GEAR TECHNOLOGY

The Journal of Gear Manufacturing

1995 BUYERS GUIDE
GEAR EXPO PRE-SHOW ISSUE

September/October 1995

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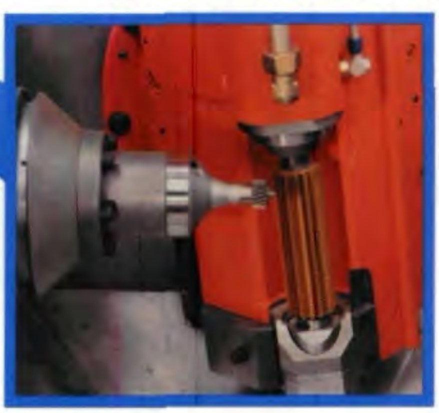

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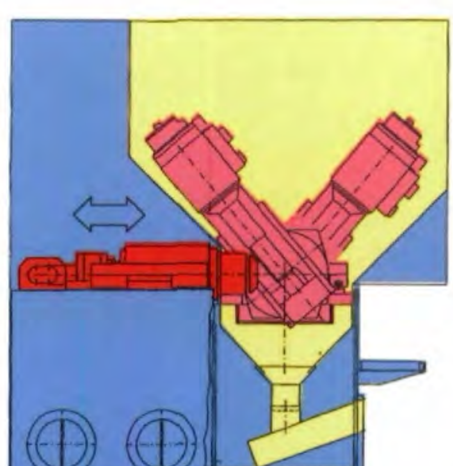

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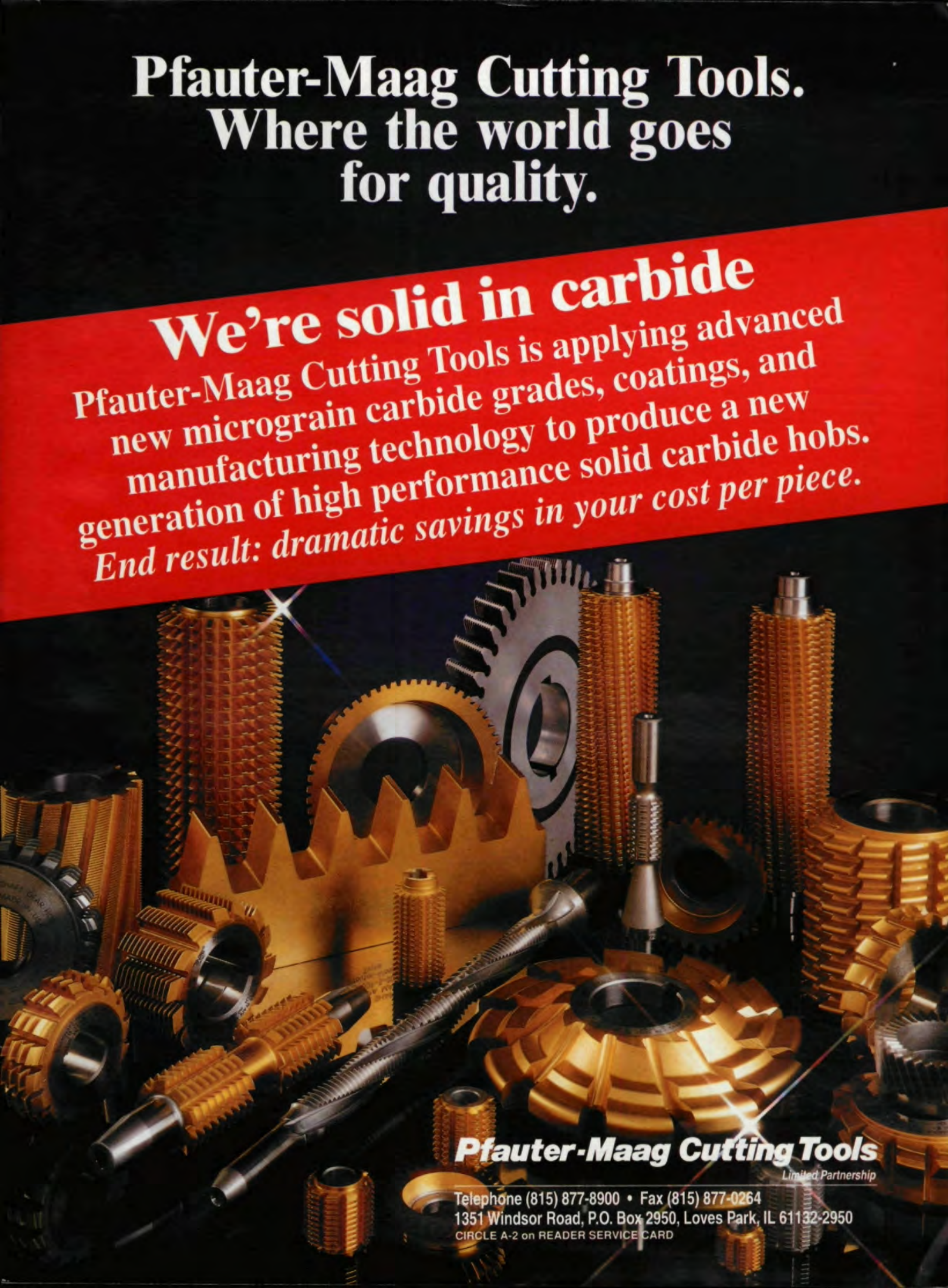
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GEAR TECHNOLOGY

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The Journal of Gear Manufacturing

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GEAR TECHNOLOGY
The Journal of Gear Manufacturing

"BPA International Publication Membership Applied for September 1994."

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VOL. 12, NO. 5

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

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DOING THE RIGHT THING

Knowing the right thing to do isn't hard. Most often, it's very obvious. Actually *doing* it is something else again. For example, we all know that we probably eat too much refined sugar and fat, but when the double chocolate cheesecake comes by, it's easy to convince ourselves that one piece won't hurt.

By the same token, it doesn't take an MBA or a doctorate in economics to figure out that investing in the best new equipment we can afford on a consistent basis to keep our factories as up-to-date as possible is a wise business decision. Better to upgrade incrementally than one day to wake up and discover the whole factory is ten, twenty or more years out of date, and almost all the equipment needs replacing right away.

So why is it so hard to do that?

A couple of recent conversations have set me wondering about this question. Some employees of a high-production division of a very large company were effusive during a recent visit about how well their business is doing—sales, production volume and profits are all setting records; business has never been better. But they are not allowed to buy any new equipment now, even though a lot of the machinery needs upgrading, and investment in past years has been lagging. There might be a recession on the horizon, the corporate decision-makers explain. Better to keep the cash.

But if the company's not going to buy new equipment when business is good, when is it going to buy it? During a recession?

A tidy sum of readily available cash on the books may be a bit like that slice of chocolate cheesecake. It gives you a good feeling to have it right now, but is it really that good for you? Wouldn't prudent investment in capital equipment be better over the long haul?

Another, more ironic recent conversation was a variation on this theme. In this case, a manufacturer told me how he lost market share in recent years to competitors selling cheaper technology that wasn't as good as his. It really hurt until customers started coming back after realizing that the "cheaper" machines really weren't, when downtime, repair and quality problems were factored into the equation. It had taken some of his customers a while to relearn the truism that cheaper isn't necessarily better.

And yet this same manufacturer, who had suffered from the "cheaper is better" philosophy of others, didn't make the connection to his own buying practices. He was still giving bottom-line price the deciding vote in purchasing decisions. Short-term benefit looked better to him than long-term investment.

This short-term strategy can burn you in the long run. In current conditions, only the companies that have invested in new equipment and training and have adapted to the changing environments in both their home and international markets will survive.

Furthermore, the effects of this kind of investment are geometric. These companies have more profits and cash flow now to continue their investment, which only gives them a greater advantage over the companies that lag behind. And the farther behind the laggard companies that hoard their cash fall, the harder it will be for them to keep up.

I'm not suggesting that price is not important or that now is the best time for every company to invest heavily in new equipment. It is possible to overinvest or to invest unwisely or in the wrong equipment. But I think the greater danger now lies in underinvestment in capital improvements that increase productivity and lower costs.

That's a judgment call businesspeople have to make for themselves. But in making that call, beware of the temptation to go for the chocolate cheesecake every time. Short-term savings always look attractive at first glance. They may not be the best thing for the overall, long-term health of your company.

Michael Goldstein
Publisher and Editor-in-Chief

Peter Kozma of
Liebherr-America, Inc.

Peter Kozma, executive vice president of Liebherr-America, Inc., talks with us about Liebherr and its partners in the Sigma Pool.

GT: Since three out of the four members of the Sigma Pool manufacture at least some similar products, how do they keep from cannibalizing one another's sales?

PK: Because Sigma Pool member technologies are actually complementary rather than competitive. Each specializes in a different aspect of gear manufacturing, which we define according to gear type and process.

Liebherr offers hobbing and grinding machines, Lorenz covers the shaping process and Klingelnberg and Oerlikon manufacture different types of spiral bevel gear manufacturing and testing equipment. Because all of the partners' machine tools are designed for gear manufacturing, the Sigma Pool's expertise is concentrated in a single field. We can give our customers objective recommendations based on workpiece, process, required geometry and quality.

Far from hurting individual company sales, Sigma Pool synergy supports even greater participation in the gear manufacturing field.

GT: We have been told that gear grinding is becoming more and more popular in the U.S. Companies that in the past would never have used ground gears—for example, Harley-Davidson—are now adopting them for the sake of noise reduction and quality improvement. Do you see gear grinding becoming a "growth" part of the industry?

Peter Kozma, executive vice president.

PK: There is definitely a growing demand for higher quality gearing. We are noticing growth in three major areas—automotive, commercial or industrial applications and production technology. In vehicles, people have become aware that excessive noise and quality are related; higher quality gears lead to reduced noise emission and increased passenger comfort. In the commercial-industrial area, there is a recognized demand for ground gears to increase performance and economy. Advances in production technology have required grinding from solid and near-net forging for economical gear development and production.

GT: Why has grinding gears been more popular in Europe than in the U.S.? Why has this technology been slower to arrive here?

PK: Because of Europe's astronomical fuel costs and its strict environmental laws, fuel efficiency has long been a more urgent concern in Europe than in the United States. Therefore, rather than controlling noise through the usual method of insulating the transmission, which adds weight and increases fuel consumption, European manufacturers have sought methods such as grinding to eliminate gear inaccuracies that are the source of operating noise.

GT: As gear grinding becomes more popular, do you see a push on the part of grinding machine customers to demand "open architecture," so that grinding wheels from one company can be used on the machines from another?

PK: Aside from cost issues, manufacturers are always trying to avoid bottlenecks and maintain flexibility. Specifically for CBN grinding wheels, we have already anticipated a demand for interchangeability among different types of machines and have responded to customers' needs.

GT: Liebherr has been very successful with its launch of a dry hobbing machine. What are the possibilities for a similar advance in dry grinding? Is this technically feasible?

PK: Every new technology introduced over the past few decades appeared at one time to be technically inpossible, so I would not doubt the feasibility of dry grinding. Currently, we are aware of attempts to develop dry grinding methods using dressable grinding tools. The challenge of dry grinding *hardened* materials is much more difficult because the process itself can cause significant changes in material properties.

GT: According to your literature, one

of Liebherr's most successful products in the recent past has been its gantry robot. Why and how did Liebherr get into materials handling?

PK: *In the 1970s, many of our customers began to ask us to automate part flow between our gear-cutting machines. As the demand grew to include linking our machine tools with the preceding and subsequent operations, Liebherr extended its periphery of machine-integrated buffers and loading units to include more comprehensive and intelligent systems. From our earliest blue steel conveyors to today's range of gantry robots, rail cars, palletizers and storage systems, we have concentrated on giving customers the degree of flexibility they really need.*

From the beginning, Liebherr has been a system integrator working with other manufacturers' machine tools. Through experience, we have developed an uncommon expertise in electrical interface and physical layout, both of which must be optimized in a reliable and efficient automation system.

GT: Has the declining value of the dollar made it more difficult for European-owned companies to compete in the U.S.? Has it hurt your business? Would this be a good time for U.S. gear manufacturing companies, which suffered badly in the 80s, to try to rebound on the global market?

PK: Certainly the declining dollar has made competition more difficult for European companies, but Liebherr and Klingelnberg both have been global competitors for many years and continually take steps to minimize the effect of currency fluctuation. The recent recession in the United States helped our long-term prospects by making us find ways to reduce customers' total investments without limiting functionality or quality. These tools—smarter manufacturing and money management—are standing us in good stead, and we continue to compete successfully despite the dollar's weakness.

With the advent of global sourcing, it is increasingly important for companies to have a global view of competition. The present currency situation makes it easier for U.S. firms to establish operations and sell their products overseas.

There is a growing demand for ground gears in three areas — automotive, commercial and industrial applications and production technology.

GT: There's a lot of talk in the industry about the development of the technology to grind gears from the solid. Is the Sigma Pool working on technology in this area?

PK: Yes, we are exploring this technology and working to stretch its current economic and technical limitations. Our Sigma Pool partner Oerlikon has been experimenting with different wheel compositions and coolant formulas. We have seen very positive results, and we are optimistic that this technology will prove effective.

GT: Both Klingelnberg and Oerlikon have gear measuring and testing product lines. Are there any new developments in this area? What are customers demanding now in terms of measuring and testing equipment?

PK: Oerlikon manufactures test machines that specialize in structure-borne noise analysis and single flank testing of complete spiral bevel and hypoid gear sets. The prevailing demand is for the testing of gear sets under simulated operational conditions.

Alternately, Klingelnberg manufactures analytical CNC inspection machines for precision measuring of all parallel axis and bevel gear tooth geometries as well as associated cutting tools. Our customers are requesting networking for statistical process control, complete inspection of all workpiece dimensions with a compensation option for eccentric workpiece clamping, customized software packages and faster inspection cycles. We are also seeing more interest in closed-loop systems that network between the inspection machine and the bevel gear generating and grinding machines for the calculation of corrective machine settings.

GT: One of the selling points of Sigma Pool is the synergy it can bring to solving gear manufacturing problems. In one of the news releases issued at IMTS, a project was mentioned where Liebherr and Oerlikon worked together to develop an automated system for lapping spiral bevel gears. Can you tell us more about this project?

PK: This system uses a CNC Liebherr gantry loader to automate a number of CNC Oerlikon lapping machines. Our challenge was to find an economical solution for automatically loading spiral bevel gear lapping machines—using automation for the first time to load pinion and gear sets of different sizes and ratios directly into a machine fixture. The Sigma Pool system achieved its goal of providing a system that reduces cycle time, increases production and, ultimately, makes a positive contribution to our customers' profitability. ○

For more information about Liebherr/Sigma Pool, please circle Reader Service No. A-100.

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University of Wisconsin-Milwaukee. Bevel Gear Systems. At the Best Western-Midway Motel, Brookfield, WI. Three-day seminar covering design, manufacture, application, assembly, maintenance of bevel gears and more. Contact UW-M Center for Continuing Engin-eering Education, 800-638-1828.

SEPTEMBER 12–14

Ohio State University, "Gear Noise Seminar." Covers measurement, sources, transmission error, rattle, reduction techniques and more. Contact Susie Young, 614-292-5860.

SEPTEMBER 12–14

EDM '95 Rosemont Convention Center (near Chicago's O'Hare Airport). Exhibition and conferences on EDM subjects. Contact Gardner Management Services 800-950-8977 or fax 513-527-8950.

SEPTEMBER 25–26

Verein Deutscher Ingenieure (VDI). Symposium on Vibration in Drives. Mainfrankensäle, Veitshöchheim, Germany. For registration information call (49) 211-62 14-431 or fax (49) 211-62 14-164.

OCTOBER 16–18

AGMA Fall Technical Meeting. Charleston, SC. Presentations on gear manufacturing and research subjects. For more information, contact AGMA at 703-684-0211 or fax 703-684-0242.

OCTOBER 23–27

American Society for Metals Seminar, Principles of Heat Treating. ASM Headquarters, Materials Park, OH. Course for those who are new to heat treating or want an update on heat treating technology. Call 800-336-5152, x613 for details.

NOVEMBER 12–15

AGMA Gear Expo '95. Indiana Convention Center, Indianapolis, IN. The one trade show devoted exclusively to the gear and gear-related products and services industry. For more information, contact AGMA at 703-684-0211 or fax 703-684-0242.

NOVEMBER 16–17

IMechE 2nd International Conference on Gearbox Noise, Vibration and Diagnostics, IMechE Headquarters, London, England. The conference will focus on both the control of gearbox dynamic behavior and the utilization of diagnostic information by enhanced analysis, measurement and case history data. For more information, contact IMechE Conference Services, Dept. C492, One Birdcage Walk, London, SW1H 9JJ. Phone: (44) 171-973-1249/1317; Fax: (44) 171-222-9881.

CALLS FOR PAPERS

1996 Japan-USA Symposium on Flexible Automation. Papers for this conference, July 7–10, 1996, in Boston, MA, should be submitted to Prof. Kim Stelson, Dept. of Mechanical Engineering, University of Minnesota, by **November 15.** For details call ASME Public Information Office at 212-705-7738.

To announce an important technical meeting, exposition or seminar, please send notification to Gear Technology Tech Calendar, P. O. Box 1426, Elk Grove Village, IL 60009. Notices should arrive in our offices six weeks prior to the date of the issue in which you wish them to appear. Items are used on a space-available basis.

Gear Expo '95

BIGGER AND BETTER

Who:
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What:
Gear Expo '95

Where:
Indiana Convention Center, Indianapolis, IN

When:
November 12–15, 1995

Why:
To See Cool Gear Stuff

How:
For more information, call AGMA at (703) 684-0211

Gear Expo '95, scheduled for November 12–15 at the Indiana Convention center in Indianapolis, IN, will attract more exhibitors from a wider array of industries than any previous show, according to the show's sponsor, the American Gear Manufacturers Association.

With more than 100 exhibitors booked and 95% of available floor space sold by mid-July, show officials are optimistic. AGMA expects exhibitor space to break all previous records with around 34,000–35,000 square feet by the time the show opens. By comparison, Gear Expo '93 in Detroit had 30,700 square feet of exhibitor space.

Of more significance to AGMA is the fact that a greater diversity of products and services will be on display. "We're trying to attract exhibits to make the industry more aware of changing technology," says Gear Expo show chairman Marty Woodhouse of Starcut Sales, Inc. Visitors at the show will see heat treaters, steel providers, abrasives manufacturers, lubricant companies, job shops and other product and service providers.

For example, companies will demonstrate the latest in plastics, powder metal and other alternative gear materials, says AGMA executive director Joe Franklin. "We've made a very conscious and significant effort to go beyond machine tool manufacturers to include other products and services that a manufacturer or user of a gear or gearbox would need."

Burgess-Norton Mfg. Co. of Muskegon, MI, a manufacturer of powder metal gears, will be exhibiting at Gear Expo for the first time this year. "We feel it's an opportunity for people who traditionally buy cut gears to get an idea of what our gears are capable of," says Tom L. Stockwell, Jr., sales manager for Burgess Norton's P/M parts and assemblies division. Stockwell points to significant advances in the last several years that have made powder metal gears cost-advantageous for many industries.

Another company trying Gear Expo for the first time is Welduction Corp., a manufacturer of heat treating equipment from Farmington Hills, MI. Welduction, which traditionally has gone only to heat treating industry shows, wants to focus on gear manufacturers, says sales engineer Marty Frania. "We've had many gear customers before, but we don't know them all," Frania says. "We're trying to broaden our customer base." The Welduction booth will have sample heat treated parts, machines and a video on the basics of induction heat treating.

AGMA officials hope that the variety of products and services on display will help attract more buying customers to the show. The association is expecting approximately 4,000 people to attend, compared with about 3,000 who came to Detroit in 1993, Franklin says. In addition, show sponsors expect the central location of the show to draw increased numbers of visitors from the U.S. manufacturing belt.

