GEAR TECHNOLOGY

The Journal of Gear Manufacturing

IMTS '96 PRE-SHOW ISSUE

July/August 1996

WHO'S AT THE GEAR GENERATION PAVILION
GEAR NOISE REDUCTION
DESIGNING SHAPER CUTTERS
PLASTIC GEAR DESIGN BASICS

Plus Gears . . . • *www.geartechnology.com* • Insider's Guide to Chicago • Addendum

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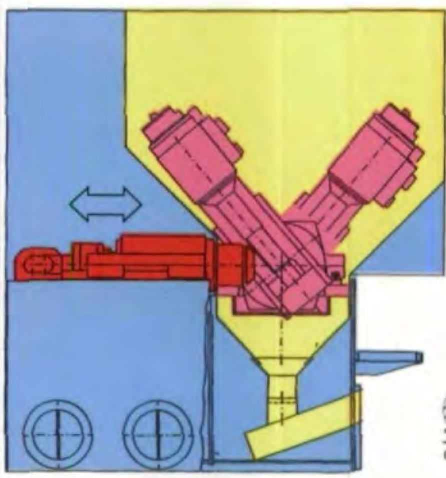
- **Flexibility for the future.** Wet or dry...carbide or HSS...soft or hard gear finishing...almost anything's possible within P100's remarkable performance range:
  - *Hob/tool speed range: 200–4,000 RPM*
  - *Workpiece/worktable max. RPM: 3,000*
  - *Max. Diametral Pitch: 10*

  The Pfauter P100's unique direct drive hob and work spindle design makes it possible—and affordable.
- **Easy to own and operate.** Low cost, compact footprint (only 2.3 cu. M), and 2 sec. auto load system are a few more reasons to buy the P100. **Call American Pfauter today at (815) 282-3000.**



The entire work area is enclosed in a stainless steel shroud (yellow) that prevents hot chips from accumulating and directs them downward into a chip conveyor. Horizontal orientation of work spindle (red) helps facilitate chip removal.

IMTS 96
CHICAGO — SEPTEMBER 4 - 11, 1996

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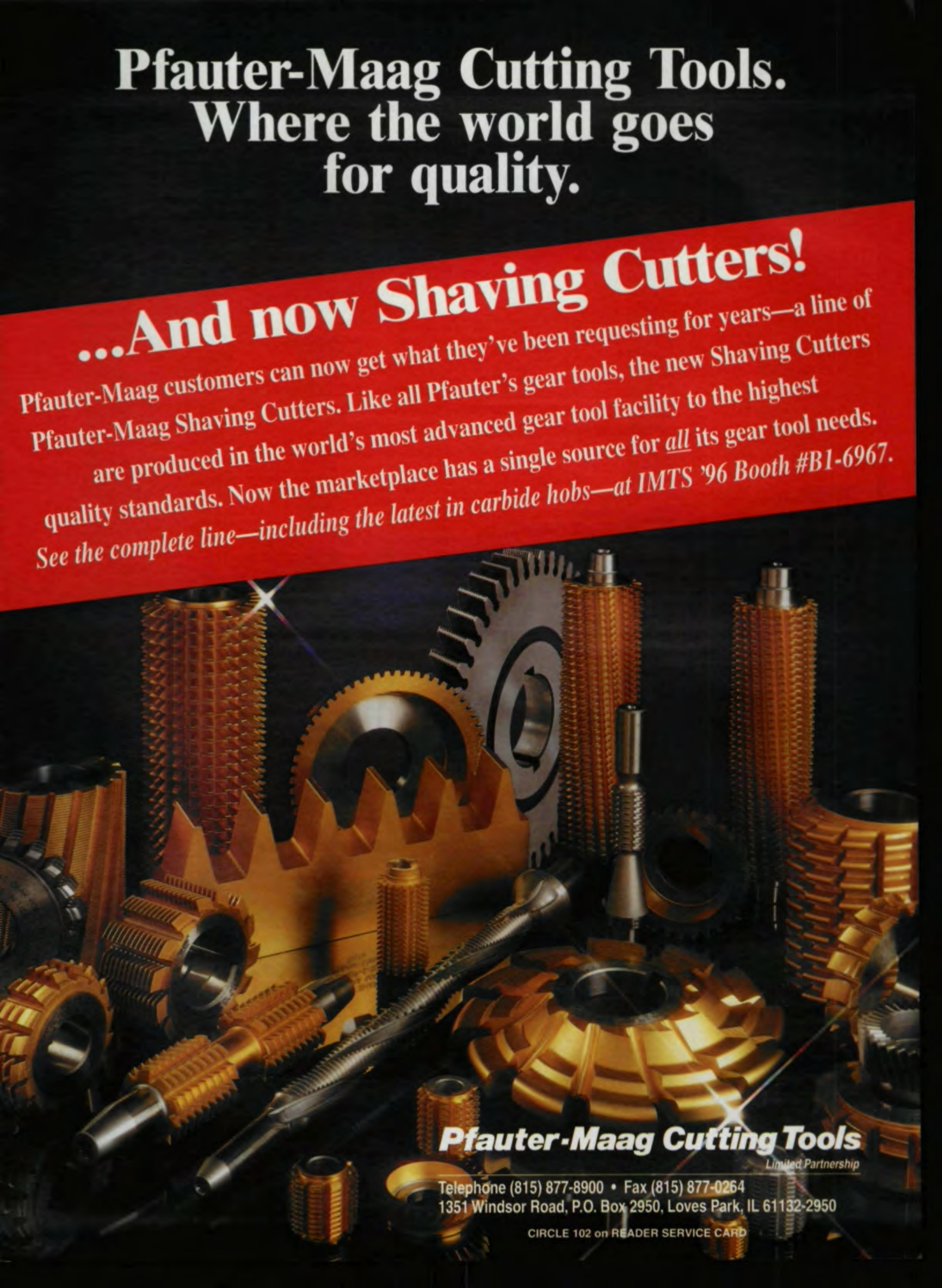
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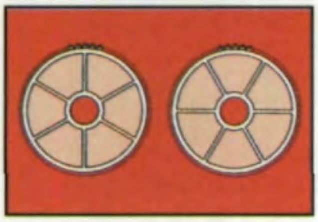
JULY/AUGUST 1996

The Journal of Gear Manufacturing

FEATURES



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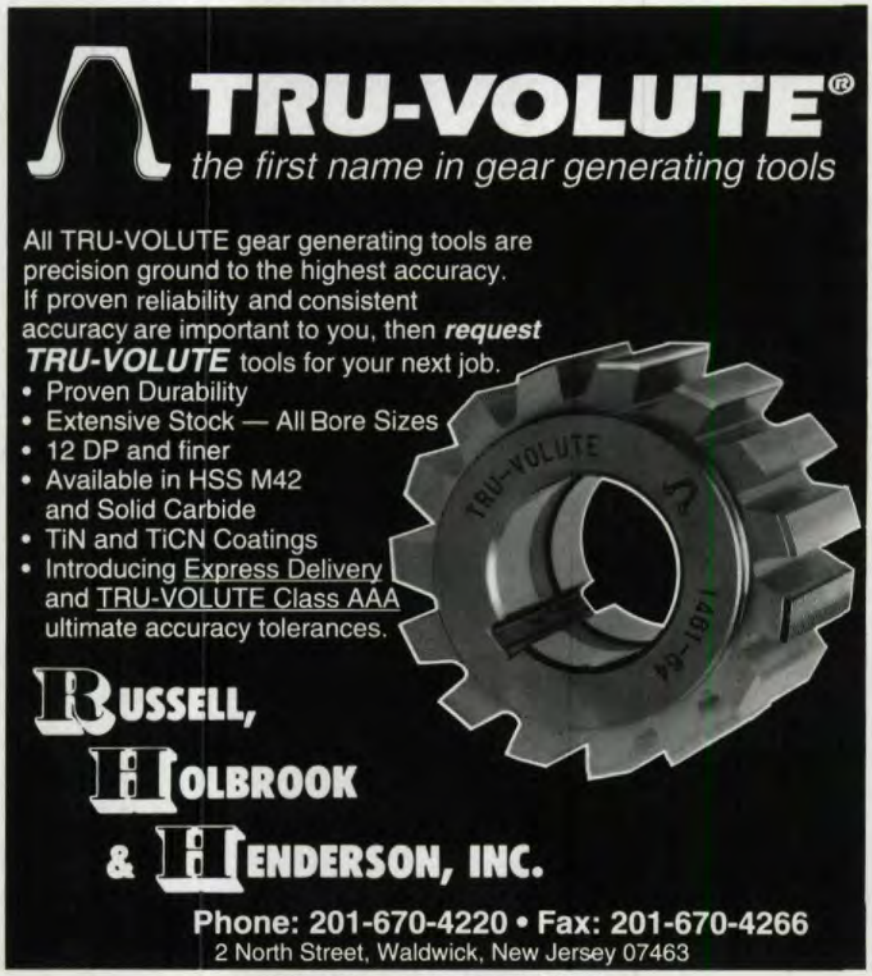

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GEAR TECHNOLOGY

The Journal of Gear Manufacturing

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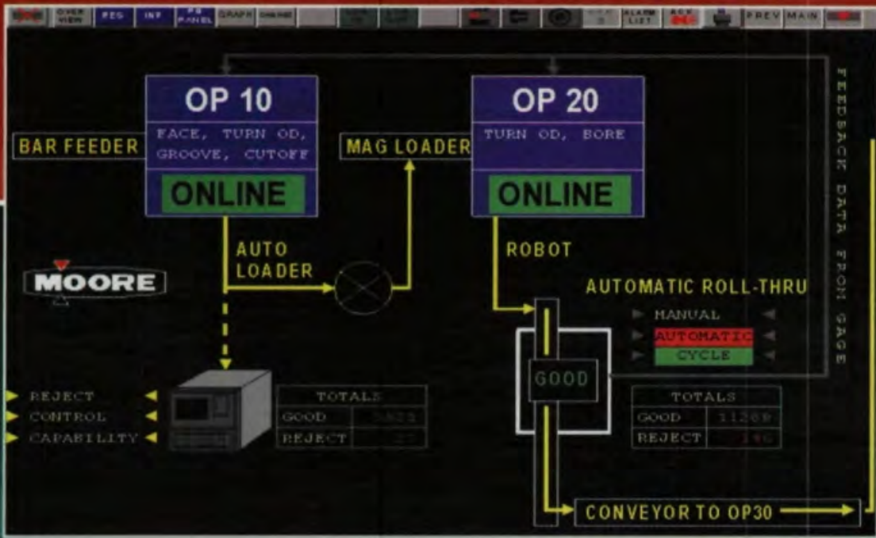

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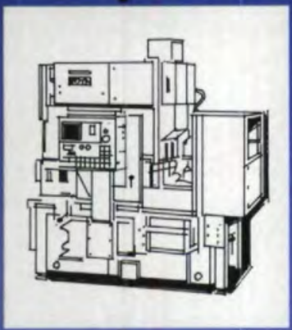

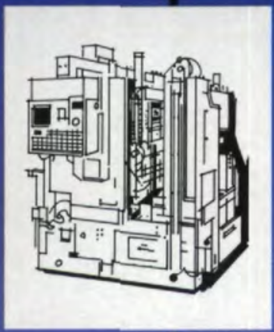

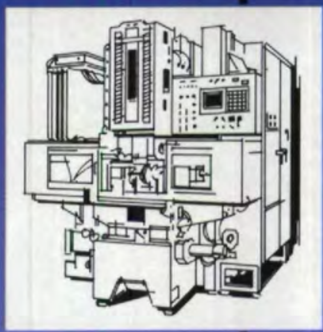

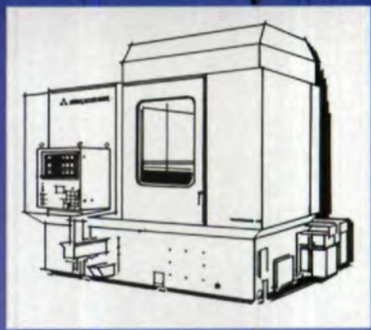

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You've been reading about it, talking about it, maybe even trying it. *Gear Technology* has jumped aboard it feet first and begun a voyage on the World Wide Web. Beginning with this issue, an electronic version of the magazine will be online. For those of us who still find the fax machine amazing technology, this is a great leap.

Because the World Wide Web and the Internet are part of a paradigm shift that may (will?) change the way we all do business, our Web site will be more than just a magazine. We have placed it in the context of the larger gear and power transmission industries. Our opening page links to the magazine, of course, but will open doors to far more. We have provided an Internet Buyers Guide to the gear industry, featuring gear machinery, equipment, tooling, accessories, services, gears and power transmission products. We are also providing links to the web pages of a number of important technical societies and other useful reference organizations.

This path is open in two directions. As a reader you can find information about the products and services you need online. As someone who wants to know how the Web can benefit your company, you will have the opportunity through our site to explore what this medium can do. We will be offering ways for your company to explore the advantages of advertising and displaying information on the Web at a very low cost. You can "rent space" on our site and, eventually, should you want to, create a link from *geartechnology.com* to your company's own Web pages.

The virtual *Gear Technology* will make things simpler and faster for you. One or two mouse clicks will take you right to important parts of the magazine. We have abstracts of current articles, previews of coming features, a current technical calendar, the complete text of our popular Addendum page and, perhaps most important, ways for you to reach us directly via computer. You can subscribe, get back issues, check a complete article index and e-mail our staff directly from our site.

This is only the beginning. Like most everyone else on the Web, we're learning how to use this resource. As time goes on, and as you provide us with input about what information you need and want on the site, we will be fine-tuning it. As the technology improves (an hourly phenomenon in Web Country), we'll be upgrading too. We want *geartechnology.com* to be useful, informative, and fun—one of the sites you list in your "favorite places" file on the Net.

For this to happen, we need your input. Interactivity—the whole point of the Internet—is a two-way street. Let us know what you like and don't like; what works and doesn't; what you want and don't want; what you need and what's a waste of cyberspace. Ask us questions. Share your ideas. E-mail and fax are fastest, but we'll still be answering the phone and opening the mail. Come along on this exciting voyage with us.

(continued page 45)

OUR WEB SITE ADDRESS IS

http://www.geartechnology.com

geartechnology.com AND OTHER ADVENTURES

Gear Technology User's Guide To IMTS '96

The companies, the machines, the booths to visit; plus, travel tips, insider information, hot times, cool sights and required reading. What you need to know to get the most out of the greatest machine show on earth.

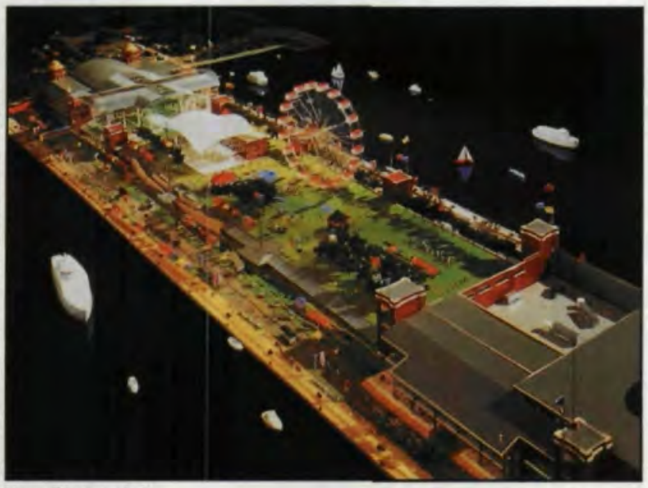
Nancy Bartels & William R. Stott

IMTS: It can be the best of times or the worst of times. The best because nowhere will you find more equipment, products and services for your business than at McCormick Place, Chicago, in September; the worst because finding your way around the show and around the city can be a hassle.

But have no fear: The intrepid scouts from *Gear Technology* are on the job. This User's Guide will tell you all you need to know to have a great (and productive) time at IMTS '96.

THE NITTY GRITTY

What: IMTS '96
Where: McCormick Place, Chicago, USA
When: September 4–11, 9:00–6:00 daily
(except Sunday, Sept. 8, 10:00–4:00)
For more info on registration, exhibiting, etc.,
call 800-322-IMTS
fax 703-893-1151
or check out ***www.imts.org*** on the Internet.
(Don't miss the "Virtual Gears").



© Chicago Convention & Tourism Bureau/Gene Hickmott, photographer.

Navy Pier at night.

Ed Ops

Manufacturing '96, the technical conference held concurrent with IMTS, is organized by show sponsor AMT and SME. Attendees will have a choice of over 70 one- and two-day courses and clinics in seven areas: automation/controls, design, forming and fabrication, machining, management, quality and tooling. Call SME's customer service center at 800-733-4763 for more information.

The Heart of the Matter

Cut to the chase. Visit the new Gear Generation Pavilion, where gear machine tool manufacturers will show off their latest technologies. Check out

- American Pfauter, L.P.
- The Gleason Works
- Hauser-Tec Co.
- Koepfer America
- Liebherr America/Sigma Pool
- Mitts & Merrill, L.P.
- Reishauer Corp.
- Star Cutter Co.
- Vermont-USA Machine Tool Group

The Inside Story

Booths you won't want to miss and what to look for when you visit . . . (* indicates location in Gear Pavilion.)

American Pfauter, L.P.—Booth #B1-6967*. See the new P100 carbide dry hobbing machine and the Kapp VAS 55P CNC form grinder, which will demonstrate topographical grinding. The Höfler ZP630 shows the latest gear measuring machine configuration and technology for gears up to 25" diameter. The new SP320 gear shaver is Pfauter's contribution to the latest CNC shaving machine technology. Pfauter-Maag Cutting Tools will display hobs, shaper cutters, form cutters, rack cutters and their new product, shaving cutters, and solid carbide hobs and thin film coatings, including TiN, TiCN and TiAlN.

Gleason Works—Booth #B1-7170*. See the Gleason PHOENIX 125GH hobbing machine with dry hobbing capability and the new PHOENIX 450HC hypoid cutting machine, a small-footprint, 6-axis CNC machine for large bevel gears.

Also on view will be the Gleason-Hurth ZS 150 shaving machine with a new part loader, the ZH 250 honing machine and the TAG 400 CNC spur & helical gear grinder. New machine software includes a PC-based knowledge system for the 125GH hobber. The system puts accumulated knowledge related to machine setup, operation, troubleshooting and maintenance at the fingertips of gear production personnel 24 hours a day.

