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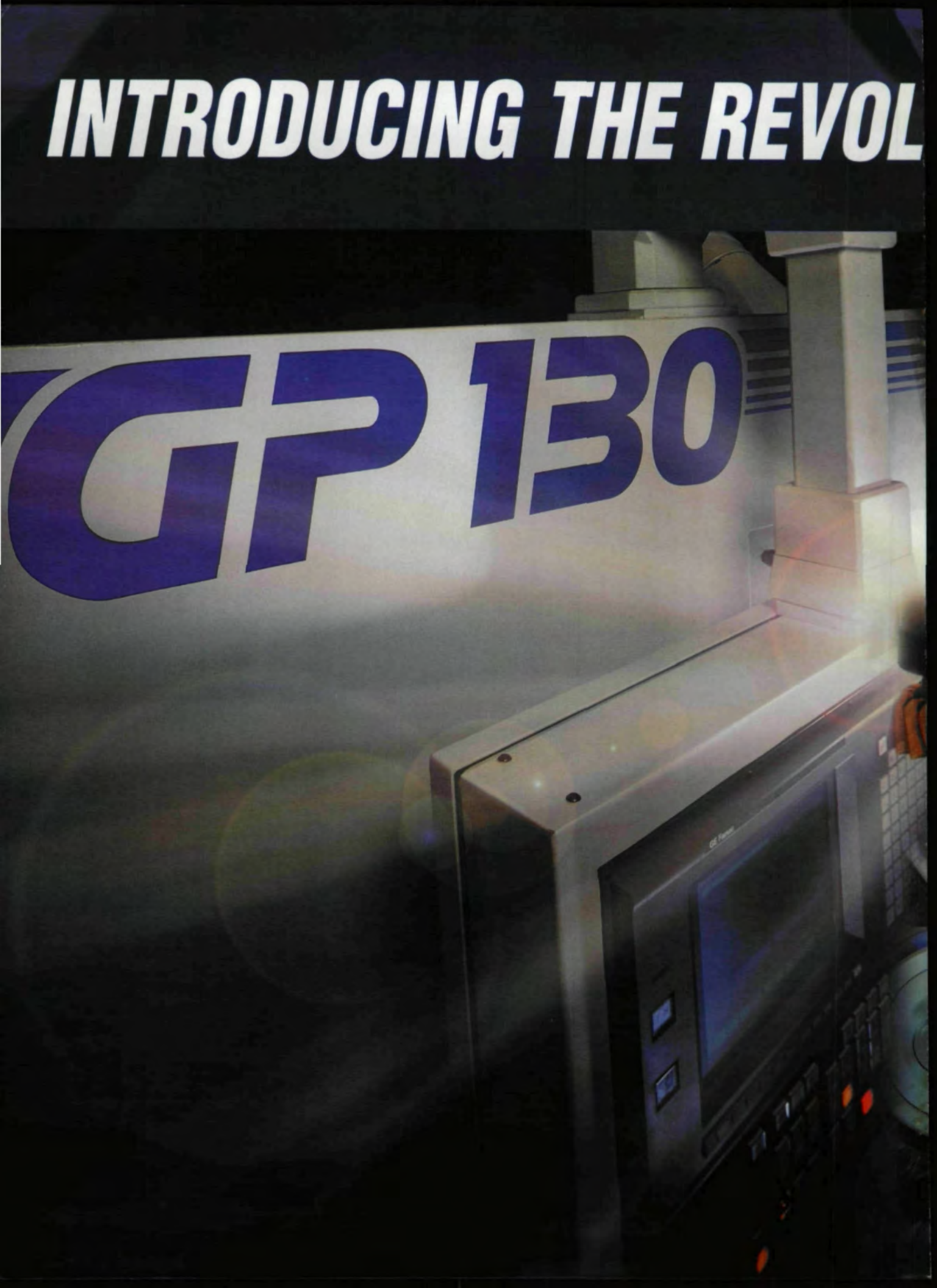

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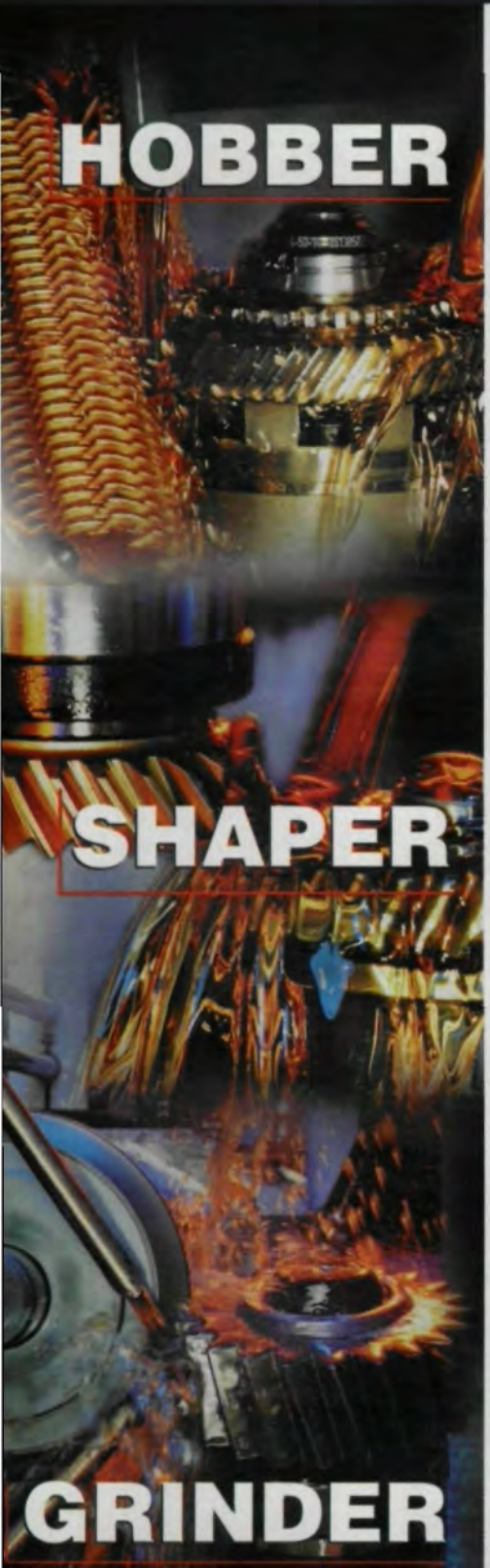

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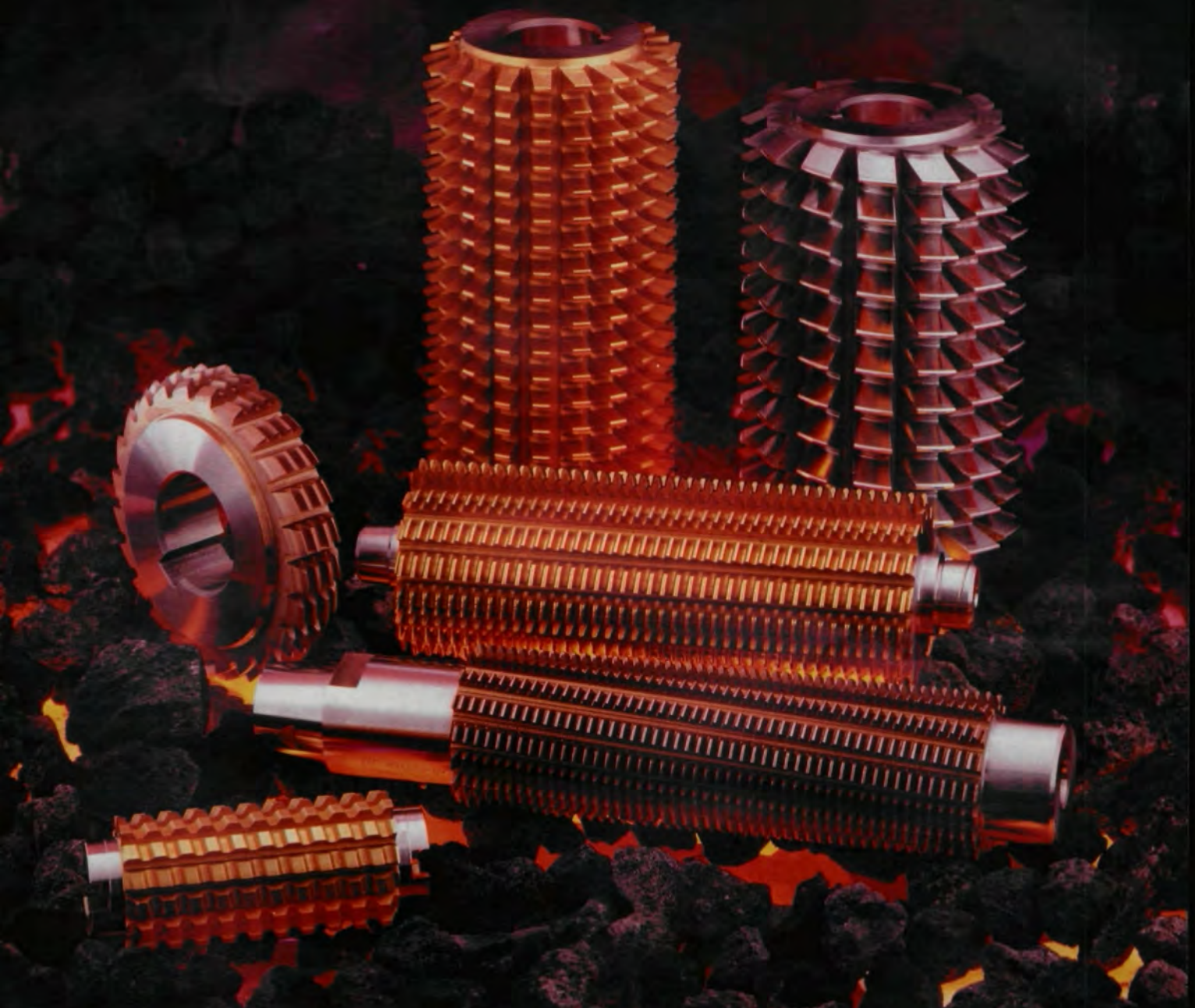

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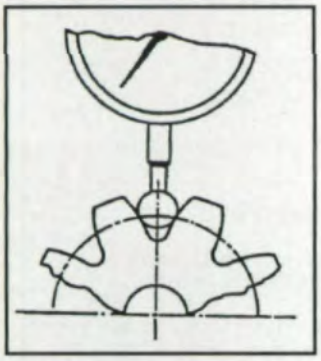

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DEPARTMENTS

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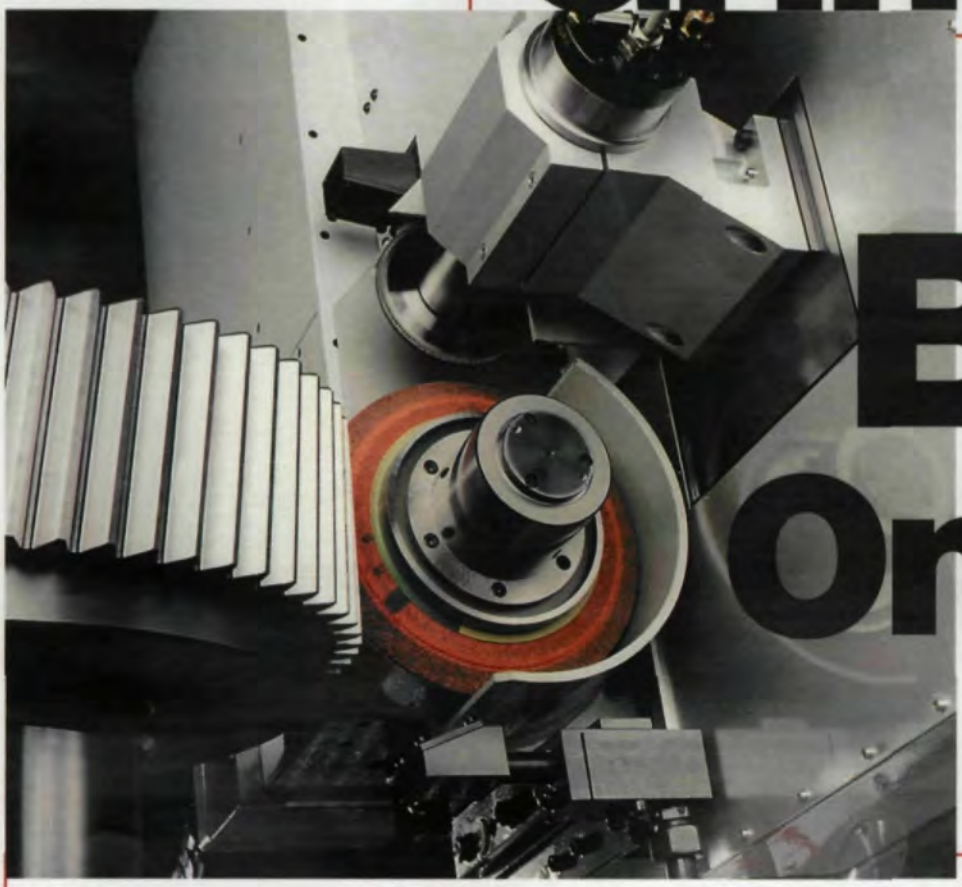

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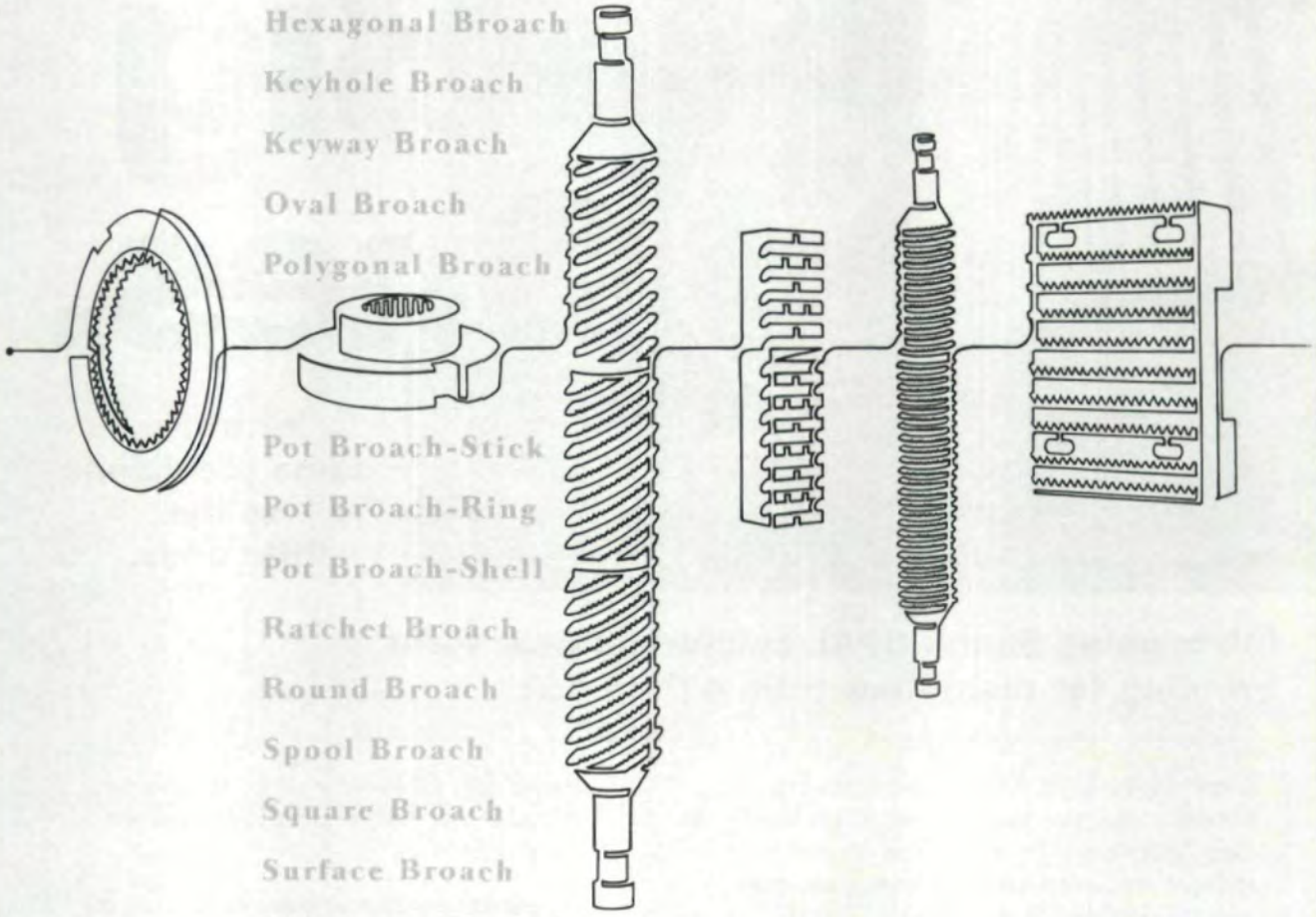

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Clouds in the CRYSTAL BALL

The carnival that is IMTS has come and gone. The aisles have been swept, and all the banners have been taken down. The fanfare of what some call the greatest machine tool show on earth has faded away.

We went to IMTS with the hopes of gaining insight into the health of both the economy and the gear manufacturing industry in America. Prior to the show, economy watchers around the world were getting skittish because of currency gyrations, political controversy and stock market fluctuations. Two months later, there is still much uncertainty. While America seems to be stable, we don't know how long it's going to last. We visited IMTS as much to have our fortune told as we did for the technological marvels of the show itself.

In many ways, IMTS lived up to its hype. It was the biggest IMTS ever. Attendance of 121,764 broke the previous high set in 1996. There were more exhibitors than ever before, filling the newly expanded McCormick Place's 1.4 million square feet to capacity. In addition, we saw the gear industry's latest technology, including 15 new gear machine models on display.

One of the most innovative machines was the new Liebherr-EMAG LCV 40 gear hobbing machine, which is built in a way that appears upside-down to someone who has spent his life around hobbing machines. The workpiece is driven from above, allowing for unobstructed chip removal below. The machine also uses a double work-spindle arrangement for automatic loading and unloading from a conveyor (one spindle is in cutting position while the other exchanges the cut gear for a new blank).

Gleason-Pfauter presented their first joint production line of machines. The GP series expands on the idea of modular machine building that has been used by other machinery manufacturers over the past several years and seems to be the direction of the future. The machines feature a common, modular base that can be equipped for hobbing, shaping or grinding, allowing the gear machine manufacturer a much faster delivery time, easier product planning and lessened inventory costs, which might translate to lower or fixed prices in the future.

CARNIVAL FORTUNE TELLERS EARN THEIR LIVINGS BY MAKING PREDICTIONS THAT ARE BOUND TO COME TRUE. THE GOOD ONES MAKE THEIR PREDICTIONS SO GENERAL THAT ANY NUMBER OF EVENTUALITIES COULD PROVE THEM RIGHT. I REGRET TO SAY THAT AFTER VISITING THE SHOW, I'M NO MORE ABLE TO GIVE YOU A CLEAR VISION OF THE FUTURE THAN A SIDESHOW TAROT READER.

Below: The UG-coated cutting tools from National Broach were one of the many new technologies at IMTS.

We also were pleased to see several technological advancements in cutting tools. Both Pfauter-Maag Cutting Tools and Mitsubishi demonstrated dry cutting with high speed steel hobs rather than the brittle, expensive carbide hobs normally used. Both companies have worked to develop new steel alloys and proprietary coatings to enable dry cutting.

National Broach has come up with a way to save money on tool coating by developing a process that allows the tools to be resharpened without recoating. The new line of UG coated hobs and shaper cutters are coated with multiple layers of titanium nitride and titanium carbide as well as their new proprietary UG coating.

I'm sure you'll see and hear more about these products from our advertisers, for those of you who were unable to attend IMTS.

