

GEAR TECHNOLOGY

MAY/JUNE 1999

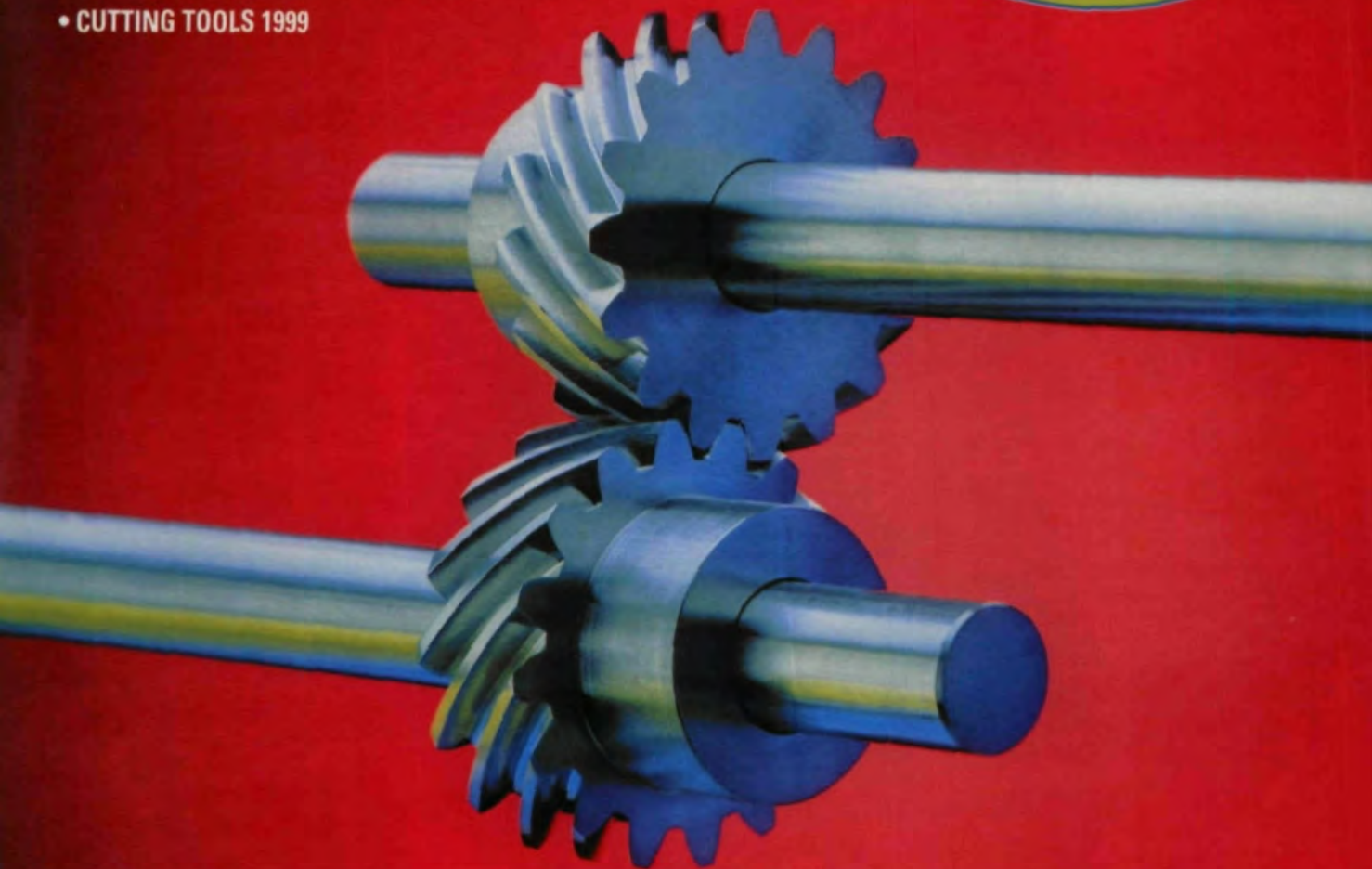
The Journal of Gear Manufacturing

GEAR BUYING

- DIRECTORY OF GEAR MANUFACTURERS
- DOS AND DON'TS OF SPECIFYING CUSTOM GEARS

GEAR DESIGN AND MANUFACTURE

- INCREASING POWER DENSITY IN GEAR TRAINS
- CUTTING TOOLS 1999



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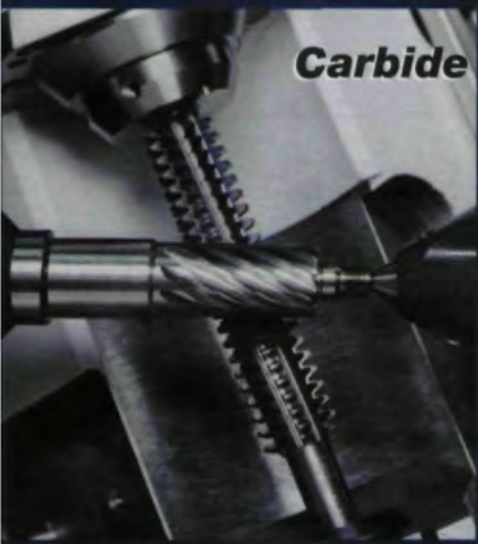
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The Journal of Gear Manufacturing

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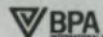
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CELEBRATIONS & EXPECTATIONS

When you're 15, you're filled with confidence and exuberance, and you have a future full of potential and room for growth. You're ready to take on the world. *Gear Technology* began publishing exactly 15 years ago, with the May/June 1984 issue, and the magazine has grown in many ways since then.

When we started, this publication was intended to be a teaching journal. Our primary purpose was to disseminate research papers and other presentations from technical conferences, clinics and seminars. As I said in my first editorial, "We will be an on-going gear clinic, ranging from the basics to the lead-edge of technology."

Today this remains the most important part of *Gear Technology's* editorial mission. But we've also recognized a need to include less technical material about our industry. When that material doesn't exist, we write it ourselves or have it written for us. We're more active than ever in finding out what our readership needs and in going to get it.

I'm proud to say that we've also grown into a role of leadership in the gear industry. We encourage you to participate in research and education, and we push you to take advantage of the latest technologies. In part this is selfish. We want you to succeed, because with your success comes ours. But we also feel it's our responsibility. We consider ourselves the voice of the gear industry, and we'll continue to speak and write with your interests in mind.

Gear Technology also serves as an important marketplace. Not only technical information, but also trade information, is exchanged through us. For example, you can count on us to let you know about new products that will help you be more efficient, productive or profitable. Over the years, many advertisers have found great value in the reach and focus that we have given them. We'll continue to do everything we can to help the buyers and sellers in this industry get together.

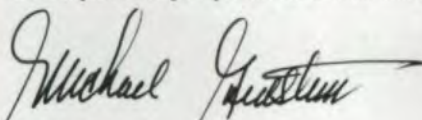
As we've grown in our goals, so too have we grown in our activities. For nearly three years now, we've been publishing on the Internet, and we've been encouraging you to explore its potential as well. These activities have enhanced the magazine by extending our reach, allowing us to disseminate even more technical information. They've also allowed us to reach you—and for you to reach us and each other—in ways that were never possible before. The Internet's strength has proven to be in building our marketplace—and its potential far outweighs its early successes.

Just as we push you to adopt the latest technology and processes in your manufacturing operations, we're doing everything we can to lead the gear industry into the next millenium of communication. We're happy to take this leadership role, and we're excited about the possibilities for ourselves and for you. Moreover, we consider it our responsibility to make sure that the gear industry is viewed as one of the most technologically advanced in the world.

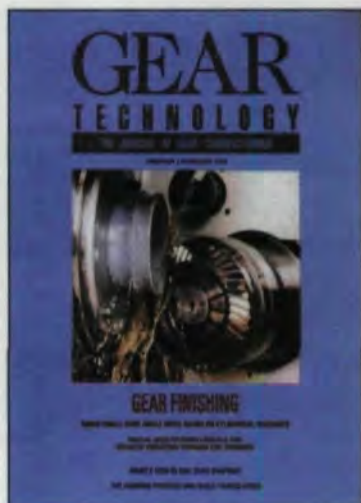
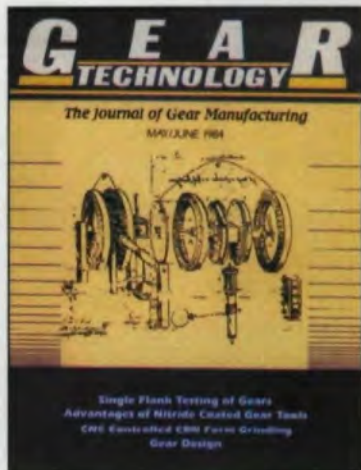
All of this is why we've put so much effort into *Show Central*, the first ever 3D virtual metalworking technology show. The official opening is May 1, 1999, so please stop by www.gear-technology.com. It will change the way you think about trade shows.

We've seen a lot of changes in our first 15 years, and the pace of that change continues to steadily increase. The next 15 years will see even more changes, not just for the business of gear manufacturing or the business of publishing, but for business in general.

I'd like to take this opportunity to thank all of you—readers and advertisers—who have made the success of our first 15 years not just possible, but also interesting and fun.



Sincerely,
Michael Goldstein, Publisher and Editor-in-Chief

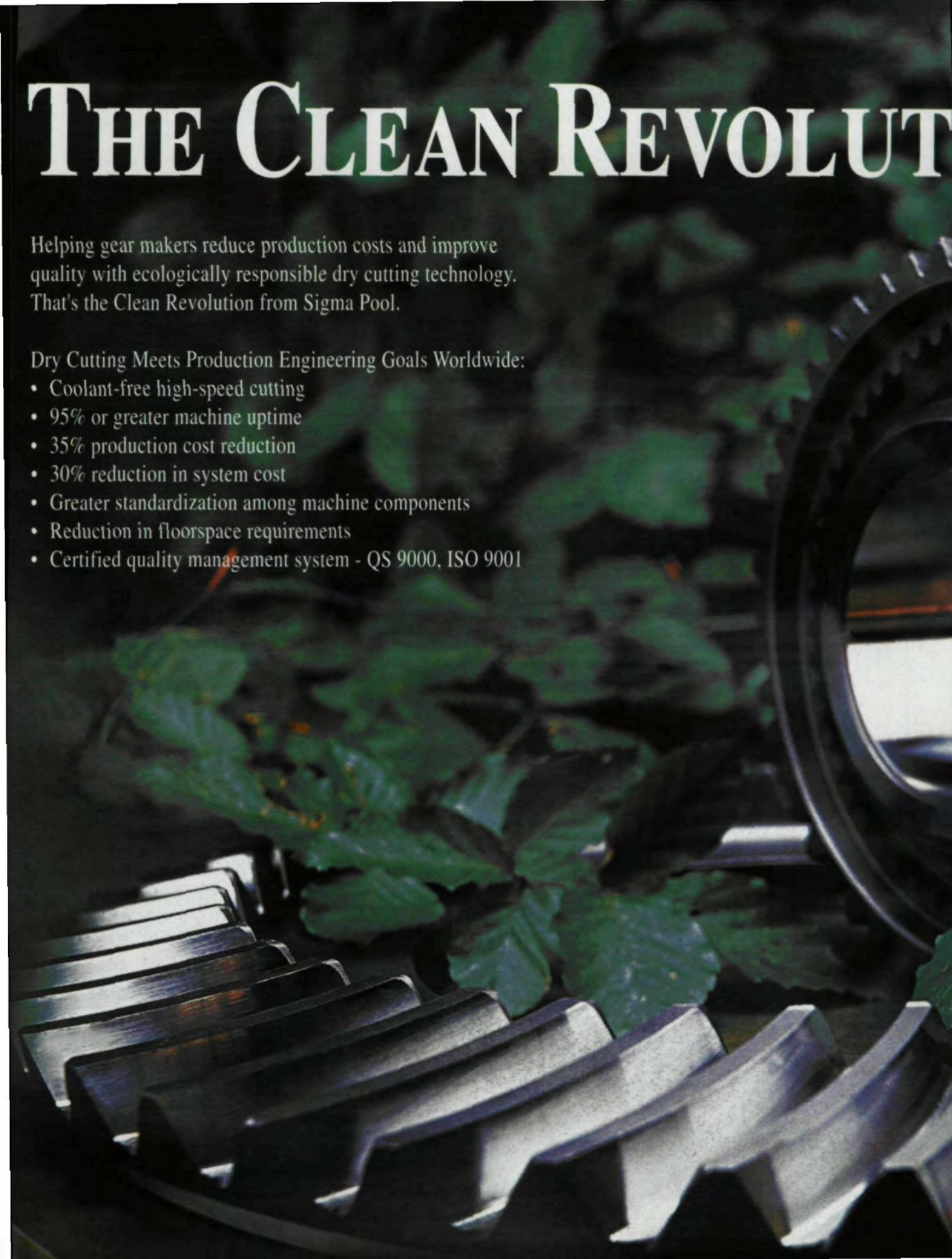


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Size Does Matter

Imagine robots the size of molecules manipulating the atoms of some raw material, turning it into something entirely new, something different, something useful on our scale: new alloys that are stronger and lighter than what we have now, active materials that change and react to their environment, even whole functional parts created by microscopic machines that can repair and duplicate themselves like the living cells they rival in size. These are nanomachines, devices that are measured in billionths of a meter. Sound like science fiction, something you'd see on Star Trek or The X-Files? According to the folks at NASA, it's closer to science fact than most people realize.

Nanogears, molecule-sized gears that are made from pipes of carbon atoms with benzene atoms attached to the outside of the pipe to form the teeth, have been simulated by a NASA supercomputer at the Ames Research Center in Mountain View, CA, as part of their ongoing research into nanotechnology.

In the NASA simulations, the gears were driven by a laser that served as a motor, creating an electric field around the nanotube with a positive charge on one side and a negative charge on the other. Together, these charges rotate the gear. This generates heat, but there were also successful simulations of cooling the gears using helium and neon gases.

Cooling is very important in this case, since, according to the simulations, the gears, each about a nanometer (one-billionth of a meter) across, rotate best at around 100 billion turns per second, or six trillion rotations per minute.

According to Al Globus, a co-author of the paper describing these simulations and a computer scientist at Ames, "hope is growing that products made of thousands of tiny machines that could self-repair or adapt to the environment can ultimately be constructed."

"One practical use for nanotechnology would be to build a matter compiler," says Creon Levit, a Globus colleague at Ames. "We would give this machine, made of nanoparts, raw materials like

natural gas. A computer would specify an arrangement of atoms and the matter compiler would arrange the atoms from the raw material to make a macro-scale machine or parts."

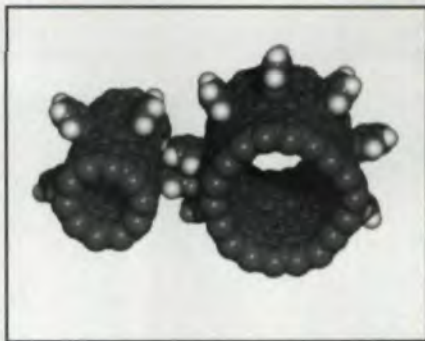
This principle is already at work today. The biotechnology industry uses peptide synthesizers that create the peptide you ask for by stringing molecules of amino acids together in the proper order. Doing the same thing with atoms requires only a change in scale.

The first step to the matter compiler is a smaller machine called the assembler/replicator. This machine could be programmed to make aerospace materials, parts and machines in atomic detail, giving these products great strength and thermal properties. Also possible are materials possessing radically improved strength to weight ratios as well as active or "smart" materials. "There is absolutely no question that active materials can be made," says Globus. "Look at your skin. It repairs itself. It sweats to cool itself. It stretches as it grows. It's an active material."

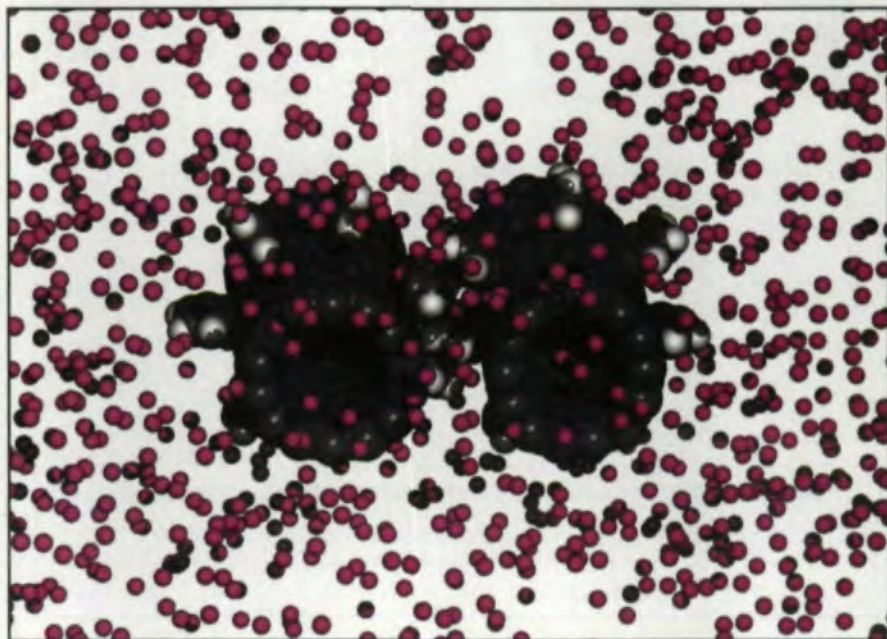
Globus strongly emphasizes that making real nanomachines may be decades away, but his computer simulations suggest the tiny machines are possible after engineers learn to build nanoparts, like gears, and to assemble nanomachines.

Circle 251

Welcome to Revolutions, the column that brings you the latest, most up-to-date and easy-to-read information about the people and technology of the gear industry. Revolutions welcomes your submissions. Please send them to Gear Technology, P.O. Box 1426, Elk Grove Village, IL 60009, fax (847) 437-6618 or e-mail people@geartechnology.com. If you'd like more information about any of the articles that appear, please circle the appropriate number on the Reader Service Card.



Simulations of nanometer sized hydrogen-benzene gears. Below, the nanogears in a cooling helium atmosphere.



OUR FIRST ISSUE IN 1984.

GEAR TECHNOLOGY

The Journal of Gear Manufacturing
MAY/JUNE 1991



Single Flank Testing of Gears
Advantages of Nitride Coated Gear Tools
CNC Controlled CBN Form Grinding
Gear Design

15 Years and Counting

This issue marks the 15th anniversary of *Gear Technology*. In the first 15 years, we've published more than 400 technical articles and more than 4,500 pages in 90 issues of the magazine.

Those of you who have read (and saved) our pages from the beginning know that the complete library of *Gear Technology* magazines occupies approximately 1 foot of shelf space.

Early issues of *Gear Technology* featured gear sketches by Leonardo da Vinci. There were 30 Leonardo covers in all,

including a self-portrait of the man himself. The last Leonardo cover was published on our July/August 1990 issue.

We'd like your input on how we should shape *Gear Technology* for the next 15 years. Please give us a call at (847) 437-6604, fax your suggestions to (847) 437-6618 or e-mail people@gear-technology.com.

Digital Supersleuth

Theodore M. Clarke's job is to find out why gears, shafts and bearings fail. That job is now getting easier and faster through the use of digital imaging.

Clarke is a senior technical specialist in metallurgical failure analysis and tribology with Case Corp., the off-road equipment manufacturer located in Burr Ridge, IL. He's written several articles in *The Microscope* and *Microscopy Today*, as well as a section on the photography of fractured parts in volume 12 of the ASM International Metals Handbook. Clarke has found that digital photomacrography takes advantage of the latest high tech gadgets to provide substantial cost and time savings over traditional film-based photographic methods.

"The industry standard is still the 4x5 instant print," Clarke says. "That gives you a high-quality photographic image. We've obtained a camera that maintains the same image quality as 4x5 instant film."

Clarke uses a Kodak MegaPlus 1.6i/AB digital camera and a bellows system modified in his home machine shop to yield digital image files with magnifications ranging from 1X to 50X in 4x5-inch prints. The camera is cabled to a PC and produces images that are immediately viewable on a 1024 x 1280-pixel monitor. This link between camera and computer makes it much faster and easier to establish proper illumination, focus and depth of field while viewing camera output on the monitor.

"It's difficult to photograph the damage or the contact pattern on a gear tooth," Clarke says. Often the operator will have to adjust lighting, positioning or camera settings to obtain a clear image.

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CIRCLE 119

Using traditional methods, it's not uncommon for the photographer to expose three or four sheets of instant film to get a single usable picture. With the digital setup, Clarke and others at the lab can make adjustments on the fly and see the changes in real time.

But the immediate time savings and convenience are only part of the advantage, Clarke says. "The big thing is that the images are stored on a server."

The images, along with the metallurgists' full report, are stored on Case Corp.'s token ring local area network, where they are accessible to any authorized employee. The digital file format also makes it easy to e-mail the metallurgical reports to Case Corp. offices around the world.

"When you have a problem with a part, the quicker you can get the response to the supplier or the plant, the more cost-effective the solution will be," Clarke says. "The faster the lab can determine the source of the problem, the faster the company can solve it."

Other companies have tried digital photography in their metallurgical labs with varying levels of success. "I've seen some pretty poor examples of digital images," Clarke says. The problem is often knowing what constitutes a high-quality image. "With film imaging, it was not a problem. Film has ample reso-

lution. I see a terrible amount of confusion with digital technology."

Part of this confusion results from a lack of standards for digital photomacrography, Clarke says. He hopes that will be one of the issues addressed at ASM's upcoming Imaging Tech 99, to be held August 17-19 at Arlington Park, IL, because more and more companies will begin trying digital imaging as the technology becomes more widespread and less expensive.

Case Corp.'s success in digital photomacrography has made them a benchmark of sorts. Recently, a major bearing manufacturer visited Clarke's office to study his setup. They ended up buying two of the Kodak Megaplug cameras and developing a similar setup of their own, Clarke says.

