GEAR TECHNOLOGY

The Journal of Gear Manufacturing

GEAR EXPO SHOW ISSUE

November/December 1995

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22

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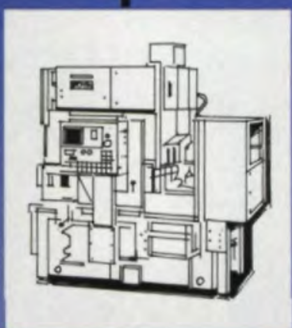
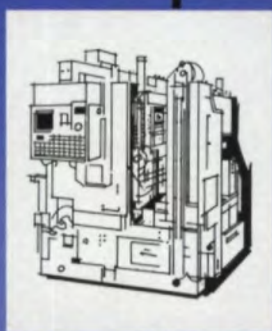
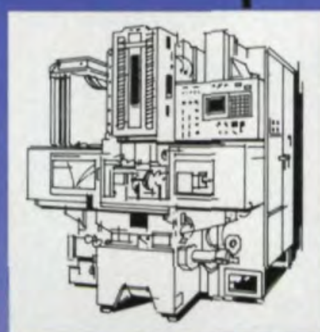
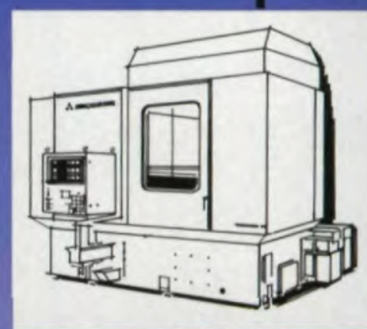

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QUESTIONS
TO KEEP YOU UP AT NIGHT

Sometimes in the pressure to meet deadlines and handle the Crisis of the Day, we lose sight of the forest for the trees. As a partial cure for this syndrome, I recently reviewed the six interviews with gear industry leaders that have appeared in our pages during the last year, trying to get a grasp of a larger picture. It struck me with renewed force how six men, each with a lifetime of experience in this business, see the gear industry forest the same way.

Each phrased it differently or pointed to a different aspect of the picture, but the conclusion in each case was the same—economic, political and technological forces are converging to force a "second industrial revolution." We are looking at changes in the way we work and do business no less momentous than the advent of the steam engine, and there's no going back; the revolution is here.

There's no point complaining or wishing it were different. We're at the beginning of a whole new ball game. Is the gear industry ready to play? Is your particular gear-related business?

As if you didn't have enough to keep you up nights, you need to start thinking about the questions in the left-hand column. Ignore them and you could become one of the 8-track tape drive manufacturers of the 1990s.

These are only a few of the questions facing us on the eve of the next industrial revolution. New ones arise every day.

1. In the light of the shake-outs and consolidations of the last 10 years, is there room in the industry for more than a half-dozen gear machine manufacturers? If not, what does that mean for machine buyers and other sellers? Is this an industry in which anyone else can make money any more? What does this shrinking supplier base mean to me as a customer?

2. What am I to make of the "gearless" gear-making machine? How many other "gearless" devices are on the drawing board, and what do they mean for the future of the industry?

3. What is the market for gears going to be like in ten years? Twenty? What is the future of my gear-related business in such an economic environment?

4. What other new technologies are lurking just around the corner that could dramatically change the way I design, produce and sell gears? Could one of them conceivably make my business irrelevant? What am I doing to find out?

5. Can I continue to serve only regional or local markets when the economy becomes more and more global every day? How?

6. What am I doing to find markets to replace those that are dead or dying?

7. How do I attract, train and keep the bright, flexible, creative and highly skilled workers I need in a world where manufacturing is considered a "dead end" job?

8. How do I ready my business to offer 24-hour turn-around, job lots of one, instant customer service, audited and documented quality systems and other demands of the new work world?

9. How prepared am I to meet the demands of customers who want me to e-mail the drawings, give them our catalog and parts lists on CD-ROM and do all the negotiating by video-conference?

10. Have I explored the possibilities offered by the Internet to help generate business, cut costs, exchange information and improve customer service?

11. How do I use the vast quantities of available information to my advantage and not be overwhelmed by them instead? How do I separate the hype from the real things about this revolution?

PLEASANT DREAMS.

Michael Goldstein

Publisher and
Editor-in-Chief

David Goodfellow of
American Pfauter, L.P.

Gear Technology *speaks with David Goodfellow, president of American Pfauter, L.P., and Pfauter-Maag Cutting Tools, L.P., to get his impressions about the state of the gear industry and its prospects for the future.*

David Goodfellow, president, American Pfauter

GT: Let's talk first about international markets. How important are they to the gear industry in general and to American Pfauter in particular? Which emerging markets are you concentrating on?

DG: I think it is necessary for companies to deal globally today. You can't afford to do business only in North America. I say North America because we all too often forget that Canada and Mexico are very important trading partners. To us at American Pfauter, export means anything off the North American shoreline.

Probably the most important international market today is Asia, the Pacific Rim—Japan, Korea, Taiwan and Malaysia. Everybody gets very excited about China, but I think we are just on the verge of learning how to do business with China. There are a lot of risks, but it is necessary to start becoming active there. And India will have a billion people in the next couple of years.

The biggest potential for us right now, though, especially here in America, is in Japan, Korea and Taiwan. Now we are seeing a lot of activity coming out of Taiwan because of their growth, especially in the moped/motorcycle market. A lot of that product is going from Taiwan into mainland China, so we are getting to China indirectly through Korea or Taiwan and sometimes Japan.

But the overwhelming reason to think about export markets is to allocate very high costs over a lot of products. When we think about the cost of developing our products today, how much time and energy are required for new product innovations, software, control systems and things like that, we no longer can allocate those costs only to America, North America or to Europe.

The Pfauter Group needs to expand three ways: a strong base in our North American market; a strong presence in Europe; and some kind of cooperation with Asian countries. In the long term you can't just export; you have to have some kind of value added, maybe in the form of joint ventures, technology transfers or mergers and acquisitions, because globally, marketing just doesn't mean import/export. Global markets mean you have to have presence. If you want to just distribute, your business will go up and down with the exchange rates. Pfauter's long-term goal is to have European operations to satisfy the European market, North American operations to satisfy the North American market and Asian operations for that market.

GT: What about South America? Do you see that as an emerging market?

DG: The automotive business in Brazil and Argentina is growing, and as a result, especially with the relationships at Ford, Volkswagen and Mercedes-Benz, all mainstay customers of ours, we see significant improvement. I think this will be a very strong market eventually, but again you have risk of exchange and political problems. But I don't think you'll see the same kind of long-term, stable growth you'll see in places like India, Korea, Japan and Taiwan.

GT: What about the pitfalls of doing business globally?

DG: Well, of course, one of the biggest downsides, if you don't have manufacturing facilities or value added in those places, is exchange rates, but maybe the most significant one is the language and cultural differences. In other countries, everything you see on a quotation request or in a written spec is really only the beginning. You can't just deliver a product according to a written specification as we do here. Asian customers want different kinds of care and help than our domestic customers do.

GT: Such as?

DG: Things like continued support for service and maybe even free service. We have a perceived need difference. People in Asia especially have been used to having very close contact with their suppliers and getting very good care from them. Since we're the outsiders, we have to learn more about that culture and can't just deliver a product that's acceptable to the U.S. or to Germany or to Italy. We're too used to saying, "But it worked fine here, or Ford was happy with it. Why isn't Toyota happy?"

Maybe the biggest difference is the length of time that Asian companies and customers take to get to know their suppliers. They want to know who you are and what their future is with you. That's why very often it takes months and years to develop a trusting relationship. They want to see what your endurance is. Are you going to be there in good times and bad times? What we can't do is treat export markets as, "Oh, by the way, business is bad in the U.S., so let's ship our products to Asia," and when business gets busy in the U.S., you turn the faucet off on them. That's what they're afraid of.

GT: Talking about domestic customers, have you seen a change in their demands in recent years?

DG: Worldwide, but especially lately in North America, our customers are demanding higher quality, faster cycle times, better maintenance and support and lower prices. That means, if you have the lowest price machine with the highest quality and the shortest delivery time, you have a very good chance of getting the order because the differences in high-quality manufacturers are not that great. The difference between us is know-how. Support of your product means service and maintenance reliability. Customers want 98 to 99% uptime. So, we're looking to have products that take less floor space, have higher output per unit and full statistical runoff and acceptance.

I think the biggest thing today is to have a system. We don't just deliver a machine, we deliver a unit, a system that is capable of producing a part statistically to a customer's requirements. Ten or fifteen years ago the large companies bought a gear cutting machine from one place, cutting tools from another and automation from a third supplier, and they put it together on the floor. Today, they don't have the people or time to do all of that work themselves, so they are putting all that burden on the supplier.

What that means for us as suppliers is that we have to provide all of the things necessary to supply the complete system. You can't just build a gear-cutting machine any more; you have to build the tool that goes with it. We make our own tooling, we make our own automation, we make our own software. The whole idea is to be self-sustaining, vertically integrated within our process capability so we can deliver a complete package to our customer.

The situation is not unique to North America. It's the same all over the world. There's a definite reduction in our customer base of specific know-how. They don't want to have all these specialists sitting around. What they are saying is, okay suppliers, you have to do that for us.

GT: It's expected?

DG: It's demanded. But this systems approach is so expensive that smaller companies can no longer afford to invent or innovate. They either have to copy or wait for somebody else to do it and have a look-alike unit or go out of business, merge, acquire or be acquired. The best solution is to be in control.

GT: How do you stay in control with such a diverse customer base?

DG: We used to think there were only a very small number of real customers. But do you know what we found out when we bought Barber Colman? There are almost 4,000 companies making gears in North America. There are something like 15 to 20,000 companies making gears worldwide. Now, not all of them are going to buy $500,000 hobbing machines or million dollar gear grinders, but all of them buy tools. What we found out is that this customer base is far more vast than we ever imagined and that we better learn how to get into it and understand it.