Ikegai America Corporation—Booth #D2-4385. On display here will be Ikegai's newest CNC gear hobbers and hob sharpeners. The SX-15 CNC gear hobber uses a 2,000 rpm spindle and a 220 rpm table. Both spindle and table are highly rigid to allow for the use of cermet hobs and small diameter multigroove hobs. The radial and axial rapid feeds are both 5000 mm/min, and the machine is equipped with a Fanuc 5-axis CNC and a hob quick-change system for straight shank hobs. The SAN-20 4-axis CNC hob sharpening machine, controlled by a 4-axis Fanuc NC, can grind both spiral and straight gear hobs.

Inductoheat, Inc.—Booth #B1-6477. Inductoheat features STATISCAN®, a versatile, general purpose induction heating system. This self-contained, vertical/horizontal scanner hardens and tempers a variety of parts. It can be set up for lift/rotate and single shot operations. Statiscan stands alone or can be integrated into new or existing lines for hardening and tempering. Inductoheat's in-line, continuous-feed hardening system surface hardens cylindrical components for mid- to high-volume operations. It can be integrated with pick-and-place automation and other material handling systems. Check out the multi-media video display of induction heat treating.

Liebherr America/Sigma Pool—Booth #B1-7176*. A wide range of gear production machines will be on display at the Sigma Pool booth. See the LC82 CNC gear hobbing machine, capable of dry cutting; the Lorenz CNC gear shaping machine; the Klingelnberg PNC 100 CNC gear inspection machine and the Oerlikon line of CNC gear equipment.

Mitsubishi Machine Tool—Booth #D2-4254. The focus here is on Mitsubishi's gear cutting capabilities. The GD20CNC is a rigid CNC stand-alone gear hobbing machine designed for job shops and quick change environments. The GD20CNC hob center is a combination machine for hobbing and finish rolling of gears for high volume production. The FB30CNC is a plunge-type gear shaving machine for fast, accurate enhancing of gear tooth quality. Mitsubishi will also have on display a high speed drilling machine with an automatic tool changer.

National Broach & Machine Co.—Booth #B1-7489*. See the newest addition to National Broach's line of Red Ring systems, the new BV-T broaching machine with a force monitoring system to monitor tool wear. The BV-T offers a small footprint, safety, flexibility, efficiency and easy maintenance, according to the manufacturer. Also on exhibit is the SPIRALGLIDE broach tool, which offers longer tool life due to constant tooth engagement. Get complete information on National Broach's full line of precision gear cutting and forming tools at the booth. *(continued p. 11)*

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Innovation...

AMS-250-1AL CNC Analytical Gear Tester

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- *Intel® PC electronics*
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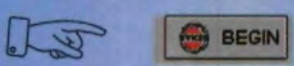

A powerful and friendly tool! This application guides operator part setup and test sequencing to automatically evaluate gear test results, then quickly produces an analysis using AGMA, DIN, ISO, or user specified tolerances. Combine this with the unrivaled flexibility of the Microsoft® Windows™ Operating System and you have a simple means for data collection, analysis, and post- process management of critical gear test results. Results never before achievable!

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Questions? We are at your service! Our proven technical staff with 175+ years of gear technology experience will help you find solutions and learn more about this remarkable instrument. For prompt assistance, call or FAX our WinSpect Product Team at:

American Sykes Company
Solutions for the Gear Manufacturer
1302 Research Park Drive
Beavercreek, OH 45432
Tel 513-427-0507 • FAX 513-427-9653

A member of the David Brown Group

Reishauer Corp.—Booth #B1-7148*. The centerpiece at this booth is the RZ362A production gear grinder, featuring Reishauer's continuous shift process which guarantees high process stability, reduced idle times, very low perishable tool costs, quick setups and super-fast grinding times, according to the manufacturer. The various dressing attachments available for the RZ362A will be shown.

Schunk Inc.—Booth #B2-7060. Schunk's line of hydraulic chucks and arbors, with guaranteed accuracies of .00012" or less will be on display. With their high torque and .00004" repeatable centering capability, Schunk arbors are well suited for applications from hobbing and turning to testing and measuring. Good for applications from cutting tool manufacturing and resharpening to milling and boring where tool life, finish and productivity are important. Also on display will be vacuum components, high-precision pneumatic and hydraulic self-centering clamping blocks for workholding applications, rotating and linear extension units, plus a comprehensive offering of parallel, angular and concentric grippers and accessories.

Star Cutter Co.—Booth #B1-7158*. Star Cutter will feature its UTG-300 tool and cutter grinder as well as a full line of gear and other cutting tools, including hobs, shaper cutters, gun drills, pressure coolant reamers and milling cutters. Also on display will be Star Cutter's line of thin-film coatings, including TiN, TiCN and TiAlN, and plated products, including grinding wheels, dressers and carbide pre-form blanks.

The Outside Story

The whole city of Chicago lies outside McCormick Place, and as any native can tell you, it always helps to have an insider to grease the wheels for you in this town. So the *Gear Tech* staff of insiders has collected some important bits of information to make your IMTS visit go as smoothly as possible.

Transportation. It's true that the last plane out before the Apocalypse will have a layover at O'Hare Airport, but once you're on the ground, the options multiply. A limo or cab ride to downtown is $25–$30. The CTA runs from the airport to downtown for $1.50, but you have to schlepp your own luggage, and you're dropped off at a downtown stop, not in front of your hotel.

Travel Secret I. If you can get an airline that will fly you to Midway, take it. The short runways make looking out the window during landing and takeoff not for the faint of heart, and the facilities are a bit scruffy, to put it kindly, but it's smaller, less crowded, saner and much closer to downtown than its gargantuan big brother out in the suburbs.

Travel Secret II. You can beat the long cab lines at IMTS by catching the Metra Electric Train (accessible from the North Building) at the 23rd St. Station near McCormick Place, which will take you to the Loop in seven minutes for the standard $1.50. The station is still partially under construction, but the train has two stops downtown, Randolph and Van Buren. Both are close to the Loop action, hotels, and cabs. And don't forget that IMTS offers free shuttle

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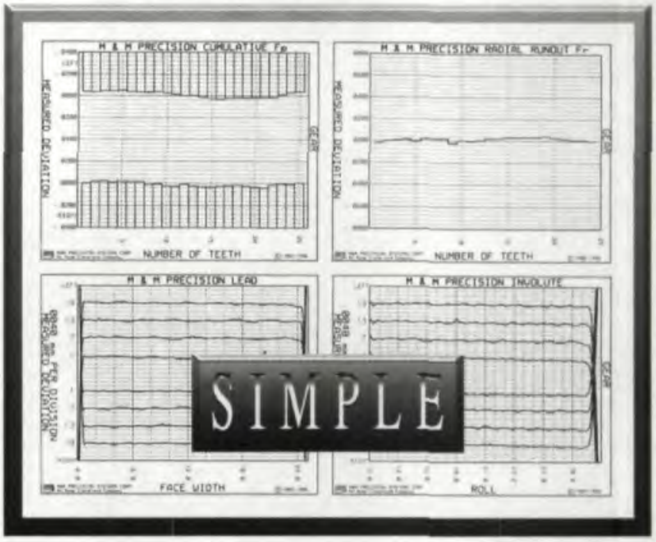

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buses every 20 minutes between McCormick Place and downtown hotels.

Stormy Weather *(Maybe).* Local myth says there are three weeks in October that make living here bearable the rest of the time, but September ain't bad either. Here's the straight scoop on IMTS weather. September is still high summer in the Midwest. Normal highs are in the mid-70s and lows in the mid-50s; however, early in the month, the high 80s or lower 90s are not uncommon. A light coat or jacket will be more than enough for warmth. Never assume it won't rain in Chicago. Pack an umbrella.

Travel Advisory. Seriously, folks, if you're planning on arriving at McCormick Place by car, beware. A ***major reconstruction*** of Lake Shore Drive in front of McCormick Place is underway and won't be done until IMTS is a fond memory. The Drive is open and traffic is moving, but a good alternative if you're arriving from the north is to get off north of Jackson Blvd. and take State St. or Michigan Ave. south to 31st St., then east to the McCormick Place parking lot. From the south, Lake Shore Drive to 31st is still your best bet.

A.K.A. . . Chicagoans have the annoying habit of naming major roads twice. Guide for the unwary traveller: 22nd St. is also Cermak Road. Lake Shore Drive is Illinois Rt. 41. Interstate 290 is known here as the Eisenhower Expressway. I-90/94 is the Kennedy, unless you're south of the Eisenhower, when it's the Dan Ryan. I-90/94 splits northwest of the city. I-90 becomes the Northwest Tollway, heading to Rockford, and I-94 is the Edens Expressway, which will take you toward Milwaukee. I-55 is the Stevenson. We won't even go into the state roads which also have street names that change as you go from one neighborhood to another. Best advice when getting directions: Make sure you've got the road number, not just the name.

Fun & Games

IMTS will leave you little time to spend playing tourist, but if you're at the show for longer than a couple of days and have the chance (or the need) to get away from McCormick Place for a few hours, there's plenty to do.

Fan City. Both major league baseball teams will be in town. The Cubs play Montreal on Sept. 9–11 and Philadelphia Sept. 13–15. The White Sox play Detroit on Sept. 2–4, Boston on Sept. 6–8 and Cleveland Sept. 16–18. The Chicago Bears will be at Soldier Field against Dallas on Sept. 2 and against Minnesota on Sept. 15th.

The Lively Arts. Opera, theater, comedy, jazz and blues clubs, movies in a dozen languages—you can find all that and more in Chicago. Two items to keep in mind. Hot Tixx (312-977-1755) sells half-price, day-of-performance theater tickets. The best current listings of entertainment of all sorts is found in *The Reader*, a free weekly newspaper distributed in record and book shops, drugstores, newsstands and restaurants all over the Loop and near north and south sides. Check it out for what's hot (the classified ad section is a real trip in itself).

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Dead Poets (and Others) Societies. The major museums in Chicago are worth the effort, but anybody who tells you it's possible to "do" one in a day or less is pulling your leg. If you only have a couple of hours, try some of the lesser known gems, which are smaller, less crowded, more intimate, and less expensive.

The Museum of Broadcast Communications is on the corner of Michigan and Washington downtown in the Chicago Cultural Center. The building itself, which used to house the public library, is an architectural beauty (there are also free concerts every Wednesday at 12:15 p.m.), and the museum is a tribute to early radio and t.v. For a different kind of souvenir, get a video of yourself playing anchorperson. You (and up to three of your friends) can read the news, weather and sports on a t.v. news set. Cost for the video is $19.95. Admission to the museum is free.

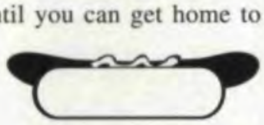
The Chicago Historical Society at Clark and North avenues has lots of early Illinois exhibits and Lincolniana. Check out the diorama of the Chicago Fire and the current exhibit, "The Last Best Hope of Earth: Abraham Lincoln and the Promise of America." Admission is $3.00. Mondays are free.

Zen & The Art of Sightseeing. Sometimes what you need most at IMTS is a breather from the noise and crowds. Chicago has 30 miles of lake front, and a stroll along a portion of it is relaxing, healthy and absolutely free. Or pick a comfy spot on some breakwater to sit, take a few deep breaths, look north by northeast and meditate on the fact that there's nothing but blue water between you and Upper Michigan.

For a more lively hike, try Navy Pier. It has shops, restaurants, an indoor botanical garden, a 15-story Ferris wheel, a carousel and plenty of street life. Free trolley rides operate along the length of the pier. Go to the end of the pier or the top of the Ferris wheel and look west for a spectacular view of the city.

A must-see after IMTS closes in the evening is the Buckingham Fountain in Grant Park. Recently refurbished, this giant classical fountain operates between May and October. A free light show is held every evening between 9:00 and 11:00 p.m. A great spot for people watching and picture taking.

Epicurean Ecstacy. Whether it's hot dogs or haute cuisine you've a craving for, some restaurant in Chicago serves it. Pick up a current copy of *Chicago* magazine (found on most newsstands) for a thorough, user-friendly guide to over one hundred area restaurants. It's by no means a comprehensive list, but it should help you make do until you can get home to momma's cooking. ✪



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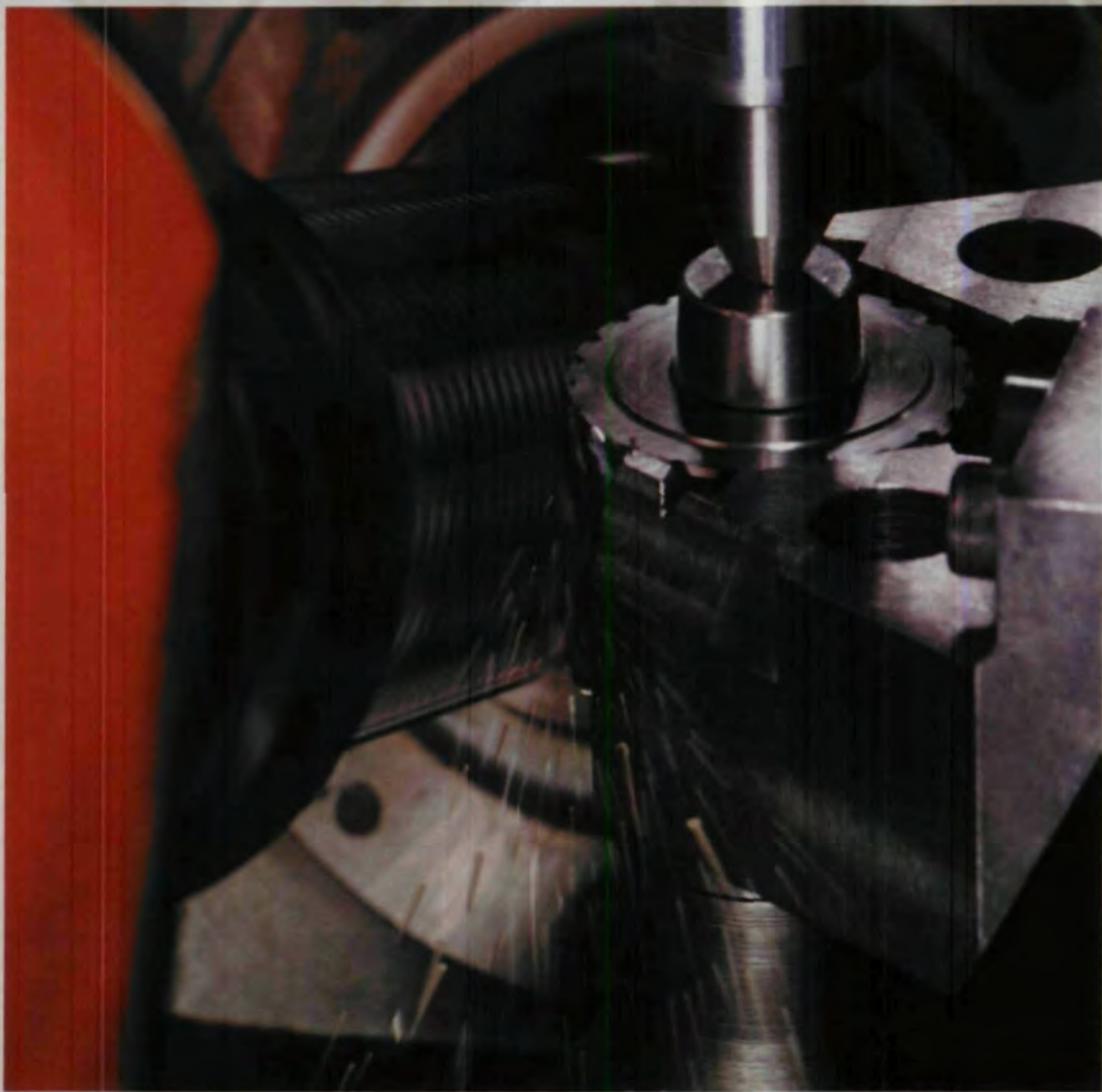

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What's News

Election News . . . AGMA elected new officers and board members at its annual meeting in Fort Lauderdale, FL. **Frank J. Posinski** of Cincinnati Gear is the new Chairman. **Adolph W. Sbihli** of the General Motors Gear Center is Senior Vice President, and **David L. George** of Falk Corp. is Treasurer. **Charles A. Brannen** of Overton Gear is Chairman Emeritus. **Bipin N. Doshi** of Schafer Gear Works and **Arlin Perry** of the Dorris Company are Vice Presidents, and **Roger A. Pennycook** of IMO Industries, **Gottfried H. Versock** of Flender Corp. and **Robert R. Wallis** of Rexnord Rotary Components were elected to the Board of Directors.

Keith J. Watkins

New Faces . . . Keith J. Watkins has been named the new president of **Mahr Corporation**, the Cincinnati, OH-based headquarters for Mahr GmbH's North American operations. Mahr markets precision surface, roundness and form measurement products to manufacturers.

Getting Together . . . American Wera, Hurth MODUL, and **Samag**, all manufacturers of metalworking machinery, have combined to offer their individual machines, auxiliary equipment, parts and service from one location in Ann Arbor, MI. **Walter Friedrich** will act as president of the combined office . . . **Thomason Mechanical Corp.**, a machinery maintenance company operating in the western U.S., and **Prager Incorporated** division of Brook Hansen, a repair facility for gearboxes, have formed an alliance with two repair centers at TMC's facilities in northern and southern California. Services will include gearbox repair, replacement gearing, redesigns, upgrades, ratio changes and custom gearbox design.

And the winners are . . . AMT — The Association For Manufacturing Technology has presented its Total Quality Implementation Award to **Extrude Hone Corp., Livernois Engineering Co.** and **National Machinery Co.**

AGMA standards distribution . . . On April 15, **Global Engineering Documents**, a division of Information Handling Services (IHS) Group, Inc., became the primary sales and distribution agent for all AGMA standards and technical documents. Global makes AGMA standards available either on paper or CD-ROM. AGMA's engineering staff will continue to handle all technical questions and to be responsible for the development and approval of all industry standards.