Gear Expo traditionally has been scheduled in conjunction with AGMA's Fall Technical Meeting so that the trade show could benefit from the meeting's usual strong attendance. As another sign of the show's expansion, the two events will be held separately. This year the Fall Technical Meeting is being held at a different time, in a different city (October 16–18 in Charleston, S.C.). "Gear Expo no longer needs a strong sister to support it, and we really don't want to take away from the technical program," says Franklin. AGMA officials feel that each event is now strong enough to stand on its own. In addition, people who go to those events will be able to focus on either buying at Gear Expo or the latest research and development at the Fall Technical Meeting, Franklin says.

With all the work that's gone into making Gear Expo '95 a better show, AGMA officials expect this year's event to be the premier event in the world for the gear industry. Says show chairman Marty Woodhouse, "Times are good. The economy is good. We're expecting a really good show." ○

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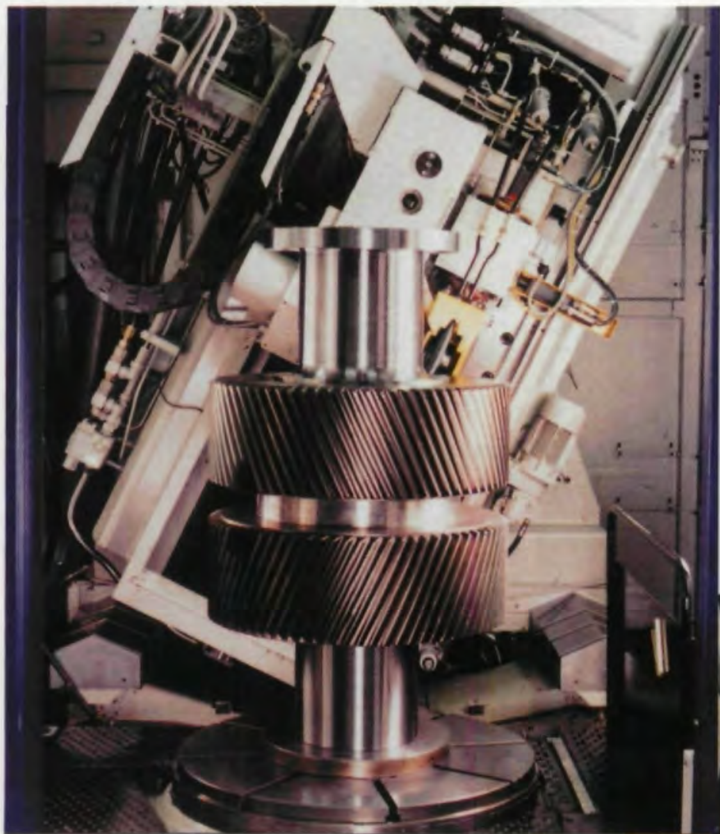

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Gleason Acquires Assets of Hurth

Rochester, NY—**Gleason Corporation** has acquired the assets of **Hurth Maschinen and Werkzeuge GmbH**, the designer and builder of cylindrical (parallel-axis) gear-making machinery and tooling based in Munich, Germany. The addition of Hurth gear shaving machines and tooling and gear honing machines will further broaden Gleason's expanding product line for manufacturers of cylindrical gears.

According to James S. Gleason, chairman and president, "Gleason sales of parallel-axis gear equipment have tripled over the past three years because of the success of our 125 GH hobbing machine and our TAG 400 threaded-wheel gear grinding machine. The addition of the Hurth machines should play an important role in our sustained growth in this market." Hurth's Modul operation (Chemitz, Germany), builders of gear hobbing and bevel gear-making machines, was not included in the acquisition.

Gleason has acquired Hurth patents, trademarks, equipment and inventories and will also assume existing obligations for installation and warranty of machines previously sold, as well as completion of customer orders in backlog.

According to David Burns, vice president, machine products, "Gleason will continue operations in Munich and will retain approximately two-thirds of the 400+ employees currently at that location. In addition to the CNC shaving machines, we are very excited about producing Hurth tooling for the shaving process. Both the Hurth machines and the shaving cutters will benefit greatly from Gleason's worldwide sales and distribution network. We're also confident that the reduced overhead structure and combined technology of the two companies will enhance the competitiveness of the shaving and honing machines."

Hurth currently has about 30% of worldwide market share for shaving machines and about 25% of the shaving tooling market. Included in the Gleason acquisition is the complete line of shaving machines and peripheral support equipment, including a shaving cutter grinder. Gleason plans to discontinue some of Hurth's older product lines.

The acquisition of Hurth was made for approximately $10.5 million in cash. The assets include a backlog of over $30 million.

Gleason plans to exhibit the Hurth machines at the AGMA Gear Expo in Indianapolis in November, 1995.

Tell Us What You Think... If you found this article of interest and/or useful, please circle Reader Service **Number A-103.**

Comparison of Surface Durability & Dynamic Performance of Powder Metal & Steel Gears

A. Yoshida, Y. Ohue & Isamu Karasuno

Table I		
	Pinion	Gear
Module mm	5	
Standard Pressure Angle	20°	
Number of Teeth	15	16
Addendum Modification Coefficient	+0.571	+0.560
Tip Circle Diameter mm	90.71	94.60
Center Distance mm	82.55	
Face Width mm	18	6
Contact Ratio	1.246	
Accuracy*	Class 1	Class 1
Tooth Surface Finishing	Grinding	
*JIS B 1702		

Table II		
Gear Specimen		ISPM
Powder Type		0.7% Mn 1.0% Cr 0.2% Mo Balance Fe
Particle diameter μm		75–106
Mixing		0.5% Graphite 0.8% Zinc Stearate
Compacting Pressure kN/cm²		64
Green Density g/cm³		6.9
Sintering		1403 K x 0.5 hr N_2 Gas
Machining		Hobbing
Induction-Hardening	Frequency kHz Heating Time s	30 7.7
Tempering		453 K x 2 hr
Finishing		Grinding

Introduction

Surface-hardened, sintered powder metal gears are increasingly used in power transmissions to reduce the cost of gear production. One important problem is how to design with surface durability, given the porous nature of sintered gears. Many articles have been written about the mechanical characteristics, such as tensile and bending strength, of sintered materials, and it is well-known that the pores existing on and below their surfaces affect their characteristics (Refs. 1–3). Power transmission gears are frequently employed under conditions of high speed and high load, and tooth surfaces are in contact with each other under a sliding-rolling contact condition. Therefore it is necessary to consider not only their mechanical, but also their tribological characteristics when designing sintered gears for surface durability.

The authors have investigated the surface durability, the failure modes and the changing of contact surfaces during the fatigue process of induction-hardened, sintered powder metal spur gears and rollers (Refs. 4–7). These investigations have shown that the surface durability of induction-hardened, sintered rollers was affected by the sintered density and the powder size, and that the failure mode was spalling (Refs. 4, 7). The failure mode of the induction-hardened, sintered gears was pitting spread over the tooth surface with spalling (Ref. 5).

In this article, induction-hardened, sintered powder metal spur gears were compared with induction-hardened, melted steel spur gears for surface durability and dynamic performance using a power circulating gear testing machine. The changes in the dynamic performance and the tooth surface of both gears were measured and observed during the fatigue processes. The differences in the surface durability and the dynamic performance between the sintered gears and the melted steel gears are discussed.

Test Gears

Induction-hardened, sintered powder metal gears (ISPM) and induction-hardened melted steel gears (ISCM) were employed as the test gears. The specifications of spur gears used in this experiment are given in Table I. These test gears had a module of 5 mm and a standard pressure angle of 20°. Case-hardened pinions (CSCM) made of chromium molybdenum alloy steel (JIS SCM415: 0.15% C) were mated with both test gears.

The manufacturing conditions of the sintered powder metal gears are given in Table II. The powder was a pre-alloyed steel. It was mixed with graphite and zinc stearate and compacted into disks having a green density of 6.9 g/cm^3. The disks were sintered, hobbed and then induction-hardened. The material of the induction-hardened, melted gears was 1.0% Cr-0.25% Mo alloy steel (JIS SCM440: 0.40% C). After hobbing, the steel gears were induction-hardened under the same conditions as the sintered gears. The tooth surfaces of both test gears were finished by grinding. The surface roughnesses along the tooth traces of gears ISPM, ISCM and CSCM were 1.6, 1.5 and 1.8 µm *Rmax*, respectively. Young's modulus and Poisson's ratio of the sintered gears were 152 GPa and 0.25. Those of the steel gears were 206 GPa and 0.3.

The hardness distributions below the tooth surfaces of the test gears and pinions are shown in Fig. 1. The hardness was measured at the working pitch point of each gear using a micro-Vickers hardness tester. The hardnesses of the tooth surfaces of test gears ISPM and ISCM were *Hv* 620 and *Hv* 700, and the total hardened depths of these test gears were 2.8 and 3.6 mm, respectively. The hardness of test gear ISPM was lower than that of ISCM in spite of the same induction-hardening conditions, since ISPM had many pores below the tooth surface. The hardness of the tooth surface of mating case-hardened pinion CSCM was *Hv* 800, and the effective hardened depth was 0.8 mm.

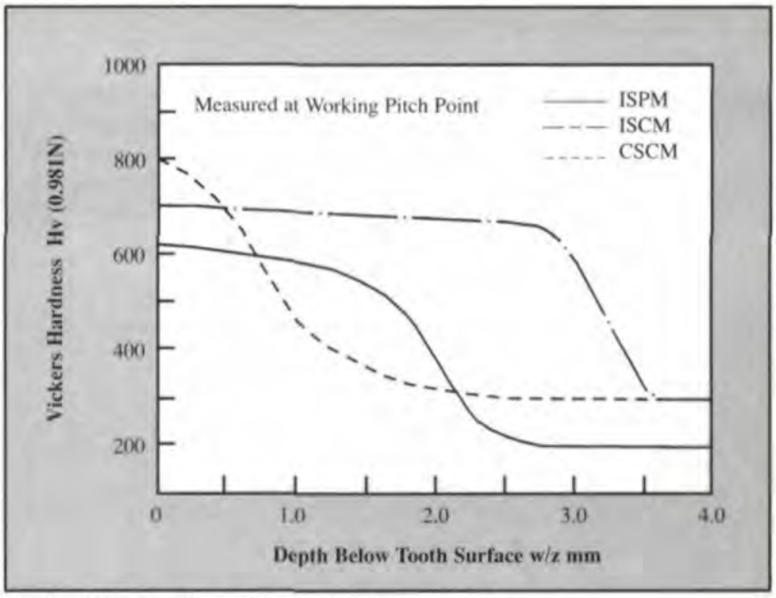

Fig. 1 — Hardness distributions of test gears and pinions.

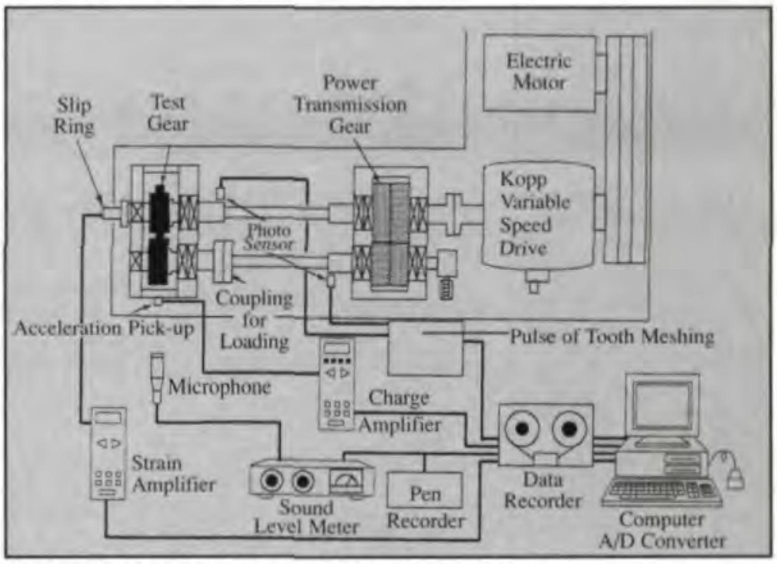

Fig. 2 — Sketch of gear testing machine and measuring system.

Experimental Procedure

Fig. 2 shows a sketch of the gear testing machine and the measuring system for tooth root strain, the vibration acceleration and the sound pressure from the gearbox. The test apparatus used in this experiment was a power circulating type gear testing machine with a center distance of 82.55 mm. This machine was operated by driving a power transmission gear set through a Kopp variable speed drive with an electric motor. The fatigue tests were conducted at a rotation speed n_2 of 1800 rpm for test gears. The lubricant employed here was a gear oil with EP additives that had a kinematic viscosity of 190.9 x 10^{-6} m^2/s at 313 K and a viscosity index of 98. The oil was supplied to the engaging side of a test gear pair at a rate of 750 ml/min. The supplied oil temperature was 313 ± 5 K. The maximum Hertzian stress p_{max} at the working pitch point was taken as a scale for loading in this experiment.

The dynamic tooth root strain was measured using a dynamic strain amplifier and a wire strain gage bonded on a compression side of the tooth fillet. The vibration acceleration of the gearbox was detected by a piezo-electric pickup through an amplifier. The sound pressure was detected by a condenser microphone fixed at a distance of 300 mm from the gearbox. To evaluate the dynamic tooth root stress, the static tooth root strain was measured at a rotation speed of 6.6 rpm for the test gear. The tooth profile measurement

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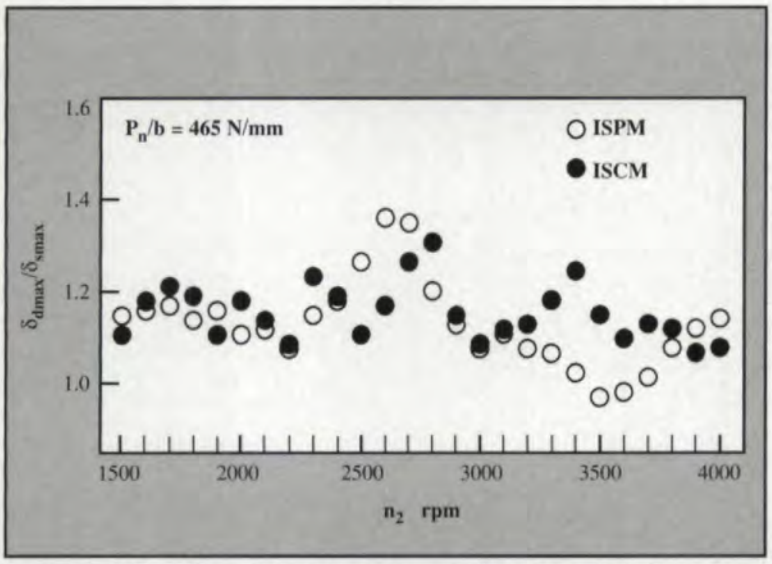

Fig. 3 — Ratio $\delta_{dmax}/\delta_{smax}$ of dynamic maximum tooth root stress to static maximum tooth root stress.

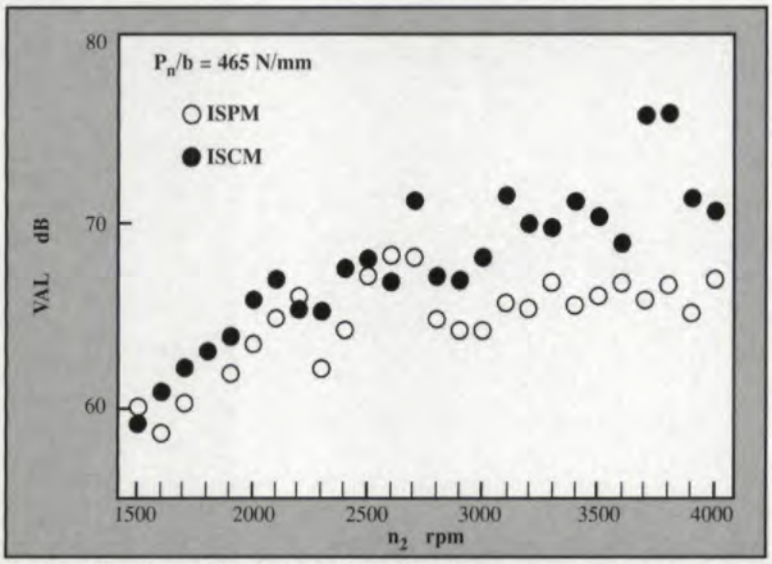

Fig. 4 — Vibration acceleration level *VAL* of gearbox.

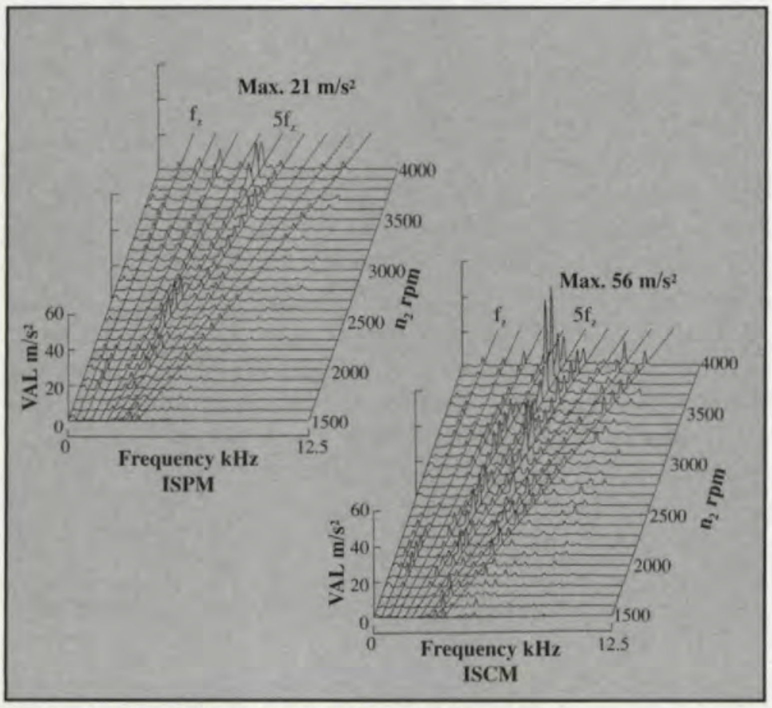

Fig. 5 — Spectra of vibration acceleration of gearbox.

and the replica observation of the tooth surface were also performed. These measurements of the dynamic performance and the observations of the test gear pair were conducted at regular intervals during the fatigue process. A vibration-sensitive shutoff transducer was fixed on the testing machine, stopping the machine automatically when a vibration increase caused by the tooth failure was detected.

Experimental Results and Discussions

Dynamic tooth root stress & vibration acceleration of a gearbox at rotational speeds of 1500–4000 rpm. To compare the dynamic performance of the sintered gear with the steel gear under a normal load per unit face width *Pn/b* of 465 N/mm, the dynamic tooth root stress and the vibration acceleration of both test gears were measured at rotational speeds n_2 of 1500–4000 rpm.

Fig. 3 shows the ratio $\delta_{dmax}/\delta_{smax}$ of the dynamic maximum tooth root stress δ_{dmax} to the static maximum tooth root stress δ_{smax}. The changes of the ratio $\delta_{dmax}/\delta_{smax}$ of both gears ISPM and ISCM were almost the same up to a rotational speed n_2 of 2400 rpm. The ratio $\delta_{dmax}/\delta_{smax}$ of ISPM was lower than that of test gear ISCM at a rotational speed n_2 of more than 300 rpm. In the range of rotational speeds n_2 of 1500–4000 rpm, the ratio $\delta_{dmax}/\delta_{smax}$ for ISPM became the peak value at a rotational speed n_2 of 2600 rpm, while the ratio for ISCM became the peak values at rotational speeds of 2800 and 3400 rpm.

Fig. 4 shows the vibration acceleration level *VAL* of the gearbox. The changes of the value of *VAL* for both ISPM and ISCM were almost the same up to a rotational speed n_2 of 2600 rpm. The values of *VAL* for ISPM were lower than those for ISCM at a rotational speed n_2 of more than 2700 rpm. Especially at rotational speeds n_2 of 3700 and 3800 rpm, the values of *VAL* for ISCM were about 10 dB higher than those for ISPM.