How do you get to these 15,000 to 20,000 customers? Small niche companies have to create synergy through acquisition, merger or joint ventures. Companies will get acquired, merge or simply go out of business. There's also the issue of absolute cost. If you can amortize the cost of buying hundreds of control packages, then you have a better bargaining position than a guy who buys 20 controls. He has more software development to spread over that cost. I think there will be shrinkage in the gear market both from our customer base and our supplier base.

Also, tool, machine and productivity technology all say we will make more pieces with fewer units of equipment. We will make more pieces with fewer tools. The tool may be more expensive, but there are going to be fewer units, so the market shrinks again. It gets smaller and harder to divide that up.

GT: Is the machine or the tool driving technology and productivity today?

DG: In this technology chase, it's very difficult to say which is leading right now. More changes have taken place, especially in gear manufacturing technology, in the last five to ten years than took place in the last fifty years. We saw machines at IMTS cutting without coolant. We and some of our competitors had machines cutting with carbides, cermets, and titanium carbonitrides. At the Milan Tool Show in Europe, we saw machines with no gears and extremely high speeds—6,000, 7,000 rpms.

Machine and related tool technology is changing so rapidly today that it scares people. It's like the computer industry. When do you buy the new laptop? Do you wait for the technology to get there? Because if you wait, you'll never buy it because a week after you buy one, it will be obsolete.

On the other hand, all these technological things are great in laboratories, but if you can't use them in a day-to-day operation in an industrial environment, they are no good. If you can't bring them in at a cost per piece that is attractive to the customer, they are also no good. We can generate the most fantastic workpiece with the highest productivity and quality available, but it might be at a cost that is not acceptable.

We need to work more closely with our customers than ever before to find out what technology to bring them that they are willing to pay for. We used to say, "Here is a new process," and customers bought it. But today they are looking very closely at cost per piece of the tool, cost per piece of the machine, the life and amortization forces—they want to know life cycles. Years ago nobody cared about this.

GT: What do you think about the common suggestion that the American gear industry is in decline?

DG: I don't think the American gear industry is in decline. I think it is in consolidation. The American gear industry is just now coming to grips with the fact that it can't be only the American gear industry. It has to be an international, global player producing gear products for the world market. There will be fewer, but more capable companies who are global players.

There is a tremendous future for American gear manufacturers. We can produce high volumes of high-quality gears in small, efficient factories with a lot less equipment and far fewer people.

We have one advantage here in the U.S. right now in that we have a workforce very sympathetic to the necessity of improving our competitive capabilities worldwide. We have a workforce today that is the most productive in the world. Our tool factory here at Pfauter-Maag runs 24 hours a day, seven days a week. From a competitive viewpoint, I think we're poised to really take advantage of some things that we have that other companies friends don't have.

GT: What's the next step in gear manufacturing?

I think the next step will be small diameter—10" and under—hobbers, shapers and grinders. These machines will be gearless. That means no index drives, no change gears, but they will have direct-driven spindles and high-speed capabilities. They will have a lot of flexibility. They will be easier and take less time to build. They will probably have more purchased parts. The whole manufacturing technology will change. You buy more and you assemble more. I think the whole life of the machine tools will change. If you go to the machine tool show today, it's hard to tell the difference between machines because they are all starting to look the same. So, I think smaller, gearless machines are going to be the biggest introduction of new technology, but they are the result of CNC controls and high-frequency spindle drives.

You can't just build a gear-cutting machine any more; you have to build the tool that goes with it. We make our own tooling, our own automation, our own software. The whole idea is to be self-sustaining.

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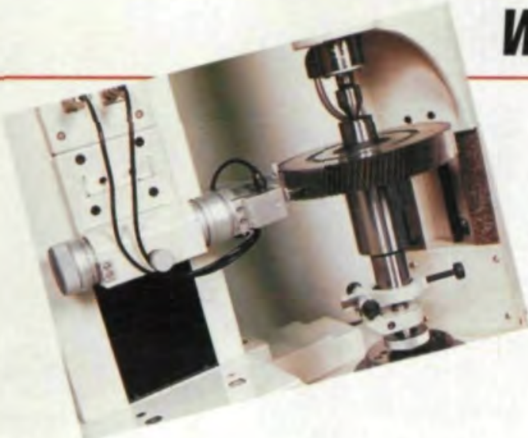

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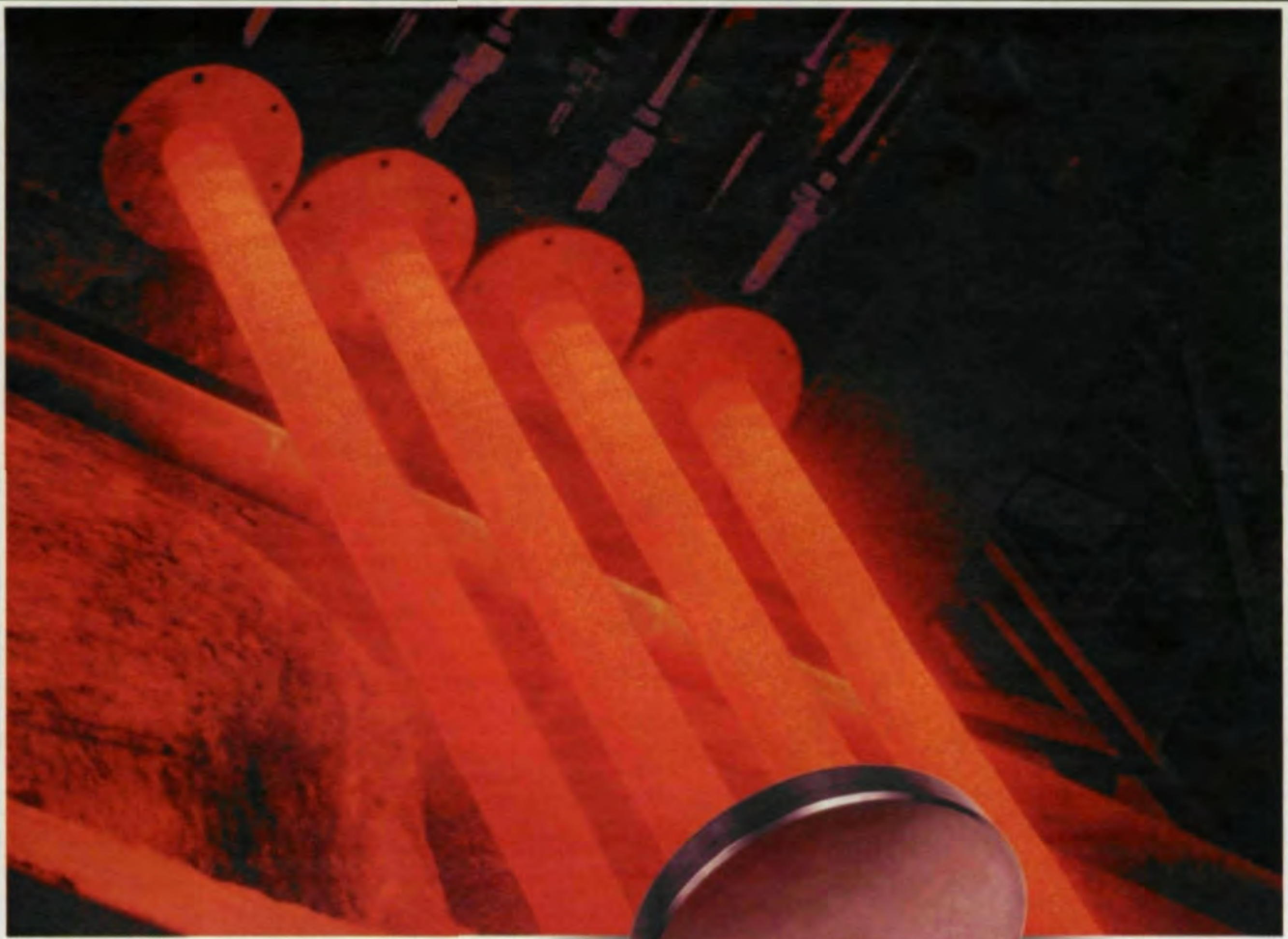

QS-9000 Rules

The 500-lb. Gorilla Speaks, and Suppliers Will Have to Listen

Nancy Bartels

Ready or not, QS-9000 is here. If you are a first-tier supplier to one of the Big Three automotive companies, you've already heard that compliance with this new quality standard is now an entry-level requirement for doing business with Ford, General Motors and Chrysler. If you're a second- or third-tier supplier, you can expect the ripple effect of this new standard to hit your company one way or another.

Exactly how big those ripples will be is still open to dispute, but, make no mistake, for the foreseeable future, QS-9000 is the standard to meet for doing business in the automotive industry.

Heavy truck manufacturers Freightliner, Mack, Navistar, Paccar and Volvo have also adopted the standard, and other major automotive players are expected to fall into line.

What is QS-9000?

QS-9000 is the industry-specific adaptation of the ISO 9000 standards for the North American auto industry. It will apply to all first-tier suppliers; that is, companies selling components to be used or installed directly in the products of the Big Three automakers. It has as its nucleus the 20 points covered in the basic ISO 9000 standard. In addition to this framework are industry-specific and customer-specific requirements that suppliers must meet.

One of the most significant differences between QS-9000 and earlier Big Three quality plans is that QS-9000 is geared toward an external, third-party audit of quality procedures. Both Chrysler and GM are demanding a third-party audit. While Ford does not at the moment, it is expected to fall into line within the year. This means that now suppliers will have to pay for outside certification instead of relying on audits provided by the customer.