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Noise Reduction in Plastic & Powder Metal Gear Sets

Robert E. Smith & Irving Laskin

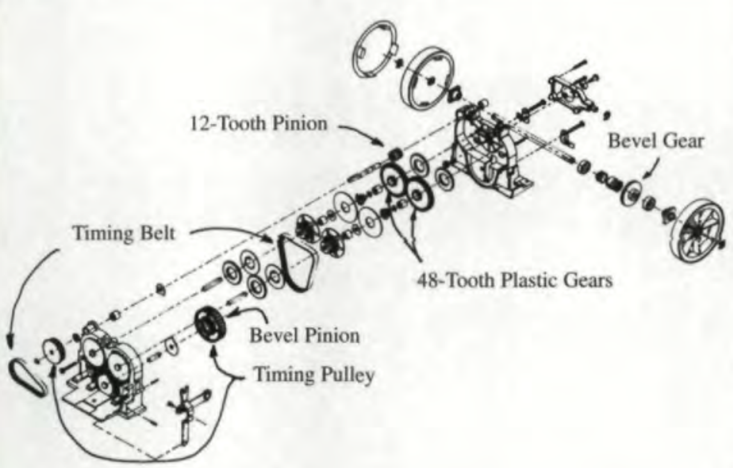

Fig. 1 — Drive system.

TABLE 1—MULTIPLES OF MOTOR SHAFT SPEED

Feature	Order of Rotation	
Motor	1st	
12T Pulley		
22T Pulley		
Main Timing Belt	12th	
	24th	2nd Harmonic
12-Bladed Cooling Fan	12th	
	24th	2nd Harmonic
	36th	3rd Harmonic
12T Pinion		
48T Gear	6.55	
	13.1	2nd Harmonic
	19.6	3rd Harmonic
	26.2	4th Harmonic
11-Bladed Vac Fan	11th	
	22nd	2nd Harmonic
	33rd	3rd Harmonic
Secondary Belt		
and Pulley	3.41	
	6.82	2nd Harmonic
	10.22	3rd Harmonic
Commutator Segments	22nd	
	44th	2nd Harmonic

Introduction

The data discussed in this article was taken from an upright vacuum cleaner. This was a prototype cleaner that was self-propelled by a geared transmission. It was the first time that the manufacturer had used a geared transmission in this application.

The transmission (Fig. 1) is driven by a timing belt takeoff from the fan motor shaft. It contains a 12-tooth powder metal pinion driving a pair of 48-tooth plastic gears. Because of the molding and sintering processes, these gears had been specified as AGMA Q6 quality. Through a clutching arrangement, one or the other of the plastic gears is driving the machine in the forward or reverse direction. Pushing or pulling on the upright handle actuates a rocker arm that engages the appropriate clutch. Another timing belt drive connects the 48-tooth gears to a final set of bevel gears. The large bevel gear is on the final drive axle.

When operating the vacuum cleaner in the self-propelled mode, a nearly pure tone whine was heard while the machine was moving in each direction. It was of a fairly high pitch and was objectionable when compared to previous non-self-propelled machines. The vacuum fan and beater bar also made considerable noise and were responsible for most of the overall dbA sound pressure level. However, because of the whine characteristic of the gear noise, it was objectionable even though it was lower than the overall sound level.

Identification of Noise Sources

Spectral Analysis. Because of the complexity of the drive assembly, it was necessary to use spectral analysis to identify the offending components (Ref. 1). This was done by a FFT real time analyzer. This takes a complex sound waveform and breaks it down into its various spectral frequencies.

Relationship to Transmission Error. Moving elements in a complex train such as this one cause airborne noise and force variations that are applied to the structure. Often the structure will act as a mechanical amplifier of the noise at frequencies that coincide with its resonant frequencies.

The gears and other elements act as exciters. The excitation from the gears and timing pulleys comes from what is known as "transmission error" (Refs. 2–3). Transmission error is a non-uniform motion that is the result of runout and errors in geometry of the gear or pulley teeth.

Comparison of Noise Frequencies. Gears will generate noise excitation at their mesh frequency and its multiples. Runout can also generate noise. This usually shows up at a once-per-revolution frequency or at once-per-revolution sideband of mesh frequency. In order to identify the offending source, one must know the operating speed of the machine and the discrete frequencies of the noise. In this case, the speed varied with load and was different for each test. Therefore, it was easier to create a table of "rotational orders" that could be used for any operating speed (See Table 1).

Measured Sound Data. Fig. 2 shows spectral data of a noise test of the prototype machine. It was taken with a sound pressure level (SPL) meter that was set for "A" weighting. This attenuates the higher and lower frequencies to approximate the response of the human ear. The mesh frequency of the 12 x 48-tooth gear set was 1,350 Hz. A marker is set at that frequency and at all harmonics of it. It can be seen in the figure that noise exists at mesh frequency and several harmonics. The second harmonic of mesh is the highest peak. This could be due to the "A" weighting mentioned above or to waviness in the tooth form. A peak can also be seen at 2,275 Hz. That is from the 11-bladed fan.

Measurement & Modification of Gears

It was decided to remove the gears from the machine and do further diagnostic testing. This consisted of transmission error testing and involute inspection. In gears of this type, noise at mesh and harmonic frequencies is most apt to be caused by lack of conjugacy or mismatch of involute profiles (Refs. 2–3). This will show up in both of the tests mentioned above.

Transmission Error Tests. Transmission error testing is usually done with high resolution optical encoders and instrumentation that measures small deviations in the smoothness of rotational motion. Typically it is done at relatively light loads. In this case, tests were run at both light and at operating loads. There was no discernable difference in the tooth-to-tooth transmission error at either load condition. This showed that tooth deflection under load was not a problem and that tip relief on the teeth was not necessary. Fig. 3 shows the results of a transmission error test. The first half of Fig. 3 shows the total transmission error curve for three revolutions of the 48-tooth gear. One can see a sine wave from each revolution of the 48-tooth gear, a sine wave from each revolution of the 12-tooth pinion and, finally, the very fine waves superimposed on the larger ones. These fine waves are from each tooth mesh and are the ones of concern as far as gear noise. The second half of Fig. 3 shows these fine waves, but magnified after removal of the long term components from the gear and pinion runout. This last chart shows 12 tooth meshes or one pinion revolution.

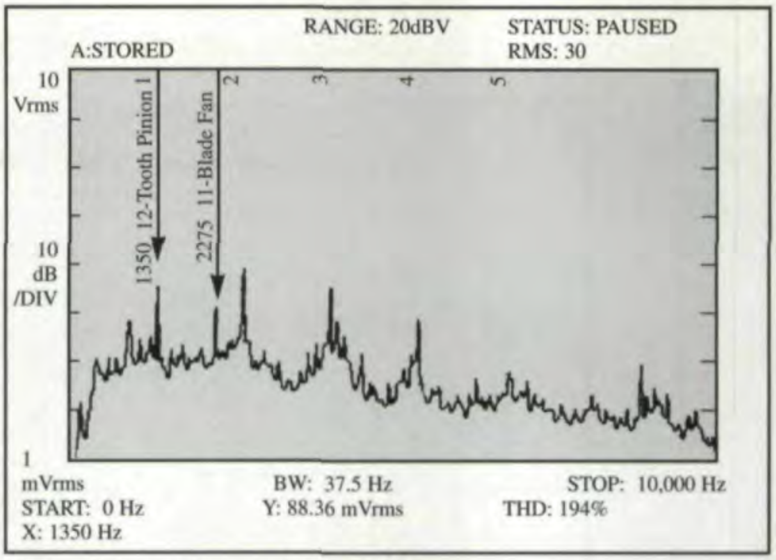

Fig. 2 — Noise spectrum—prototype machine.

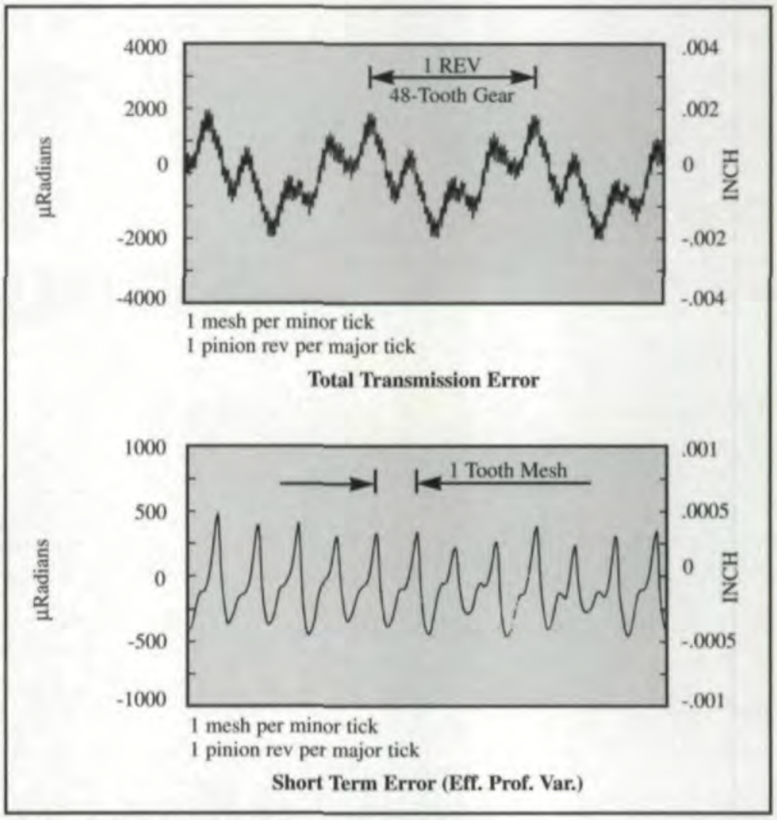

Fig. 3 — Transmission error test results—noisy set.

This tooth-to-tooth transmission error has a sawtooth characteristic, as well as a double bump in each tooth mesh The sawtooth characteristic will generate noise at all harmonics of tooth mesh, and the double bump will accentuate the

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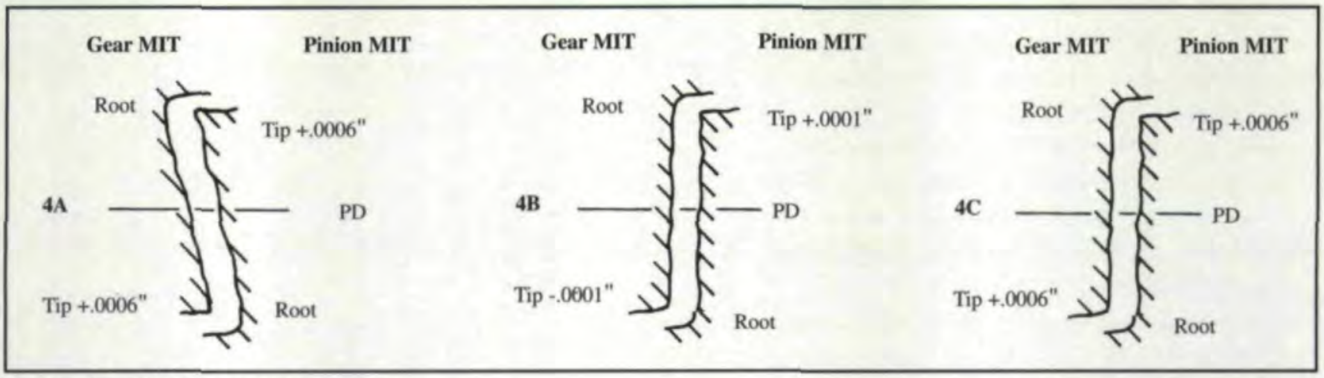
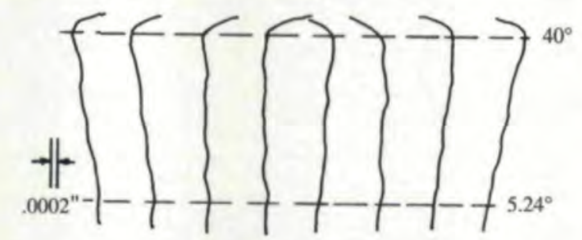


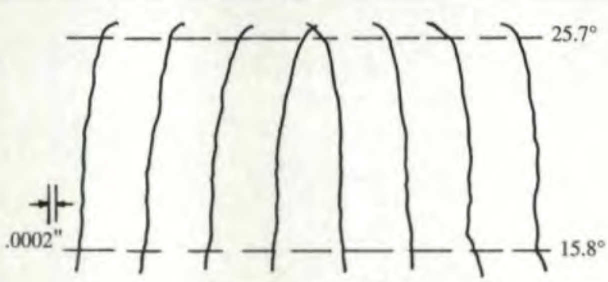
Fig. 4 — Mean involute traces (MIT).



Results — 1/10,000"

	Left Flank				Right Flank			
	4	3	2	1	1	2	3	4
fHα	9.4	9.5	1.7	1.8	3	-0.7	5.5	10.2
fHαm (MIS)	5.6				4.5			

Fig. 5 — Involute tests of 12-tooth pinion from noisy gear set.



Results — 1/10,000"

	Left Flank				Right Flank			
	4	3	2	1	1	2	3	4
fHα	-6	-7.3	-7.5	-6.6	-4.8	-6.7	-5.6	-4.8
fHαm (MIS)	-6.8				-5.5			

Fig. 6 — Involute tests of 48-tooth gear from noisy gear set.

second harmonic of mesh. In addition, the peak-to-peak amplitude of each tooth mesh is in the order of .0007" to .0009", which is a very significant amount. It indicates that the mating teeth are not very conjugate.

Involute Tests

Evaluation Method. The traditional method for evaluating these traces is to fit them within a tolerance zone. The AGMA tolerance zone is a "K" chart. The width of the "K" zone is determined by the tolerance allowed in the different quality grades. On the other hand the ISO tolerance zone is rectangular. These zones are sufficiently wide to allow for involute variation that is the result of runout in addition to the variation in tool quality. This is all right for the determining a quality rating, but it is insufficient for controlling gear noise.

Conjugacy. In order for a pair of gears to be smooth and quiet (minimal tooth-to-tooth transmission error), they have to be conjugate. This means that they must have the same operating pressure angle (Ref. 4).

Mean Involute Slope (MIS) and Mean Involute Trace (MIT). The best indicator from involute traces of conjugacy is the MIS (known as fHαm in the ISO system). The AGMA "K" chart system does not address this characteristic.

The MIS is determined by fitting a line to the individual involute traces. CNC involute checking machines usually do this by a least-squares-best-fit of a straight line. When doing it manually, one can fit a line by eye between two control diameters. The slope of this line for four teeth approximately 90° apart is averaged to determine the MIS.

If the four involute traces are averaged together, a Mean Involute Trace (MIT) is established. Fig. 4 shows MIT diagrams of several examples. Each one is the average of four involute traces taken approximately 90° apart on each mating member. This is a very useful bit of information that would be easy for CNC inspection machines to do, but so far, none of them do.

The gear trace is inverted in relation to the pinion trace in order to show how they visually match each other. The first example shows a combined mismatch of .0012" (not conjugate). The second example shows a pair that is conjugate and of the correct pressure angle. The third example shows a pair that is conjugate, although of a pressure angle different than specified.

For example, a pinion and gear could both be classed as AGMA Q8. The pinion teeth could have a MIS of +.0006". The gear teeth could have a MIS of -.0006". They would not be conjugate and would therefore be noisy (Fig. 4a). Another pair, also AMGA Q8, could have an individual tooth involute variation of .0006", a MIS of ±.0001, and be nearly conjugate, as well as quiet. Both sets, however, are no better than AGMA Q8. This example is shown in Fig. 4b.

In another example, the pinion and gear could both have a MIS of +.0006" (still only a Q8) and also be quiet. These are shown in Fig. 4c.

Involute Measurements. Further diagnostic tests were done using elemental involute measurements. Four teeth on each part, approximately 90° apart, were measured. The results of the 12-tooth, p/m pinion are shown in Fig. 5. Fig. 6 shows the results of the 48-tooth plastic gears.

It should be noted again that the slope of each involute trace varies as the result of runout in the part. This slope, between the EAP and SAP, is noted for each trace (fHα). Another important number on these charts is the value for (fHαm), the MIS. (These symbols are from ISO. There are no equivalent AGMA symbols).

It can be seen that these parts were not very conjugate, even though they might be classified as AGMA Q8 gears. The 12-tooth pinion has a MIS (fHαm) of about +.0005", and the 48-tooth gear had a MIS (fHαm) of approximately -.0005".

Putting this deviation into terms of pressure angle, it was like running a 19.5° pinion with a 20.5° gear.

This conversion was made with the following equation:

$$\phi_A = \phi - (57.3^\circ)\ \frac{2\ (\text{MIS})}{d_B\ (\varepsilon_2 - \varepsilon_1)\ \tan\phi}$$

Where:

ϕ_A = actual pressure angle (degrees)

ϕ = nominal (or setup) pressure angle (degrees)

MIS = mean involute slope

d_B = nominal (or setup) base circle diameter

$\varepsilon_2, \varepsilon_1$ = upper, lower roll angles over which the MIS is measured

For the pinion:

$\phi = 20^\circ$

MIS = + .0005"

d_B = .4698"

ε_2 = 40.00° at .573" diameter

ε_1 = 5.24° at .4718" diameter

and from the equation:

ϕ_A = 19.45°

For the gear equation:

$\phi = 20^\circ$

MIS = - .0005"

d_B = 1.8794"

ε_2 = 25.72° at 2.060" diameter

ε_1 = 15.53° at 1.9472" diameter

and from the equation:

ϕ_A = 20.47°

Experimental Results. In order to prove that MIS was a good measure of conjugacy and quietness, even for low quality gears, some pinions were reworked to match the -.0005" tip MIS of the

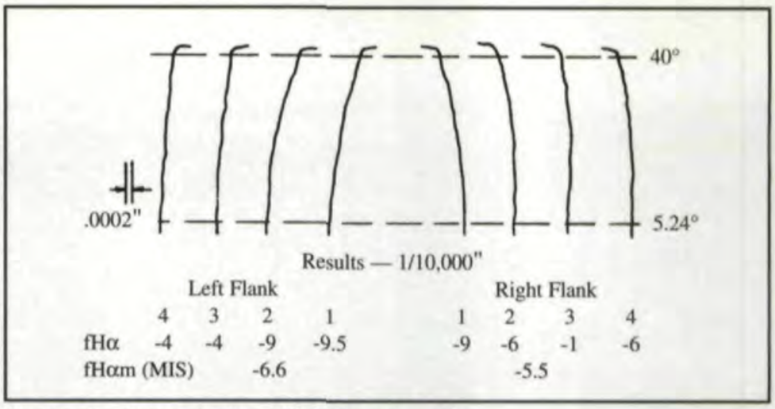


Fig. 7 — Involute tests of modified 12-tooth profile.