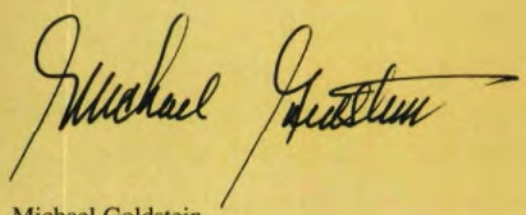
Despite all the positives that came out of the show, there was still a persistent feeling of uncertainty among the exhibitors. Many were less than enthusiastic about the quality and quantity of the traffic they saw at the show. In fact, the final attendance numbers suprised some who thought numbers might have been down by as much as 20-25%. All the exhibitors went home with a handful of sales leads, but nearly everyone's attitude was "let's wait and see if any of these pan out."

Immediate sales at a show like IMTS are hard to come by. But one success story we heard came from Star Cutter Co., who sold a CNC sharpening machine right off the show floor and who is currently negotiating the sale of a CNC automatic broach sharpener as a direct result of a contact made at the show.

Carnival fortune tellers earn their livings by making predictions that are bound to come true. The good ones make their predictions so general that any number of eventualities could prove them right. I regret to say that after visiting the show, I'm no more able to give you a clear vision of the future than a sideshow tarot reader.

We saw and heard much at IMTS to give us an optimistic outlook on our industry's chances for the next couple of years. But at the same time, the caution evident before the show doesn't seem to have gone away.

Caution isn't necessarily bad. When things are going well, we have more to look out for. The stakes are higher. In economic times like these, it's hard to ignore the headlines. But we know from our sources that sales of gear cutting tools are still very strong. We also know that at least one gear machine tool manufacturer has already sold nearly to capacity for 1999, and another company is raising its build forecast for '99 by 20%. This tells me that a lot of teeth are still being cut in America and that, for at least the near future, the American gear industry seems solid.



Michael Goldstein,
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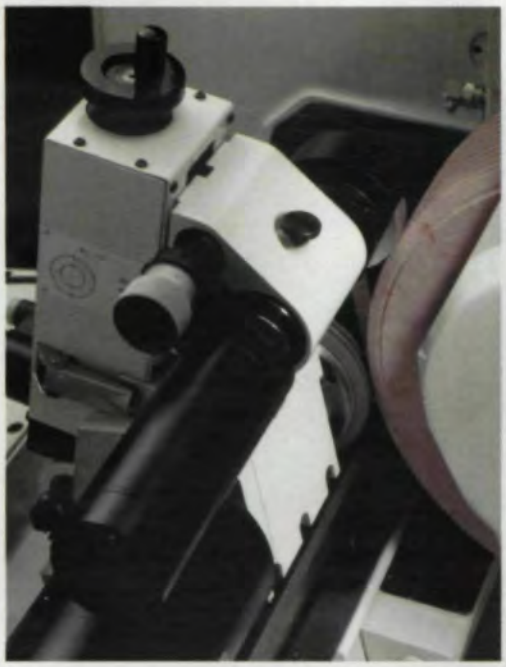

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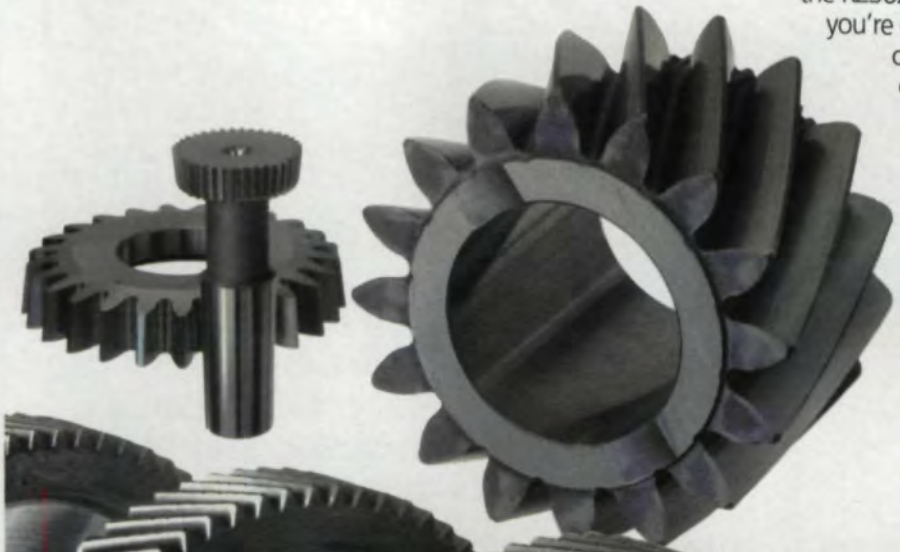

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Calculating Spur and Helical Gear Capacity with ISO 6336

Surface compressive (pitting) and tooth bending strength using ISO 6336-2; Calculation of surface durability (pitting) using ISO 6336-3; Calculation of tooth bending strength

Don McVittie

This is the third article in a series exploring the new ISO 6336 gear rating standard and its methods of calculation. The opinions expressed herein are those of the author as an individual. They do not represent the opinions of any organization of which he is a member.

Pitting strength

ISO 6336-2 shows how to calculate the maximum contact stress and the permissible contact stress. It is based on the same Hertzian surface compressive stress theory as AGMA 2001, so we should expect similar equations. The fundamental ISO contact stress equations are:

$$\sigma_H = Z_B \sigma_{HO} \sqrt{K_A K_V K_{H\beta} K_{H\alpha}} \le \sigma_{HP} \quad \text{ISO6336-2...(1)}$$

$$\sigma_{HO} = Z_H Z_E Z_\varepsilon Z_\beta \sqrt{\frac{F_t}{d_1 b} \frac{u+1}{u}} \quad \text{ISO6336-2...(2)}$$

$$\sigma_{HP} = \frac{\sigma_{H\,lim} Z_{NT}}{S_{H\,min}} Z_L Z_V Z_R Z_W Z_X \quad \text{ISO6336-2...(3)}$$

where:

σ_H is the calculated contact stress, similar to s_c in AGMA 2001.

σ_{HO} is the nominal contact stress.

σ_{HP} is the permissible contact stress.

$\sigma_{H\,lim}$ is the allowable contact stress number from ISO 6336-5, similar to s_{ac} in AGMA 2001.

The ISO 6336-2 equations look quite different at first, but they are similar to the AGMA equations. The terms Z_B, Z_H, Z_E, Z_ε, Z_β and $(u+1)/u$ serve the same purpose as the AGMA I factor. When combined, they are nearly identical to $\sqrt{I}$. The differences are:

• Z_B, which moves the calculated stress point from the pitch point to the lowest point of single tooth contact for spur gears, is not included in the nominal stress equation. Z_B is equal to 1.0 for helical gears.

• The value of Z_ε is a function of the transverse contact ratio ε_α. For spur gears it decreases the calculated stress from the AGMA value by 9% when ε_α is 1.5. There is no equivalent factor for spur gears in the AGMA standards. Z_ε is also used to interpolate between spur gears where ε_β is zero and true helical gears where ε_β is 1.0 or more.

• The value of Z_β is $\sqrt{\cos\beta}$. With Z_ε it approximates the value of F/l_{min} in the AGMA standards. The value tends to "run away" at high helix angles, so ISO

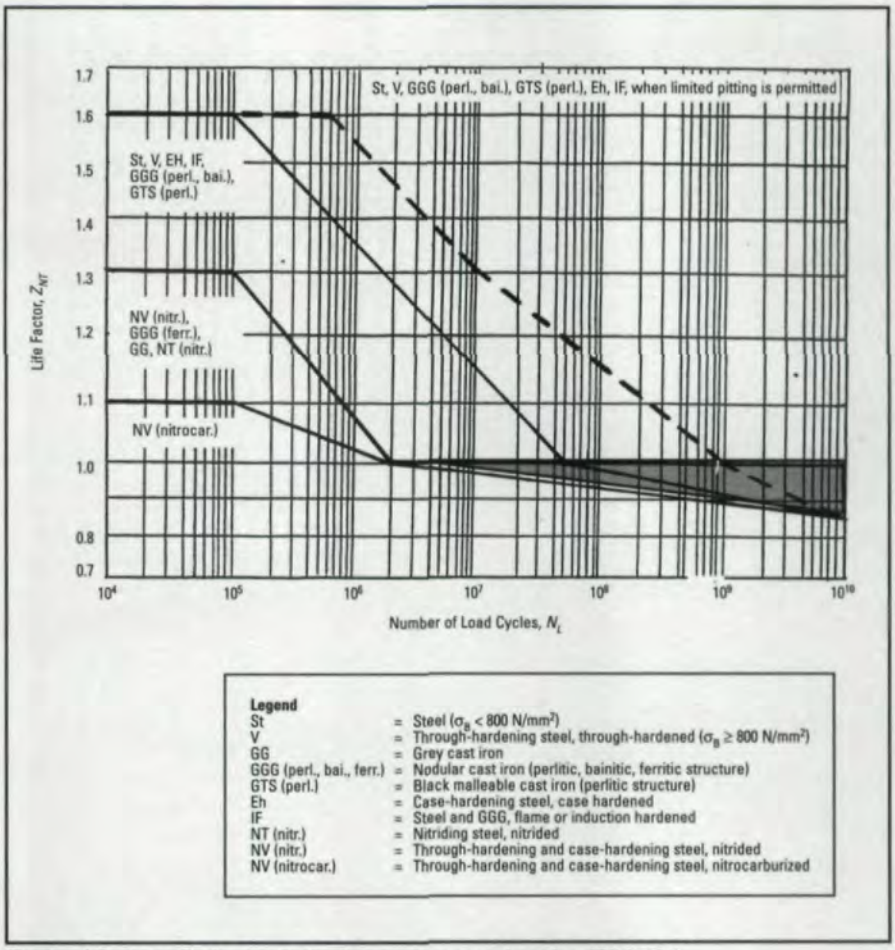

Fig. 1 — Life factor Z_{NT} for standard reference test gears, based on ISO 6336-2.

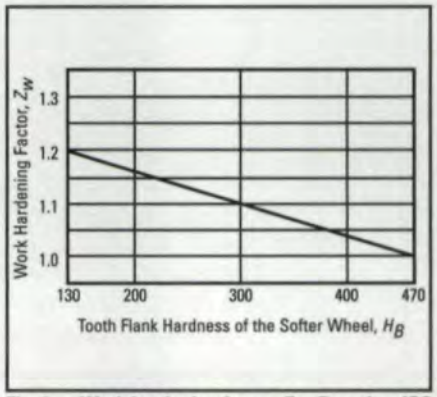

Fig. 2 — Work hardening factor, Z_W. Based on ISO 6336-2.

6336-1 suggests that users confirm their results by experience when operating helix angles exceed 30°. It is equal to 1.0 for spur gears.

The additional terms in the ISO equations are:

• K_A, K_v, etc. are the general influence factors from ISO 6336-1.

• $S_{H\ min}$ is the minimum safety factor input for contact stress.

• Z_{NT} is the life factor from Figure 1. Note that the life factors are similar to but different from AGMA practice, with a higher value if some pitting is permitted.

• Z_L, Z_v and Z_R are related influence factors accounting for the effects of lubricant viscosity, surface roughness and pitch line velocity on the permissible contact stress. Additional inputs for surface finish and lubricant viscosity are required. The combined effect of these three factors is usually less than 10% for industrial gears.

• Z_W is similar to the AGMA work hardening factor and accounts for the beneficial effect of running a harder pinion against a softer gear. Values are taken from Figure 2.

• Z_X is a size factor used to reduce the permissible stress for coarse pitch gears. It accounts for the greater possibility of encountering a material defect in the larger stressed volume of larger gears. The size factor is set to 1.0 for contact stress.

Root bending stresses

ISO 6336-3 shows how to calculate the root fillet tensile stress and the permissible bending stress. It is based on cantilever beam stress theory similar to AGMA 2001, with several significant differences:

• The point of critical stress is taken at the point on the root fillet which is tangent to an inscribed equilateral triangle, rather than the Lewis parabola. The location of this critical stress point agrees well with the other standards for "normal" gears, but diverges for gears with a small number of teeth and for gears with high operating pressure angles. ISO/TC60/SC2/WG6 has appointed an ad hoc group to study this area of the standard, but results are expected to take a few years. ISO 6336-1 suggests that users confirm their results by experience when operating pressure angles exceed 25° (Fig. 3).

• The stress concentration factors are based on strain gauge research performed on test gears at FZG[1], rather than on the photo elastic research of Dolan and Broghammer.

• The effect of the compressive component of tooth loading on the root tensile stress is ignored.

• There is no rim thickness factor similar to AGMA's K_B.

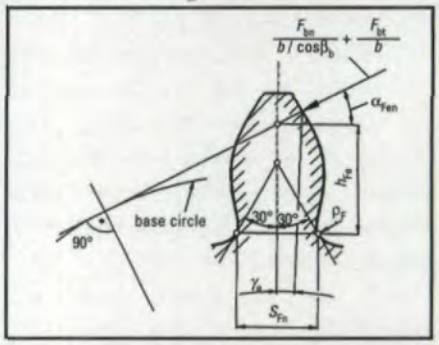

Fig. 3 — Determination of the normal chordal dimensions of the tooth root critical section for Method B. Based on ISO 6336-3.

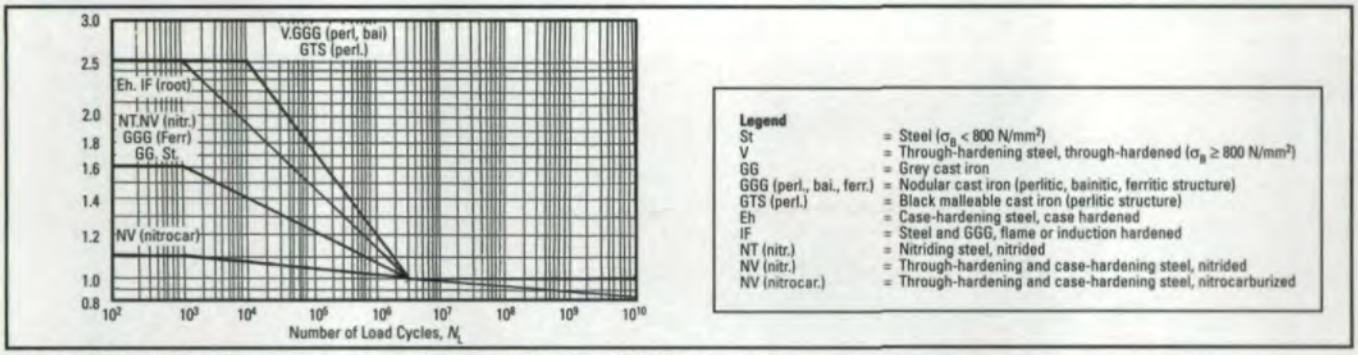

Fig. 4 — Life factor, Y_{NT}, for standard reference test gears. Based on ISO 6336-3.

The fundamental ISO root bending stress equations are:

$$\sigma_F = \sigma_{FO} K_A K_V K_{F\beta} K_{F\alpha} \leq \sigma_{FP} \qquad \text{ISO6336-3...(1)}$$

$$\sigma_{FO-B} = \frac{F_t}{b\ m_n} Y_F Y_S Y_\beta \qquad \text{ISO6336-3...(2)}$$

$$\sigma_{FP} = \frac{\sigma_{H\,lim} Y_{ST} Y_{NT}}{S_{F\,min}} Y_{\sigma\,rel\,T} Y_{P\,rel\,T} Y_X \qquad \text{ISO6336-3...(3)}$$

where:

σ_F is the calculated bending stress, similar to s_t in AGMA 2001.

σ_{F0-B} is the nominal bending stress, The "–*B*" in the subscript indicates that method B is being used. An optional simplified method to find the geometry factors from graphs is called method C.

σ_{FP} is the permissible bending stress.

$\sigma_{F\,lim}$ is the allowable bending stress number from ISO 6336-5, similar to s_{at} in AGMA 2001. The terms Y_F, Y_S and Y_β serve the same purpose as the AGMA *J* factor. The values are not the same because of the differences in underlying assumptions described above.

The additional terms in the ISO equations are:

- $S_{F\,min}$ is the minimum safety factor input for bending stress.
- Y_{ST} is an experimental stress correction factor, set to 2.0.
- Y_{NT} is the life factor from Figure 4. Note that the life factors are similar to but different from AGMA practice.
- $Y_{\sigma\,rel\,T}$ and $Y_{R\,rel\,T}$ are material related influence factors which account for the effects of notch sensitivity and surface roughness on the permissible bending stress.
- Y_X is a size factor used to reduce the permissible stress for coarse pitch gears. It accounts for the greater possibility of encountering a material defect in the larger stressed volume of larger gears. The size factor is taken from Figure 5.

CORRECTION

Errors were introduced during editing to Fig. 3 of "Comparing Standards: The keys to understanding ISO 6336-1 gear rating" in the September/October 1998 issue. Below is the corrected illustration.

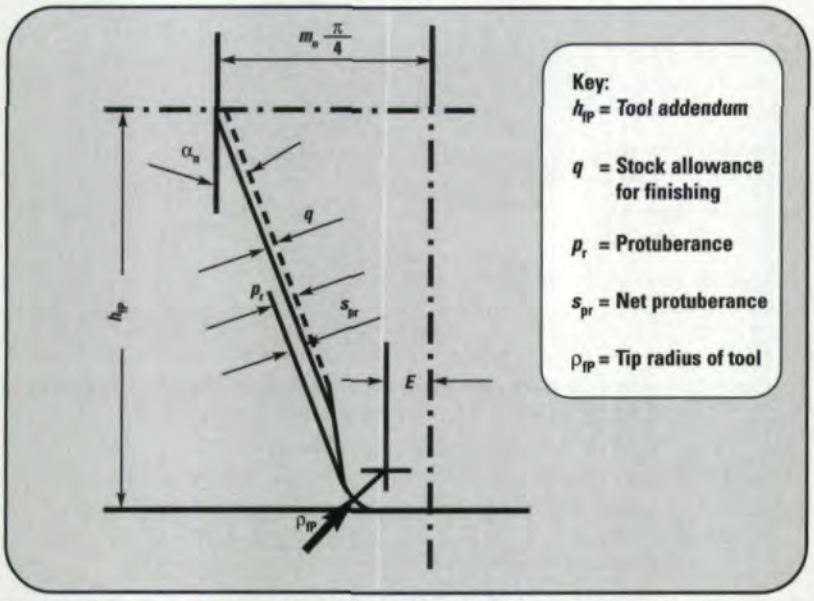

Fig. 3 — Dimensions and basic rack profile of the teeth (finished profile with undercut).

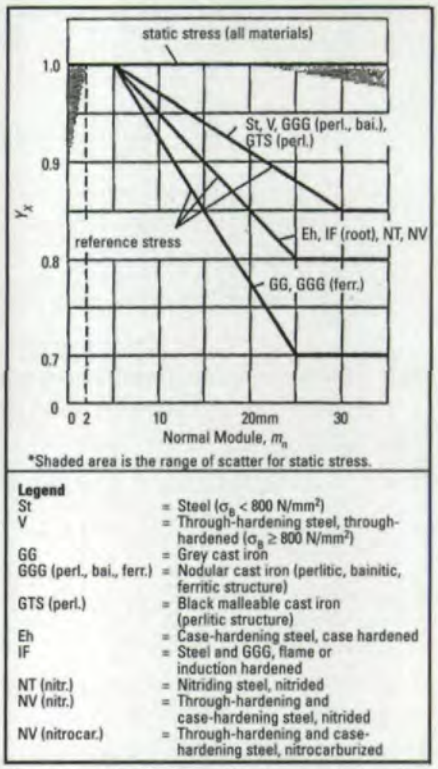

Fig. 5 — Size factor, Y_X, for tooth bending strength. Based on ISO 6336-3.

The material properties to be used in these stress equations come from ISO 6336-5, *Strength and quality of materials*. The ISO material quality requirements and allowable stress levels are similar to AGMA's. The differences in material requirements will be pointed out in the last article of this series.

It is difficult to make a general comparison between the ISO and AGMA gear capacity calculation methods, since the details of the individual example can have a big effect on the results. We'll demonstrate this by comparing the calculated capacities of some actual gear sets by the ISO and AGMA methods in that article.