Fig. 5 shows the spectra of the vibration acceleration of the gearbox. For both test gears, the main components of the vibration acceleration of the gearbox were the tooth meshing frequency f_z and its harmonics. The components of a tooth meshing frequency of $5f_z$ at rotational speeds n_2 of 3700 rpm ($5f_z$ = 4.93 kHz) and 3800 rpm ($5f_z$ = 5.07 kHz) were considerably higher than the others. The vibration of the gear pairs caused by tooth meshing at these rotational speeds was resonated with the natural frequency of the gearbox, since the gearbox of the testing machine used in this experiment had a natural frequency of about 5 kHz. The values of spectra at $5f_z$ of test gear ISPM were lower than those of test gear ISCM at a rotational speed n_2 of more than 2700 rpm.

Since the vibration of the gear pair caused by tooth meshing travels to the gearbox through the shafts and bearings supporting the gear, the damping characteristics of gears can be evaluated by the dynamic tooth stress and the vibration of the gearbox. These results show that the damping characteristics of the sintered gear ISPM are slightly better than those of the steel gear ISCM at the rotational speeds n_2 of 1500–4000 rpm in this experiment.

Surface durability and failure mode. Fig. 6 shows the relationship between the maximum Hertzian stress p_{max} at the working pitch point and the number N_2 of cycles to failure. The percentage of the pitted area is defined as a ratio of total pitted areas to total areas of working tooth surfaces on both gear and pinion. In the case of ISPM, the failure mode was pitting with spalling (Ref. 5), and the fatigue life for pitting was taken as a number of cycles of the test gear when a percentage of pitted area reached 5%. The pitted areas also included spalled areas.

In the case of test gear ISCM, the failure mode was tooth breakage caused by pitting near the working pitch point, and the fatigue life was taken as the number of cycles made by the test gear when tooth breakage due to pitting automatically stopped the testing machine. In this case, the tooth breakage caused by pitting occurred before the percentage of pitted area reached 5%. The test gear ISCM, fatigue-tested under a Hertzian stress p_{max} of 1600 MPa, did not fail up to a number N_2 of 10^8 cycles. The surface durability at a number N_2 of 10^8 cycles in ISPM was 870 MPa, and that in ISCM was 1600 MPa.

Fig. 7 shows photographs of whole failed tooth surfaces and magnified photographs on the dedendum tooth surfaces of both test gears at a final fatigue stage. Those photographs were taken by a scanning electron microscope. On the failed tooth of test gear ISPM, which had some large pits, one can observe many small pits. On the dedendum tooth surface, pits having diameters of 10 to 100 μm were observed, while on the failed tooth of ISCM, large pits were observed near the working pitch point. The tooth breakage caused by pitting in test gear ISCM occurred from the bottom of the large pits near the working pitch point. On the dedendum tooth surface, the surface was smooth and a few small pits were observed.

The percentage of the pitted area in ISPM increased progressively, because the number of small pits increased gradually (Ref. 5). Spalling failure was also observed on the tooth surface near the working pitch point during the fatigue process (Ref. 5). On the other hand, the percentage of the pitted area in ISCM increased sharply, because large pits appeared rapidly at the final fatigue stage. Spalling failure was not observed in these fatigue tests. Under a Hertzian stress p_{max} of 1600 MPa, pits were not observed on the tooth surfaces of ISCM up to a number N_2 of 10^8 cycles.

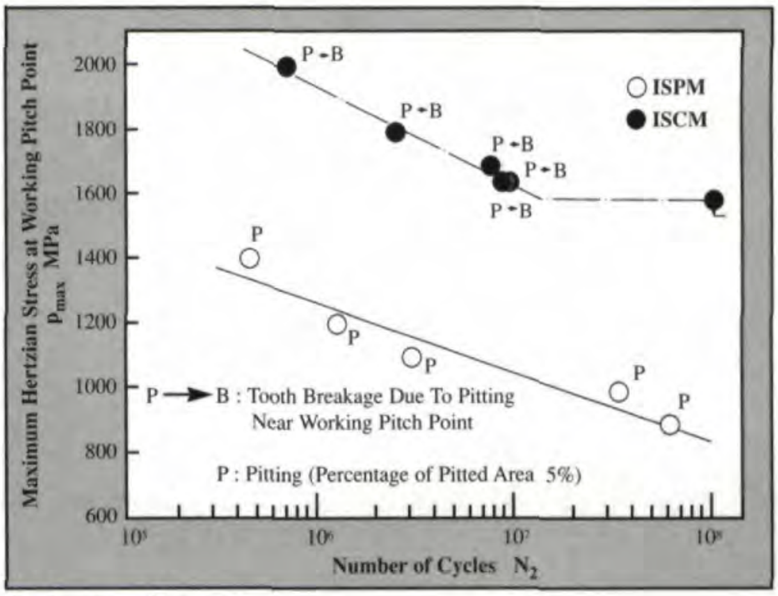

Fig. 6 — p_{max} - N_2 curves.

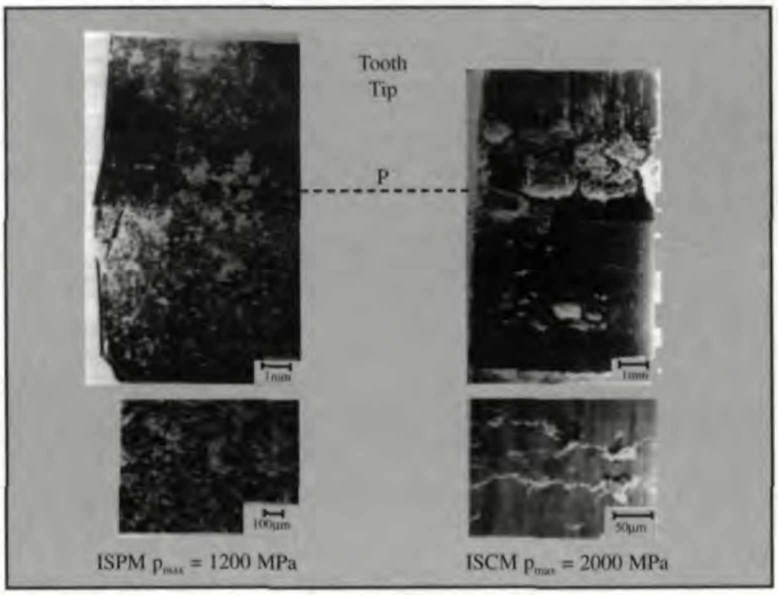

Fig. 7 — Failed tooth surfaces observed by *SEM*.

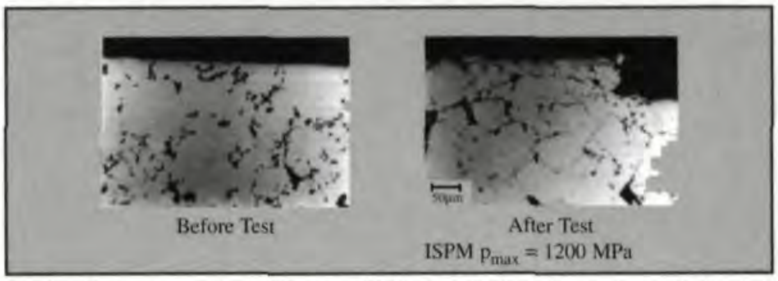

Fig. 8 — Transverse sections of test gear ISPM near tooth surface before and after test.

Fig. 8 shows transverse sections near the tooth surface of test gear ISPM before and after the fatigue test. The pores existing below the tooth surface are visible. The mean size of pores in the transverse section is about 15 μm in diameter. In

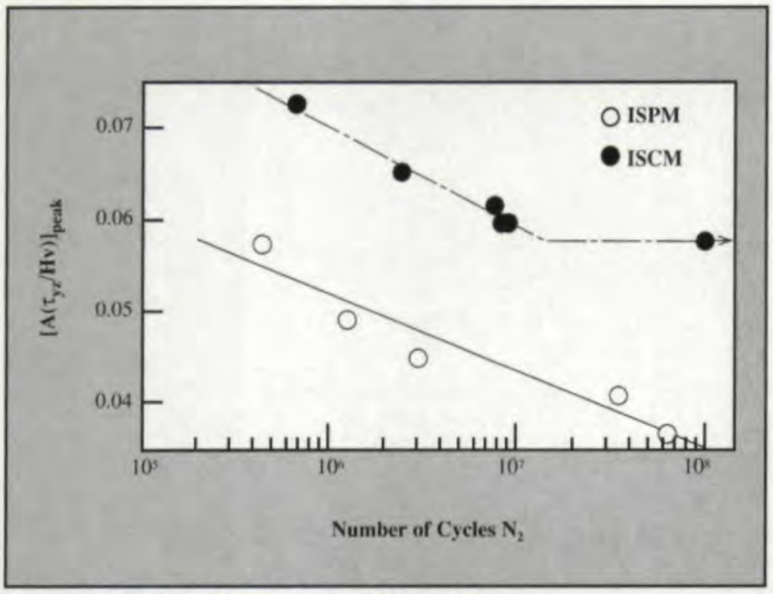

Fig. 9 — Relationships between $[A(\tau_{yz}/Hv)]_{peak}$ and N_2.

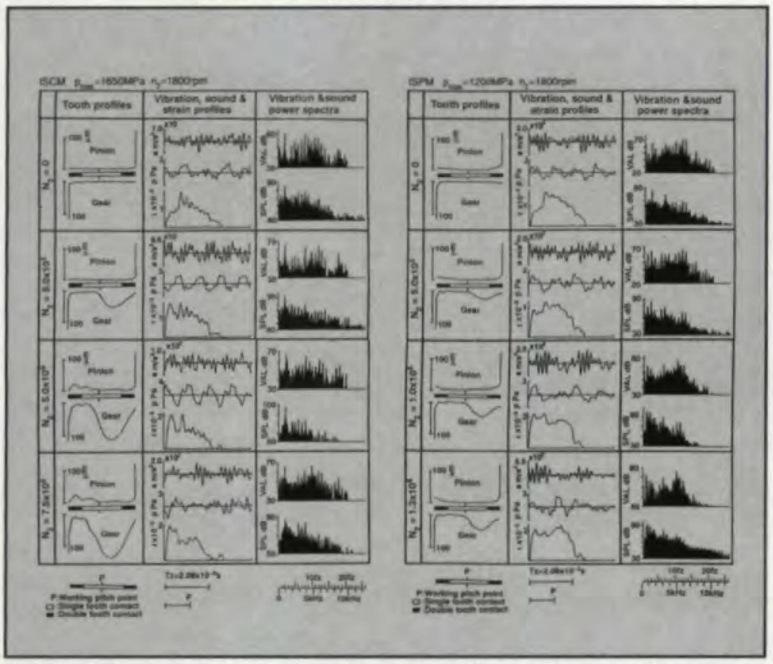

Fig. 10 — Changes in tooth profiles and dynamic performance during fatigue process.

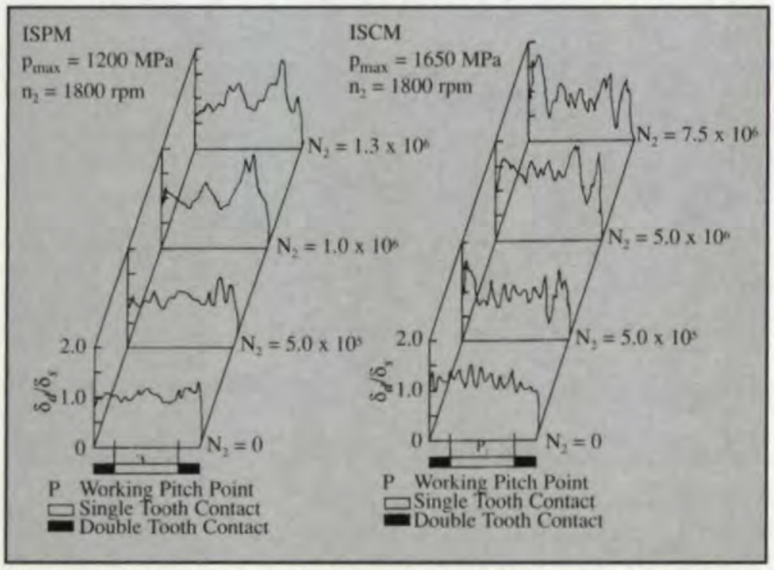

Fig. 11 — Changes in ratio δ_d/δ_s of dynamic tooth root stress to static tooth root stress during fatigue process.

the post-test photograph, the pores are linked to each other by cracks. Therefore, it can be assumed that these cracks caused small pits, and the formation mechanism of pits in sintered gears is different from that in steel gears.

In order to clarify design methods to reduce spalling failure rates in surface-hardened steel rollers and gears, the authors have studied their surface durability using an amplitude of the ratio of orthogonal shear stress to Vickers hardness below the surface (Refs. 8–9). The calculation methods of the spalling fatigue life and the allowable load for spalling were proposed using the amplitude of the ratio of shear stress to hardness (Ref. 8). In this article, the same method was also applied to a sintered gear. Fig. 9 shows the relationship between the peak amplitude $[A(\tau_{yz}/Hv)]_{peak}$ of the ratio of orthogonal shear stress τ_{yz} to Vickers hardness Hv and the number N_2 of cycles. The stresses below the tooth surface at the working pitch point were calculated by an analytical method after Smith and Liu (Ref. 10). It was also assumed here that the material strength of each test gear is directly proportional to each Vickers hardness. In this fatigue test, the spalling failure for test gear ISCM was not observed. But the relationship $[A(\tau_{yz}/Hv)]_{peak}$ - N_2 in test gear ISCM was located lower than that in ISPM because of the porous quality of the sintered gear. This fact indicates that the relationship between the material strength and the hardness in the sintered gear is different from that in the steel gear.

Changes in dynamic performance during fatigue process. Fig. 10 shows an example of the changes in the tooth profiles of gear and pinion, vibration acceleration a, sound pressure p, compressive tooth root strain ε, and vibration and sound spectra during a fatigue process at a rotational speed n_2 of 1800 rpm. Since the Hertzian stress p_{max} for test gear ISPM was different from that for test gear ISCM in Fig. 10, ISPM was qualitatively compared with ISCM on dynamic performance. Concerning the tooth profile change, wear of both ISPM and ISCM occurred on the dedendum tooth surface at an initial fatigue stage and developed in the direction of the working pitch point as the number of cycles increased. The tooth profile of the mating pinions of both test gears did not change remarkably during the fatigue stage. The profiles of vibration acceleration and sound pressure change periodically at tooth meshing period Tz at the initial fatigue stage. As the number of cycles increased, the profiles of both of them changed gradually through the fatigue process. But the profile did not change periodically at the final fatigue stage.

In the results of the spectra analysis, the main components of the spectra of both *VAL* and *SPL* were the tooth meshing frequency f_z and its harmonics at the initial fatigue stage. But the values of the components, except for the tooth meshing frequency and its harmonics, became gradually higher as the number of cycles increased. Comparing the profile change of the tooth root strain near the final fatigue stage with that at the initial fatigue stage, we can see that the load in the test gear was not smoothly transmitted at the recess contact zone. These dynamic performances during the fatigue tests were qualitatively similar in both test gears.

To evaluate the dynamic tooth root stress quantitatively, the dynamic tooth root stress was evaluated by comparing the changes of the ratio δ_d/δ_s of dynamic tooth root stress δ_d to static tooth root stress δ_s at each contact position during the fatigue process. Fig. 11 shows the changes of the ratio δ_d/δ_s during the fatigue process. At the initial fatigue stage, the value of the ratios δ_d/δ_s for each test gear was near 1.0 through tooth meshing. The profile of the ratio for ISPM changed more smoothly through the tooth meshing compared with that for ISCM. This fact indicates that the damping characteristic of ISPM was superior to that of ISCM. As a number of cycles increased, the profile of the ratio for both test gears changed gradually. Especially at the final fatigue stage for both gears, the profile of the ratio at the recess contact zone changed rapidly because of the wear of the tooth surface. In the case of test gear ISCM, the profile of the ratio δ_d/δ_s also fluctuated widely at the beginning of the tooth meshing from the early fatigue stage.

Conclusions

To discover how to apply surface-hardened, sintered, powder metal gear technology to power transmission gears, an induction-hardened, sintered powder metal spur gear was compared with an induction-hardened, melted steel spur gear for surface durability and dynamic performance. The fatigue tests were conducted using a power circulating gear testing machine having a center distance of 82.5 mm. The results are summarized as follows:

1. Under the same normal load per unit face width, the sintered gears were slightly superior to the steel gears on the dynamic tooth stress and the vibration acceleration of the gearbox at rotational speeds of 1500–4000 rpm.

2. The surface durability of the sintered gear was lower than that of the steel gear. The failure mode of the sintered gear was pitting with spalling, while that of the steel gear was tooth breakage due to pitting near working pitch point. The pitted area of the sintered gear increased gradually during the fatigue process. On the other hand, that of the steel gears increased rapidly at the final fatigue stage. The pitting of the sintered gear was mainly caused by the porous nature of the material. The pores existing on and below the tooth surface of the sintered gear played an important role in pit formation.

3. In both cases, the wear of the tooth profile occurred at the dedendum tooth surface because of tip interference between gear and pinion, and was developed in the direction of the working pitch point during the fatigue process. The changes in the dynamic performance of both test gears were almost the same qualitatively during the fatigue process. ○

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Originally presented at the 1994 International Gearing Conference, University of Newcastle upon Tyne, U.K., September, 1994.

A Huge Success

Sivyer Steel casts 62' bull gear in seventeen weeks from purchase order to shipping.

Nancy Bartels

Sivyer Steel Corporation, Bettendorf, IA, an ISO-9002-certified casting specialist, is familiar with tackling tough jobs. The company has built an international reputation as a supplier of high-integrity castings, especially those which require engineering and/or full machining. It's not unusual for Sivyer's customers, especially those in the mining, recycling, power generation, valve and nuclear fields, to ask the foundry to produce a one-of-a-kind casting—often something revolutionary—but AmClyde Engineered Products' request was a special challenge, even for Sivyer.

AmClyde, a designer and manufacturer of large specialty equipment for lifting, pulling, moving and mooring the heaviest loads in the offshore oil and gas market, asked Sivyer to create a gear to turn large platforms or similar structures. Though the basic specs—a high-strength alloy steel per ASTM-A-148, Grade 115/95, with minimum 115,000 psi ultimate tensile strength, minimum 95,000 psi yield strength, minimum 14% elongation and minimum 30% reduction of area—were well within the ordinary, the size was not. The cast tooth bull gear required a diameter of 62 feet.

Fig. 1 — A close up view of the gear shows how the toothed sections were assembled during the roundup. Sections had to fit together with a very tight tolerance of ±5 mm on the 62' diameter.

Project Constraints

Other project constraints, though common to gearing, became crucial, because of the massive size of the gear. The 2" profile teeth had to be cast into each segment with zero draft angle allowed. The casting tolerances were extremely tight, and during roundup, all twenty segments had to be leveled and bolted together. When shipped, the gear had to meet Level 1 requirements—the casting industry's highest quality standard.

As Sivyer's design engineers looked at the project, they broke it down into several phases:

- Redesign for efficient manufacture at Sivyer's large, no-bake facility.
- MAGMAsoft® simulation modeling of mold filling and solidification.
- Building of new pattern equipment.
- First article approval.
- Production pouring.
- Heat treatment.
- Machining.
- Full radiography.
- Roundup.
- Shipment on time.

As Sivyer's engineers originally looked at the project, the biggest concerns were with the solidification modeling, heat treatment, machining and roundup. There were special customer requests on the last three, and the first was crucial to the success of the entire project.

However, once the purchase order was signed, there was an overriding concern: The process, which would normally take twenty-eight to thirty weeks, had a mere seventeen-week schedule. Scheduling, managerial and teamwork skills would really be put to the test.

Despite the fact that the foundry schedule in the floor molding area was extremely tight, Sivyer's engineers were sure the job could be completed on time if everything worked smoothly. But success hinged in the early days on their ability to use computer modeling to design the patterns and related process parameters.

The final design called for casting in twenty segments, each 6" high x 6" wide, with a 2" cast tooth profile, cast onto the outside diameter. Sivyer's previous cast tooth gear projects had involved an identical number of teeth per segment. But because of the design of the 114.86" circular arc (based on the inside radius), this project would be different. In the final design, the 62-foot gear had a total of 558 teeth, 0.75 DP, 20° PA stub tooth form. It would be manufactured in eighteen segments containing 28 teeth per segment and two segments with 27 teeth per segment. Each segment would weigh 1600 lbs. and be 117 inches long. The designers were aware that any final adjustments would have to be handled at roundup stage.