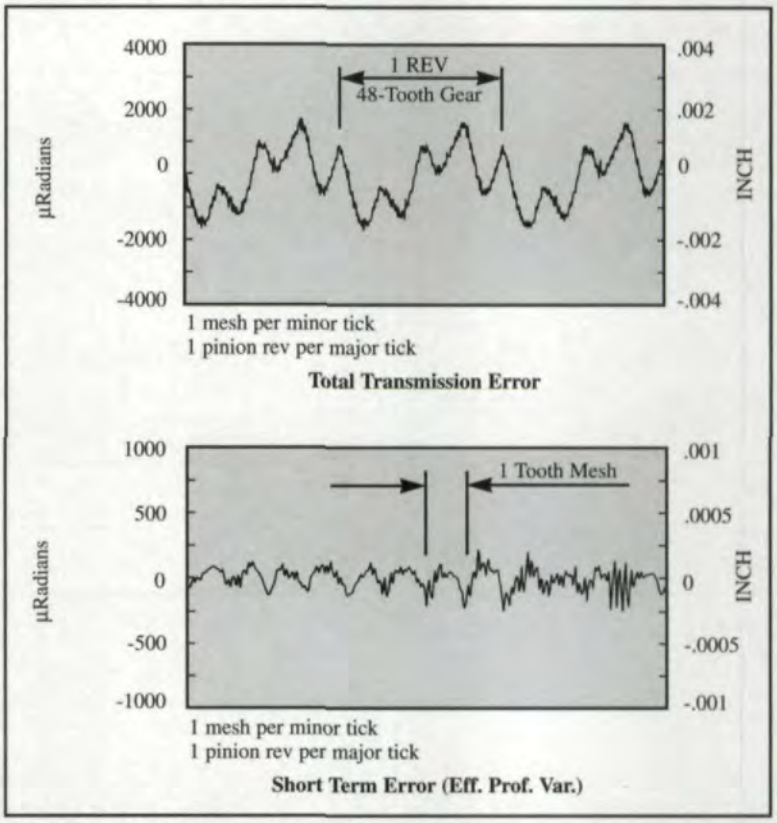


Fig. 8 — Transmission error test results—quiet set.

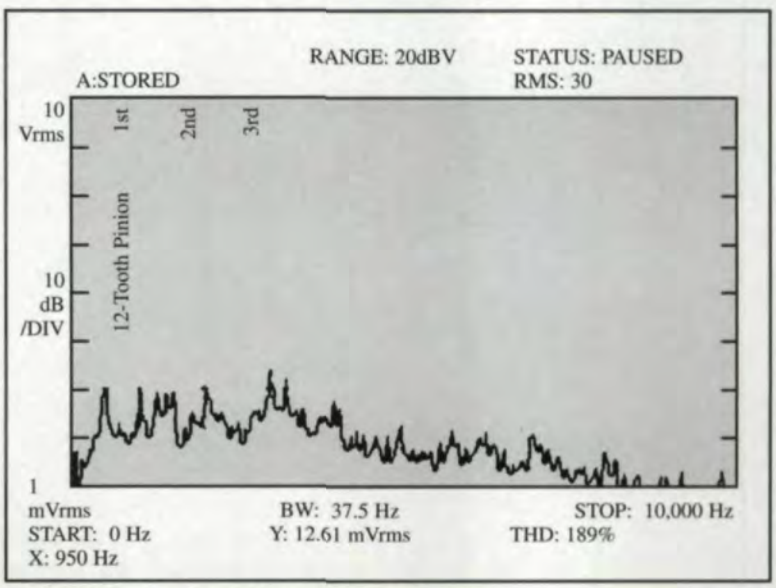


Fig. 9 — Noise spectrum of improved gear set.

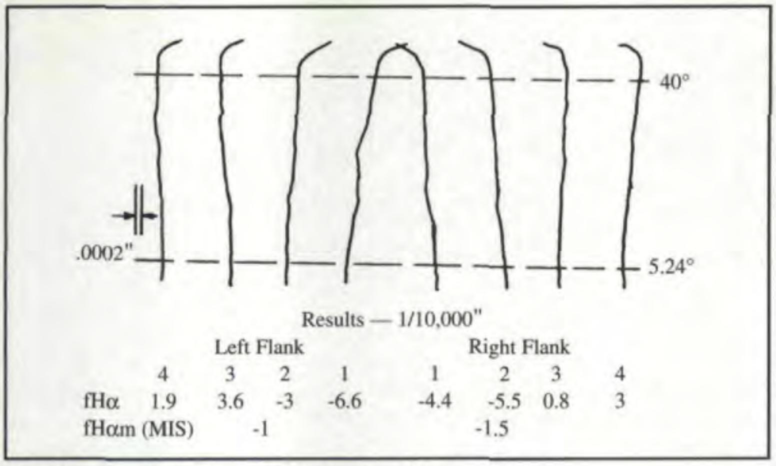


Fig. 10 — Involute tests—final production, 12-tooth pinion.

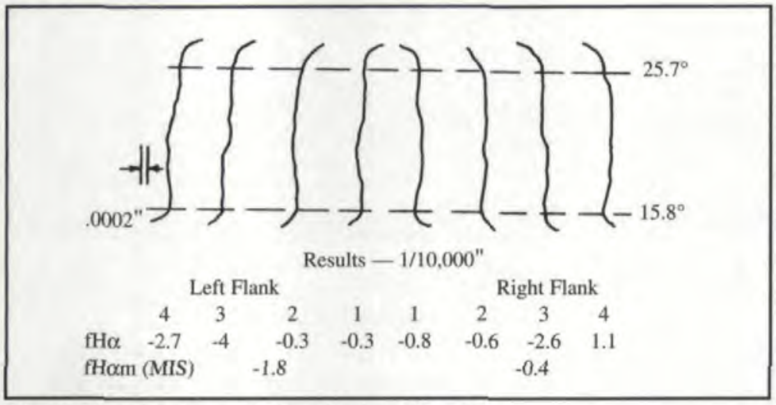


Fig. 11 — Involute tests—final production, 48-tooth gear.

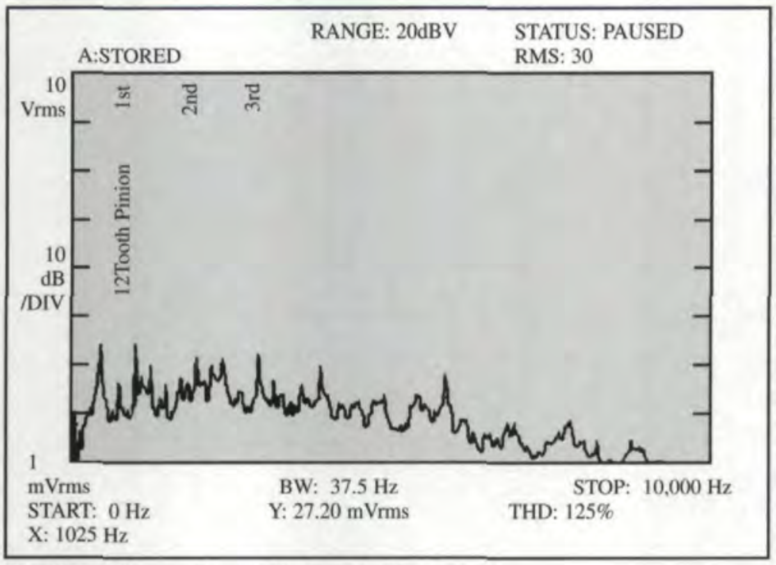


Fig. 12 — Noise spectrum of final production gear set.

48-tooth plastic gears. The pinions were made to have a -.0005" to -.0006" tip MIS also.

The involute results are shown in Fig. 7. They now have basically the same pressure angle as the 48-tooth gears.

Fig. 8 shows the improved results on the transmission error test. The spectrum chart in Fig. 9 shows the improved noise test. It is difficult to see peaks in the spectrum that relate to the gear mesh and harmonic frequencies, and the subjective whine was gone.

New Tolerance Specifications

The makers of the gears felt that they couldn't make gears to a quality level better than AGMA Q6. However, meeting a specification of MIS is more of a development problem than a quality problem. This involves making the tools right in the first place. In this case, the tool is the cavity.

The specification was changed to AGMA Q7 to keep the total composite variation down and avoid a tight mesh condition. To control noise, a requirement of a MIS (fHαm) within ± .0002" for each member of the pair was also specified. The ± .0002" limit on MIS was based on prior experience with many other applications.

Manufacturing Process in Relation to Profile

P/M Pinion. With steel powder metal parts, the profile shape will be determined primarily by the shape of the tool. There isn't much net change in the shape of the part as it is removed from the cavity and is sintered. There usually is a very slight increase in size, which is largely offset by the slight shrinkage in sintering, as the part expands when leaving the cavity. Therefore, obtaining the proper tooth shape depends on getting the cavity developed right in the first place. It isn't possible to play with other process variables such as temperature to change part geometry.

Molded Plastic Gear. Molded plastic gears are another story. The cavity size has to be determined by knowing accurately the shrink rate of the material being used. Typical gear materials might have a shrink rate that varies from .005" per inch to .030" per inch, depending on material as well as fillers, such as glass fibers. This has to be taken into account when designing the size of the cavity. Other process variables, such as temperature and pressure, will also affect the shrink rate and therefore the resulting part size and profile shape.

Redesign of Mold Cavity (Plastic Gears)

Measurement of Parts from First Cavity. Molded plastic parts made of unreinforced material generally shrink at a nearly uniform rate. In this case, the material was an acetal (Delrin 500). The original cavity was designed for a specific shrink rate. The resulting parts were measured for various diameters such as outside, root, rim and hub diameters. The teeth were also measured for involute by adjusting the base diameter until the MIS was near zero. This showed that the base diameter shrunk at nearly the same rate as all the other diameters. The mold cavity was also measured for these various diameters. From these measurements, it was determined that the original parts shrunk more than expected. This resulted in the gears having a higher pressure angle than desired.

Cavity Redesign. A new cavity was designed and made to the new actual shrink rate for the material and process being used. This resulted in parts that were closer to the desired specification.

Evaluation of Final Production Parts

Final Involute Tests. Involute results of the new parts are shown in Figs 10–11. The MIS for both mating parts are within .0002", meaning that they are nearly conjugate.

Final Noise Test. Noise tests of the final parts show little indication of gear noise in the spectrum. Gear-related peaks are no worse than peaks from other sources, such as the timing pulley and the fan. Fig. 12 shows these results.

Process Control of Molded Gear Profile

Relation of Profile Variation to Shrink Variation. A study was conducted to establish the shrink rate vs. process variables such as temperature and pressure. The purpose was to find a method of controlling the involute by adjusting a process variable. Changing temperature is not as desirable as changing the pressure, because it has a greater effect on material properties such as strength.

Gears were molded at various molding pressures from 7,500 to 13,000 psi. Gears from each pressure level were checked for MIS and outside diameter. The results were plotted and are shown in Fig. 13. This shows a reasonably linear relationship between pressure and mean involute slope. It also shows a good relation between outside diameter and MIS. Therefore, molding pressure became a good process variable for control of the desired parameter.

Control of Shrink (Involute) by Control of Outside Diameter. The discussion in the section above showed that all diameters, including the base diameter, shrink at a nearly uniform rate. Therefore a decision was made to use the outside diameter measurement as a control of mean involute slope (See Fig. 14). As long as the same mold cavity dimensions are used, this relationship will hold true. A fixture was made that could be used for quick measurements of the OD of the gear teeth. This has now been used successfully in production for over two years.

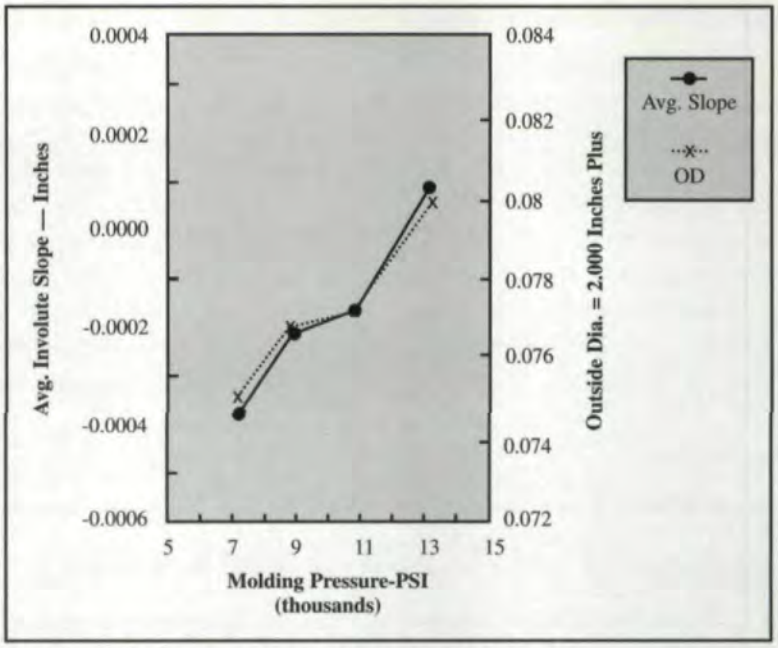


Fig. 13 — PSI vs. average involute slope and outside diameter.

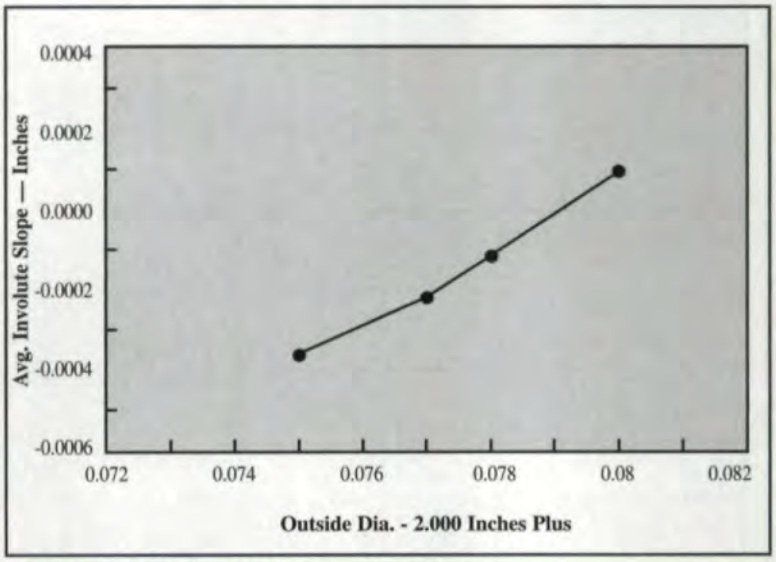


Fig. 14 — Outside diameter vs. average involute slope.

References:

1. Smith, R. E. "The Relationship of Measured Gear Noise to Measured Gear Transmission Errors," AGMA Fall Technical Meeting, 87FTM6, Cincinnati, OH, October 6–7, 1987.
2. Smith, R. E. "Identification of Gear Noise With Single Flank Composite Inspection," AGMA Fall Technical Meeting, 85 RTM12, San Francisco, CA, 1985.
3. Smith, J. D. *Gears and Their Vibration*. Marcel Dekker, 1983.
4. Maag Gear Company. *Maag Gear Book*. Maag Gear Company, Ltd., Zurich, Switzerland, 1990, pp. 318–320.

Acknowledgements:

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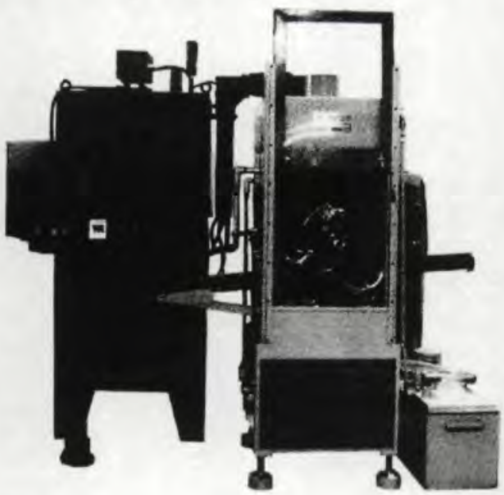

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Gear Noise As a Result of Nicks, Burrs and Scale—What Can Be Done

DuWayne Paul

There are many different causes of gear noise, all of them theoretically preventable. Unfortunately, the prevention methods can be costly, both in equipment and manpower. If the design of the gear and its application are appropriate, in theory all that is necessary is to have a tight control on the process of producing the finished gear. In reality, there are many variables that can cause a process, no matter how well-controlled, to deteriorate, and thus cause errors, some of which will cause a gear to produce unwanted noise when put to use.

One of the main causes of gear noise can be plus material on the active profile of one or more teeth. When a gear tooth has plus material on its active profile, it can cause gear noise, which gives the impression of a poor quality product. There are three main causes of plus material on gear teeth: nicks, burrs and heat treat scale.

Nicks

Controlling the manufacturing process to avoid nicks on gear teeth is always a hotly debated issue. By their nature, nicks are caused by part handling, usually in the green, and not by gear processing machines. Part handling is the part of the gear production process probably the most susceptible to variables and process deviation.

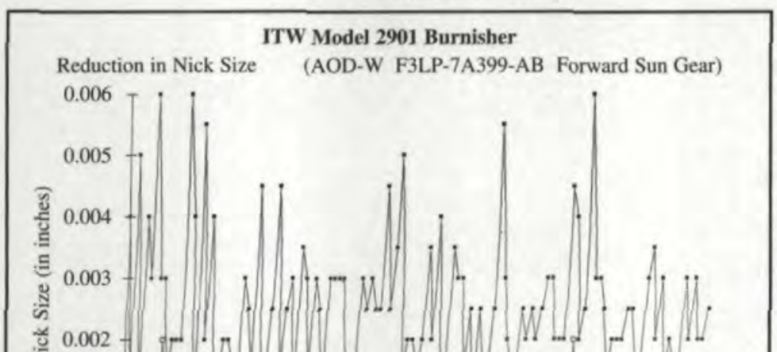

Fig. 1 — Reduction in nick size before and after burnishing.