An important difference between ISO 9000 and QS-9000 is the requirement of the automotive standard for "continuous improvement." Under ISO 9000, all you have to do is document your present procedures, good or bad. On the other hand, QS-9000 requires a regular, documented procedure for addressing the question, is there a better way to do this process?

Another difference is that QS-9000 is "documentation-driven," says Mark Jagger, vice president-quality for Eagle Picher's Hillsdale Automotive Division. Under the new standard, "if you can't provide documentation for a process, it never happened," he says.

QS-9000 also pays more attention to procedures. According to Michael Kerwin, director of quality and productivity for The Gleason Works, ISO 9000 sets certain quality standards, but QS-9000 also mandates the processes you must use to achieve them.

Why QS-9000?

The rationale behind the standard, from the point of view of the automakers, is twofold. First, it is an attempt to address supplier concerns about the difficulty of meeting different criteria for each automaker. Designed to replace the previous company standards like Q1 and Pentastar, QS-9000 is a plan to bring significant commonality to automotive quality requirements for suppliers.

The reason the Big Three did not simply adopt ISO 9000 as their standard was the concern that certain issues important to the industry were not covered. Curtis Davis of Perry Johnson, Inc., providers of quality systems management, consulting and training services, says, "The Big Three felt that in some respects, to merely adopt ISO 9000 would be taking a step backward in terms of their quality requirements."

Outside observers suggest other motives as well. Under

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Nancy Bartels
is Gear Technology's senior editor.

the new system, the cost of the audits will be borne by the suppliers rather than the Big Three. Charles Brannen, vice president of Overton Gear & Tool, points out that QS-9000 is a mechanism to cut internal costs for the Big Three. Under this system, they can be assured of getting the parts they want without having to go through the internal costs to get them.

Davis also suggests that a certain level of "politics" went into the new standard. "The Big Three view themselves in a world of their own, and they wanted their own standard," he says.

The Good, The Bad & The In-Between

Regardless of the motives driving QS-9000, it has a great many fans. For many who are implementing the standard, the key advantage is the discipline it instills. Says ISO 9000 consultant Ralph Teetor, "QS-9000 documents what works. It's a way of keeping track of what you should be doing anyway—documenting processes, auditing reality against the document and taking corrective action where needed."

Charles Brannen takes a dual position. As current president and spokesman for AGMA, he takes no position

Coming Attractions: TE-9000

Not being a first-tier Big Three supplier does not let you off the quality standard compliance hook. In the works is a Son-of-QS-9000 standard for suppliers of tooling and equipment, tentatively called TE-9000.

Few specific details are known about TE-9000, although bootleg copies of draft versions are in circulation. The official version may be released as early as the end of 1995.

Those who have seen draft copies say that the structure of TE-9000 will be similar to QS-9000; that is, it will be in three sections, with ISO 9000 as its core and industry- and customer-specific requirements in addition. One difference from QS-9000 is that TE-9000 seems to place more emphasis on self-certification. There is also a sense that requirements may be a bit looser, with the question of how critical this component is to the end product being an important criterion for deciding the details of certification. These views, of course, are all preliminary and may change when the actual standards are released.

According to Chrysler spokesman Russ Jacobs, companies affected by TE-9000 will be notified by mail and sent a packet containing a copy of the standard, deadlines for compliance and details about training and implementation programs and seminars.

Many major players in the gear machine and tooling sectors, including Gleason, Pfauter-Maag and Star Cutter, are already making plans to qualify for TE-9000.

at all. AGMA's view is that seeking certification must be an individual company decision. On the other hand, as vice president of Overton Gear and Tool, which is seeking QS-9000 certification, he sees real benefit in the required documentation.

"It's very helpful in terms of knowledge transfer," he says. "When a new employee comes on, we can show him the documentation and say, 'Here's your job. This is how it's done.' It makes sure a lot of things don't fall through the cracks. It also gives that employee the chance to question why things are done the way they are. That in itself leads to a kind of continuous improvement."

The Gleason Works' Mike Kerwin says that in spite of the cost of outside auditors, the QS-9000 system is easier than dealing with separate standards for each customer. "There's more consistency. You only have to deal with one assessor. Even if you have to pay one outside auditor, it's still cheaper than having to provide help for all the individual company auditors."

John R. S. Wendland of Eagle Picher's Gasket Division is "very enthusiastic" about QS-9000. "It's a wonderful opportunity to grow . . . to step back and look at the business, to see how we're really doing things."

Still, there is a downside. In spite of promised savings, costs remain an issue. Registrars are charging between $800 and $1200 a day for audits, which can last anywhere from four to 21 days, depending on a company's size, according to Robert Armstrong, QS-9000 operations manager for Lloyd's Register Quality Assurance. And these numbers do not include internal costs incurred in getting ready for the outside auditors or yearly reassessments.

Some observers think that QS-9000 is hard on smaller suppliers. It was written with high-volume parts manufacturers in mind. Jeff White of Reef Gear, another company seeking QS-9000 certification, says documentation requirements are especially hard on smaller firms. John Wendland suggests that keeping track of QS-9000 documentation could be a full-time job for one person, not a task that can be shuffled off on secretaries to do "when there's time." That alone could be a hardship for a smaller firm. Dan Phebus, director of quality for Fairfield Manufacturing, speculates that the effect of QS-9000 may be to limit the number of small suppliers in the market.

Other, more immediate problems also require attention. Many see a danger in the customer-specific portion of the standard. While people like John Shea, corporate QS-9000 spokesman for GM, insist that the company-specific portions of the standards are not too divergent, others are concerned that Big Three insistence on these procedural differences puts suppliers back where they were before the standard was imposed—trying to meet three separate sets of customer standards.

An ancillary concern is what QS-9000 means for the whole ISO 9000 movement. On the one hand, QS-9000 certification includes an automatic ISO 9000 award as well. But Charles Brannen questions what will happen if other industries follow suit with individual standards. What then happens to the idea of one, universally accepted criterion for assessing quality? "That could put the supplier back in the position of having to meet all kinds of different standards," he says.

On the other hand, Dan Phebus predicts that over time, the differences may level out. He points out that the Big Three also need to reduce costs, and demanding all kinds of special documents and procedures is expensive for them as well as for their suppliers.

Amy Zuckerman, author and ISO 9000 expert, is also concerned that the growth of industry-specific standards will complicate developing an international registrar agreement and will also lead to lots of duplicated efforts.

Suppliers should also be aware that many automotive customers don't require QS-9000, but have their own sets of requirements. The Japanese automakers, for example, have not signed on. Dan Phebus asks, How do you justify one quality system that includes PFMEAS, control plans, etc., when all customers do not demand this level of documentation.

QS-9000 also puts pressure on first-tier suppliers to demand the same level of quality from their suppliers that the Big Three is now demanding of them. John Wendland asks, "How do we cascade this system down the supply chain? How do we handle small shops, people who are good, trusted suppliers, who are not geared up for this kind of elaborate q.c. system?"

Another concern is whether or not QS-9000 is just another "flavor-of-the-month" system that will be obsolete in five years. Although some in the industry express this concern, and, in truth, there is nothing to prevent the Big Three from changing their minds, most people we spoke with feel reasonably confident that Ford, Chrysler and GM are in for the long haul on QS-9000. They have invested a great deal of time and money in developing this standard. Furthermore, because ISO 9000, which is internationally recognized, is at the core of QS-9000, there is additional motivation to go with this framework.

Finally, QS-9000 is by no means cast in bronze. It is already into a first set of revisions, with more to come. Some of these revisions are welcome. Fred Teetor of FQS points out that the original standards contained a number of demands that were, "nuts, self-serving and stupid." As time goes on, many of these will fall by the board. On the other hand, the changing nature of the standard is just one more concern for suppliers.

To Jump or Not

And where does this leave the supplier wanting to deal with the Big Three? How serious are they? Is there a way to do business with them and not have to go through the elaborate, expensive set of QS-9000 hoops? Yes and no—mostly no.

As little as six months ago, many suppliers were hoping the whole thing would go away; that when push came to shove, there would be a way to avoid certification. That view is changing. Everyone we spoke to concurs that the Big Three are very serious indeed about requiring certification. As Jeff White puts it, "If you're going to play, you're going to have to be part of the team."

However, there may be some exceptions to this rule. Price is still going to be an important factor in determining who gets Big Three business. As Dan Phebus points out, "Quality is only one-third of the procurement triangle. Delivery and price are still factors, and it's possible the Big Three will still count them as much as certification." Furthermore, if you're in the fortunate position of providing a unique product that is not easily obtainable elsewhere, you may have some wiggle room.

On the other hand, no one recommends betting the Big Three will change their minds about QS-9000. Even vocal critics like Ralph Teetor recommend getting your company ready internally for a QS-9000 audit now, even if you wait until it's absolutely necessary to get certification.

Time Crunch

But don't wait too long. GM and Chrysler are requiring certification by the end of 1997 at the latest. Ford wanted its suppliers ready for a self-assessment upon receipt of QS-9000 documents in June of 1995. In the meantime, according to Rick Clements of the National ISO 9000 Support Group, presently only 24 companies are authorized registrars, although this number will increase. That's 24 companies to audit 21,000 auto industry suppliers.

Under those circumstances, a bottleneck in the certification process is almost inevitable. In order to avoid being at the end of a long waiting list, your company should be involved in talks with potential registrars now.

Not being a first-tier supplier doesn't entirely let you off the hook either. If you're a supplier to a company going through a QS-9000 audit, it's wise to be in conversations with it to find out what the trickle-down effect, if any, of this new system is going to be on your procedures.

Don't Panic

On the other hand, it's important to keep QS-9000 in perspective. You may not need QS-9000 certification at all. If your particular customers don't require certification, the entire issue is irrelevant. Furthermore, if you've already qualified for ISO 9000 or one of the earlier Big Three quality standards, you're already well on the way to QS-9000 certification. Even if you've done neither, but have a good, documentable quality system in place, qualifying should not be an intolerable burden.

