "over balls" and "over pins" apply only to external gears. Internal gears are measured "between balls" or "between pins," but because external gears are far more common than internal ones, the term "over" sometimes gets used universally.

The terms "over balls" and "over pins" are also sometimes misapplied with external gears. This happens when the measurement called for is actually a "dimension over one ball" or a "dimension over one pin." To measure a gear over one ball or pin, an arbor is used to establish the center, which is the zero reference for the measurement. All external gears can be measured over one ball or over one pin.

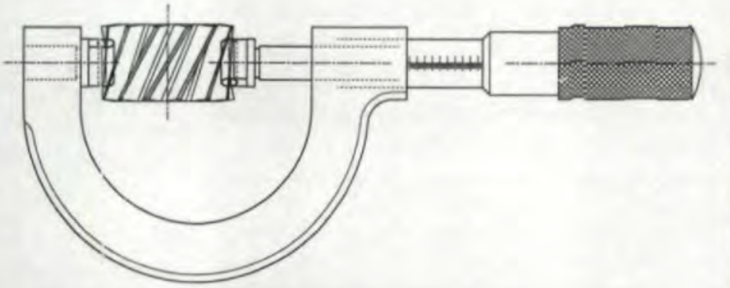


Fig. 1 — Orientation of gear and pin anvils.

All external spur gears can be measured over two balls or over two pins, but when the gear being measured has an odd number of teeth, the dimension over two balls or pins is less than twice the dimension over one ball or pin because no two tooth spaces will lie on a diameter. What is actually being measured in that case is a chord, not a diameter. To eliminate any confusion, some designers always specify the size of external gears as a dimension over one ball or pin and never as a dimension over two balls or pins.

In the case of internal gears, size is always specified in terms of "between balls" or "between pins" since, in most cases, there is no way to establish the center of the gear to measure a dimension "between one ball" or "between one pin."

Using Pins Instead of Balls

Theoretically, for external gears with an even number of teeth, the dimension obtained by measuring over two balls will be the same as the dimension obtained by measuring over two pins of the same diameter. In practice, sometimes, such as when the part is hobbed, it is desirable to measure over two pins instead of over two balls. In that case, a ball may fall in the scallops of the hobbed tooth on one measurement and then ride up on a high spot of the hobbed surface on the next measurement. This causes the measurements to be inconsistent, making it difficult to determine what size the gear really is.

When pins are used instead of balls, they contact only the high spots of the hobbed surface every time the gear is measured. This makes the readings consistent, thereby making it possible to control the size of the gears. However, when two pins are used to measure helical gears with an odd number of teeth, a measurement error is induced.

Whenever pins are used to measure internal helical gears, an error is induced. In this article we will deal with external helical gears only.

Construction of Measuring Instruments

The accepted method of construction for pin micrometers and for specialized over-pin measuring instruments is to constrain the two pins to always lie in planes that are parallel to one another. This is done by rigidly mounting the pins to anvils whose axes lie on the same line; in other words, the anvil shafts are coaxial. The anvil shafts are free to rotate 360°.

The orientation of the gear and the pin micrometer in the following example is with the axis of the gear vertical and the anvil shafts of the micrometer lying in the transverse plane (see Fig. 1).

Error Induced by Using Pins

To illustrate what happens when one tries to measure an external helical gear with an odd number of teeth over pins, let's imagine that we can remove the pin anvils from the pin micrometer.

Let's say that we want to measure an external helical gear using two pins instead of two balls. The gear has 13 teeth, a helix angle of 30°, a design pitch diameter of 1.531" and a dimension over two .125" diameter balls of 1.825". Let's assume that the pin contact diameter of the gear is exactly at the design pitch diameter, which is usually pretty close to being the case for most gears and pin sizes.

Now, with the anvils removed from the pin micrometer, we engage the pins in tooth spaces on the gear that lie as close to a diameter as possible, with the axes of the anvils lying in the same transverse plane.

In order for the axes of both anvil shafts to lie in the same transverse plane, they must lie on radius lines of the gear, with both pins fully engaged in the tooth spaces. These radius lines will be separated by an angle of 360°/(2•13) or 13.846°. In other words, the angle between each anvil shaft and the horizontal line that intersects the axis of each shaft at the centers of the pins (of each anvil) is 13.846°/2, or 6.923° (see Fig. 2). Since this is not the configuration the shafts are constrained to be in when they are in the pin micrometer, it is clear that there will be an error induced when they are moved to that position. Assuming the pin contact diameter of the gear was exactly at the design pitch diameter, the angle between the vertical plane in which the anvil shaft lies and the axis of the pin is the helix angle of the gear or 30°.