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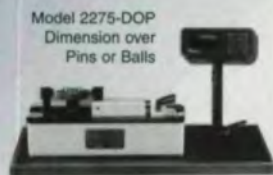
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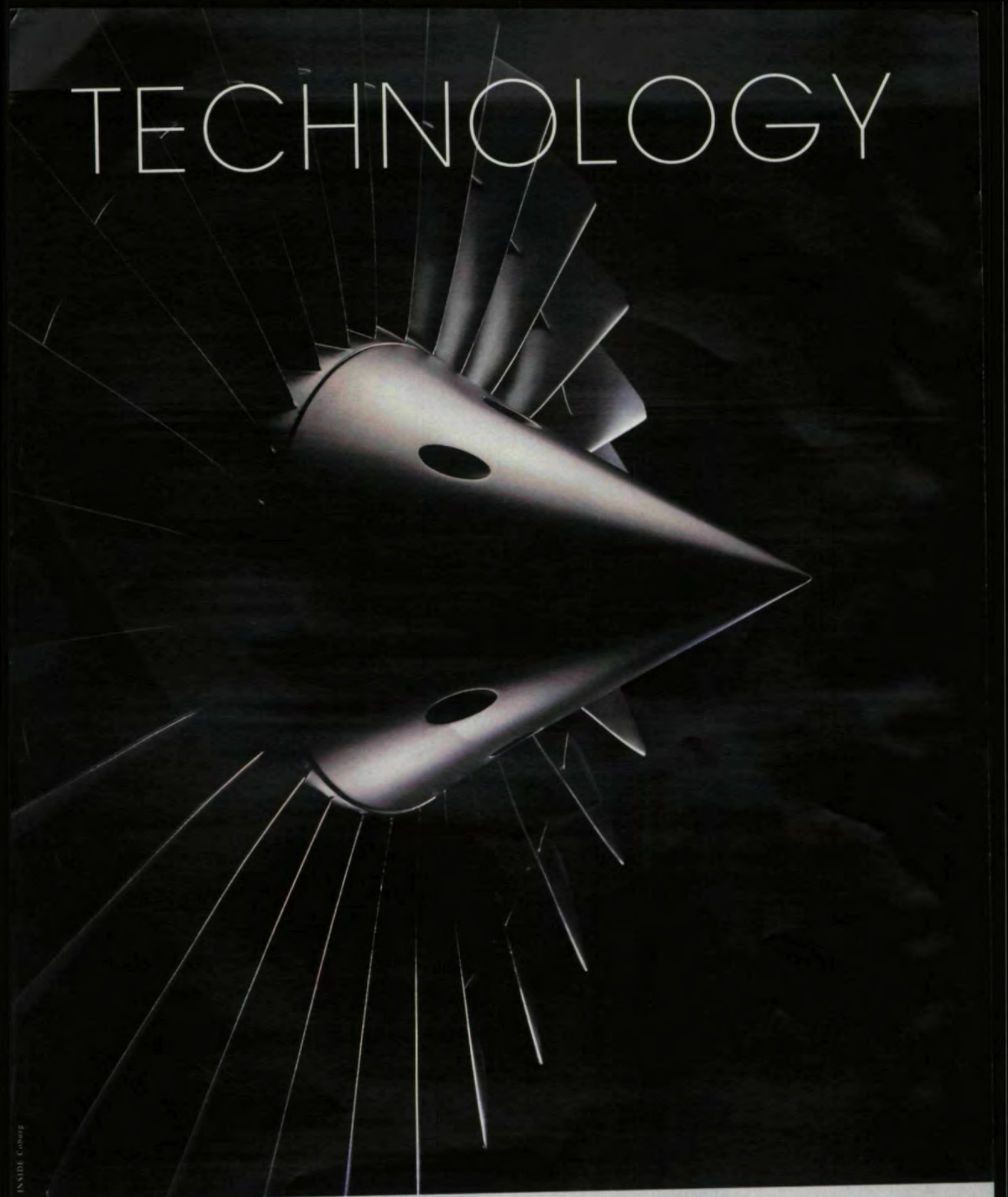


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Theodore M. Clarke of Case Corp. using digital photomacrography equipment.

TECHNOLOGY



INSIDE Cover

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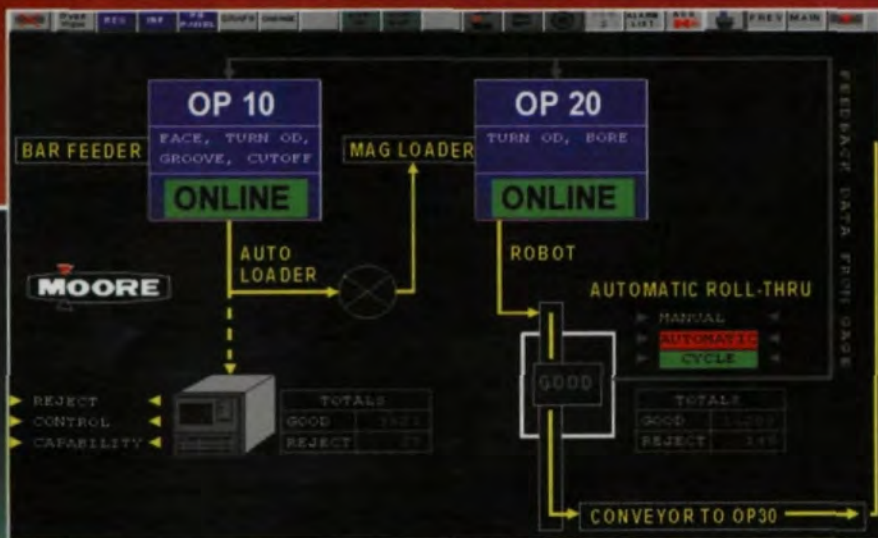
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Cutting Tools Roundup

Today there is a movement in certain industries away from traditional wet cutting technology. What does dry cutting offer and does this shift spell the end for oils and coolants in metal cutting applications?

Charles M. Cooper

The cutting tool industry has undergone some serious changes in the last couple of years in both technology and the way the industry does business. The emerging technology today, as well as for the foreseeable future, is dry cutting, especially in high volume production settings. Wet cutting continues to be as popular as ever with lubrication advances making it more economical and environmentally friendly. There has also developed a process called "near dry cutting." This process offers many of the benefits of fluids while eliminating many of the associated problems.

The real question many manufacturers have is which technology is best to use. Do you stay with your wet process or move on to dry? How do you decide? That is where having a partnership with your cutting tool supplier becomes essential. These enhanced relationships can provide you with the information as well as the technical experience and advice you will need to make this decision.

The Cutting Tool Partnership

"There is a change being made in the culture of the cutting tool industry," declared Starcut Sales' marketing man-

ager, Bill Maples. He was talking about the move away from traditional buyer/seller relationships in the cutting tool industry and toward partnering between customer and supplier. "The industry's habit was to simply quote tool prices, and the customer would use that price as the sole criterion for making the decision to buy. Customers were never made aware of all the services a manufacturer could and would provide to support that tool. Manufacturers also realized that they were, in part, responsible for the situation," Maples explained. "Customers had to know that there was a lot more

to a product than just the cost, that a reputable vendor could provide the kind of current information customers need." By focusing on cost alone, the customers forgot that the application needs to drive the choice of technology. So, they were often purchasing tools that were ill-suited to their application, or using the correct tools incorrectly, often leading to production and mechanical problems, downtime and lost revenue.


This can be avoided by the adoption of a partnership relationship aimed at developing custom tooling for the customer. Before the tool is made, the customer informs the cutting tool manufacturer of the material to be cut, its hardness, whether or not it has been heat treated, the kind of machine to be used, the quality of the end product, and many other parameters that need to be taken into account in order to correctly specify a custom cutting tool. The manufacturer then makes that tool, or even an entire system if necessary, to the customer's specifications.

After delivery, the manufacturer of the tool is there to assist if problems should arise, consulting with the customer's own engineers or going out to the customer personally. "We diagnose problems brought to us by our clients," says



Fig. 1—Coated carbide cutting tools. Courtesy of Ion Vacuum Technologies Corp.

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CIRCLE 135

TECHNICAL FOCUS

Maples. "We can then offer solutions."

Rick Chambers, cutting fluid product manager for Valenite, Inc., agrees, seeing this approach at work in his company as well. "We produce both cutting tools and cutting fluids. When we spec a tool for a client we're working with, we also make sure to spec the right cutting fluid to meet their application requirements."

The shift toward partnerships is solving many problems. By partnering with a supplier, a customer can get the support he needs to make informed decisions while knowing that the company he is working with is committed to the success of his application. After all, according to Maples, "the ultimate objective is to produce gears with the minimum number of tools at the lowest cost per gear."

Partnerships are helping to make that happen, but along with these changes come practical advances in cutting tool technology that offer faster, cleaner production for less money. The emerging technology that promises this is dry cutting.

Dry Cutting Technology

More and more in the high-volume, fast turnaround shops of the automotive industry, the emerging technology for gear cutting in the 21st century is dry cutting. Dry cutting is simply the cutting of metal or other materials without the use of cutting oils or fluids, and it does offer certain advantages. First, since dry cutting eliminates the need for cutting fluids, it thereby eliminates the costs as well as health and environmental problems associated with these liquids. Second, it is usually faster and

can provide better surface characteristics on the workpiece than conventional wet cutting.

However, dry cutting also requires special machines that can handle higher speeds and temperatures than are seen in wet cutting, machines that can also remove chips that would normally be washed away by the flowing cutting fluid. It also requires special coatings on the tools themselves to keep the tools from melting during the cutting process. Finally, while dry cutting applications were initially done using carbide cutting tools, improvements in coatings have led to more and more high speed steel tools being used due to their lower cost and greater toughness.

Materials. Cutting tools—hobs, shapers, cutters, etc.—are made from one of two materials, either high speed steel (HSS) or cemented carbide materials, usually made of tungsten or titanium. Soon, however, there may be more materials available to cutting tool manufacturers. According to Maples, Starcut is experimenting right now with materials that "bridge" the capabilities between high speed steel and carbides. In the near future, such "bridge materials" may be a viable alternative to both carbide and high speed steel.

High Speed Steel. High speed steel is typically an alloy of tungsten, molybdenum, chromium, vanadium and carbon. It can be hardened to a high initial room temperature hardness (anywhere from 63 Rc up to 70 Rc) and it retains sufficient hardness, at the 1,000° to 1,100° F temperatures generated by the cutting

process, to do the job. Also, high speed steel will return to its original hardness upon cooling. Mitsubishi is currently working to improve these characteristics in high speed steel with their new Mach 7 high speed steel alloy, which is used with their GN series of dry hobbers.

Over the years, engineers have learned that even the best high speed steel cutting tools need to be coated. This was not always the case, but today, since the benefits of coatings are well known, high speed steel cutting tools are almost always coated. "90% of the hobs we ship have some kind of coating on them," says Glen Schlarb, engineering manager for Gleason Pfauter Hurth. "And the 10% that are ordered without coating usually are coated at some point."

Cemented Carbides. These are a group of alloys based primarily on tungsten, molybdenum and cobalt. They are also called sintered carbides, solid carbides, as well as just carbides. The various types of carbide include tungsten carbides, crater resisting carbides and titanium carbides. Today, almost all carbide tools have some coating applied to them just like their high speed steel counterparts.

These materials retain their hardness (between 86 RcA and 93 RcA) up to 1,400° F and can therefore achieve higher speeds than their HSS counterparts. Carbides also have great wear resistance and produce very good surface finishes on the workpiece. The real drawback that carbides have in comparison with high speed steel is brittleness. This means the tool will be more likely to chip and break, whereas the

tougher high speed steel just wears down and can be re-sharpened and recoated.

Both Starcut and Gleason Pfauter Hurth are working to make carbide hobs reliable and available for dry cutting applications, while the engineers at Mitsubishi are concentrating their efforts on developing their Mach 7 high speed steel. But carbide, high speed steel or even Mach 7 are just the base. It is the coating that makes dry cutting viable.

Coatings. After being fabricated, the high speed steel or carbide cutting tool base material, or substrate, is coated with titanium carbide (TiC), titanium nitride (TiN), aluminum oxide (Al₂O₃) or titanium aluminum nitride (TiAlN). The primary purpose of the coating is to protect the substrate from heat and wear. The secondary purpose, and the topic of many arguments, is to improve the surface characteristics of the workpiece. The majority of engineers swear that the coating makes a difference while a dwindling minority is just as adamant that it does not. It's an argument that is likely to rage on for some time.

One of the things that makes dry cutting possible is the use of titanium aluminum nitride, a coating material that works particularly well at high temperatures. "It [the TiAlN coating] needs a high surface feed and the high temperatures that go along with it," says Maples. "Under those conditions, the coating forms a barrier that takes the heat away from the substrate in addition to the usual mechanical protection." These observations have also been made by Gleason Pfauter Hurth.

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According to Brian Cluff, Gleason Pfauter Hurth's vice president of worldwide sales and marketing, "basic substrate material with a single layer of TiAlN coating performs better dry than it does with coolant, but multiple layers—alternating layers of TiAlN and TiN—improve the performance characteristics when using coolants."

Advances in coating technology have centered around adding lubricity to the coating as a way to further reduce the amount of generated heat.

According to Schlarb, "Gleason Pfauter Hurth's new PowerLube™ coating is a two layer system. First the titanium aluminum nitride is laid down on the substrate. Then a layer of tungsten carbide carbon (WC/C) is added over that. The additional layer of WC/C provides a high level of lubricity that cuts down on the friction heat and helps the TiAlN layer work better." This new technology makes dry

cutting easier and more efficient, adding to the economy provided by dry cutting.

The Costs of Carbide vs. High Speed Steel. With dry cutting, tool costs are comparable when measured per part in spite of the use of higher priced carbide cutters. According to Gleason Pfauter Hurth, the blade cost per part for high speed steel blades and carbide blades is \$2.16. This, in spite of the fact that a HSS blade costs around \$72.00 and a carbide blade costs \$230.00. This kind of cost equivalence is possible because advances in cutter and machine tool technology allow dry cutting tools to last longer even though the machines operate at speeds that are twice as fast as those of conventional cutters.

Tool Design. Dry cutting tools, especially hobs, have undergone some relatively minor changes in geometry to make heat and chip removal more efficient as well as to decrease the cutting time for

high speed steel to match that of carbide tools. According to Schlarb, "high speed steel hobs are slower than carbide hobs. What we have done is change the number of threads on the hob so that there are more starts. This decreases the cutting time and makes the tool comparable to a similar carbide hob."

Starcut has been working along the same lines, experimenting with the number of threads on their hobs as well as the tooth shapes, in order to take advantage of the higher speeds found in dry cutting machines. In fact, it is within the machines that Maples says the real difference between wet and dry hobbing processes resides. "There is no difference between a dry hob and a wet hob," says Maples. "The difference is how the machine is designed."

Dry Cutting Machine Tools. One of the reasons that wet cutting tools will not go the way of the eight-track tape

or the Betamax video format anytime soon is that there are simply too many wet cut machines still in operation all around the country. Dry tools can be used with these wet machines, but because of the machine tool's reliance on a stream of cutting oil or liquid coolant to wash away the chips and cool the tool, the machine and the workpiece, there would be no real benefit.

Dry cutting machines use gravity to remove chips from the work area, not a liquid stream. The chips are then either collected by a conveyor, as with the Mitsubishi dry hobbing machines, or gravity fed into a collector.

"Mitsubishi's GN Series hobbing machine has been designed to work in conjunction with the Super Dry Hob™ (a tool made from Mitsubishi's Mach 7 high speed steel and coated with their proprietary coating)," says Bob Strack, an engineer at Mitsubishi Machine Tools. "The GN series machine has been designed to reduce thermal distortion." This is accomplished by removing the super-heated chips as quickly as possible. By changing the orientation of the machine from vertical to horizontal, chips are allowed to fall into the chip conveyor, taking their excess heat away without the need for cutting fluids.

The other difference is the way that dry machines handle the heat produced by the cutting action itself. Since these machines work at much higher speeds than conventional cutting machines, the associated temperatures are much higher than normal. Dry cutting machines are specifically made to dissipate that heat



Fig. 2—Wet hobbing of a helical gear. Courtesy of LMT-Fette.

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CIRCLE 142

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TECHNICAL FOCUS

ing their lungs or escaping into groundwater or into the atmosphere to cause acid rain.

Why Many Won't Switch.

While all this may be true of cutting oils and coolants, and true of the dry cutting process, it is also true that wet cutting technology has a very firm grasp on the cutting industry and is not going to be supplanted by dry cutting anytime soon.

The reasons for this are really twofold. First, as mentioned above, there are simply too many wet cut machines in use today. The capital expenditure to replace them all would really be prohibitive. How many shops would be willing to scrap their existing machines and purchase new ones if they don't need the speed or have problems disposing of their waste coolants? Second, not every application calls for dry cutting. If the most intelligent approach is to permit the application to choose the type of technology that is used, then wet cutting must remain a viable alternative. Still, many gear makers find themselves somewhere in the middle, worrying about the costs associated with wet cutting and yet not wishing to incur the expense of switching their production over to the dry technology. For these people, one company has come up with an interesting solution.

Near Dry Cutting

Somewhere in the grey area between wet and dry cutting, and enjoying some of the benefits of both, is a process referred to as "near dry cutting." As the name implies, the workpiece and cutter are not flooded with cooling lubricant. Rather, they are covered in a fine mist

that is consumed during the cutting process, thereby producing no waste except for the chips, which are handled in much the same way as dry cutting machines.

This is a process that has been developed by the ITW Fluid Products Group of Glenview, IL, with their Accu-Lube line of cutting lubricants. "Accu-Lube is an all-natural, plant-based lubricant," says Rob Myers, product manager for ITW, "that requires only a small amount to work. Instead of filling a sump with 60 gallons of synthetic cutting fluid, for example, you would use only about 2 ounces of Accu-Lube during the day. What's more, the lubricant is burned

**"THERE IS NO
DIFFERENCE
BETWEEN A
DRY HOB
AND A
WET HOB.**

**THE DIFFERENCE
IS HOW THE
MACHINE IS
DESIGNED."**

**—BILL MAPLES,
STARCUT.**

away in the cut, eliminating the need for fluid collection, recycling or removal. Also," Myers adds, "because the fluid is plant-based, you don't have the same health, safety or environmental concerns that you would have with conventional cutting fluids."

According to Myers, customers testing the near dry process with the Accu-Lube system have reported dramatic increases in tool life as well as easier machine maintenance.

Conclusions

As the clock ticks down to January 1, 2000, the cutting tool industry is certainly going through some changes that promise to improve both the quality of its products and the quality of its customer service.

With the advent of tier suppliers to major industrial sectors, as well as the realization among customers that the lowest bidder isn't always the best choice, partnerships are springing up between cutting tool manufacturers, suppliers and end users.

Dry cutting is the emerging cutting tool technology for the beginning of the 21st century. It provides a cleaner, faster, and often cheaper alternative to traditional wet cutting. However, due to the number of machines in use throughout the country that rely on cutting oil and coolant fluids to function, the new technology will not replace wet cutting for some time to come.

Wet cutting technology is advancing every bit as vigorously as its dry cutting counterpart. Recognizing that fluids can be difficult and expensive to work with and dispose of, the fluid industry is working to reformulate them into cleaner, easier to handle flu-

ids. Straight oils are being replaced by water soluble oils as well as synthetic and semi-synthetic cutting fluids with higher bio-stability and biocide protection, increased lubricity, higher cooling capacity and considerably less impact on the environment.

However, between the two, the rapidly growing near dry technology is developing its niche in the market, as well as some adherents, by promising many of the benefits of dry cutting while allowing the continued use of existing wet machines.

Wet, dry, near dry, if you are trying to figure out which technology is right for your shop then maybe you should take the words of Gleason Pfauter Hurth's Brian Cluff to heart when he says, "There is no one right process here. You have to let the application decide on the process you will use. It's the old engineering maxim that form follows function." ☉

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CIRCLE 154

Specifying Custom Gears

C. Kent Reece & Charles M. Cooper

Gear design and specification are not one and the same. They are the first two steps in making a gear. The designer sits down and mathematically defines the gear tooth, working with the base pitch of the gear, the pressure angle he wants to employ, the number of teeth he wants, the lead, the tooth thickness, and the outside, form and root diameters. With these data, the designer can create a mathematical model of the gear. At this stage, he will also decide whether the gear will be made from existing cutting tools or whether new tools will be needed, what kind of materials he will use, and whether or not he will have the gear heat treated and finished.

That is the design end. The specifications are the data given to the manufacturer that permit

him to properly make and test your gear. Here we are discussing the design drawing you submit as well as the information that should and should not be included. At this point in the process, any vagaries in your design, such as the effects of heat treating or finishing, should have already been resolved. When you are ready to write your specifications, you should be ready to make your gear.

Designing Your Gear

Gears are usually designed from their cutters (hobs, shaper cutters, etc.) and, likewise, cutting tools are often designed from the specifications of the gears being made. If you create a new gear, it is possible that you will be able to use existing tools to manufacture it, but the odds are that you will want to create a new tool to handle the new design. The data you will need to accomplish this come from the basic design elements of the gear itself. All of the following parameters can be delineated in either metric (millimeters) or English (inches) units.

A word should be said about metric and English measurements. The global market today is primarily metric. The prevalence of English measurements in the United States is, for the most part, due to the vast number of cutting tools in the inventory that are already specified in inches. Since it is likely that you will have to convert your gear measurements to metric anyway, as long as you are going to design the tool as well as the gear, you will save yourself some work by designing the gear in metric to begin with.

Base Pitch. This is the base circle circumference divided by the number of teeth. It is a constant distance between each of the teeth along the line of action. The symbol for base pitch is P_b in both metric and English designs. The term *Normal Base Pitch* refers to the base pitch in the normal plane of an involute helical gear.

Pressure Angle. The angle, measured in degrees, between the line of pressure and the plane tangent to the pitch circle at the pitch point (the point of tangency between two pitch circles). The pressure angle is labeled α or α_p .

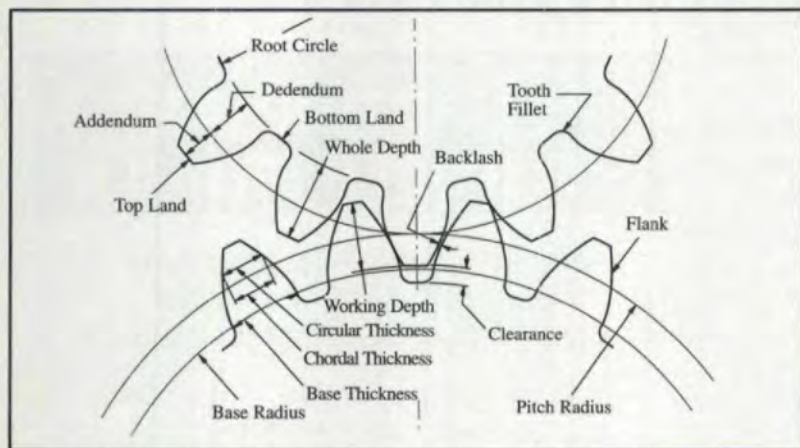


Fig. 1—Gear design nomenclature. Courtesy of Van Gerpen and Reece Engineering.

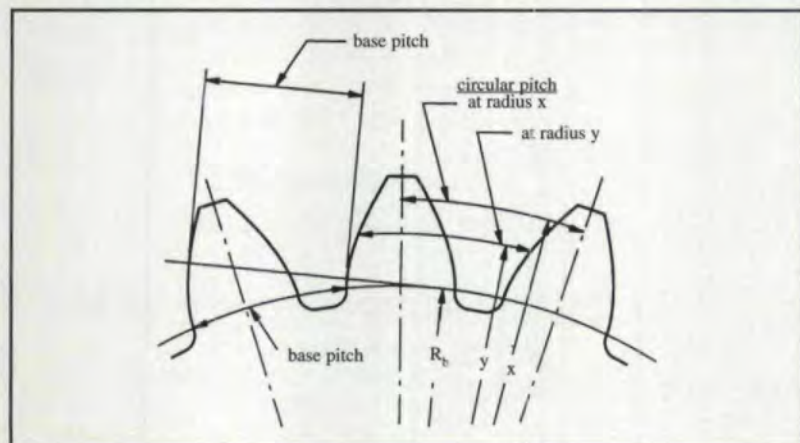


Fig. 2—Base pitch and circular pitch. Courtesy of Van Gerpen and Reece Engineering.

Number of Teeth. The number of teeth your gear has along its entire circumference. The symbol is z_2 . In spur gears, this parameter is determined from the pitch diameter (D) and the diametral pitch (P) with the formula $N = D \times P$. For helical gears, the formula is $N = D \times P \times \cos(\beta)$ where β is the helix angle.

Lead and Hand of the Helix. Lead is a measurement of the axial advance of the helix for one complete turn. Hand is the direction of the turn, specified as either right or left. The lead symbol is p_z .

Helix Angle vs. Lead. Specify the lead of a gear rather than the helix angle because lead is a constant value while helix angle is not. Finding the helix angle depends upon knowing the diameter of the circle associated with the angle.