Obviously, if the parts are subject to a great deal of manual handling, they will be vulnerable to nick creation. Most handling processes call for delicacy and attention to quality, but also fall prey to the process falling apart when production schedules are tight or the end of the shift is getting close. Any time a part in the green state is handled or moved, it is subject to nicking. This is why an automated part handling system can also create nicks.

A nick is plus material anywhere on the part. It is usually caused by gouging, which creates plus material that remains on the surface to be hardened into the part. Because of their action with other teeth, gear teeth with nicks on their active profiles cause noise. On the other hand, while a minus material gouge in the active profile is certainly not desirable, it will not create noise in most instances.

Noise from gear tooth nicks can give the impression of a poorly produced product, thus sending the wrong message to valued customers. Through experience, transmission manufacturers have found that nicks greater than .002" can cause transmission noise. If the gearbox or transmission is part of another device, such as an automobile or electric motor, it can give the customer the impression that the entire product is poorly produced.

Burrs

Burrs are raised material normally found where the involute profile meets the face. After hobbing or shaping, there are very large burrs left on the face of the gear, and the next operation is typically a face deburring and chamfering. Since this face deburring works the face of the gear, there is a natural tendency to roll a very small burr back onto the involute profile. This burr will become hardened after heat treatment, thus causing the potential for gear noise when put into use.

Heat Treat Scale

Heat treat scale is oxidized material left after the heat treating process. Left on the gear, this scale can cause noise, or if it comes loose, it can put contamination into the transmission.

Such small defects can cause large problems. Some nicks, burrs and heat treat scale will burnish themselves away when put into use. But the question still remains, "What happens to the debris from this natural burnishing effect, and will it cause other problems?" What most likely will happen is contamination of the transmission, causing future problems.

Solutions for Nicks

So what can be done? First of all, a tolerance for nicks has to be developed. Determine what level of nick causes a problem. If the product is such that gear noise is not an issue, then nothing needs to be done. On the other hand, if a .002" nick on the active profile causes noise problems, then something below that number should be the tolerance, and procedures should be implemented to reduce the occurrence of larger ones. The methods of reducing nicks can take many shapes and forms and can cost varying amounts.

Part Handling. Obviously, the first way to reduce nicks is to instill careful and delicate part handling on the green side of gear production. Use every method of employee training possible and study equipment variables to eliminate unnecessary moving of parts. This method takes constant micromanagement and intense attention to detail.

Form Finish Grinding. Beyond this, there are in-line equipment options that can be utilized. One is using a form finish grinding process that will touch all of the active profiles of the tooth and deburr the tooth ends. This can give the part an excellent finish and assure a closely toleranced gear. The downside is that it takes a highly accurate (and expensive) grinder and is too slow when doing gears in quantity, thus making it a very costly process as a final operation before inspection.

Hard Honing. Yet another method is to use hard honing to remove nicks and burrs and give the gear a much improved tooth finish. An advantage of honing is the potential ability to correct errors in the gear tooth profile, lead, spacing, etc. On the other hand, this approach again takes a fairly expensive piece of equipment and a considerable amount of tooling. As with grinding, wheel dressing is required and can sometimes add considerably to the costs. Honing will essentially produce a good gear with no nicks or burrs and a very good tooth surface, but it can be slow and very costly as a method of removing plus material before final inspection.

Shaving. Shaving is a third choice as a finishing operation in the hard condition. As with honing and grinding, an expensive piece of equipment is required, and the tooling cost can be significant. The advantages are that it can correct errors in tooth profile, lead and spacing, impart a crowned tooth form and remove very large nicks.

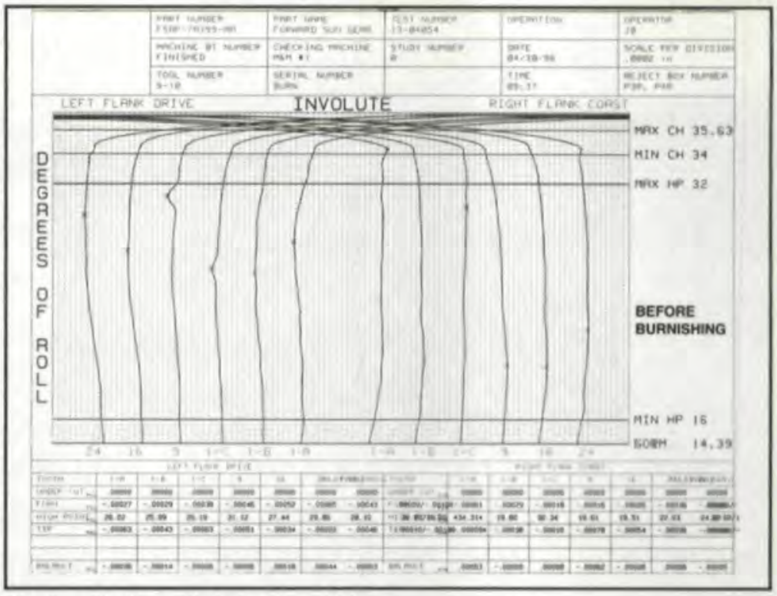

Fig. 2 — Tooth profile before burnishing.

Burnishing. A fourth method is to burnish the gears. It is very effective in dealing with all three types of plus material at a cost-efficient rate. Burnishing is typically done by capturing the gear between burnishing dies and rolling it in tight mesh with them. Most of the time this action is accompanied by oscillation of the gear in a parallel plane with the bore of the burnishing dies and flooding the work area with coolant. The oscillation allows for maximum burnishing effect, and the coolant prolongs tool life. Burnishing equipment usually costs half as much as a finish grinder or honing machine. The initial cost of burnishing dies may be higher than the tooling cost for grinding, honing or shaving. However, the life of burnishing dies is significantly longer (typically 500,000–750,000 cycles), and there is no ongoing maintenance, such as wheel dressing, making the total tooling cost significantly less.

The Gerac Burnishing System (patented by ITW) incorporates the use of three separate dies acting on the piece part, each of which works a different part of the gear tooth. Each of the three different profile dies operates on its own heavy duty spindle in a triangular configuration. The three dies have the following functions:

Burnishing Die A operates at a lower pressure angle than the operating pressure angle of the piece part.

Burnishing Die B has a shortened base pitch. This causes the burnishing die to come in contact with the tips of the gear teeth, jarring loose particles off the tip and flattening surface imperfections.

Burnishing Die C operates at a higher pressure angle than the operating pressure angle range of the piece part.

DuWayne Paul

is marketing & sales director for gear equipment at ITW Heartland, Alexandria, MN. ITW has been designing and building burnishing and inspection equipment for gear manufacturing since 1936.

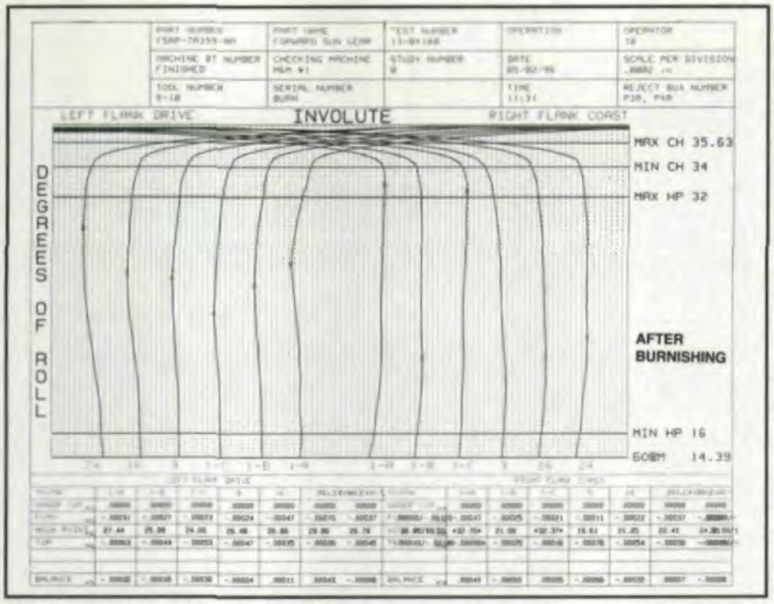

Fig. 3 — Tooth profile after burnishing.

The purpose of Dies A and C is to have a sliding action through the piece part's operating pressure angle range. The "rubbing" action wears the surface of the tooth to improve the finish and to remove nicks, burrs and scale.

The "arborless" system patented by ITW meshes the workpiece gear under pressure between the three burnishing dies, one of which is powered. In addition, a reciprocating oscillatory mechanism moves the workpiece in an oscillation movement parallel to its axis. Two of the burnishing die spindles have automatic spherical positioning to equally distribute the burnishing force across a straight, crowned or tapered tooth configuration.

Burnishing is not an abrasive method or metal removing process, and therefore does not change the tooth profile. It cannot correct errors in tooth profile, lead, spacing or damage where a large portion of the tooth has been rolled over. It is more of a "rubbing action," which takes the plus material and either knocks it off the tooth or smooths it back into the area from which it came. It is highly appropriate for high-production situations and can also be adapted to lower production runs by the use of tooling changeovers. It operates on very short cycle times (5–10 seconds) and can be very cost-efficient on a cost-per-piece basis.

Fig. 1 is a chart representing the results of a nick reduction study done with an ITW Heartland Model 2901 burnisher. In this study (done at a customer facility), 125 gears were inspected for nicks, burnished, and then inspected again to analyze the reduction in nick size.

Figs. 2 and 3 are the result of a study done to analyze the effects an ITW burnisher has on the tooth profile (involute).

Grinding, honing or burnishing all will remove plus material on gear teeth and improve the surface finish of the gear. Which of them would work best in a given situation should be determined by specifications, cycle times and budgets.

100% Inspection

In truth, the best method of absolutely ensuring that gear teeth are free of plus material is to inspect 100% of the gears produced. Many times this is not feasible or not considered necessary. On the other hand, the part of gear production that causes nicks is the hardest part of the process to control. If the lead is unwinding during heat treating, you can catch it by doing process inspection and making corrections. If the profile is not in specification, you can discover it by verifying setup and by process inspection, and then make your adjustments to the hob. But in the case of plus material induced either in the green or in heat treatment, there is no proven method of making sure every gear does not have plus material. Process inspection will not suffice because unless 100% inspection is utilized, some gears with potential nicks, burrs or scale will not be checked.

If 100% inspection is used, you do have options as to how to use equipment for nick reduction or nick elimination. One option is to put all gears through the equipment chosen before inspection. The other is to further process only those rejected for nicks, burrs or scale. Quite often, hand de-nicking and deburring with hand-held grinders is used to remove this material after inspection. This can work, but leaves much room for error. For instance, the hand de-nicking can cause other changes to the gear tooth profile or other gear geometry features. In either case, inspection is the only sure way to know that gears are going into assembly without plus material that is out of tolerance. Keep in mind that all gears which are inspected should be washed and dried before inspection.

The best quality possible is what we are all after in gear manufacturing processes and products. The most frustrating gear defects to control are nicks, burrs and scale. Your processes can produce a geometrically perfect gear, but if it has a nick or burr of .0015" which causes noise, the product quality has just been downgraded by the end user. If nicks, burrs and scale are not tolerable in the end product, methods such as those discussed in this article must be used to deal with them. ○

Acknowledgement: *The author wishes to thank Jim Pospisil, Engineering & Operations Manager for ITW Heartland, for his editorial and technical support and Pat Flinn, manufacturing engineer at Ford Powertrain, for supplying the charts used in this article.*

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Design Implications for Shaper Cutters

Nathan C. Ainsworth

A gear shaper cutter is actually a gear with relieved cutting edges and increased addendum for providing clearance in the root of the gear being cut. The maximum outside diameter of such a cutter is limited to the diameter at which the teeth become pointed. The minimum diameter occurs when the outside diameter of the cutter and the base circle are the same. These theoretical extremes, coupled with the side clearance, which is normally 2° for coarse pitch cutters and 1.5° for cutters approximately 24-pitch and finer, will determine the theoretical face width of a cutter.

At some point between the theoretical outside diameter extremes, there lies a desirable shaper cutter design. There are several factors that will limit the outside diameter, one being the necessity of ensuring that a reasonable amount of land remains on the tips of the cutter teeth. This amount ranges from a minimum of .100" on a 2-pitch cutter to .002" at 200 pitch. For example, a 6-pitch, 20° pressure angle cutter will have a minimum tip land of .060".

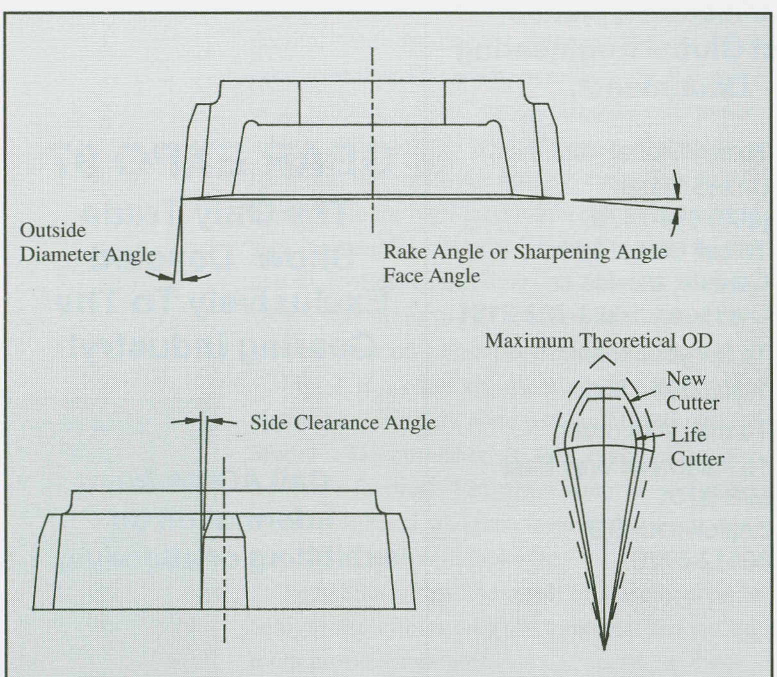

Fig. 1 — Cutter clearance angles and the sharpening angle.

All outside diameters of gear shaper cutters are ground to be tapered at the outside angle. This angle is so calculated as to produce a constant tooth thickness and depth of cut at the new and the approximate life positions of the cutter. The amount of this outside angle is dependent upon the operating pressure angle between the cutter and the work and the amount of the side clearance. These angles range from approximately 4° on a 30° pressure angle, 2° side clearance, up to 7.5°–8° on a 14.5° pressure angle and 2° side clearance (Fig. 1).

There are some cases where it is desirable to have a minor change in the involute from the Start of Active Profile (SAP) point to the outside diameter. This is quite common in finish cutting to alter bearing patterns, especially on heat treated parts, or to help improve profile in shaving operations. Most spur gear shaper cutters in the coarse pitch range are made with 2° side clearance angles and a 5° face angle. On this basis a 1° change in face angle will result in a .0013" change in profile on a 1-pitch rack. Other pitches are proportional; i.e., on a 6 DP gear, the change would be .0013/6" or .000217".

A higher face angle, say 8°, would result in a lower pressure angle or a plus involute of .00065" on a 6 DP gear. Conversely, a 2° face angle would result in a higher pressure angle or a minus involute of .00065" on the same 6 DP gear. Generally, face angles of less than 0° or above 10° are not recommended. An angle of 10° weakens the cutting tool edges and makes tools more prone to chipping. Relieving the tip approximately to the corner break at 0° face angle to improve cutter life is a common procedure on coarse pitch work (Fig. 2).

Fig. 2 shows the effect of changing the face to change the pressure angle produced. This will also change the amount of stock on the involute at the tip of the gear.

A Word of Caution: We have seen in Fig. 2 how changing the face angle can change the pressure angle. If one is not careful in sharpening the shaper cutter at the designated face angle, then an error in involute can be inadvertently imposed on the part being cut.

How to determine a new outside diameter and the new tooth thickness after a grind back or a design reduction is shown below.

$$\text{New } OD = OD - 2 * GB * \text{Tan}(ODA) \quad (1)$$

$$\text{New arc } T = PD * \left[\frac{\text{arc } T}{PD} - \frac{GB * \text{Tan}(SCA)}{BR} \right] \quad (2)$$

OD = Outside Diameter
GB = Grind Back
ODA = Outside Diameter Angle
arc$T$ = Arc Tooth Thickness at Pitch Diameter
PD = Pitch Diameter
SCA = Side Clearance Angle
BR = Base Radius

In Equation 2, the fraction of $\frac{GB * \text{Tan}(SCA)}{BR}$ is a small arc on the base diameter, as is $\frac{T}{PD}$.

Equation 2 is simply the arc length formula of $L = a * r$, where L is the arc length, a is the angle under the arc and r is the radius.

Fig. 3 shows the angles involved in finding the new tooth thickness after a grind back. Remember the formula for arc length: $L = a * r$

where:
L = Arc Length
a = Central Angle in Radians Described by the Arc
r = Radius to the Arc

Cutter manufacturers may define the side clearance angle either at the pitch diameter or the base diameter. If the SCA is defined at the pitch diameter, it may be converted to an angle on the base diameter.

Treating the SCA as a helix angle, we can use the proportion below to express the SCA at the base diameter.

$$\frac{\text{Tan}(SCA \text{ at } BD)}{BD} = \frac{\text{Tan}(SCA \text{ at } PD)}{PD} \quad (3)$$

$$\text{Tan}(SCA \text{ at } BD) = \frac{BD * \text{Tan}(SCA \text{ at } PD)}{PD} \quad (4)$$

The proportion in Equation 3 was derived from the formula for lead and the fact that the lead is constant and only the diameter and helix will change.

In cases where a cutter is designed to produce a specific part, the outside diameter of the cutter is determined so that the generated fillet or trochoid does not come above the start of active profile (SAP) or form diameter, based on the cutter having normal cornering (Fig. 4). The minimum diameter is designed to avoid excessive tip modification in the case of large gears or to avoid excessive undercut when cutting low pressure angle gears with small numbers of teeth (Fig. 5).