To determine the amount of error induced, we need to calculate how much the pins move when the anvil shafts are moved to be coaxial to each other. They now lie in the same transverse plane, but not on the same chord by an angle of 6.923°. To move them first swing the shafts of the anvils so that the pins stay engaged in the tooth spaces and rotate about their (the pins') axes (see Figs. 3–4). When we do this, both anvil shafts lie in the same vertical plane, but they are not coaxial, and they do

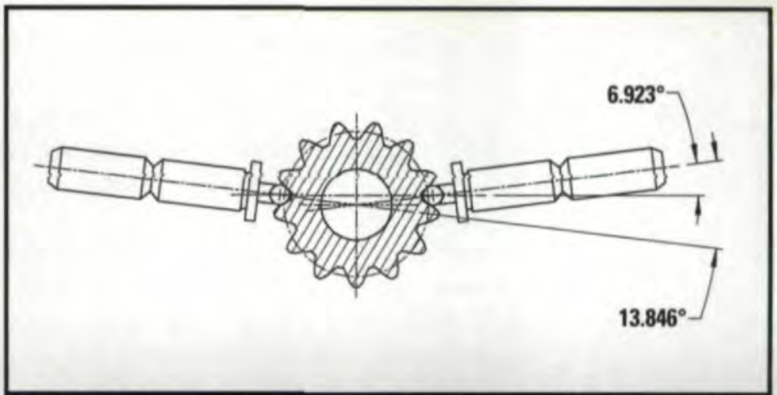


Fig. 2 — Pin anvils removed from micrometer with pins fully engaged in tooth spaces of gear.

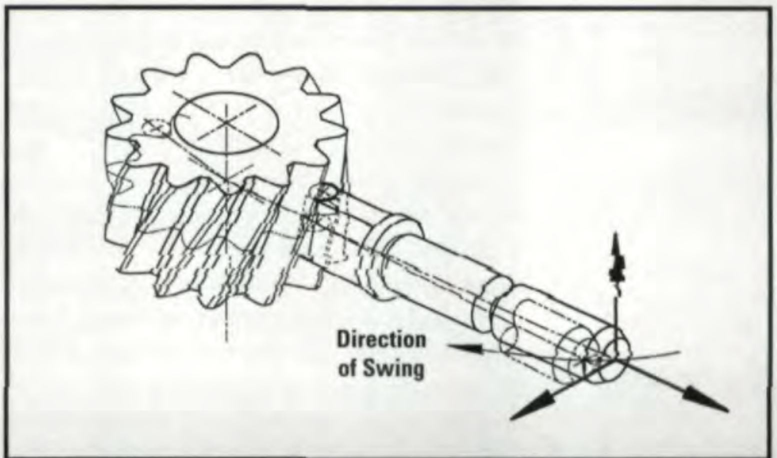


Fig. 3 — Direction of swing of right-hand anvil shaft. Left-hand anvil shaft swings the same amount in the opposite direction.

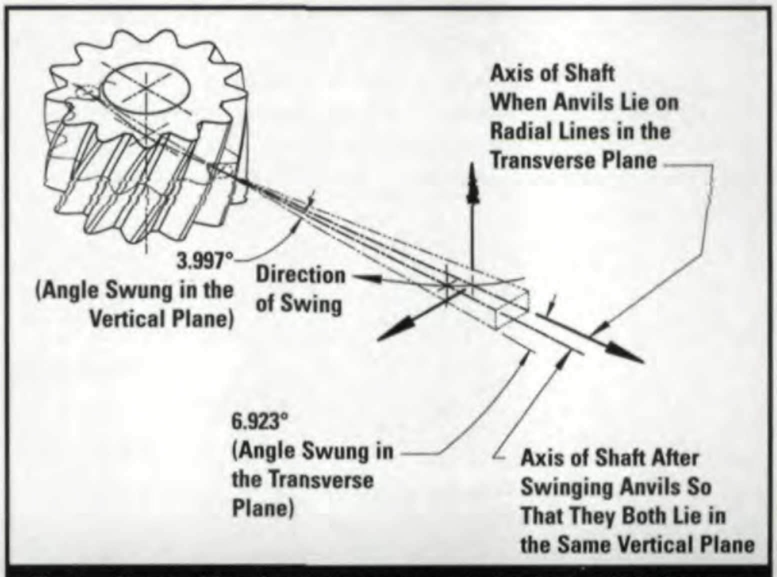


Fig. 4 — New position of anvil shafts after swinging them to lie in the same vertical plane.

Richard D. Keiper
is a product engineer with Moore Products Co. Gage Division, Spring House, PA.

not lie in the transverse plane anymore. After we have swung the anvil shafts, the angle between these shafts and the transverse plane is 6.923° • (tan 30°) or 3.997°. So, to move both anvil shafts to be coaxial and lie in the transverse plane, we need to swing them both in the same vertical plane through an angle of 3.997° (see Fig. 5).

When we do this, the positions of the pin anvils are what they would be if constrained in the pin micrometer. If the line of contact on the tooth were a straight line instead of a helix, the amount that the center of each pin (i.e., the point of intersection of the axis of the shaft and the axis of the pin) would move out away from the center of the other pin would be equal to half the vertical length of each pin times the tangent of the angle of swing, or $\sqrt{[\{(L/2) \cdot (\sin 30°) \cdot (\sin 6.923°)\}^2 + \{(L/2) \cdot (\cos 30°)\}^2]} \cdot (\tan 3.997°)$, where L is the length of the pins (see Fig. 6).