Tooth Thickness. The arc thickness of the tooth at a given radius from the mounting center of the gear. As a specification, this measurement is also referred to as *circular tooth radius*. The metric symbol for tooth thickness is s . In English units it is t . To mathematically find the normal tooth thickness in a standard spur gear, use the diametral pitch (P) in the formula $t_t = 1.5708/P$. For the normal tooth thickness in a helical gear, use the normal tooth thickness ($t_n = 1.5708/P_n$ where P_n is the normal circular pitch and is found with $P_n = P/\cos\beta$) and the helix angle in the formula $t_t = t_n/\cos\beta$. Because rack shaped cutters (i.e. hobs) operate in the normal plane, the transverse diametral pitch is not usually specified as it tends to confuse things.

There are several ways of directly measuring tooth thickness. These include tooth calipers that measure chordal thickness at a given radius; span micrometers, which measure the distance across several teeth; center distance with a master gear; and dimensions over balls, pins or wires, which gives you a dimension over two balls placed in opposing tooth spaces. The problems associated with specifying tooth thickness based on any one of these methods are the implication that this is the only viable method for checking the gear, the usually false belief that the balls will measure the tooth thickness at the nominal pitch circle, and the need to recalculate the tolerance on the dimension over balls when changing the size of the ball. How these difficulties are eliminated by adopting the convention of specifying circular tooth thickness as normal tooth thickness measured at the base circle will be discussed in the specifications section.

Outside Diameter. This is defined as the diameter of the addendum circle. In bevel or

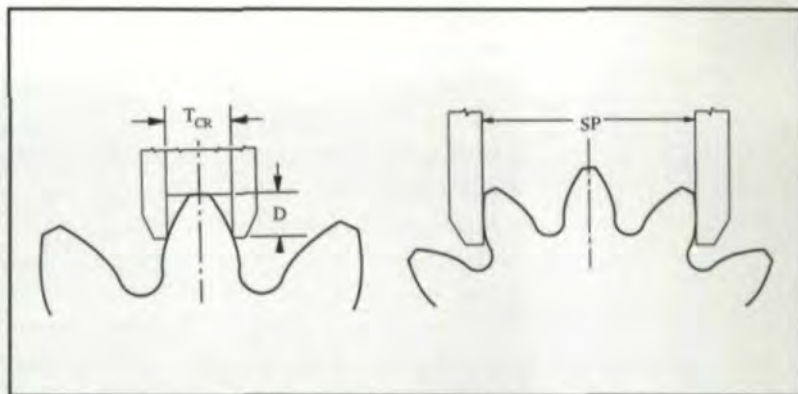


Fig. 3a—Tooth calipers. Courtesy of Van Gerpen and Reece Engineering.
Fig. 3b—Span Micrometer. Courtesy of Van Gerpen and Reece Engineering.

hypoid gearing, however, the O.D. is the diameter of the crown circle. In metric gear designs, the symbol for outside diameter is d_{a2} and in English designs it is D_o . In spur and helical gears, the outside diameter can be found using pitch diameter (D) and addendum (a) in the formula $D_o = D + 2a$. In straight and spiral bevel gears, the formula uses pitch diameter (D), the addendum (a) and the pitch angle (Γ) of the gear. The formula is $D_o = D + 2a_{oG} \cos \Gamma$. The pitch angle of the gear is determined from the pitch angle of the pinion with the formula $\Gamma = 90^\circ - \gamma$ ($\Gamma = \tan^{-1} z/Z$, where z is the number of teeth on the pinion and Z is the number of teeth on the gear).

Form Diameter. This is the diameter of the circle intersecting the trochoid formed by the cutting tool and the involute tooth profile. It is also the limit of tooth contact between mating gears. The symbol is $d'f$.

Root Diameter. This is the diameter of the root circle. When considering bevel gears, it is the diameter of the root circle at the outside ends of the teeth. The symbol is d_{f2} . In spur gears, root diameter can be determined by $d_{f2} = D - 2b$ (where b = dedendum and D = pitch diameter). In a worm, the formula is $d_{f2} = d_o - 2h_t$ (where d_o is the outside diameter of the pinion and h_t is the whole depth of tooth).

These various design elements will allow you to define your gear mathematically. They will either appear as, or be used to get, the specifications that will appear on your drawings to guide the manufacturer in the creation of the cutting tool needed to make the gear.

Other Useful Design Elements

You will need to specify other things about your gear that, while not directly related to the design of the cutting tool, will have a great impact on the manufacture of your gear.

Topland Width. Topland is the thickness of the top of the tooth as measured in the direction

C. Kent Reece

and Harlan Van Gerpen have been designing gears for over 40 years, the first 25 years with the John Deere Product Engineering Center and the last 15 with the Van Gerpen-Reece Engineering consulting partnership. During this time they have developed and improved software for gear design and cutter recycling. They sell the software and also use it in their consulting activities. They have written a book on gear fundamentals, "Gear Design with Computer Applications," and have also presented a number of seminars dealing with gear design and manufacturing. In recent years, their efforts have been directed toward developing software to provide high contact ratio gears for noise reduction. In addition, they have worked with suppliers to provide quality molded gears.

Charles M. Cooper

is Gear Technology's Senior Editor.

of rotation. Topland width measures the same surface perpendicular to the direction of rotation. It is, therefore, a measurement of how thick the gear teeth will be. This is important because the designer has to guard against the top-land width approaching zero.

Backlash. Measured on the operating pitch circle, backlash is the amount of space between mating teeth in a gear pair when the driving tooth is in contact with the driven tooth. All gear pairs must have backlash if they are to operate properly. When you are designing your gear, you must consider runout and center distance tolerances as these will cause variance in the circular pitch at the operating pitch circle, and that is the parameter you use to determine backlash. As a rule of thumb, you can determine backlash for a given pitch as follows: 0.030 to 0.050 inches divided by the diametral pitch. For example, a 3 DP gearset would have a 0.010 to 0.017 inch backlash.

Contact Ratio. The ratio of the transverse arc of action to the transverse base pitch, this element is found by dividing the length of mesh along the line of contact by the transverse base pitch.

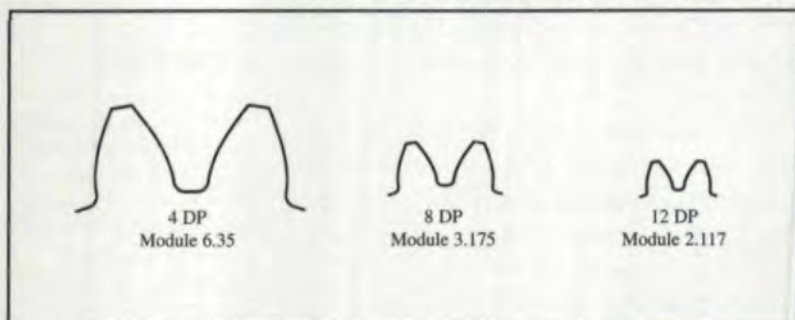


Fig. 4—Diametral Pitch and Module. Courtesy of Van Gerpen and Reece Engineering.

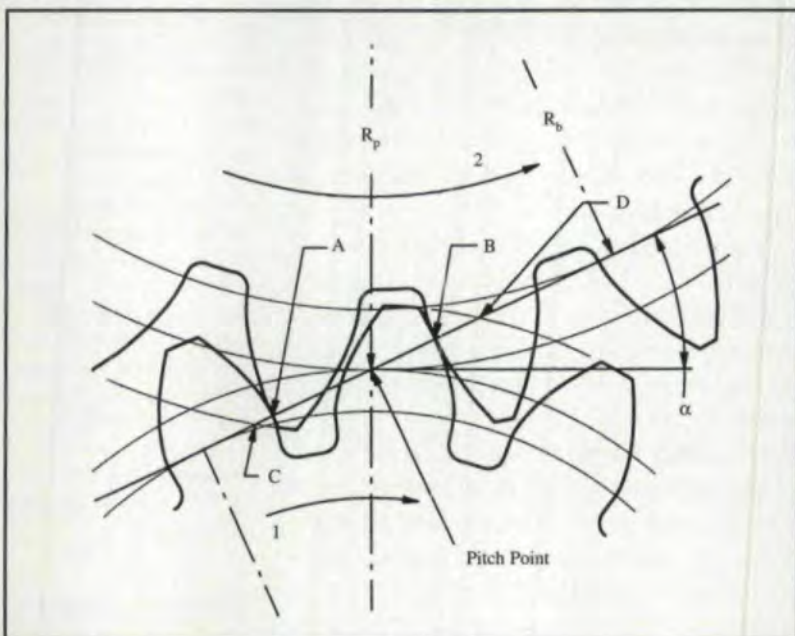


Fig. 5—Base tangent line. Courtesy of Van Gerpen and Reece Engineering.

Materials. The selection of materials is usually based on the type of application you are designing. According to Dudley's Gear Handbook: "The use of a specific gear material should be based on several factors, chief of which is the service application for which the component is designed. Other considerations for the use of a particular material would be material availability, raw stock cost, load-carrying capacity, environmental considerations such as corrosion—corrosion protection and manufacturing requirements."

Materials are divided into two categories: ferrous and nonferrous gear materials. Ferrous materials include all the various types and grades of iron and steel available. These are the most widely used gear materials today. They are cheap and can be heat treated to improve their hardness and increase their load capacity. Ferrous metals are used when strength, durability and safety are paramount.

Nonferrous gear materials include aluminum alloys, zinc alloys, bronzes, plastics, nonmetallic laminates and other, more exotic materials. They are often used when gears must be light weight, as in aerospace applications; or the load they will carry is minimal, as with computer printers and other light duty consumer applications. They are also useful in precision instruments where the inertia of turning gears must be minimal, when the gear's operating environment would be too hostile for iron or steel, or when low cost mass production is needed.

Post-Manufacture Processing. This includes the whole gambit of finishing procedures from grinding and honing to heat and cryogenic treatments. These procedures are performed to improve the surface characteristics of the gear in order to reduce or eliminate transmission errors that lead to noise and vibration. For example, honing has been shown to have a profound effect on the sound characteristics of the gear (see "An Experimental Study on the Effect of Power Honing on Gear Surface Topography," *Gear Technology*, January/February 1999).

Heat treatments of various kinds including flame hardening, induction hardening, carburizing, carbonitriding, nitriding and other procedures are used to harden and temper steel and certain kinds of iron by changing the chemical and/or grain structure to make them more resistant to wear, pitting and cracking.

Case Depth and Hardness. If you have chosen a ferrous metal gear for your application, you have to be concerned with case hardness and case

depth, as these parameters affect the load capacity of your gear. Heat treatments that introduce carbon or nitrogen into the surface of a metal create a hardened shell, called a case, around a core of somewhat softer metal. Case depth is a measure of how thick that hardened shell is, while case hardness is a measure of how hard the shell is.

Hardness can be measured on any one of a variety of scales; however, Rockwell C hardness or Brinell Hardness Number (BHN) are the most prevalent. A steel with a 250 BHN is equivalent to a Rockwell C24 rating. This steel is soft, easy to cut, and has a moderate load capacity. A steel with a 610 BHN is equivalent to a Rockwell C58 rating. At this level of hardness, the gear would have to be ground, not cut, and would have a very high load capacity. It is not unusual after heat treatment for a gear to have a 250 BHN core and a 610 BHN case. The advantage of the case hardening process is that the core of softer material is much tougher and more ductile, with better bending fatigue strength, than the hardened but more brittle case, which has better pitting, cracking and load carrying properties.

Quality. This refers to the tightness of your design tolerances as well as to the standard by which you are going to measure your gear. Will you use AGMA, ISO, DIN or some other standard? What class within the standard are you trying to achieve? AGMA Class Q10 gears, for example, are machine cut and show a good level of precision with an achievable tolerance of 0.0125 mm to 0.05 mm. Q10 gears have far tighter tolerances than AGMA Class Q5, which are die cast, commercial quality gears with a tolerance range of 0.05 mm to 0.125 mm. AGMA Class Q14, however, are precision ground and have a tolerance range of 0.0025 mm to 0.0125 mm. Be aware that it is possible to have different quality levels with respect to alignment (lead), profile and runout.

You should also understand the relationship between heat treatment and quality levels. As a basic rule of thumb, you will lose at least two quality levels after heat treating. This means that a gear rated to AGMA Q10 before going through heat treatment will come out as an AGMA Q8 gear due to the distortions involved in heating and quenching the metal. This is important to know because you will have to decide whether to live with the lower quality or put the gear through a finishing process to get those lost quality levels back.

These parameters will round out your description of the gear itself. However, to get the

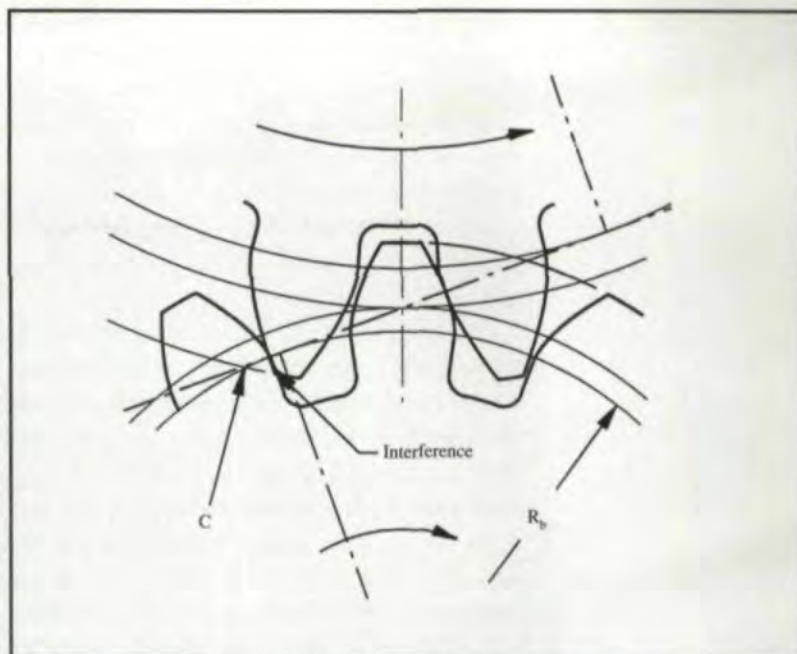


Fig. 6—Interference. Courtesy of Van Gerpen and Reece Engineering.

complete picture, your designer or manufacturer will need to know something of the application itself. Specifically, he will need to understand the gearbox.

The Gearbox. Understanding how your gear is to interact with the other gears in the gearbox, and what kind of output you expect to get from that gearbox, is essential for good gear design. You will need to know the size of the gearbox as well as the width of the cavity in which the gear being designed will be installed. You should also know how many gears will be inside the gearbox, their configuration and the lubrication you are planning for. The speed you expect from both the gear itself and the gearbox as a whole, as well as the torque and turning force you expect to generate, are also important considerations.

Issues of Gear Specification

Specifying a gear for manufacture is a straightforward process once you have all the data the manufacturer will need to do the work. This is not the same as gear design, which is a process primarily focused on developing the tooth form, but it does use some of the same design elements you developed during the design stage. Specification is the next step, where your design parameters are put into action.

The real trick to gear specification is getting in all the necessary information while excluding everything else. The most common pieces of unnecessary information include part number and data regarding the mating gear, backlash with the mating gear (in spite of its importance in the design stage), cutting tool part numbers,

dimension over specific wires or balls, and pitch circle diameter other than the base circle. Overspecifying your gear can mean that you don't know enough about involute gear design, that you are unnecessarily restricting the shop to certain tools and processes, or that there is a problem with double-dimensioning on the gear leading to uncertainty as to which measurements are correct.

There are only eight items required to properly specify a gear. Mentioned earlier are *number of teeth*, *circular tooth thickness*, and *lead and hand of helix*. The other specifications, which are based on the design elements, are: *base circle radius*, *outside radius*, *true involute form radius*, *root radius* and *face width*. By including these with your specification drawing, along with the tolerances on these dimensions, you will make sure your manufacturer has enough information to both produce and inspect your gear correctly.

Base Circle Radius. The easiest way to specify the base circle size of your gear is to use the untoleranced radius of the base circle. You can also specify the base circle radius mathematically using the *module* (the same as the normal diametral pitch) (m), the pressure angle (α_n), helix angle (β) and the number of teeth (Z) specified at the same point on the gear tooth. If you specify these values from different points on the tooth, you will make errors that will be hard to find and correct. Another problem arises if these values are provided along with the base circle diameter, as this often leads to confusion over which values to use. Assuming that you have all your values correct, the equation for finding the base circle radius is:

$$R_b = \frac{Z \cos[\tan^{-1}(\tan \alpha_n / \cos \beta_g)]}{2m \cos \beta_g}$$

Outside Radius. Also referred to as the *addendum circle radius*, this value can either be determined from the *outside diameter* or by tracing a circle with a radius extending from the mounting center of the gear to the farthest point on a tooth. In specifying this parameter, be sure to give the maximum effective diameter as well as the minimum actual diameter.

True Involute Form Circle. This circle crosses the involute surface where the involute surface becomes usable. This surface must remain within tolerance from that point to the outside circle (or to some other specified form

point). This parameter can be rendered as a radius, as degrees of involute roll to the form point, or as the length of the base tangent line to the form point (you need to know the length of the base tangent).

Root Radius. In order to prevent interference, the root radius must be specified. This parameter is measured from the center of rotation to the deepest point in the tooth fillet, or it can be developed from the root diameter mentioned above. It should be noted that if the clearance between the root circle and the mating gear tooth were allowed to be zero, then it would be possible for the corner of the mating tooth to interfere with the fillet between the root circle and the form circle.

Face Width. This is the length of the tooth in the plane (the axial direction) of spur, helical or herringbone gears, essentially the axial width of the gear. It is used to make the blank and to calculate stresses. You can find it by dividing the length of the teeth by the cosine of the helix angle:

$$F = \frac{T_L}{\cos \beta}$$

Conclusions

There is other information which your designer or manufacturer will ask you to provide, other decisions to make, but they come later in the process. You must begin with the basics of your design and effectively communicate the geometry, materials, finishing, quality requirements and post-manufacturing processing of the gear, as well as the demands your application will place upon it, to your designer or manufacturer. Your ability to provide this information clearly and accurately will make the entire design and manufacturing process smoother right from the start. ☉

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For more information about Van Gerpen-Reece Engineering, Inc., circle 204.

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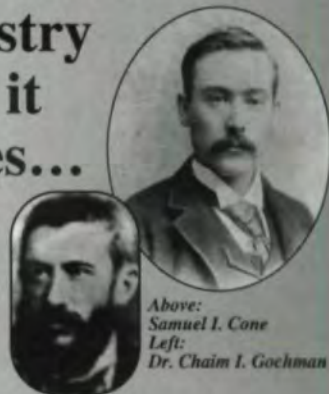


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Advanced Heat Treat Expands Again

Advanced Heat Treat is expanding into their new service center and corporate offices, a 40,000 square foot facility that will be up and running this year. Meanwhile, the two present service centers in Waterloo, IA, and Monroe, MI, are anticipated to increase unit shipments of all kinds of heat-treated parts for the automotive, tool and die, construction, farm machinery, plastics, aerospace and auto racing industries.

Almost 20 years ago, AHT's engineer CEO Gary Sharp identified an emerging market within the heat treating industry—



Advanced Heat Treat's expansion project.

plasma ion nitriding. The growth and success of this venture over the years has been dramatic. Added employees and equipment, expanded services and expertise, ISO-9002 and QS-9000 registrations have all led the company to expand its facilities over the years, first in Monroe and now once more in Waterloo.

plasma ion nitriding. Sharp purchased the necessary vacuum chamber equipment and began business in Waterloo.

Because Advanced Heat Treat was one of the few companies in the heat treat industry offer-

Changes at the Top for Inductoheat

Edward J. Rylicki has been recently promoted to president of Inductoheat's Mass Heating Division. Rylicki has been with Inductoheat since 1991 and has 35 years of experience in the induction heating industry.

Jerome Sinkowski has also been recently promoted to the position of director of quality assurance and production control. Sinkowski will be responsible for management representation



Edward J. Rylicki



Jerome Sinkowski

for Inductoheat's ISO 9001 and Ford Q-1 Quality systems, ensuring the company's continuous improvement of products, processes and customer satisfaction. He has been with Inductoheat since 1972.

Colonial Tool Group Purchases Val-U-Tool & Gage Company

Colonial Tool Group, based in Windsor, Ontario, has announced the purchase of the business and facilities of Val-U-Tool & Gage Company, a designer and builder of precision tools, checking fixtures and prototypes, based in Westland, Michigan. The company's name will be changed from Val-U-Tool & Gage to Colonial Tool Sales & Service.

According to Paul Thrasher, Colonial's vice president of operations, "this acquisition significantly adds 15,000 square feet of needed assembly floor space and some new manufactur-

ing and machine shop capabilities that will expand our overall services to our automotive customers. The purchase will also add 30 additional employees to our workforce, bringing our total employment to 120. Tom Klosowski is continuing to serve as general manager of the Val-U-Tool facility and is optimistic about the possibilities and the good fit."

Brett Froats, Colonial's vice president of sales and marketing adds: "Our business activity in the design and manufacture of RASTM precision machine spindles, broaches and spline rolling racks has grown incrementally over the past five years. We created the need for some type of expansion, particularly in the United States and at close proximity to more of our automotive customers. The addition of Val-U-Tool meets that current need."

Welduction Hires New Engineering Manager

The Welduction Corporation of Farmington Hills, MI, has named Jack Westfall its new engineering manager. With over 25 years of experience, Westfall had previously been a private consultant to numerous companies in the areas of mechanical design and engineering procedures.

Welduction is a full service, Q-1 and ISO-9001 certified induction heat treating equipment supplier specializing in automatic, flexible heat treating systems, thermal bonding and radio frequency generators. A complete line of standard induction hardeners, power supplies, accessory items and spare parts is also available.

Valenite Appoints New Marketing Communications Manager

Barbara Ann Craig has been named Valenite's new marketing communications manager. She will be responsible for the planning and implementation of Valenite's advertising, public relations and marketing communications. She will also be responsible for video, trade shows, corporate logos and Valenite's marketing via the World Wide Web.

A veteran of the advertising industry, Craig brings 13 years of marketing communications experience to her new job. Most recently, she was an account supervisor at Stone, August, Medrich & Company Advertising, Troy, MI, where she was responsible for such clients as Weight Watchers, Valenite and Durakon. Prior to that, Craig worked at Donor Advertising for 10 years representing retail accounts, and at Alcon Marketing.

Middendorf Joins Falk's Cincinnati Office

Michael Middendorf has joined the Falk Corporation's Cincinnati, OH, office as an outside sales engineer. In his new



Michael Middendorf

position, Middendorf will join district manager Jim Nowicki in serving the company's customers throughout southwestern Ohio, central and western Kentucky and central and southern Illinois. A graduate of the University of Dayton with a BS in mechanical engineering technology, Middendorf brings extensive

technical experience to Falk gleaned from eight years at HK Systems and Littleford Day.

Guhring Expands West Coast Operation with New Cutting Tool Specialist

Robert H. Cox has just joined Guhring's fast-growing Irvine, CA, operation as a cutting tool specialist supporting Guhring's standard and special cutting tool sales throughout southern California, Arizona, Colorado, Utah and New Mexico.

Cox brings to Guhring an extensive background in engineering and manufacturing CNC precision-machined components for the aerospace, defense and electronics industries. "Bob has spent 17 years running CNC machining departments—his experience and knowledge will be of tremendous value to our aerospace, automotive and medical device customers in the region," said Paul Jaques, Guhring's sales and marketing manager. "The



Robert H. Cox

role of our regionally located application engineers is to work one-on-one with customers to identify and capitalize on opportunities for machining performance improvement with better holmaking technology. Bob has been on the other side of the table. He knows what is expected and how to make a difference."