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1. Hirt, M. *Einfluß der Zahnfußausrundung und des Festigkeit von Geradstirnrädern.* Doctorate dissertation, Technische Universität München, 1974. Also available in English translation from AGMA.
2. Brossmann, U. *Über den Einfluß der Zahnfußausrundung und des Schrägungswinkels auf Beanspruchung und Festigkeit schrägverzahnter Stirnräder.* Doctorate dissertation, Technische Universität München, 1979.

Don McVittie

is one of Gear Technology*'s technical editors. He is president of Gear Engineers, Inc., Seattle, WA and a former president of AGMA. McVittie is a licensed professional engineer in the state of Washington and has been involved with gear standards development for more than 25 years.*

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TECHNICAL CALENDAR

Nov. 3–5. Electronics Inc. Blast Cleaning and Shot Peening Workshop and Trade Show. Electronics Inc., Atlanta, GA. This three-day comprehensive training course covers all aspects of shot peening and blast cleaning in 25 technical class sessions. A trade show is held concurrently with over 40 vendor exhibit booths. Register online at *www.shotpeener.com*.

Nov. 3–5. Wall Colmonoy Brazing School. Wall Colmonoy Corp., Troy, MI. A three-day comprehensive course in modern furnace brazing. The school covers techniques, the latest in controlled and vacuum atmospheres and state-of-the-art joint design technology. The course also provides practical problem solving assistance by recognized industry leaders. For more information contact Marianne Huesing at (248) 585-6400 or by e-mail at *mhuesing@colmonoy.com*.

Nov. 3–6. UTS Plastic Gear Design School. Universal Technical Systems, Inc., Rockford, IL. Classes deal with the following topics: understanding gear geometry and design concepts, tools and methods for solving gear products, design and problem-solving skills and solutions to specific gear design problems brought in by the students. To register or for more information contact UTS at (800) 435-7887.

Nov. 8–10. 5th International AFS Conference on Molten Aluminum Processing. Sheraton World Resort, Orlando, FL. Conference will feature practical information about the latest technology and products for melting and processing aluminum. For more information contact the American Foundryman's Association at (847) 824-0181.

Nov. 16–20. AGMA Training School for Gear Manufacturing. Richard J. Daley College, Chicago, IL. This basic course provides five days of classroom and hands-on training and includes basic gearing, efficient machine setup techniques, accurate gear inspection and gearing calculation. For more information contact Susan Fentress at AGMA at (703) 684-0211.

Nov. 30–Dec. 3. Defense Manufacturing Conference '98. INFAC, New Orleans, LA. Manufacturing technology for affordability, readiness and modernization. For more information call (937) 426-2808.

Dec. 7–10. Balancing Theory and Applications Seminar. State University of New York, Farmingdale, NY. A four-day seminar sponsored by Schenck Trebel and SUNY—Farmingdale that covers units of measurement, conversion of units, ratio (proportion and manipulating simple balancing formulas), rectangular and polar coordinates, angles of rotation and radian measure, vector analysis, tooling consideration and more. For more information contact Schenck Trebel Educational Services at (800) 873-2352 Ext. 259, or log on to *http://www.schenck-usa.com*.

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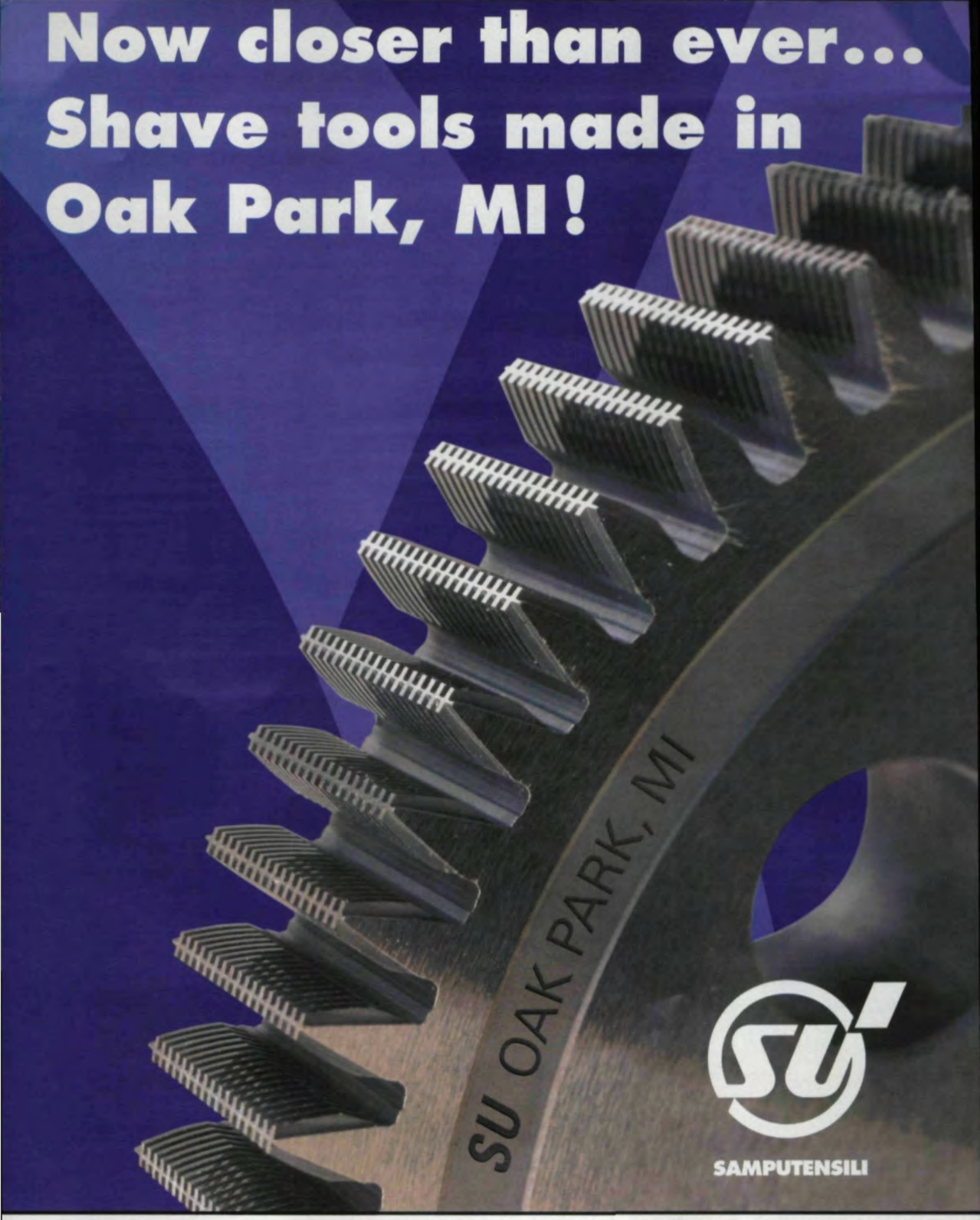

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CIRCLE 109

Gears on the Firing Line

High-volume centrifugal compressors push the limits of gear quality and reliability in this case study from Acme Gear, Cooper Turbocompressor and Reishauer

Dennis Richmond

Air compressors are a good example of industrial machinery with components that rotate at very high speeds, up to 80,000 rpm. They are subject to very high rotational forces and often variable loads. Strong, high-precision gears for the power transmission trains that drive the impellers are critical components of machinery operating under such conditions.

Compressors often operate around the clock in these applications. High reliability (up time), energy efficiency and vibration-free operation (typically, gear noise cannot be heard over the gas compression and flow noise) of compressors are important considerations. The results of a gearbox failure can be catastrophic—resulting in plant operation shut down and damage to drive shafts and impellers. Repairs or rebuilds can be costly.

Cooper Turbocompressor in Buffalo, NY, manufactures a wide range of oil-free centrifugal compressors for plant air and process applications. Typically they are the source of compressed air for process machine tool operation, pneumatic tools and even snow-making equipment, with power ratings from 150 to more than 1,200 horsepower. Cooper is also an industry leader for compressors in the air separation industry (suppliers of liquid oxygen, nitrogen and other gases) up to 22,000 hp.

Acme Gear supplies Cooper Turbocompressor with dynamically balanced, single helical bull gears, in sizes up to 32.68 in. pitch diameter, and pinions for their TA2000, TA3000 and C-8 centrifugal compressor lines as well as custom-engineered compressors rated between 2,000 and 7,000 hp. In many instances Acme supplies all of the gearing for a particular compressor. Acme also provides gearing for custom-engineered compressors, some with two separate gearboxes run in series off the same drive motor. Reishauer CNC gear grinding machines are employed for production, including a new Reishauer RZ820 for the larger bull gears.

Fig. 1 – Joe Gelles, president of Acme gear, with the modified Reishauer RZ820 used to grind centrifugal compressor gears.

Fig. 2 – Cooper Turbocompressor gear being ground with 5° bevel.

Fig. 3 – Finished bull gear being removed from Reishauer RZ820.

The gearboxes and drive trains of Cooper's single and multi-stage compressors are an integral part of the entire assembly. A single main drive or bull gear will drive one to three pinions. They must reliably drive compressor impellers to pinion speeds of up to 80,000 rpm, provide vibration-free rotation of all drive shafts and impellers and balance out and absorb varying thrust loads for high-efficiency operation.

Centrifugal compressor gearing is some of the most difficult to produce due

to its complexity and the stringent requirements for material quality and dimensional tolerances. And, consistent, high-precision machining of hard alloy steels is a tough job that places great demands on both operations and the production machinery used to make them.

Acme's compressor gears are manufactured with through-hardened, aircraft-quality alloy steels, which are subjected to both destructive and nondestructive testing procedures. Tolerances of 1/10,000 (.0001) in. are necessary. Some specific areas require tolerances held to +/- fifty millionths (.00005) in. In the case of ground, hardened steel parts, there is no distortion due to machining stresses. Final tolerances are achieved without subsequent stress relief and grinding or polishing, as might be the case with gears produced by gear hobbing or shaping machines.

The gearing Acme supplies is ground to AGMA 12 and 13+ levels. Cooper also has its own set of proprietary specifications related to the manufacturing of centrifugal compressor quality gearing, and Cooper's operations are ISO 9001 certified.

Cooper Turbocompressor's quality department audits Acme three to four times a year in addition to an annual "Supplier Quality Performance Review," which is a thorough review of products and procedures on both a quantitative and qualitative basis. Cooper also has very formal rejection and disposition procedures as well as cause and corrective action reporting requirements. Acme Gear consistently scores in the highest 10 percent of their supplier base.

Acme consistently meets such stringent requirements through a close relationship based upon mutual benefit and respect both with Cooper and with their own suppliers of materials and production machinery. For Cooper, it is very important that suppliers employ, maintain and upgrade their machinery and processes to the levels necessary to reliably and consistently produce the gearing quality that Cooper and, ultimately, their customers require.

Supplying the High Performance Gears

Originally founded as Marine Boat Engine Company in 1929, Acme Gear of Englewood, NJ, was initially in the business of rebuilding marine engines. In 1955, the company moved from Long Island City to its present site in Englewood and was renamed Acme, "because it represents the highest point,

Fig. 4 – Each turbocompressor gear is quality checked for accuracy and dimensionality of bevels.

the culmination," states Joe Gelles, Acme president.

In the mid-1960s, the business began to shift. Acme became heavy in the cut gear business. Government contractors such as Grumman, Fairchild and Republic were relocating, cutting back or just closing down. Around 1967, Acme decided to make the shift from cut gears to precision ground gears because of the evolving niche requiring high quality components.

Acme Gear began to produce high speed, precision gears for existing customers like Borg Warner Corporation, Carrier Industries, Bendix and Hillcraft. Demands on the gearing have changed dramatically in the last 30 years. In 1967, "high speed" was around 2,000 rpm. Today, Acme produces precision gears capable of about 120,000 rpm. "It's more than just speed," says Gelles. "In the printing industry, for example, magazine presses have more than seven colors being overlapped while running at tremendous speeds. The precision required to maintain those exacting registrations demands a lot from the gearing."

Acme Gear has recently installed a modified version of a Reishauer RZ820 machine. It enables Acme to produce a 32.68" precision gear for Cooper Cameron as part of a high efficiency refrigeration compressor. Acme worked in conjunction with Reishauer to modify an RZ820 to meet the customer's needs for a larger workpiece from the standard 32" capacity. "Acme had been producing a lot of gearing in the 27" range, which fit wonderfully on the other Reishauer RZ series machines, but when a new, larger design came up at Cooper, we sat down with the Reishauer people and together came up with the perfect solution," says Gelles.

Other new features on the RZ820 machine in addition to the larger capacity included a more powerful grinding motor (5.5 kw), variable speed grinding spindle (1100–2150 rpm) that can be selected for individual passes, manually actuated fine balancing and hydraulic tailstock.

Joe Gelles predicts an increase in the usage of high speed precision gears throughout the industry. The demand for more efficient performance in compressors, elevators, mining equipment and locomotives. As for the automotive industry, Gelles concludes, "While they're shaving and honing a lot of them still, the consumer will demand transmissions that will last longer, make less noise and operate more efficiently. This will be especially true as the auto industry moves into the era of electric cars. We'll be ready for them when it happens." ○

Dennis Richmond

is vice president of Reishauer Corporation, Elgin, IL, manufacturers of precision gear grinding machinery.

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

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Brad Foote Gear Works
Burgess-Norton Mfg. Co.
Carbon City Products
Caron-Vector
Caterpillar Industrial Products Inc.
C-B Gear & Machine
Chicago Gear-D. O. James
Ciateq, A. C.
The Cincinnati Gear Co.
CMD (UK) Ltd.
Curtis Machine Co. Inc.
Davall Gear Co. Ltd.
David Brown Group PLC
Dee-Kay Gears
Electrex Ltd. (India)
Elmass North America
EMCO Gears, Inc.
Engelhardt Gear Co.
Fairfield Mfg. Co.
Falk Corp.
Foote-Jones/Illinois Gear
G&N Rubicon Gear
The Gear Works-Seattle
Gears & Drive Systems
Globe Gear Co.
Great Taiwan Gear Ltd.
Grupos Diferenciales
Hamilton Gear
HCI Supply
Hico
Hitachi America Ltd.
Horsburgh & Scott
Hub City, Inc.
Indiana Power Transmission Systems
Industrial Supply Co.
Intech Corporation
Keystone Powdered Metal
Klingelnberg Söhne GmbH
Krupp Engineering Inc.
Lampin Corp.
Linn Gear Co.
M.G. Minigears Inc.
M.S. Engineers
Masiero Antonio SpA
Micron Instrument Corp.
Midwest Gear & Tool
Milford Gear Works
Moore Gear Mfg. Co.
Nissei Corp. of America
Oerlikon Geartec AG
Ohio Gear
Omni Gear
Philadelphia Gear Corp.—Houston
Philadelphia Gear Corp.—King of Prussia
PIC Design
Precision Gear Co.
Precision Gear Inc.
Presrite Corp.
The Purdy Corporation
Qualicast Corp.
Quality Transmission Components
Reliance Gear Corp.
Riverside Spline & Gear
Rush Gears Inc.
SEW-Eurodrive
Shanthi Gears Ltd.
Springer Company Inc.
Standard Industrial Products Co.
Stock Drive Products/ Sterling Instrument
Suda International Gear Works
Tech Sales Inc.
Tri-Power MPT
United States Gear
Von Ruden Mfg.
Wedin International
West Industries Inc.
Westech Gear
Winzeler Gear

Gears—Spur

A-1 Gears
ABA-PGT Inc.
Acme Gear Co., Inc.
ACR Industries, Inc.
Action Gear & Broaching
The Adams Company
Adobe Precision Gear
Advance Gear & Machine
Aero Gear
Aerocom Industries Inc.
Akron Gear & Engineering
Albro Gear & Instrument
Allied Devices Corp.
Allied Gear Co.
Amarillo Gear Co.—Russellville
American Gear & Engineering
American Mach. & Gear
American Metric Corp.
American Precision Gear
Aplus Engineering Inc.

Wes-Tex Gear Inc.
Windsor Gear Co.
Winzeler Gear
Wohlert Corporation
Worcester Gear Works
Worrall Grinding Co.
Xtek Inc.
Zhuhai Intercontinental Pulleys Ltd.

Gears—Straight Bevel

A-1 Gears
ACR Industries, Inc.
The Adams Company
Adobe Precision Gear
Advance Gear & Machine
Aero Gear
Akron Gear & Engineering
Allied Devices Corp.
Allied Gear Co.
Amarillo Gear Co.—Amarillo
American Gear & Engineering
American Mach. & Gear
American Metric Corp.
American Precision Gear
Arrow Gear Company
Asco Sintering Co.
Ashot Ashkelon Indust.
Ashot USA Inc.
Astron Midwestern Inc.
Bearings & Industrial Sales
Bengal Industries
Bevel Gears (India)
Bilgram Gear Co.
Bonfiglioli Riduttori
Bonfiglioli U.K.
Boston Gear
Boxx Gear Mfg., Inc.
Brad Foote Gear Works
Brewer Machine & Gear
Burgess-Norton Mfg. Co.
Calicut Eng. Works Ltd.
Carbon City Products
Caterpillar Industrial Products Inc.
C-B Gear & Machine
Chardam Gear Co.
Charles Bond Co.
Chicago Gear-D. O. James
Chicago Gear Works
Ciateq, A. C.
Circle Gear & Machine
CMD (UK) Ltd.
Commercial Gear & Sprocket
Cornell Forge Co.
Curtis Machine Co. Inc.
Custom Gear & Machine
Custom Gears, Inc.
Dabko Industries Inc.
Davall Gear Co. Ltd.
David Brown Group PLC
Dayton Gear & Tool
Dee-Kay Gears
Engelhardt Gear Co.
Fairfield Mfg. Co.
Falk Corp.
Federal Gear Corp.
Fisher's Gear & Machine
Fleet Tools Ltd.
Foote-Jones/Illinois Gear
G&N Rubicon Gear
Gear Company of America
The Gear Works-Seattle
Gears & Drive Systems
Geartronics Industries
Generated Gear & Machine
Globe Gear Co.
Great Taiwan Gear Ltd.
Grupos Diferenciales
GW Plastics
Hamilton Gear
Harder Precision Components
HCI Supply
Hub City, Inc.
Indiana Power Transmission Systems
Industrial Supply Co.
Intech Corporation
J&E Hofmann Engineering
Jackson Gear Co.
Keystone Powdered Metal
Krupp Engineering Inc.
Lawler Gear Corp.
Link Gear & Machine
Linn Gear Co.
M.G. Minigears Inc.
M.J.H. Gear & Tool Co.
Martin Sprocket & Gear
Mascotech-Braun
Masiero Antonio SpA
Midwest Gear & Tool
Milford Gear Works
Minipart P.T. Co. Ltd.
Mitrpak Power Transmission Products
Moore Gear Mfg. Co.
Moore Machine & Gear
Nissei Corp. of America
Nixon Gear
Nord Gear Corporation
Nordex, Inc.
Ohio Gear
Oliver Gear, Inc.
Omni Gear
P.T. International Corp.
Penn Machine Company
Perry Technology Corp.
Philadelphia Gear Corp.—Houston
Philadelphia Gear Corp.—King of Prussia
PIC Design
Precipart Corp.
Precision Gear Co.
Presrite Corp.
Process Industries
Progressive Engineering
Quality Transmission Components
Rawling Gear Inc.
Reliance Gear Co. Ltd.
Reliance Gear Corp.
Ronson Gears Pty. Ltd.
Rush Gears Inc.
Satellite Gear
Seitz Corporation
SEW-Eurodrive
Shanthi Gears Ltd.
Spicer Industries
Springer Company Inc.
Sri Venkateshwara Gear
Standard Industrial Products Co.
Stock Drive Products/Sterling Instrument
Textile Parts & Machine
Torque Transmission
Tracey Gear & Machine
Tri-Power MPT
Trogetec
UFE Incorporated
United States Gear
Von Ruden Mfg.
Wedin International
West Industries Inc.
Westech Gear
Windsor Gear Co.
Winzeler Gear
Worcester Gear Works
Xtek Inc.
Zero-Max, Inc.