But since the line of contact is a helix, the amount that the helix moves out of the plane that is perpendicular to the axis of the anvil shaft, over half the length of the pin, must be subtracted from the amount the pins move out away from each other. The amount the helix moves out from the plane is equal to $(1.531/2) \cdot [1-\cos\{360° \cdot (L/2) \cdot \cos(90°-30°)/(\pi \cdot 1.531)\}]$.

The expression that describes the amount that the center of one pin moves out away from the center of the other pin then becomes $\sqrt{[\{(L/2) \cdot (\sin 30°) \cdot (\sin 6.923°)\}^2 + \{(L/2) \cdot (\cos 30°)\}^2]} \cdot (\tan 3.997°) - (1.531/2) \cdot [1-\cos\{360° \cdot (L/2) \cdot \cos(90° - 30°)/(\pi \cdot 1.531)\}]$.

Since this is the amount that each pin moves out, the total amount of error is twice this amount, or $2 \cdot (\sqrt{[\{(L/2) \cdot (\sin 30°) \cdot (\sin 6.923°)\}^2 + \{(L/2) \cdot (\cos 30°)\}^2]} \cdot (\tan 3.997°)) - 1.531 \cdot [1-\cos\{360° \cdot (L/2) \cdot \cos(90°-30°)/(\pi \cdot 1.531)\}]$.

In general form, this error is expressed as

$$e = 2 \cdot (\sqrt{[\{(L/2) \cdot (\sin \psi) \cdot (\sin(360°/4N))\}^2 + \{(L/2) \cdot (\cos\psi)\}^2]} \cdot \{\tan((360°/4N)\tan\psi)\}) - PD \cdot [1-\cos\{360° \cdot (L/2) \cdot \cos(90°-\psi)/(\pi \cdot PD)\}]. \quad (1)$$

Since the quantity $\{(L/2) \cdot (\sin\psi) \cdot (\sin(360°/4N))\}^2$ will always be essentially zero (except for cross-axis gears), the general form can be approximated by

$$e = L \cdot (\cos\psi) \cdot \{\tan((360°/4N)\tan\psi)\} - PD \cdot [1-\cos\{360° \cdot (L/2) \cdot \cos(90°-\psi)/(\pi \cdot PD)\}]. \quad (2)$$

where: e = error
L = length of pins
N = number of teeth in gear
ψ = helix angle of gear
PD = pitch diameter of gear

This approximation is only accurate when the pins are relatively short. When the gear tooth is relatively long and the pins are relatively long, that is, long enough that the pin intersects the vertical plane that passes through the diameter of the part and is parallel to the anvil shafts, then the error is no longer a function of the length of the pins (see Fig. 7).

The length of the pin that is needed to intersect this vertical plane is given by

$$CL = PD \cdot (\sin(360°/4N))/(\sin\psi). \quad (3)$$

where: CL = critical length of pins
PD = design pitch diameter of gear
N = number of teeth on gear
ψ = helix angle of gear

In our example the pin length that intersects this plane would be $1.531 \cdot (\sin(360°/52))/(\sin 30°) = .369"$.

When the pin length is greater than or equal to this "critical length," and the tooth on the gear is long, then the error is limited to the error calculated from Equation 2, using this CL as the length of the pins.

In order for the critical length of the pins to be the limiting factor, the tooth length on the gear must also be greater than or equal to the critical length of the pins.

The tooth length on the gear can be approximated by

$$TL = FW/\cos\psi. \quad (4)$$

where: TL = tooth length on gear
FW = face width of gear
ψ = helix angle of gear

When the pin length is greater than the critical length, but the tooth length is less than the critical length, then the error is limited to the error calculated from Equation 2, using this TL as the length of the pins (see Fig. 8).