Modeling

Producing the gear in the traditional manner would have involved weeks of trial and error, even with Sivyer's skilled and experienced staff—weeks they didn't have. In order to determine more efficiently where to best place the chills and related process components for successful pouring, company engineers turned to their computers and a software program known as MAGMAsoft.

MAGMAsoft is an extremely accurate mold-filling and solidification modeling software. With it, the design engineer is able to simulate a prototype of the actual mold and casting prior to its creation. By manipulating the location of the process particulars on screen, the software can accurately predict where faults, failures and shrinkage will appear in the actual casting process. Because of the program's 3-D capabilities, this computerized trial run shows trouble spots and allows for redesign of the mold to eliminate them, effectively ensuring the integrity of the actual casting.

While that work was being processed, other departments prepared for the pouring and the crucial steps that would follow. When the castings were ready for heat treatment, they would require normalization, as well as quench and temper processes. Arrangements also had to be made for special fixturing during loading to prevent warpage.

Machining

The specs called for top and bottom faces ground to dimension, milled ends machined to proper radial angle and milled pilot holes drilled for the splice joints. During machining, nine holes were drilled through the height of the gear for bolt-down. No machining was necessary on the teeth, thanks to exceptional dimensional accuracy and surface quality.

Fig. 2 — A view of the floor as the gear was being assembled gives some idea of the magnitude of the gear. A special site had to be found for the assembly process, and every piece fit together and leveled properly.

Roundup

The last step was roundup. The specs called for the radius to have an extremely tight tolerance of ± 10 mm. Sivyer engineers arranged a site for the roundup and the necessary equipment. With specifications as tight as they were, each segment of the 62' diameter gear had to be individually leveled, then bolted together to ensure overall uniformity of roundness. Highly accurate measurements were made using laser technology to verify that the critically important assembly dimensions were held to ± 5 mm.

At roundup, the customer asked for only one alteration. Because of the final shipping weight—over 34,200 pounds—he requested that lifting holes be drilled into each segment to make transportation easier. This done, the project shipped on time.

Project Management Skills Crucial to Success

A special combination of skills was required to make a success of the AmClyde project. Sivyer's technical know-how, project management expertise and its experience in handling short turnaround times and turnkey projects were essential. So was the company's recognition that sometimes, in order to keep a project on schedule, parts of it may have to be jobbed out—even if they are tasks the organization is normally capable of handling. In the AmClyde project, a local machine shop handled the machining under Sivyer's supervision. According to Patrick J. Comparin, Sivyer's vice-president, it was this combination of background, skills and teamwork that made the AmClyde gear project doable and account for Sivyer's success in the castings market. ○

For more information about Sivyer Steel, please circle Reader Service No. A-105.

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Nancy Bartels
is Gear Technology's Senior Editor.

The Beginner's Guide to Powder Metal Gears

What you should know about this gear cutting alternative.

George Shturtz

Increasingly gear designers and product engineers are capitalizing on the economic advantages of powder metallurgy (P/M) for new and existing gear applications. Powder metal gears are found in automobiles, outdoor power equipment transmissions and office machinery applications as well as power hand tools, appliances and medical components.

Helical, bevel (both straight and spiral), rack, face, internal and external spur gears, including compound gears, can be manufactured to final shape with no machining operations. Consequently, material scrap losses are eliminated. Internal configurations (splines, keys, keyways) are formed simultaneously with the gear profile, eliminating subsequent machining operations. P/M gear shapes produced by two or more compacted powder preforms that are sinter-bonded or sinter-brazed together result in complex, single-piece geometries that cannot be produced economically by other manufacturing methods. This efficient utilization of materials and energy increases the competitiveness of the P/M process.

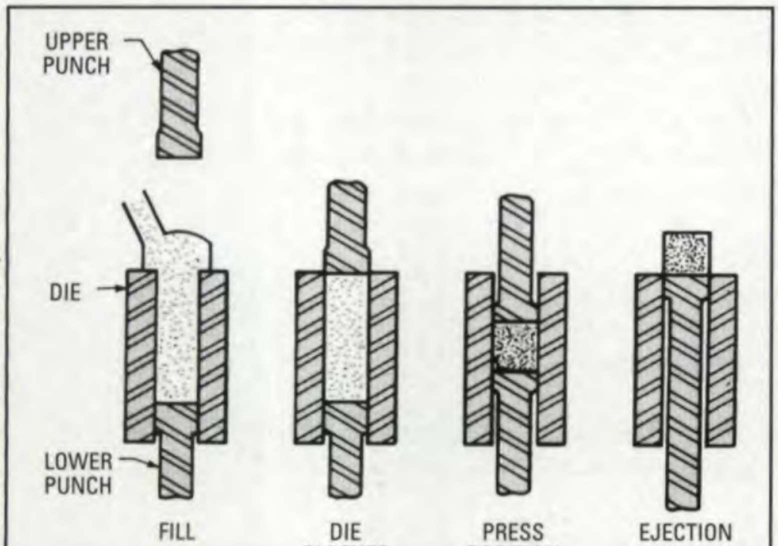


Fig. 1 — Typical tool motions during a powder compaction cycle.

Metal Powder Industries Federation. Used with permission.

Powder metallurgy offers a unique combination of benefits for gear manufacturing that presents a cost-effective alternative to traditional metal forming techniques. A wide variety of base metals are currently available in powder form; brass, bronze, iron and numerous steel grades, including stainless. Customized mixing and blending of elemental powders provides a variety of possibilities for the development of alloy compositions formulated for specific mechanical properties.

Conventional powder metallurgy involves the forming of blended metal powders, usually at room temperature, at pressures typically between 20–50 tsi (tons per square inch) of projected surface area. Generally, P/M molds or tooling come in several pieces. The mold for a single-level gear consists of a die, an upper punch and a lower punch. If the particular part to be formed requires a bore or other ID configuration, a core rod(s) is also part of the tooling. Multi-level compound gears or other complex parts may have two or more upper and/or lower punches.

To form the gear, the die is filled with powder at a ratio of approximately two times the parts thickness: e.g., a spur gear that has a thickness of .750" will be compacted from a column of powder 1.500" thick. During the compaction cycle of the most commonly used type of press, the upper punch enters the die while the lower punch, which in the fill position seals off the bottom of the die, remains stationary. As the upper punch travels downward, the compressive forces cause the die assembly to move downward in relationship to the lower punch, resulting in the same effect as if the lower punch were moving upward during the compaction stroke. The rate of movement and pressure of the upper punch and the motion of the die are relatively equal to ensure uniform density within the compacted preform.

After completion of the compaction cycle, the upper punch retracts from the die, and the lower punch initiates an upward motion, ejecting the preform from the die. (See Fig. 1.) The compacted preform is the exact shape of the final part. Depending on the final part shape, secondary operations may be required.

The shape of the compacted preform is determined by the shape of the tooling and the axial motion of the compaction press. Two main factors influence part design; the flow behavior and characteristics of the metal powders and the movement of the tools within the pressing cycle. Metal powders do not flow hydraulically, and the allowance for friction between the powder particles themselves and with the moving tool members must be factored in the final P/M part design. The pressing action from both top and bottom largely governs the shape, length and dimensional details of the preform.

The compacted preform then must be thermally processed or sintered. Sintering is the metallurgical bonding of the powder particles at a temperature below the melting point of the base material. Sintering at temperatures of approximately 2050°F produces tensile properties from 18,000–90,000 psi, depending on material composition. The addition of heat treatment can increase the ultimate tensile properties of a single, compacted/sintered component to 130,000 psi and higher. Depending on the required mechanical and physical properties and dimensional specifications, the gear may be complete at the end of the compact-sinter cycle or after heat treatment if required.

Designing P/M Gears

Six major factors need to be taken into consideration when designing a new or existing gear for the P/M process.

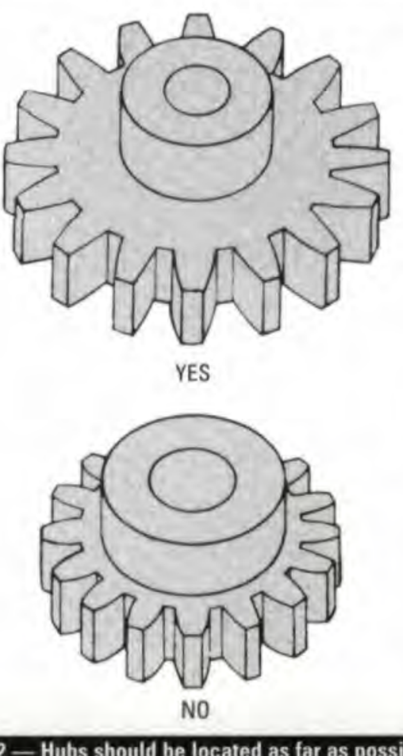
1. *The configuration of the gear should allow for ejection from the die.* While P/M is considered a net-shape technology, some features must be eliminated from the final part design or added through secondary machining operations because they would inhibit ejection of the preform from the die. For example, undercuts, reverse angles, details at right angles to the direction of pressing (for example, holes or grooves), threads, diamond knurls and re-entrant angles, all might interfere with smooth ejection.

2. *The configuration of the gear should allow for movement of the metal powders throughout the tool members during the compaction cycle.* As mentioned previously, metal powders do not flow hydraulically. Therefore extremely thin-walled sections, very narrow grooves and deep counterbores should be avoided because metal powders will not fill these parts of a die cavity.

3. *The configuration of the gear should allow for "practical" tooling.* Tooling life can be improved and production efficiencies enhanced by avoiding narrow deep grooves, very sharp edges, complete spherical profiles and knife-thin tool thicknesses. Often design simplification of these features will allow for a more robust or "practical" set of compaction tools without adding machining operations. Another consideration for gear design is to maintain sufficient clearance between the ID and the root diameter, which can range from .035" on small pinions to .300" for more demanding applications.

4. *The configuration of the gear should limit the changes in section thickness.* P/M processes work very well with compound gear geometries. Because the gear profiles are formed during compaction within the tooling, complex compound gears such as gear-pinion and spur-face combinations are well within the capability of the process. Uniform density and high strength is best achieved by limiting the number of section thickness changes (levels) that are designed into the preform. The number of levels a part may have is determined by the specific type of compaction press and/or the design of the compaction tooling.

5. *The configuration of the gear should minimize right angle intersections.* Radii should be incorporated at right angle intersections of section thickness changes. These radii improve the integrity of the preform. Gear engagement should be designed to occur above the radius. Often



Metal Powder Industries Federation. Used with permission.

Fig. 2 — Hubs should be located as far as possible from gear's root diameter.

George Shturtz
is the general sales manager for Carbon City Products, St. Marys, PA, suppliers of powder metal components.

How To Specify P/M Parts

The importance of discussing the part application with your P/M parts manufacturer cannot be overstated. When requesting a quotation, accurate part information must be provided. Refer to the Metal Powder Industries Federation Standard 35 for P/M materials, properties and specifications. In describing a part, stress function and critical requirements for satisfactory service. For optimum results and efficiencies, give the P/M parts manufacturer the widest possible latitude in specifying material, design, physical characteristics, dimensional tolerances, etc. Typical information needed includes the following:

- Information about quantities, including initial needs and a future demand forecast. This enables the most economical approach to costs, manufacturing integration and delivery.
- Detailed drawings of the part and any assembly drawings. Actual samples or prototypes would be helpful. Transmit any information such as knowledge of materials that have worked well in the application.
- Information as to whether the part design can be modified without affecting function. If so, where?
- Part history and usage. Will the P/M part replace one currently in production, or is this a new application? Is the application military, aerospace, medical, etc.?
- Actual service conditions: heat, moisture, impact, corrosiveness, etc.
- Necessary physical, mechanical, corrosion resistance or special properties (tensile, elongation, hardness, flatness, conductivity, impact energy, fatigue strength, etc.)
- The finish required (plating, oxide coating, surface finish).
- Any machining or secondary operations the P/M supplier will be required to perform.
- For gears, specific data are required: a) number of teeth, b) diametral pitch, c) pressure angle, d) measurement over wires, e) tooth thickness, f) backlash, g) helix angle, h) AGMA quality class.

Tools for each P/M part are custom designed and developed specifically for that part. The expense of the tooling may justify the more economical approach of initially testing prototypes machined from P/M slugs.

The quality level and inspection techniques required contribute to the cost of a P/M part. Programs such as SPC and ISO 9000, for example, should be thoroughly discussed and specified by the purchaser and manufacturer prior to submission of a quotation.

More P/M Gear Design Hints

- Carbide dies provide long life and accuracy.
- Residual part porosity tends to dampen sound.
- P/M gears can be made with blind corners, thus eliminating the need for undercut relief.
- P/M gears can be combined with other parts such as cams, ratchets, other gears and various components.
- Helical gears are possible; copper infiltration is sometimes used to improve teeth densities.
- Since tooth configuration is not a problem, true involute gear forms are easier to make than by other methods.

When designing P/M gears:

- Note that hole locations relative to the gear shape itself are affected by the running tolerances of the various tool members. This makes it more difficult to hold the close TIRs (Total Indicator Readings) obtainable with arbor-cut gears, and hubs or pinions that increase the number of concentric tool members increase the TIR tolerance needed. TIRs can be reduced by grinding gear IDs true to the gear pitch diameter.
- As the AGMA class of gear increases, so does the cost of the gear because of the secondary operations required to meet the tighter tolerances.
- To avoid having too-thin members, gear hubs or pinions should be located as far as possible from gear root diameters. (See Fig. 2.)

raised surface features can be added to the compacted preform to assist in this engagement.

6. *The configuration of the gear should incorporate edge detail (i.e., chamfers on top and bottom of gear teeth and on ODs and IDs).* This edge detail or chamfer has two main purposes. First, it increases the density in the teeth. Higher tooth density results in improved mechanical properties, particularly strength. It also reduces adverse effects of burrs. The chamfer detail will in most cases keep the burr within the overall thickness (width) of the gear. These burrs are a result of fit clearance of the tooling and, if necessary, can be removed by a vibratory finishing (tumbling) operation or a machining operation.

Typically gears produced in powder metallurgy are in the AGMA range of 6 to 8, with higher AGMA classifications possible, depending on size of the compacted gear and with additional secondary operations.

Conclusion

The net-shape forming capability of the P/M process produces certain forms and geometries (hubs, bosses, counterbores and cam shapes) which are not practical through other manufacturing technologies. Powder metallurgy produces high strength gears of consistent quality at high production volumes while offering very significant economies. P/M deserves serious consideration when designing new gear components, when analyzing current gears for improvement in functional properties or evaluating cost reduction conversion alternatives.

Gear applications that blend the functional requirements of the end use with the fundamentals of powder metallurgy will allow gear designers and engineers to realize the maximum advantages the P/M can offer for long term reliability in demanding applications. While powder metallurgy is best suited and most widely known for high volume production quantities, there are numerous applications where small quantities (as low as a few thousand pieces) can still offer cost benefits over traditional manufacturing methods. ○

For more information about Carbon City Products, Inc., please circle Reader Service No. A-107.

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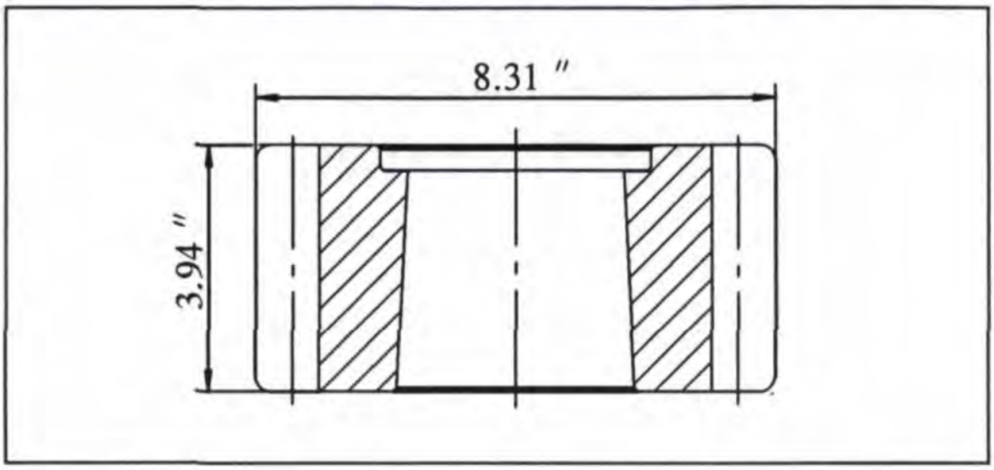
Ground in 13.5 Minutes



GEAR DATA:

Outside Diameter	:	8.31 ″
Face width	:	3.94 ″
No. of Teeth	:	17
D.P.	:	2.38
Helix Angle	:	0 °
Grinding Stock per flank	:	0.007 ″
Profile Modification	:	0.002 ″
Lead Modifikation	:	0.004 ″
Hardness	:	62 HRc
Quality	:	AGMA 13

Total Grinding time: 13.5 min.
(including grinding wheel dressing)

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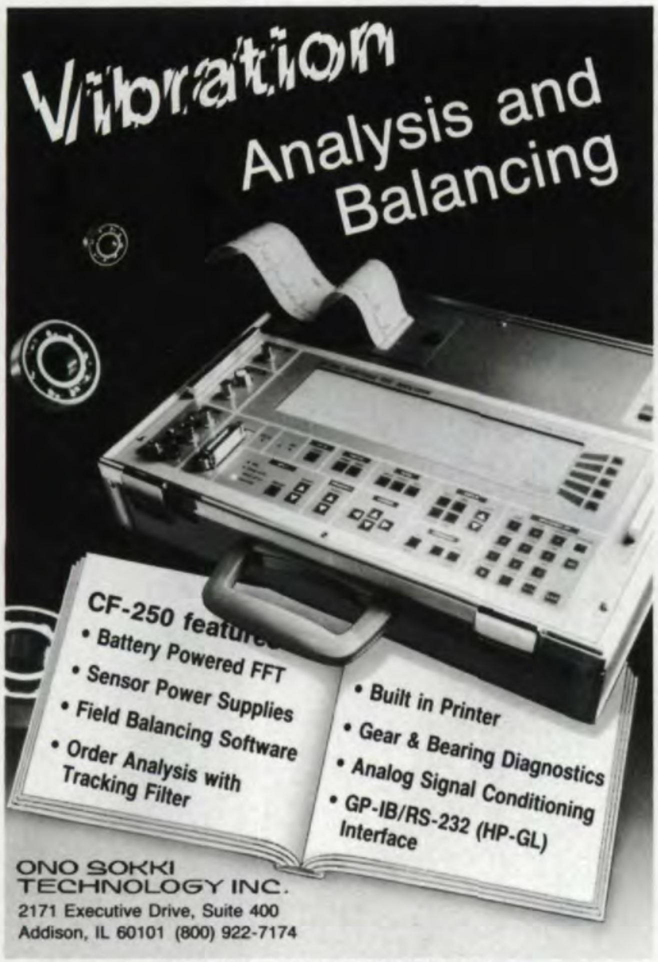

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Metaplas Ionon
Pacific Industrial Furnace Co.
Pillar Industries
Quench Press Specialists
Surface Combustion Inc.
Therm Alliance Co.
TOCCO Inc.
Walmil Company

Hobbing Machines

Ace World Company
American Pfauter, L.P.
Basic Machine Tools
Bourn & Koch Machine Tool
Fayscott Co./Lees-Bradner
Fellows Corp.
The Gleason Works
Koepfer America, L.P.
Liebherr/Sigma Pool
Mitsubishi Machine Tool
National Broach & Machine Co.
V&R Associates
Vic Machine Tools
W.C. Divers & Associates
WMW Machinery Company

Honing Machines

American Pfauter, L.P.
Basic Machine Tools
Bates Technologies Inc.
Bluegrass Precision Machinery
Engis Corp.
The Gleason Works
Miller Industrial Services Inc.
National Broach & Machine Co.
Reishauer Corporation
Sunnen Products Co.
V&R Associates
W.C. Divers & Associates

Inspection Machines

American Pfauter, L.P.
American Sykes Co.
Basic Machine Tools
Best Engineering Co.
Bluegrass Precision Machinery
Bourn & Koch Machine Tool
Brown & Sharpe Mfg.
Fellows Corp.
FGT Gage & Systems,
The Gleason Works
ITW Heartland
JRM International Inc.
Kokusai Inc.
Liebherr/Sigma Pool
M&M Precision Systems
Moore Products Co.—Gage Div.
National Broach & Machine Co.
National Metrology
NewAge Industries Inc.
Ono Sokki Technology
Profile Engineering
Reishauer Corporation
Spline Gauges Ltd.
SU America, Inc.
USACH Technologies
V&R Associates
W.C. Divers & Associates

Keyseating Machines

Basic Machine Tools
Elmass North America
Mitts & Merrill L.P.