Gears—Worm

A-1 Gears
ABA-PGT Inc.
Acme Gear Co., Inc.
ACR Industries, Inc.
Action Gear & Broaching
The Adams Company
Adobe Precision Gear
Advance Gear & Machine
Aero Gear
Akron Gear & Engineering
Allied Devices Corp.
Allied Gear Co.
American Gear & Engineering
American Mach. & Gear
American Metric Corp.
American Precision Gear
Aplus Engineering Inc.
Bearings & Industrial Sales
Bengal Industries
Bevel Gears (India)
Bilgram Gear Co.
Blanchat Machine Co.
Bonfiglioli Riduttori
Bonfiglioli U.K.
Boston Gear
Boxx Gear Mfg., Inc.
Brad Foote Gear Works
Brewer Machine & Gear
Buckeye Gear Co.
CMD (UK) Ltd.
Calicut Eng. Works Ltd.
Caron-Vector
C-B Gear & Machine
Charles Bond Co.
Chicago Gear-D. O. James
Chicago Gear Works
Ciateq, A. C.
The Cincinnati Gear Co.
Circle Gear & Machine
Commercial Gear & Sprocket
Cone Drive Operations
Custom Gear & Machine
Custom Gears, Inc.
Davall Gear Co. Ltd.
David Brown Group PLC
Dayton Gear & Tool
Dee-Kay Gears
Electra-Gear
Elmass North America
EMCO Gears, Inc.
Engelhardt Gear Co.
Euclid Universal Corp.
Falk Corp.
Federal Gear Corp.
Fisher's Gear & Machine
Fleet Tools Ltd.
Flender Corporation
Foote-Jones/Illinois Gear
Forest City Gear
Franke Gear Works Inc.
Gear Company of America
Gear Products Inc.
Gear Systems Inc.
Gear Works, Inc.
The Gear Works-Seattle
Gears & Drive Systems
Geartronics Industries
General Gear Corporation
Generated Gear & Machine
Gerhardt Gear Co.
Globe Gear Co.
Great Taiwan Gear Ltd.
Greenshpon Engineering Works Ltd.
Grove Gear
GW Plastics
Hamilton Gear
Harder Precision Components
Holroyd Machine
Horsburgh & Scott
Hub City, Inc.
Indiana Power Transmission Systems
Indiana Tool/Indiana Gear
Industrial Supply Co.
Insco Corporation
Intech Corporation
Involute Tooling Corp.

J&E Hofmann Engineering
Jackson Gear Co.
Jennings Machine & Gear
KA-Wood Gear & Machine
Keystone Threaded Products
Lawler Gear Corp.
Link Gear & Machine
Linn Gear Co.
M.G. Minigears Inc.
M.J.H. Gear & Tool Co.
Martin Sprocket & Gear
Milford Gear Works
Minipart P.T. Co. Ltd.
Moore Gear Mfg. Co.
Moore Machine & Gear
Mostar Gear & Machine
Mr. Gears, Inc.
National Broach & Machine Co.
Nissei Corp. of America
Nixon Gear
Nordex, Inc.
OEM Industries Inc.
Ohio Gear
Oliver Gear, Inc.
Omni Gear
Omni Gear & Machine
O'Neill Gear
Ontario Drive & Gear
Patterson Gear & Machine
Peerless-Winsmith Inc.
Penn Machine Company
Pennsylvania Gear Corp.
Penntech
Perry Technology Corp.
Philadelphia Gear Corp.—Houston
Philadelphia Gear Corp.—King of Prussia
PIC Design
Poly Hi Solidur
Precipart Corp.
Precision Gear Co.
Precision Gear Inc.
Precision Gears, Inc.
Process Industries
Progressive Engineering
Rapid Gear
Rawling Gear Inc.
Reliance Gear Co. Ltd.
Reliance Gear Corp.
Renold Power Transmission Corp.
Rexnord Corporation
Riley Gear Corp.
Riverside Spline & Gear
Ronson Gears Pty. Ltd.
Rush Gears Inc.
Santasalo North America
Satellite Gear
Schafer Gear Works, Inc.
SEW-Eurodrive
Shanthi Gears Ltd.
Springer Company Inc.
Sri Venkateshwara Gear
Standard Industrial Products Co.
STD Precision Gear
Sterling Electric
Stock Drive Products/ Sterling Instrument
Suda International Gear Works
Textile Parts & Machine
Tifco Gage & Gear
Tracey Gear & Machine
Tri-Power MPT
Trojon Gear Inc.
UFE Incorporated
Wedin International
West Industries Inc.
Westech Gear
Windsor Gear Co.
Winzeler Gear
Worcester Gear Works

Ratchets

ACR Industries, Inc.
Action Gear & Broaching
Adobe Precision Gear
Akron Gear & Engineering
American Gear & Engineering
American Precision Gear
Bengal Industries
Boxx Gear Mfg., Inc.
Buckeye Gear Co.
Capitol Stampings Corp.
C-B Gear & Machine
Chandler Machine Co.
Circle Gear & Machine
Commercial Gear & Sprocket
Davall Gear Co. Ltd.
Dayton Gear & Tool
Engelhardt Gear Co.
Fisher's Gear & Machine
Forest City Gear
Gear Company of America
Gear Works, Inc.
Generated Gear & Machine
Gerhardt Gear Co.
Great Taiwan Gear Ltd.
Harder Precision Components
Intech Corporation
J&E Hofmann Engineering
Jackson Gear Co.
Milford Gear Works
Mostar Gear & Machine
Nordex, Inc.
OEM Industries Inc.
Oliver Gear, Inc.
Perry Technology Corp.
Precision Gear Co.
Precision Gears, Inc.
Production Gear & Broach
Rawling Gear Inc.
Ronson Gears Pty. Ltd.
Sri Venkateshwara Gear
STD Precision Gear
Stock Drive Products/ Sterling Instrument
Tracey Gear & Machine
Trojon Gear Inc.
Wedin International

Serrations

Acme Gear Co., Inc.
ACR Industries, Inc.
Action Gear & Broaching
Adobe Precision Gear
Aero Gear
Akron Gear & Engineering
Albro Gear & Instrument
Allied Gear Co.
Amarillo Gear Co.—Russellville
American Gear & Engineering
American Mach. & Gear
American Precision Gear
Boxx Gear Mfg., Inc.
Brad Foote Gear Works
Buckeye Gear Co.
C-B Gear & Machine
Chandler Machine Co.
Circle Gear & Machine
Davall Gear Co. Ltd.
David Brown Group PLC
Dayton Gear & Tool
Dee-Kay Gears
Elmass North America
Fisher's Gear & Machine
Fleet Tools Ltd.
Forest City Gear
G&N Rubicon Gear
Gear Company of America
Gear Works, Inc.
General Gear Corporation

Generated Gear & Machine
Gerhardt Gear Co.
Great Taiwan Gear Ltd.
Harder Precision Components
Invincible Gear Co.
Invo Spline Inc.
J&E Hofmann Engineering
Jackson Gear Co.
Jennings Machine & Gear
Milford Gear Works
Moore Gear Mfg. Co.
Mostar Gear & Machine
Mr. Gears, Inc.
OEM Industries Inc.
Oliver Gear, Inc.
Orlandi Gear
Overton Gear & Tool
Pennsylvania Gear Corp.
Perry Technology Corp.
Precision Gear Co.
Precision Gears, Inc.
Production Gear & Broach
Pulley Manufacturers Inc.
Rack & Pinion, Inc.
Rapid Gear
Rawling Gear Inc.
Ronson Gears Pty. Ltd.
Satellite Gear
Schafer Gear Works, Inc.
SEW-Eurodrive
Shanthi Gears Ltd.
Sri Venkateshwara Gear
STD Precision Gear & Instrument
Tracey Gear & Machine
Trojon Gear Inc.
Wedin International

Splines

A-1 Gears
Acme Gear Co., Inc.
ACR Industries, Inc.
Action Gear & Broaching
The Adams Company
Adobe Precision Gear
Advance Gear & Machine
Aero Gear
Aerocom Industries Inc.
Akron Gear & Engineering
Albro Gear & Instrument
Allied Devices Corp.
Allied Gear Co.
Amarillo Gear Co.—Russellville
American Gear & Engineering
American Mach. & Gear
American Metric Corp.
American Precision Gear
Aplus Engineering Inc.
Arrow Gear Company
Ashot Ashkelon Indust.
Bevel Gears (India)
Bilgram Gear Co.
Blanchat Machine Co.
Boonville Mining Services
Boxx Gear Mfg., Inc.
Brad Foote Gear Works
Buckeye Gear Co.
Burgess-Norton Mfg. Co.
Calicut Eng. Works Ltd.
Capstan Atlantic
Carbon City Products
Caterpillar Industrial Products Inc.
C-B Gear & Machine
Chandler Machine Co.
Chardam Gear Co.
Chicago Gear-D. O. James
Ciateq, A. C.
The Cincinnati Gear Co.
Circle Gear & Machine
Cloyes Gear & Products—Auburn Hills
CMD (UK) Ltd.
Cold Forming Technology
Columbia Gear Corp.
Commercial Gear & Sprocket
Curtis Machine Co. Inc.
Custom Gear & Machine
Custom Gears, Inc.
Dabko Industries Inc.
Davall Gear Co. Ltd.
David Brown Group PLC
Dayton Gear & Tool
Dearborn Gear & Tool Co.
Dee-Kay Gears
Elmass North America
Engelhardt Gear Co.
Euclid Universal Corp.
Fairfield Mfg. Co.
Federal Gear Corp.
Fisher's Gear & Machine
Fleet Tools Ltd.
Foote-Jones/Illinois Gear
Forest City Gear
Franke Gear Works Inc.
G&N Rubicon Gear
GA-Heartland Machine Tool
Gear Company of America
Gear Products Inc.
Gear Systems Inc.
Gear Works, Inc.
The Gear Works-Seattle
Gears & Drive Systems
Geartronics Industries
General Gear Corporation
Generated Gear & Machine
Gerhardt Gear Co.
Global Gear
Globe Gear Co.
Great Taiwan Gear Ltd.
HMC
Hamer Gear
Hamilton Gear
Hand Screw Machine
Hanover Gear Mfg. Co.
Harder Precision Components
Harmonic Drive Technologies
Horsburgh & Scott
Howard's Machine Shop
Hub City, Inc.
Indiana Power Transmission Systems
Indiana Tool/Indiana Gear
Industrial Supply Co.
Insco Corporation
Invo Spline Inc.
Involute Tooling Corp.
J&E Hofmann Engineering
Jackson Gear Co.
Jade Precision Gear Co.
Jennings Machine & Gear
KA-Wood Gear & Machine
Keller Machine Co.
Keystone Powdered Metal
Kreiter Geartech
Krupp Engineering Inc.
L&H Welding & Machine
Lawler Gear Corp.
Link Gear & Machine
Linn Gear Co.
Lyon Gear
M.G. Minigears Inc.
M.J.H. Gear & Tool Co.
M&M Precision Systems
Micromatic Textron
Midwest Gear Corp.
Midwest Gear & Tool
Milford Gear Works
Milwaukee Gear Co.
Minipart P.T. Co. Ltd.
Modified Gear & Spline
Moore Gear Mfg. Co.
Moore Machine & Gear
Mostar Gear & Machine
Mr. Gears, Inc.
National Broach & Machine Co.
Niagara Gear Corp.
Nissei Corp. of America
Nixon Gear
OEM Industries Inc.
Oliver Gear, Inc.
Omni Gear & Machine
O'Neill Gear
Ontario Drive & Gear
Orlandi Gear
Overton Gear & Tool
Patterson Gear & Machine
Penn Machine Company
Pennsylvania Gear Corp.
Penntech
Perry Technology Corp.
Philadelphia Gear Corp.—Houston
Philadelphia Gear Corp.—King of Prussia
Precipart Corp.
Precision Gear Co.
Precision Gear Inc.
Precision Gears, Inc.
Process Industries
Production Gear & Broach
Progressive Engineering
Pulley Manufacturers Inc.
The Purdy Corporation
R.L. Wagner & Assoc.
Rack & Pinion, Inc.
Rapid Gear
Rawling Gear Inc.
Reef Gear Mfg. Inc.
Reliance Gear Corp.
Riley Gear Corp.
Riverside Spline & Gear
Rj Link International
Ronson Gears Pty. Ltd.
Rush Gears Inc.
Sales Consultants
Santasalo North America
Satellite Gear
Schafer Gear Works, Inc.
SEW-Eurodrive
Shanthi Gears Ltd.
Springer Company Inc.
Sri Venkateshwara Gear
St. Marys Carbon Co.
Standard Industrial Products Co.
STD Precision Gear
Stock Drive Products/Sterling Instrument
Tech Sales Inc.
Tifco Gage & Gear
Tracey Gear & Machine
Trogetec Inc.
Trojon Gear Inc.
UFE Incorporated
United States Gear
Von Ruden Mfg.
Walter Machine Co., Inc.
Wedin International
West Industries Inc.
Westech Gear
Western Spline Gage
Wes-Tex Gear Inc.
Windsor Gear Co.
Worcester Gear Works
Xtek Inc.
Zhuhai Intercontinental Pulleys Ltd.

Sprockets

A-1 Gears
Acme Gear Co., Inc.
Action Gear & Broaching
The Adams Company
Adobe Precision Gear
Aero Gear
Akron Gear & Engineering
Allied Devices Corp.
Allied Gear Co.
American Gear & Engineering
American Mach. & Gear
American Metric Corp.
American Precision Gear
Asco Sintering Co.
Bearings & Industrial Sales
Bengal Industries
Bestmetal Corporation
Blanchat Machine Co.
Boonville Mining Services
Boston Gear
Boxx Gear Mfg., Inc.
Brad Foote Gear Works
Brewer Machine & Gear
Buckeye Gear Co.
Burgess-Norton Mfg. Co.
Capitol Stampings Corp.
Capstan Atlantic
Carbon City Products
C-B Gear & Machine
Chandler Machine Co.
Chicago Gear-D. O. James
Circle Gear & Machine
Cloyes Gear & Products—Auburn Hills
Custom Gear & Machine
Custom Gears, Inc.
Davall Gear Co. Ltd.
David Brown Group PLC
Dayton Gear & Tool
Dee-Kay Gears
Elmass North America
EMCO Gears, Inc.
Engelhardt Gear Co.
Fairfield Mfg. Co.
Fisher's Gear & Machine
Fleet Tools Ltd.
Forest City Gear
Gear Company of America
Gear Works, Inc.
Gears & Drive Systems
Generated Gear & Machine
Gerhardt Gear Co.
Global Gear
Globe Gear Co.
Great Lakes Industry, Inc.
Great Taiwan Gear Ltd.
GW Plastics
Hamer Gear
Hamilton Gear
Harder Precision Components
HCI Supply
Industrial Supply Co.
Insco Corporation
Intech Corporation
Involute Tooling Corp.
J&E Hofmann Engineering
Jackson Gear Co.
Jade Precision Gear Co.
Jennings Machine & Gear
Keller Machine Co.
Keystone Powdered Metal
Kreiter Geartech
L&H Welding & Machine
Lampin Corp.
Lawler Gear Corp.
Link Gear & Machine
Linn Gear Co.
Lyon Gear
Martin Sprocket & Gear
Midwest Gear Corp.
Minipart P.T. Co. Ltd.
Moore Gear Mfg. Co.
Mostar Gear & Machine
Mr. Gears, Inc.
National Broach & Machine Co.
Nixon Gear
Nordex, Inc.
OEM Industries Inc.
Oliver Gear, Inc.
Ontario Drive & Gear
P.T. International Corp.
Pennsylvania Gear Corp.
Penntech
Perry Technology Corp.
PIC Design
Poly Hi Solidur
Precision Gear Co.
Precision Gears, Inc.
Presrite Corp.
Production Gear & Broach
Pulley Manufacturers Inc.
Putnam Precision Molding
Rapid Gear
Rawling Gear Inc.
Reef Gear Mfg. Inc.
Reliance Gear Corp.
Renold Power Transmission Corp.
Riverside Spline & Gear
Rj Link International
Ronson Gears Pty. Ltd.
Rush Gears Inc.
Ryle Manufacturing Co.
Santasalo North America
Satellite Gear
Schafer Gear Works, Inc.
Seitz Corporation
SEW-Eurodrive
Shanthi Gears Ltd.
Spicer Industries
Sri Venkateshwara Gear
Standard Industrial Products Co.
STD Precision Gear
Stock Drive Products/Sterling Instrument
Textile Parts & Machine
Torque Transmission
Tracey Gear & Machine
Transmission Developments Co. Ltd.
Tri-Power MPT
Trogetec Inc.
Trojon Gear Inc.
United States Gear
V.T.M. Co. Ltd.
Van Zeeland Mfg. Inc.
Waterjet Connection/Richel Inc.
Wedin International
West Industries Inc.
Wes-Tex Gear Inc.
Xtek Inc.
Zenith Sintered Products
Zhuhai Intercontinental Pulleys Ltd.

Timing Pulleys

A-1 Gears
Acme Gear Co., Inc.
Action Gear & Broaching
Aero Gear
Akron Gear & Engineering
Allied Gear Co.
American Gear & Engineering
American Mach. & Gear
American Metric Corp.
American Precision Gear
Asco Sintering Co.
Bearings & Industrial Sales
Bengal Industries
Bestmetal Corporation
Boston Gear
Boxx Gear Mfg., Inc.
Brewer Machine & Gear
Buckeye Gear Co.
C-B Gear & Machine
Chandler Machine Co.
Circle Gear & Machine
Cloyes Gear & Products—Auburn Hills
Davall Gear Co. Ltd.
David Brown Group PLC
Dayton Gear & Tool
Elmass North America
Engelhardt Gear Co.
Euclid Universal Corp.
Fisher's Gear & Machine
Fleet Tools Ltd.
Gear Company of America
Gear Works, Inc.
Gears & Drive Systems
Generated Gear & Machine
Gerhardt Gear Co.
Great Taiwan Gear Ltd.
Harder Precision Components
HCI Supply
Industrial Supply Co.
Intech Corporation
J&E Hofmann Engineering
Jade Precision Gear Co.
Jennings Machine & Gear
Lampin Corp.
Lawler Gear Corp.
Linn Gear Co.
Minipart P.T. Co. Ltd.
Mostar Gear & Machine
Mr. Gears, Inc.
Nordex, Inc.
OEM Industries Inc.
Oliver Gear, Inc.
P.T. International Corp.
Perry Technology Corp.
PIC Design
Poly Hi Solidur
Precision Gears, Inc.
Pulley Manufacturers Inc.
Putnam Precision Molding
Rapid Gear
Rawling Gear Inc.
Reef Gear Mfg. Inc.
Reliance Gear Co. Ltd.
Rj Link International
Ronson Gears Pty. Ltd.
Rush Gears Inc.
Santasalo North America
Schafer Gear Works, Inc.
Seitz Corporation
SEW-Eurodrive
Shanthi Gears Ltd.
STD Precision Gear
Stock Drive Products/Sterling Instrument
Tracey Gear & Machine
Transmission Developments Co. Ltd.
Tri-Power MPT
Trojon Gear Inc.
UFE Incorporated
V.T.M. Co. Ltd.
Wedin International
Zhuhai Intercontinental Pulleys Ltd.

Worms

A-1 Gears
ABA-PGT Inc.
Acme Gear Co., Inc.
The Adams Company
Adobe Precision Gear
Advance Gear & Machine
Aero Gear
Akron Gear & Engineering
Allied Gear Co.
American Gear & Engineering
American Mach. & Gear
American Metric Corp.
American Precision Gear
Andantex USA
Bearings & Industrial Sales
Bengal Industries
Boonville Mining Services
Boston Gear
Boxx Gear Mfg., Inc.
Brad Foote Gear Works
Brewer Machine & Gear
Caron-Vector
C-B Gear & Machine
Circle Gear & Machine
Custom Gear & Machine
Custom Gears, Inc.
Davall Gear Co. Ltd.