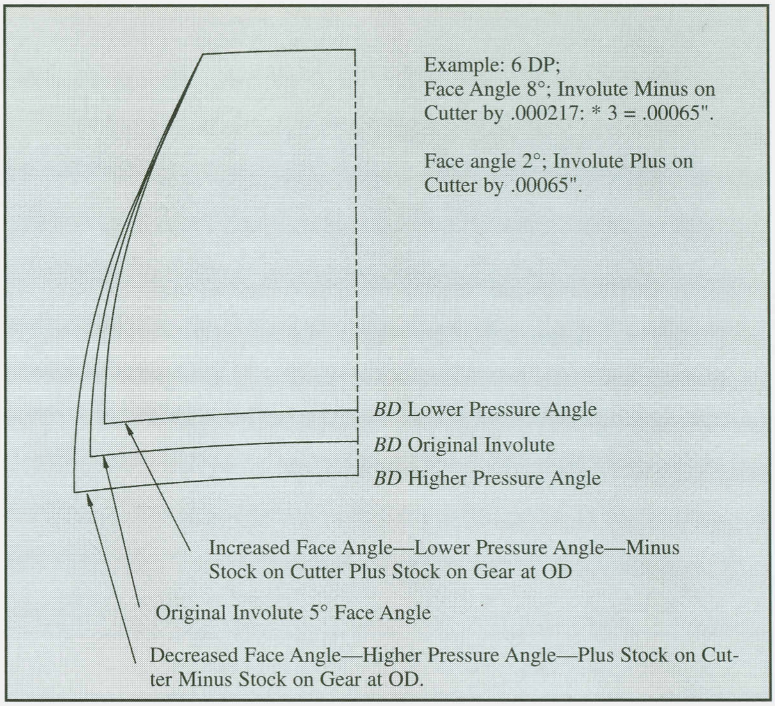

Fig. 2 — The effect of changing the face angle to change the pressure angle.

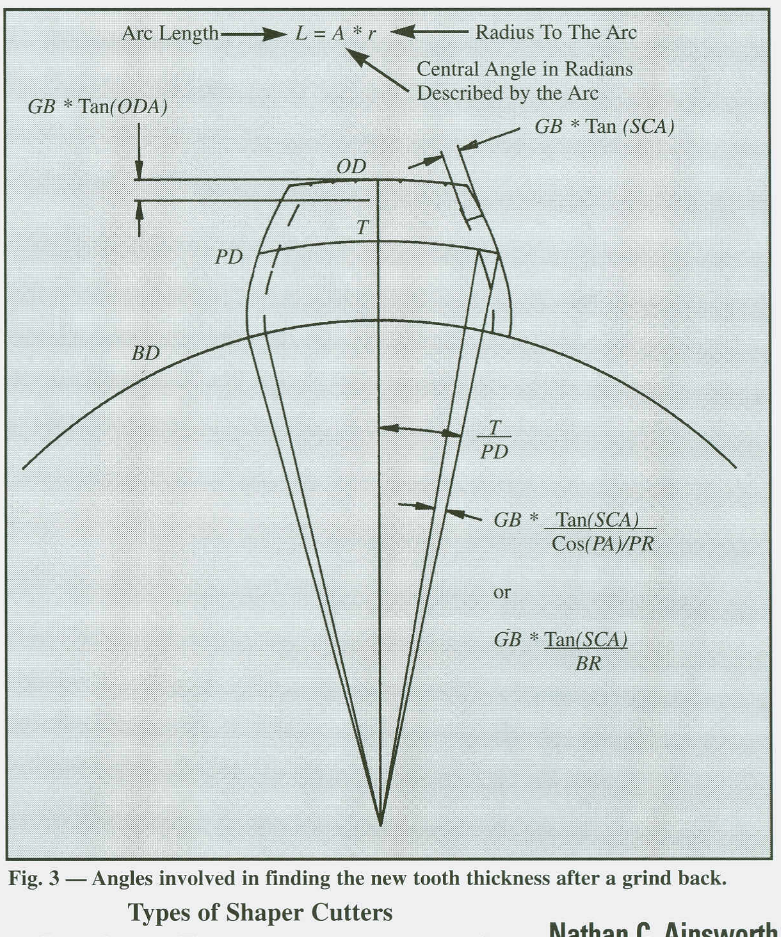

Fig. 3 — Angles involved in finding the new tooth thickness after a grind back.

Types of Shaper Cutters

Disc Cutter. These are the common pancake-type blanks with a minimum extended hub. Sizes normally run from 1" pitch diameter with a 1/2" hole up to 8" or 9" with 4" holes for use on larger capacity gear shapers. Most gear shaper cutters for modern gear shapers are equipped with unaligned driving keys to prevent cutters from

Nathan C. Ainsworth
is a senior cutter design engineer with Fellows Corporation, Springfield, VT. He has been at Fellows for 16 years and has presented materials on shaper cutters at technical conferences around the country.

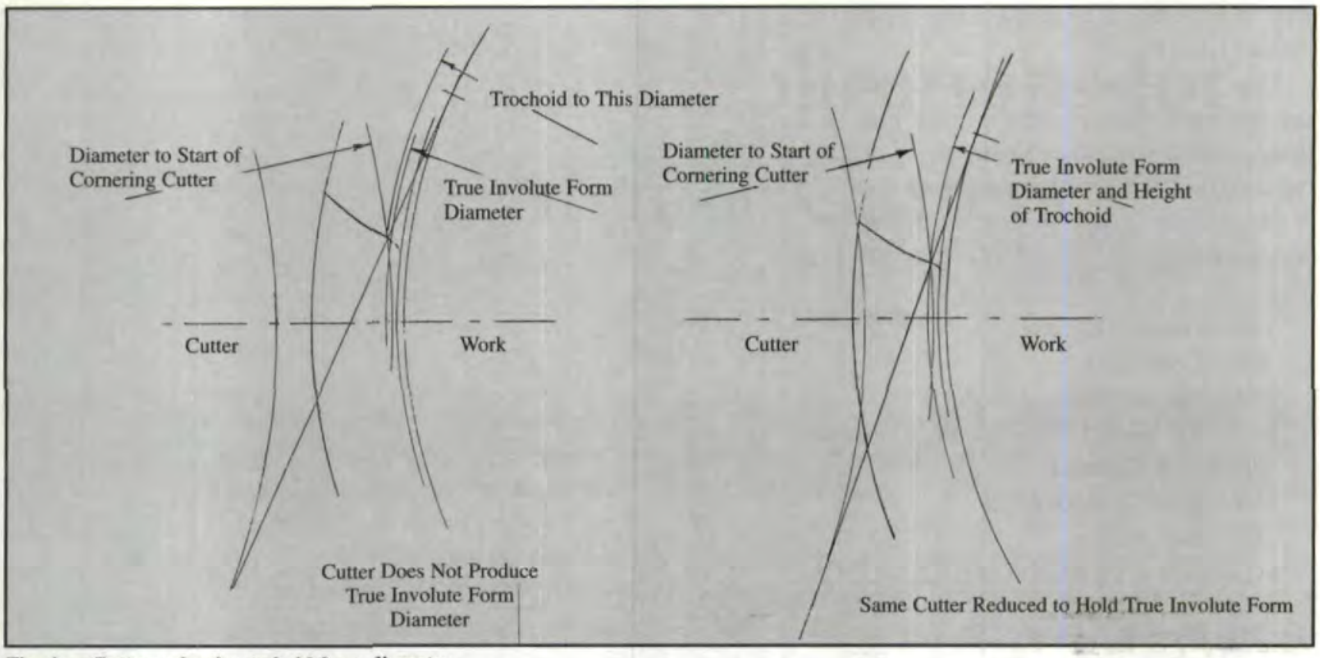

Fig. 4 — Cutter reduction to hold form diameter.

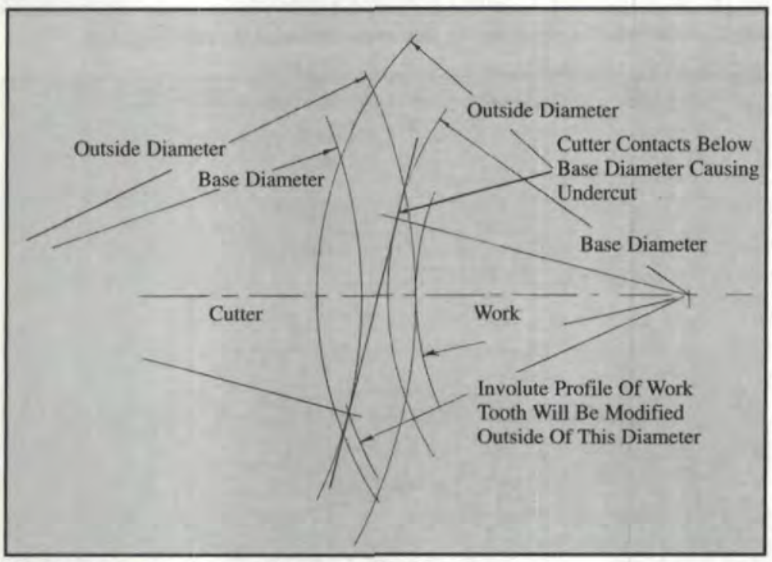

Fig. 5 — Example of tip modification and undercut.

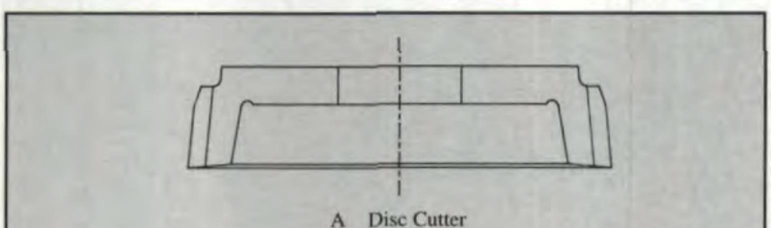

Fig. 6 — Typical blank designs.

slipping on the locating pilot under the higher feeds being used. Hole sizes are generally limited to 1/2", 3/4", 1", 1 1/4", 1 3/4" and 4". (See Fig. 6a).

Deep Counterbore Cutters. These are disc cutters with the addition of hubs to provide a deeper counterbore to permit recessing of the cutter holding nut or screw throughout the life of the cutter. Normally they are used for cutting internal gears or shoulder gears. To minimize the overall blank thickness of deep counterbore cutters, it is desirable to have available short-nosed adapters and screw-type clamping screws (Fig. 6b).

Taper Shank Cutters. These are normally used for cutting internal gears. They can be manufactured with as few as 4 teeth and a pitch diameter as small as .1875". The length of the shank must be sufficient to cut the face width of the part, plus over-travel, plus any recess over the top of the teeth, life of the cutter or any other thickness of the fixture hold-down plate that may be required. They are normally made in four taper sizes (Fig. 7a & b).

Solid Disposables. These cutters are generally used in high production applications where tool sharpening and machine adjustment are eliminated. These cutters are of optimum design; that is, the best possible design within the given gear parameters. A cutter adapter of the appropriate diameter will add more rigidity to the cutter. This type of shaper cutter can be used for both helical and spur applications (Fig. 6c).

Shaping Internal Gears

In cutting internal teeth, conditions relating to tooth profiles and tooth modifications occur which are similar to those already described for external gears. Obviously, there is no natural undercut produced on internal work. Tip modifications are more prevalent on internal work due to the wrap-around effect between the cutter and the work (Fig. 7).

Taper shank cutters are usually furnished when the required pitch diameter is approximately 2" or less. As previously mentioned, the length below the taper must be long enough to cut the face width of the part, but the resulting length below taper versus the barrel diameter of the cutter may produce a cutter that does not have sufficient bending strength. These cutters will deflect, causing tapered work, excessive rub and, in extreme cases, breakage. By adding flutes along the barrel (Fig. 8), the beam strength has been improved about 50%. There are some cases when, due to the small diameter and/or wide face width of the part to be cut, there is no choice but to make a cutter that exceeds accepted deflection limits.

Most modern gear shapers are equipped to make multiple cuts at a high rotary feed, greatly reducing the cutter force between cutter and work. The last cut is generally taken at a normal rotary feed, which gives the same finish and accuracy as conventional cutting. This method is quite common and will allow the cutting of splines that require long and slender cutters.

Cutter rub is almost always present to some degree when cutting internal gears. All gear shaping machines relieve either the cutter or the work on the return stroke to avoid scuffing the cutting edges during the return stroke and before starting the next cutting stroke. The amount of relief depends upon the make and type of machine. When cutting some internal parts, a wrapping effect of the internal part around the cutter results, causing the cutter to interfere or rub with the internal teeth when it is pulled back to give cutting edge relief. Fig. 9 illustrates one type of cutter rub called rough side rub or trailing side rub.

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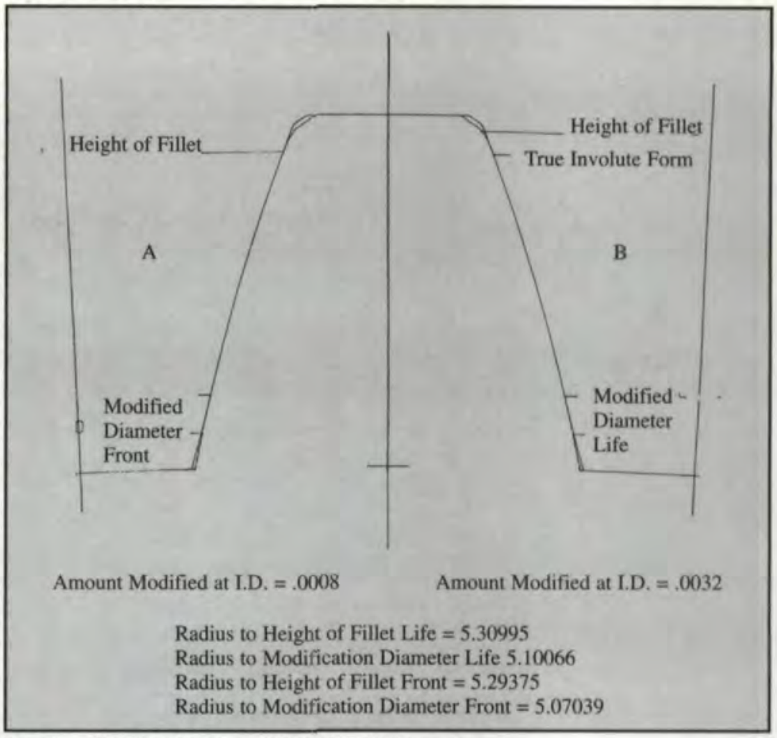


Fig. 7 — Tip Modification: 6/8 DP 20° PA internal gear.

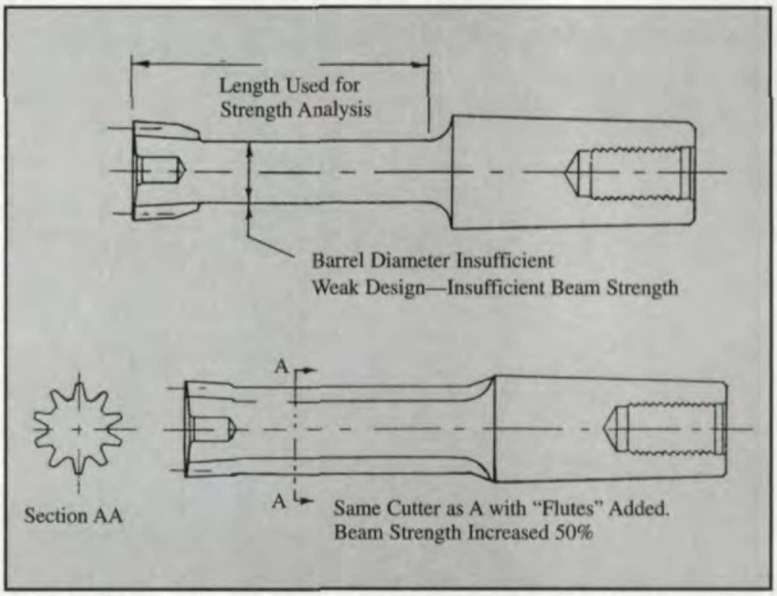


Fig. 8 — Effect of adding flutes to the barrel of a taper shank cutter.

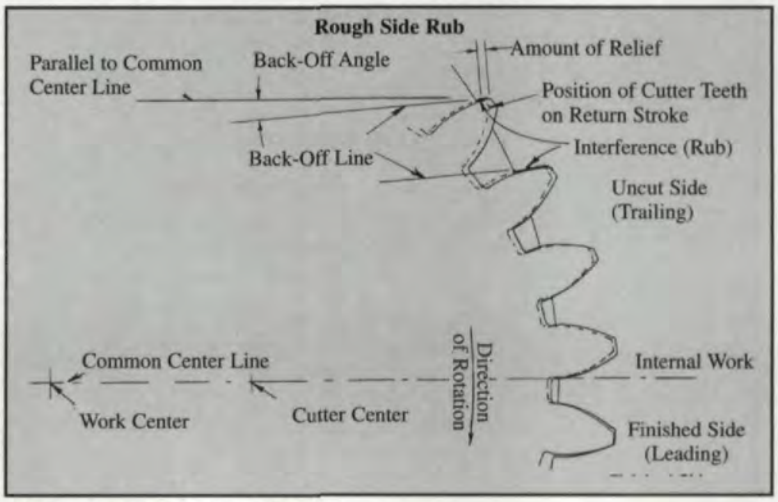
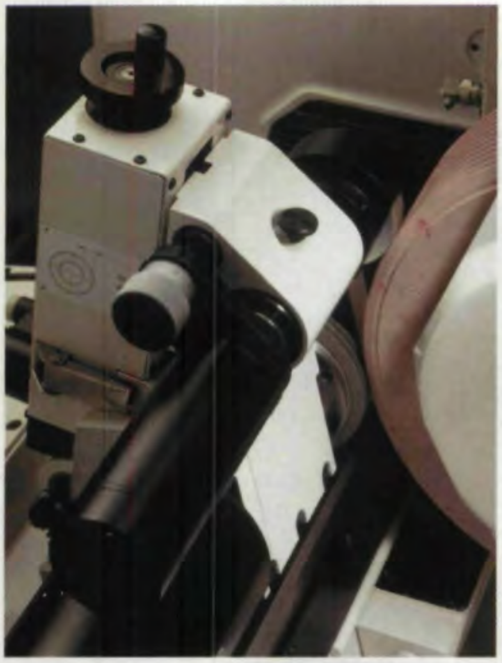


Fig. 9 — Rough or trailing side rub.



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Plastic Gear Design Basics

LNP Engineering Plastics, Inc.