Lapping Machines

Basic Machine Tools
The Gleason Works
Lapmaster International
Miller Industrial Services Inc.

Measuring Machines

American Pfauter, L.P.
American Sykes Co.
Basic Machine Tools
Bluegrass Precision Machinery
Bourn & Koch Machine Tool
Brown & Sharpe Mfg.
Fellows Corp.
FGT Gage & Systems,
Liebherr/Sigma Pool
M&M Precision Systems
National Broach & Machine Co.
Ono Sokki Technology
Profile Engineering
Spline Gauges Ltd.
SU America, Inc.
USACH Technologies
W.C. Divers & Associates

Shaping Machines

American Pfauter, L.P.
American Wera Inc.
Basic Machine Tools
Bourn & Koch Machine Tool
Elmass North America
Fellows Corp.
Liebherr/Sigma Pool
Micromatic Textron
Mitsubishi Machine Tool
National Broach & Machine Co.
V&R Associates
W.C. Divers & Associates

Shaving Machines

American Pfauter, L.P.
Basic Machine Tools
Elmass North America
GMI
Mitsubishi Machine Tool
National Broach & Machine Co.
V&R Associates
W.C. Divers & Associates

Spline Rolling Machines

GMI
Micromatic Textron
National Broach & Machine Co.
W.C. Divers & Associates

Testing Machines

American Sykes Co.
Basic Machine Tools
Euro-Tech Corporation
The Gleason Works
Jack Dustman & Assoc.
Krautkramer Branson
M&M Precision Systems
National Metrology
NewAge Industries Inc.
Ono Sokki Technology
Parker Industries Inc.
Precision Gage Co.
Profile Engineering
Spline Gauges Ltd.
SU America, Inc.
W.C. Divers & Associates

Turning Machines

American Wera Inc.
The Daniluk Corp.
Fellows Corp.
Miller Industrial Services Inc.
Mitsubishi Machine Tool
V&R Associates
Vic Machine Tools

Worm Milling Machines

American Pfauter, L.P.
Basic Machine Tools
Bourn & Koch Machine Tool
Koepfer America, L.P.

Gear Manufacturing Machines—Other

Comtorgage Corporation—Hand-Held Dimensional Gages
Daniluk Corp.—Machining Centers
Euro-Tech Corp.—Spline Gaging Machines
Finishing Equipment Inc.—Cleaning Machines
Harper Surface Finishing Systems—Finishing Machines
Hoglund Technology Corporation—Gear Wheel Dressers
JRM International—Rack Milling, Rack Grinding, Part Marking, Broach Milling Machines
Koepfer America, L.P.—Hob Sharpening Machines
Manufacturing Technology Inc.—Inertia/Friction Welders
National Metrology—Optical Comparators
Normac Inc.—CNC Grinding Wheel Dressers
Redin Corporation—Design/Build Special Machines
Sala/BLM Corp.—Saws & Sawing Systems
Schenck Turner—Pointing Machines
Sunnen Products Co.—Surfacers, Boring Machines
Walmil Co.—Parts Washers

GEAR MATERIALS

Gear Materials—Plastics

ABA-PGT, Inc.
American Machine Works
Best Engineering Co.
Equitable Engineering
GW Plastics Inc.
Harder Precision Components
Hoechst Celanese Corp.
Howard's Machine Shop
Moore Gear & Mfg.
Trogetec Inc.
Worcester Gear Works

Gear Materials—Powder Metal

Alpha Sintered Metals
Asco Sintering Co.
Capstan Atlantic
Carbon City Products
Interlake Hoeganaes
Keystone Carbon Company
St. Marys Carbon Co.
TPI Powder Metallurgy
TPS Inc.
Zenith Sintered Products, Inc.

Gear Materials—Steel

Ace World Company
American Machine Works
Cincinnati Gear Co.
Crucible Service Centers
Disston Precision Inc.
Equitable Engineering
Harder Precision Components
Howard's Machine Shop
Latrobe Steel Co.—Div. of Timken
Moore Gear & Mfg.
RD Industries
Trogetec Inc.
Worcester Gear Works

Gear Materials—Other

Dura-Bar—Continuous Cast Iron Barstock
Trogetec Inc.—Nonferrous Metals
Wells Manufacturing—Iron

GEAR SERVICES

Cryogenics

Boeing Precision Gear
Detroit Flame Hardening
FPM Heat Treating
Gearcoa
Merit Gear Corp.
Robotronix Drive Systems

Fault Analysis

Akron Gear & Engineering
Ashot Ashkelon Industries
Aston Metallurgical Services
Brown & Sharpe Manufacturing Co.
Ciateq
Drive Systems Technology
Fairfield Manufacturing
Gear Research Institute
Geartech
Harnischfeger
Penn State University/NCADT
Reilly Engineering Inc.
Robotronix Drive Systems
Technimet Corp.
Xtek Inc.

Gear Blanks

A.W. Sadler Machine
Accu-Prompt Inc.
Accurate Specialties Inc.
The Adams Company
Akron Gear & Engineering
American Machine Works
Ancon Gear & Instrument Corp.
Arrow Gear Co.

Boeing Precision Gear
Bourn & Koch Machine Tool
Boxx Gear Manufacturing
Bucyrus-Erie Co.
Capstan Atlantic
Charles Bond Co.
Chicago Gear Works
Cincinnati Gear
Clarke Gear Co., Inc.
Clifford-Jacobs Forging
Columbia Gear Corp.
Cornell Forge Co.
Disston Precision Inc.
DMS Inc.
Engratec de Mexico
Fairfield Manufacturing
Fairlane Gear Inc.
Fellows Corp.
Fuller Company
Gear Motions
Gearcoa
Gears & Drive Systems
Geartronics Industries
Generated Gear & Machine
The Gleason Works
Harder Precision Components
Highway Machine Co.
Howard's Machine Shop
Keller Machine Co.
Linamar
Mattoon Precision Manufacturing Inc.
Merit Gear Corp.
Mid-State Machine Co.
Moore Gear & Manufacturing Co.
Moore Machine & Gear
PIC Design
Presrite Corp.
Process Industries
Qualicast Corp.
RD Industries
Reef Gear Manufacturing
Robotronix Drive Systems
Schafer Gear Works Inc.
Schmid Tool & Engineering
Southern Gear & Machine
Tifco Inc.
Trogetec Inc.
Trojon Gear Inc.
Van Becelaere Machine Works
Viking Air Tools
Wedin International Inc.
Wells Manufacturing
Westerman Inc.
Wohlert Corp.
Worcester Gear Works

Gear Design

A. W. Sadler Machine
ABA-PGT Inc.
Accu-Prompt Inc.
The Adams Company
Akron Gear & Engineering
Arrow Gear Co.
Ashot Ashkelon Industries
ATA Gears Inc.
Axicon Technologies
C-Dot Engineering
Capstan Atlantic
Caterpillar Industrial Products Inc.
Charles Bond Co.
Chicago Gear-D. O. James
Chicago Gear Works
Ciateq
Cincinnati Gear
Columbia Gear Corp.
Contour Hardening Inc.
Deco-Technologies
DMS Inc.
Drive Systems Technology
Dynamic Tool Grinding Service
Engratec de Mexico
Equitable Engineering
Fairfield Manufacturing
Fairlane Gear Inc.
Fellows Corp.
Gear Research Institute
Gear Systems Inc.
Gearesearch Assoc.
Gears & Drive Systems
General Electric—Marine Products Div.
Generated Gear & Machine
The Gleason Works
GW Plastics Inc.
Highway Machine Co.
Hy-Mech Systems Inc.
Invo Spline Inc.
ITW Spiroid
Labeco
McGinty Gear
Merit Gear Corp.
Mississippi State University
Mobile Pulley & Machine Works
Moore Machine & Gear
Power Eng. & Mfg. Ltd.
Process Industries
Qualicast Corp.
RD Industries
Reef Gear Manufacturing
Reilly Engineering Inc.
Robotronix Drive Systems
SDMG, Inc.
Southern Gear & Machine
Southern Sales & Engineering
Sussex Gear Company
Technimet Corp.
Trogetec Inc.
Universal Technical Systems
Van Gerpen-Reece Engineering
Von Ruden Manufacturing
Wedin International Inc.
Winzeler Gear
Wohlert Corp.
Xtek Inc.

Gear Engineering

A. W. Sadler Machine
ABA-PGT Inc.
Accu-Prompt Inc.
The Adams Company
Akron Gear & Engineering
Ashot Ashkelon Industries
ATA Gears Inc.
Axicon Technologies
Bourn & Koch Machine Tool
Brown & Sharpe Manufacturing Co.
C-Dot Engineering
Calicut Engineering Works Ltd.
Capstan Atlantic
Caterpillar Industrial Products Inc.
Charles Bond Co.
Chicago Gear-D. O. James
Chicago Gear Works
Cincinnati Gear
Columbia Gear Corp.
Consulting & Design Service
Contour Hardening Inc.
Dabko Industries Inc.
DMS Inc.
Drive Systems Technology
Dynamic Tool Grinding Service
Equitable Engineering
Fairfield Manufacturing
Fairlane Gear Inc.
Fellows Corp.
Gear Research Institute
Gear Systems Inc.
Gearesearch Assoc.
Gears & Drive Systems
Geartech
General Electric—Marine Products Div.
Generated Gear & Machine
The Gleason Works
GW Plastics Inc.
Harder Precision Components
Harnischfeger
Highway Machine Co.
Hy-Mech Systems Inc.
Invo Spline Inc.
Labeco
McGinty Gear
Mobile Pulley & Machine Works
Moore Machine & Gear
Morrison Knudsen
Power Eng. & Mfg. Ltd.
Precision Engineering Services
Process Industries
Profile Engineering
Qualicast Corp.
Reef Gear Manufacturing
Reilly Engineering Inc.
Riley Gear Corp.
Robotronix Drive Systems
Southern Gear & Machine
Southern Sales & Engineering
Spline Gauges Ltd.
Sussex Gear Company
Technimet Corp.
Trogetec Inc.
Universal Technical Systems
Von Ruden Manufacturing
Wedin International Inc.
Winzeler Gear
Wohlert Corp.
Xtek Inc.

Gear Grinding

Accu-Prompt Inc.
Aerocom Industries Inc.
Akron Gear &

Engineering
American Pfauter, L.P.
Arrow Gear Co.
Ashot Ashkelon Industries
Boeing Precision Gear
Bourn & Koch Machine Tool Co.
Caterpillar Industrial Products Inc.
Charles Bond Co.
Cincinnati Gear
Columbia Gear Corp.
Dynamic Tool Grinding Service
Equitable Engineering
Fairfield Manufacturing
Fairlane Gear Inc.
Fellows Corp.
Gear Motions
Gearcoa
Gears & Drive Systems
Generated Gear & Machine
The Gleason Works
Invincible Gear Co.
Invo Spline Inc.
Merit Gear Corp.
Midwest Gear
Modified Gear & Spline
Moore Gear & Manufacturing Co.
Moore Machine & Gear
Niagara Gear Corp.
Patterson Gear & Machine
Power Eng. & Mfg. Ltd.
Precision Gear Co.
Pro-Gear Co. Inc.
Process Industries
Qualicast Corp.
RD Industries
Reef Gear Manufacturing
Riley Gear Corp.
Riverside Spline & Gear
Robotronix Drive Systems
SDMG, Inc.
Simon International Distribution
Southern Gear & Machine
Tifco Inc.
USACH Technologies
Viking Air Tools
Wedin International Inc.
Xtek Inc.

Gear Inspection

A. W. Sadler Machine
ABA-PGT Inc.
Ace World Company
Accu-Prompt Inc.
Akron Gear & Engineering
Alpha Precision Inc.
American Pfauter, L.P.
American Stress Technologies
American Sykes Co.
Arrow Gear Co.
Ashot Ashkelon Industries
Aston Metallurgical Services
Boeing Precision Gear
Bourn & Koch Machine Tool Co.
Brown & Sharpe Manufacturing Co.
Charles Bond Co.
Chicago Gear Works
Cincinnati Gear
Columbia Gear Corp.
Contour Hardening Inc.
Equitable Engineering
Fairfield Manufacturing
Fairlane Gear Inc.
Fellows Corp.
Forest City Gear Co.
Fuller Company
Gear Motions
Gearcoa
Gears & Drive Systems
Generated Gear & Machine
The Gleason Works
Harder Precision Components
Highway Machine Co.
Invo Spline Inc.
Island Machinery
Jack Dustman & Assoc.
M&M Precision Systems
Merit Gear Corp.
Moore Gear & Manufacturing Co.
Moore Machine & Gear
National Broach & Machine Co.
National Metrology
Niagara Gear Corp.
Patterson Gear & Machine
Penn State University/NCADT
Pfauter-Maag Cutting Tools
Precision Gage Co.
Precision Gear Co.
Precision Gears Inc.
Process Industries
Profile Engineering
Qualicast Corp.
RD Industries
Reef Gear Manufacturing
Riley Gear Corp.
Riverside Spline & Gear
Roto-Technology, Inc.
SDMG, Inc.
Southern Gear & Machine
Spline Gauges Ltd.
Tifco Inc.
Trogetec Inc.
UBM Corporation
United Tool Supply
Viking Air Tools
Von Ruden Manufacturing
Wedin International Inc.

Heat Treating

The Adams Company
Ajax Magnethermic
American Metal Treating
American Pfauter, L.P.
Applied Process Inc.
Arrow Gear Co.
Ashot Ashkelon Industries
Boeing Precision Gear
Bucyrus-Erie Co.
Caterpillar Industrial Products Inc.
Charles Bond Co.
Cincinnati Gear
Clifford-Jacobs Forging
Contour Hardening Inc.
Detroit Flame Hardening
Disston Precision Inc.
Dynamic Metal Treating
Euclid Heat Treating Co.
Fairfield Manufacturing
Fellows Corp.
FPM Heat Treating
Gearcoa
Gears & Drive Systems Inc.
Generated Gear & Machine
The Gleason Works
Harnischfeger
Howard's Machine Shop
Inductoheat Inc.
Linamar
Lindberg Heat Treating
Merit Gear Corp.
Metlab Co.
Mobile Pulley & Machine Works
Molon Gear & Shaft
Moore Gear & Manufacturing Co.
Moore Machine & Gear
National Broach & Machine Co.
Penn State University/NCADT
Pillar Industries
Progressive Engineering
Qualicast Corp.
RD Industries
Robotronix Drive Systems
Simon International Distribution
TOCCO Inc.
Wedin International Inc.
Wells Manufacturing
Wohlert Corp.
Xtek Inc.

Shot Peening

The Adams Company
Arrow Gear Co.
Ashot Ashkelon Industries
Boeing Precision Gear
Cincinnati Gear
Columbia Gear Corp.
Fairfield Manufacturing Co.
Fellows Corp.
Generated Gear & Machine
Mobile Pulley & Machine Works
Qualicast Corp.
RD Industries
Wohlert Corp.

Tool Coating

American Pfauter, L.P.
Balzers Tool Coating
Best Engineering Co.
DiamondBLACK Technologies Inc.
Dynamic Metal Treating Inc.
Fellows Corp.
Fette Tool Systems
General Magnaplate Corp.
Jack Dustman & Assoc.
Moore Gear & Manufacturing Co.
Multi-Arc Inc.
P.F. Markey Inc.
Pfauter-Maag Cutting Tools
Star Cutter Co.
Wohlert Corp.

Gear Services—Other

Accurate Specialties Inc.—Bronze Gear Blanks
AGMA—Standards Development
Ascent Drafting Service—Drafting Service
Aston Metallurgical Services—Metallurgical, Mechanical & Chemical Testing
ATA Gears Inc.—Custom Gearbox Design
Capital Associates International—Machinery Leasing & Financing
Detroit Flame Hardening—Vibratory Stress Relief
Fairlane Gear Inc.—Noise Evaluation
Fuji Univance Corp.—Gear Transmissions
Geartech—Gear Seminars
Hy-Mech Systems Inc.—Technical Seminars on Gearing
International Financial Services—Machinery & Equipment Financing
Kluber Lubrication—Lubrication Analysis
Koepfer America, L.P.—Hob Sharpening
Koro Sharpening Service—Hob Sharpening
Metlab Co.—Annealing & Stress Relieving
Mikrofinish—Wear Enhancement
Modified Gear & Spline—Crown Gear Grinding
NASA Lewis Research Center—Consultation, Performance Testing
Ohio Broach & Machine Tool—Broaching Services
Precise Inspection—Instrument Repair
Precision Gear Co.—Gear Shaving, Broaching
Repair Parts Inc.—Hob Sharpening
Sales Consultants—Marketing Consulting, Executive Recruiting
Spline Gauges Ltd.—Master Gear Regrinding, NAMAS/NIST Calibration
Star Cutter—Hob Sharpening
Stearns Financial—Consultants, Machinery Financing
Technimet Corp.—Metallurgical Testing & Consulting
U.S. Tech Corporation—CNC Integration, Consulting and Software

GEAR SOFTWARE

Software—Custom

Ace World Company
American Pfauter, L.P.
American Sykes Co.
Axicon Technologies
Bourn & Koch Machine Tool Co.
C-Dot Engineering
Ciateq
Drive Systems Technology
Euro-Tech Corporation
Gearesearch Assoc.
Gearsoft Design
The Gleason Works
Hoglund Technology Corporation
M&M Precision Systems
Metrscope Corp.
NASA Lewis Research Center
PC Enterprises
Power Eng. & Mfg. Ltd.
Profile Engineering
R.H. Software
Roto-Technology, Inc.
Scott Machine Tool Co.
Software Engineering Service
Trogetec Inc.
U.S. Tech Corporation
Universal Technical Systems
User Solutions Inc.
Van Gerpen-Reece Eng.
WMW Machinery Company

Software—Gear Design

ABA-PGT Inc.
Accu-Prompt Inc.
American Gear Mfgrs. Assn.
Axicon Technologies
Bluegrass Precision Machinery
Ciateq
Contour Hardening Inc.
Drive Systems Technology
Ernst Winter & Son
Fairfield Manufacturing
Gearesearch Assoc.
Gearsoft Design
Geartech
The Gleason Works
NASA Lewis Research Center
PC Enterprises
Power Eng. & Mfg. Ltd.
Roto-Technology, Inc.
Software Engineering Service
Trogetec Inc.
Universal Technical Systems
Van Gerpen-Reece Eng.

Software—Gear Inspection

American Pfauter, L.P.
American Sykes Co.
Best Engineering Co.
Bourn & Koch Machine Tool Co.
Brown & Sharpe Mfg.
Contour Hardening Inc.
Euro-Tech Corporation
FGT Gage & Systems
The Gleason Works
Liebherr/Sigma Pool
M&M Precision Systems
Metrscope Corp.
PC Enterprises
Penn State University/NCADT
Pfauter-Maag Cutting Tools
Precision Gage Co.
Profile Engineering
R.H. Software
Roto-Technology Inc.
Scott Machine Tool Co.
Software Engineering Service
Trogetec Inc.
Universal Technical Systems

Software—Shop Management

American Pfauter, L.P.
Bourn & Koch Machine Tool Co.
JobBOSS Software, Inc.
Metrscope Corp.
Power Eng. & Mfg. Ltd.
R.H. Software
Scott Machine Tool Co.
Trogetec Inc.
U.S. Tech Corporation
User Solutions Inc.
WMW Machinery Company

Other Software

Engis Corp.—Gear Grinding Software

GEAR TOOLING & ACCESSORIES

Abrasives

American Pfauter, L.P.
American Sykes Co.
Bates Technologies Inc.
Best Engineering Co.
Bluegrass Precision Machinery
Bourn & Koch Machine Tool Co.
Cincinnati Milacron
Engis Corp.
Ernst Winter & Son Inc.
GMI
Hoglund Technology Corporation
Lapmaster International
Meister Grinding Tech.
P. F. Markey Inc.
Redin Corp.
Rex-Cut Products Inc.
Sidley Diamond Tool
Star Cutter Co.
Sunnen Products Co.