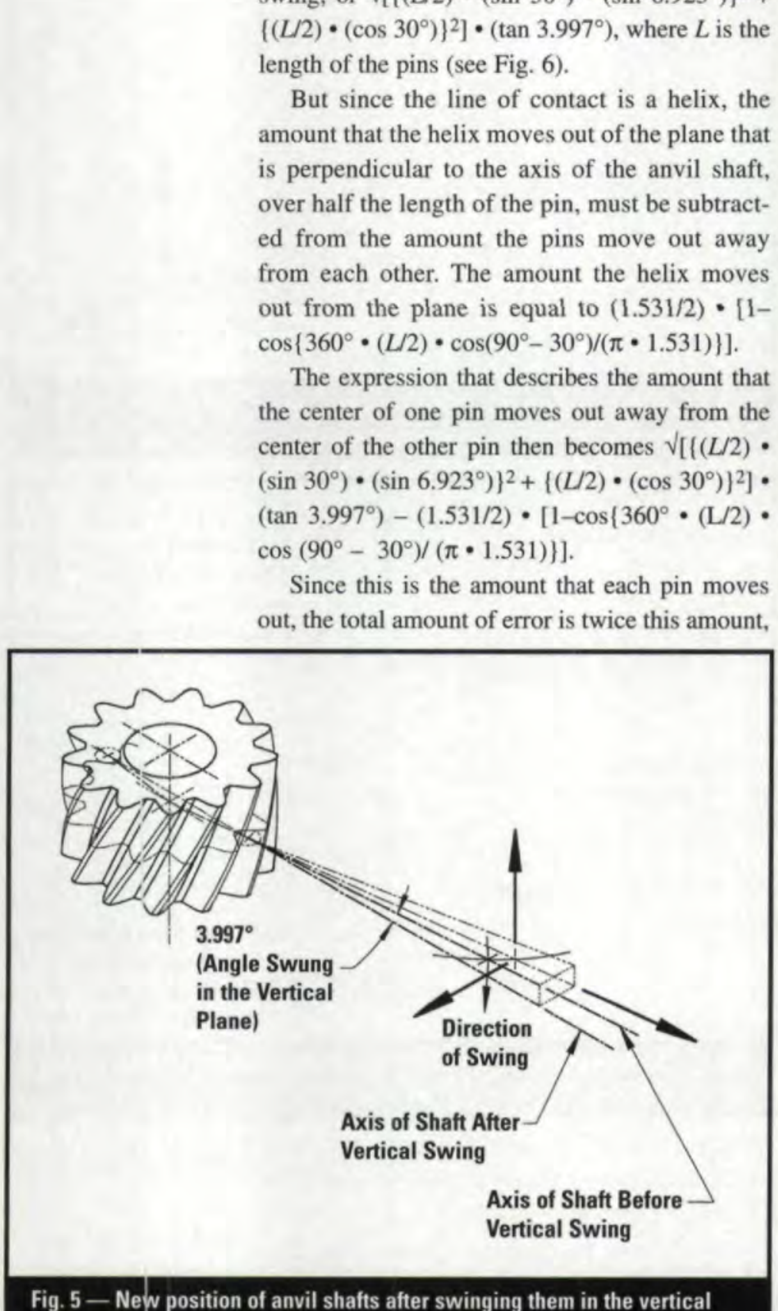


Fig. 5 — New position of anvil shafts after swinging them in the vertical plane to lie in the same transverse plane and be coaxial.

Then the error can be calculated by using the least of the three lengths—actual pin length, critical pin length (Equation 3) or tooth length (Equation 4) as the pin length in Equation 2.

In our example the limiting factor is the critical length of the pins. When we use this as the length in Equation 2, we obtain: $e = .369 \cdot (\cos 30°) \cdot (\tan((360°/52) \cdot \tan 30°)) - 1.531 \cdot [1 - \cos\{360° \cdot (.1845) \cdot \cos(60°)/4.810\}] = .0112"$.

This error would have to be subtracted from the measurement obtained using pins to obtain the correct dimension over balls for this gear.

It should be noted that when pins shorter than the critical length are used, or when the tooth length on the gear is less than the critical length, the pins contact the gear at a point. In theory, the type of contact between the pins and the gear teeth is always point contact, but when the pins and the teeth are sufficiently long, the lines on the surface of the pin parallel to the pin's axis that contact the gear teeth are tangent to the involute helicoid at the contact diameter of the gear. This is not the case when either the pins or the gear teeth are less than the critical length. When the pin length is less than the critical length, the pins contact the gear at the end of the pins. When the tooth length is less than the critical length, the pins contact the gear at the end of a tooth. When either of these is the case, any advantage gained by the use of pins in contacting only the high spots may be negated by the fact that contact between the pin and the gear is point contact, and the point of contact of the pin may fall into scallops on the hobbed surface.

Correcting for the Error

Pins longer than the "critical length" can be used to obtain consistent measurements on rough helical gears with an odd number of teeth, but the measurement should be made on a measuring instrument that allows fixturing of the part to ensure that the axis of the part is held perpendicular to the axis of the anvil shafts. A pin micrometer should not be used.

This method can be used to control a process without knowing what the actual size of the gear is. If it is important to know the correct size of the gears, then the correct dimension over balls can determined by subtracting the error, calculated in Equation 2, from the dimension measured over pins.

Illustrations for this article were done by Paul Romanowsky.

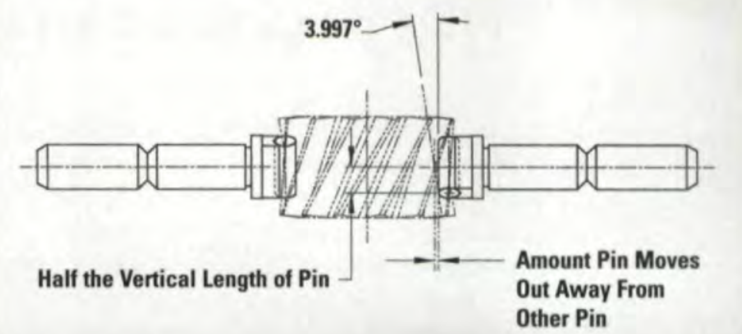


Fig. 6 — Distance pin moves out away from the other pin when anvil is swung in the vertical plane.