Good planning will go a long way toward easing implementation. Conversations with your customers now and a self-assessment of your current quality system will give you an idea of what you need to do.

Finally, remember that whether it's ISO 9000, QS-9000 or some other quality standard, these kinds of documentable and procedurally driven programs are the direction in which the industry is going. If your customers aren't demanding one now, they probably will be in the future. Whether you seek certification or not, now may be the time to pull up your socks and begin preparing your company to meet these kinds of customer demands. ✪

Tell Us What You Think... If you found this article of interest and/or useful, please circle Reader Service **Number A-102.**

The Goof-Off Guide to INDY

Photo courtesy of Indiana Convention & Visitors Assoc.

Trade shows can be exhausting.

You work hard all day, meeting people, wheeling and dealing, walking the aisles. After a long day of working the show, sometimes you just need to relax for awhile. With Gear Expo '95 fast approaching, *Gear Technology* has gone ahead and done some of the legwork for you. We've come up with some places to go and things to do that have absolutely nothing to do with gears.

For starters, you'll need someplace to eat. We spoke with our Indiana correspondent, "Dave," to find out the best places for good Hoosier food. Dave says you can find good eats at the following restaurants, all located within walking distance or a short cab ride of the Convention Center.

• **Iaria's Italian Restaurant**. This is a "pretty good Italian restaurant" that's off the beaten path, on the Southeast edge of the downtown area, says Dave. The tourists don't know about it, so it's where the locals go for good pasta. 317 S. College Ave.

• **St. Elmo's Steakhouse**. A very nice steakhouse, with very nice prices, so bring your expense accounts. Also, this restaurant is "cigar-friendly" for anyone interested in lighting up a stogie after dinner, says Dave. 127 S. Illinois Ave.

• **Shapiro's Deli**. At this cafeteria-style eatery, you can request your favorite deli meats on your favorite deli breads with your favorite deli spreads. Dave's review: "Not a quiet dinner by any means, but it's good food." 808 S. Meridian St.

• **Rick's Cafe Americain**. If you're tired of fast food and eating on the run, this is a sit-down restaurant that's basically a "fancy hamburger place," (with somewhat fancy prices) Dave says, but the menu has a wide selection, and the food is very good. Located in Union Station.

• **Sports Bar**. For night life, Dave recommends the bars on Meridian Street near Union Station. The Sports Bar features several individual connected bars, each with it's own variety of live music. 225-233 S. Meridian.

Fun Facts About Indy

- **Population: 818,000, the 12th largest U.S. city.**
- **Average Temperature in November: 41.8°F**
- **Taxi Fares: $2.70 for the first mile, $1.80 each additional mile (prices may vary).**
- **Approximately half the population of the U.S. is within a day's drive of Indianapolis.**

Cool Places Within Walking Distance of the Convention Center

▼

• **Indianapolis City Center.** A 13-by-13-foot model of the downtown area comes alive at the touch of a button to give you the highlights of the city. More than 300 free maps, schedules and brochures are available. Also has a souvenir gift shop. On Capital Avenue, across from the dome.

• **Circle Centre.** The city's newest shopping center opened in September with approximately 100 stores on 4 levels. The center is connected to area hotels and the convention center by skywalk. Also features the Artsgarden, an 8-story glass rotunda suspended over the street. Two blocks East of the convention center on Maryland Street.

• **The Indiana State Capitol.** Tour the Indiana Supreme Court and the House and Senate Chambers. Feel the history. Across from the convention center.

• **Union Station.** Built in 1888, this was America's first union railway depot. Recently renovated with 20 fast food restaurants, seven full-service restaurants and 45 specialty shops. Connected to the convention center by skyway, through the Crowne Plaza Hotel.

Hot Times In Indy While You're Here

▼

November 9–11 — Bands of America. Grand Nationals high school marching band competition. At the RCA Dome, (800) 848-BAND.

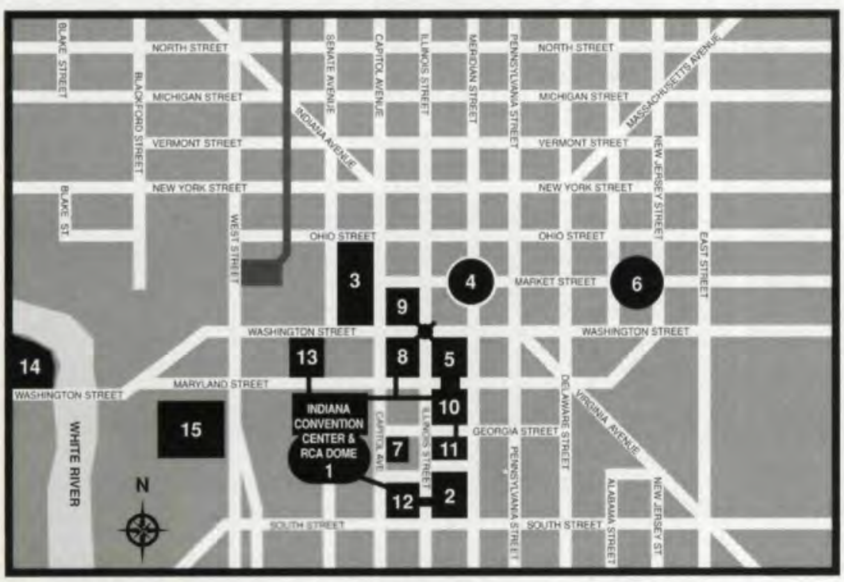
November 10 — Sacramento Kings at Indiana Pacers. Market Square Arena, (317) 263-2100.

November 10 — Winterland Christmas display begins. A drive-through park featuring more than 400 themed, lighted displays. More than 2 million lights will decorate a $2^1/_2$-mile drive. At the Indiana State Fairgrounds, (317) 927-7500.

November 12–15 — Gear Expo '95. Meet gear enthusiasts and professionals from around the world. Be there.

November 13 — Victorian Christmas display begins at the President Benjamin Harrison Home, (317) 631-1898.

November 18 — Carquest Dodge Monster Drags. Don't miss this exciting monster truck action! At the RCA Dome, (317) 236-6515.



Key to Buildings
1. Indiana Convention Center & RCA Dome
2. Union Station
3. Indiana State Capitol
4. Monument Circle
5. Circle Center Mall
6. Market Square Arena
7. City Center
8. Hyatt Regency Hotel
9. Embassy Suites Hotel
10. Canterbury Hotel
11. Omni Severin Hotel
12. Crowne Plaza Hotel
13. Westin Hotel
14. Indianapolis Zoo
15. Indianapolis Indians Baseball Park

GUIDE TO THE GOODS

Gear Expo '95 promises to be the biggest show ever put on by the American Gear Manufacturers Association. The following* Gear Technology *advertisers are exhibiting at the show. All booth and exhibitor information valid as of 9/25/95.

SHOPPING THE SHOW

Booth #100 — American Pfauter, L.P., will introduce to North America the unique Pfauter P100 wet/dry hobbing machine. Also in the booth is the Zeiss Höfler ZP400/630 gear measuring system and the Kanzaki gear shaving machine. Kapp-Coburg will display a unique grinding module for topological gear grinding. **Pfauter Maag Cutting Tools, L.P.**, will display its complete line of hobs, shaper cutters and form cutters. The company will show its new TiN, TiCN and TiAlN coating unit.

Booth #101 — Sunnen Products Company will feature its EC-3500 high production honing machines for the sizing and finishing of gear bores. In addition, visitors will see the CGM-5000 Krossgrinding® System for precision gear honing and bore sizing.

Booth #121 — Nye Lubricants, Inc., a manufacturer of specialty lubricants for more than 150 years, will be exhibiting a line of synthetic gear greases and oils. Visitors can stop by and ask about Nye's exclusive ultra-filtration service for contaminated greases and oils.

Booth #124 — Fellows Corp. Representatives will discuss the increasing integration of CNC capabilities into their unique Hydrostroke gear shaping machines to optimize feed rates and production cycles. Also featured will be the Fellows line of cutters.

Booth #127 — Perry Technology Corporation specializes in shaped internal and external helicals, face gears, aircraft splines cut in exotic materials, short lead-time prototypes, helical broaching and copper and graphite gear electrodes compensated for shrinkage and overburn.

Booth #131 — Welduction Corporation. Meet Pat Anderson, Gil Traverse and Dan Williams from this manufacturer of induction heat treating equipment. They will discuss induction heat treatment of gears, sprockets and splines and how you can manufacture complete turnkey systems with cell-type concepts.

Booth #132 — The Gleason Works. The Gleason exhibit has a theme of "Process Flexibility for Spur and Helical Gears." It features the new Phoenix 200GH CNC hobber for gears up to 205 mm OD, the TAG 400 gear grinder and the latest Hurth CNC shaving machine. Process options such as wet vs. dry hobbing and contour dressing for gear grinding will also be addressed at the booth.

Booth #150 — Reishauer Corporation is unveiling its newest large machine, the RZ 820. The machine includes many new features that the company says will improve quality, reduce setup times and reduce grinding times by as much as 20-25%.

Booth #200 — Star Cutter Company will exhibit a complete line of hobs and shaper cutters, including carbide hobs for dry cutting. Also on display will be its thin-film PVD coatings, such as TiN, TiCN and TiAlN. The booth will feature a universal CNC sharpening machine, model #UTG-600, with demonstrations of hob, shaper cutter and broach sharpening.

Booth #214 — SU America Inc. will feature the SCT3 universal gear chamfer/deburr machine, along with master gears and SU America's full line of gear cutting tools, including chamfering tools, deburring tools, hobs, shaving cutters and shaper cutters. In addition, visitors will be able to see worms, screws, rotors and internal and external gears ground on SU America's CNC grinding machinery.