David Brown Group PLC
Dayton Gear & Tool
Dee-Kay Gears
Electra-Gear
Elmass North America
EMCO Gears, Inc.
Euclid Universal Corp.
Fisher's Gear & Machine
Foote-Jones/Illinois Gear
Forest City Gear
Gear Company of America
Gear Products Inc.
Gears & Drive Systems
Generated Gear & Machine
Great Taiwan Gear Ltd.
Harder Precision Components
HCI Supply
Indiana Power Transmission Systems
Industrial Supply Co.
Intech Corporation
Involute Tooling Corp.
J&E Hofmann Engineering
Jackson Gear Co.
Jennings Machine & Gear
Lawler Gear Corp.
Linn Gear Co.
Minipart P.T. Co. Ltd.
Moore Gear Mfg. Co.
Mostar Gear & Machine
Mr. Gears, Inc.
Nordex, Inc.
OEM Industries Inc.
Oliver Gear, Inc.
Omni Gear
Peerless-Winsmith Inc.
Pennsylvania Gear Corp.
Perry Technology Corp.
PIC Design
Precision Gear Co.
Precision Gear Inc.
Precision Gears, Inc.
Quality Transmission Components
Rawling Gear Inc.
Ronson Gears Pty. Ltd.
Rush Gears Inc.
Santasalo North America
Satellite Gear
Schafer Gear Works, Inc.
Seitz Corporation
SEW-Eurodrive
Shanthi Gears Ltd.
Springer Company Inc.
Standard Industrial Products Co.
STD Precision Gear
Stock Drive Products/ Sterling Instrument
Suda International Gear Works
Tracey Gear & Machine
Tri-Power MPT
Trojon Gear Inc.
UFE Incorporated
Wedin International

Other Gears & Drives

Acme Gear Co., Inc.—*Open Gearing*
Akron Gear & Engineering—*General Machining*
American Gear & Engineering—*Clutches*
Bevel Gears (India)—*Face Clutches, Custom-Made Gear Boxes*
Bonfiglioli Riduttori—*Planetary Gear Boxes*
Boonville Mining Services Inc.—*Fabrications*
Capitol Stampings Corp.—*Steering Sectors*
Commercial Gear & Sprocket—*Jaw Clutches, Large Diameter Gears*
Cone Drive Operations—*Double-Enveloping Worm Gears*
Crown Gear B.V.—*Face Gears, Cylkro Gears*
Custom Gear & Machine—*Gear Assemblies*
Custom Gears, Inc.—*Miter Gears, Cut Plastic Gears*
Davall Gear Co. Ltd.—*Spiradrive® (Spiroid®)*
East Point Foundry—*Custom Gear Casting*
Fairfield Mfg. Co.—*Custom Mechanical Assemblies. Design or build to print*
Federal Gear Corp.—*Gearbox Rebuild & Recondition*
Fleet Tools Ltd.—*High-Precision Gearheads*
Flender-Graffenstaden—*High Speed & Epicylic*
Franke Gear Works Inc.—*Double Enveloping Worm & Gear Sets*
Gajra Gears Ltd.—*Gear Transmissions*
Gear Company of America—*Evoloids*
Geartronics Industries—*Generated Pinion Rod*
General Gear Corporation—*High Helix Gears, Speed-ometer Gears & Rotors*
Globe Gear Co.—*Metric Gears*
Hand Screw Machine—*Serrations for Strapping*
Harmonic Drive Technologies—*Very Fine Pitch*
Involute Tooling Corp.—*Ground Gears*
ITW Spiroid—*Spiroid & Helicon Gearsets*
J&E Hofmann Engineering—*Gearing to 14,000 mm Dia by 2500 mm Face Width*
Keller Machine Co.—*Custom Gear Manufacturing*
Mahr Corporation—*Metering Pumps for Textile & Petrochemical*
Micron Instrument Corp.—*Gearheads*
Nixon Gear—*Ground Gears*
Ohio Gear—*Transmissions*
P.T. International Corp.—*Ground Gears*
Philadelphia Gear Corp.—King of Prussia—*Epicyclic*
Precision Gear Co.—*Non-Involute Forms*
Production Gear & Broach—*Internal Broaching*
The Purdy Corporation—*Curvic Couplings*
Snow-Nabstedt Power Transmission—*Planetary Gear Drives*
Standard Industrial Products Co.—*Rotors*
STD Precision Gear & Instrument—*Special Forms*
Suda International Gear Works—*Curvic Couplings*
Sussex Gear Company—*Linear Actuators*
Teijin Seiki/NIMAC America—*Cycloidal Drives*
Trogetec Inc.—*Cycloidal Gears & Harmonic Gearing*
Waterjet Connection/ Richel Inc.—*Abrasive Waterjet Machining*
Westech Gear—*Specials*
Worrall Grinding Co.—*Film Sprockets*
Zero-Max, Inc.—*Torque Limiters*

GEAR MANUFACTURING MACHINES

Bevel Gear Generating Machines

American Machinery
Ataka Engineering
Basic Machine Tools
Gleason-Pfauter GmbH
Gleason-Pfauter-Hurth
The Gleason Works
Klingelnberg Söhne GmbH
Liebherr/Sigma Pool
Oerlikon Geartec AG
Sales Consultants
V & R Associates
WMW Machinery

Broaching Machines

American Broach & Machine Co.
American Machinery
Colonial Tool Group Inc.
Detroit Broach
Fässler Corp.
General Broach & Eng.
Jack Dustman & Assoc.
Kingsford Broach & Tool
Miller Industrial Service
National Broach & Machine Co.
The Ohio Broach & Machine Co.
Oswald Forst GmbH
Sales Consultants
Ty Miles Inc.
U.S. Broach & Machine

Burnishing Machines

ITW Heartland
M&M Precision Systems
Spline Gauges Ltd.

Chamfering Machines

American Machinery
American Wera Inc.
Ataka Engineering
Basic Machine Tools
Chamfermatic, Inc.
Eltech Inc.
Gleason-Hurth GmbH
Gleason-Pfauter GmbH
Gleason-Pfauter-Hurth
The Gleason Works
Jack Dustman & Assoc.
National Broach & Machine Co.
SU America Inc.
Schenck Turner
V & R Associates
WMW Machinery

Cutting Tool Sharpening Machines

American Broach & Machine Co.
American Machinery

Basic Machine Tools
Colonial Saw Co.
Gleason-Hurth GmbH
Gleason-Pfauter GmbH
Gleason-Pfauter-Hurth The Gleason Works
Huffman Corporation
Klingelnberg Söhne GmbH
Koepfer America, LLC
Liebherr/Sigma Pool
Micromatic Textron
Mitsui Machine Technology
National Broach & Machine Co.
Oerlikon Geartec AG
Star Cutter Co.

Deburring Machines
American Machinery
Basic Machine Tools
Burlytic Systems
Eltech Inc.
Gleason-Hurth GmbH
Gleason-Pfauter GmbH
Gleason-Pfauter-Hurth The Gleason Works
GMI
Holroyd Machine
Jack Dustman & Assoc.
Progressive Technologies
Redin Corporation
SU America Inc.
Schenck Turner

EDM Machines
Bluegrass Precision Machinery
Charmilles Technologies
Easco-Sparcatron
Hansvedt Industries Inc.
KGK International Corp.
Makino
Mecatool USA Ltd.
Okamoto Corp EDM Div.
Raycon Corporation

Gear Grinding Machines
American Machinery
Basic Machine Tools
Bluegrass Precision Machinery
Bourn & Koch Machine Tool Co.
Eltech Inc.
Gleason-Pfauter GmbH
Gleason-Pfauter-Hurth The Gleason Works
GTI Technologies
Hermes Machine Tool
Höfler Maschinenbau
Hoglund Technology
Holroyd Machine
Huffman Corporation
Kapp Sales & Service
Klingelnberg Söhne GmbH
Liebherr/Sigma Pool
Meccanica Nova Corp.
Miller Industrial Service
Mitsubishi Machine Tool
National Broach & Machine Co.
Normac Inc.
Oerlikon Geartec AG
Okamoto Corp EDM Div.
Reishauer Corporation
Sales Consultants
SU America Inc.
WMW Machinery

Heat Treating Equipment
Ajax Magnethermic Corp.
Basic Machine Tools
Bluegrass Precision Machinery
Can-Eng Furnaces Ltd.
Contour Hardening, Inc.
Detroit Flame Hardening
Engineered Heat Treat
Fluxtrol Manufacturing
The Grieve Corporation
Holcroft
Inductoheat Inc.
K.H. Huppert Co.
Klingelnberg Söhne GmbH
Lepel Corporation
McEnglevan Industrial Furnace
Oerlikon Geartec AG
Pacific Industrial Furnace
Pillar Industries
Quench Press Specialists
Radyne Corporation
Surface Combustion Inc.
TOCCO Inc.
Therm Alliance Co.
V.T.M. Co. Ltd.

Hobbing Machines
American Machinery
Basic Machine Tools
Bourn & Koch Machine Tool Co.
GA-Heartland Machine Tool
Gleason-Pfauter GmbH
Gleason-Pfauter-Hurth The Gleason Works
Hermes Machine Tool
Koepfer America, LLC
Lees Bradner Div. Fayscott Co.
Liebherr/Sigma Pool
Mitsubishi Machine Tool
Mitsui Machine Technology
National Broach & Machine Co.
Reishauer Corporation
Sales Consultants
V & R Associates
WMW Machinery

Honing Machines
Basic Machine Tools
Bates Technologies
Bluegrass Precision Machinery
Fässler Corp.
Gleason-Hurth GmbH
Gleason-Pfauter GmbH
Gleason-Pfauter-Hurth The Gleason Works
GTI Technologies
Klingelnberg Söhne GmbH
Micromatic Textron
National Broach & Machine Co.
Oerlikon Geartec AG
Sidley Diamond Tool Co.
Sunnen Products Co.

Inspection Machines
Alpha Precision Inc.
American Machinery
Basic Machine Tools
Bluegrass Machinery
Bourn & Koch Machine Tool Co.
D.I.G.I.T., Inc.
Dyer Company
FGT Gage & Systems Inc.
Gleason-Pfauter GmbH
The Gleason Works
ITW Heartland
Jack Dustman & Assoc.
Klingelnberg Söhne GmbH
Kokusai Inc.
Liebherr/Sigma Pool
M&M Precision Systems
Mahr Corporation
Manufactured Gear & Gage
Miller Industrial Service
Moore Products Co.
National Broach & Machine Co.
NewAge Industries Inc.
Oerlikon Geartec AG
Ono Sokki Technology
Precision Gage Co.
Profile Engineering, Inc.
Progressive Technologies
Roto-Technology, Inc.
Spline Gauges Ltd.

Keyseating Machines
American Machinery
Colonial Tool Group Inc.
Elmass North America
Mitts & Merrill L.P.
The Ohio Broach & Machine Co.

Lapping Machines
Bluegrass Precision Machinery
Gleason-Pfauter GmbH
Gleason-Pfauter-Hurth The Gleason Works
Klingelnberg Söhne GmbH
Lapmaster International
Liebherr/Sigma Pool
Oerlikon Geartec AG

Measuring Machines
Alpha Precision Inc.
American Machinery
Basic Machine Tools
Bluegrass Precision Machinery
Dyer Company
Holroyd Machine
ITW Heartland
Klingelnberg Söhne GmbH
Krautkramer Branson
Liebherr/Sigma Pool
M&M Precision Systems
Mahr Corporation
Miller Industrial Service
Oerlikon Geartec AG
Ono Sokki Technology
Precision Gage Co.
Profile Engineering, Inc.
Spline Gauges Ltd.
United Tool Supply

Milling Machines
American Machinery
Bourn & Koch Machine Tool Co.
Gleason-Pfauter-Hurth
Mitsubishi Machine Tool

Powder Metal Presses
Wabash MPI

Quenching Presses
Wabash MPI

Shaping Machines
American Machinery
Basic Machine Tools
Bluegrass Precision Machinery
Elmass North America
Fellows Corp.
Gleason-Pfauter GmbH
Gleason-Pfauter-Hurth The Gleason Works
Hermes Machine Tool
Liebherr/Sigma Pool
Mitsubishi Machine Tool
Parker Industries Inc.
WMW Machinery

Shaving Machines
American Machinery
Basic Machine Tools
Bluegrass Precision Machinery

Gleason-Hurth GmbH
Gleason-Pfauter GmbH
Gleason-Pfauter-Hurth
The Gleason Works
Liebherr/Sigma Pool
Micromatic Textron
Mitsubishi Machine Tool
National Broach & Machine Co.

Spline Rolling Machines

Colonial Tool Group Inc.
General Broach & Eng.
M&M Precision Systems
Micromatic Textron
Moore Products Co.
National Broach & Machine Co.

Testing Machines

American Machinery
Basic Machine Tools
Fellows Corp.
Gleason-Pfauter GmbH
The Gleason Works
Holroyd Machine
Klingelnberg Söhne GmbH
Krautkramer Branson
Liebherr/Sigma Pool
Manufactured Gear & Gage
NewAge Industries Inc.
Oerlikon Geartec AG
Ono Sokki Technology
Parker Industries Inc.
Precision Gage Co.
Profile Engineering, Inc.
Trisys
UBM Corporation

Turning Machines

American Machinery
Bluegrass Precision Machinery
Hermes Machine Tool
Jack Dustman & Assoc.
Miller Industrial Service
Mitsubishi Machine Tool
V & R Associates
WMW Machinery

Worm Milling Machines

American Machinery
Basic Machine Tools
Eltech Inc.
Gleason-Pfauter GmbH
Gleason-Pfauter-Hurth
The Gleason Works
Koepfer America, LLC
WMW Machinery

Other Gear Manufacturing Machines

American Wera Inc.—*Polygon Cutting (Profilating)*
Ataka Engineering—*Cutter Sharpening Machines*
Colonial Saw Co.—*Hob Sharpeners*
DoAll—*Sawing Machines & Blades*
Hoglund Technology Corp.—*Computerized Wheel Dressers*
Koepfer America, LLC—*hread Whirling and Milling Machines*
Manufacturing Technology Inc.—*Friction Welding Machines*
Mitsubishi Laser—*Laser Cutting Machines*
National Broach & Machine Co.—*Die Rolling Machines*
NewAge Industries Inc.—*Hardness Testers—Auto Traverse*
Oberlin Filter Co.—*Filtration Equipment, Pressure Filters*
One Cryo Inc.—*Cryogenic Tempering Equipment*
Progressive Technologies—*Surface Treatment*
Raycon Corporation—*Laser Welders*
Ty Miles Inc.—*Ballizing Machines*
USACH Technologies—*ID & Face Grinders*

GEAR MATERIALS

Cast Iron

The A.B.A. Company
Adobe Precision Gear
Dura-Bar
Great Taiwan Gear Ltd.
J&E Hofmann Engineering
Lovejoy Steel—Cincinnati
Rush Gears Inc.
Sales Consultants
Scot Forge
Wes-Tex Gear Inc.
Zhuhai Intercontinental Pulleys Ltd.

Gear Blanks

Accurate Specialties Inc.
Adobe Precision Gear
Akron Gear & Engineering
Bengal Industries
Blanchat Machine Co.
Cornell Forge Co.
Dabko Industries Inc.
Dura-Bar
East Point Foundry
Elmass North America
Forging Specialties
The Gear Works-Seattle
Globe Gear Co.
Horsburgh & Scott
Howard's Machine Shop
J&E Hofmann Engineering
Lovejoy Steel—Cincinnati
Lufkin Industries Gear Repair
McInnes
Milford Gear Works
Mobile Pulley & Machine
Moore Machine & Gear
Nordex, Inc.
Orlandi Gear
Penntech
PIC Design
Precipart Corp.
Presrite Corp.
Process Industries
Pulley Manufacturers Inc.
Qualicast Corp.
Rush Gears Inc.
Sales Consultants
Stock Drive Products/ Sterling Instrument
Trogetec Inc.
Wes-Tex Gear Inc.
Wohlert Corporation
Worrall Grinding Co.

Plastics

Adobe Precision Gear
Bengal Industries
The Gear Works-Seattle
Globe Gear Co.
Great Taiwan Gear Ltd.
Hoechst Celanese Corp.
Howard's Machine Shop
Intech Corporation
Pulley Manufacturers Inc.
Rush Gears Inc.
Trogetec Inc.

Powdered Metals

Asco Sintering Co.
Bestmetal Corporation
Burgess-Norton Mfg. Co.
Carbon City Products
The Gear Works-Seattle
Great Taiwan Gear Ltd.
Metal Powder Industries Federation
Rush Gears Inc.

Steels

The A.B.A. Company
Adobe Precision Gear
Crucible Service Centers
Forging Specialties
The Gear Works-Seattle
Globe Gear Co.
Great Taiwan Gear Ltd.
Impact Strategies Inc.
J&E Hofmann Engineering
Latrobe Steel Company
Lovejoy Steel Company—Charlotte
Lovejoy Steel—Cincinnati
Lovejoy Steel Company—Streetsboro
Lovejoy Steel Company—York
McInnes
Moore Machine & Gear
Pulley Manufacturers Inc.
Rush Gears Inc.
Scot Forge
Trogetec Inc.
Wes-Tex Gear Inc.

Other Materials

The A.B.A. Company—*Rolled Rings*
Crucible Service Centers—*High Speed Steel For Cutting Tools*
Forging Specialties—*Ring Forgings*
Intech Corporation—*Plastic/Metal Composite*
Lovejoy Steel Company—Charlotte, Streetsboro, York—*Cast Iron*
Mc Innes—*Steel Forgings, Seamless Rolled Rings.*
Portland Forge—*Steel Forgings*
Presrite Corp.—*Forged Tooth Gears*
Scot Forge—*Gear Weldments, Forged Rings & Hubs.*
SIFCO Selective Plating—*Brush Plated Stop-Off and Wear-in Coatings, Brush Plating Chemicals*
Trogetec Inc.—*Special*

GEAR SERVICES

Broaching Services

Action Gear & Broaching
The Adams Company
American Broach & Machine Co.
American Mach. & Gear
Buckeye Gear Co.
Chandler Machine Co.
Circle Gear & Machine
Columbia Gear Corp.
Davall Gear Co. Ltd.
Dayton Gear & Tool
Detroit Broach
Elmass North America
Fisher's Gear & Machine
Gear Company of America

Power Integrated Pop-up™

Lift/Rotate Induction Heat-Treating System

Radyne's Power Integrated Pop-up™ heat-treat center is a self-contained system for hardening and tempering components in a lift/rotate, submerged quench method to meet the specific needs of the heat treater. A user-friendly machine interface panel and PLC control enable quick and easy setup and operation. An integrated, modern, efficient, transistorized inverter power supply can match a wide variety of heating coils with easy-to-change tuning capacitors and a multitap output isolation transformer.

The lift actuator assembly includes a ball bearing linear way mounted under a stainless steel sink through double lip wave seals. A chrome-plated stainless steel spindle is mounted on a tapered roller bearing, enclosed in a steel housing. The lift mechanism allows load/unload, heat and quench positions.

The Perfect Integration

The combination of Radyne's Power Integrated Pop-up™ and APEX QA™ Quality Assurance system represents the latest in induction heat-treating technology.