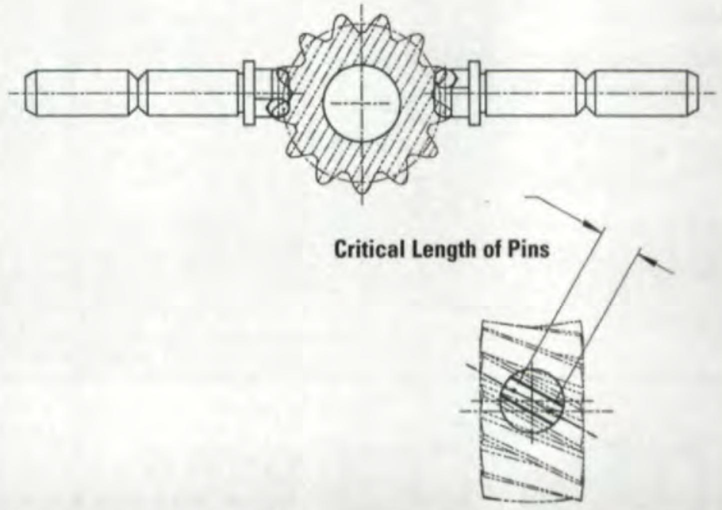


Fig. 7 — The critical length of the pins for this particular gear.

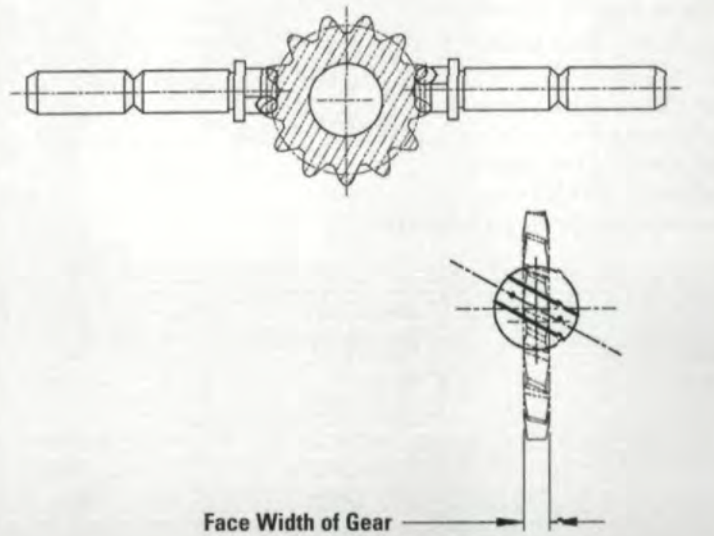


Fig. 8 — A gear where the limiting factor is the tooth length because it is less than the critical length of the pins.

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.

Cost Estimates in 60 Seconds or Less

"Point and click" your way to accurate cost estimates for gears and parts in 60 seconds with **Costimator® Rapidcost™** for Windows®. The new system runs under all versions of Windows and simplifies cost estimating by using predetermined manufacturing times to calculate the cost of discrete parts. It can provide estimating accuracy to within ±5% or better of actual manufacturing times and costs. It also prints estimates and shop travelers. Available from Manufacturers Technologies, Inc.

Circle 300

GearShop for Windows 2

PC Enterprises has released Version 2 of its GearShop for Windows gear design software. This version allows on-screen design of internal and external gears, racks, generated and non-generated gears and more. Functions include cut, inspect mesh, animate, zoom and pan, tooling design, selection and setup adjustment, and inspection for backlash, meshing radii and tooth curvatures. Prints or plots to any scale.

Circle 301

Adjustable Speed Gear Motor System

Dodge® announces the new APG adjustable speed gear motor system, which the company says has the most advanced power-dense design in the industry, allowing higher reducer ratios for wider speed ranges. Case-carburized and precision-ground helical gears assure higher strength and improved durability. The system's Reliance Electric A-C motors can be specified in one through five horsepower packages. Its SP500 A-C PWM inverter drive features a 200–230 VAC three-phase input or single phase with 50% derate.

Circle 302

Job Order Tracking System

The Job Order Tracking System is a new product of **Analytical Science Corporation**. The software allows the user to immediately locate where an order is and what stage of completion it has achieved and to print out a hard copy report for internal or customer use. Status records can be viewed and edited directly on screen, allowing the pinpointing of critical process improvements.

Circle 303

CIMNET® Add-On Software

JNL Industries, Inc. has announced the addition of job tracking capabilities to its CIMNET Folders manufacturing information control system. The addition extends the functionality of the "paperless factory" shop floor environment to include work flow management linkages. The Job Tracking option monitors quantity required, quantity finished and quantity scrapped, with graphs for yield, efficiency, machine load and estimated completion date.

Circle 304

AutoCAD Add-On Software

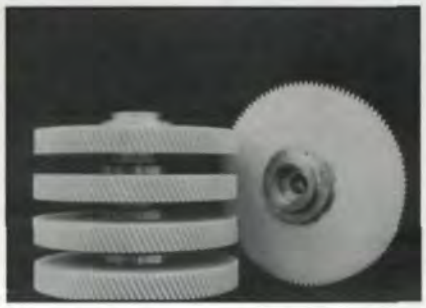
EMT Software introduces MECH SHAFT, a new parametric shaft designer and symbol library, and MAKE*IT*3D, which allows AutoCAD Release 13 users to turn 2-D multi-view drawings into 3-D solids. MECH SHAFT works with AutoCAD Releases 12 and 13 to give users a faster way to design 2-D and 3-D shafts. It creates designs inside AutoCAD according to a variety of user-specified parameters including number of segments, diameter, length, tapering, chamfer or fillet requirements and format (ACIS, AME or 2-D). MAKE*IT*3D also includes two tools for creating 2-D drawings. TRACE produces construction lines and circles that can be traced around for drawing outer or inner design contour, and ORTHO uses intelligent projection lines to build orthographic views of a part after an initial view has been created.