Booth #224 — American Sykes Company will display its model AMS-250-1AL gear metrology system, which allows non-contact motion of its measurement axes through the use of aerostatic bearings. In addition, the booth will feature James deburring and chamfering systems and American Sykes' full line of gear cutting tools.

Booth #232 — M & M Precision Systems will show how its line of gear inspection machines can be networked with an off-site PC for SPC and data gathering. In addition, M&M will introduce a new version of its machines with a smaller footprint, and the Master Gears/Spline Gages division will show a new dimensions-over-pins gage.

Booth #244 — Oberlin Filter Company will demonstrate a completely automatic filtration system for oil, water-based or synthetic coolants that company officials

Wind
TACKE
Energy with a Future
More and more wind turbines are being used around the world to supply us with economical electric energy, without harm to our environment.
The requirements placed on wind turbine drive systems are extraordinarily high. They must be compact and operate with absolute reliability. Noise must be held to a mere whisper.
Today, most of the gears used in wind turbine drive systems are ground on HÖFLER machines. They satisfy all the special requirements to the industry's fullest satisfaction.
HÖFLER gears, quiet as a whisper.
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HÖFLER Corp.
P.O. Box 127
Sky Manor Rd.
Pittstown, N.J. 08867
Phone: (908) 996-6922
Telefax: (908) 996-6977
HÖFLER GmbH
P.O. Box 0452
76258 Ettlingen
Germany
Phone: -49-7243-599-0
Telefax: -49-7243-599-165
Höfler gear grinding machines from specialists, for specialists

say improves quality and reduces "cake" disposal, media usage and coolant replacement costs. The system is applicable to gear grinding, surface grinding, creep-feed grinding and related operations.

Booth #300 — GMI will display gear deburring machines utilizing wheels and brushes. In addition, the booth will have gear cutting tools, including bevel gear tools, hobs, Maag cutting tools, shaving cutters, etc., and special tools for hard gear finishing machines, including honing wheels and diamond dressing devices.

Booth #318 — *Gear Technology*. If this isn't your very own copy of *Gear Technology*, stop by and fill out a qualification form for a FREE subscription. We'll have extra copies of the November/December Show Issue and a limited quantity of the September/October Buyers Guide. *Stop by and say "Hello" to our entire gear gang.*

Booth #348 — Mitsubishi Machine Tool presents its MMT (Minimum for Maximum Thru-put) technology, featuring the GD20CNC Gear Hobber with simplified setup by quick-change tooling and rigid construction for maximum cutting capabilities. The FB 30 CNC Gear Shaver and the TC 8 BCNC Turning Center will be on display.

Booth #406 — Diamond Black Technologies. Increase power density, increase gear life and reduce warranty costs using Diamond Black's high volume physical vapor deposition process for boron carbide. According to company representatives, this process can extend the life of gears sevenfold at 50% of the cost of grinding.

Booth #414 — American Gear Manufacturers Association, the sponsor of Gear Expo '95, is an organization for the manufacturer of gears and gear products and those with a direct interest in the engineering and application of gears and flexible couplings. Representing 350 international companies, AGMA develops standards for ANSI and is an active participant in ISO.

Booth #415 — Multi-Arc Inc. is a leading supplier of physical vapor deposition (PVD) coatings, technology and equipment. Stop by its booth to learn more about ION BOND® coatings, which provide increased wear and corrosion resistance to industrial cutting tools, metal forming dies, plastic molds, wear parts and medical devices.

Booth #422 — Niagara Gear Corporation. On exhibit will be illustrations of its state-of-the-art gear grinding equipment, including the Gleason TAG-400, enlarged Cpk charts and other SPC-related systems. Visit the booth to receive free golf tees and a chance for Top Flite golf balls or the grand prize of a genuine "Big Bertha" Callaway golf club.

Booth #423 — Sytec Corp./Benemac S.A. will feature Benemac cages, which accurately locate the pitch diameter of the gear and allow the machining of surfaces concentric and perpendicular to the P.D. The staff will be demonstrating hard turning of a gear on an OJUMA LCC15-2S, showing how the cages increase productivity and accuracy.

Booth #442 — Colonial Tool Group, a broaching tool manufacturer, will feature its complete line of broaching tools and spline rolling racks, including the company's new helical spline broaches. Also, the company will feature machine spindles and a turnkey setup for broaching keyways, internal gears and other parts.

Booth #500 — JRM International, Inc., will exhibit a Kesel CNC rack milling machine with auto leveling, Kesel high pressure centering and standard vises, Schrem hydraulic locknuts, Saazor inserted blade hobs and Baublys marking machines.

Booth #509 — WMW Machinery Company, Inc. will highlight its complete line of gear machinery, including gear generating and profile grinding machines from Niles (Germany), gear hobbing machines from HURTH MODUL (Germany) and gear hobbing and shaping machines from TOS CELAKOVICE (Czech Republic).

Booth #514 — ITW Heartland will show its complete line of inspection and burnishing equipment. Featured will be high-speed automatic inspection and burnishing machines, manual gear rollers, DOP units, computerized gear rollers and master gears.

Booth #523 — Amarillo Gear Co., specializing in spiral bevel gears, hypoid gears, right-angle pump drives and cooling tower fan drives, will have on display samples of its products, including loose spiral bevel gears, a cutaway right-angle drive and a segment from a 74" diameter ring gear.

Booth #524 — Bourn & Koch Machine Tool Co. will demonstrate its model 25H gear hobbing machine, which can hob gears of 1" diameter. The 25H is designed for high production of small gears or shafts. Bourn & Koch will also show other machines and capabilities.

Booth #525 — Profile Engineering, Inc., will demonstrate the PC-20 Composite Gear Analyzer®, a double-flank composite gear measuring instrument with a computer data acquisition and analyzing system. The PC-20 has a rotary encoder that monitors the circumferential position of the master gear. It can display center distance variations in either manual or automatic mode.

Booth #530 — Basic Incorporated Group is the national distributor for Wolf gear machines. Its product line includes shapers, shavers, hobbers, honers, test equipment and more. Basic also offers service for Wolf gear machines and other makes. Stop by the company's booth to see a program-controlled hobber, a 20" shaper, a 12" honer and various test equipment.

Booth #606 — Global Gear is an OE manufacturer of high quality, precision helical and spur gears. Representatives at the booth will discuss with you their "modern, flexible manufacturing systems" and how they strive to provide "the best value" and "on-time delivery."

Booth #609 — Dura-Bar. Continuous cast gray and ductile iron from Dura-Bar offers many advantages to manufacturers of gears. Dura-Bar's continuous casting process eliminates the scrap that results from shrinkage, porosity and tool wearing inclusions. Dura-Bar round bars are available in diameters ranging from 5/8" to 20".

Booth #614 — American Metal Treating Co. will be displaying sectioned single-tooth induction hardened gears. The company's capabilities include single-tooth contour hardening and submerged induction hardening using the Delapena process. Technical staff will be on hand to discuss your heat treat and distortion problems.

Booth #622 — Schunk Intec will have on display its line of precision hydraulic expansion arbors and chucks in standard and special designs, with repeatability of .00004" and TIR < .00012". Also, see custom designed tools, Schunk gripping systems and vacuum components and the TANDEM two-jaw clamping system which offers centering repeatability of .0004", available with integrated base plates and top jaws.

Booth #642 — Sigma Pool will demonstrate a range of gear production machines including the Liebherr LC 82 CNC hobbing machine, capable of dry cutting; the Klingelnberg PNC 33 CNC gear checking machine; and the Oerlikon L20 CNC lapping machine.

Booth #700 — Höfler Maschinenbau GmbH will present its line of high performance, high accuracy gear grinding machines, including innovative gear grinding processes such as Höfler's deep feed grinding process—HDF. The booth will feature a variety of actual grinding examples, photographic material and process literature.

Booth #705 — Windsor Gear & Drive will display gears ranging in quality from AGMA 6 to AGMA 15 as well as several specialty gear drives, including a marine drive for a light-armored amphibious vehicle, components from a drive unit used in electric vehicles and a helicopter camshaft with exotic gear work and cam grinding.

Booth #706 — National Broach & Machine Co. has plenty of new ideas for Gear Expo visitors. The SPIRALGLIDE broach tool offers increased tool life; the CNC BVT workpiece transfer broaching machines allow loading at either the top or bottom of the stroke; and the VBM pot broach features automatic pot changing. Also on display will be the KA-80 hobber for hard finish hobbing and the RED RING gear checker.

Booth #715 — Merit Gear Corporation, a full service gear producer and manufacturer of custom powertrain components, specializes in spur and helical gears, OEM enclosed drives and ground gearing to AGMA class 12. Merit also has full service in-house heat treating, including NATCO submerged tooth-by-tooth contour hardening.

Booth #722 — Six Star Gears (Yieh Chen Co.) started manufacturing precision gears in 1975 and has become a leading gear maker in Taiwan. Its products include spur gears, helical gears, chain sprockets, straight bevel gears, worm wheels, splined shafts, pins, clutch flanges, gearboxes, gear pumps and gear grinding services.

Booth #726 — A/W Systems will present its line of finisher cutters with interchangeable blades for ring gear production. Made in the U.S.A., the complete finisher package includes bodies from 5" through 9" diameter, hardware and finisher blades designed and precision manufactured to be quickly exchanged as needed.

Booth #730 — Roto-Technology, Inc., will be demonstrating two machines—the standard RC-400-12 and the Micro-6 gear inspection machine. Both machines will run Roto-Technology's complete software library and both have the new rotary probe with an AGMA 15 level of accuracy. There will be other technological improvements and innovations, including testing fine pitch gear inspection with the Micro-6 and adding camshaft testing.