Downturn in Machine Tool Consumption

U.S. machine tool consumption for December 1998 totaled an estimated \$482 million, according to AMTDA, the American Machine Tool Distributors' Association, and AMT, the Association for Manufacturing Technology. This was down 4% compared to the revised estimate of \$503 million for November, and down 39% compared to the estimated \$787 million total for December 1997.

"After a five year ride to the top, machine tool consumption cooled in 1998," said AMTDA president Ralph J. Nappi. "While the fundamental indicators for manufacturing are still sound, we will likely experience a sporadic year for capital equipment expenditures with various industries hitting peaks and declines throughout 1999."

The statistics cited are computed from reports submitted by companies participating in the United States Machine Tool Consumption (USMTC) report. Analysis of machine tool consumption provides a reliable leading economic indicator as manufacturing industries invest in capital metalworking equipment to increase capacity and improve productivity. ⚙

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Welcome to the 1999 *Gear Technology* Gear Manufacturing Directory. Here you'll find the names and manufacturing capabilities of hundreds of top custom gear manufacturers, gear manufacturing job shops and gear sellers. Complete contact information for each company can be found in the Company Index (p. 49). *Gear Technology* advertisers are shown in boldface type. To find the pages on which their ads appear, see the Advertisers Index on p. 29.

Many of the companies shown here can also be found on *The Power Transmission Home Page™*, which has a far more comprehensive directory of gear types and specifications as well as listings of many other power transmission components. Because of space restrictions, we've had to limit our categories here. However, if you visit www.powertransmission.com, we're confident you'll find the supplier information that you're looking for.

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

If your company is not listed and you would like to be included in next year's directory, e-mail people@geartechnology.com or call (847) 437-6604, and we'll add you to our mailing list.

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FORGED & CAST TOOTH GEARS

Company	Min Dia.	Max Dia.	Quality
Advance Gear & Machine Corp.	.5"	36"	AGMA 14
American Metric Corporation	Call	Call	Call
Cornell Forge Company	Call	Call	Call
Custom Gear & Machine	2"	60"	AGMA 6
Falk Corporation	Call	46"	Call
Flex Manufacturing Inc.	All	All	All
Great Taiwan Gear Corp., Ltd.	Call	Call	Call
Griffin Gear	.5"	240"	AGMA 8
Nanchang Gear Works	35 mm	120 mm	ISO 8
Presrite Corporation	Call	18"	Call
Rush Gears, Inc.	Call	Call	Call
Santasalo North America Inc.	Call	Call	Call
Stock Drive Products/Sterling Instruments	44 mm	205 mm	ISO 8
Transmission Engineering Co. Inc.	Call	Call	Call
Xtek, Inc.	6"	216"	AGMA 10

GROUND GEARS

Company	Min Dia.	Max Dia.	Quality	DP/Module*
Acme Gear Company	2"	32.67"	AGMA 13	Call
ACR Industries, Inc.	.25"	21"	AGMA 14	4
Advance Gear & Machine Corp.	.5"	36"	AGMA 14	.4
Aero Gear, Inc.	1"	12"	AGMA 12	Call
Akron Gear & Engineering, Inc.	10"	36"	Call	Call
Allied Gear Co.	2"	24"	AGMA 12	2
Amarillo Gear Company—Russellville	2.5"	39.4"	AGMA 13	3
American Machine & Gear	Call	Call	Call	Call
Arrow Gear Company	.5"	28"	AGMA 13	3
Atch-Mont Gear Company, Inc.	2"	40"	AGMA 12	2
Butler Gear	1"	48"	Call	Call
Cardinal Engineering Co.	1"	3"	AGMA 12	12
Chalmers & Kubeck Inc.	2.5"	49"	AGMA 12	1.5
Chardam Gear Company	Call	Call	Call	Call
Chicago Gear - D.O. James Corp.	Call	Call	Call	Call
Circle Gear & Machine Co., Inc.	1"	36"	AGMA 12	2
Columbia Gear Corp.	.5"	30"	AGMA 15	3.5
Cone Drive Operations	Call	Call	Call	Call
Cotta Transmission Co.	Call	24"	AGMA 12	2.5
Fairfield Manufacturing Co., Inc.	Call	Call	Call	Call
Falk Corporation	Call	Call	Call	Call
Flex Manufacturing Inc.	All	All	All	All
Forest City Gear	Call	Call	Call	Call
G&N Rubicon	Call	Call	AGMA 14	Call
Generated Gear & Machine Inc.	Call	12"	Call	Call
Great Taiwan Gear Corp., Ltd.	Call	Call	Call	Call
Griffin Gear	.5"	72"	AGMA 12	.5
Hamilton Gear Inc.	.5"	100"	AGMA 15	1
Horsburgh & Scott	6"	102"	AGMA 12	.75
Indiana Power Transmission Systems Inc.	Call	Call	Call	Call
Indiana Tool-Indiana Gear	2"	44"	AGMA 14	1.8
Inco Corporation	Call	Call	Call	Call
Jackson Gear Company	2"	24"	AGMA 10	3
Kreiter Geartech	2"	61.5"	AGMA 14+	1
Lawler Gear	1"	27"	AGMA 12	3
Link Gear & Machine Company	3"	49"	AGMA 12	Call
Merit Gear Corp.	1"	15.75"	AGMA 12	3
Midwest Gear & Tool	Call	Call	Call	Call
Midwest Gear Corp.	Call	72"	AGMA 12	1
Niagara Gear Corporation	Call	Call	Call	Call
Nixon Gear Inc.	.5"	27"	AGMA 15	Call
O'Brien Gear Company	1"	50"	AGMA 10	1
Oliver Gear, Inc.	1"	27.5"	AGMA 12	3.5
Perry Technology Corp.	0"	20"	AGMA 12	2
Philadelphia Gear Corp.	Call	Call	Call	Call
Precision Gear Inc.	1"	15"	AGMA 15	1
Pro-Gear Co., Inc.	1"	27.5"	Call	3.5
Quality Transmission Components	10 mm	300 mm	JIS 1	8 module
Reliance Gear Corp.	3"	30"	AGMA 13	Call
Riverside Spline & Gear Inc.	.75"	28"	All	Call
Rush Gears Inc.	.25"	36"	AGMA 12	2
Santasalo North America Inc.	Call	Call	Call	Call
Selector Spline Products Inc.	.250"	12"	AGMA 14	4
Shanthi Gears	10 mm	1500 mm	DIN 6	30 module
Southern Gear & Machine	1"	10"	AGMA 13	6
Springer Company	6"	64"	AGMA 16	Call
Stock Drive Products/Sterling Instruments	11 mm	246 mm	ISO 5	3 module
SUDA International Gear Works	.5"	94"	AGMA 14	1
Sungear, Inc.	.5"	12"	AGMA 12	6
Transmission Engineering Co. Inc.	Call	Call	Call	Call
Unicor, Inc.	.375"	6"	AGMA 12	4
Xtek, Inc.	6"	Call	AGMA 12	.375

* Note: Coarsest DP/Module is shown throughout the index.

HELICAL GEARS

Company	Min Dia.	Max Dia.	Quality	DP/Module	Max Face
A-1 Gears	3"	24"	Call	Call	Call
Acme Gear Company	.75"	60"	AGMA 10	14	Call
ACR Industries, Inc.	.25"	21"	AGMA 14	4	Call
The Adams Company	.75"	24"	AGMA 10	3	Call
Addison Precision Products	.375"	6"	AGMA 9	14	10"
Advance Gear & Machine Corp.	.5"	27"	AGMA 14	.4	Call
Aero Gear, Inc.	1"	12"	AGMA 12	Call	Call
Akron Gear & Engineering, Inc.	1"	84"	Call	1.25	Call
Allied Gear Co.	2"	80"	Call	1.25	Call
Amarillo Gear Company	1"	36"	AGMA 11	2.5	9"
Amarillo Gear Company—Russellville	2.5"	39.4"	AGMA 13	Call	Call
American Machine & Gear	Call	Call	Call	Call	Call
American Precision Gear Company	Call	Call	Call	Call	Call
Arrow Gear Company	.5"	24"	AGMA 13	3	8"
Atch-Mont Gear Company, Inc.	1"	60"	AGMA 9	2	15"
Bonfiglioli Riduttori S.p.A.	Call	Call	Call	Call	Call
Boston Gear	Call	Call	Call	Call	Call
Brad Foote Gear Works	Call	Call	Call	Call	Call
Brewer Machine & Gear	.5"	24"	AGMA 8	2.5	16"
Burgess Norton	.125"	6.5"	Call	Call	Call
Butler Gear	1"	84"	Call	Call	24"
Carbon City Products	Call	Call	Call	Call	Call
Cardinal Engineering Co.	.25"	6"	AGMA 10	12	2"
Carnes-Miller Gear Co., Inc.	.25"	16"	AGMA 10	3	12"
Caron-Vector	Call	Call	Call	Call	Call
C-B Gear & Machine, Inc.	Call	Call	Call	Call	Call
Chalmers & Kubeck Inc.	2"	98"	AGMA 8	1.5	12"
Chardam Gear Company	Call	Call	Call	Call	Call
Chicago Gear - D.O. James Corp.	Call	Call	Call	Call	Call
Chicago Gear Works	0"	16"	AGMA 10	4	Call
Cincinnati Gear Company	Call	Call	Call	Call	Call
Circle Gear & Machine Co., Inc.	.25"	120"	AGMA 10	1.5	30"
Clarke Engineering	.1"	7.1"	AGMA 13	8	7.90"
Cloyes Gear/Rush Metal Division	Call	Call	Call	Call	Call
Columbia Gear Corp.	.5"	36"	AGMA 12	2.5	16"
Cotta Transmission Co.	Call	24"	AGMA 12	2.5	15"
Crown Gear B.V.	0 mm	1100 mm	DIN 6	Call	Call
Custom Gear & Machine	1"	30"	AGMA 8	Call	Call
Davall Gear Company Ltd.	3 mm	450 mm	Call	Call	Call
David Brown Group plc	Call	Call	Call	Call	Call
Electra-Gear	Call	Call	Call	Call	Call
Emerson Power Transmission Corp.	Call	Call	Call	Call	Call
Fairfield Manufacturing Co., Inc.	Call	Call	Call	Call	Call
Falk Corporation	10"	552"	Call	.5	Call
Fisher's Gear & Machine, Inc.	Call	Call	Call	Call	Call
Flender Corporation	Call	Call	Call	Call	Call
Flex Manufacturing Inc.	All	All	All	All	All
Foote-Jones/Illinois Gear	Call	Call	Call	Call	Call
Forest City Gear	.06"	16"	AGMA 11	3.5	Call
G&N Rubicon	Call	Call	Call	Call	Call
Gateway Precision Gear, Inc.	.125"	6"	AGMA 14	16	10"
Gear Products, Inc.	4"	17"	AGMA 7	5	4"
Gear Research Inc.	Call	12"	AGMA 12	Call	Call
The Gear Works—Seattle, Inc.	Call	Call	Call	Call	Call
Generated Gear & Machine Inc.	Call	36"	Call	Call	Call
Global Gear	Call	Call	Call	Call	Call
Great Taiwan Gear Corp., Ltd.	Call	Call	Call	Call	Call
Greenshpon Engineering Works Ltd.	Call	Call	Call	Call	Call
Griffin Gear	.5"	240"	AGMA 12	.5	40"
Hamilton Gear Inc.	.5"	160"	AGMA 9	Call	Call
Heclyn Precision Gear, Inc.	.188"	16"	AGMA 10	2	15"
HMC, Inc.	Call	Call	Call	Call	Call
Horsburgh & Scott	6"	280"	AGMA 9	.375	36"
Hub City, Inc.	2"	12"	AGMA 10	2.5	4"
Indiana Power Transmission Systems Inc.	Call	Call	Call	Call	Call
Indiana Tool-Indiana Gear	2"	60"	AGMA 9	1.8	15"
Industrial Supply Co., Inc.	Call	Call	Call	Call	Call
Inso Corporation	Call	Call	Call	Call	Call
Intech Corporation	Call	Call	Call	Call	Call
Involute Tooling Corporation	Call	Call	Call	Call	Call
Jackson Gear Company	2"	72"	AGMA 8	1	20"
Jade Precision Gear	Call	Call	Call	Call	Call
Kreiter Geartech	2"	154"	AGMA 9	1.25	36"
L.M. Gear Company	Call	Call	Call	Call	Call
Lawler Gear	1"	90"	AGMA 8	2	Call
Link Gear & Machine Company	1"	16"	AGMA 10	Call	Call
Linn Gear Co.	2"	96"	Call	1	24"
Machine Renewal	1"	14"	All	Call	Call
Maddox Metal Works, Inc.	.5"	72"	AGMA 10	Call	36"
Marine Associates	.75"	14"	AGMA 11	3	24"
Master Metal Engineering, Inc.	.083"	16"	AGMA 9	20	16"
Merit Gear Corp.	1.5"	24"	AGMA 8	2.5	8"
mg miniGears	Call	Call	Call	Call	Call
Midwest Gear & Machining	1"	24"	Call	Call	10"
Midwest Gear Corp.	Call	72"	AGMA 12	1.25	22"

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Circle 179

GEAR MANUFACTURING DIRECTORY

HELICAL GEARS (Continued)

Company	Min Dia.	Max Dia.	Quality	DP/Module	Max Face
Milwaukee Gear	Call	Call	Call	Call	Call
MO Star Gear & Machine	Call	Call	Call	Call	Call
Moore Gear Manufacturing	.5"	90"	AGMA 8	1.5	16"
Mr. Gears Inc.	Call	Call	Call	Call	Call
Murray Brothers Manufacturing Co.	3"	16"	AGMA 10	6	Call
Nanchang Gear Works	30 mm	800 mm	ISO 7	Call	Call
Niagara Gear Corporation	Call	Call	Call	Call	Call
Nissei Corp. of America	Call	Call	Call	Call	Call
Nixon Gear Inc.	.25"	120"	Any	Call	Call
Nord Gear Corporation	Call	Call	Call	Call	Call
O'Brien Gear Company	1"	166"	AGMA 10	1	19"
Oliver Gear, Inc.	1"	100"	AGMA 9	.75	26"
Overton Gear & Tool Corp.	Call	Call	Call	Call	Call
P.T. International Corp.	Call	Call	Call	Call	Call
Perfection Gear, Inc.	.5"	18"	Call	3	Call
Perry Technology Corp.	0"	36"	AGMA 12	2	7"
Philadelphia Gear Corp.	Call	Call	Call	Call	Call
PIC Design	.44"	2.06"	AGMA 10	48	.1875"
Poly Hi Solidur	Call	Call	Call	Call	Call
Precipart Corporation	Call	Call	Call	Call	Call
Precision Gear Inc.	1"	15"	AGMA 15	1	12"
Pro-Gear Co., Inc.	1"	27.5"	Call	3.5	Call
The Purdy Corporation	Call	Call	Call	Call	Call
Quality Transmission Components	10 mm	2500 mm	JIS 1	25 module	60 mm
Rapid Gear	Call	Call	Call	Call	Call
Rawling Gear Inc.	Call	Call	Call	Call	Call
Reef Gear Manufacturing	1"	24"	Call	4	6"
Reliance Gear Corp.	Call	Call	Call	Call	Call
Riverside Spline & Gear Inc.	.5"	36"	All	2	40"
Rlink International, Inc.	1.5"	25"	AGMA 9	Call	Call
Robertson Mfg. Co.	0"	48"	AGMA 8	3	14"
Ronson Gears Pty. Ltd.	Call	Call	Call	Call	Call
Rush Gears Inc.	.25"	36"	AGMA 12	2	8"
Santasalo North America Inc.	Call	Call	Call	Call	Call
Schafer Gear Works, Inc.	1"	52"	Call	3	Call
Seitz Corporation	Call	Call	Call	Call	Call
Selector Spline Products Inc.	2"	16"	AGMA 8	6	3"
Shanthi Gears	10 mm	3200 mm	DIN 6	30 module	Call
Southern Gear & Machine	.125"	72"	AGMA 12	1	30"
Springer Company	Call	Call	Call	Call	Call
SriVenkateshware Gear Wheels	Call	Call	Call	Call	Call
STD Precision Gear & Instrument	Call	Call	Call	Call	Call
Stock Drive Products/Sterling Instruments	20 mm	116 mm	Call	3 module	25 mm
SUDA International Gear Works	.5"	118"	AGMA 1	11	18"
Sumitomo Machinery Corp. of America	Call	Call	Call	Call	Call
Sungear, Inc.	.5"	12"	AGMA 12	6	6"
Transmission Engineering Co. Inc.	Call	Call	Call	Call	Call
Tsubakimoto Chain Co.	180 mm	630 mm	Call	Call	Call
Unicor, Inc.	.375"	10"	AGMA 10	8	4"
United States Gear Corp.	Call	Call	Call	Call	Call
The Walter Machine Company	Call	Call	Call	Call	Call
The Will-Burt Company	.25"	16"	AGMA 9	5	6"
Xtek, Inc.	6"	216"	AGMA 12	.5	98"

INTERNAL GEARS

Company	Min Dia.	Max Dia.	Quality	DP/Module	Max Face
A-1 Gears	1"	28"	Call	Call	Call
Acme Gear Company	Call	36"	AGMA 10	Call	8"
ACR Industries, Inc.	.25"	19"	AGM 14	4	4"
The Adams Company	1"	18"	AGMA 8	4	5"
Advance Gear & Machine Corp.	.5"	30"	AGMA 10	Call	Call
Aero Gear, Inc.	Call	Call	Call	Call	Call
Akron Gear & Engineering, Inc.	1"	36"	Call	3	Call
Allied Gear Co.	1"	36"	Call	3	Call
Amarillo Gear Company—Russellville	2"	18"	AGMA 9	Call	Call
American Precision Gear Company	Call	Call	Call	Call	Call
Arrow Gear Company	.5"	17"	AGMA 13	3.6	8"
Atch-Mont Gear Company, Inc.	1"	36"	AGMA 9	2	6"
Avon Bearings	Call	Call	Call	Call	Call
Boston Gear	Call	Call	Call	Call	Call
Brad Foote Gear Works	Call	Call	Call	Call	Call
Brewer Machine & Gear	.5"	36"	AGMA 8	3	6"
Burgess Norton	.125"	6.5"	Call	Call	Call
Butler Gear	1"	48"	AGMA 12	Call	Call
Carbon City Products	Call	Call	Call	Call	Call
Cardinal Engineering Co.	1"	3"	AGMA 6	32	1"
Carnes-Miller Gear Co., Inc.	.5"	20"	AGMA 10	3	5"
Chalmers & Kubeck Inc.	1.5"	32"	AGMA 8	3	5.75"
Chandler Machine Co.	Call	Call	Call	Call	Call
Chicago Gear - D.O. James Corp.	Call	Call	Call	Call	Call
Chicago Gear Works	0"	10"	AGMA 8	10	1.75"

INTERNAL GEARS (Continued)

Company	Min Dia.	Max Dia.	Quality	DP/Module	Max Face
Cincinnati Gear Company	Call	Call	Call	Call	Call
Circle Gear & Machine Co., Inc.	Call	42"	AGMA 9	2	8"
Clarke Engineering	.1"	10"	AGMA 12	4	5"
Columbia Gear Corp.	.5"	36"	AGMA 12	2	10"
Cone Drive Operations	Call	Call	Call	Call	Call
Cotta Transmission Co.	1.5"	22"	AGMA 9	3	4"
Custom Gear & Machine	2"	30"	AGMA 8	Call	Call
Davall Gear Company Ltd.	15 mm	200 mm	AGMA 13	Call	Call
David Brown Group plc	Call	Call	Call	Call	Call
Emerson Power Transmission Corp.	Call	Call	Call	Call	Call
Fairfield Manufacturing Co., Inc.	Call	Call	Call	Call	Call
Falk Corporation	Call	Call	Call	Call	Call
Fisher's Gear & Machine, Inc.	Call	Call	Call	Call	Call
Flender Corporation	Call	Call	Call	Call	Call
Flex Manufacturing Inc.	All	All	All	All	All
Foot-Jones/Illinois Gear	Call	Call	Call	Call	Call
Forest City Gear	.25"	17"	AGMA 11	3.5	5"
G&N Rubicon	Call	Call	Call	Call	Call
Gateway Precision Gear, Inc.	.75"	3"	AGMA 10	24	.75"
Gear Products, Inc.	1"	47"	AGMA 6	2	8"
Gear Research Inc.	Call	Call	AGMA 12	Call	Call
The Gear Works—Seattle, Inc.	Call	Call	Call	Call	Call
Generated Gear & Machine Inc.	Call	20"	Call	Call	Call
Giuliante Machine Tool, Inc.	.5"	20"	AGMA 9	4	5"
Global Gear	Call	Call	Call	Call	Call
Great Taiwan Gear Corp., Ltd.	Call	Call	Call	Call	Call
Greenshon Engineering Works Ltd.	Call	Call	Call	Call	Call
Griffin Gear	1"	120"	AGMA 10	1	7"
Hamilton Gear Inc.	0"	50"	ISO 8	2	9"
Heclyn Precision Gear, Inc.	.188"	16"	AGMA 10	2	4"
HMC, Inc.	Call	Call	Call	Call	Call
Horsburgh & Scott	10"	80"	AGMA 8	1	24"
Hub City, Inc.	2"	16"	AGMA 10	8	Call
Indiana Power Transmission Systems Inc.	Call	Call	Call	Call	Call
Indiana Tool-Indiana Gear	1"	72"	AGMA 9	1.8	15"
Industrial Supply Co., Inc.	Call	Call	Call	Call	Call
Intech Corporation	Call	Call	Call	Call	Call
ITW Spiroid	Call	Call	Call	Call	Call
Jackson Gear Company	2"	36"	AGMA 8	3	6"
Jade Precision Gear	Call	Call	Call	Call	Call
Kreiter Gearteck	4"	48"	AGMA 9	2.5	6"
Lawler Gear	1"	36"	AGMA 8	3	Call
Link Gear & Machine Company	1"	22"	AGMA 10	Call	Call
Linn Gear Co.	1"	96"	Call	2	10"
Machine Renewal	.5"	30"	All	Call	Call
Maddox Metal Works, Inc.	.5"	36"	AGMA 10	Call	6"
Marine Associates	1"	18"	AGMA 9	3	4"
Master Metal Engineering, Inc.	.375"	10"	AGMA 10	20	4.5"
Merit Gear Corp.	1"	24"	AGMA 8	3	6"
mg miniGears	Call	Call	Call	Call	Call
Midwest Gear & Machining	.75"	18"	Call	Call	5"
Midwest Gear Corp.	Call	100"	AGMA 9	1.25	8.25"
MO Star Gear & Machine	Call	Call	Call	Call	Call
Moore Gear Manufacturing	1"	36"	AGMA 8	3	4"
Mr. Gear Inc.	Call	Call	Call	Call	Call
Niagara Gear Corporation	Call	Call	Call	Call	Call
Nissei Corp. of America	Call	Call	Call	Call	Call
Nixon Gear Inc.	.5"	36"	AGMA 10	Call	Call
O'Brien Gear Company	.25"	125"	AGMA 10	.75	18"
Oliver Gear, Inc.	1"	36"	AGMA 9	3	6"
Orlandi Gear Company	Call	Call	Call	Call	Call
Overton Gear & Tool Corp.	Call	Call	Call	Call	Call
Perfection Gear, Inc.	.5"	8"	Call	Call	Call
Perry Technology Corp.	0"	36"	AGMA 10	2	8"
Philadelphia Gear Corp.	Call	Call	Call	Call	Call
Precipart Corporation	Call	Call	Call	Call	Call
Precision Gear Inc.	3"	20"	AGMA 15	1	12"
The Purdy Corporation	Call	Call	Call	Call	Call
Quality Transmission Components	50 mm	2000 mm	JIS 3	8 module	40 mm
Randy's Ring & Pinion	Call	Call	Call	Call	Call
Rapid Gear	Call	Call	Call	Call	Call
Rawling Gear Inc.	Call	Call	Call	Call	Call
Reef Gear Manufacturing	1"	24"	Call	4	6"
Reliance Gear Corp.	Call	Call	Call	Call	Call
Riverside Spline & Gear Inc.	.125"	28"	All	2	Call
Rjlink International, Inc.	2"	36"	AGMA 9	Call	Call
Robertson Mfg. Co.	0"	36"	AGMA 8	3	5"
Ronson Gears Pty. Ltd.	Call	Call	Call	Call	Call
Rush Gear Inc.	.25"	36"	AGMA 12	2	8"
Santasalo North America Inc.	Call	Call	Call	Call	Call
Schafer Gear Works, Inc.	1"	36"	Call	Call	Call
Seitz Corporation	Call	Call	Call	Call	Call
Selector Spline Products Inc.	.5"	16"	AGMA 8	5	3"
Shanthi Gears	36 mm	1600 mm	AGMA 10	Call	165 mm
Southern Gear & Machine	1"	24"	AGMA 12	1	5"