Circle 305

New PVD Coatings

Multi-Arc Inc. announces the introduction of two new PVD coatings, ION BOND® TiAlN and ION BOND® TiCN. The company says this second-generation TiAlN provides over twice the life of its first-generation coating when machining titanium- and nickel-based alloys, stainless steels and cast materials. It is ideal for high-speed machining, dry hobbing and other machining operations where high temperature is generated at the point of cut. The TiCN is a multilayer titanium carbonitride coating recommended for machining difficult-to-machine steel alloys and high-speed cutting when moderate temperatures are generated at the cutting edge. Recommended machining operations include turning, milling, drilling, reaming, tapping and punching.

Circle 306



Composite Gears

Power-Core™ composite gears from **Intech Corporation** can replace metal gears for reduced maintenance and faster production during the deep drawing of aluminum or steel cans. The gears, which require no lubrication, are ideal for food and beverage packaging operations and for use in limited access installations where steel gears wear out prematurely from lack of lubrication. The one-piece gear offers a secure metal-to-metal shaft connection, permitting transmission of high torque through the gear's cast-in metal hub.

Circle 307

AutoCAD 13 Solid Editor

Context Cad, Inc. announces Version 1.5 of the CSG Editor for AutoCAD Professionals using solids in Release 13. The CSG Editor provides graphical editing, making it easy to move, resize or replace components of a solid model, change the radius of solid fillets, redefine extrusion profiles and paths and more. It supports WBLOCK and INSERT functions and includes an AME-to-CSG converter to change R12 AME solid models into editable R13 solids. Available for DOS, Windows, Windows NT or DEC Alpha.

Circle 308

KIMOS Gear Software

Klingelnberg has introduced an advanced software module for designing, manufacturing and inspecting spiral bevel gears. KIMOS software allows gear producers to make spiral bevel gears according to design, permitting interchangeability of pinions and gears. The program runs on 486 PCs. The KIMOS package supports production of the four most popular ring and pinion gearing systems—Klingelnberg, Gleason, Wiener and Oerlikon. It manages all steps of design and manufacturing including dimensioning, optimizing, checking and production.

Circle 309

Timing Pulleys & Belts

York Industries now produces and stocks a complete line of PowerGrip® GT® pulleys and belts for synchronous belt applications. They are available in 2 and 3 mm pitches in materials including aluminum, steel and injection-molded plastics. The company also offers timing pulley stock in a variety of pitches in aluminum and steel, pulley flanges and timing belts in polyester cord urethane, Kevlar® cord urethane and fiberglass cord neoprene.

Circle 310

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

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

U.S. POSTAL SERVICE STATEMENT OF OWNERSHIP, MANAGEMENT & CIRCULATION AS OF 9/29/95

Publication: Gear Technology, The Journal of Gear Manufacturing

ISSN No.: 0743-6858

Published: Bimonthly, 6 issues per year

Annual Subscription Price: $40.00

Mailing Address of Publication:
1425 Lunt Ave., Elk Grove Village,
Cook County, IL 60007

Name and Mailing Address of Publisher:
Randall Publishing, Inc., 1425 Lunt Ave.,
Elk Grove Village, Cook County, IL 60007

Name and Mailing Address of Editor:
Michael Goldstein, 1425 Lunt Ave.,
Elk Grove Village, IL 60007

Name and Mailing Address of Managing Editor:
James K. Spalding, 1425 Lunt Ave.,
Elk Grove Village, IL 60007

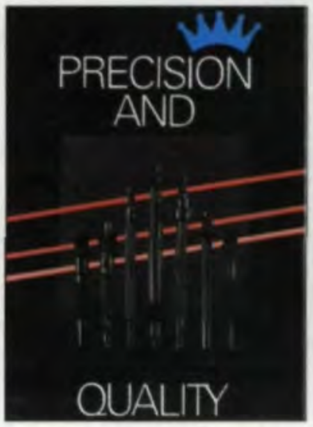
Name and Mailing Address of Owner:
Michael Goldstein, 1425 Lunt Ave.,
Elk Grove Village, IL 60007
Richard Goldstein, same

Known Bondholders: None

Nature & Extent of Circulation	Average No. of Copies Each Issue During Preceding 12 Months	Actual No. of Copies of Single Issue Published Nearest to Filing Date
Total No. Copies	12,798	12,316
Paid and/or Requested Circulation (not mailed)	10	1
Mail Subscription	7,908	6,448
Total Paid and/or Requested Circulation	7,918	6,449
Free Distribution by Mail	4,371	5,512
Free Distribution Outside the Mail (Carriers or Other Means)	162	21
Total Free Distribution	4,533	5,533
Total Distribution	12,451	11,982
Copies Not Distributed	347	334
Total	12,798	12,316
Percent Paid and/or Requested Circulation	64%	54%

ADVERTISING SECTION

LITERATURE MART



Machined Parts

Herzog GmbH & Co. is a manufacturer of high quality machined parts, such as exzenters, gears, armatures, spindles, connecting pins, elbows and complete assemblies. All parts are made according to customer-specific requirements. Herzog is the solution for your applications! For further information, please contact Simon at (502) 737-3983 or fax at (502) 769-1875.