Booth #736 — Bevel Gears (India) Pvt. Ltd. manufactures spiral and straight bevel gears from 0.5 module to 20 module, with spiral bevel grinding capabilities. The company also provides complete gearboxes for applications such as machine tools, railroad equipment, mining equipment, automobiles, hand tools and others. Its booth will have samples of gears and gearboxes.

Booth #817 — Redin Corporation will demonstrate its dual-purpose cleaning and deburring machine. Without a cleaning process, the mixture of cutting oils and grinding dust created by deburring can cause problems for the finished part. Redin integrated the cleaning and deburring processes, using a self-contained filtration system. ○

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Effect of Web & Flange Thickness on Nonmetallic Gear Performance

Abiy Tessema, Doug Walton & David Weale

Nomenclature

b	face width (mm)	d_p	pitch diameter (mm)
F	force (N)	K_B	rim thickness factor
t	rim thickness (mm)	T	torque (Nm)

Introduction

Gears are manufactured with thin rims for several reasons. Steel gears are manufactured with thin rims and webs where low weight is important. Nonmetallic gears, manufactured by injection molding, are designed with thin rims as part of the general design rule to maintain uniform thickness to ensure even post-mold cooling. When a thin-rimmed gear fails, the fracture is through the root of the gear, as shown in Fig. 1a, rather than the usual fillet failure shown in Fig. 1b.

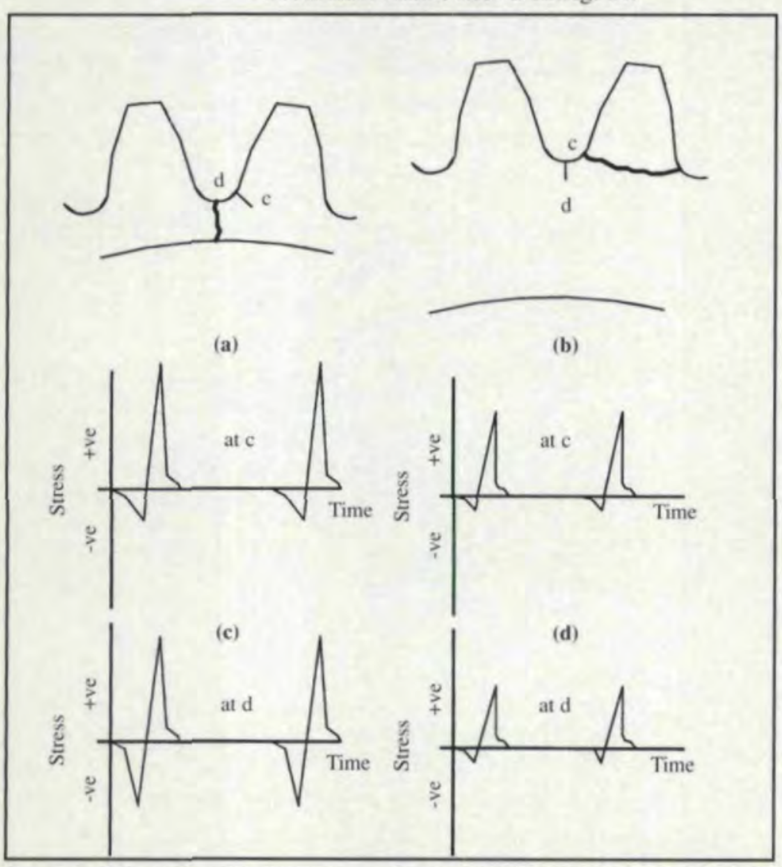

Fig. 1 — Failure due to bending stress for (a) thin-rimmed gears and (b) thick-rimmed gears. Tooth bending stresses for (c) thin-rimmed gears and (d) thick-rimmed gears.

The failure of thin-rimmed gears through root fracture was first explored by Drago (Ref. 1). He showed that for thin-rimmed gears, the bending stress varied from a larger compressive stress to an even larger maximum tensile stress (see Fig. 1c). For thick-rimmed gears, the bending stress varied between a small compressive and a large tensile stress (Fig. 1d). Comparing the root and fillet of thin-rimmed gears, it is possible to see that the higher compressive stress is found at the root of the gear; thus, the alternating stress at the root of the gear tooth is higher than at the fillet, making the root of the gear the critical section for fatigue failure. The compressive part of the stress for thin-rimmed gears is the result of compressive deflection caused by the preceding tooth pair. Drago compared his experimental result with finite element analysis, where good agreement was found. The finite element analysis involved calculating both the compressive and tensile stresses for different points from the fillet to the root to determine the maximum alternating stress and its position. Drago's later work on rim factors, which accounts for the difference in stress level between thin- and thick-rimmed gears, is now incorporated in AGMA 2001 (Ref. 2). Gulliot and Tordion (Ref. 3) have analyzed the bending stress of thin-rimmed gears with keyways using finite element methods. They plotted a nondimensional stress number, σ (defined in Eq. 1 as a function of maximum root stress, pitch diameter, normal force and face width), as a function of the ratio of the rim thickness to the pitch diameter, t/d_p.

$$\sigma = \frac{\sigma d_p b}{F} \qquad (1)$$

However, this shows only maximum stresses as a function of rim thickness, not the alternating stresses. Because of this, its application is limited, since it does not address the main failure mode of thin-rimmed gears, which is fatigue.

These researchers used two-dimensional finite element methods. For nonmetallic gears molded with a web and flange, the problem is three-dimensional. Considering this, Davoli *et al* (Ref. 4) tried to determine the optimum web and flange thickness based on deflection analysis. Their conclusion suggested a minimum rim thickness of about 3 times the module. Their work, however, did not consider load sharing, the running of polymer gears against steel, nor the distribution of stresses or deflection across the gear face width, and experimental work in this field appears to be nonexistent.

The objective of this work was to make a detailed assessment of the effect of web and flange thicknesses on the performance of nonmetallic gears. The analyses considered the running of polymer gears against each other and against steel. The work was achieved by the use of three-dimensional finite element analysis. Experimental work was also done to supplement and compare with computer simulations.

Finite Element Model for Nonmetallic Gears

Nonmetallic gears made by injection molding cannot have a solid body, thick sections or large differences of thickness between contiguous parts because of differential cooling and shrinking after molding. Thick sections also result in longer cycle times when molding. The maximum practical wall thickness in plastic moldings is about 12 mm. For these reasons, nonmetallic gears typically have the features shown in Fig. 2. The important parts are the teeth, the rim or flange, the web, the hub and often a metal insert. The function of the metal insert is mainly to avoid failure at the hub under load. The rim is tapered by about 2 degrees to facilitate ejection after molding. On the other hand, cut nonmetallic gears have solid bodies.

For all practical purposes, in modeling nonmetallic gears, the effect of the metal insert can be neglected, as its influence on tooth bending stress and deflection is negligibly small. Because of symmetry, it is only necessary to model half the gear (see Fig. 3a). The driver and driven gears were modeled together, making contact at the pitch point (Fig. 3b). This is because, for nonmetallic gears, the pitch point is the contact position where a single tooth pair is most likely to carry the full load and probably results in the maximum root stress (Ref. 5). To minimize computing time while retaining a reasonable degree of accuracy, the models shown in Fig. 4 were compared.

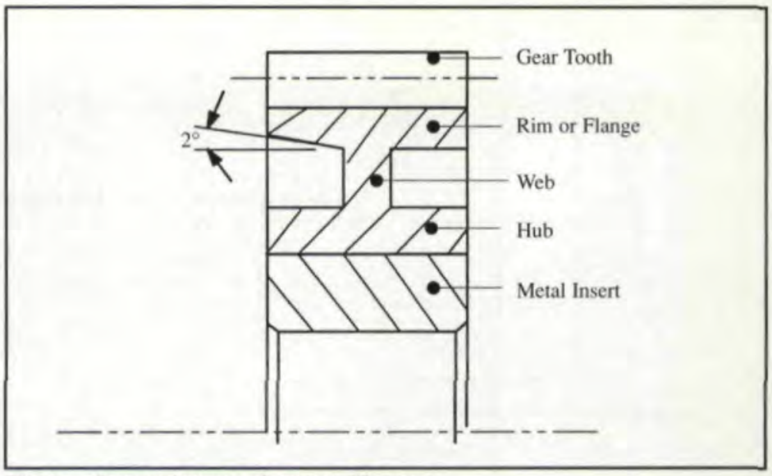

Fig. 2 — General features of nonmetallic gears.

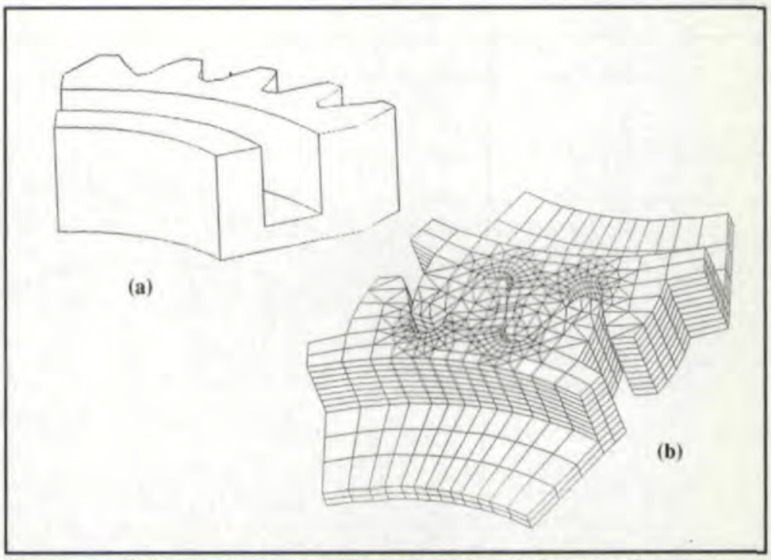

Fig. 3 — (a) Half model for nonmetallic gears; (b) model of gear tooth contact.