RADYNE

Innovators in Induction Heating

1-800-236-8360

211 W. Boden Street
Milwaukee, WI 53207, U.S.A.
(414) 481-8360 • Fax: (414) 481-8303
e-mail: radyne@execpc.com
http://www.radyne.com

CIRCLE 139

Great Taiwan Gear Ltd.
Harder Precision Components
Lawler Gear Corp.
Milwaukee Gear Co.
Moore Gear Mfg. Co.
Mr. Gears, Inc.
National Broach & Machine Co.
Oswald Forst Gmbh
Pennsylvania Gear Corp.
Perry Technology Corp.
Precision Gear Inc.
Precision Gears, Inc.
Pulley Manufacturers Inc.
The Purdy Corporation
Rawling Gear Inc.
Rj Link International
Ronson Gears Pty. Ltd.
Rush Gears Inc.
Schafer Gear Works, Inc.
Tracey Gear & Machine
Trojon Gear Inc.
Ty Miles Inc.
U.S. Broach & Machine
Wedin International

Consulting

Action Gear & Broaching
Adobe Precision Gear
Advance Gear & Machine
Akron Gear & Engineering
Aplus Engineering Inc.
Applied Mechaniques
Aston Metallurgical Services
Axicon Technologies
Bourn & Koch Machine Tool Co.
Carbon City Products
C-B Gear & Machine
C-Dot Engineering
CETIM
Ciateq, A. C.
The Cincinnati Gear Co.
Contour Hardening, Inc.
Custom Gear & Machine
D.L. Borden, Inc.
Dabko Industries Inc.
Davall Gear Co. Ltd.
Dayton Gear & Tool
Diamond Solutions, Inc.
Drive Systems Technology
Drivetrain Technology Center
Fairfield Mfg. Co.
Fisher's Gear & Machine
Gary P. Mowers, Inc.
Geartech
Geartech Ltd. - Tecnologia de Engrenagens
Great Taiwan Gear Ltd.
Guy Crader Consulting
GW Plastics
Horsburgh & Scott
Hy-Mech Systems Inc.
I.S.P.J.A.E.
Impact Strategies Inc.
Industrial Technology Institute
Intech Corporation
J&E Hofmann Engineering
Jack Dustman & Assoc.
James Reid Gear Services
Labeco
Liebherr/Sigma Pool
McGinty Gear
Manufactured Gear & Gage
Mechanical & Structural Design & Software
Metal Powder Industries Federation
Milburn Engineering
Milford Gear Works
Milwaukee Gear Co.
Moore Gear Mfg. Co.
Moore Machine & Gear
Mostar Gear & Machine
Mr. Gears, Inc.
NASA Lewis Research Center
National Broach & Machine Co.
Packer Engineering
Performance Gear Systems Inc.
Powertrain Engineers
Precision Engineering
Precision Gear Inc.
R. Cushman & Assoc.
R.E. Smith & Co.
Reilly Engineering Inc.
Riley Gear Corp.
Roto-Technology, Inc.
Santasalo North America
SBR Consulting
Seitz Corporation
Software Engineering Service
Spline Gauges Ltd.
Sussex Gear Company
Swiglo Metallurgical Consulting
Technimet
Tifco Gage & Gear
Trogetec Inc.
U.S. Tech Corp.
Ultron Incorporated
Universal Technical Systems
Van Gerpen-Reece Engineering
Wedin International
Westech Gear
Wes-Tex Gear Inc.

Cryogenics

American Brazing
Best Engineering, Inc.
C-B Gear & Machine
Dynamic Metal Treating
Horsburgh & Scott
Impact Strategies Inc.
Iron Bound Heat Treating
J&E Hofmann Engineering
One Cryo Inc.
Paulo Products Company —Bessemer
Paulo Products Company —Memphis
Paulo Products Company —Murfreesboro
Paulo Products Company —Peculiar
Paulo Products Company —St. Louis
Sales Consultants
Trogetec Inc.

Cutting Tool Sharpening

Action Gear & Broaching
American Broach & Machine Co.
American Mach. & Gear
Apex Broach & Machine
Bean Tool, Die & Engineering
Best Engineering, Inc.
Dayton Gear & Tool
Forest City Gear
Fubri s.r.l.
Gleason-Pfauter GmbH
Gleason-Pfauter-Hurth
The Gleason Works
GMI
J&E Hofmann Engineering
Koepfer America, LLC
Koro Sharpening Service
Mill Max Tools Pvt. Ltd.
Moore Gear Mfg. Co.
Mr. Gears, Inc.
Multi-Arc Inc.
National Broach & Machine Co.
Pfauter-Maag Cutting Tools
Reef Gear Mfg. Inc.
Richter Precision Inc.
Ronson Gears Pty. Ltd.
Sales Consultants
Schafer Gear Works, Inc.
Star Cutter Co.
Wedin International

Fault Analysis

Adobe Precision Gear
American Stress Technologies
Applied Mechaniques
Ashot Ashkelon Indust.
Ashot USA Inc.
Aston Metallurgical Services
C-B Gear & Machine
CETIM
Ciateq, A.C.
The Cincinnati Gear Co.
D.L. Borden, Inc.
Drive Systems Technology
Fairfield Mfg. Co.
Forest City Gear
Horsburgh & Scott
Hy-Mech Systems Inc.
I.S.P.J.A.E.
J&E Hofmann Engineering
Lambda Research
Lufkin Industries Gear Repair
Mechanical & Structural Design & Software
Milburn Engineering
Modern Industries Inc.
Mr. Gears, Inc.
NASA Lewis Research Center
National Metrology
Packer Engineering
Paulo Products Company —Peculiar
Performance Gear Systems Inc.
Philadelphia Gear Corp.—Houston
Powertrain Engineers
R. Cushman & Assoc.
Reilly Engineering Inc.
RTS Rework Inc.
Seitz Corporation
Surface Technology, Inc.
Technimet
Trogetec Inc.
Wedin International
Westech Gear
Wes-Tex Gear Inc.

Gear Coatings

Diamond Black Technologies
Dynamic Metal Treating
Great Taiwan Gear Ltd.
J&E Hofmann Engineering
Multi-Arc Inc.

Gear Design

Action Gear & Broaching
Adobe Precision Gear
Advance Gear & Machine
Akron Gear & Engineering
Allied Devices Corp.
Aplus Engineering Inc.
Applied Mechaniques
Ashot Ashkelon Indust.
Ashot USA Inc.
Axicon Technologies
Blanchat Machine Co.
Carbon City Products
Caterpillar Industrial Products Inc.
C-Dot Engineering
CETIM
Ciateq, A.C.
The Cincinnati Gear Co.
CMD (UK) Ltd.
Contour Hardening, Inc.
Cunningham Industries
Custom Gear & Machine
D.L. Borden, Inc.
Davall Gear Co. Ltd.
Drive Systems Technology
Drivetrain Technology Center
Dynamic Tool Grinding
Fairfield Mfg. Co.
Gear Works, Inc.
The Gear Works-Seattle
Gearesearch Assoc.
Geartech Ltd. - Tecnologia de Engrenagens
Global Gear
Great Taiwan Gear Ltd.
Guy Crader Consulting
GW Plastics
Harder Precision Components
HMC
Holroyd Machine
Horsburgh & Scott
Hy-Mech Systems Inc.
I.S.P.J.A.E.
Insco Corporation
Intech Corporation
Invo Spline Inc.
J&E Hofmann Engineering
Kreiter Geartech
Labeco
Lufkin Industries Gear Repair
McGinty Gear
Mechanical & Structural Design & Software
Milburn Engineering
Milford Gear Works
Milwaukee Gear Co.
Moore Machine & Gear
Mr. Gears, Inc.
NASA Lewis Research
O'Neill Gear
Packer Engineering
PC Enterprises
Pennsylvania Gear Corp.
Penntech
Performance Gear Systems Inc.
Power Engineering & Mfg. Ltd.
Powertrain Engineers
Precipart Corp.
Precision Engineering
Qualicast Corp.
R. Cushman & Assoc.
Reilly Engineering Inc.
Riley Gear Corp.
Rj Link International
Ronson Gears Pty. Ltd.
Santasalo North America
SBR Consulting
Seitz Corporation
Spline Gauges Ltd.
Sussex Gear Company
Tifco Gage & Gear
Trogetec Inc.
UFE Incorporated
Van Gerpen-Reece Engineering
Von Ruden Mfg.
Wedin International
West Industries Inc.
Westech Gear
Wes-Tex Gear Inc.
Winzeler Gear
Xtek Inc.

Gear Engineering

Action Gear & Broaching
Adobe Precision Gear
Advance Gear & Machine
Akron Gear & Engineering
Allied Devices Corp.
Aplus Engineering Inc.
Applied Mechaniques
Ashot Ashkelon Indust.
Ashot USA Inc.
Aston Metallurgical Services
Axicon Technologies
Blanchat Machine Co.
C-Dot Engineering
CETIM
Ciateq, A.C.
The Cincinnati Gear Co.
Cloyes Gear & Products—Auburn Hills
CMD (UK) Ltd.
Contour Hardening, Inc.
Custom Gear & Machine
D.L. Borden, Inc.
Dabko Industries Inc.
Davall Gear Co. Ltd.
Dayton Gear & Tool
Drive Systems Technology
Drivetrain Technology Center
Dynamic Tool Grinding
Fairfield Mfg. Co.
Federal Gear Corp.
Foote-Jones/Illinois Gear
Gear Company of America
Gear Research Institute
The Gear Works-Seattle
Gearesearch Assoc.
Gears & Drive Systems
Geartech Ltd.—Tecnologia de Engrenagens
Global Gear
Great Taiwan Gear Ltd.
Guy Crader Consulting
Harder Precision Components
Holroyd Machine
Horsburgh & Scott
Hy-Mech Systems Inc.

I.S.P.J.A.E.
Insco Corporation
Intech Corporation
Invo Spline Inc.
J&E Hofmann Engineering
Kreiter Geartech
Labeco
Lufkin Industries Gear Repair
Lyon Gear
Mechanical & Structural Design & Software
Milburn Engineering
Milford Gear Works
Milwaukee Gear Co.
Modern Industries Inc.
Moore Machine & Gear
Mostar Gear & Machine
Mr. Gears, Inc.
NASA Lewis Research Center
Nixon Gear
O'Neill Gear
Packer Engineering
Patterson Gear & Machine
Pennsylvania Gear Corp.
Penntech
Performance Gear Systems Inc.
Perry Technology Corp.
Philadelphia Gear Corp.—Houston
Power Engineering & Mfg. Ltd.
Powertrain Engineers
Precipart Corp.
Precision Engineering
Process Industries
Qualicast Corp.
R. Cushman & Assoc.
Reilly Engineering Inc.
Riley Gear Corp.
Rj Link International
Santasalo North America
SBR Consulting
Seitz Corporation
Software Engineering Service
Spline Gauges Ltd.
Stock Drive Products/Sterling Instrument
Sussex Gear Company
Tifco Gage & Gear
Trisys
Trogetec Inc.
UFE Incorporated
Universal Technical Systems
Van Gerpen-Reece Engineering
Vesta Works USA, Inc.
Wedin International
West Industries Inc.
Westech Gear
Wes-Tex Gear Inc.
Winzeler Gear
Xtek Inc.

Gear Grinding Services

Advance Gear & Machine
Aerocom Industries Inc.
Allied Gear Co.
American Mach. & Gear
Aplus Engineering Inc.
Ashot Ashkelon Indust.
Ashot USA Inc.
Blanchat Machine Co.
Bourn & Koch Machine Tool Co.
Bucyrus International, Inc.
CMD (UK) Ltd.
Caterpillar Industrial Products Inc.
C-B Gear & Machine
Chardam Gear Co.
The Cincinnati Gear Co.
Columbia Gear Corp.
Davall Gear Co. Ltd.
Dayton Gear & Tool
Fairfield Mfg. Co.
Federal Gear Corp.
Foote-Jones/Illinois Gear
G&N Rubicon Gear
The Gear Works-Seattle
Gears & Drive Systems
Great Taiwan Gear Ltd.
Hamilton Gear
Hanover Gear Mfg. Co.
Höfler Maschinenbau
Horsburgh & Scott
Insco Corporation
Invo Spline Inc.
J&E Hofmann Engineering
Kreiter Geartech
Lawler Gear Corp.
Lufkin Industries Gear Repair
Lyon Gear
Meccanica Nova Corp.
Merit Gear Corp.
Midwest Gear Corp.
Milwaukee Gear Co.
Modern Industries Inc.
Modified Gear & Spline
Nakanishi Gear
NASA Lewis Research
National Broach & Machine Co.
Niagara Gear Corp.
Nixon Gear
Oliver Gear, Inc.
Overton Gear & Tool
P.F. Markey, Inc.
Patterson Gear & Machine
Pennsylvania Gear Corp.
Penntech
Philadelphia Gear Corp.—Houston
Precision Gear Inc.
Process Industries
Pro-Gear Co. Inc.
The Purdy Corporation
Qualicast Corp.
Riley Gear Corp.
Riverside Spline & Gear
Ronson Gears Pty. Ltd.
Spline Gauges Ltd.
SU America Inc.
Tifco Gage & Gear
Trogetec Inc.
Westech Gear
Wedin International
Xtek Inc.

Heat Treating Services

Accurate Ion Technologies
Advanced Material Process Corp.
Ajax Magnethermic Corp.
Alfe Heat Treating
Alfred Heller Heat Treating
American Brazing
American Metal Treating
Aplus Engineering Inc.
Applied Process Inc.
Ashot Ashkelon Indust.
Ashot USA Inc.
Blanchat Machine Co.
Caterpillar Industrial Products Inc.
The Cincinnati Gear Co.
Commercial Steel Treating
Contour Hardening, Inc.
D.L. Borden, Inc.
Detroit Flame Hardening
Disston Precision Inc.
Drivetrain Technology Center
Dynamic Metal Treating
Engineered Heat Treat
Euclid Heat Treating Co.
Fairfield Mfg. Co.
Fellows Corp.
Fluxtrol Manufacturing
Foote-Jones/Illinois Gear
FPM Heat Treating
Gear Company of America
General Surface Hardening
Gleason-Pfauter GmbH
Gleason-Pfauter-Hurth
The Gleason Works
Great Taiwan Gear Ltd.
Hamilton Gear
Horsburgh & Scott
Hudapack Metal Treating—Addison
Hudapack Metal Treating—Elkhorn
Impact Strategies Inc.
Iron Bound Heat Treating
J&E Hofmann Engineering
Kolene Corporation
Lepel Corporation
Lufkin Industries Gear Repair
Merit Gear Corp.
Metlab Co.
Mill Max Tools Pvt. Ltd.
Milwaukee Gear Co.
Modern Industries Inc.
Molon Gear & Shaft
Moore Gear Mfg. Co.
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Nitrex Metal Technologies
Oliver Gear, Inc.
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Patterson Gear & Machine
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Paulo Products Company—Memphis
Paulo Products Company—Murfreesboro
Paulo Products Company—Nashville
Paulo Products Company—Peculiar
Paulo Products Company—St. Louis
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Wedin International
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West Industries Inc.
Westech Gear
Xtek Inc.

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Allied Devices Corp.
Alpha Precision Inc.
American Stress Technologies
Aplus Engineering Inc.
Ashot Ashkelon Indust.
Ashot USA Inc.
Aston Metallurgical Services
Axicon Technologies

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Best Engineering, Inc.
Blanchat Machine Co.
Bucyrus International, Inc.
CETIM
The Cincinnati Gear Co.
Contour Hardening, Inc.
Davall Gear Co. Ltd.
Drivetrain Technology Center
Euro-Tech Corp.
Fellows Corp.
Forest City Gear
Fubri s.r.l.
Gear Company of America
The Gear Works-Seattle
Gerhardt Gear Co.
Gleason-Pfauter-Hurth
Great Taiwan Gear Ltd.
Harder Precision Components
Horsburgh & Scott
Interstate Tool Corp.
Invo Spline Inc.
J&E Hofmann Engineering
Krautkramer Branson
Kreiter Geartech
Lufkin Industries Gear Repair
Lyon Gear
M&M Precision Systems
Mahr Corporation
Manufactured Gear & Gage
Merit Gear Corp.
Milwaukee Gear Co.
Modern Industries Inc.
Mr. Gears, Inc.
National Metrology
Niagara Gear Corp.
Nixon Gear
Overton Gear & Tool
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Penntech
Perry Technology Corp.
Philadelphia Gear Corp.—Houston
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Precision Gear Inc.
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Roto-Technology, Inc.
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Scott Machine Tool Co.
Spline Gauges Ltd.
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West Industries Inc.
Westech Gear
Wes-Tex Gear Inc.
Xtek Inc.

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Ashot USA Inc.
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J&E Hofmann Engineering
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Diamonex Performance Products
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Gleason-Pfauter-Hurth
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Reid Tool Service Inc.
Richter Precision Inc.
Russell Holbrook & Henderson
Star Cutter Co.
Surface Technology Corp.

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Akron Gear & Engineering—*Large Diameter Turning, CNC Milling*
American Brazing—*Brazing*
American Gear & Engineering—*Slotting, CNC Turning*
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The Cincinnati Gear Co.—*Gearbox Overhaul & Field Service*
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Drivetrain Technology Center—*Testing & Measuring*
East Point Foundry—*Custom Casting*
Eltech Inc.—*Hob Sharpening*
Fluxtrol Manufacturing—*Induction Heat Treating*
Globe Gear Co.—*Cut Teeth, Reverse Engineering*
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J&E Hofmann Engineering —*On-site Gear Installations, Reconditioning & Alignment*
Kolene Corporation—*Molten Salt Bath Heat Treating*
Lambda Research—*X-Ray Diffraction Laboratory*
McGinty Gear—*Spline Design*
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Modern Industries Inc.—*Metallurgical Evaluation*
Moore Products Co.—*Program Management Gage Systems*
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Paulo Products Company—St. Louis—*Brazing*
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Redin Corporation—*Gear Deburring*
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CIRCLE 165

I98-03

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Rebco Industrial Products
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Star Cutter Co.
SU America Inc.
Tri-Wire, Inc.

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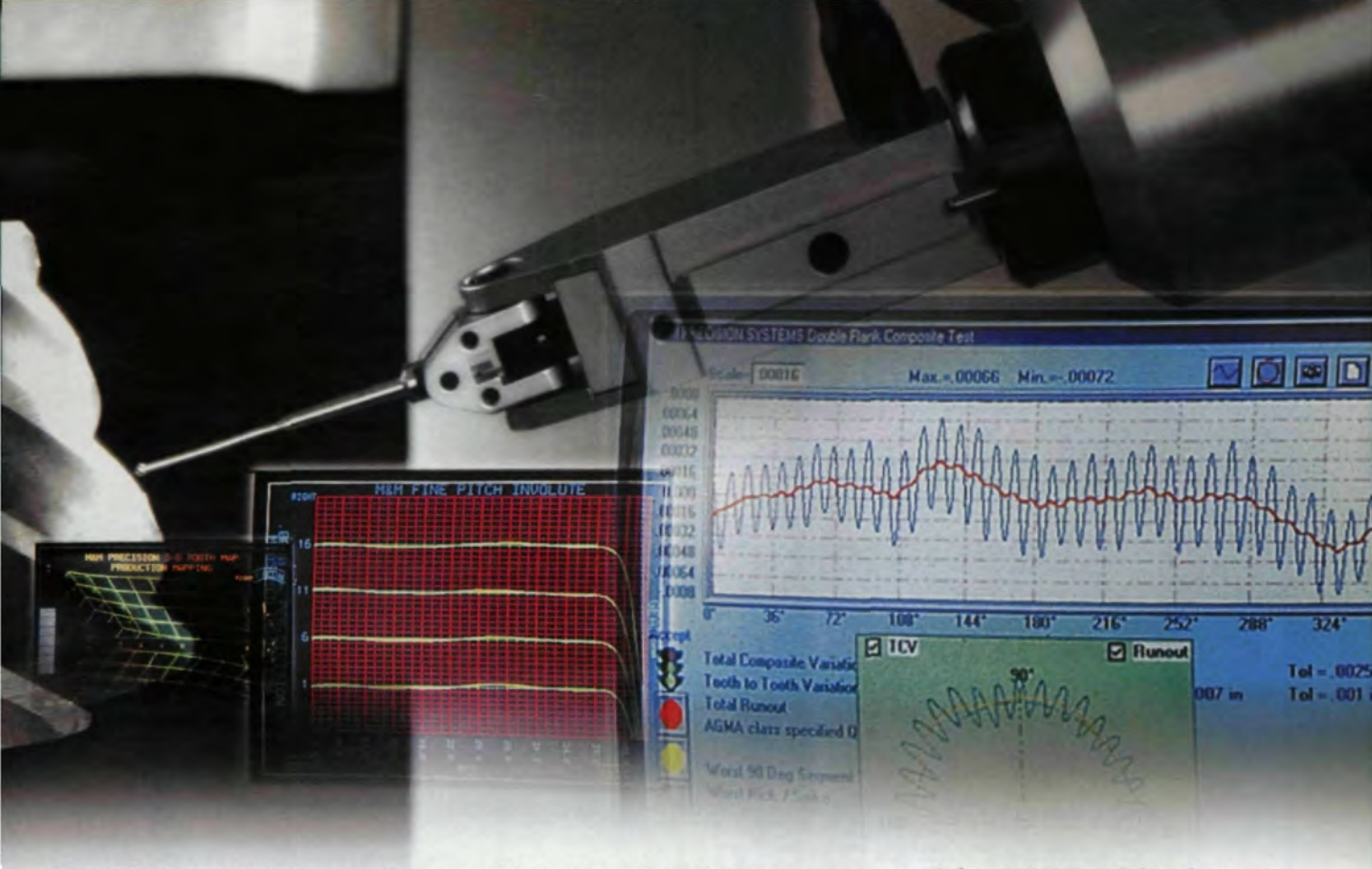