Plastic gears are serious alternatives to traditional metal gears in a wide variety of applications. The use of plastic gears has expanded from low-power, precision motion transmission into more demanding power transmission applications. As designers push the limits of acceptable plastic gear applications, more is learned about the behavior of plastics in gearing and how to take advantage of their unique characteristics.

Plastic gears provide a number of advantages over metal gears. They have less weight, lower inertia and are quieter than metal. Plastic gears often require no lubrication or can be compounded with internal lubricants such as PTFE or silicone. Plastic gears usually have a lower unit cost than metal gears and can be designed with part consolidation in mind to incorporate other features needed in an assembly. These gears are also resistant to many corrosive environments.

The use of thermoplastic materials for gears is hampered by a lack of established load carrying and wear performance data, at least when compared to that available for metal gears; nonetheless, there are certain guidelines available for estimating the technical feasibility of their use. However, these guidelines have evolved from equations originally worked out for metals and do not take into account some of the unique behavior found in thermoplastic materials.

This article will attempt to reveal some of the important points that must be considered when using these equations and techniques to evaluate thermoplastic gears. The focus will be on spur gears; however, the basic points covered can be extended to other types as well.

Plastic Gear Tooth Design

Hobs used to cut teeth in metal gears are available off the shelf, and for cost reasons, designers of commercially cut gears seldom use any other tooth forms. Injection-molded gears are not affected by the constraints of these standard hobs, since special tooling must be used when cutting the mold to compensate for shrinkage. If a hob with a standard pressure angle is used to cut a mold, a serious tooth profile error will result due to the mold shrinkage of the material. The gear designer is therefore free to use a variety of techniques to maximize the performance of his gear. While a variety of plastic gear tooth profiles are available, they all use basic plastic design techniques to optimize the design of the gear tooth.

Full Fillet Tooth Radius Modification. Sharp corners in plastic molded parts are undesirable since they act as stress risers. Using a full fillet radius between two teeth in a gear eliminates these sharp corners and can reduce stress by up to 20% or more. Full fillet radii should be used in all plastic gears.

Tip Relief Modification. When a tooth deflects under load, it can get in the way of the next oncoming tooth. This happens in heavily loaded metal gears and to a varying extent in most plastic gears. This type of interference can cause noise, excessive wear and a loss of smooth uniform motion. To compensate, the tip of the tooth is gradually thinned from half way up the addendum. This modification is most useful in gears that are highly loaded (for their material) and is not always required in plastic gears.

Elimination of Undercut. The teeth of gears having a small number of teeth will often be undercut at the root of the gear. This will weaken the gear tremendously and should be avoided in plastic gears.

Balanced Circular Tooth Thickness. If two gears in mesh are designed as standard, then the gear with the smaller number of teeth (the pinion) will have teeth that are thinner at the root than the teeth of the gear. The pinion will not be able to transmit as much power as the gear could carry and will be the weak link in the design. In order to optimize the load carrying capability of the gear set, the circular tooth thickness of the pinion should be increased and the circular tooth thickness of the gear should be decreased.

Two tooth forms for plastic gears that incorporate these modifications are the PGT tooth forms (Fig. 1) and the ISO R53 Modified (Fig. 2). These tooth forms are essentially the same, differing only in nomenclature. The ISO form uses the metric module, m, while the PGT

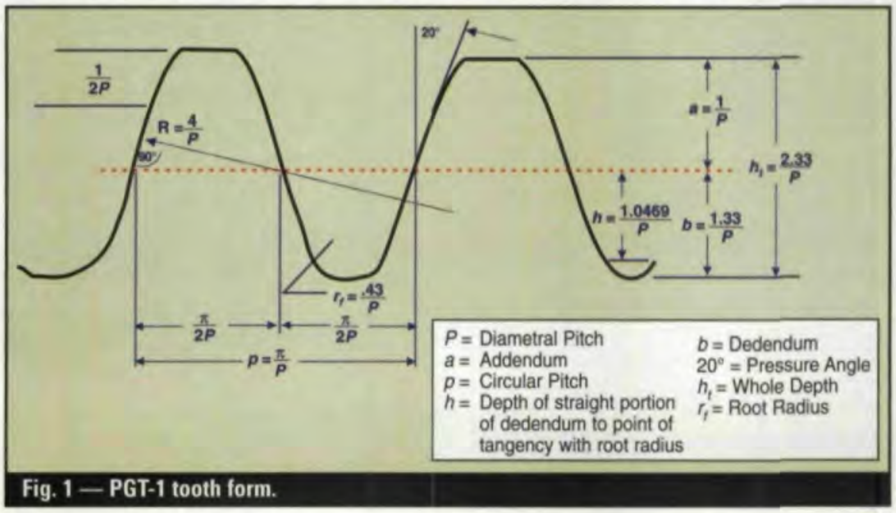

Fig. 1 — PGT-1 tooth form.

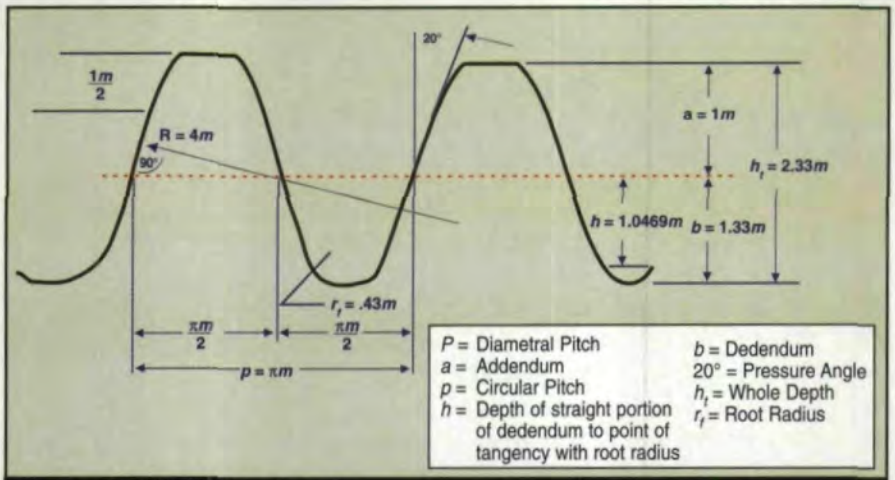

Fig. 2 — Modified ISO basic rack.

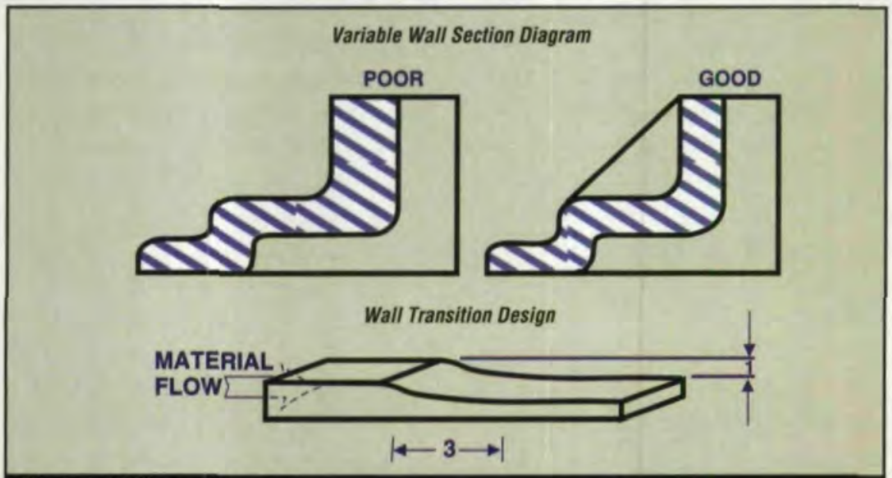

Fig. 3 — Wall transition design.

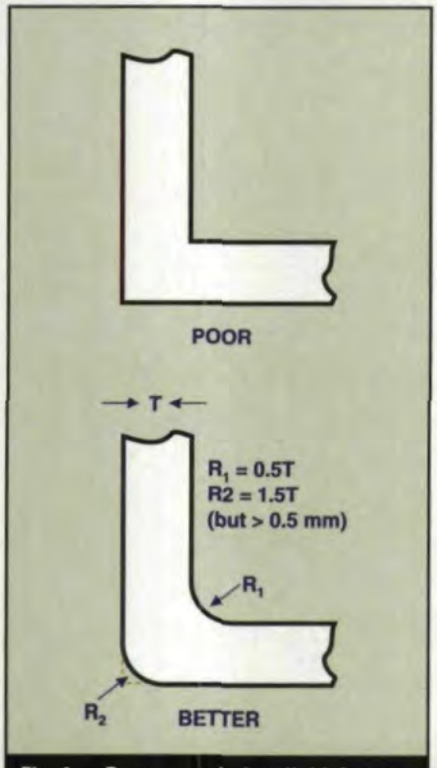

Fig. 4 — Recommended wall thickness design.

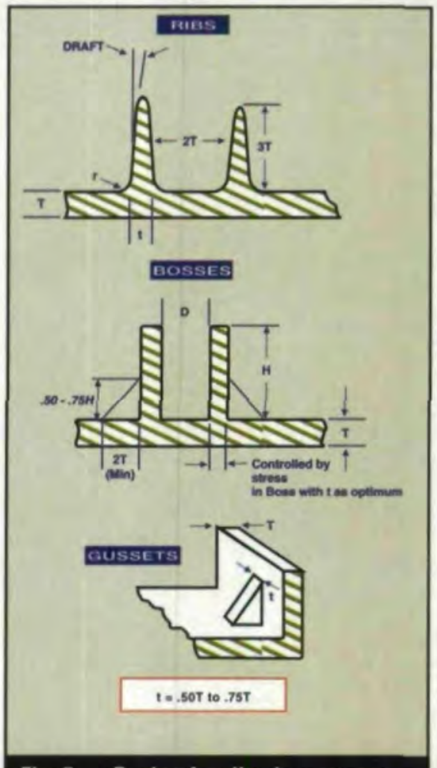

Fig. 5 — Design for ribs, bosses, gussets and projections.

tooth forms use diametral pitch, *P*. While these forms are useful, they are by no means the only forms available. Other designs may be used to optimize a gear set for its particular application.

When using these types of modifications, some adjustment must be made to the equations for tooth bending stress and allowable stress. If tooth thickness has been modified, the Lewis form factors for standard tooth thickness should be multiplied by the ratio of the thickness of the modified tooth to the thickness of the standard tooth.

Overall Part Design

The modifications above apply to the design of the gear tooth itself, but are adaptations of basic plastic part design guidelines. When designing any plastic part, these rules must be taken into consideration. Since plastic gear teeth will be attached to some plastic part, these rules must also apply to the overall design.

One of the most important features in a good plastic design is the nominal wall. The nominal wall is the feature which gives the part its shape. The thickness of the nominal wall will influence the strength, cost, weight and precision of the part. Typical injection molding techniques work best when the nominal wall of the part is in the range of 0.030"–0.200" thick. Although there is no such thing as an average wall thickness for an injection- molded plastic part, 0.125" is a very common dimension. It is also very important that changes in the nominal wall should be held to less than 25% for low-shrink materials and 15% for high-shrink materials. If a more radical change in wall thickness is needed, it should be made in several steps (Fig. 3). *The biggest problem associated with* large changes in wall thickness is that the thicker sections will not cool as quickly as the thin sections and will therefore shrink more. This can result in part warpage and out-of-tolerance parts. One way to keep a uniform wall thickness is to core the part equally from both sides.

When two walls meet in a plastic part and form a corner, there is a potential for stress concentrations and a reduction in flow. By radiusing the inside corner, stresses are spread out over a larger area.

By radiusing an outside corner, you improve the material flow path and maintain a nominal wall thickness. The general recommendation is for inside corners to be radiused a minimum of 25% and a maximum of 75% of the nominal wall. Larger radii reduce stress concentrations, but the design trade-off is the resulting thick section of material. When an inside corner has a corresponding outside corner, the outside radius should be sized to maintain a uniform wall. If the inside radius is 50% of the nominal wall thickness, then the outside radius should be 150% (Fig. 4).

All but the simplest plastic parts have projections of some type off the nominal wall. These projections can come in the form of reinforcing ribs, gussets and bosses. The most common projection is the reinforcing rib. Reinforcing ribs are generally added to a part to increase its stiffness or to control the flow of the melt across the cavity. In general, the height of the rib should be no more than $2^1/_2$–3 times the thickness of the nominal wall. Although a taller rib will increase the stiffness of the part, it will be difficult to mold properly. Tall ribs are difficult to fill, vent and eject. For this reason it is usually preferable to add two shorter ribs in the place of one tall one.

The thickness of a rib should be approximately half that of the nominal wall for high-shrink materials and 75% of the wall in low-shrink materials. This will help control the shrinkage at the junction of the rib and wall. The junction should be radiused a minimum of 25% of the nominal wall thickness. Larger radii will increase the thickness of the junction and create sink marks in the surface opposite the reinforcing rib. When using multiple ribbing, the ribs should be no closer to each other than two times the thickness of the nominal wall. Ribs placed closer together will be very difficult to cool and may result in a large amount of molded-in stress (Fig. 5).

Gear Layout

When designing a gear to be molded out of thermoplastic material, it is important to remember the basic plastic design guidelines outlined above. The simplest gear is the flat gear with no rim or hub gated in the center. This gear will not have any differential shrinkage, since it has a single nominal wall with no changes in thickness. These gears should not be more than 0.250" thick, and web and hub designs may become more practical if the gear is over 0.180" thick.

When designing a plastic gear that has a hub and a rim, careful consideration must be given to the thickness of the various parts. Tooth thickness and height have already been determined by the requirements of tooth strength. The difficulty lies in deciding which part of the gear is the nominal wall, and what is the relationship between that feature and the other parts. Each part of the gear should be designed to perform the desired function without forgetting the basic plastic design guidelines. As with any design guidelines, compromise will undoubtedly have to be made.

If the gear teeth are treated as a projection off a wall (the rim), the thickness

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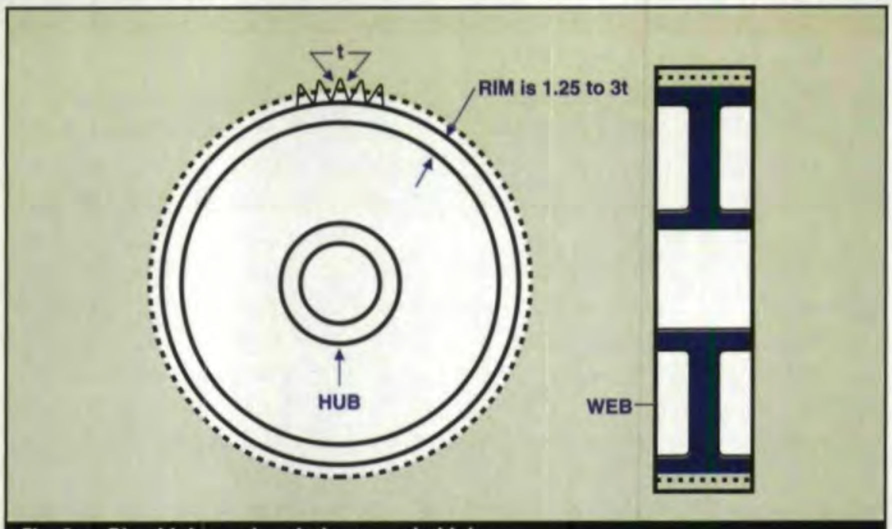

Fig. 6 — Rim thickness in relation to web thickness.

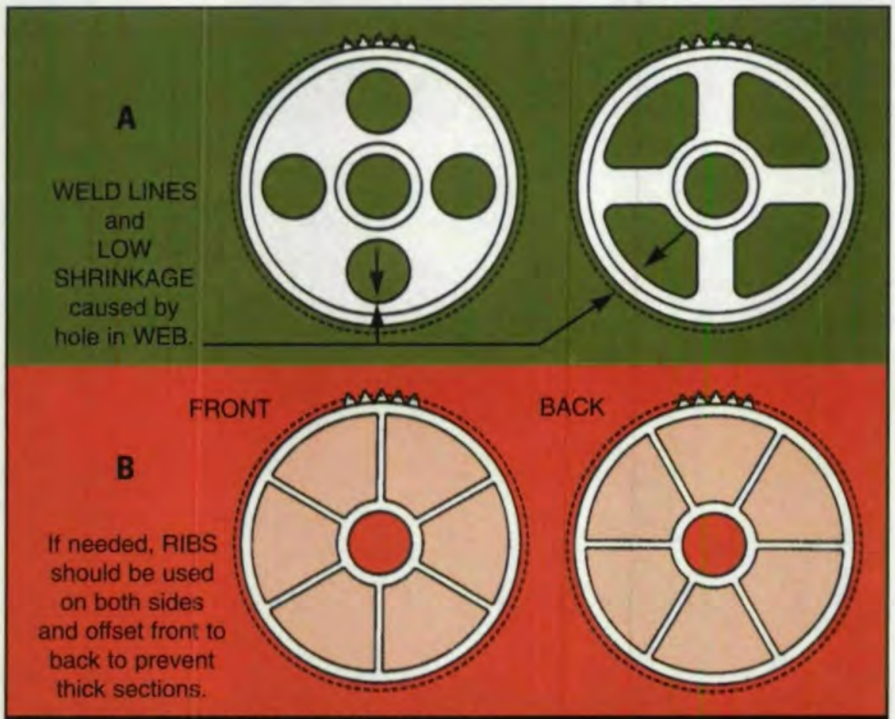

Fig. 7 — Recommended hole and rib placement.

Table 1 — Common Allowances for Moisture	
Material	**M(in/in)**
Acetal	0.0005
Nylon 6/6	0.0025
Nylon 6/6 + 30% glass fiber	0.0015
Polycarbonate	0.0005

Formula For Increasing Center Distance

$$\Delta_c = \frac{T_{ct_1} + T_{ct_2}}{2} + C\left[(T-70)\left(\frac{\alpha_1 N_1 + \alpha_2 N_2}{N_1 + N_2} - \alpha_H\right) + \left(\frac{M_1 N_1 + M_2 N_2}{N_1 + N_2} - M_H\right)\right] + \frac{TIR_1 + TIR_2}{2}$$

of the rim should be $1^1/_4$–3 times the thickness of the gear tooth (Fig. 6). The web and hub should be at least as thick as the rim. Since most gears are gated on the web, the web could be made thicker than the hub and rim for better filling. Once again, the web should not be more than $1^1/_4$–3 times thicker than rim and hub. If the hub must be thick, the gear should be gated on the hub or diaphragm-gated in the center. In all cases, center diaphragm gates will provide the most even fill and are recommended. Remember to radius all inside corners 50–75% of the wall thickness.