USACH Technologies
W. E. Litwin Assoc.

Broaching Tools

American Sykes Co.
Apex Broach & Machine Co.
Barit International
Best Engineering Co.
Detroit Broach Co.
Elmass North America
General Broach & Engineering Co.
Jack Dustman & Assoc.
National Broach & Machine Co.
The Ohio Broach & Machine Co.
P.F. Markey Inc.
Parker Industries Inc.
Reid Tool Service Inc.
Spline Gauges Ltd.
Ty Miles Inc.
W.C. Divers & Associates

Chamfering Tools

American Pfauter, L.P.
American Sykes Co.
Best Engineering Co.
GMI
Interstate Tool Corp.
Jack Dustman & Assoc.
JRM International
P. F. Markey Inc.
Reid Tool Service Inc.
SU America, Inc.

Deburring Tools

Ace World Company
American Sykes Co.
Best Engineering Co.
Bourn & Koch Machine Tool Co.
GMI
Jack Dustman & Assoc.
JRM International Inc.
M&M Precision Systems
P. F. Markey Inc.
Redin Corp.
Reid Tool Service Inc.

EDM Tooling & Supplies

AGIE USA Ltd.
Bluegrass Precision Machinery
Charmilles Technologies
Current EDM, Inc.
Easco-Sparcatron
EDM Solutions Co.
Engemaq U.S.A.
Hansvedt Industries, Inc.
Hermes Machine Tool Co., Inc.
Hitachi EDM Products
KGK International Corp./Sodick EDM
Koolant Koolers Inc.
LeBlond Makino Machine Tool Co.
Mecatool USA Ltd.
Mitsubishi EDM/MC Machinery
Okamoto Corp. EDM
Raycon Corp.
Victek Machinery, Inc.
Xermac, Inc.

Form Grinding Wheels

Abrasive Technology
American Pfauter, L.P.
Best Engineering Co.
Bluegrass Precision Machinery
Bourn & Koch Machine Tool Co.
Dianamic Abrasive Products Inc.
Engis Corp.
Ernst Winter & Son
Höfler Maschinenbau GmbH
Hoglund Technology Corporation
Liebherr/Sigma Pool
P. F. Markey Inc.
Pfauter-Maag Cutting Tools
Sidley Diamond Tool
Star Cutter Co.
SU America, Inc.
USACH Technologies
W. E. Litwin Assoc.
Wendt Diawal

Hobs

Ace World Company
American Pfauter, L.P.
American Sykes Co.
Barit International
Basic Machine Tools
Best Engineering Co.
Bourn & Koch Machine Tool Co.
Fellows Corp.
Fette Tool Systems
GMI
Harder Precision Components
Interstate Tool Corp.
JRM International Inc.
Koepfer America, L.P.
Kromhard Twist Drill
Liebherr/Sigma Pool
Mitsubishi Machine Tool
National Broach & Machine Co.
P.F. Markey Inc.
Parker Industries Inc.
Pfauter-Maag Cutting Tools
Rebco Industrial Products
Reid Tool Service Inc.
Russell, Holbrook & Henderson
Star Cutter Co.
SU America, Inc.
Vic Machine Tools
W.C. Divers & Associates

Keyseat Cutters

Elmass North America Inc.
Fette Tool Systems
Interstate Tool Corp.
Mitts & Merrill L.P.
P. F. Markey Inc.
Reid Tool Service Inc.
Star Cutter Co.
W. E. Litwin Assoc.

Lapping Compounds

Bates Technologies Inc.
Cincinnati Milacron
Engis Corp.
Lapmaster International
P. F. Markey Inc.
Reid Tool Service Inc.
Sidley Diamond Tool

Lubricants/Coolants

Cincinnati Milacron
D. A. Stuart Co.
Etna Products Inc.
Fiske Brothers Refining
Houghton International
Jack Dustman & Assoc.
Kluber Lubrication North America
Nye Lubricants Inc.
Oberlin Filter Co.
P. F. Markey Inc.
Reid Tool Service Inc.
Sunnen Products Co.

Shaper Cutters

American Pfauter, L.P.
American Sykes Co.
Barit International
Basic Machine Tools
Best Engineering Co.
Bourn & Koch Machine Tool Co.
Elmass North America
Fellows Corp.
GMI
Interstate Tool Corp.
JRM International Inc.
Kromhard Twist Drill
Liebherr/Sigma Pool
Mitsubishi Machine Tool
National Broach & Machine Co.
P.F. Markey Inc.
Parker Industries Inc.
Pfauter-Maag Cutting Tools
Rebco Industrial Products
Reid Tool Service Inc.
Russell, Holbrook & Henderson
Star Cutter Co.
W.C. Divers & Associates

Shaver Cutters

American Pfauter, L.P.
American Sykes Co.
Barit International
Best Engineering Co.
Fellows Corp.
GMI
Interstate Tool Corp.
JRM International Inc.
Micromatic Textron
Mitsubishi Machine Tool
National Broach & Machine Co.
P.F. Markey Inc.
Parker Industries Inc.
Pfauter-Maag Cutting Tools
Rebco Industrial Products
Reid Tool Service Inc.
SU America, Inc.

W.C. Divers & Associates

Worm Milling Cutters

American Pfauter, L.P.
American Sykes Co.
Barit International
Best Engineering Co.
Fette Tool Systems
GMI
Interstate Tool Corp.
JRM International Inc.
Koepfer America, L.P.
Kromhard Twist Drill
Parker Industries Inc.
Pfauter-Maag Cutting Tools
Reid Tool Service Inc.
Russell, Holbrook & Henderson
Star Cutter Co.

Gear Tooling & Accessories—Other

A/W Systems Co.—Spiral Gear Cutters
ABA-PGT Inc.—Thermal Plastic Injection Molds
Abrasive Technology Inc.—Honing Tools, Diamond Tools
American Wera Inc.—Tooling for Wera Profilators
American Sykes Co.—Gear Hones, Rack Cutters, Adjustable Floating Reamers
Barit International Corp.—Form-Relieved Milling Cutters
Best Engineering Co.—Rack Cutters
Buckeye Gear Co.—Change Gears
Clipper Diamond Tool Co.—Diamond Dressing Rolls & Tools
Etna Products Inc.—Quenching Oils, Rust Preventatives
GW Plastics Inc.—Prototype & Production Molds
Höfler Maschinenbau GmbH—Double-Tapered Grinding Wheels
Hoglund Technology Corporation—Plated CBN Grinding Wheels
ITW Heartland—Burnishing Dies
Koolant Koolers Inc.—Industrial Liquid Coolers/Chillers
M&M Precision Systems—Powder Metal Dies for Gears
Micromatic Textron—Spline & Thread Rolling Tools
P.F. Markey Inc.—Hones
Pfauter-Maag Cutting Tools—Form Milling Cutters
Richter Precision Inc.—Titanium Nitride Coatings, Coating Equipment
Spline Gauges Ltd.—Powder Metal/Cold Forging Tools
SU America, Inc—Rotors
Sunnen Products Co.—Precision Bore Gages

GEAR WORKHOLDING & FIXTURING

Arbors

American Pfauter, L.P.
American Sykes Co.
Bates Technologies Inc.
Best Engineering Co.
Bluco Corp.
Bourn & Koch Machine Tool Co.
Drewco Corp.
Elmass North America
Ernst Winter & Son Inc.
Euro-Tech Corporation
Fairlane Gear Inc.
Fellows Corp.
General Broach & Engineering Co.
The Gleason Works
Harder Precision Components
Invo Spline Inc.
Jack Dustman & Assoc.
JRM International Inc.
LeCount, Inc.
M&M Precision Systems
National Broach & Machine Co.
P.F. Markey Inc.
Parker Industries Inc.
Profile Engineering
Reid Tool Services Inc.
Schunk Intec Inc.
Spline Gauges Ltd.
Toolink Engineering
Triangle Machine Tool
U.S. Tech Corporation
USACH Technologies
W.C. Divers & Associates
W.E. Litwin Assoc.

Chucks

Ajax Chuck Jaws Inc.
American Pfauter, L.P.
American Sykes Co.
Bates Technologies Inc.
Best Engineering Co.
Bluco Corp.
Bluegrass Precision Machinery
Bourn & Koch Machine Tool Co.
Drewco Corp.
Euro-Tech Corporation
Fellows Corp.
General Broach & Engineering Co.
The Gleason Works
Harder Precision Components
Invo Spline Inc.
Jack Dustman & Assoc.
M&M Precision Systems
Mobile Pulley & Machine
P.F. Markey Inc.
Reid Tool Services Inc.
Schunk Intec Inc.
Toolink Engineering
Triangle Machine Tool
USACH Technologies
W.C. Divers & Associates
W.E. Litwin Assoc.

Modular Fixtures

Ace World Company
American Pfauter, L.P.
American Sykes Co.
Bates Technologies Inc.
Bluco Corp.
Bluegrass Precision Machinery
Drewco Corp.
Elmass North America
Fellows Corp.
General Broach & Engineering Co.
Harder Precision Components
JRM International Inc.
Moore Products Co.—Gage Div.
P.F. Markey Inc.
Paul W. Marino Gages,
Reid Tool Services Inc.
Schunk Intec Inc.
Sunnen Products Co.
Sytec Corp.
Triangle Machine Tool
U.S. Tech Corporation
USACH Technologies
Viking Air Tools
W.E. Litwin Assoc.

Toolholders

American Pfauter, L.P.
Bates Technologies Inc.
Best Engineering Co.
Bluegrass Precision Machinery
Drewco Corp.
Elmass North America
Euro-Tech Corporation
Fellows Corp.
General Broach & Engineering Co.
Harder Precision Components
Jack Dustman & Assoc.
JRM International Inc.
Mobile Pulley & Machine
P.F. Markey Inc.
Profile Engineering
Reid Tool Services Inc.
Schunk Intec Inc.
Star Cutter Co.
Toolink Engineering
Triangle Machine Tool
U.S. Tech Corporation
USACH Technologies
Viking Air Tools
W. E. Litwin Assoc.

Gear Workholding & Fixturing—Other

A/W Systems Co.—Cutter Bodies for Spiral Gear Cutter Blades
Bluco Corp.—Expanding Mandrels
Drewco Corp.—Hobbing/Shaving Fixtures
Fellows Corp.—Automation for Gear Production Systems
Interstate Tool Corp.—Herringbone Gear Cutter Sharpening Fixtures
Invo Spline Inc.—Rolling Fixtures
JRM International Inc.—Centering Vises, Hydraulic Locknuts, Quick-change Shaper Adapters
Kaman Aerospace Corp.—Test Rig for Gearboxes
Paul W. Marino Gages, Inc.—Machine Probe Stylus
Schunk Intec Inc.—Centric Clamping Systems
Sytec Corp.—Pitch Line Workholding
Tifco Inc.—Spline Arbors
Ty Miles Inc.—Broach Tooling

MACHINERY/EQUIPMENT DISTRIBUTORS

Ace World Company—Jed Heavy Industry (Korea)
American Pfauter, L.P.—Zeiss-Höfler, Hurth, Kapp
American Sykes Co.—James Technologies
American Wera Inc.—Wera Werk Herman Werner GmbH
Bluegrass Precision Machinery—Mitsubishi
Bourn & Koch Machine Tool—Hamai gear inspection machines
Brown & Sharpe Mfg. Co.—Leitz CMMs
Eltech Inc.—SU America, M&M Precision Systems, Niles Grinders
Euro-Tech Corporation—Frenco
Gear Group International—Katsa, Parkano, Tasowheel
The Gleason Works—Fässler
Jack Dustman & Assoc.—American Broach, Cogsdill Tool Products, Speedgrip Chuck, Rohm of America, All Lube International
JRM International Inc.—Kesel, Saazor, Schrem, Baublys, Saacke, Höfler, American Sykes,
James Deburring
Mid-State Machine Co.—Victor Machinery
Miller Industrial Services Inc.—Tornos, Ahlburg, Posalux, Mollart, Agathon, UVA, Kadia, Sulmecanica
National Metrology—Metronics, Heidenhain
Precision Gage Co.—Vari-Roll gear testers
R.L. Wagner & Assoc.—Reef Gear, Ascoforge
Reid Tool Service Inc.—Fellows
Scott Machine Tool Co.—Carl Zeiss, Rank Taylor Hobson
Simon International Distribution—Herzog GmbH
Southern Sales & Engineering—Horsburgh & Scott
Star Cutter Co.—Stieber
Toolink Engineering—MTM König
U.S. Tech Corporation—Richardon GmbH
V&R Associates—Hurth, Gould & Eberhardt, Laschet & Partner
W. C. Divers & Associates—National Broach
W. E. Litwin Assoc.—Special Tools, etc.
WMW Machinery Co.—Niles Werkzeug-maschinen

TRAINING & EDUCATION

Colleges & Universities

Mississippi State Univ.
N. E. Wisconsin Technical College
Penn State University/NCADT
Purdue University—Indianapolis

Gear Schools

American Gear Mfgrs. Assn.
American Pfauter, L.P.
Best Engineering Co.
Bourn & Koch Machine Tool
Drive Systems Technology
Fellows Corp.
The Gleason Works
Hane Industrial Training
Koepfer America, L.P.
National Broach & Machine Co.
Pfauter-Maag Cutting Tools
Trogetec Inc.
Universal Technical Systems
Van Gerpen-Reece Eng.

Research Institutions

Gear Research Institute
Gearesearch Assoc.
M.J. Gallagher & Assoc.
NASA Lewis Research Center
Penn State University/NCADT

Trade Associations

American Gear Manufacturers Assn.
American Society of Mechanical Engineers
ASM International
Metal Powder Industries Federation
Society of Manufacturing Engineers

COMPANY INDEX

Welcome to the newly expanded and revised 1995 *Gear Technology* Buyers Guide. This year we bring you more listings and more categories to help you find the gear products and services you need.

Use this Company Index to locate the complete address, phone number and fax number for each company listed in the Products and Services directory. *Gear Technology* advertisers are shown in boldface type. To find the pages on which their ads appear, see the Advertisers Index on page 32.

While *Gear Technology* has made every effort to ensure that company names and addresses are correct, we cannot be held responsible for errors of fact or omission. If your company was not listed in this directory and would like to be included in 1996, call 708-437-6604 or fax 708-437-6618, and we will add you to our mailing list.

A

A & E Gears BV
Bedrijvenpark Twente 4
NL 7602 KA Almelo
Netherlands
(31) 546-576145
Fax: (31) 546-576155

A. W. Sadler Machine Co.
2840 E. Crescentville Rd.
W. Chester, OH 45071
513-771-5374
Fax: 513-771-0485

A/W Systems Co.
612 Harrison
Royal Oak, MI 48067
810-544-3852
Fax: 810-544-3922

ABA-PGT Inc.
1395 Tolland Turnpike
Manchester, CT 06040
203-649-4591
Fax: 203-643-7619

Abar Ipsen Industries
3260 Tillman Dr.
Bensalem, PA 19020
215-244-4900
Fax: 215-244-7954

Abrasive Technology Inc.
8400 Green Meadows Dr.
Westerville, OH 43081
614-548-4100
Fax: 614-548-7617

Accu-Prompt Inc.
100 83rd St. N.E. Suite. 101
Fridley, MN 55432
612-783-1020
Fax: 612-783-1022

Accurate Specialties Inc.
N12 W24360 Bluemound Rd.
Waukesha, WI 53188
414-547-5450
Fax: 414-547-5892

Ace World Company
306 Busse Highway
Park Ridge, IL 60068
708-698-5538
Fax: 708-824-8327

The Adams Company
100 E. Fourth St.
Dubuque, IA 52001
319-583-3591
Fax: 319-583-8048

Aerocom Industries Inc.
2870 Wilderness Place
Boulder, CO 80301
303-440-8106
Fax: 303-440-8108

AGIE USA Ltd.
185 Hansen Ct., Suite 100
Wood Dale, IL 60191
708-238-0570
Fax: 708-238-0620

Ajax Chuck Jaws Inc.
4949 S. Pitchin Rd.
Springfield, OH 45502
800-543-5998
Fax: 800-552-5320

Ajax Magnethermic Corp.
1745 Overland Ave.
Warren, OH 44482
216-372-8511
Fax: 216-372-8644

Akron Gear & Engineering
501 Morgan Ave.
Akron, OH 44309
800-258-6608
Fax: 216-773-9005

Albro Gear & Instrument
86-L Horseblock Rd.
Yaphank, NY 11980
516-345-0657
Fax: 516-345-0663

Alliance Gear Inc.
4717 Edgemont St.
Philadelphia, PA 19137
215-533-3522
Fax: 215-533-3524

Alpha Precision Inc.
11500 Rockfield Ct.
Cincinnati, OH 45241
513-772-4266
Fax: 513-772-6950

Alpha Sintered Metals, Inc.
RD1, Box 43D Montmorenci Rd.
Ridgway, PA 15853
814-773-3191
Fax: 814-776-1009

Amarillo Gear Co.
2401 Sundown Lane
Amarillo, TX 79105
806-622-1273
Fax: 806-622-3258

American Gear
Manufacturers Assn.
1500 King St., Suite 201
Alexandria, VA 22314-2730
703-684-0211
Fax: 703-684-0242

American Machine Works
1210 Jackson St.
Omaha, NE 68102
402-342-4881
Fax: 402-342-8061

American Metal Treating
1043 E. 62nd St.
Cleveland, OH 44103
216-431-4492
Fax: 216-431-1508

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

American Society of Manufacturing Engineers
345 E. 47th Street
New York, NY 10017
212-705-7338

American Speed Reducer
3375 Richmond St.
Philadelphia, PA 19134
215-426-9115
Fax: 215-426-9101

American Stress Technologies
61 McMurray Rd.
Pittsburgh, PA 15241
412-854-0789
Fax: 412-854-1290

American Sykes Co.
1302 Research Park Dr.
Beavercreek, OH 45432
513-427-0507
Fax: 513-427-9653

American Wera Inc.
4630 Freedom Dr.
Ann Arbor, MI 48108
313-973-7800
Fax: 313-973-3053

Ancon Gear & Instrument Corp.
149 Verdi St.
Farmingdale, NY 11735
516-694-5255
Fax: 516-694-5056

Anderson-Cook Inc.
44785 Macomb Ind. Dr.
Clinton Twp., MI 48036
810-954-0700
Fax: 810-954-0706

Anderson International Corp.
6200 Harvard Ave.
Cleveland, OH 44105-4896
216-641-1112
Fax: 216-641-0709

Apex Broach & Machine Co.
6401 E. Seven Mile Rd.
Detroit, MI 48234
313-891-8600
Fax: 313-891-5083

Applied Process Inc.
12238 Newburgh Rd.
Livonia, MI 48150-1046
313-464-2030
Fax: 313-464-6314

Arrow Gear Co.
2301 Curtiss St.
Downers Grove, IL 60515
708-969-7640
Fax: 708-969-0253

Ascent Drafting Service
7050 Rodney Dr. #4
Los Angeles, CA 90027
213-913-2711

Asco Sintering Co.
2750 S. Garfield Ave.
Commerce, CA 90040
614-882-7460
Fax: 614-882-7396

Ashot Ashkelon Indust.
P.O. Box 21
78100 Ashkelon
Israel
972-7-729186
Fax: 972-7-728167

ASM International
Materials Park, OH 44073
216-338-5151
Fax: 216-338-4634

Aston Metallurgical Services
4201 N. Ravenswood Ave.
Chicago, IL 60613
312-528-9830
Fax: 312-929-0773