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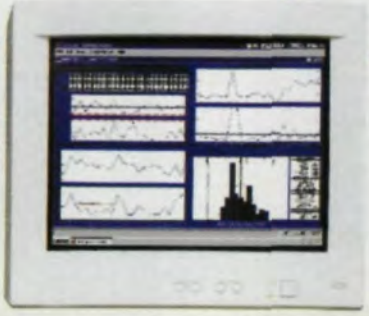

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GMI
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Rebco Industrial Products
Reid Tool Service Inc.
Russell Holbrook & Henderson
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Other Tooling & Accessories

A/W Systems Co.—*Cutter Bodies and Blades*
Bates Technologies—*Honing Tools*
Bijur Lubricating Corp.—*Lubricating Equipment*
Cold Forming Technology—*Spline Rolling Tools, Thread Rolling Tools*
Detroit Broach—*Broaching Tool Holders*
Euro-Tech Corp.—*Spline Gage Certification*
Fubri s.r.l.—*Special Milling Cutters*
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Gleason-Hurth GmbH—*Honing Tools*
Gleason-Pfauter GmbH—*Honing Tools*
The Gleason Works—*Honing Tools*
GMI—*Hard Gear Wheels, Diamond Dressing Devices, Maag Tools*
Hermes Machine Tool—*Tooling Packages for Specific Machine Tool Purchase*
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ITW Heartland—*Burnishing Dies*
Kapp Tech L.P.—*CBN Gear & Form Grinding Wheels*
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Mahr Corporation—*Setting Rings & Discs, Plugs, Wires & Gage Balls*
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Star Cutter Co.—*Gear & Spline Milling Cutters*
Universal Superabrasives—*Dressing Equipment*
Wendt Dunnington—*Diamond Dressing Rollers, Dressing Equipment*

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Gleason-Pfauter GmbH
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The Gleason Works
Hermes Machine Tool
Jack Dustman & Assoc.
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Mahr Corporation
Manufactured Gear & Gage
Mitsubishi Machine Tool
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Best Engineering, Inc.
Bluegrass Precision Machinery
Cameron Hydraulic Workholding
Emuge Corp.
Euro-Tech Corp.
Gleason-Hurth GmbH
Gleason-Pfauter GmbH
Gleason-Pfauter-Hurth
The Gleason Works
Hermes Machine Tool
Jack Dustman & Assoc.
JRM International
LeCount Inc.
Mahr Corporation
Manufactured Gear & Gage
P.F. Markey, Inc.
Reid Tool Service Inc.
Roto-Technology, Inc.
Schunk Inc.
Speedgrip Chuck Inc.
Star Cutter Co.
Sytec Corporation
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Toolink Engineering
Trogetec Inc.
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Gleason-Pfauter GmbH
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Mitsubishi Machine Tool
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Scott Machine Tool Co.
Sytec Corporation
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Bluegrass Precision Machinery

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Interstate Tool Corp.
Jack Dustman & Assoc.
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Speedgrip Chuck Inc.
Star Cutter Co.
SU America Inc.
Toolink Engineering
Trogetec Inc.
W. E. Litwin Assoc.

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Bluco Corp.—*Expanding Mandrels For Broaches*
Cameron Sabertooth Mandrel—*Mandrels & Workholding Devices*
Emuge Corp.—*Precision Workholding*
Euro-Tech Corp.—*Compensating Washers or Hobs*
Madison Face Driver—*Face Driving Centers*
Meccanica Nova Corp—*Custom Grinding Fixturing & Workholding*
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Ty Miles Inc.—*Broach Fixturing*

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Pfauter-Maag Cutting Tools
Philadelphia Gear Corp.
Roto-Technology, Inc.
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Van Gerpen-Reece Engineering
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Gearesearch Assoc.
I.S.P.J.A.E.
Industrial Technology Institute
Lambda Research
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CIRCLE 108

COMPANY INDEX

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GIHP indicates companies whose pages can be found on *The Gear Industry Home Page™* at www.geartechnology.com. PTHP indicates companies whose pages can be found on *The Power Transmission Home Page™* at www.powertransmission.com.

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www.contourhardening.com

Cornell Forge Co.
6666 W. 66th St.
Chicago IL 60638
Ph: 773-767-4242
Fax: 773-767-9443

Cotta Transmission Co.
P.O. Box 5727
Rockford IL 61125-0727
Ph: 815-394-7400 PTHP
Fax: 815-394-7428
cottatrans@aol.com
http://members.aol.com/cottatrans/index.htm

Crown Gear B.V.
Buurserstraat 200
Enschede NL-7544 RG PTHP
Netherlands
Ph: (31) 53-477-3622
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Crucible Service Centers
5639 W. Genesee St.
Camillus NY 13031-0991
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Fax: 315-487-4028

Cunningham Industries
102 Lincoln Ave.
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Ph: 203-324-2942
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Curtis Machine Co. Inc.
2500 East Trail
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Dodge City KS 67801
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Fax: 316-227-2971
curtis@curtismachine.com
www.curtismachine.com

Custom Gear & Machine
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Fax: 510-895-5417

Custom Gears, Inc.
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Cyclo Transmissions Ltd.
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D. A. Stuart Co.
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D.I.G.I.T., Inc.
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D.L. Borden, Inc.
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Fax: (91) 22-5563843 or
(91) 22-5680864
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http://deekaygears.home.ml.org

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Engineered Heat Treat, Inc.
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Fax: 248-588-6533
www.eht-inc.com

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www.fpmht.com

Franke Gear Works Inc.
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www.vermontel.net/~gwi/index.html

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Seattle WA 98108-0886 PTHP
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www.thegearworks.com

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73743.1322@compuserve.com

Gears & Drive Systems, Inc.
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Spring House PA 19477-0109
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drives@erols.com
www.gears-drives.com

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Hydro Honing Laboratories, Inc.
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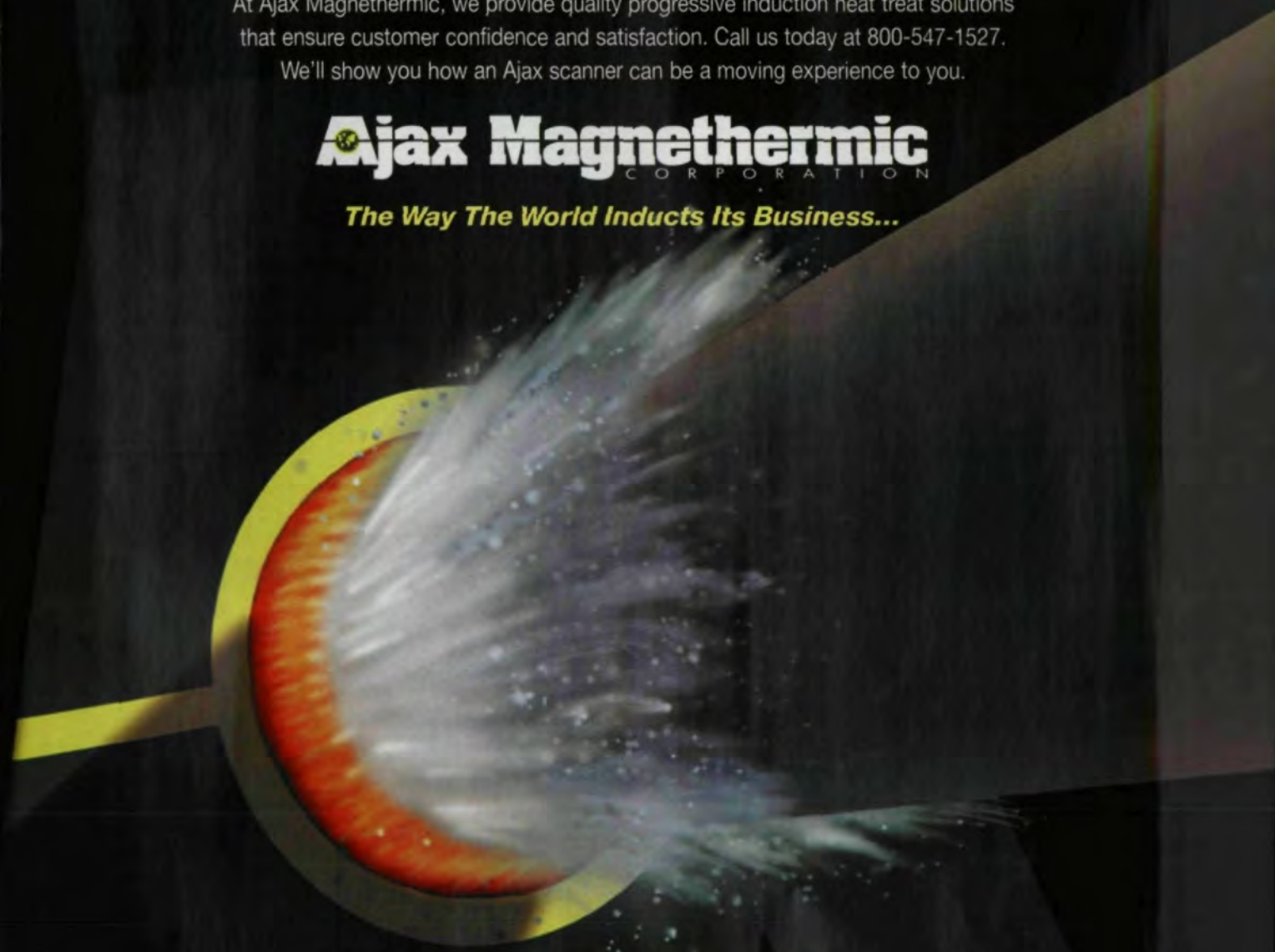

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CIRCLE 161

The Basics of Gear Metrology and Terminology Part II

Edward Lawson
Senior Applications Engineer, Mahr Corporation

In the last section, we discussed gear inspection; the types of errors found by single and double flank composite and analytical tests; involute geometry; the involute cam and the causes and symptoms of profile errors. In this section, we go into tooth alignment and line of contact issues including lead, helix angles, pitch, pitchline runout, testing and errors in pitch and alignment.

Tooth Alignment

Helical Lead and Helix Angles. The lengthwise profile of an involute helicoid gear tooth is a simple helical lead. Testing of this parameter is still commonly referred to as lead testing despite the changes in the AGMA standard, which now more precisely terms this parameter as tooth alignment. The helical lead of a gear tooth has the same geometry as the helical lead of a screw thread. It is defined by the axial advance (the lead) per 360 degrees of rotational displacement upon a cylinder. For spur gears, the lead is infinite (Fig 1).

While the typical screw thread embodies many complete helical leads, the typical gear tooth embodies only a fraction of one lead. It is, therefore, more difficult to visualize the helical geometry of the gear tooth. However, the helical gear tooth, which appears to be simply tilted at an angle to the gear axis is, in fact, both tilted and wrapped around a cylinder, thereby producing the helical geometry. If a gear tooth alignment is considered by unwrapping the pitch cylinder of the gear onto a flat surface, it will then truly appear as a straight line inclined at an angle to the gear axis. The helix/lead angles will be determined by the relationship of the diameter of the cylinder and the length of the lead specified for the tooth.

The helix angle is found between the tooth alignment and the gear axis while the lead angle is found between the tooth alignment and the transverse plane. It is common for these terms to be incorrectly used interchangeably. A close visual examination of a helical gear tooth will reveal that as the cylinder diameter increases, the helix angle also increases. It is important to note that this phenomenon is a function of differing diameters while the lead remains the same for all diameters of the gear tooth.

Testing Tooth Alignment. This characteristic of helical gear teeth allows for a simple tooth alignment test not unlike the generative tests described in Part I (*Gear Technology*, Sept./Oct.1998). In this case, a sensitive probe is brought into contact with the tooth at any diameter and is then carried in a direction parallel to the gear axis while the gear is rotated. The gear rotation must be in a direct relationship with the axial motion of the probe according to the lead of the gear. If the gear was to be rotated a complete 360 degrees, the probe would move axially a distance equal to the lead. If the tooth alignment being tested is perfect, the sensitive probe will measure no error.

Most such generative tooth alignment testing instruments use some sort of helix guide or sine bar arrangement. CNC devices test tooth alignment by controlling the movements of a rotary axis (spindle) and verticle slide that are not connected by any mechanical components. They are each caused to move under computer control in the same fashion as the classic mechanical instrument

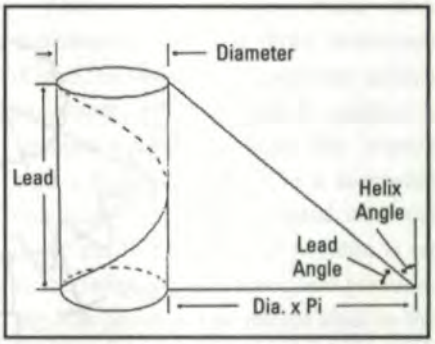

Fig. 1 — Tooth alignment (formerly "Lead"). Courtesy of AGMA.

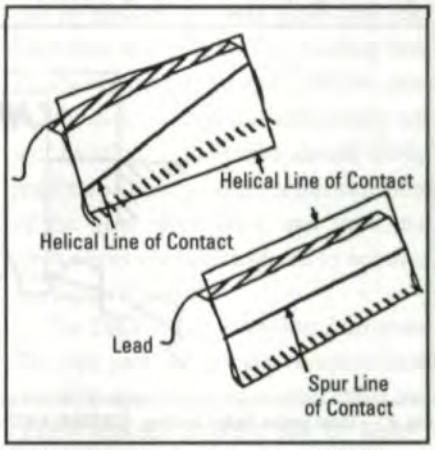

Fig. 2 — Line of contact. Courtesy of AGMA.

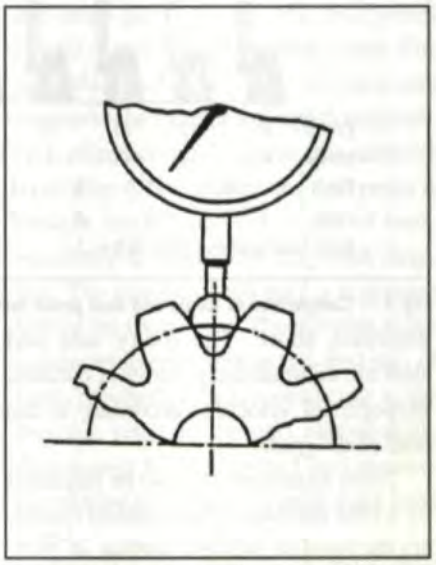

Fig. 3 — Pitchline Runout. Courtesy of AGMA.

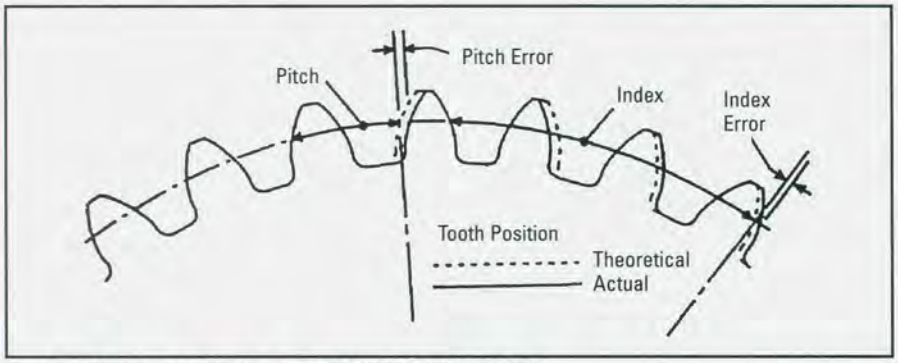

Fig. 4 — Pitch error and index error. ©AGMA/ANSI 2000-A88.

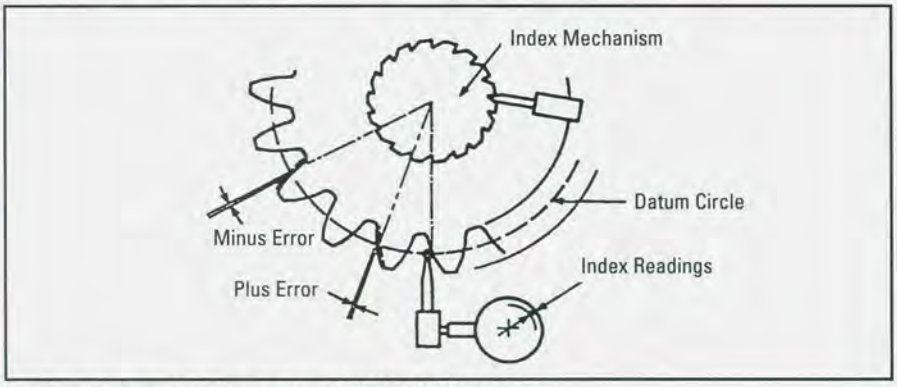

Fig. 5 — Single probe index testing. ©AGMA/ANSI 2000-A88.

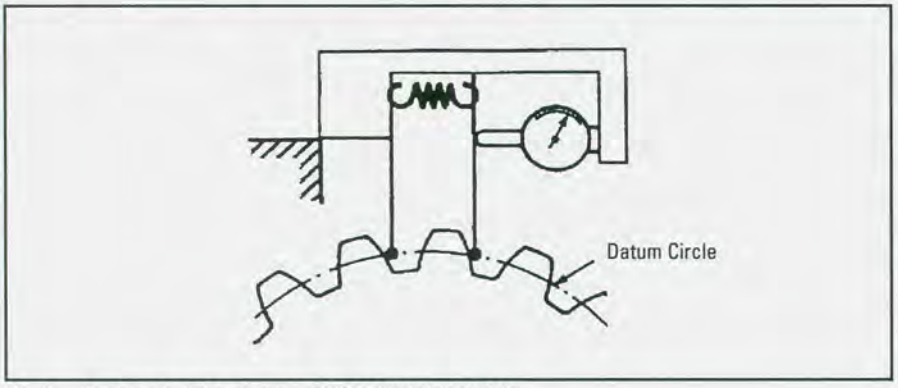

Fig. 6 — Dual probe index testing. ©AGMA/ANSI 2000-A88.

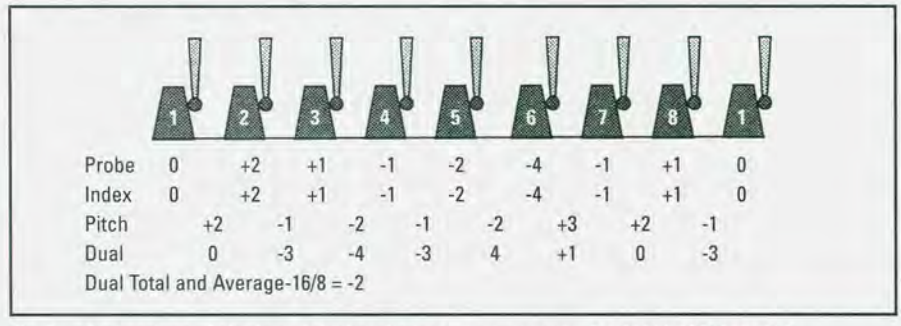

Fig. 7 — Comparison of single and dual probe test measurements. ©AGMA/ANSI 2000-A88.

described above. The rotary axis and slide are commanded to move at constant proportional velocities according to the lead of the gear.

Tooth alignment can also be inspected by CMM machines. This method considers the involute helicoid surface in rectilinear coordinates, a considerably more complex process than the classic generative method described above and an uncommon one.

Types of Tooth Alignment Errors. The primary concern associated with tooth alignment errors is their adverse effect upon gear strength and durability. Tooth strength ratings are normally calculated assuming that the torque load will be applied uniformly across the full face width of the gear. Tooth alignment errors can reduce the region of contact between mates, significantly increasing both the structural stresses and surface contact stresses on the tooth, reducing the gear's actual strength and durability values.