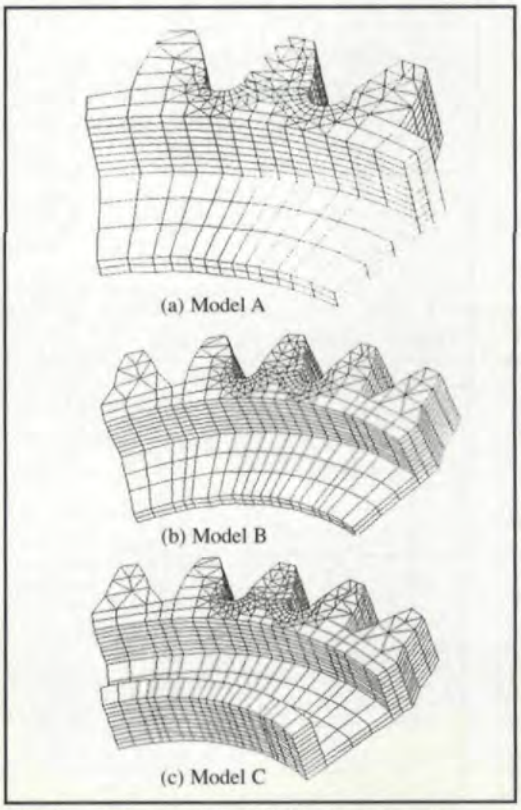

Fig. 4 — Various models of finite element mesh.

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Dr. David Weale
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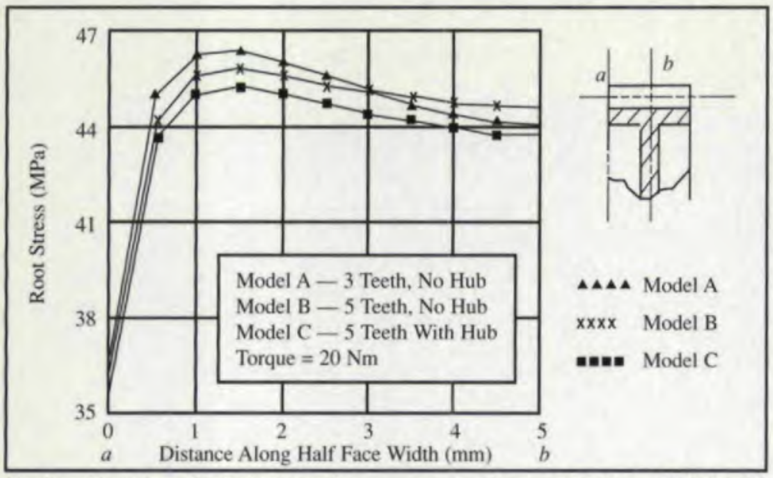


Fig. 5 — Variation of principal bending stress across the gear half face width for different finite element models.

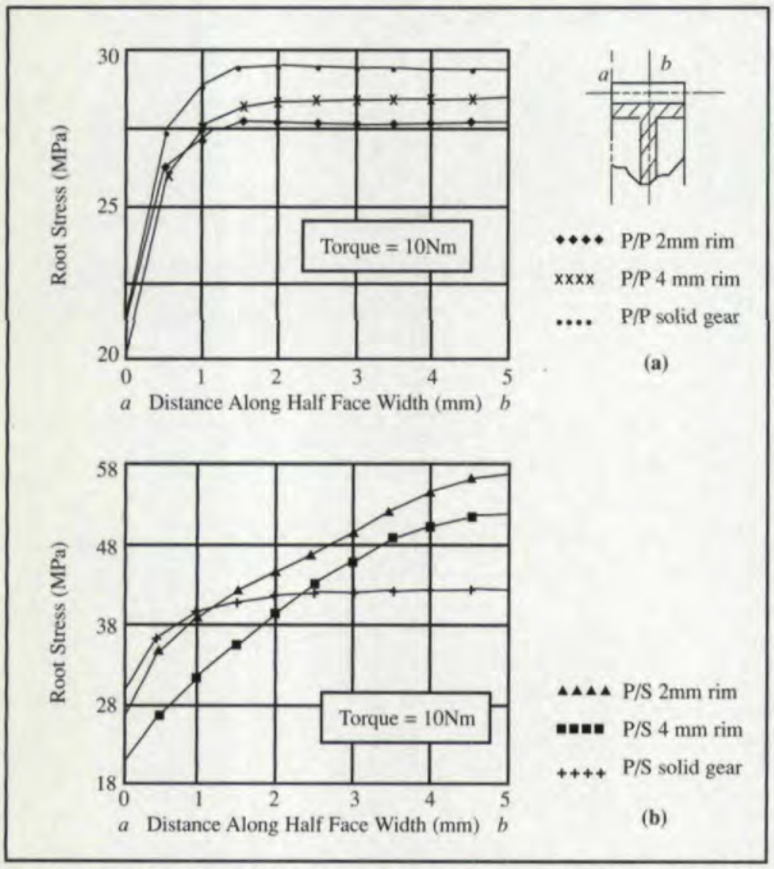


Fig. 6 — Variation of principal root bending stresses across the gear half face width for (a) polymer/polymer gear pairs and (b) polymer/steel gear pairs.

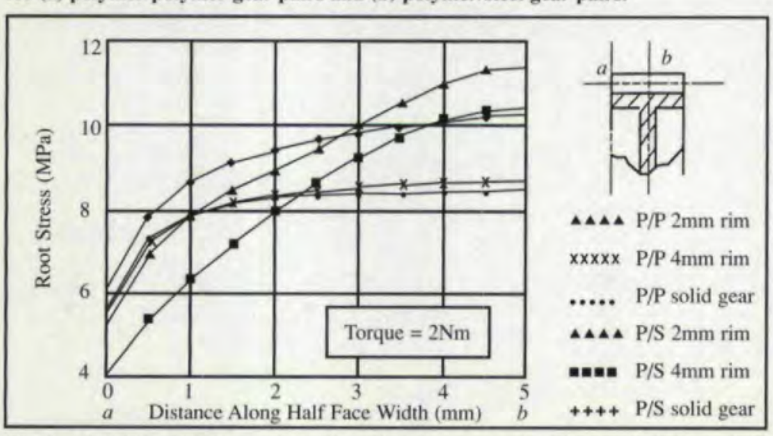


Fig. 7 — Variation of principal root bending stresses across the gear half face width for 2 Nm.

Linear brick and wedge elements were used for the gear mesh. The wedge elements were used only to smooth the transition from fine to coarse mesh. Model A was made up of 3 teeth with no hub. The web of the gear was assumed to end on top of the hub. Model B was the same as Model A, except that it was made up of 5 teeth. Model C consists of all the features of nonmetallic gears, except the metal insert, and was also made up of 5 teeth. All these models were loaded to the same torque. The stress distributions for all three models are shown in Fig. 5. As seen in this diagram, the difference in stress levels between the three models was small. For computing efficiency Model A was chosen and all analyses in this report were based on this model.

All the analyses in this work are for a module 2 mm gear with 30 teeth and a 20° pressure angle, with standard gear tooth proportions to BS 436:1970 (Ref. 6). A relatively low face width of 10 mm was used to reduce the computing time involved. Web and flange thicknesses were made variable.

Stress Distributions for Polymer/Polymer and Polymer/Steel Gear Pairs

The effect of web and flange thicknesses on the performance of polymer gears was investigated by plotting stress distributions across the gear face width (see Fig. 6), showing both polymer gears running against each other (P/P) and with steel (P/S). An elastic modulus of 207 and 3 GPa was taken for steel and polymers, respectively. A modulus of 3 GPa is representative of acetal and nylon. In each case, the thicknesses of the rim and the web were made equal, and only the values of the rim thickness are shown in the figures. The applied torque of 10 Nm represents a typical value when running polymer gears against steel for the dimensions of the gears described above.

Fig. 6a shows that the stress distribution across the face width is nearly the same for all values of web and flange thicknesses investigated. The slight increase in maximum stress with increasing web and flange thicknesses is caused by the load sharing effect; i.e, these sections result in larger tooth deformations, leading to increased load sharing. However, the increase in load sharing is caused by edge contact. The plot for polymer gears running against steel (Fig. 6b) shows a distinct difference between solid and webbed gears. Thin web and flange thicknesses result in an increased maximum stress and an uneven stress distribution across the face width. A solid—that is, rimless gear gives the minimum stress levels and the most uniform stress distribution.

In general, the main difference between the P/P and P/S gear pairs is that the latter increase stress and distribute it more widely across the face width for the same applied load because of the difference in flexibility between polymer and steel gears. Polymer gears deflect about 100 times more than steel gears under the same load. Making polymer gears with web and flange features also creates a difference in flexibility across the face width, where the middle part is less flexible than the outer part because of the stiffening effect of the web.

Influence of Applied Load on the Effect of Web and Flange Thicknesses

The effects of web and flange thicknesses are load dependent. Looking at Fig. 7 for P/P gear combinations, the maximum stress levels increase with decreasing rim thickness. For 4 mm web and flange thicknesses, the gear is sufficiently thick to give almost the same stress level as that of the solid, nonrimmed gear. This is in contrast to the results for a torque of 10 Nm shown in Fig. 6. For 2 Nm the load is not sufficiently high to produce any appreciable load sharing effect. This figure also shows that running polymer gears against steel produces an uneven stress distribution across the face width.

Influence of Face Width on the Effect of Web and Flange Thicknesses

Gears with narrow face widths can experience buckling and misalignment, while too large a face width may be subjected to non-uniform load distributions because of twisting. This effect is shown in Fig. 8. A torque of 1 Nm/mm face width was applied for 10 mm and 17 mm face width gears. In both cases, the web and flange thicknesses of the polymer gears were kept to 4 mm. Both of the models were meshed with a solid nonrimmed steel gear. The plot for the 17 mm face width polymer gear shows a high maximum root stress and a wider variation in stress distribution across the gear face width compared to the narrower gear. This figure indicates that there is a dependence between web and flange thicknesses and face width. Wide-faced polymer gears should have a thicker rim (or reinforcing axial webs) than narrow face width polymer gears for the same load per unit face width.