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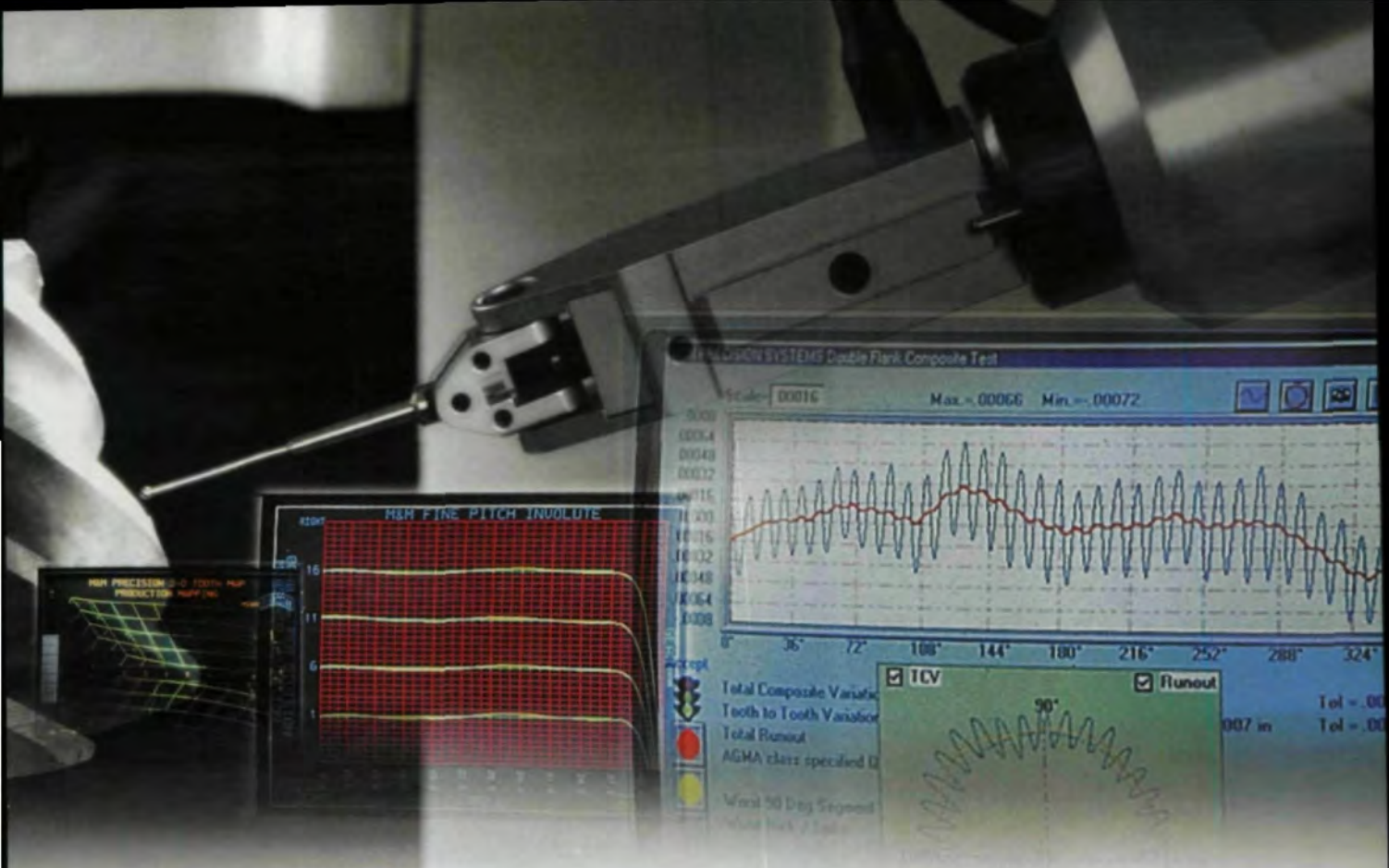
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CIRCLE 140

GEAR MANUFACTURING DIRECTORY

INTERNAL GEARS (Continued)

Company	Min Dia.	Max Dia.	Quality	DP/Module	Max Face
Springer Company	Call	Call	Call	Call	Call
SriVenkateshware Gear Wheels	Call	Call	Call	Call	Call
STD Precision Gear & Instrument	Call	Call	Call	Call	Call
Stock Drive Products/Sterling Instruments	58 mm	118 mm	ISO 8	1 module	10 mm
SUDA International Gear Works	Call	63"	AGMA 14	2.1	11.8"
Sungear, Inc.	.5"	14"	AGMA 12	6	4"
Transmission Engineering Co. Inc.	Call	Call	Call	Call	Call
Trogetec Inc.	Call	Call	Call	Call	Call
Unicor, Inc.	1"	18"	AGMA 10	3	3"
United States Gear Corp.	Call	Call	Call	Call	Call
W&H Stamping & Fineblanking	.125"	4"	Call	Call	Call
The Will-Burt Company	.5"	36"	AGMA 10	3	6"
Xtek, Inc.	12"	51"	AGMA 9	1.5	12"

PLASTIC GEARS (INJECTION MOLDED)

Company	Min Dia.	Max Dia.	Quality	DP/Module	Max Face
ABA-PGT, Inc.	Call	Call	Call	Call	Call
Boston Gear	Call	Call	Call	Call	Call
Davall Gear Company Ltd.	3 mm	250 mm	Call	Call	Call
Ensinger, Inc.	Call	Call	Call	Call	Call
Flex Manufacturing Inc.	All	All	All	All	All
GW Plastics	Call	Call	Call	Call	Call
Industrial Supply Co., Inc.	Call	Call	Call	Call	Call
Mr. Gears Inc.	Call	Call	Call	Call	Call
Nor Elektronik, Ltd.	Call	Call	Call	Call	Call
Performance Gear Systems Inc.	Call	Call	Call	Call	Call
Poly Hi Solidur	.5"	6"	AGMA 8	16	1"
Putnam Precision Molding, Inc.	.4"	300"	Call	Call	Call
Quality Transmission Components	7 mm	100 mm	JIS 8	1 module	10 mm
Riverside Spline & Gear Inc.	Call	Call	Call	Call	Call
Rush Gears Inc.	.25"	36"	AGMA 12	2	8"
Seitz Corporation	Call	Call	Call	Call	Call
Spicer Industries	Call	Call	Call	Call	Call
Stock Drive Products/Sterling Instruments	15 mm	141 mm	Call	3 module	19 mm
Transmission Engineering Co. Inc.	Call	Call	Call	Call	Call
Winzeler Gear	Call	Call	Call	Call	Call

POWDER METAL GEARS

Company	Min Dia.	Max Dia.	Quality	DP/Module	Max Face
3D Craft Corporation	Call	Call	Call	Call	Call
Advance Gear & Machine Corp.	Call	Call	Call	Call	Call
Asco Sintering Co.	Call	3"	Call	Call	Call
Burgess Norton	.125"	6.5"	Call	Call	Call
Carbon City Products	Call	Call	Call	Call	Call
Cloyes Gear/Rush Metal Division	Call	Call	Call	Call	Call
Crown Gear B.V.	Call	Call	Call	Call	Call
David Brown Group plc	Call	Call	Call	Call	Call
Foote-Jones/Illinois Gear	Call	Call	Call	Call	Call
Great Taiwan Gear Corp., Ltd.	Call	Call	Call	Call	Call
Indiana Power Transmission Systems Inc.	Call	Call	Call	Call	Call
Industrial Supply Co., Inc.	Call	Call	Call	Call	Call
ITW Spiroid	Call	Call	Call	Call	Call
Masiero Antonio S.p.A.	Call	Call	Call	Call	Call
mg miniGears	Call	Call	Call	Call	Call
Minipart P.T. Co.	Call	Call	Call	Call	Call
Quality Transmission Components	10 mm	150 mm	JIS 6	Call	Call
Rush Gears Inc.	.5"	50"	AGMA 9	Call	Call
Selector Spline Products Inc.	.5"	16"	AGMA 8	5	3"
Sungear, Inc.	.5"	12"	AGMA 12	6	6"
Transmission Engineering Co. Inc.	Call	Call	Call	Call	Call
Trogetec Inc.	Call	Call	Call	Call	Call

RACKS

Company	Min Length	Max Length	Quality	DP/Module
ACR Industries, Inc.	3"	15"	AGMA 12	6
Akron Gear & Engineering, Inc.	Call	46"	Call	3
American Metric Corporation	Call	Call	Call	Call
American Precision Gear Company	Call	Call	Call	Call
Aitch-Mont Gear Company, Inc.	6"	100"	6	1.25
Boston Gear	Call	Call	Call	Call

RACKS

Company	Min Length	Max Length	Quality	DP/Module
Carbon City Products	Call	Call	Call	Call
Cardinal Engineering Co.	.75"	3"	AGMA 8	16
C-B Gear & Machine, Inc.	Call	Call	Call	Call
Chicago Gear - D.O. James Corp.	Call	Call	Call	Call
Chicago Gear Works	Call	Call	Call	Call
Cincinnati Gear Company	Call	Call	Call	Call
Circle Gear & Machine Co., Inc.	8"	120"	AGMA 8	1.5
Davall Gear Company Ltd.	Call	Call	Call	Call
Fairfield Manufacturing Co., Inc.	Call	Call	Call	Call
Fisher's Gear & Machine, Inc.	Call	Call	Call	Call
Flex Manufacturing Inc.	All	All	All	All
Footo-Jones/Illinois Gear	Call	Call	Call	Call
The Gear Works—Seattle, Inc.	Call	Call	Call	Call
Generated Gear & Machine Inc.	Call	60"	Call	Call
Globe Gear Company	Call	Call	Call	Call
Great Taiwan Gear Corp., Ltd.	Call	Call	Call	Call
Griffin Gear	30"	144"	AGMA 10	.5
Heclyn Precision Gear, Inc.	2.5"	32"	AGMA 8	2
HMC, Inc.	Call	Call	Call	Call
Industrial Supply Co., Inc.	Call	Call	Call	Call
Innovative Rack & Gear Company	12"	120"	AGMA 12	2
Jade Precision Gear	Call	Call	Call	Call
Lawler Gear	3"	144"	AGMA 8	4
Linn Gear Co.	12"	144"	Call	1.5
Master Metal Engineering, Inc.	6"	48"	AGMA 8	2
MO Star Gear & Machine	Call	Call	Call	Call
Moore Gear Manufacturing	6.75"	150"	AGMA 9	1.5
O'Brien Gear Company	9"	100"	AGMA 10	1
Oliver Gear, Inc.	6"	72"	AGMA 8	1
Perry Technology Corp.	20"	75"	AGMA 8	1
Philadelphia Gear Corp.	Call	Call	Call	Call
PIC Design	.2"	36"	AGMA 10	24
Poly Hi Solidur	Call	Call	Call	Call
Pulley Manufacturers Inc.	Call	Call	Call	Call
Quality Transmission Components	200 mm	2000 mm	JIS 1	20 module
Rapid Gear	Call	Call	Call	Call
Riverside Spline & Gear Inc.	10"	30"	Call	2
Robertson Mfg. Co.	12"	72"	AGMA 8	2
Ronson Gears Pty. Ltd.	Call	Call	Call	Call
Rush Gears Inc.	.25"	36"	AGMA 12	2
Santasalo North America Inc.	Call	Call	Call	Call
Selector Spline Products Inc.	2"	48"	AGMA 12	5
Shanthi Gears	50 mm	1120 mm	DIN 8	6
Southern Gear & Machine	Call	Call	Call	Call
Sri Venkateshwara Gear Wheels	Call	Call	Call	Call
STD Precision Gear & Instrument	Call	Call	Call	Call
Stock Drive Products/Sterling Instruments	8 mm	1021 mm	ISO 8	3 module
Stroba Manufacturing Co.	1"	36"	AGMA 3	16
SUDA International Gear Works	11.8"	125"	AGMA 14	11
Sungear, Inc.	4"	18"	AGMA 12	6
Transmission Engineering Co. Inc.	Call	Call	Call	Call
Trogetec Inc.	Call	Call	Call	Call
W&H Stamping & Fineblanking	.1875"	6"	Call	Call
The Will-Burt Company	2"	72"	AGMA 9	5
Xtek, Inc.	16"	96"	AGMA 8	.375

SPLINED SHAFTS

Company	Min Dia.	Max Dia.	Quality	DP/Module	Max Length
A-1 Gears	Call	Call	Call	Call	Call
Acme Gear Company	.5"	10"	AGMA 10	Call	36"
ACR Industries, Inc.	.25"	12.5"	AGMA 13	Call	60"
The Adams Company	.5"	5"	Call	.5	36"
Addison Precision Products	.375"	3"	AGMA 9	14	2'
Advance Gear & Machine Corp.	.5"	16"	Call	Call	56"
Aero Gear, Inc.	1"	12"	AGMA 12	Call	Call
Akron Gear & Engineering, Inc.	Call	18"	Call	2.5	55"
Allied Gear Co.	1"	10"	Call	3	120"
Amarillo Gear Company—Russellville	.5"	29.5"	AGMA 10	Call	Call
American Machine & Gear	Call	Call	Call	Call	Call
American Metric Corporation	Call	Call	Call	Call	Call
American Precision Gear Company	Call	Call	Call	Call	Call
Arrow Gear Company	.5"	24"	Call	Call	Call
Atch-Mont Gear Company, Inc.	1"	8"	AGMA 9	2	15"
Brad Foote Gear Works	Call	Call	Call	Call	Call
Butler Gear	1"	16"	Call	Call	144"
Cardinal Engineering Co.	.25"	6"	AGMA 8	16	3"
Carnes-Miller Gear Co., Inc.	.25"	16"	AGMA 10	3	12"
C-B Gear & Machine, Inc.	Call	Call	Call	Call	Call
Chalmers & Kubeck Inc.	2"	6"	AGMA 8	Call	32"
Chandler Machine Co.	Call	Call	Call	Call	Call
Chardam Gear Company	Call	Call	Call	Call	Call
Chicago Gear - D.O. James Corp.	Call	Call	Call	Call	Call
Chicago Gear Works	0"	16"	AGMA 10	Call	18"

GEAR MANUFACTURING DIRECTORY

SPLINED SHAFTS (Continued)

Company	Min Dia.	Max Dia.	Quality	DP/Module	Max Length
Cincinnati Gear Company	Call	Call	Call	Call	Call
Circle Gear & Machine Co., Inc.	.5"	12"	AGMA 8	Call	120"
Clarke Engineering	.1"	7.1"	AGMA 12	4	20"
Columbia Gear Corp.	.5"	36"	AGMA 7	3	36"
Cotta Transmission Co.	Call	25.5"	AGMA 8	4	28"
Custom Gear & Machine	.5"	6"	AGMA 8	Call	Call
Davall Gear Company Ltd.	5 mm	200 mm	Call	Call	Call
David Brown Group plc	Call	Call	Call	Call	Call
Delroyd Worm Gear Division	Call	Call	Call	Call	Call
Fairfield Manufacturing Co., Inc.	Call	Call	Call	Call	Call
Fisher's Gear & Machine, Inc.	Call	Call	Call	Call	Call
Flex Manufacturing Inc.	All	All	All	All	All
Foote-Jones/Illinois Gear	Call	Call	Call	Call	Call
Forest City Gear	.06"	16"	AGMA 11	3.5	32"
G&N Rubicon	Call	Call	Call	Call	Call
Gateway Precision Gear, Inc.	.125"	6"	Call	16	10"
Gear Products, Inc.	.5"	14.5"	AGMA 8	3.5	16"
Gear Research Inc.	Call	Call	Call	Call	Call
The Gear Works—Seattle, Inc.	Call	Call	Call	Call	Call
Generated Gear & Machine Inc.	Call	8"	Call	Call	Call
Giuliante Machine Tool, Inc.	.375"	10"	AGMA 8	4	4"
Great Taiwan Gear Corp., Ltd.	Call	Call	Call	Call	Call
Griffin Gear	1"	60"	AGMA 8	.5	144"
Hamilton Gear Inc.	Call	Call	Call	Call	Call
Heclyn Precision Gear, Inc.	.188"	16"	AGMA 10	2	15"
Horsburgh & Scott	Call	Call	Call	Call	Call
HPC Drives Ltd.	14 mm	54 mm	Call	Call	300 mm
Hub City, Inc.	1"	1.75"	Call	Call	10
Indiana Power Transmission Systems Inc.	Call	Call	Call	Call	Call
Indiana Tool-Indiana Gear	Call	Call	Call	Call	Call
Industrial Supply Co., Inc.	Call	Call	Call	Call	Call
Inscop Corporation	Call	Call	Call	Call	Call
Involute Tooling Corporation	Call	Call	Call	Call	Call
Jackson Gear Company	2"	18"	AGMA 8	Any	50"
Jade Precision Gear	Call	Call	Call	Call	Call
Kreiter Geartech	2"	30"	AGMA 6	1	36"
Lawler Gear	1"	4"	Call	4	36"
Link Gear & Machine Company	1"	12"	AGMA 10	Call	Call
Linn Gear Co.	Call	Call	Call	Call	Call
Machine Renewal	1"	34"	Call	Call	Call
Maddox Metal Works, Inc.	.5"	16"	AGMA 10	Call	48"
Marine Associates	.75"	8"	AGMA 9	Call	36"
Master Metal Engineering, Inc.	.125"	8"	AGMA 9	8	16"
Merit Gear Corp.	1"	12"	Call	Call	Call
mg miniGears	Call	Call	Call	Call	Call
Midwest Gear & Machining	.75"	Call	Call	Call	Call
Midwest Gear Corp.	Call	16"	AGMA 9	1.25	36"
Milwaukee Gear	Call	Call	Call	Call	Call
Minipart P.T. Co.	Call	Call	Call	Call	Call
MO Star Gear & Machine	Call	Call	Call	Call	Call
Moore Gear Manufacturing	.5"	8"	AGMA 8	4	48"
Mr. Gears Inc.	Call	Call	Call	Call	Call
MRA Industries (Anderson Cook)	Call	Call	Call	Call	Call
Murray Brothers Manufacturing Co.	1"	3"	AGMA 10	10	Call
Nanchang Gear Works	20 mm	125 mm	ISO 7	Call	600 mm
Niagara Gear Corporation	Call	Call	Call	Call	Call
Nissei Corp. of America	Call	Call	Call	Call	Call
Nixon Gear Inc.	Call	Call	Call	Call	Call
O'Brien Gear Company	1"	16"	AGMA 10	1	108"
Oliver Gear, Inc.	.5"	36"	Call	3	72"
Orlandi Gear Company	Call	Call	Call	Call	Call
Overton Gear & Tool Corp.	Call	Call	Call	Call	Call
Perfection Gear, Inc.	.75"	18"	Call	Call	36"
Perry Technology Corp.	0"	36"	CL 4	2	Infinite
Philadelphia Gear Corp.	Call	Call	Call	Call	Call
Precision Gear Inc.	2"	36"	CL4	1	16"
Pulley Manufacturers Inc.	Call	Call	Call	Call	Call
The Purdy Corporation	Call	Call	Call	Call	Call
Quality Transmission Components	10 mm	200 mm	JIS 4	8 module	800 mm
Rapid Gear	Call	Call	Call	Call	Call
Rawling Gear Inc.	Call	Call	Call	Call	Call
Reef Gear Manufacturing	Call	Call	Call	Call	Call
Reliance Gear Corp.	Call	Call	Call	Call	Call
Riverside Spline & Gear Inc.	.125"	16"	Call	3	56"
Rjlink International, Inc.	1"	3.5"	AGMA 9	Call	Call
Robertson Mfg. Co.	Call	Call	AGMA 8	Call	Call
Ronson Gears Pty. Ltd.	Call	Call	Call	Call	Call
Rush Gears Inc.	.25"	36"	AGMA 12	2	72"
Santasalo North America Inc.	Call	Call	Call	Call	Call
Schafer Gear Works, Inc.	1"	52"	Call	4	Call
Selector Spline Products Inc.	.5"	8"	AGMA 12	5	40"
Shanthi Gears	Call	Call	Call	Call	Call
Southern Gear & Machine	.125"	20"	AGMA 12	1	60"
Springer Company	Call	Call	Call	Call	Call
Sri Venkateshwara Gear Wheels	Call	Call	Call	Call	Call
STD Precision Gear & Instrument	Call	Call	Call	Call	Call

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CIRCLE 108

GEAR MANUFACTURING DIRECTORY

SPLINED SHAFTS (Continued)

Company	Min Dia.	Max Dia.	Quality	DP/Module	Max Length
Stock Drive Products/Sterling Instruments	17 mm	30 mm	Call	call	270 mm
Sungear, Inc.	.5"	12"	AGMA 12	6	18"
Transmission Engineering Co. Inc.	Call	Call	Call	Call	Call
Trogetec Inc.	Call	Call	Call	Call	Call
Unicor, Inc.	.5"	6"	AGMA 10	4	6"
United States Gear Corp.	Call	Call	Call	Call	Call
The Walter Machine Company	Call	Call	Call	Call	Call
The Will-Burt Company	.25"	16"	AGMA 8	Call	36"
Xtek, Inc.	8"	80"	Call	Call	240"
Zhuhai Intercontinental Pulleys Ltd.	13 mm	120 mm	Call	Call	Call