A common category of tooth alignment error is slope error. This type of error causes increased loading on the tooth ends, the place they are least capable of carrying increased stress.

Tooth alignment errors are not commonly associated with noise problems. A gear can have a substantial tooth alignment error and still produce excellent conjugate action if the involute geometry in the reduced region of mesh is of good quality. Tooth alignment errors can, however, increase noise levels for a given transmission error signature by increasing the loading on the gear teeth during meshing action.

Causes of Tooth Alignment Errors. Machine tool alignment problems produce tooth alignment errors that are consistent when one observes teeth located at various positions around the gear. Such tool alignment errors made in a direction perpendicular to tool feed produce tooth alignment errors of equivalent direction and slope on opposite tooth flanks. Errors parallel to the tool feed direction produce tooth alignment errors of different direction and slope on opposite tooth flanks.

Errors in gear blank accuracy or mounting produce tooth alignment errors that vary when one observes teeth located at different positions around the gear. One category of accuracy or mounting error is simple eccentricity wherein the axis of the gear feature is parallel with, but offset from, the axis of rotation. The other category of accuracy or mounting error is axial runout (a.k.a. wobble or cranking) wherein the axis of the gear feature is not parallel with the axis of rotation.

Both categories of accuracy or mounting error cause tooth alignment errors varying in slope in a sinusoidal pattern around the gear. However, only axial runout will adversely affect the performance of the gear. Simple eccentricity produces only apparent tooth alignment

errors (as was the case with involute profiles). It is usually visible only in cases of high helix angles and large face widths. Simple eccentricity has no measurable effects upon the accuracy of spur gear tooth alignment. Segregation of the two categories of accuracy or mounting error is moderately complex and is not commonly done.

Line of Contact

As mentioned in Part I, gear teeth only contact one another within the plane tangent to their base cylinders. An interesting feature of the involute helicoid is that its intersection with the plane of action is always a straight line, so involute helicoid gear teeth are always contacting one another along straight line elements within their surfaces called lines of contact.

A line of contact for a spur gear is the same as a tooth alignment line. For helical gears, the line of contact is inclined across the tooth face at an angle (Fig. 2). It is thereby affected by both errors of involute profile and tooth alignment, which may combine in either a cumulative or compensatory fashion.

Observation of line of contact traces may permit acceptance of a gear with significant errors which are compensatory in nature. It is important in such cases to recall that the process is not operating properly even though the product is OK to ship. As a composite of the involute profile and tooth alignment parameters, the line of contact usually does not correlate well with process variables.

The line of contact is always inclined to the helix angle at the base circle of the gear. It is possible to test the line of action by moving a sensitive probe within the plane of action at the base helix angle while in contact with the tooth flank. Mechanical testers have been developed to do this test. CNC testers can also be programmed to make this test move. Line of contact testing is not common and AGMA standards do not tolerance it.

Pitchline Runout

Pitchline runout testing is an old and simple method of limited value. The test gear is mounted on a spindle free to rotate. A sensitive probe is brought into orientation to measure in a radial direction. A ball or other shape is selected to make contact with both flanks of the gear near the pitchline or other reference diameter. The probe is then moved into the tooth space until it reads zero while contacting both flanks and that position is set to be repeated on subsequent tooth spaces. The probe is then moved clear so the gear can be rotated, then moved back into the next tooth space. This process continues until measurements are taken on all the tooth spaces of the gear. The assumption is that a gear with no radial runout will produce all zero readings on the probe (Fig. 3).

Since this test is a double flank radial direction test, it relates only indirectly to gear performance. Pitchline runout test data can reveal radial eccentricity or out-of-round errors which produce gear transmission error. Certain manufacturing processes (e.g., shaving) often produce gears with significant angular errors that cannot be detected by double flank testing.

Pitchline runout errors typically result from gear blank geometry problems or gear blank mounting errors. These mistakes cause cyclic angular tooth position errors comparable to tooth index errors with respect to both duration and amplitude, variation of backlash (which becomes a major consideration in applications where minimum backlash is required), and apparent profile slope variation (which has little effect on gear performance).

Pitch and Index

Index Error. This is the displacement of any tooth on a gear relative to any other tooth, measured in a tangential direction. Index errors are commonly called cumulative pitch errors. This parameter is ideal for observing tooth position errors of longer duration such as eccentricity (one cycle per revolution) or out-of-round (Fig. 4).

Pitch Error. This is the displacement of any tooth on a gear relative to an adjacent tooth, measured in a tangential direction. Commonly called adjacent pitch error, this parameter is ideal for observing tooth position errors of shorter duration associated with localized meshing conditions. Less commonly used is the spacing error parameter—the difference between the pitch value for one pair of teeth and the pitch value for the adjacent pair of teeth.

Pitch Testing. Testing tooth location parameters is done with two types of instruments: the single probe and the dual probe. The single probe is usually seen as providing more reliable information, especially in the presence of larger numbers of teeth. However, the dual probe may be superior for very large diameter gears.

The Single Probe Pitch Test Instrument. The single probe instrument (Fig. 5) compares tooth positions against an accurate dividing head. In practice, a sensitive probe is brought into contact with a tooth, measuring in a tangential direction. The gear is rotated until the probe reads zero, and that position is set as the reference for subsequent positioning. The probe is then moved clear so the gear can rotate to the next tooth position. The probe is then brought back into contact to measure the next tooth until each tooth has been tested. The dividing head accurately rotates the gear 360°/N, placing the next tooth at its theoretically correct location so the probe should always read zero. This provides a direct reading of the gear index error, and from that, pitch errors can be calculated by subtracting adjacent values.

The Dual Probe Pitch Test Instrument. The dual probe instrument compares tooth positions against the pitch of an initial, randomly selected adjacent pair of teeth. It measures the differences between that pair and other pairs of teeth. The two probes consist of a fixed and movable probe. The moveable probe measures displacement relative to the fixed probe, which establishes a reference point against the adjacent tooth (Fig. 6). In practice, the dual probe is brought into contact with a pair of teeth, measuring in a generally tangential direction. The gear is rotated until it is stopped against the fixed probe. The movable probe is then set to read zero on this first pair of teeth. The dual probe is moved clear so the gear can rotate to the next pair of teeth, then moved back to contact and measure the relative pitch until all teeth have been tested.

To calculate pitch errors from dual probe data, it is first necessary to find the

average value for all the relative pitch measurements. All measurements would be equal to that average value if the gear were perfect. Subtracting the average from measured values gives the pitch errors for the gear. Successive summation of those pitch error values produces the index error values for the gear. It is a common misconception that the dual probe test instrument will directly measure pitch errors. It is important to understand that the average value must be subtracted before pitch error values are produced.

Figure 7 displays the various tooth location parameters. It shows an eight-tooth gear which has been unwrapped into a straight line. A sensitive probe is brought into contact with the first tooth and zeroed. It is then moved to the theoretically correct position on each subsequent tooth and the tooth position is measured as shown in the first line of data. This data shows that tooth #2 is 2 increments out of position to the right (+2), and that tooth #5 is 2 increments out of position to the left (-2). Notice that the index errors relative to tooth #1 are measured directly by this procedure, which is the equivalent to a single probe test. The worst index error (total error) is 6 increments and occurs between tooth #2 (measured +2) and tooth #6 (measured -4). The index error is not given a + or - sign since that would depend upon the direction taken around the gear from #2 to #6.

Pitch error data can be derived from the index data by successive subtraction. For example, the +2 pitch error of tooth pair 7 and 8 is found by subtracting the #7 value (-1) from the #8 value (+1). The error is + since the teeth are too far apart rather than too close together. A possible set of dual probe values for this gear is also provided. The average is found to be -2. Subtraction of that average value from the actual measurements will produce the same pitch values as the single probe approach. Successive summation of pitch values will produce index values. The +1 index value for #8 equals the #7 index value (-1) plus the pair 7 and 8 pitch value (+2).

The Causes of Pitch and Index Errors. Pitch and index errors are both caused by three things: problems with machine tools, cutting tool problems and gear blank and mounting errors.

Kinematic errors in machine tools, including simple looseness, can generate pitch errors when used with certain design processes that transfer the imperfections of the cutting tool directly to the work piece such as hobbing a gear with a multiple thread hob where the number of hob threads is a factor of the number of teeth on the gear. That process will result in the thread spacing errors of the hob transferring directly to pitch errors on the gear. Index errors may be associated with processes that do not control the angular positioning of the gear during cutting (e.g., shaving), but another possible cause is runout in a change gear, causing the production gear to accelerate/decelerate its rotation during cutting.

Gear blank and mounting errors include both eccentricity and out-of-

round problems and are the primary cause of index errors. A gear that is otherwise perfect except for being eccentric by .005 mm will display a sinusoidal pitchline runout of .010 mm. This will result in an acceleration/deceleration of the points of contact with the mating gear teeth along the line of action of .010 mm. Eccentricity in the gear blank can produce pitch errors in an apparant sinusoidal pattern that is especially noticeable when the number of teeth is relatively small. However, this apparent pitch error will not adversely affect gear meshing action performance. As with the involute profile and helical tooth alignment, if a proper observation of simple eccentricity is applied to the pitch data in an appropriate fashion, the resulting modified pitch error data is valid for observations of localized tooth meshing conjugacy.

Problems Arising From Pitch and Index Errors. Pitch errors lead to gear noise by being a significant source of transmission error. However, the noise produced by a pitch error is typically less objectionable than the equivalent noise produced by profile errors. This is because some tooth pairs show plus pitch errors and others minus errors, causing a less consistent transmission error characteristic than profile type errors. Index errors are not often associated with gear noise trouble, though the cyclic modulation they can produce may be noticeable. It is also possible for the increased loading of a planetary set caused by index errors to cause increased noise levels. Index errors are also a common cause of ghost harmonics, an error which may appear in index test data if they occur at lower than mesh frequencies.

Both pitch and index errors lead to strength problems since dynamic loading promotes fatigue. The shock load that occurs when mispositioned teeth enter mesh adversely affects the strength of those teeth because the dynamic stresses involved will be higher than the tooth was designed to take. Localized pitting and other durability problems can also occur in the region of initial contact between mispositioned mating teeth.

Other strength and durability problems associated with index errors include increases in dynamic loading in high-power, high-speed gear drives due to cyclic changes in rotational velocity and backlash variation if the problem is caused by pitchline runout. Index errors also significantly reduce load sharing in planetary gear sets, increasing the importance of single flank testing, either composite or analytical, on gears produced for automotive style automatic transmissions as those are often finished by shaving.

Finally, index errors can degrade the performance of gears that must maintain timing relationships. This includes positioning applications such as robots and media movement applications such as printing presses. ○

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Changes In The Gear Industry

PFAUTER-MAAG CUTTING TOOLS RECIEVES ISO 9001 REGISTRATION

Pfauter-Maag Cutting Tools is now registered as an ISO 9001 company under KPMG Quality Registrar. This registration makes Pfauter-Maag Cutting Tools one of the first gear cutting tool manufacturers to meet this important international quality standard. This ISO 9001 certification stems from the company's commitment to meet or exceed the world's highest quality and consistency standards.

"Our facilities here and abroad are among the best in the world for the design and manufacture of advanced gear cutting tools," said Pfauter-Maag Cutting Tools quality manager Jim Argyle. "Management commitment, continuous improvement, investment in training, state-of-the-art equipment and other critical resources are necessary to meet or exceed the toughest quality and performance standards of our customers. That's what differentiates us from other suppliers."

NORD GEAR CORPORATION EXPANDS SALES AND ASSEMBLY OPERATIONS IN NORTH AMERICA

Nord Gear announces the opening of a 40,000 sq. ft. sales and assembly facility in Brampton, Canada; a 20,000 sq. ft. sales and assembly facility in Charlotte, NC and regional sales offices in Auburn Hills, MI. The addition of these facilities will support Nord Gear's efforts to significantly reduce lead times and improve overall customer service. Nord Gear also announces plans to break ground for an additional 30,000 sq. ft. of manufacturing space and 20,000 sq. ft. of administrative office space at its North American headquarters in Waunakee, WI.

NATIONAL BROACH WELCOMES NEW PRESIDENT AND CHIEF OPERATING OFFICER

Carmen Calabrese, Ph.D. has joined National Broach and Machine Co. as President and Chief Operating Officer. His diverse experience in upper-level management, marketing, sales, business development, manufacturing and business education will be an asset to National Broach and Machine Co. Dr. Calabrese's extensive experience with multi-national companies including Murata Machinery; Asea Brown Boveri (ABB) Ltd.; Robert Bosch, GmbH; the Midland-Ross Corporation; and E.I. DuPont De Nemours, Inc., provides him with a keen understanding of today's global marketplace. He holds a Ph.D. from the University of Pennsylvania in Materials Science and Engineering; an MBA in Marketing/Management from Eastern Michigan University and a BS in Metallurgical Engineering from Drexel University.

Dr. Calabrese has stated four goals for National Broach, each interrelated. First, National Broach must create an environment where employees are both committed and dedicated. Secondly, the company must provide quality products that meet and exceed customer expectations. The third goal is to generate and maintain customer satisfaction and loyalty. Finally, the natural outcome of the previous goals is a return on investment to the stockholders.

EMCO MAIER CORPORATION NAMES NEW PRESIDENT

Robert J. Pernsteiner has been named President of EMCO Maier Corp. He comes to the post with over 30 years of experience in the machine tool industry. "I believe in being a hands-on team player to achieve EMCO Maier's long-term objectives," said Pernsteiner. "I am charged with using my experience to effectively manage our EMCO Maier team. Our primary goal is to steadily increase U.S. market share for EMCO Maier."

Pernsteiner began his professional career with Kerney & Trecker Corp., spending 18 years managing such diverse areas as production planning, purchasing and materials. In 1986 he moved over to Okuma where, over 12 years, he advanced in the areas of operations and customer service management, materials management, sales and marketing. "Bringing EMCO Maier to a leadership position in the American marketplace presents an exciting and fresh challenge for me," said Pernsteiner. "It is one I look forward to with great anticipation. I have no doubt that our staff has the commitment and fortitude necessary for the task at hand."

HURCO MACHINE TOOLS NAMES NEW PRESIDENT

Richard Blake

Hurco Machine Tool Products has announced the appointment of Richard Blake as President, with responsibilities for sales and service in North America and Europe. Trained as a tool and die maker, Blake brings more than 20 years of experience in the machine tool industry. With Hurco for the last 10 years, Blake most recently served as Managing Director of Hurco Europe in High Wycombe, England. His foremost goal now is to grow Hurco in North America.

"We are now the number two supplier of vertical machining centers to Germany. Throughout Europe over the last four years, we have enjoyed significant growth and increased market share. We need to carry that success into North America. To do this, we must focus on a very high level of support for our key distribution and to continue to exceed our customers' needs in all aspects in their machine tool requirements." ○

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CIRCLE 115

New Gear Deburring Machines From American Wera

American Wera, Inc. has added three new machines to its line of gear-related machining solutions. The ZEM-180 is a new spur gear deburring machine designed to be easily adapted to new or existing gear hobbing machines. The KEM 200 and KEM 500 are bevel gear deburring machines with five-axis CNC capabilities.

Designed for limited floor space (55"x51"), the ZEM-180 is equipped with an integrated dual-gripper pick-and-place station. Positioning this machine next to a gear hobber, you would turn the hobbing machine work station into an automatic production cell. The five-axis bevel gear deburring KEM machines are designed to deburr both toe and heel gear teeth in a single chucking. The CNC-controlled tool axis of the KEM machines swivels automatically to its programmed position. The KEM-200 can also be equipped with a ring loader and a double-gripper pick-and-place station. The KEM-500 is a larger version of the same machine. For more information contact American Wera, 4630 Freedom Drive, Ann Arbor, MI 48108 or call (313) 973-7800.

Circle 300

Basic Machine Tools Unveils New Gear Hobber

Basic Machine Tools, national distributor of 75 models of gear machines, announces their new WOLF model GH32-19LS gear hobbing machine. According to W.F. Wolf, CEO of Basic, "The new GH32-19LS is a unique gear hobber, the answer to many manual horizontal hobbers so popular in the past but no longer available as new machines."

The GH32-19LS is especially suited for long shaft work. Up to 5" diameter shafts can be inserted into the work table and up through a bushing in the tailstock an unlimited distance. The new GH32-19LS can cut gears up to 32" diameter and pitches to 2.5 DP. Differential gears provide helix angles to 45°. The vertical work piece axis permits better chip fall away than the old horizontal machines. For more information contact Basic Machine Tools, P.O. Box 36276, Los Angeles, CA 90036 or call (323) 933-7191.

Circle 301

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Poemetry In Mesh

As we at Addendum have long known, within every gear man (and woman) lies the soul of a poet.

To prove it, we present the following piece by David B. Dooner.

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

History has pegged wheels in mesh circa 2600 BC
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List of concerns needed prior to angle of approach
so success will be a measure of market share encroach
as all claim to cut cost and none are for free!

Traces of gears were put in print with work of Aristotle,
not as science but as machine drives for a future throttle.
For fifteen centuries advancements had little to show
where materials matters were mute and speeds were slow
as increased revolutions spurred designers to model.

The design of a gear set requires ratings and an initial guess;
to evaluate inertial, bending, contact, and thermal is *shear* stress.
Splined, keyed, webbed, or rimmed: a choice one must make
prior to determining if fatigue is critical and at stake
as the decision to FEA the calculations can make a mess.

In 1694 Philip de la Hire sired the tooth type involute;
years 150 later Euler fathered details with circular evolute.
Abandoned is the widespread cycloidal profile;
notwithstanding timepieces, tooth types anew are rendered futile
as details are often dimensioned as mathematically convolute.

First, to fabricate a gear set requires a machine at last;
CNC or not, options are to press, mill, forge or cast.
EDM and RP are not mass production like generating hardware
where the number of teeth in mesh can occur anywhere,
so hunt a ratio and shave, hone, or burnish the finish fast.

Nomenclature needed to number the tooth parts with pitch:
diametral, circular, axial, and transverse; *normally* known is which.
EAP, HPSTC, and tip relief are all aspects of addendum;
TIF, SAP, LPSTC, fillet, root, and base define dedendum
as clearance, backlash and contact ratio are added to enrich.

TiN, TiAlN, and XYZ to be can wear a better rate
as tooth films or tool coatings when cutting its mate.
To gage the amount necessary is to measure when
the film thickness is distributed evenly thin
as choices PVD, CVD, or NEW can create a heated debate.

Different gear types make many classes too:
rack & pinion, non-circular, and worm identify a few.
Matters not whether cylindrical, conical, or hyperboloidal
for all degenerate cases are ordered cylindroidal
as spiral, spur, and straight are species sighted at a gear zoo.

Caution, post processing produces profile modification
with fluctuations in I/O relation as well as noise and vibration.
Be it at a tooth mesh frequency or sideband,
a runout of envelope calculations are easy and off-hand,
so consider carefully as resonance can cease utilization.

To EGT or PGT is differential only in name
for the motions made vary the same.
So be it central, intermediate, annulus, carrier, and case;
otherwise call it sun, planet, ring, arm, and base
as other families of motions are made via a simple gear train.

To optimize is to search for numbers in vain;
gear paramaters are balanced with a gradient to constrain.
Material may be plastic, bronze, aluminum, iron "ore" steel;
as all must be considered to generate the best deal,
for a favorite is found with increasing power to weight gain.

Differential geometry is a topological tool with a goal;
the objective is to minimize the amount of slide-to-roll.
Euler-Savory defines surfaces of conjugate curvature
and laws of gearing guarantee fundamentals of nature
as freedom from efficiency is the price of the toll.

ISO—a metric that is independent of ips and cgs,
along with a gear doctor that can cure mis-alignment for fps or mks.
Be it hard to know when to Bhn, Rc, HSc, or mho;
for it's time to trade schools when masters do not know
enough to tell when to DIN, AGMA, or BS.

Tribology of contact can be studied to a point
where friction at contact gets graphite, grease or oil to anoint.
Be it centipoise, stokes, micro-reyns, saybolts, or else
temperature rise at mesh must maintain before gear set melts;
as EHD lubrication is an item of aim at each joint.

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