Holes in the web should be avoided, as they only serve to weaken the gear by adding knit lines and inducing variable areas of high and low shrinkage in the rim, which leads to difficulty controlling tolerances (Fig. 7a). Ribs can also affect tolerances for the same reason and should be avoided unless absolutely necessary. If ribs must be added, they should be added to both sides of the gear, and they should not be directly opposite each other (Fig. 7b).

Assemblies

The four modifications to standard gear and basic thermoplastic part design guidelines outlined above will provide stronger injection molded plastic gears. However, the gears must remain in mesh at the proper points. When two gears are brought into close mesh, the distance between their centers is half the sum of their standard pitch diameters and is referred to as the standard center distance. Spur and helical gears will operate at a wide range of center distances, and it is rare that the best operating center distance is the standard center distance. Also, the gear designer must compensate for any environmental conditions that might affect the center distance. If the center distance between the gears is too small, thermal and environmental effects may cause the center distance to close in and bind the gears.

Factors which can affect the operating center distance of the gears include thermal expansion of the gears, shafts and housing, dimensional changes due to moisture absorption, runout in the bearings used to locate the gears and the overall accuracy of the gears themselves.

In order to prevent the gears from binding because of these changes, it may be necessary to increase the center distance. This increase can be calculated with the equation displayed on page 38, where:

Δ_c = required increase in center distance

T_{ct} = maximum total composite tolerance in gear

C = close mesh center distance

T = maximum operating temperature gears will see in °F

α = coefficient of linear thermal expansion of the material (in/in/°F)

M = expansion due to moisture absorption of hub material (in/in)

TIR = maximum allowable runout of bearing

The subscripts 1, 2, and H refer to gear 1, gear 2 and the housing. The coefficient of linear thermal expansion can usually be found on material data sheets provided by the material supplier. Expansion due to moisture absorption is not readily available and is not the same as the rate of water absorption normally reported on data sheets. If the gears in question will not immediately be exposed to high humidity, the expansion of most plastics is minimal and may be offset by the slight shrinkage of the plastic that occurs as molded-in stresses relax gradually over time.

For hygroscopic materials, such as nylon, the expansion may be more important. Some common allowances are shown in Table 1. For materials not shown on this table, you can use the polycarbonate numbers for low moisture materials and the Nylon 6/6 numbers for hygroscopic materials.

Part Consolidation

One of the most useful features of thermoplastic injection molded gears is the ability to consolidate a number of parts into one multi-functional design. The simplest form of this is molding the gear shaft and gear as a single unit. It is also very common to mold two or more spur or helical gears as a one-piece unit called a compound gear. When molding compound gears, it is important to remember the rules concerning nominal wall thickness and radii. Simply stacking one gear on another will lead to thick sections, unequal cooling and low tolerance. Fig. 8 shows the difference between a good design and one that is too thick.

Gear Testing

Plastic and metal gears fail in the same ways if the gear materials design limits are exceeded. All new applications should be prototype tested near or at operational conditions. The only way to really know how a gear will perform is to test a prototype molded gear.

Accelerated tests at speeds higher than required of a given application are often of no value. Increasing temperature above the normal working temperature may cause rapid failure, whereas under normal operating conditions, the gear may work well. Test conditions should always come as close to actual conditions as possible.

Gear Failure Mechanisms.

Adhesive or "normal" wear. This type of wear results from the intermittent welding and tearing of small areas of the opposing wear surfaces. If the welding is at a microscopic level, then the result will be a normal uniform wear rate. External lubrication of the gears works to keep the surfaces separated and inhibit wear. PTFE compounded into the thermoplastic acts as a lubricant by forming

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a thin film on both the gear and its mate. This PTFE transfer film has low friction and wear rates. In plastic-on-plastic gear pairs, at least one of the gears should contain PTFE. Using an external lubricant with PTFE lubricated gears may not give as good a result, since the grease may act as a release agent and prevent the formation of the transfer film. However, since there is a period of break-in, PTFE-lubricated gears will have a higher wear rate while the transfer layer forms. A light external lubrication may slow the wear of the gear on start-up if it does not inhibit the formation of the layer.

In unlubricated plastic gears, failure at the pitch line usually occurs due to nonuniform or excessive wear. This kind of wear increases frictional heat (softens material) and increases the pitch line load on a tooth with a reduced cross-section. This usually bends the tooth over at the pitch line, resulting in tooth smearing or complete breakage. This may look like a fatigue failure, but it is really a wear failure. If a gear is well lubricated, then frictional forces are reduced, which will lower the heat build-up and wear.

In general, dissimilar materials wear better than similar ones. However, this is not always the case, and some sort of wear testing should be performed followed by prototype testing of the gear pair in question if the wear test results look acceptable. If a plastic gear is to be run against a metal gear, the metal gear face should have a finish of 12–15 μin. for good wear resistance.

Abrasive. Abrasive wear takes place whenever a hard particle is present between the contact surfaces. This material may be wear debris from one of the gears or dirt from the environment. This type of wear may also be present if one of the gears (usually metal) has a rougher surface than the other. The particles first penetrate the material and then "plow" off pieces of material from the surface. Design for abrasive wear should be avoided.

Pitting. Pitting is defined as a surface fatigue failure that occurs when the endurance limit of the material is exceeded. Gears under load are subject to surface and subsurface stresses. If the loads are high enough and the stress cycles repeated often enough, areas will fatigue and fall from the surface. The area of the pitch line receives the highest stress and is most prone to pitting. Pitting is fatigue related and is generally independent of lubrication. Pitting is rare in plastic, but can occur, especially if the system is well-lubricated (low wear).

Plastic Flow. Plastic flow is caused by high contact stresses and the rolling and sliding action of the mesh. It is a surface deformation resulting from the yielding of the surface and subsurface material. Since plastics are insulators and have low melting temperature (compared to metals) they tend to melt and flow in situations where metal gears would score. In plastic gears, the initial plastic flow is in the radial direction. It may not be detrimental, as it may relieve itself. However, in more severe cases, the flow will be in the axial direction, and tooth breakage will soon follow. Plastic flow indicates that the operating conditions are too severe and that failure is not far away. Lubrication (internal and external) can help prevent this condition by lowering the amount of heat generated by friction.

Fracture. Fracture is failure by tooth breakage of a whole tooth or at least a good part of it. This can be the result of overloading (stall, impact) or from cycle stressing (fatigue) of the tooth beyond the endurance limit of the material. These types of fractures generally occur at the root fillet and propagate along the base of the tooth. Fractures in unlubricated systems ar"e usually due to overload. Fractures high on the tooth are usually wear related.

Thermal Cyclic Fatigue. Unlubricated and lubricated gears may fail due to thermal cyclic fatigue. Tooth bending stresses always result i some hysteresis heating and since plastics are such good thermal insulators, this results in a material operating temperature rise. This temperature rise can lower the strength of the material and cause pitch line deformation failure (tooth fold over).

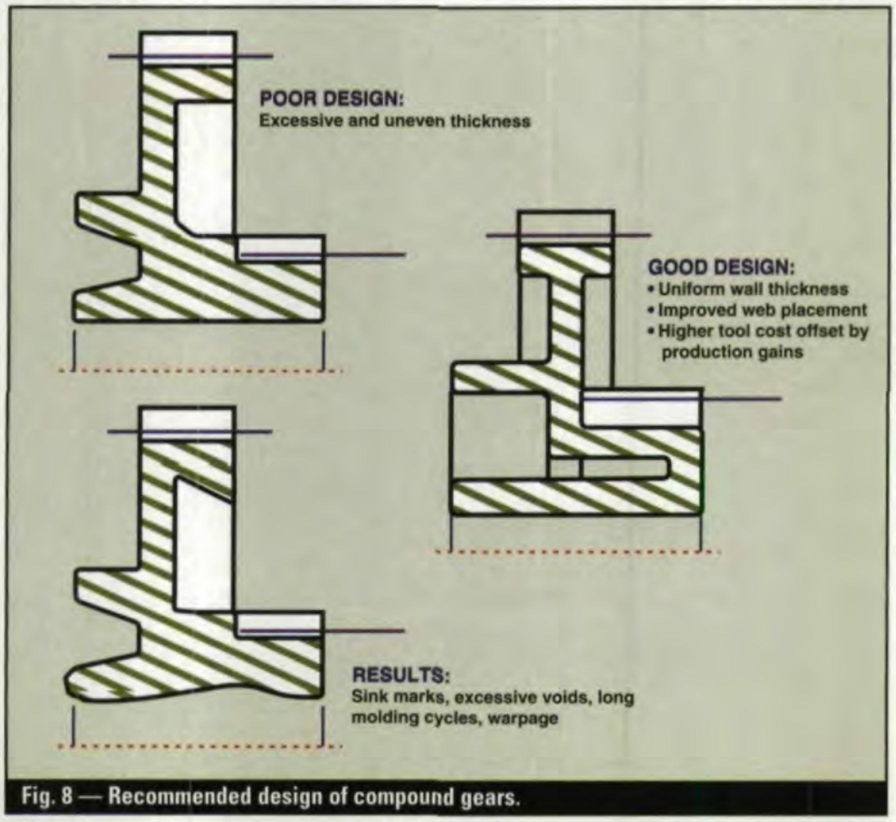

Fig. 8 — Recommended design of compound gears.

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If you provide a product or service to the gear industry, your company should be listed in *Gear Technology*'s annual Buyers Guide. This guide is designed to be the definitive directory of products and services for the gear industry. It will be mailed out to **12,000 of your potential customers** with the November/December 1996 issue.

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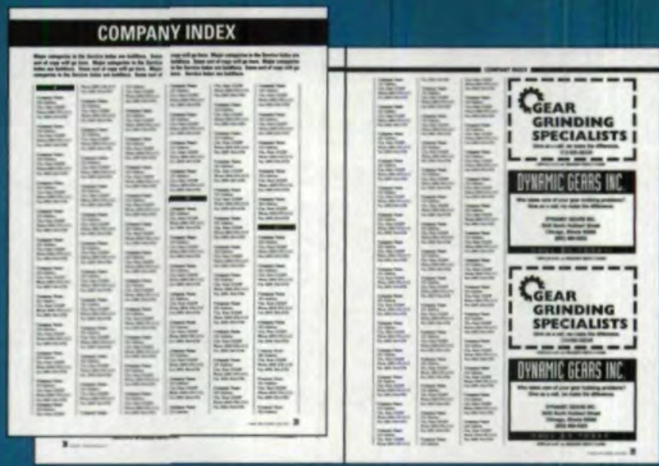

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(continued from page 7.)

Finally, a word to our readers who have not yet (and may never) "go digital." Even though we've joined the masses out there exploring cyberspace, don't worry that you'll be left behind. We're still committed to making the print version of *Gear Technology* your most useful magazine resource. We'll continue to bring you the most complete information about the gear industry available the old fashioned way—on paper.

Gear Technology has come a long way from the days when an entire issue could be produced from one desk. Publishing, like most other things, has become a lot more complicated, but it's also a lot more exciting. Our Web site is only the next step in what's beginning to look like a continual journey. Come on along with us. Take the plunge. So far, the water's fine.

Michael Goldstein
Publisher & Editor-in-Chief

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Gears Around the World (Wide Web)

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

More Gears in Cyberspace

Dial in to the web site of Chicago's Museum of Science and Industry for an online version of the museum's *Gears from the Century of Progress* exhibit.

At *www.msichicago.org/exhibit/gear* you can see pictures of geared devices with brief descriptions of their functions—such as changing rotary motion to straight-line motion. They even have animated movies of the gears in action.

The gears were originally part of the Borg Warner exhibit at the Century of Progress Exposition held in Chicago in 1933. **BONUS:** Those of you going to IMTS can visit the real-world exhibit in Chicago, where you can turn cranks to see the mechanisms in action.

Momma, Don't Let Your Babies Grow Up to Be Gear Engineers

How do you teach gear ratios to a four-year-old? Let him play with his Legos®. Believe it or not, Lego makes worm gears, racks, spur gears, crown gears, bevel gears and two kinds of differential housings.

The spur gears come in easy-to-work-with configurations of 8, 16, 24

and 40 teeth. And very important to junior transmission designers, Lego parts are manufactured to a tolerance of +/- .005 mm.

Addendum discovered Lego gears through Richard Wright, an instructor at the PCS Centers for Enriched Learning in Boise, Idaho. PCS emphasizes hands-on discovery and real-world application of knowledge for the 450 students aged 4–18 enrolled in its four schools in Idaho, Washington and California.

Legos are one of the fundamental teaching tools (building blocks, if you will) used at PCS. "The reason we use Legos is that they're very intuitive, and they're very non-threatening," Wright says. "I can literally take a four-year-old and have him build a gear train."

Wright has an internet site devoted exclusively to Lego gears *(www.pcsedu.com/pcs/centers/boise/lego/gears.htm).* The site has descriptions of gear types, pictures of Lego gears and even a gear ratio quiz.

Really Big Gears . . . We Have A Winner

Last issue we asked you to help us find the world's biggest gears. And the biggest of the big gear stories comes from...(drum roll, please)...**Russell G. Shomperlen**, technical supervisor for draglines at Bucyrus-Erie, the company that manufactured a **75-foot gear** in 1966.

The 168,000-lb. gear is part of the Bucyrus-Erie Dragline 4250W, the largest machine of its kind ever built. The dragline is installed at Central Ohio Coal's Muskingum Mine in Cumberland, OH.

The gear is part of the third and final reduction, also known as the "swing rack," in the dragline. It has 336 teeth, a diametral pitch of 0.375 and an outside diameter of 75 feet. It meshes with 10 pinions that together deliver a torque of 1.4 billion inch-pounds. The gear was manufactured and shipped in 24 segments, each weighing about 7,000 lbs.

Can anyone top that?

See Addendum online at *www.geartechnology.com*

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

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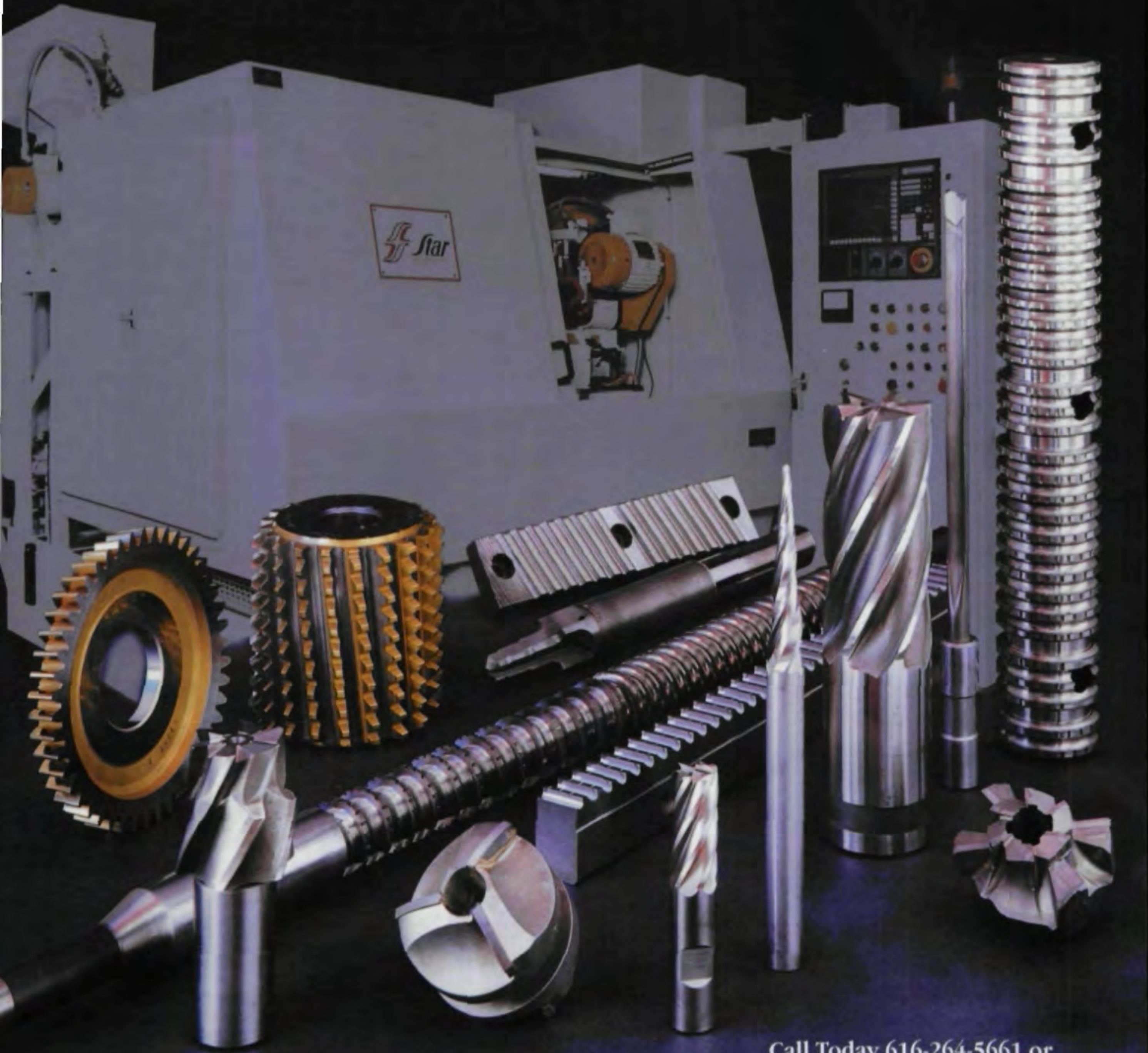

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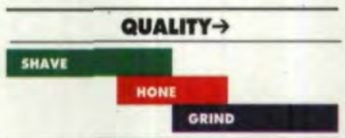

In some cases, a Hob/Heat Treat/ Hone sequence can eliminate a previously-required shaving operation while improving quality. Depending on stock removal and quality requirements, honing can potentially replace grinding, with significant cost savings per gear.

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