CIRCLE READER SERVICE #113

Gear Process Control

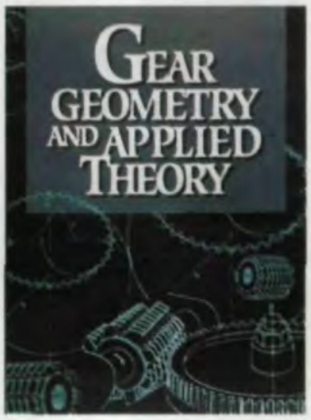
Introducing the new 3000 SS Series gear manufacturing process control system with Pentium® technology and an industry-leading **3 Year Warranty**. Proven reliability, accuracy, technology, service and support provide today's best value. Call 513-859-8273 or fax 513-859-4452.

M&M Precision Systems Corporation,
300 Progress Road,
West Carrollton, OH, 45449.

CIRCLE READER SERVICE #114

Free NASA Literature

COSMIC, NASA's computer software technology transfer center, offers a free brochure describing 15 computer programs in the general area of structural analysis that were developed for internal use by NASA. These programs are made available in source code form for reuse within the U.S. Contact COSMIC, 382 East Broad Street, Athens, GA 30602-4272. Ph: (706) 542-3265. Fax: (706) 542-4807.



The Complete Gear Book

Gear Geometry & Applied Theory, by Faydor L. Litvin, covers the modern theory of gearing, geometry, design and computerized simulation of meshing and contact for almost all gears; the geometry for face-gear drives; double circular-arc helical gears; CNC applications and new approaches for tool design. **Prentice-Hall**, 1994. $72.00. To order call (800) 947-7700.

CLASSIFIEDS

HELP WANTED

EXCEPTIONAL ENGINEERING OPPORTUNITIES

American Axle & Manufacturing, Inc. is a multi-billion dollar manufacturer of automotive driveline, steering and forging products. This Tier One automotive components supplier now has exceptional opportunities for the following:

BEVEL GEAR ENGINEER

In this position, located at our new world-class technical center in Rochester Hills, MI, you will be responsible for the design, validation and release of products for automotive applications, as well as interfacing with customers, manufacturers and suppliers.

Qualifications include a minimum of 2-3 years' experience in hypoid gear design, development and manufacturing and a Bachelor's degree in engineering or equivalent training. Must be knowledgeable in gear metrology methods including "SFT" and "CMM", gear mesh noise generation theory, and gear heat treat practices. Familiarity with basic machine tools and metal forming preferred. Computer literacy is essential.

AMERICAN AXLE & MANUFACTURING

GEAR DEVELOPMENT ENGINEER

You will coordinate the planning, timing, implementation, and follow-up of current and new gear design and development into the manufacturing process. These duties will relate to gear noise, gear strength and gear measurement systems.

Qualifications include a Bachelor's degree in Mechanical Engineering or equivalent training, and a minimum of 7 years' experience in gear development and/or coordinating measuring equipment. Candidates must have basic knowledge of hypoid gear machinery, design, tooling, gauging, manufacturing processes, noise measurement equipment, and reading/interpreting engineering-related drawings.

These positions require a high level of interpersonal skills, availability to travel on job-related assignments, flexibility to change work hours as needed, and computer literacy.

We offer a highly competitive compensation package. Send your resume (including salary history) to: **AMERICAN AXLE & MANUFACTURING, INC., Corporate Human Resources Dept., 1840 Holbrook Drive, Detroit, MI 48212-3488. FAX: (313) 974-3090.** We are an Equal Opportunity Employer.

ENGINEERING SALES

Sales position for Gear Manufacturing Engineer. Position includes direct contact with customers, estimating, application, engineering, gear design and reverse engineering. CAD experience desirable. Send resume to

C-B GEAR & MACHINE, INC.
P.O. Box 111278
Houston, TX 77293

Reps wanted for open/enclosed gear manufacturer. Seek sales reps for: Arkansas, Alabama, Missouri, Kentucky, Tennessee, Georgia, North and South Carolina. Seeking a professional organization or individuals with gear sales experience. **Reply in writing. Box AB, c/o GEAR TECHNOLOGY, P.O. Box 1426, Elk Grove Village, IL 60009.**

TO ADVERTISE CALL 708-437-6604

HEAT TREATING

MERIT GEAR HEAT TREAT

810 HUDSON ST. ANTIGO, WI 54409

Induction Hardening
Tooth by Tooth NATCO
Carburizing
Carbonitriding
Stress Relieving
Normalizing
Annealing
Blasting & Straightening
Metallurgical Laboratory