ATA Gears Inc.
1340 Depot St.
Cleveland, OH 44116
216-331-2231
Fax: 216-356-0289

Axicon Technologies
1521-A Shattuck Ave.
Suite 203
Berkeley, CA 94709
510-843-8300
Fax: 510-268-1165

B

Balzers Tool Coating Inc.
661 Erie Ave.
N. Tonawanda, NY 14120
800-435-5010
Fax: 716-695-1995

Barit International Corp.
3384 Commercial Ave.
Northbrook, IL 60062
708-272-8128
Fax: 708-272-8210

Basic Machine Tools
2619 Exposition Blvd.
Los Angeles, CA 90018
213-933-7191
Fax: 213-933-7487

Bates Technologies Inc.
9059 Technology Dr.
Fishers, IN 46038
800-331-6778
Fax: 317-841-9443

Bengal Industries Inc.
11346 53rd St. North
Clearwater, FL 34620
813-572-4249
Fax: 813-573-2428

Best Engineering Co.
2385 S. 162nd St.
New Berlin, WI 53151

414-784-2200
Fax: 414-784-2541

Bluco Corp.
135 E. St. Charles Rd.
Carol Stream, IL 60188
800-535-0135
Fax: 708-690-4683

Blue Water Industrial Service
2880 Bardamar
Fort Gratiot, MI 48059
810-385-1820
Fax: 810-385-1820

Bluegrass Precision Machinery
442 Three Springs Rd.
Bowling Green, KY 42104
502-842-7201
Fax: 502-842-7242

Boeing Precision Gear
5136 S. New England
Chicago, IL 60638
312-847-4211

Boston Gear—Div. of IMO
14 Hayward St.
Quincy, MA 02171
617-328-3300
Fax: 617-479-6238

Bourn & Koch Machine Tool
2500 Kishwaukee St.
Rockford, IL 61104
815-965-4013
Fax: 815-965-0019

Boxx Gear Mfg.
1314 Central Pkwy SW
Decatur, AL 35601
205-355-4611
Fax: 205-355-4661

Brown & Sharpe Mfg. Co.
200 Frenchtown Rd.
North Kingstown, RI 02852
401-886-2369
Fax: 401-886-2970

Buckeye Gear Co.
5130 Richmond Rd.
Bedford Heights, OH 44146
216-292-6424
Fax: 216-292-6454

Bucyrus-Erie Co.
1100 Milwaukee Ave.
S. Milwaukee, WI 53172
414-768-4361
Fax: 414-768-4750

C

C-Dot Engineering
14900 Robinwood
Plymouth, MI 48170-2660
810-726-5286
Fax: 810-726-5239

Calicut Engineering Works Ltd.
26A, Camac St.
Calcutta, W.B. 700016
INDIA
(91) 33-2475693
Fax: (91) 33-2476072

Can-Eng Furnaces Ltd.
P.O. Box 235
Niagara Falls, NY 14302
905-356-1327
Fax: 905-356-1817

Capital Associates International
4598 Valleyview Dr., Suite 200
West Bloomfield, MI 48323
810-855-0855
Fax: 810-855-0972

Capstan Atlantic
10 Cushing Drive
Wrentham, MA 02093
508-384-3100
Fax: 508-384-3196

Carbon City Products
150 Ford Rd.
St. Marys, PA 15857
814-834-2886
Fax: 814-834-9091

Case Corp.
700 State St.
Racine, WI 53404
414-636-0266
Fax: 414-636-7132

Caterpillar Industrial
Products Inc.
100 N. E. Adams St.
Peoria, IL 61629-4355
309-675-4059
Fax: 309-675-6457

Chardam Gear Co.
40810 Brentwood
Sterling Heights, MI 48310
810-795-8900
Fax: 810-795-8908

Charles A. Templeton
Machine Inc.
2727 N. Golder
Odessa, TX 79764
915-332-2932
Fax: 915-332-0412

Charles Bond Co.
1035 Louis Dr.
Warminster, PA 18974
800-922-0125
Fax: 215-957-7900

Charmilles Technologies Corp.
560 Bond St.
Lincolnshire, IL 60069
708-913-5300
Fax: 708-913-5340

Chicago Gear-D. O. James
2823 W. Fulton St.
Chicago, IL 60612
312-638-0508
Fax: 312-638-7161

Chicago Gear Works
1805 S. 55th Ave.
Cicero, IL 60650
708-863-2700
Fax: 708-863-2749

Ciateq
Retablo 150
Queretaro 76150
QRO, Mexico
(52) 42163808
Fax: (52) 42169963

Cincinnati Gear
5657 Wooster Pike
Cincinnati, OH 45227
513-271-7700
Fax: 513-271-0049

Cincinnati Milacron
4701 Marburg Ave.
Cincinnati, OH 45209
513-841-8121
Fax: 513-841-7178

Clarke Gear Co., Inc.
8058 Lankershim Blvd.
N. Hollywood, CA 91605
818-768-0690
Fax: 818-767-5577

Clifford-Jacobs
Forging Co.
2410 N. Fifth Street
Champaign, IL 61824
217-352-5172
Fax: 217-352-4629

Clipper Diamond Tool Co.
47-16 Austell Pl.
Long Island City, NY 11101
718-392-3671
Fax: 718-392-4124

Cloyes Gear & Products Inc.
4520 Beidler Rd.
Willoughby, OH 44094
216-942-8200
Fax: 216-942-1422

Columbia Gear Corp.
530 County Road 50
Avon, MN 56310
612-356-7301
Fax: 612-356-2131

Comtorgage Corporation
58 NS Industrial Dr.
Slatersville, RI 02876
401-765-0900
Fax: 401-765-2846

Consulting & Design Service
17033 E. Aloe
Fountain Hills, AZ 85268
602-837-8283
Fax: 602-837-8211

Contour Hardening Inc.
7898 Zionsville Rd.
Indianapolis, IN 46268
317-876-1530
Fax: 317-879-2484

Cornell Forge Co.
6666 W. 66th St.
Chicago, IL 60638
312-767-4242
Fax: 312-767-9443

Crucible Service Centers
5639 W. Genesee St.
Camillus, NY 13031-0991
315-487-0800
Fax: 315-487-4028

Cunningham Industries
102 Lincoln Ave.
Stamford, CT 06902
203-324-2942
Fax: 203-324-6039

Current EDM, Inc.
2577 Leghorn St.
Mountain View, CA 94043
415-966-9676
Fax: 415-966-1881

Custom Electric Mfg.
48973 West Rd.
Wixom, MI 48393
810-305-7700
Fax: 810-305-7705

D

D. A. Stuart Co.
7575 Plaza Court
Willowbrook, IL 60521
708-655-4595
Fax: 708-655-1088

Dabko Industries Inc.
61 E. Main St.
Forestville, CT 06010
800-437-3398
Fax: 203-583-6902

Dana Corp.
2424 W. State
Fort Wayne, IN 46801
219-481-3437
Fax: 219-481-3115

The Daniluk Corp.
8200 S.W. 29th St.
Oklahoma City, OK 73179
405-745-6644
Fax: 405-745-6646

Davis Tool & Engineering
19250 Plymouth Rd.
Detroit, MI 48228
313-835-6000
Fax: 313-837-7220

Dayton Gear & Tool
500 Fame Rd.
Dayton, OH 45449
513-866-4327
Fax: 513-866-0408

Dearborn Gear & Tool Co.
4300 Cabot
Detroit, MI 48210
313-581-3111
Fax: 313-581-3115

Deco-Technologies
1360 E. Big Beaver
Troy, MI 48083
810-524-9800
Fax: 810-524-9804

Delroyd Worm Gear—Div. of IMO
121 First Ave.
Trenton, NJ 08650
800-432-0121
Fax: 609-890-6800

Designatronics
2101 Jericho Turnpike
New Hyde Park, NY 11042-5416
516-328-3300
Fax: 516-326-8827

Detroit Broach Co.
431 S. Buncombe Rd.
Greer, SC 29651
803-879-7641
Fax: 803-879-8811

Detroit Flame Hardening
17644 Mt. Elliott
Detroit, MI 48212
313-891-2936
Fax: 313-891-3150

Diamond BLACK
Technologies Inc.
100 Somerset Dr.
Conover, NC 28613
704-327-7442
Fax: 704-322-4636

Dianamic Abrasive
Products Inc.
2566 Industrial Row
Troy, MI 48084
810-280-1185
Fax: 810-280-2733

Disston Precision Inc.
6795 State Rd.

Philadelphia, PA 19135
215-338-1200
Fax: 215-338-7060

DMS Inc.
554 W. Wood
Palatine, IL 60067
708-359-7882
Fax: 708-359-8481

Drewco Corp.
3745 Nicholson Rd.
Franksville, WI 53126
414-886-5050
Fax: 414-886-5872

Drive Systems Technology
24 Marlborough Ln.
Glen Mills, PA 19342-1519
610-358-0785
Fax: 610-358-2776

Dura-Bar
2100 W. Lake Shore Dr.
Woodstock, IL 60193
815-338-7800
Fax: 815-338-1549

Dynamic Metal Treating Inc.
7857 Ronda Dr.
Canton Twp., MI 48187
313-459-8022
Fax: 313-459-7863

Dynamic Tool Grinding Service
872 Ridge Ave.
Lombard, IL 60148
708-620-5044
Fax: 708-620-0177

E

Easco-Sparcatron
10799 Plaza Dr.
Whitmore Lake, MI 48189
800-523-4449
Fax: 313-449-4447

Eaton Corp.
Highway 29 S.
Kings Mountain, NC 28086
704-937-7411
Fax: 704-937-4354

EDM Solutions Co.
2010 East Touhy Ave.
Elk Grove Village, IL 60007
708-981-3361
Fax: 708-981-0158

Elmass North America Inc.
N114 W19320 Clinton Dr.
Germantown, WI 53022
414-255-5644
Fax: 414-255-6509

Engemaq U.S.A.
Montville Business Center
20 Chapin Rd., Unit 1002A
Pine Brook, NJ 07058
201-808-2665
Fax: 201-808-5258

Engis Corp.
105 W. Hintz Rd.
Wheeling, IL 60090
708-808-9400
Fax: 708-808-9430

Engratec de Mexico
Poniente 128, #425
Nueva Vallejo, D.F. 07750
Mexico
(52) 567-73-43
Fax: (52) 567-32-06

Equitable Engineering
1840 Austin
Troy, MI 48099
810-689-9700
Fax: 810-689-0281

Ernst Winter & Son Inc.
100 Wilhelm Winter St.
Travelers Rest, SC 29690
803-834-4145
Fax: 803-834-3730

Etna Products Inc.
16824 Park Circle Dr.
Chagrin Falls, OH 44022
216-543-9845
Fax: 216-543-1789

Euclid Heat Treating Co.
1408 E. 222nd St.
Cleveland, OH 44117
216-481-8444
Fax: 216-481-3473

Euro-Tech Corporation
14665 W. Lisbon Rd.
Brookfield, WI 53005
414-781-6777
Fax: 414-781-2822

F

Fairfield Mfg. Co.
U. S. 52 South
Lafayette, IN 47903-7940
317-474-3474
Fax: 317-477-7342

Fairlane Gear Inc.
8182 Canton Center Rd.
Canton, MI 48187
313-459-2440
Fax: 313-459-2941

Fayscott Co.
225 Spring St.
Dexter, ME 04930
207-924-7331
Fax: 207-924-5510

Fellows Corp.
Precision Dr.
Springfield, VT 05156
802-886-8333
Fax: 802-886-2700

Fette Tool Systems
3725-I No. 126 St.
Brookfield, WI 53005
414-783-7606
Fax: 414-783-5043

FGT Gage & Systems, Inc.
2624 S. 162nd St.
New Berlin, WI 53151
414-827-0558
Fax: 414-781-2284

Finishing Equipment Inc.
3640 Kennebec Dr.
St. Paul, MN 55122
612-452-1860
Fax: 612-452-9851

Fiske Brothers Refining Co.
1500 Oakdale Ave.
Toledo, OH 43605
800-347-5343
Fax: 419-693-3806

Flender Corp.
1589 Aztec Ln.
Mount Pleasant, SC 29464
803-856-0108
Fax: 803-856-0104

Forest City Gear Co.
11715 Main St.
Roscoe, IL 61073
815-623-2168
Fax: 815-623-6620

FPM Heat Treating
1501 S. Lively Blvd.
Elk Grove Village, IL 60007
708-228-2525
Fax: 708-228-5912

Franke Gear Works Inc.
4401 Ravenswood Ave.
Chicago, IL 60640
312-561-0950
Fax: 312-561-9078

Fuji Univance Corp.
38505 Country Club Dr.
Suite 204
Farmington Hills, MI 48331
810-489-5641
Fax: 810-489-5642

Fuller Company
South 10th & Mill St.
Allentown, PA 18103
610-770-7400
Fax: 610-770-7429

G

Gearcoa
14300 Lorain Ave.
Cleveland, OH 44111
216-671-5400
Fax: 216-671-5825

Gear Group International
1825 I St., N.W.
Washington, DC 20006
202-429-2734
Fax: 703-522-7153

Gear Motions
1750 Milton Ave.
Syracuse, NY 13209
315-488-0100
Fax: 315-488-0196

Gear Research Institute
1801 Maple Ave.
Evanston, IL 60201
708-491-5900
Fax: 708-491-5986

Gear Systems Inc.
23400 Apollo Ct.
Lake Villa, IL 60046
708-356-1606
Fax: 708-356-1631

Gearesearch Assoc.
750 Indian Wells Rd.
Banning, CA 92220-5308
909-845-5822
Fax: 909-845-5822

Gears & Drive Systems Inc.
1364 Welsh Rd.
Spring House, PA 19477-0109
215-540-0820
Fax: 215-540-0360

Gears for Industry Inc.
1925 S. Moorland Rd.
New Berlin, WI 53151
414-797-9960
Fax: 414-797-9245

Gearsoft Design
8/26 Huxtable Ave.
Lane Cove 2066
Australia
(61) 2-4111282
Fax: (61) 2-4111282

Geartech
1017 Pomona Ave.
Albany, CA 94706
510-524-8943
Fax: 510-524-7060

Geartronics Industries
100 Chelmsford Rd.
North Billerica, MA 01862
617-933-1400
Fax: 508-667-3130

General Broach & Engineering Co.
13231 Twenty-Three Mile Rd.
Shelby Twp., MI 48315-2713
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What's Happening Now— The News, The Names, The Numbers

Movin' on up . . . **M & M Precision Systems Corp.**, West Carrollton, OH, has announced the appointment of **William S. Miller** as national sales manager, CNC metrology systems. Miller will direct all field sales activities for metrology systems in the U.S. and Canada. . . **Charles Brannen** is the new president of AGMA. Brannen, vice president of **Overton Gear & Tool Corp.**, Addison, IL, was elected at the group's annual meeting in Tucson, AZ. . . . **Daniel T. Koenig** was named the 114th president of the **American Society of Mechanical Engineers** at the Society's meeting in Kansas City, KA. Koenig is senior vice president, manufacturing technology, at **AAVID Thermal Technologies, Inc.**, Laconia, NH. . . **Dr. Debabrata Paul** joins **Monitoring Technology Corporation's** Advanced Technology Group as a signal processing engineer. The Fairfax, VA, company develops new methods of applying vibration analysis to the monitoring of rotating machinery. . . . **Jack Carlson** joins **Reishauer Corp.**, Elgin, IL, as the company's new service manager.

Corporate Notes . . . **Brown & Sharpe** of North Kingstown, RI, and **Dassault Systemes**, Paris, France, have announced a joint project to develop a new graphical off-line CMM programming module to provide an automated path between CAD/CAM operations and computer-aided inspection. . . **Deckel Maho Gildemeister**, now known as **DMG America Inc.**, has opened its new North American headquarters in Schaumburg, IL. The new headquarters will house all sales, application engineering, parts and service resources for the company's North American operations. . . **General Broach Company**, Morenci, MI, has been awarded Ford Motor's Q1 award. It is only the second broaching company to receive the Ford quality award. . . **Schafer Gear Works, Inc.**, South Bend, IN, has expanded its plant in the "Studebaker Corridor" near the city's downtown. The 48,500 sq. ft. facility represents the company's commitment to the redevelopment of this major South Bend industrial area. . . **Burgess-Norton**, full-service gear manufacturer in Geneva, IL, is implementing a new "factory within a factory" organizational concept with the goal of improving reponse to customer needs for flexible sceduling, smaller quantity requirements, lower costs, short lead-times and J.I.T. deliveries. . . **DiamondBLACK®**, Conover, NC, has been awarded a contract with one of the "Big Three" automakers to apply the company's patented coating to transmission gears for 1996 models. . . .

Society News. . . The proceedings of the First International Conference on Induction Hardened Gears and Critical Components, held last May in Indianapolis, IN, are available from the **Gear Research Institute** (708-491-5900). They include the 23 papers presented at the conference.

The Numbers Game. . . The **Association for Manufacturing Technology (AMT)** has released figures on machine tool orders through April, 1995. Total year-to-date orders were $1,669.20 million, 17.57% ahead of 1994 figures for the same period. Metal cutting machine tool orders were $1,073.55 million, up 16.77% from the first quarter of 1994, and year-to-date metal forming orders totaled $595.65 million, 19.05% ahead of comparable 1994 figures. The April, 1995, machine tool order backlog was $2,414.35 million, compared with $1,676.45 million in April, 1994.

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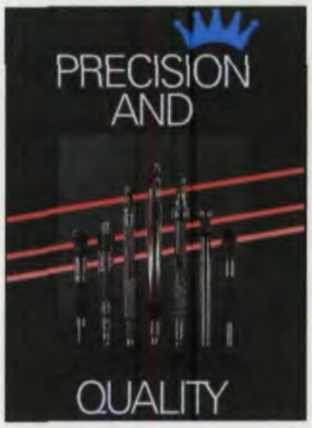

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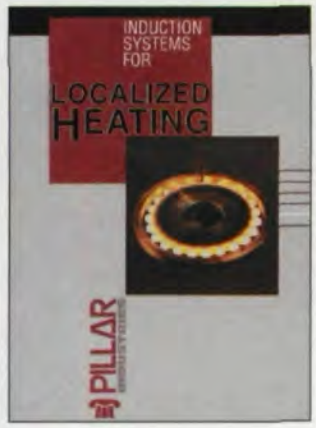

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Gear Inspection For The Long Haul

Beating the controller obsolescence demon.

Douglas Beerck & Mark Cowan

Question:

We just received permission to purchase our first CNC gear inspection system. With capital approvals so hard to come by, especially for inspection equipment, I want to be sure to purchase a system I can count on for years to come. My past experience with purchasing CNC equipment has shown me that serviceability of the computer and the CNC controller portion of the system can be a problem in just a few years because of the obsolescence factor. What information do I need to look for when selecting a supplier to reduce the risk of obsolescence, as well as to reduce the long-term servicing costs in the computer and controls portion of the system?

Answer:

As we have all painfully discovered, obsolescence of our CNC controls, computer hardware and software, machine tools, inspection equipment, etc., can be expensive. We have come to expect a long life out of the mechanical portion of our CNC inspection machines. After all, inspection machines don't see the tooling forces applied to machine tools, and they typically operate in a cleaner, more temperature-controlled environment than other equipment. But the electronic and computer hardware and software are victims of a rapidly changing technology, with a much shorter serviceability. Keeping ahead of product developments in these areas is a constant battle.

When purchasing CNC gear inspection systems with the goal of maximizing product life and serviceability, a number of "optimum design factors" should be taken into account. These include cost, reliability, performance, flexibility, upgradability and serviceability. Another factor of increasing importance is the networking capability of the system. Let's take a look at each of these factors, keeping in mind their long-term design considerations, costs and points to remember when researching suppliers.

Cost

When we talk about cost in this article, we are not looking at the initial system cost or a cost breakdown of the computer controller itself. We are referring to the long-term cost associated with the design of the software and computer controller itself. The overall system price may or may not be attractive at the time of purchase, but the real question is, can the product, which you expect to be using for years to come, be economically serviced in the future? What design criteria were used on the computer controller? Some initial questions that can be asked easily without being an electronics or software genius include:

1. Did the system supplier design the controller specifically for the application, or is this unit a generic off-the-shelf package?