SPROCKETS

Company	Min Dia.	Max Dia.	CP	DP/Module
A-1 Gears	1"	28"	Call	Call
Acme Gear Company	2"	48"	Call	Call
ACR Industries, Inc.	.25"	12.5"	.625"	Call
The Adams Company	.75"	24"	1.25"	Call
Akron Gear & Engineering, Inc.	1"	120"	3"	Call
Allied Gear Co.	1"	80"	2.5"	Call
Amarillo Gear Company—Russellville	Call	Call	Call	Call
American Metric Corporation	Call	Call	Call	Call
American Precision Gear Company	Call	Call	Call	Call
Asco Sintering Co.	Call	3"	Call	Call
Atch-Mont Gear Company, Inc.	1"	60"	2"	Call
Biscoe Foundry & Machine	Call	Call	Call	Call
Boston Gear	Call	Call	Call	Call
Brad Foote Gear Works	Call	Call	Call	Call
Brewer Machine & Gear	1"	72"	.125"	Call
Burgess Norton	.125"	6.5"	Call	Call
Capitol Stampings Corp.	Call	Call	Call	Call
Carbon City Products	Call	Call	Call	Call
Cardinal Engineering Co.	.25"	6"	.25"	12
Carnes-Miller Gear Co., Inc.	.25"	20"	Call	1
C-B Gear & Machine, Inc.	Call	Call	Call	Call
Chalmers & Kubeck Inc.	2"	98"	3"	Call
Chandler Machine Co.	Call	Call	Call	Call
Cincinnati Gear Company	Call	Call	Call	Call
Circle Gear & Machine Co., Inc.	Call	120"	3"	Call
Clarke Engineering	.1"	16"	3"	4
Cloyes Gear/Rush Metal Division	Call	Call	Call	Call
Custom Gear & Machine	1"	60"	Call	Call
Dalian FTZ Yield Year International	13.06 mm	647.47 mm	Call	Call
Davall Gear Company Ltd.	10 mm	450 mm	Call	Call
David Brown Group plc	Call	Call	Call	Call
Fairfield Manufacturing Co., Inc.	Call	Call	Call	Call
Fisher's Gear & Machine, Inc.	Call	Call	Call	Call
Flex Manufacturing Inc.	All	All	All	All
Foote-Jones/Illinois Gear	Call	Call	Call	Call
Forest City Gear	.125"	16"	1"	Call
Gateway Precision Gear, Inc.	.25"	6"	.375"	Call
Gear Products, Inc.	2"	12"	1.5"	Call
Gear Research Inc.	Call	Call	Call	Call
The Gear Works—Seattle, Inc.	Call	Call	Call	Call
Generated Gear & Machine Inc.	Call	26"	Call	Call
Giuliante Machine Tool, Inc.	1"	15"	.5"	4
Global Gear	Call	Call	Call	Call
Great Lakes Industry, Inc.	Call	Call	Call	Call
Great Taiwan Gear Corp., Ltd.	Call	Call	Call	Call
Griffin Gear	.5"	240"	Call	.5
Hamilton Gear Inc.	Call	Call	Call	Call
Heclyn Precision Gear, Inc.	.188"	16"	10"	2
Indiana Tool-Indiana Gear	10"	60"	10"	2
Industrial Supply Co., Inc.	Call	Call	Call	Call
Inscop Corporation	Call	Call	Call	Call
Intech Corporation	Call	Call	Call	Call
Involute Tooling Corporation	Call	Call	Call	Call
Jade Precision Gear	Call	Call	Call	Call
Kreiter Geartech	12"	154"	Call	Call
Link Gear & Machine Company	1"	18"	Call	Call
Linn Gear Co.	Call	Call	.25"-3"	Call
Machine Renewal	1"	34"	Call	Call
Maddox Metal Works, Inc.	1"	72"	Call	Call
Master Metal Engineering, Inc.	.75"	10"	1.5"	200
Merit Gear Corp.	1.5"	24"	Call	.25
mg miniGears	Call	Call	Call	Call
Midwest Gear & Machining	Call	Call	Call	Call
Midwest Gear Corp.	Call	92"	3"	Call
Milwaukee Gear	Call	Call	Call	Call
Minipart P.T. Co.	Call	Call	Call	Call
MO Star Gear & Machine	Call	Call	Call	Call
Moore Gear Manufacturing	.5"	90"	1.5"	Call

GEAR MANUFACTURING DIRECTORY

SPROCKETS (Continued)

Company	Min Dia.	Max Dia.	CP	DP/Module
Mr. Gears Inc.	Call	Call	Call	Call
Nixon Gear Inc.	.5"	120"	Call	Call
O'Brien Gear Company	2"	166"	3"	1
Oliver Gear, Inc.	.5"	100"	.125"	Call
P.T. International Corp.	Call	Call	Call	Call
Perry Technology Corp.	Call	36"	Any	Call
PIC Design	.3"	5"	.0982"	Call
Poly Hi Solidur	1"	40"	Call	Call
Pulley Manufacturers Inc.	Call	Call	Call	Call
Putnam Precision Molding, Inc.	Call	Call	Call	Call
Rapid Gear	Call	Call	Call	Call
Rawling Gear Inc.	Call	Call	Call	Call
Reef Gear Manufacturing	1"	24"	Call	4
Reliance Gear Corp.	Call	Call	Call	Call
Rexnord Corporation	Call	Call	Call	Call
Riverside Spline & Gear Inc.	1.5"	36"	Call	2
Rjlink International, Inc.	2"	25"	Call	Call
Robertson Mfg. Co.	Call	72"	2.5"	Call
Ronson Gears Pty. Ltd.	Call	Call	Call	Call
Rush Gears Inc.	.25"	36"	All	2
Ryle Manufacturing Company	Call	Call	Call	Call
Santasalo North America Inc.	Call	Call	Call	Call
Seitz Corporation	Call	Call	Call	Call
Selector Spline Products Inc.	1"	16"	1.25"	Call
Shanthi Gears	29 mm	1500 mm	6.25 mm	Call
Southern Gear & Machine	.125"	90"	Call	Call
Spicer Industries	Call	Call	Call	Call
Sri Venkateshwara Gear Wheels	Call	Call	Call	Call
STD Precision Gear & Instrument	Call	Call	Call	Call
Stock Drive Products/Sterling Instruments	10 mm	255 mm	Call	Call
Sungear, Inc.	.5"	12"	12"	6
Torque Transmission	Call	Call	Call	Call
Transmission Developments Co. Ltd.	9 mm	1000 mm	Call	Call
Transmission Engineering Co. Inc.	Call	Call	Call	Call
Trogetec Inc.	Call	Call	Call	Call
Tsubakimoto Chain Co.	120 mm	1700 mm	Call	Call
United States Gear Corp.	Call	Call	Call	Call
Van Zeeland Manufacturing, Inc.	Call	Call	Call	Call
W&H Stamping & Fineblanking	.25"	5"	Call	Call
The Will-Burt Company	.25"	36"	.375"	Call
Xtek, Inc.	6"	216"	8.375"	.375
Zhuhai Intercontinental Pulleys Ltd.	21.25 mm	1250 mm	Call	Call

SPUR GEARS

Company	Min Dia.	Max Dia.	Quality	DP/Module	Max Face
A-1 Gears	1"	28"	Call	Call	Call
Acme Gear Company	.75"	60"	AGMA 10	Call	14"
ACR Industries, Inc.	.25"	21"	AGMA 14	4	12.5"
The Adams Company	.75"	24"	AGMA 10	3	Call
Addison Precision Products	.375"	6"	AGMA 9	14	10"
Advance Gear & Machine Corp.	.5"	36"	AGMA 14	Call	Call
Aero Gear, Inc.	1"	12"	AGMA 12	Call	Call
Akron Gear & Engineering, Inc.	1"	120"	Call	1	Call
Allied Gear Co.	1"	80"	Call	1.25	22"
Amarillo Gear Company—Russellville	2.5"	32"	AGMA 13	Call	Call
American Machine & Gear	Call	Call	Call	Call	Call
American Metric Corporation	.5"	24"	AGMA 13	3	13"
American Precision Gear Company	Call	Call	Call	Call	Call
Arrow Gear Company	.5"	24"	AGMA 13	3	8"
Asco Sintering Co.	Call	3"	Call	Call	Call
Aitch-Mont Gear Company, Inc.	1"	72"	AGMA 9	1.25	18"
Avon Bearings	Call	Call	Call	Call	Call
Boston Gear	Call	Call	Call	Call	Call
Bowmar Technologies	Call	Call	Call	Call	Call
Brad Foote Gear Works	Call	Call	Call	Call	Call
Brewer Machine & Gear	.5"	72"	AGMA 8	1	Call
Burgess Norton	.125"	6.5"	Call	Call	Call
Butler Gear	1"	84"	Call	Call	24"
Capitol Stampings Corp.	Call	Call	Call	Call	Call
Carbon City Products	Call	Call	Call	Call	Call
Cardinal Engineering Co.	.25"	6"	AGMA 10	12	2"
Carnes-Miller Gear Co., Inc.	.25"	20"	AGMA 10	3	5"
C-B Gear & Machine, Inc.	Call	Call	Call	Call	Call
Chalmers & Kubeck Inc.	2"	98"	AGMA 8	1.5	18"
Chandler Machine Co.	Call	Call	Call	Call	Call
Chardam Gear Company	Call	Call	Call	Call	Call
Chicago Gear - D.O. James Corp.	Call	Call	Call	Call	Call
Chicago Gear Works	Call	16"	AGMA 10	4	12"
Cincinnati Gear Company	Call	Call	Call	Call	Call
Circle Gear & Machine Co., Inc.	.5"	120"	AGMA 8	1.25	30"
Clarke Engineering	.1"	16"	AGMA 13	4	12"

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SPUR GEARS

Company	Min Dia.	Max Dia.	Quality	DP/Module	Max Face
Cloyes Gear/Rush Metal Division	Call	Call	Call	Call	Call
Columbia Gear Corp.	.5"	36"	AGMA 12	2.5	16"
Cotta Transmission Co.	Call	24"	AGMA 12	2.5	15"
Crown Gear B.V.	Call	Call	Call	Call	Call
Custom Gear & Machine	1"	60"	AGMA 8	Call	Call
Davall Gear Company Ltd.	3 mm	450 mm	Call	Call	Call
David Brown Group plc	Call	Call	Call	Call	Call
Emerson Power Transmission Corp.	Call	Call	Call	Call	Call
Fairfield Manufacturing Co., Inc.	Call	Call	Call	Call	Call
Falk Corporation	10"	552"	Call	.5	Call
Fisher's Gear & Machine, Inc.	Call	Call	Call	Call	Call
Flender Corporation	Call	Call	Call	Call	Call
Flex Manufacturing Inc.	All	All	All	All	All
Foote-Jones/Illinois Gear	Call	Call	Call	Call	Call
Forest City Gear	.06"	17"	AGMA 12+	3.5	18"
G&N Rubicon	Call	Call	AGMA 14	Call	Call
Gateway Precision Gear, Inc.	.125"	6"	AGMA 14	16	10"
Gear Products, Inc.	3"	60"	AGMA 8	2	8"
The Gear Works—Seattle, Inc.	Call	Call	Call	—	—
Gear Research Inc.	Call	12"	AGMA 12	Call	Call
Generated Gear & Machine Inc.	Call	36"	Call	Call	Call
Giuliante Machine Tool, Inc.	.5"	20"	AGMA 9	3.5	5"
Global Gear	Call	Call	Call	Call	Call
Great Gear Corp.	Call	Call	Call	Call	Call
Great Lakes Industry, Inc.	Call	Call	Call	Call	Call
Greenhpon Engineering Works Ltd.	20 mm	420 mm	ISO 6	Call	Call
Griffon Gear	.5"	240"	AGMA 12	.5	40"
Hamilton Gear Inc.	Call	160"	AGMA 10	8	48"
Heclyn Precision Gear, Inc.	.188"	16"	AGMA 10	2	15"
HMC, Inc.	Call	Call	Call	Call	Call
Horsburgh & Scott	6"	480"	AGMA 8	.375	48"
Hub City, Inc.	2"	12"	AGMA 8	4	Call
Indiana Power Transmission Systems Inc.	Call	Call	Call	Call	Call
Indiana Tool-Indiana Gear	Call	Call	Call	Call	Call
Industrial Supply Co., Inc.	Call	Call	Call	Call	Call
Innovative Rack & Gear Company	Call	6"	AGMA 8	12	10"
Inscor Corporation	Call	Call	Call	Call	Call
Intech Corporation	Call	Call	Call	Call	Call
Involute Tooling Corporation	Call	Call	Call	Call	Call
ITW Spiroid	Call	Call	Call	Call	Call
Jackson Gear Company	2"	72"	AGMA 10	1	20"
Jade Precision Gear	Call	Call	Call	Call	Call
Kreiter Geartech	2"	154"	AGMA 7	1	36"
L.M. Gear Company	Call	Call	Call	Call	Call
Lawler Gear	1"	90"	AGMA 8	2	Call
Link Gear & Machine Company	1"	36"	AGMA 10	Call	Call
Linn Gear Co.	1"	96"	Call	1	18"
Machine Renewal	.379"	34"	Call	Call	Call
Maddox Metal Works, Inc.	.5"	72"	AGMA 10	Call	36"
Marine Associates	.75"	14"	AGMA 11	Call	Call
Master Metal Engineering, Inc.	.083"	16"	AGMA 9	20	16"
Merit Gear Corp.	1"	24"	AGMA 8	2	Call
mg miniGears	Call	Call	Call	Call	Call
Midwest Gear & Machining	.75"	24"	Call	Call	Call
Midwest Gear Corp.	Call	92"	AGMA 9	1.25	24"
Milwaukee Gear	Call	Call	Call	Call	Call
Minipart P.T. Co.	Call	Call	Call	Call	Call
MO Star Gear & Machine	Call	Call	Call	Call	Call
Moore Gear Manufacturing	.5"	90"	AGMA 8	1.5	18"
Mr. Gears Inc.	Call	Call	Call	Call	Call
MRA Industries (Anderson Cook)	Call	Call	Call	Call	Call
Murray Brothers Manufacturing Co.	3"	16"	AGMA 10	6	Call
Nanchang Gear Works	20 mm	800 mm	ISO 7	Call	Call
Niagara Gear Corporation	Call	Call	Call	Call	Call
Nissei Corp. of America	Call	Call	Call	Call	Call
Nixon Gear Inc.	.5"	120"	AGMA 10	Call	Call
O'Brien Gear Company	.25"	166"	AGMA 10	.75	19"
Oliver Gear, Inc.	1"	100"	AGMA 9	.75	26"
Orlandi Gear Company	Call	Call	Call	Call	Call
Overton Gear & Tool Corp.	Call	Call	Call	Call	Call
P.T. International Corp.	Call	Call	Call	Call	Call
Perfection Gear, Inc.	Call	18"	Call	Call	Call
Perry Technology Corp.	Call	36"	AGMA 12	2	8"
Philadelphia Gear Corp.	Call	Call	Call	Call	Call
PIC Design	.28"	6"	AGMA 12	20	.375"
Poly Hi Solidur	.5"	20"	Call	Call	Call
Precipart Corporation	Call	Call	Call	Call	Call
Precision Gear Inc.	1"	15"	AGMA 15	1	12"
Pro-Gear Co., Inc.	1"	27.5"	Call	3.5	Call
Pulley Manufacturers Inc.	Call	Call	Call	Call	Call
The Purdy Corporation	Call	Call	Call	Call	Call
Putnam Precision Molding, Inc.	.4"	300"	Call	Call	Call
Quality Transmission Components	10 mm	2500 mm	JIS 1	25 module	90 mm
Rapid Gear	Call	Call	Call	Call	Call
Rawling Gear Inc.	Call	Call	Call	Call	Call
Reef Gear Manufacturing	1"	24"	Call	4	6"

GEAR MANUFACTURING DIRECTORY

SPUR GEARS

Company	Min Dia.	Max Dia.	Quality	DP/Module	Max Face
Reliance Gear Corp.	1"	26"	AGMA 11	Call	Call
Riverside Splines & Gear Inc.	Call	Call	Call	Call	Call
Rjlink International, Inc.	1.5"	36"	AGMA 9	Call	Call
Robertson Mfg. Co.	Call	72"	AGMA 8	1.5	Call
Ronson Gears Pty. Ltd.	Call	Call	Call	Call	Call
Rush Gears Inc.	.25"	36"	AGMA 12	2	8"
Ryle Manufacturing Company	Call	Call	Call	Call	Call
Santasalo North America Inc.	Call	Call	Call	Call	Call
Schafer Gear Works, Inc.	1"	52"	Call	3	Call
Seitz Corporation	Call	Call	Call	Call	Call
Selector Spline Products Inc.	.5"	16"	AGMA 8	5	3"
Shanthi Gears	10 mm	3200 mm	DIN 9	.846	Call
Southern Gear & Machine	.125"	90"	AGMA 14	1	30"
Spicer Industries	Call	Call	Call	Call	Call
Springer Company	6"	120"	AGMA 10	Call	Call
Sri Venkateshwara Gear Wheels	Call	Call	Call	Call	Call
STD Precision Gear & Instrument	Call	Call	Call	Call	Call
Stock Drive Products/Sterling Instruments	3.75 mm	186 mm	ISO 8	3 module	30 mm
SUDA International Gear Works	Call	118"	AGMA 14	1.05	18"
Sungear, Inc.	.5"	12"	AGMA 12	6	6"
Transmission Developments Co. Ltd.	9 mm	1000 mm	Call	Call	Call
Transmission Engineering Co. Inc.	Call	Call	Call	Call	Call
Trogetec Inc.	Call	Call	Call	Call	Call
Unicor, Inc.	.5"	12"	AGMA 10	3	12"
United States Gear Corp.	Call	Call	Call	Call	Call
Van Zeeland Manufacturing, Inc.	Call	Call	Call	Call	Call
W&H Stamping & Fineblanking	.25"	5"	Call	Call	Call
The Walter Machine Company	Call	Call	Call	Call	Call
The Will-Burt Company	.25"	36"	AGMA 10	3	6"
Xtek, Inc.	6"	216"	AGMA 12	.375	98"
Zhuhai Intercontinental Pulleys Ltd.	Call	Call	Call	Call	Call

STRAIGHT & SPIRAL BEVEL GEARS

Company	Straight Dia.	Straight Quality	Straight DP/Mod.	Spiral Dia.	Spiral Quality	Spiral DP/Mod.
A-1 Gears	Call	Call	Call	2-8"	Call	Call
ACR Industries, Inc.	.5-14"	AGMA 11	2.5	25-34"	AGMA 15	2.5
The Adams Company	1-14"	AGMA 8	3	—	—	—
Advance Gear & Machine Corp.	.5-12"	AGMA 11	3	.5-12"	AGMA 11	3
Aero Gear, Inc.	1-8"	AGMA 12	Call	1-16"	AGMA 12	Call
Akron Gear & Engineering, Inc.	1-24"	Call	3	—	—	—
Allied Gear Co.	1-36"	Call	1.5	—	—	—
Alpha Gear Drives	Call	Call	Call	Call	Call	Call
Amarillo Gear Company	—	—	—	3-100"	AGMA 10	.6
Amarillo Gear Company—Russellville	Call	Call	Call	Call	Call	Call
American Machine & Gear	Call	Call	Call	—	—	—
American Metric Corporation	Call	Call	Call	Call	Call	Call
American Precision Gear Company	Call	Call	Call	—	—	—
Arrow Gear Company	.38-16"	AGMA 9	2.5	.38-28"	AGMA 13	1.5
Asco Sintering Co.	0-3"	Open	13	—	—	—
Astron Midwestern, Inc.	1-36"	AGMA 9	Call	1-36"	AGMA 11	Call
Atch-Mont Gear Company, Inc.	1-52"	AGMA 6	1.25	—	—	—
Bonfiglioli Riduttori S.p.A.	Call	Call	Call	Call	Call	Call
Boston Gear	Call	Call	Call	Call	Call	Call
Bowmar Technologies	Call	Call	Call	—	—	—
Brad Foote Gear Works	Call	Call	Call	Call	Call	Call
Brewer Machine & Gear	.5-12"	AGMA 8	3	—	—	—
Brook Hansen	Call	Call	Call	—	—	—
Butler Gear	1-36"	Call	1	—	—	—
Carnes-Miller Gear Co., Inc.	.5-8"	AGMA 10	3	—	—	—
C-B Gear & Machine, Inc.	Call	Call	Call	—	—	—
Caron-Vector	—	—	—	Call	Call	Call
Chicago Gear - D.O. James Corp.	Call	Call	Call	Call	Call	Call
Chicago Gear Works	0-8"	AGMA 8	4	—	—	—
Cincinnati Gear Company	—	—	—	Call	Call	Call
Circle Gear & Machine Co., Inc.	0-48"	AGMA 8	2	—	—	—
Cloyes Gear/Rush Metal Division	Call	Call	Call	—	—	—
Crown Gear B.V.	18-1100 mm	DIN 6	Call	18-1100 mm	DIN 6	Call
Custom Gear & Machine	1-24"	AGMA 8	Call	—	—	—
Dalian FTZ Yield Year International	37.4-237 mm	Call	Call	38.8-650.26 mm	Call	Call
Davall Gear Company Ltd.	0-200 mm	Call	Call	0-200 mm	Call	Call
David Brown Group plc	Call	Call	Call	Call	Call	Call
Emerson Power Transmission Corp.	Call	Call	Call	Call	Call	Call
Fairfield Manufacturing Co., Inc.	Call	Call	Call	Call	Call	Call
Falk Corporation	10-34"	Call	Call	10-34"	Call	1
Fisher's Gear & Machine, Inc.	Call	Call	Call	—	—	—
Flender Corporation	Call	Call	Call	Call	Call	Call
Flex Manufacturing Inc.	All	All	All	All	All	All
Foote-Jones/Illinois Gear	Call	Call	Call	Call	Call	Call
G&N Rubicon	Call	Call	Call	Call	AGMA 14	Call
Gateway Precision Gear, Inc.	.1875-4.4375"	AGMA 10	10	Call	Call	Call
Gear Research Inc.	Call	Call	Call	—	—	—

GEAR MANUFACTURING DIRECTORY

STRAIGHT & SPIRAL BEVEL GEARS (Continued)