1-800-75-MERIT
Fax: 715-627-2558

CIRCLE 150 on READER REPLY CARD

Contour Induction Hardening Specialists

Spur, helical and bevel gears

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

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

CIRCLE 151 on READER REPLY CARD

GEAR TOOLING

GEAR CUTTING TOOLS

"On the Shelf Inventory"

DIAMETRAL & MODULE
- HOBS
- SHAPER CUTTERS

1DP and finer
Made to AGMA standard

SPECIAL MADE TO ORDER TOOLS

- HOBS
- SHAPER CUTTERS
- SHAVING CUTTERS
- FORM RELIEVED INVOLUTE MILLING CUTTERS

BARIT INTERNATIONAL CORPORATION
3384 COMMERCIAL AVE.
NORTHBROOK, IL USA 60062-1909
TEL: 708-272-8128 FAX: 708-272-8210

CIRCLE 152 on READER REPLY CARD

SERVICE

COMPUTER AIDS

No Time Like The Present

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

There's nothing like a new year—with the possible exception of birthdays ending in zero—to remind one of the passage of time. Keeping track of time has always been part of the brief of the gear engineer. One of the earliest gear assemblies is the remains of the Antikythera machine, a calendar/calculator dating from the first century B.C. Until the industrial revolution, clock makers and gear designers were usually the same people.

Therefore, in the interest of keeping our readers in touch with their professional roots, we bring you the following observations about time.

It Flies When You're Having Fun

Time is both relative and a measurable commodity. You'd be amazed how much you can get done in a given amount of time if you put your mind to it. According to Stuart A. Sandow (*Durations*, New York Times Books, 1977):

• Light can travel 30 centimeters in a billionth of a second.

• In .000024 seconds, a stick of dynamite will detonate.

• A car's air bag will inflate in .04 seconds.

• The same car travelling at 30 mph will go 44' in one second.

• At the Coke bottling plant, 340 16-oz. bottles are filled every minute.

• In one hour, you can de-ice 10 miles of a two-lane road by spreading rock salt from a truck.

• In one day, 100 photographers shot 60,000 pictures for the *Life* magazine bicentennial edition.

• It takes one year to build a Steinway grand piano—or for a broken femur to mend.

We Don't Want To Pressure You, But . . .

There are other ways to measure time, of course. You can ask how much you've accomplished in the time you've had. Jeremy Baker in *Tolstoy's Bicycle* (St. Martin's Press, 1982) reminds us that:

• Mozart gave his first European concert tour when he was 6; at the same age Shirley Temple was earning $1,250 a week (1934 dollars).

• At 13, John Quincy Adams was secretary to the U.S. minister to Russia in St. Petersburg;

• Sixteen-year-old Ivan (later to be known as "The Terrible,") was crowned Czar; at the same age, Leonardo da Vinci became an apprentice in the workshop of Andrea del Verrochhio;

• At 17, George Washington was the county surveyor of Culpepper, VA;

• At 20, Guglielmo Marconi began his first experiments in radio transmission. He took out his first patent at 22 and started his own radio company at 23.

• Edwin Land dropped out of Harvard at 21. Two years later he invented the Polaroid.

• At 21, Thomas J. Watson. Sr., hired on at National Cash Register, and Steve Jobs, with help from Stephen Wozniak, built the first Apple computer in his garage.

On the Other Hand . . .

• Leo Tolstoy took his first bicycle lesson at 67; Queen Victoria began lessons in Hindustani at the same age.

• Ginger Rogers, 68, did three weeks of shows with the Rockettes; Nicolas Copernicus was also 68 when he published *De revolutionibus orbium coelestium*, thus laying the foundations for modern astronomy;

• At 71 John Houseman won his first Oscar for "The Paper Chase";

• At 80 Konrad Adenauer (Germany), Eamon DeValera (Ireland), Jomo Kenyatta (Kenya), Marshal Tito (Yugoslavia), General Franco (Spain) and John Diefenbaker (Canada) were all heads of state.

• Conductor Leopold Stokowski, 94, signed a 6-year recording contract;

• Adolf Zukor, 100, was appointed Honorary Chairman of the Board of Paramount Pictures.

And now our time—and space—are just about up. All that's left is for us to wish all of you a Happy New Year. ○

"Folks, I feel as if we're turning a corner."

The Addendometer: If you've read this far on the page and enjoyed it, please **circle 214.**

Plus the process-optimizing resources that will put the right gear-making technology to work for you.

Hob, shave, grind, hone...the choices for precision cylindrical gears are many, and we have the advanced machines and expertise to make your process cost-effective and precisely productive.

Affordable PHOENIX® CNC hobbers deliver rigid high-speed wet or dry cutting for reduced cycle times and consistent accuracy.

Gear finishing options have never been greater, starting with the proven efficiency of Hurth CNC shaving machines and cutters. Our fully-automatic threaded-wheel grinder and Hurth spheric honing machines can eliminate entire process steps. Chamfering/deburring machines round out the line.

130 years of experience also back our ongoing commitment to bevel and hypoid gear-making machines, testers, tooling, design and development software, and support. Continent to continent, our worldwide resources are unique and ready to serve you.

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

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

Gleason

CIRCLE 100 on READER SERVICE CARD