2. Does the system supplier make the controller, or is it purchased complete? From whom?

3. Will the system supplier agree to service the controller as well as the machine? If not, who will?

Off-the-shelf, generic CNC controls may appear to be more cost-effective at the time of sale, but they may or may not lend themselves to future upgrading or component-only replacement.

A CNC system supplier should be intimately familiar

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

Douglas Beerck
is marketing manager for M & M Precision Systems Corporation, designers and manufacturers of high-accuracy CNC gear inspection, generative inspection and motion systems.

Mark Cowan
is manager of product development for M & M Precision Systems Corporation.

with the design of the controller and its operating software if he is, in fact, going to service this equipment for you. He or she should be able to tell you things about the design of the controller that reduce the cost of service for you in the years to come.

PC or Not PC?

Today's machine controllers are more and more moving into the PC environment for a number of reasons, including cost. If the system supplier's control hardware is not PC-based, find out why not.

What specific advantages can a CNC PC-based system offer? Perhaps the biggest is that the design utilizes the industry standard architecture (ISA) bus to ensure multiple vendor selection of components and international service support. With multiple vendor selection of the system's computer and control components, the cost of service typically is reduced. Your system supplier is not held hostage by one component supplier, a situation that raises his cost of doing business with you.

A PC-based system will also function with a standard operating system, such as DOS. Maintenance of control and software can be addressed more easily with the use of such a standard operating system. File maintenance, updates, etc., can more easily and more cost-effectively take advantage of standard modem technology in the PC environment.

As mentioned earlier, CNC gear inspection systems usually have machine hardware that outlives the computer and control hardware and software from a functional standpoint. Newer computer hardware usually means faster processing speed. The computer industry has gone from 286 processors to Pentiums in about 10 years. By using a PC-based platform, standardization of much of the computer/controller hardware lends itself to multiple sources for upgrading, retrofitting, etc., for the years to come.

Reliability and Performance

Questions regarding reliability and performance follow the same logic as those relating to the system as a whole. All suppliers of CNC gear inspection equipment typically quote impressive uptime percentages, accuracy and inspection times. How does the supplier back up these statements? Can the supplier give you the names of other customers who are using the type of controller hardware and software he is offering you? How many systems using this configuration are in the field operating today?

Flexibility

Will this system be able to address not only your present needs, but also your future ones? Can software options be added later? How much will it cost to do so? Can the software be modified by the supplier if your needs change over time? How much software customization is done by this company? Can the vendor provide you with the names of customers for whom software was modified? Does the supplier offer a computer/controller package that allows you to purchase replacement components (i.e. monitor, keyboard, CPU, etc.) direct from the component manufacturer if you choose? Are these standard components truly "standard," available from several sources?

Upgradability

Chances that the system you purchase today will meet all your requirements five years from now are usually slim if your company is adding products, changing designs, improving processes, taking on new customers, etc. Does your supplier offer the ability to upgrade your system's software and computer hardware over time?

etc., work with a PC-based system. Look at the supplier's ability to assist you in networking as well as his or her ability to interface to your existing network if you are already using one.

Closed Loop Process Control. With the advancement of gear inspection software and CNC technology, some manufacturers offer the ability to link the inspection system directly to the machine tool, sending machine tool setting change data based on the inspection results. Even if your current machine tools do not offer the ability to interpret this data, what about your future machine tool purchases? If you are considering this degree of process control, the selection of a CNC inspection system should include research into the supplier's capability in this area and the willingness to work with you and the machine tool manufacturer.

Fig. 1 — M & M Precision's 4-axis, Model 3025 PC gear process control system.

Networking Capability

Once again, analyze your future requirements. Will you have a need for multiple systems? Will you have the need to do off-line part parameter entry or tolerance modification as your needs change? What about downloading data to a central computer where information can be evaluated, stored, etc., by another source? What costs are associated just with the networking requirements? If networking is or may be a requirement for you, this is another reason to look at a PC-based system. Today's PCs offer plenty of power and lower networking costs than most other alternatives. Most end users that utilize a centralized data analysis site for their SPC, process control,

Serviceability

Last, but certainly not least, is the serviceability factor of the equipment you are purchasing. There are basically two schools of thought among end users. Some users of computer-controlled equipment prefer servicing the equipment themselves as much as possible after the warranty period expires in an effort to keep costs at a minimum. If this is your view, consider a number of points. Can the computer itself be serviced locally by either factory or independent sources after the warranty expires? When dealing with a machine made overseas, look at some of the critical components—CPU, drive boards, etc. Are these standard components that can be purchased from more than one source? Is the system supplier willing to help you go directly to the component manufacturer if you need to? How about the diagnostic capability of the system? What documentation is supplied for maintenance and serviceability? Is diagnostic software available and accessible by the end user?

ONE OF THE ADVANTAGES OF THE PC-BASED SYSTEM IS THAT IT USES THE STANDARD ISA BUS, ENSURING MULTIPLE VENDOR SELECTION AND BROAD SERVICE SUPPORT.

Many end users look for the system supplier to be their sole support arm. If this is your view, make sure the company you deal with has an adequate service staff. Does the company handle all service calls directly or does it contract out to independent service companies? If your system is made overseas, where are the people who will service it based?

Longevity

The future and stability of your proposed vendor's business is a consideration as well. How long has the company been in business? What is its position in the industry? Is it profitable? Getting service on equipment manufactured by a company no longer in business or no longer servicing your market can be extremely difficult.

Conclusion

As with all capital equipment, selecting the appropriate CNC inspection system and vendor requires research. Obsolescence and serviceability considerations also require you to look into the future a bit more than some other purchases might. Look at the long-term view and your future requirements. Looking at the big picture today can mean big savings tomorrow when it comes to meeting your CNC gear inspection system needs well into the future. ○

For more information about M&M Precision Systems Corporation, please circle Reader Service No. A-110.

Tell Us What You Think... If you found this article of interest and/or useful, please circle Reader Service **Number A-111.**

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

Single-Column Gear Inspection

Zeiss Höfler has introduced a new line of gear inspection systems that feature a revolutionary single-column design with improved accessibility compared to competitive two-column systems. The ZP400 and ZP630 systems offer a 400 or 630 mm diameter x 850 mm high measuring envelope to accommodate a wide range of internal/external gears, shaper cutters, shaver cutters, hobs, worms and bevel gears. Both feature the tailstock and measuring slides in a single column, eliminating the thermal differences and potential accuracy problems of two-column systems.

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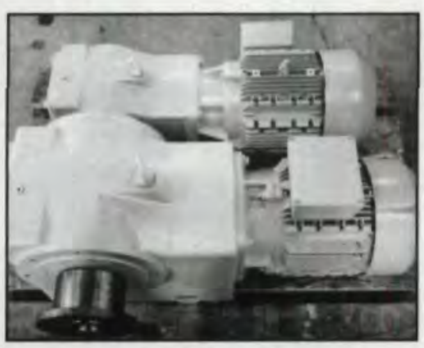

Dual Agitation Stacked Mixer Drives

Nord Gear Corp. offers dual agitation, stacked mixer drives for heavy duty service in industrial and food processing uses where mixing applications must withstand torque and heavy bending stress. Available in sizes from 1/4 to 200 hp and output torques up to 221,200 in-lbs.

Circle Reader Service No. A-51

Wizard DROs

Anilam Electronics, Inc., has introduced its new Wizard Series line of DROs that think, calculate, compensate, remember and recall so the operator doesn't have to. Features include "smart" power supplies to help regulate power fluctuations, interlinking keyboard modules for fast upgrading, VFD displays for easy readability, interactive display windows with help messages and a visual feedrate display to take the guesswork out of milling.

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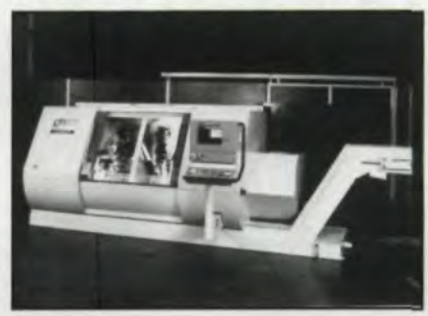


CTX Twin Coaxial CNC Lathe

Gildemeister has added a new coaxial turning machine with double-sided machining capability to its CTX series of CNC 2-axis turning machines. The CTX Twin features two identical, integrated 25 hp (18kW) spindle motors and two 12-station turrets to enable machining of both sides of a component in a single cycle or parallel machining of two similar components using the two spindles separately. The machine features the new Gildemeister/Grundig "Turn Plus" CNC Control with "window" technology, interactive graphic component description and fully automatic program development.

Circle Reader Service No. A-53

Promat CNC 200 Form Type Grinder

Höfler has developed a small form type gear grinding machine dedicated to gear manufacturers who have large and small lot sizes of spur gears to grind. The economically priced machine's operating range covers spur gears up to 8" (200 mm) OD and face widths of 6" (150 mm). The machine's high grinding performance and versatility lead to low per-gear machining costs.

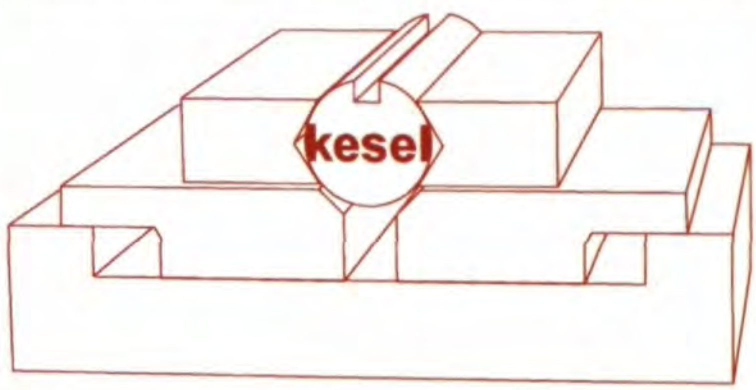
Please Circle Reader Service No. A-54

Bison Series 650

New Gear Motors

Bison Gear & Engineering *introduces three new lines of gear motors.* The parallel shaft Series 650 offers compact size and extremely high torque ratings. It delivers torques up to 720 in-lbs. with a gearbox measuring only 5" x 6-1/4" x 5-3/4". Speeds range from 1 to 160 rpm. A choice of motors, either permanent split capacitor AC or permanent magnet DC, with ratings of 1/20 hp, 1/6 hp and 1/2 hp is available.

The Series 950 are parallel shaft gear motors and C-face reducers with power ratings up to 3 hp. The new high-quality heavy duty line is designed for applications calling for long life and critical loads. Torques from 242–2830 in-lbs. Available in single-phase, capacitor start and 3-phase AC motors and permanent magnet DC motors.



PRODUCT NEWS

The Series 800 are heavy-duty right angle gear motors available with integral AC or DC motors and as C-face reducers. They are rated from 1/4 hp–1 hp with torques from 179–501 in-lbs. and speeds from 23–257 rpm. Available gear ratios run 7:1 to 80:1. They are available with permanent split capacitor or 3-phase AC motors and permanent magnet DC motors.

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Spiral Bevel Gearboxes

The new "Z" Series spiral bevel gearboxes, available from **Andantex USA, Inc.**, comes in 27 sizes and 6 types with 30 different mounting configurations. The units offer 11 different ratios from 0.5:1 to 6:1, counterclockwise and clockwise rotation of input and output shafts, 5000 lb-ft. torque capacity and speeds to 3500 rpm. Efficiency of the units is from 96–99%. They are rated for either 10,000 or 15,000 hours of life and are grease-, oil-splash- or force-feed-lubricated, according to the application.

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The Case of This Issue's Column

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

221B Baker Street

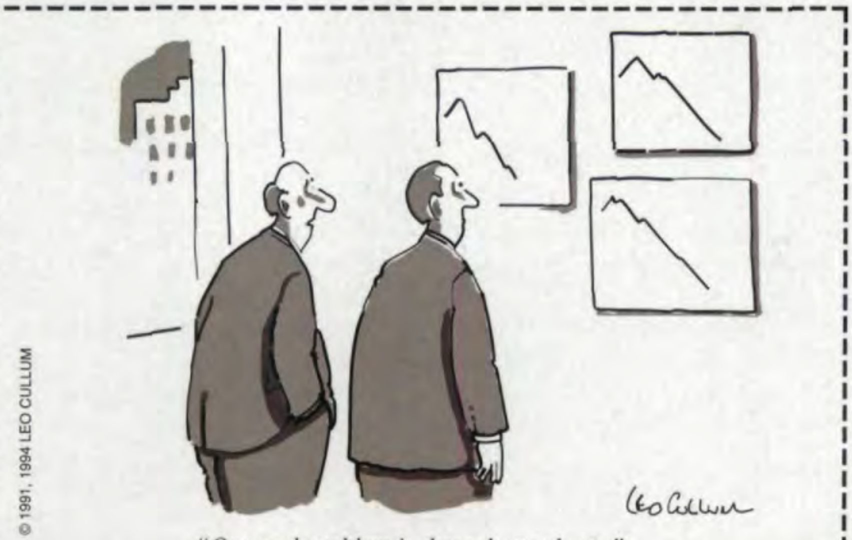
We've always said that gears show up in all the best places, even, it turns out, among the papers of that most famous of detectives, Sherlock Holmes. "The Adventure of the Engineer's Thumb" is, according to Dr. Watson, a case "so strange in its inception and so dramatic in its details," that it merits a mention even in our exalted pages.

Young Victor Hatherly, the hydraulic engineer, is having a hard time getting his business off the ground, so he's tempted by the mysterious Colonel Lysander Stark, who's offering him 50 guineas (about $262.50 in 1890s money) for an hour's work diagnosing the problem with his hydraulic stamping machine, which has "got out of gear." The only kicker is that Hatherly is sworn to absolute secrecy: he must tell no one where he's going, and he has to be there at midnight.

We won't say more except that there's a beautiful lady with a foreign accent, a creepy old house, unusual applications for a hydraulic press and other matters of interest to the "world's first consulting detective." The engineering theory may be a bit dodgy (Watson was an M.D., after all), but as a mystery story, it has its moments.

Meanwhile, in Traverse City, MI . . .

If detective stories strike you as too frivolous, and you just can't get enough metal cutting at work, we have the solution—*The Home Shop Machinist*. According to its tagline, this bimonthly magazine published in Traverse City, MI, is "dedicated to precision metalworking." Its audience is those millions (well, maybe thousands) of people driven by lathe lust to hang out in their basements and garages working on handy home metalworking projects. The issue we saw covered "Serious Milling With the Lathe," "Reviving a Lunch Break Shaper" and "Chatterless Countersinks," among other things. It also has great ads for tooling, equipment, videos and books. We intend to include *The Machinist's Bedside Reader*, Vols. 1, 2, & 3, in our letter to Santa. For more information, call 800-447-7367.



"Our real problem is these damn charts."

. . . enter a gentleman wearing the ribbon of a foreign order . . .

Feeling megalomaniacal? Having delusions of grandeur? Fed up with your life as you know it? Addendum can help. For $13.00 you can buy a book called *How to Start Your Own Country* by Erwin Strauss. According to the publicity blurb, the book contains information on acquiring land, picking a flag, establishing diplomatic relations, printing stamps and money, collecting taxes (of course) and other information vital to wannabee potentates. Available from *Real Goods®* in Ukiah, CA. 1-800-762-7325.

The Interactive Section

Surely we at Addendum can't be the only people stumbling across gears and their applications, odd and otherwise. If you have an Addendum weirdness, fact, joke or piece of trivia you'd like to share, send it to us at *Gear Technology*. The keepers will throw it into our cage along with our dinners. Your reward—same as ours: the notice, if not the respect and admiration, of your peers and all the Gummi Bears you can eat (but the Addendum editor gets all the pale yellow ones).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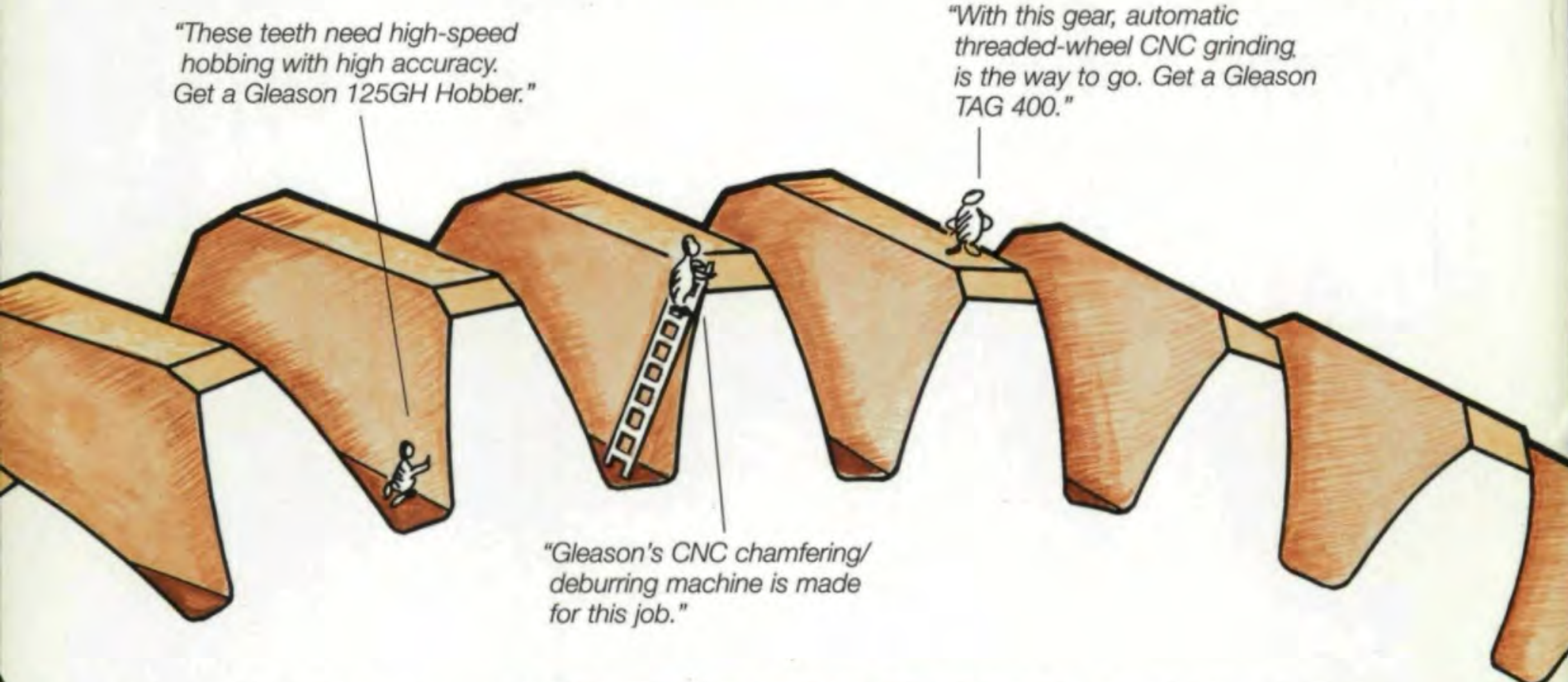

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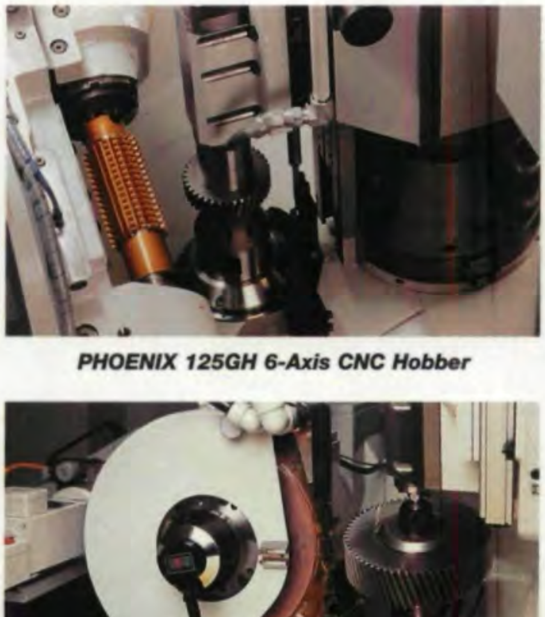

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