Company	Straight Dia.	Straight Quality	Straight DP/Mod.	Spiral Dia.	Spiral Quality	Spiral DP/Mod.
The Gear Works—Seattle, Inc.	Call	Call	Call	—	—	—
Generated Gear & Machine Inc.	0-12"	Call	Call	—	—	—
Global Gear	Call	Call	Call	Call	Call	Call
Great Taiwan Gear Corp., Ltd.	Call	Call	Call	Call	Call	Call
Greenshpon Engineering Works Ltd.	Call	Call	Call	Call	Call	Call
Griffin Gear	5-63"	AGMA 8	.5	1-72"	AGMA 12	1
Hamilton Gear Inc.	0-26"	AGMA 7	2	0-36"	AGMA 9	2
Hub City, Inc.	3-8"	AGMA 8	Call	Call	Call	Call
Indiana Power Transmission Systems Inc.	Call	Call	Call	—	—	—
Industrial Supply Co., Inc.	Call	Call	Call	Call	Call	Call
Intech Corporation	Call	Call	Call	Call	Call	Call
Jackson Gear Company	2-24"	AGMA 8	1	—	—	—
Lawler Gear	1-12"	AGMA 8	4	—	—	—
Link Gear & Machine Company	1-14"	AGMA 9	Call	3-49"	AGMA 14	Call
Linn Gear Co.	Call	Call	1.5	1-60"	Call	1.5
Machine Renewal	1-12"	Call	Call	—	—	—
Marine Associates	.625-14"	AGMA 9	2.5	.625-7"	AGMA 9	4
Masiero Antonio S.p.A.	Call	Call	Call	Call	Call	Call
Master Metal Engineering, Inc.	.25-3"	AGMA 8	20	—	—	—
mg miniGears	Call	Call	Call	Call	Call	Call
Midwest Gear & Tool	Call	Call	Call	Call	Call	Call
Minipart P.T. Co.	Call	Call	Call	—	—	—
MO Star Gear & Machine	Call	Call	Call	—	—	—
Moore Gear Manufacturing	1-16"	AGMA 8	3	2-16"	AGMA 8	2.5
Nanchang Gear Works	25-500 mm	ISO 7	Call	40-400 mm	ISO 7	Call
Nissei Corp. of America	Call	Call	Call	Call	Call	Call
Nixon Gear Inc.	0-48"	AGMA 10	Call	—	—	—
Nord Gear Corporation	Call	Call	Call	—	—	—
O'Brien Gear Company	1-36"	AGMA 10	1	1-36"	AGMA 10	1
Ohio Gear	Call	Call	Call	Call	Call	Call
Oliver Gear, Inc.	.25-36"	AGMA 8	1	—	—	—
P.T. International Corp.	Call	Call	Call	—	—	—
Perry Technology Corp.	0-5"	Call	6	—	—	—
Philadelphia Gear Corp.	Call	Call	Call	Call	Call	Call
PIC Design	3-2.5"	AGMA 12	48	—	—	—
Precipart Corporation	Call	Call	Call	—	—	—
The Purdy Corporation	Call	Call	Call	Call	Call	—
Quality Transmission Components	10-1500 mm	JIS 1	25 module	10-800 mm	JIS 1	12 module
Rawling Gear Inc.	Call	Call	Call	Call	Call	Call
Reliance Gear Corp.	3-24"	AGMA 8	Call	3-30"	AGMA 13	Call
Ronson Gears Pty. Ltd.	Call	Call	Call	—	—	—
Rush Gears Inc.	.25-36"	AGMA 12	2	.25-36"	AGMA 12	2
Santasalo North America Inc.	Call	Call	Call	Call	Call	Call
Seitz Corporation	Call	Call	Call	—	—	—
Shanthi Gears	12-1650 mm	DIN 8/9	30 module	30-850 mm	DIN 9	16 module
Southern Gear & Machine	.125-24"	12	4	—	—	—
Spicer Industries	Call	Call	Call	—	—	—
Springer Company	Call	Call	Call	4-102"	AGMA 10	Call
Sri Venkateshwara Gear Wheels	Call	Call	Call	Call	Call	Call
STD Precision Gear & Instruments	Call	Call	Call	Call	Call	Call
Stock Drive Products/Sterling Instruments	9-136 mm	ISO 8	3 module	32-134 mm	ISO 4	3 module
SUDA International Gear Works	—	—	—	1-45"	AGMA 13	2
Sumitomo Machinery Corp. of America	Call	Call	Call	Call	Call	Call
Torque Transmission	Call	Call	Call	—	—	—
Transmission Engineering Co. Inc.	Call	Call	Call	Call	Call	Call
Tsubakimoto Chain Co.	Call	Call	Call	—	—	—
United States Gear Corp.	Call	Call	Call	Call	Call	Call
Xtek, Inc.	6-60"	AGMA 8	.625	—	—	—
Zero-Max, Inc.	Call	Call	Call	—	—	—
Zhuhai Intercontinental Pulleys Ltd.	Call	Call	Call	—	—	—

WORMS & WORMWHEELS

Company	Worm Dia.	Worm Length	Worm Quality	Worm DP/Mod.	Wormwheel Dia.	Wormwheel Quality	Wormwheel # of Teeth
A-1 Gears	Call	Call	Call	Call	3-25"	Call	Call
Acme Gear Company	5-36"	Call	AGMA 12	Call	2-60"	AGMA 10	Call
ACR Industries, Inc.	.25-2"	2"	AGMA 11	6	5-12.5"	AGMA 11	6-400
The Adams Company	.75-6"	10"	Ground	4	1-24"	AGMA 8	10 and up
Advance Gear & Machine Corp.	5-12"	36"	Call	3	5-27"	AGMA 9	Call
Akron Gear & Engineering, Inc.	Call	Call	Call	Call	Call	Call	Call
Allied Gear Co.	1-10"	40"	Call	2	1-80"	Call	Call
American Metric Corporation	Call	Call	Call	Call	—	—	—
Amarillo Gear Company—Russellville	—	—	—	—	Call	Call	Call
American Precision Gear Company	Call	Call	Call	Call	Call	Call	Call
Atch-Mont Gear Company, Inc.	1-12"	30"	Call	2	2-50"	AGMA 8	Call
Bonfiglioli Riduttori S.p.A.	Call	Call	Call	Call	Call	Call	Call
Boston Gear	Call	Call	Call	Call	Call	Call	Call
Brad Foote Gear Works	Call	Call	Call	Call	Call	Call	Call
Brewer Machine & Gear	.5-6"	24"	AGMA 8	3	5-24"	AGMA 8	Call
Butler Gear	—	—	—	—	1-84"	Call	Call
Cardinal Engineering Co.	.25-1.25"	1.25"	AGMA 10	20	25-3"	AGMA 8	Call
Carnes-Miller Gear Co., Inc.	.5-6"	12"	AGMA 10	3	5-16"	AGMA 10	Call
Caron-Vector	Call	Call	Call	Call	Call	Call	Call
C-B Gear & Machine, Inc.	Call	Call	Call	Call	Call	Call	Call
Chalmers & Kubeck Inc.	—	—	—	—	4.8-62"	AGMA 8	Call
Chicago Gear - D.O. James Corp.	Call	Call	Call	Call	Call	Call	Call

GEAR MANUFACTURING DIRECTORY

WORMS & WORMWHEELS (Continued)

Company	Worm Dia.	Worm Length	Worm Quality	Worm DP/Mod.	Wormwheel Dia.	Wormwheel Quality	Wormwheel # of Teeth
Chicago Gear Works	0-4"	6"	10	4	0-16"	10	12-120
Cincinnati Gear Company	Call	Call	Call	Call	Call	Call	Call
Circle Gear & Machine Co., Inc.	0-14"	96"	AGMA 12	1.5	0-120"	AGMA 10	Call
Clarke Engineering	.1-4"	6"	AGMA 12	8	.1-7.1"	AGMA 13	3-999
Cleveland Gear Company	Call	Call	Call	Call	Call	Call	Call
Cone Drive Operations	.87-13"	Call	Call	Call	Call	Call	Ca
Custom Gear & Machine	2-30"	Call	AGMA 6	Call	—	—	—
Davall Gear Company Ltd.	Call	Call	Call	Call	10-450 mm	Call	Call
David Brown Group plc	Call	Call	Call	Call	Call	Call	Call
Delroyd Worm Gear Division	Call	Call	Call	Call	Call	Call	Call
Electra-Gear	Call	Call	Call	Call	Call	Call	Call
Emerson Power Transmission Corp.	Call	Call	Call	Call	Call	Call	Call
Fairfield Manufacturing Co., Inc.	Call	Call	Call	Call	Call	Call	Call
Fisher's Gear & Machine, Inc.	Call	Call	Call	Call	—	—	—
Flender Corporation	Call	Call	Call	Call	Call	Call	Call
Flex Manufacturing Inc.	All	All	All	All	All	All	All
Foot-Jones/Illinois Gear	Call	Call	Call	Call	Call	Call	Call
Forest City Gear	.06-7"	20"	AGMA 12	6	.125-17"	AGMA 12+	2-999
Gateway Precision Gear, Inc.	.1875-5"	6"	AGMA 12	16	.375-6"	AGMA 10	6-94
Gear Products, Inc.	2-14"	17"	AGMA 8	4	4-18"	AGMA 7	20-120
Gear Research Inc.	—	—	—	—	Call	Call	Call
The Gear Works—Seattle, Inc.	Call	Call	Call	Call	Call	Call	Call
Generated Gear & Machine Inc.	0-6"	Call	Call	Call	0-36"	Call	Call
Global Gear	Call	Call	Call	Call	Call	Call	Call
Great Taiwan Gear Corp., Ltd.	Call	Call	Call	Call	Call	Call	Call
Greenshon Engineering Works Ltd.	Call	Call	Call	Call	20-420 mm	ISO 7	Call
Griffin Gear	1-24"	120"	AGMA 10	1	1-240"	AGMA 10	Call
Grove Gear	Call	Call	Call	Call	Call	Call	Call
Hamilton Gear Inc.	0-16"	240"	AGMA 10	Call	0-160"	AGMA 9	Call
Heclyn Precision Gear, Inc.	Call	Call	Call	Call	.25-16"	AGMA 8	6-360
HMC, Inc.	Call	Call	Call	Call	Call	Call	Call
Horsburgh & Scott	Call	Call	Call	Call	Call	Call	Call
Hub City, Inc.	.75-3"	5"	AGMA 8	Call	3-12"	AGMA 10	25-100
Indiana Power Transmission Systems Inc.	Call	Call	Call	Call	Call	Call	Call
Indiana Tool-Indiana Gear	1-10"	18"	Ground	2	1-44"	Ground	Call
Industrial Supply Co., Inc.	Call	Call	Call	Call	Call	Call	Call
Inso Corporation	Call	Call	Call	Call	Call	Call	Call
Intech Corporation	Call	Call	Call	Call	Call	Call	Call
Jackson Gear Company	2-40"	36"	AGMA 8	3	2-60"	AGMA 8	6-100
L.M. Gear Company	Call	Call	Call	Call	Call	Call	Call
Lawler Gear	1-6"	24"	Call	Call	1-24"	AGMA 8	Call
Link Gear & Machine Company	Call	Call	Call	Call	1-16"	Call	Call
Linn Gear Co.	.5-12"	48"	Call	1.75	Call	Call	Call
Machine Renewal	1-14"	Call	Call	Call	.75-28"	All	4-256+
Maddox Metal Works, Inc.	Call	Call	Call	Call	.5-72"	Call	Call
Marine Associates	1-6"	18"	AGMA 9	Call	1-13"	AGMA 9	Call
Master Metal Engineering, Inc.	.125-1"	4"	AGMA 8	.16	—	—	—
Midwest Gear & Machining	2-24"	Call	Call	Call	—	—	—
Minipart P.T. Co.	Call	Call	Call	Call	Call	Call	Call
MO Star Gear & Machine	Call	Call	Call	Call	Call	Call	Call
Moore Gear Manufacturing	Call	36"	Call	Call	Call	AGMA 8	Call
Mr. Gears Inc.	Call	Call	Call	Call	Call	Call	Call
Nissei Corp. of America	Call	Call	Call	Call	Call	Call	Call
Nixon Gear Inc.	Call	Call	Call	Call	0-72"	Call	Call
O'Brien Gear Company	.5-15"	100"	AGMA 10	1	.25-123"	AGMA 10	Call
Ohio Gear	Call	Call	Call	Call	Call	Call	Call
Oliver Gear, Inc.	1-9"	60"	AGMA 8	3	1-72"	AGMA 8	Call
Orlandi Gear Company	—	—	—	—	0-72"	Call	Call
Perfection Gear, Inc.	0-6"	36"	Call	3	0-18"	Call	Call
Perry Technology Corp.	0-20"	Any	Call	Call	0-26"	Call	2 and up
PIC Design	.33-.5"	.75"	AGMA 10	48	.62-5.6"	AGMA 10	30-360
Poly Hi Solidur	Call	Call	Call	Call	Call	Call	Call
Quality Transmission Components	10-300 mm	Call	JIS 1	25 module	10-1500 mm	JIS 1	20-300
Rapid Gear	Call	Call	Call	Call	Call	Call	Call
Rawling Gear Inc.	Call	Call	Call	Call	Call	Call	Call
Reliance Gear Corp.	Call	Call	Call	Call	Call	Call	Call
Rexnord Corporation	Call	Call	Call	Call	—	—	—
Riverside Spline & Gear Inc.	.25-12"	48"	Call	3	.25-28"	Call	12-999
Robertson Mfg. Co.	—	—	—	—	0-24"	AGMA 8	Call
Ronson Gears Pty. Ltd.	Call	Call	Call	Call	Call	Call	Call
Rush Gears Inc.	.25-36"	72"	AGMA 12	2	.25-36"	AGMA 12	Call
Santasalo North America Inc.	Call	Call	Call	Call	Call	Call	Call
Schafer Gear Works, Inc.	Call	Call	Call	Call	Call	Call	Call
Seitz Corporation	Call	Call	Call	Call	—	—	—
Shanthi Gears	10-260 mm	3000 mm	Call	15	25-3000 mm	DIN 6	125
Southern Gear & Machine	.9-8"	60"	AGMA 12	1	.125-90"	AGMA 12	Call
Springer Company	Call	Call	Call	Call	0-60"	Call	Call
Sri Venkateshwara Gear Wheels	Call	Call	Call	Call	Call	Call	Call
STD Precision Gear & Instrument	Call	Call	Call	Call	Call	Call	Call
Stock Drive Products/Sterling Instruments	10-50 mm	45 mm	Call	3 module	11-300 mm	Call	20-100
SUDA International Gear Works	0-13.7"	47.3"	Call	1	0-39.4"	AGMA 14	Call
Sungear, Inc.	.5-10"	18"	AGMA 12	6	.5-10"	AGMA 12	4-8
Transmission Engineering Co. Inc.	Call	Call	Call	Call	Call	Call	Call
Tsubakimoto Chain Co.	Call	Call	Call	Call	—	—	—
Unicor, Inc.	—	—	—	—	.5-6"	AGMA 10	Call
The Will-Burt Company	.0625-6"	25"	AGMA 8	3	.5-16"	AGMA 8	4-400

COMPANY INDEX

Welcome to the Company Index of the 1999 *Gear Technology* Directory of Gear Manufacturers. Use this index to locate the complete contact information for each company listed in the Gear Manufacturing Directory. *Gear Technology* advertisers are shown in boldface type. To find the pages on which their ads appear, see the Advertisers Index on page 29. PTHP indicates companies that can be found on The Power Transmission Home Page™ at www.powertransmission.com.

While we have made every effort to ensure that company names and addresses are correct, we cannot be held responsible for errors of fact or omission. If your company was not listed in this directory, and you would like to be included in the next one, please call 847-437-6604.

A

A-1 Gears
B/302, Vishal, Apts #3
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Andheri (E) Mumbai, MH 400 069
India
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Fax: (815) 359-7522

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Gardena CA 90247-0378
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E-mail: angison@ix.netcom.com

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Web: www.aerogear.com

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Ph: (800) 258-6608
Fax: (330) 773-9005

E-mail: steveag@lek.net
Web: www.akrongear.com

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Chicago IL 60644
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Amarillo Gear Company
P.O. Box 1789
Amarillo TX 79105
Ph: (806) 622-1273
Fax: (806) 622-3258
E-mail: tyoungblood@amarillogear.com
Web: www.amarillogear.com

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Russellville AR 72811
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American Machine & Gear
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Laurens SC 29360
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Fax: (864) 876-2630
E-mail: service@ametric.com
Web: www.ametric.com

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Ph: (650) 595-3664
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Web: www.amgear.com

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Fax: (630) 969-0253
E-mail: gl@arrowgear.com
Web: www.arrowgear.com

Asco Sintering Co.
635 Park Meadow, Suite 102
Columbus OH 43081
Ph: (614) 882-7460
Fax: (614) 882-7396
E-mail: ewheeler@ascosintering.com
Web: www.ascosintering.com

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Hodgkins IL 60525
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Fax: (708) 354-2810
E-mail: info@astronmidwestern.com
Web: www.astronmidwestern.com

ATA Gears, Inc.
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Rocky River OH 44116
Ph: (216) 356-0289
Fax: (216) 356-0289
Web: www.ata-gears.fi

Atch-Mont Gear Company, Inc.
37 Industrial Drive
Ivyland PA 18974
Ph: (215) 355-5146
Fax: (215) 355-3570

Avon Bearings
1500 Nagle Road
Avon OH 44011
Ph: (440) 871-2500
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E-mail: sales@avonbearings.com
Web: www.avonbearings.com

B
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499 Ocean Avenue
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E-mail: wbergcatalogs@wmborg.com
Web: www.wmberg.com

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Highway 24-27 West
Biscoe NC 27209
Ph: (910) 428-2151
Fax: (910) 428-3468

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Web: www.bonfiglioli.com

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Cicero IL 60650
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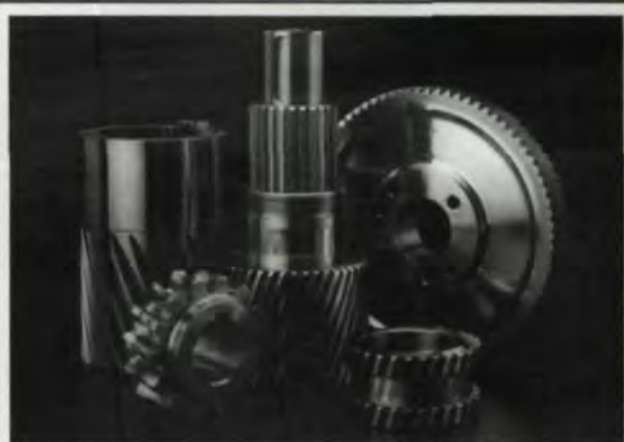
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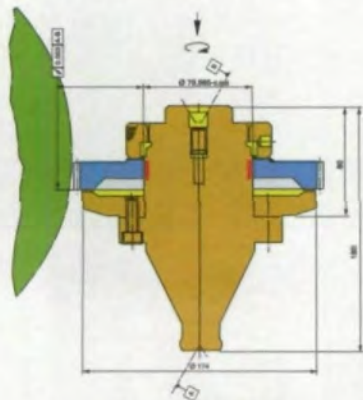
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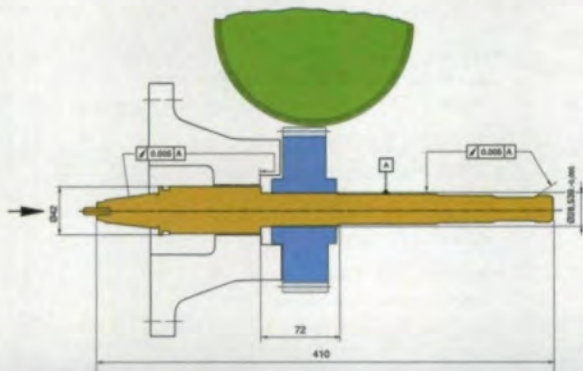
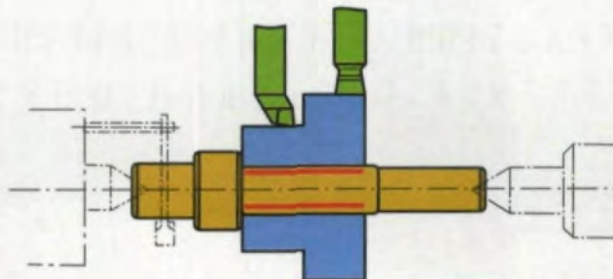
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Tips for Increasing Power Density in Gear Trains

William R. Mack

Introduction

Gear designers today are continually challenged to provide more power in less space and improve gear performance. The following article looks at some of the most common ways to increase the power density or improve the performance of gear trains. The author also takes an in-depth look at the case of a steel worm mating with a plastic helical gear and explores ways to optimize this increasingly common configuration.

Generated Involute Profiles

A generated standard tooth profile for pinions with about 20 teeth or fewer will show undercut near the bases of the teeth (see the 10-tooth standard pinion shown in Fig. 1). The bending strength of the pinion teeth is reduced significantly by the thinning of the bases of the teeth caused by this undercut. The most common approach to minimizing or eliminating this problem is discussed below.

Enlarged or Long Addendum Pinion Tooth Modification

In Figure 2, we have removed the undercut by creating an enlarged (or long addendum) pinion. This is done by moving the theoretical hob cutting position away from the center of the pinion and then adding full radii to the tips of the hob teeth. The result is a tooth profile that is significantly thicker at the root and has full fillet curves. Tooth bending strength is much improved, both by the increased tooth thickness and by the reduced root stress concentration provided by the full fillet curves. For molded gear teeth, the full fillet curves have the added benefit of improving plastic material flow.

The tooth bending strength factor is called the J-factor (see AGMA 908-B89). It is calculated using equations that consider the gear teeth as loaded cantilevered beams with stresses con-

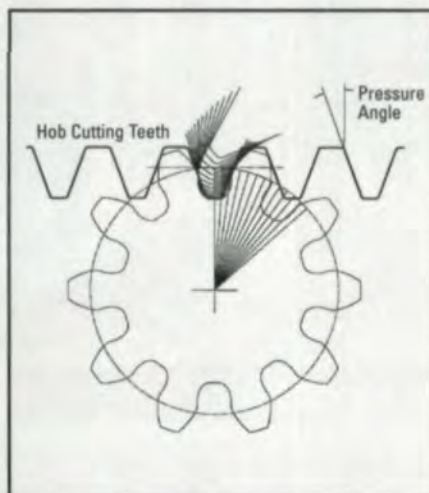


Fig. 1 — Hob-generated standard tooth profiles.

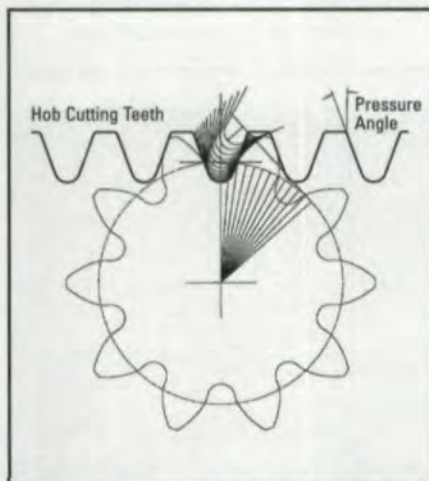


Fig. 2 — Hob-generated enlarged (or long addendum) tooth profiles.

centrated at the bases of the teeth.

To quantify the benefits of the above 10-tooth pinion modification, the tooth bending strength factor for the standard pinion is 0.0958 (see Fig. 3), and for the enlarged pinion it is 0.127 (see Fig. 4), when the pinions are mated with the same 36-tooth gear. The modified pinion has a 33% higher bending strength, in this case, equal to that of the mating 36-tooth gear (see Fig. 4). Equal bending strengths of the pinion and gear are a desirable design condition, assuming their face widths and material strengths are about equal. Pinion

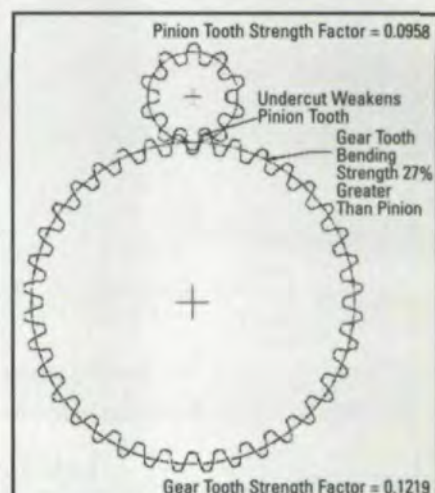


Fig. 3 — Standard addendum 10-tooth pinion with standard addendum 36-tooth gear.

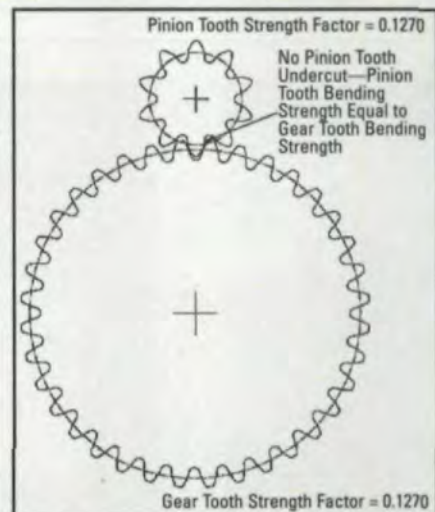


Fig. 4 — Long addendum 10-tooth pinion with standard addendum 36-tooth gear.

William R. Mack

has 38 years of mechanical design experience, with 25 of those years in the design and analysis of high volume plastic and metal gearing for the automotive industry. Mack retired from General Motors in 1992 and is currently a gear design and analysis consultant for Plastic Gearing Design and Analysis, Inc. His expertise is in designing for optimized power density in worm, helical and spur gear sets, analysis of existing gear sets, comparative analysis of proposed and existing gear sets, and analysis for high ambient temperature ranges and high impact applications. He has significant practical knowledge in actuators and other geared motor systems.



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and gear bending strengths are directly proportional to their face widths and material strengths.

Tooth Modifications to Reduce Mesh Interference caused by Tooth Deflection

Figure 5 shows a condition that is more pronounced with low modulus gear materials, such as plastics, but that also applies to metal gears. The deflection of the mating pinion and gear teeth causes a tooth position error as the gear tooth to the right of the centerline rolls into an interference condition with the mating pinion tooth. This would likely result in noise, wear and/or loss of mesh efficiency.

Figure 6 shows a close-up of the interference and how a modification called "tip relief" would be applied to the gear teeth. Tip relief consists of a radius or curve developed to permit the smooth entry of the gear tooth into the pinion tooth space.

Ideally, this kind of interference condition would be modeled by finite element analysis (FEA) or some other beam analysis technique and the tip relief would then be accurately developed from the deflected model. More typically, however, standard tip relief geometry techniques are applied with satisfactory results (see AGMA 1006-A97). A pinion and gear that drive in both directions would require tip relief on both sides of the teeth.

Often, pinion and gear tooth tips are tip relieved to deal with common tooth-to-tooth error tolerances, even when tooth deflections are relatively low.

Optimization of a Steel Worm Mating with a Plastic Helical Gear

In order to maximize the power density of a steel worm mating with a plastic helical gear, we must first consider the most common failure modes for these gear sets.

Shear stress failure, caused by the worm thread outside diameter shearing through the plastic gear teeth, often occurs at high temperatures, when plastic gear materials generally degrade significantly in strength. This type of failure can be accelerated by high gear tooth contact stresses resulting in wear of the plastic gear teeth over the life of the gear set. Exceeding the Pressure-Velocity (PV) capability of the gear material can also contribute to gear tooth wear-related failures, especially in

high speed, high torque worm and gear applications.

High stall friction at the worm and gear interface, which is sometimes caused by high impact loading at stall, can cause a jamming failure. This creates a condition where the available worm torque is not sufficient to overcome the friction and reverse the mechanism.

Worm and gear wear, caused by an abrasive plastic filler like glass fibers, can cause wearing of the steel worm thread and the plastic gear teeth. This can lead to premature failure and high friction caused by metal debris at the mesh interface. In most cases, it is advisable to harden worm thread surfaces that will interface with an abrasive plastic filler.

A standard worm and gear set is defined as one where both the worm and gear have tooth thicknesses equal to one-half the circular pitch (see Fig. 7). If the worm and gear materials were equal in strength, standard or near-standard tooth thicknesses would be specified.

When a steel worm mates with a helical gear made from a lower strength material, such as plastic, the shear strength, compressive strength and bending strength of the worm can be significantly greater than that of the gear. Therefore, the thickness of the mating gear teeth should be increased above the standard thickness and the worm thread thickness reduced, correspondingly, to below the standard thickness. This balances the worm and gear strengths and yields a higher power density in the same package size. This concept is illustrated in Figure 8.

Other worm and gear modifications are also important for increased power density:

- Minimizing the worm and gear pressure angles will reduce mesh separating forces, increase gear tooth thickness near the tips of the teeth where shear failures can occur, increase mesh efficiency and contact ratio, and provide more teeth to share the loads.

- Maximizing the worm and gear tooth depths can also add significantly to the mesh contact ratio, thus increasing power density.

There are manufacturing limitations, however, controlling the degree to which worm threads can be thinned, worm pres-

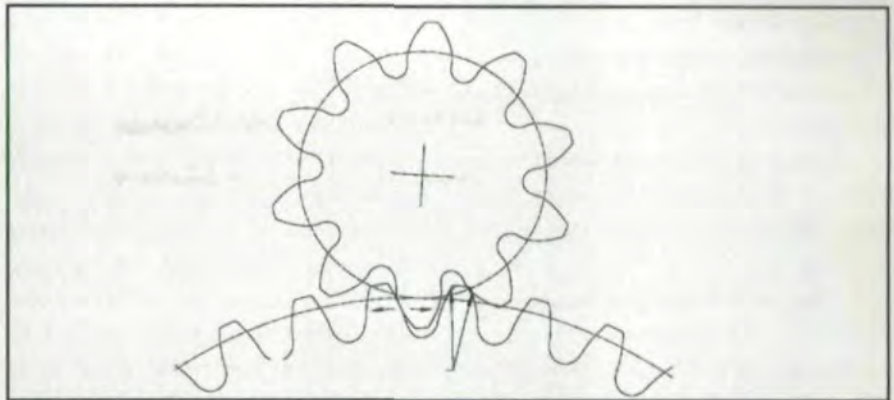


Fig. 5 — Mesh interference due to tooth deflections under load.

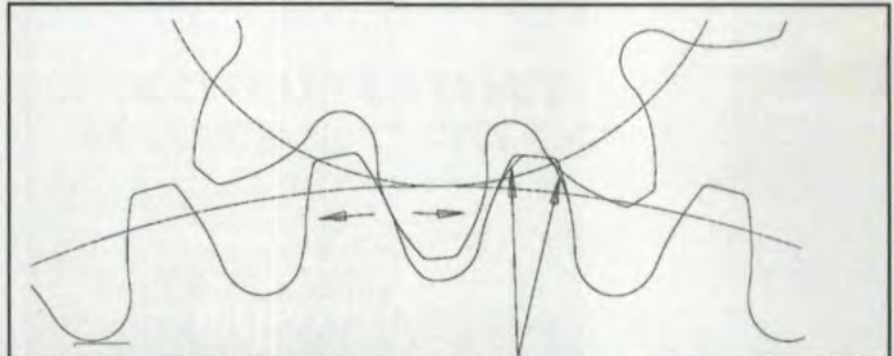


Fig. 6 — Tip relief to overcome mesh interference due to tooth deflections under load.

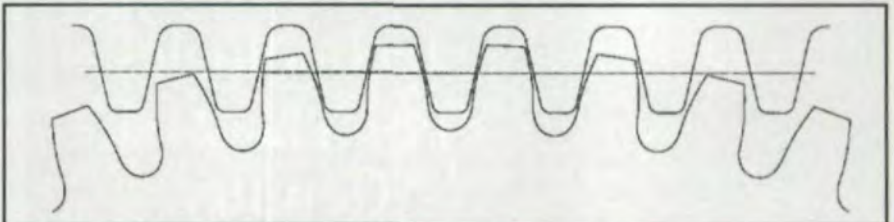


Fig. 7 — Standard tooth thickness worm and gear.

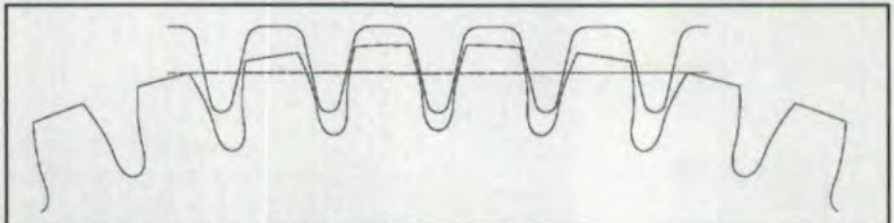


Fig. 8 — Thinned worm tooth, thick gear tooth modification.

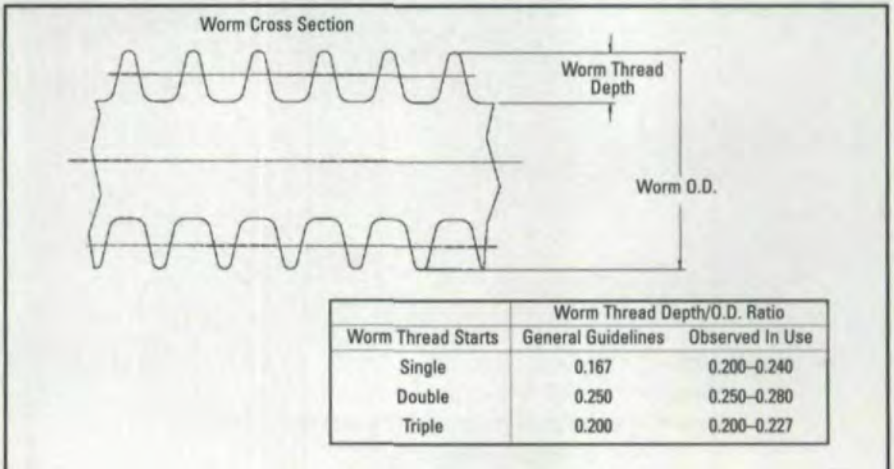


Fig. 9 — Rolled worm thread depth and outside diameter guidelines.

sure angles can be reduced and worm thread depths can be increased. The selected worm manufacturing process will affect these limitations.

The most common worm thread manufacturing processes are machining (hobbing, chasing, or grinding) and rolling (cold forming).

Worm Rolling Optimization Characteristics

In brief, the worm rolling process consists of two cylindrical, rotating rolling

dies that move from opposite sides into a plain shaft blank to form the desired threads. This is done using a machine designed specifically for thread rolling.

Rolled worm threads are commonly specified for high volume applications. While the tooling costs for rolled worms can be much higher than for machined worms, they are generally offset by a production cycle time that is three to six times faster than machining. The rolled worm cycle time is even more advantageous

when comparing rolled multi-start worms with machined multi-start worms that sometimes require multiple passes.

Another advantage of rolling threads is a generally higher quality thread flank surface texture than that which is typical of single-pass machined worm threads. Better surface texture can maximize mesh efficiency, reduce wear on the mating gear teeth and yield a quieter gearset. The quietness improvement, however, assumes that the rolled worm thread has the same quality, in terms of runout and other critical thread dimensions, as a machined worm. This assumption is not generally a good one, as discussed below.

Work-hardened thread flank surfaces, resulting from the compression of the metal during the rolling process, can produce a harder and more durable surface.

The Effects of the Worm Rolling Process on Gear Set Optimization

Rolled worms have more manufacturing limitations affecting the optimization process than machined worms. These limitations affect the following key thread elements:

- Tooth depth
- Tooth thickness
- Pressure angle

When you optimize any one of these thread elements, you limit the optimization of the other two. Therefore, a balance must be achieved by seeking the best combination of the three elements to produce an optimized worm and gear set.

Tooth Depth Optimization. This is a very effective tool in gear set optimization. Rolled worm thread Depth/O.D. guideline data is shown in **Figure 9**. This guideline data shows that the overall quality of a worm thread, especially in terms of runout, is more easily achieved for an even number of thread starts than it is for an odd number. The reason is that the rolling die teeth are directly opposite one another when rolling an even start worm, and are offset from one another when rolling an odd start worm. Offset die teeth tend to cause more bending (runout) of the worm during the rolling process. However, rolled worm runout can be improved by the addition of a straightening operation after rolling.

Tooth thickness optimization. Thinning is also a very effective optimization tool



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because thickened mating gear teeth reduce their shear and bending stresses. Tooth thinning optimization in rolled worms is limited by the requirement that some minimum tip radii must be specified so the material will flow properly to the tips to allow for a knit line void where the two sides of the thread meet during rolling. The size of the tip radius limits how thin the thread can be. Generally, a tip radius of about 0.010" is the minimum.

Pressure Angle Optimization. Reduction for rolled worms requires the rolled material to flow up a steeper slope to fill the rolling die profiles, making it more difficult to achieve acceptable profile quality and thread flank surface texture. Pressure angles as low as 10–11° have been rolled, but this can limit tooth thickness and tooth depth optimization.

Power Density Optimization Characteristics of the Worm Machining Process

Some of the most common worm thread machining processes are hobbing, grinding and chasing. When optimizing the design of a worm thread, the same basic optimization characteristics apply to all three processes. Again, we'll consider the optimization of the following key thread elements:

- Tooth depth
- Tooth thickness
- Pressure angle

Tooth depth. This is limited only by how small the worm minor diameter can be before causing excessive deflection and/or bending stresses under load. Also, care should be exercised to avoid undercut of the mating gear profiles caused by a deeper-than-standard worm thread.

Tooth Thickness Optimization. Thinning is limited by reaching the point where the thread tips come to a sharp edge. However, a sharp-edged thread has the potential disadvantages of production handling damage, injury to workers handling it, and scraping and wearing of the loaded mating gear teeth. In addition, a worm thread can be thinned to the point where it becomes so weakened that it could fracture under load.

Pressure Angle Optimization. Reduction has limitations relative to thread surface texture. A machined pressure angle in the 10–12° range will make it more difficult to control surface texture than a pres-

sure angle in the 14.5–20° range. Machine settings can be adjusted to deal with surface texture control, but cycle time and tooling costs may increase.

A major advantage of machined worms, relative to rolled worms, is their ability to hold thread runout closer than rolled worms, which results in fewer noise and wear issues.

In conclusion, if a machined worm thread can compete with a rolled worm thread in meeting cost and quality goals, the gear

designer has a greater advantage in designing a higher power density gear set. ⚙

This article is based on materials that were first presented at the SAE Plastic Gears for Power Applications TOPTEC held August 26–27, 1998 in Dayton, OH.

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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.



Flame Treating Systems Introduces New Flame-Treating Machine

Oliver Gear of Buffalo, NY, is now hardening gear teeth on a machine built by Flame Treating Systems, Inc., that treats the flanks of teeth ranging in size from 1 to 4 diametral pitch. Usually used for pinions on reducers, the gears range in size from 18 to 52 cut teeth, 13.64 to 54.67 inches in diameter and from 2.5 to 4.5 inches thick with weights of 80 to 3,500 pounds.

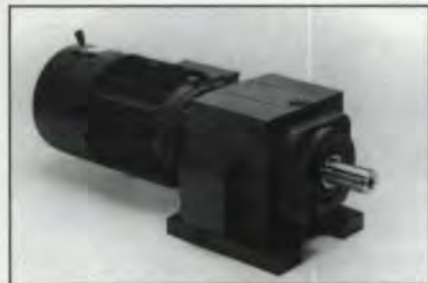
The teeth, SAE 4140-4150 steel, are hardened to 500-600 Brinell to depths of 0.125 inches on the pitch line without hardening the gear hub. The process also strengthens the teeth by creating internal compression stresses that counteract external tension stresses. Original and operating costs of the FTSI machine are considerably less than those for a comparable induction heating system.

The machine's components include two water quenched brass flame heads with either 1 inch or 3/4 inch heating width; a cabinet with controls for the flow of oxygen and fuel, flame temperature and heating time; a yoke assembly for the heads; a water-cooled, high-capacity heating torch mounted in a BUG-O scanning mechanism holder; a quench collection tank with pumps, heater and manual turntable with stops; and a fan-style heat exchanger with a 1-hp pump. The gears rest on a free-spinning turntable that is locked in place by a spring-loaded V-block inserted between teeth, then manually retracted after the heating of each tooth is complete. The rate of movement of the flame heads along the teeth is automatically

controlled. The hardening times per tooth range from 1 to 2 minutes at pressure gage settings of 50 psi for oxygen and 20 psi for fuel.

For more information contact Mark Serrine at FTSI at (800) 435-5312 or by fax at (919) 956-5057.

Circle 301



Dodge Introduces New Modular High-Torque Gear Drive

Dodge has unveiled its new line of Quantis In-Line Helical (ILH) gearmotors and reducers. The Quantis ILH offers the most advanced helical gear and design technology on the market. It is specifically engineered to deliver higher torque performance in a compact housing. Quantis features a complete modular design to ensure shorter delivery cycles. Its one-piece case construction is designed to optimize overhung loads while its all ground gearing provides greater power with lower noise. Quantis ILH gear drives deliver efficiency ratings up to 97%.

With Quantis, users can now downsize and still achieve higher horsepower ratings size for size, ensuring improved cost containment and process reliability. Output torque ratings are up to 14,870 inch-pounds, with input power ranges from 1/4 horsepower to 20 horsepower. More than 2 million combinations are possible from stock and non-stock parts, and Quantis is dimensionally interchangeable with major global competitors.

For more information on the new line of Dodge Quantis ILH gearmotor and reducer, call Rockwell Automation Power Systems at (864) 297-4800 or fax (864) 281-2433 and request literature DMR-1987-1.

Circle 302



Special Racks and Pinions Eliminate Need to Design Around Standard Gear Components

Design engineers can design mechanical movements into their equipment more practically using custom made racks and pinions rather than designing around a standard gear component. These special pinions and racks, manufactured by Rack and Pinion, Inc., are often more cost effective than standard components. What's more, these components can be made in less than a week (4-6 weeks is standard).

Pinions are available up to 6-inch outside diameter with shaft lengths up to 10 feet. Racks can be ordered in lengths to meet specific requirements. A wide range of materials, heat treating and noncorrosive plating is available.

"Now an engineer can specify a rack and pinion that fits his design rather than trying to design around a standard rack and pinion," said Jim Geisman, Rack and Pinion, Inc. CEO. "Glass cutters find the quality of the special rack teeth and gears provide smoother cutting head travel for better accuracy during the cutting process. Plus, die and injection mold makers appreciate a rack and pinion making source that helps them solve special part ejector applications along with delivering a quality product when promised."

A 16-page catalog is available. To obtain a copy, or to receive more information, contact Rack and Pinion, Inc., at (800) 722-5008 or by fax at (517) 563-8874.

Circle 303

Pinpoint Accuracy in CNC Inspection

A CNC inspection machine capable of measuring wormwheel gear cutting hobs and flytools has now been developed by Holroyd. Calibration results have confirmed the measurements of this machine to within 2-3 microns. This machine pinpoints the profile, pitch, lead and divide of hobs as well as relevant vital details for single-point flytools.

For inspection, the cutting tool is placed in the machine's vertical axis and

then measured by a contact probe linked to encoders. Stepper motors position the probe and enable digitized measurement information to be fed into a computer. This gives the operator detailed readouts of tool condition both on-screen and in the form of printed statistics and graphs. This piece of equipment is being used by Holroyd to help manufacture new hobs by verifying accuracy, monitoring tool wear and confirming the accuracy of the resharpening

process, and by producing digital representations of the profiles to simulate the contact condition generated by the cutter using computer modeling techniques.

For more information about the CNC inspection machine, contact Holroyd at ++(44) 1706-526590 or visit their Web site at www.holroyd.com.

Circle 304



Roundness Measuring Machine has Style and Substance

New from Taylor Hobson, the Talyrond 265 marks a radical departure in precision instrument design. Not only does it have many performance enhancements such as high accuracy vertical straightness, it also blends engineering excellence with ergonomics and aesthetics. This is the first in a new series of inspection machines that is designed to increase overall ease of use while decreasing overall cost of ownership.

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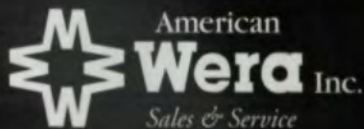
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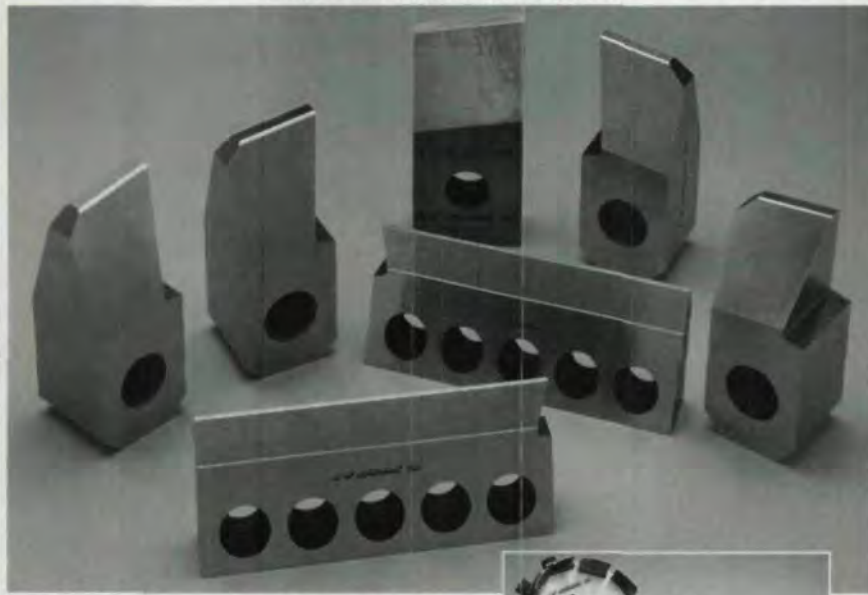
The data sheet describes the variety of configurations possible when the units are coupled in tandem, allowing overall length to be held to a minimum in a more compact design than can be achieved with standard gearboxes. Available in seven sizes, the units offer a 5 to 800 HP range, with constant horsepower at each ratio. The units have input speeds of 2000 RPM and 12 to 288 speed changes are available by coupling four units. These units may be equipped with either standard or special ratios.

Copies of the Multi-Speed Drive data sheet are available from Andantex U.S.A., Inc., 1705 Valley Road, Wanamassa, NJ, 07712 or log on to their Web site at www.andantex.com for further information.

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For more information about Chem Cut HX CNC 11 NS, contact Paul LaGrippe at CLC Lubricants Company at (800) 543-0505 or by fax at (630) 232-7915.

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Cool Gears

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



It's nice to have a claim to fame. "We're probably the world's foremost authorities on making gears out of ice," says Jeff Root of Virtual Engineering, Plymouth, MI.

Root's firm built what is believed to be the first working clock ever to be made out of ice for the 17th Annual Plymouth International Ice Festival, held January 14-18, in Plymouth, Michigan.

"We wanted to get into the *Guinness Book of World Records*," Root says, "and none of us thought we could sit on a flagpole for two years, so this is what we came up with."

The 6 x 12-foot clock included 11 working gears, all made from ice, the largest of which was four feet across and weighed 77 pounds. The ice gears were designed using Pro/E gear models that the company keeps available for free download at their Web site (www.veng.com).

The models were converted into G-Code and transferred to a homemade CNC router. The router was used to make plywood templates of each gear. The ice clock gears were manufactured from the templates on-site using a custom-made, three-axis router arm that was made out of garage door hinges and plywood.

The Virtual Engineering team wanted a nice line of gears that accomplished a

3600:1 ratio. "We had to use a lot of extremely nonstandard DPs to get everything to line up right," Root says. "Careful examination of the picture will reveal that we also used some dramatically different tooth profiles to get the job done."

Unfortunately, warm weather prevented the team from running their clock for very long. The temperature had risen to about 43°F the day they were supposed to run the clock, so they disassembled it and put all the pieces under snow-covered tarps. The next morning, at about 4 a.m., they ran the clock for about 15-20 seconds just to prove that it worked, Root says. However, though they had designed the clock to work via ice weights without external power, the team planned to use an electric motor to power the clock for continuous operation.

Even though the clock only ran for a few seconds, the Virtual Engineering team considers their effort a success. The company used the project mainly to demonstrate their capabilities and to recruit potential new engineers, Root says. Plans are already underway to build an even better ice clock for the next festival.

"We're the first to admit that there's absolutely no possibility for commercial applications made out of ice," Root says. ⚙



Top: The ice clock used a straight line of gears to achieve a 3600:1 ratio.
Middle and Bottom: The homemade CNC router used to make gear templates.

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

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