Effect of Web Thickness on Stress Distribution

An analysis was made by varying the thickness of the web for a fixed flange thickness and face width; the results are shown in Fig. 9. The stress distribution for the 2 mm flange and 4 mm web thicknesses is between the 2 and 4 mm web and flange thicknesses. The implication of this result is that changes in web and flange thicknesses have much the same effect on stress distributions.

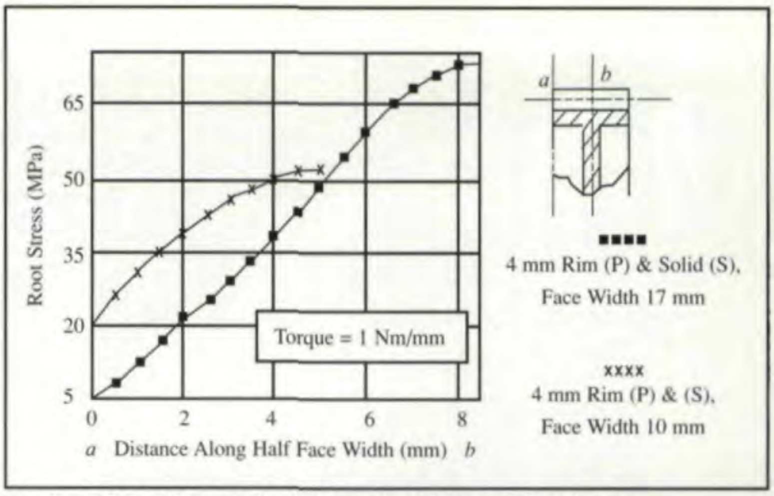


Fig. 8 — Effect of face width relative to rim thickness on bending stress.

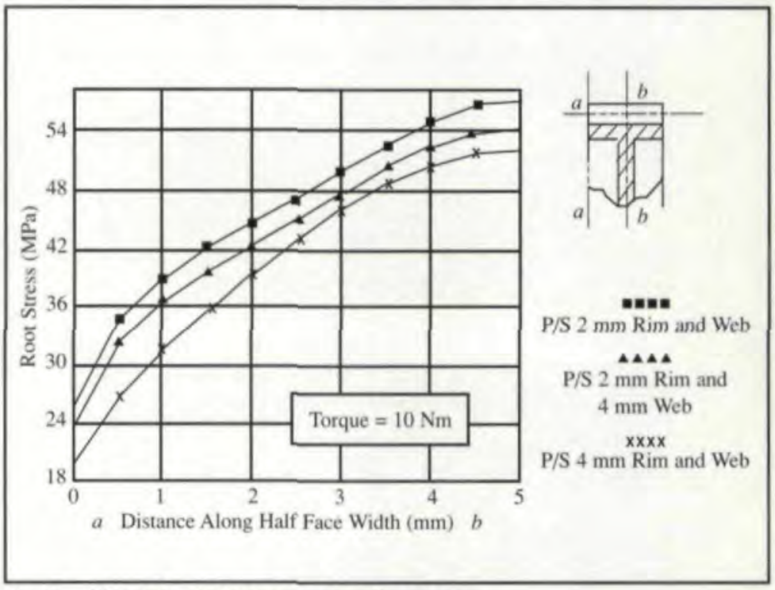


Fig. 9 — Effect of web thickness on bending stress.

Modes of Rim Failures in Nonmetallic Gears

Fatigue tests were carried out on 2 and 4 mm web and flange nylon gears running against steel. The modes of rim failures observed are shown in Fig. 10. Fig. 10a shows a typical failure mode for solid gears. Fig. 10b shows the typical failure mode of thin-rimmed gears with a fatigue crack running from the tooth fillet through to the rim of the gear, as discussed in Section 1. Fig. 10c shows a similar rim failure as in Fig. 10b, but where the fracture has extended from the tooth root to an area of high stress between the flange and the web.

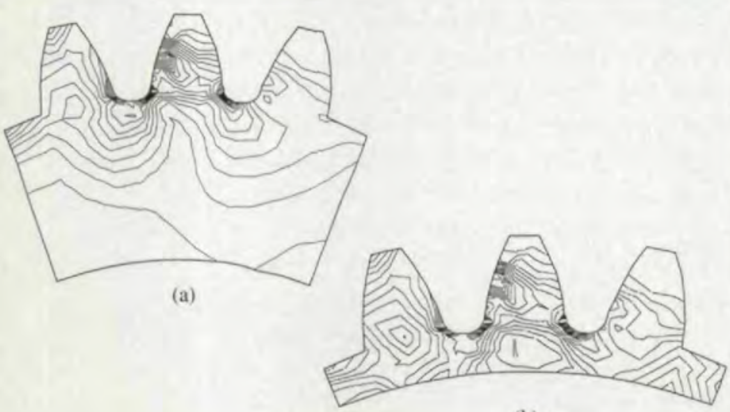
As previously mentioned, Drago explained the failure at the root of thin-rimmed gears rather than at the fillet. On the other hand, experiments have shown that cracks can initiate at the fillet and propagate through the rim of the gear (Fig. 10b). To find an explanation for the failure of thin-rimmed gears in this way, analysis of the stress distribution pattern for thin- and thick-rimmed

(a)

(b)

(c)

Fig. 10 — Modes of rim failure for nonmetallic gears for (a) a solid gear and (b–c) thin-rimmed gears.



Von Mises Stress Distribution for (a) solid rim and (b) thin rim gears.

Fig. 11 — Stress distribution for (a) thick-rimmed gears and (b) thin-rimmed gears.

gears was made using the finite element method. The results are shown in Figs. 11a and b, where for solid gears, the stress intensity in the body of the gear is considerably less than at the tooth fillet, and hence fatigue cracks might not progress to the bulk of the gear. However, for thin-rimmed gears, since the stress intensity in the rim of the gear is much the same as that at the tooth fillet, there is a greater possibility for the crack to propagate across the rim (Fig. 11b).

Remedies for the Effect of Web & Flange Thicknesses

It has been shown that nonmetallic gears with thin webs and flanges result in a difference of flexibility across the gear face width. The middle part is less flexible than the outer face because of the stiffening effect of the web. The effect of this on the stress distribution across the gear face width for polymer/polymer gear combinations was found to be minimal. Web and flange thicknesses 2 to 3 times the module were found to perform the same as solid, nonrimmed, polymer/polymer gear pairs. This was confirmed by experimental tests carried out on acetal/acetal gear pairs by varying web and flange thicknesses (Ref. 7).

For polymer/steel gear pairs, thin web and flange thicknesses on the polymer gear have been shown to result in increased stress levels and a nonuniform stress distribution across the gear face width. From these results, we concluded that polymer gears intended to run against other polymer gears should be designed differently than when they are intended to be run against metal. The use of solid, nonrimmed polymer gears against steel is one solution. This solution, however, is only applicable for cut polymer gears. For molded nonmetallic gears, axially reinforcing webs can be used as an alternative. Running a flexible metallic gear against the polymer gear could be possible if materials of lower elastic modulus, such as aluminum and copper, were used. However, the use of these materials against polymers is not recommended according to BS 6168(8) because of wear-related problems. For wide-faced gears, it has been shown that metallic gears with very thin web and flange thicknesses might be flexible enough to get a near uniform stress distribution across the polymer gear face. Because of the limited number of experimental tests, the limit as to how much the steel gear can be thinned has not been investigated (Ref. 9). In general, running nonmetallic gears against thin-webbed and flanged steel gears has been shown to be advantageous. However, this potential improvement in the performance of polymer/steel gear combinations needs further investigation, as does the use of counter-crowned or double, low-helical-angle polymer gears (Ref. 10).

The effect of web and flange thicknesses on the stress distribution in polymer gears is dependent on load, face width, module and Young's modulus. For this reason, finding a simple analytical formula for the optimum web and flange thicknesses may not be possible. The optimization of a given design by using the finite element method would still appear to be the best option, although for many applications this level of analysis may not be justified. The general results of this research in recommending rim thickness are, however, useful for general applications.

Rim Factor

To account for the effect of rim thickness in calculating bending stresses for steel gears, Drago proposed a rim thickness factor which was included in AGMA 2001 (Ref. 2). The rim thickness factor proposed by Drago is based on measured stress levels at the root of a gear tooth under static conditions. This implies that the rim factor is somewhat similar to a stress concentration factor and accounts only for the geometry of the gear. More conveniently, a rim thickness factor, analogous to the strength reduction factor, which takes into account geometry, material and operating conditions, can be determined from fatigue tests using the following equation (see Fig. 12).

$$K_B(l,r_t) = \frac{T_s}{T_r}$$

Where K_B is the rim factor as a function of life, l, and rim thickness, r_t. T_s is the torque for the solid, nonrimmed gear, and T_r the torque for the rimmed gear; both for a life of l cycles.

In the equation above, T_s and T_r can be replaced by corresponding bending stresses calculated using the Lewis equation. Clearly a large number of tests would need to be carried out on a range of gear rim and web thicknesses and polymer materials in order to determine K_B values for inclusion in practical designs.

Conclusions

This study shows that making nonmetallic gears with thin webs and flanges results in a difference of flexibility across the face width and, consequently, an uneven stress distribution. This effect was most pronounced when running polymer gears against steel. From this we see that the design of polymer gears to run against steels should be different from their design when they are intended to run against other polymer gears. The influence of lead and face width relative to web and flange thicknesses has been investigated where the effect of web thickness was found to be the same as flange thickness.

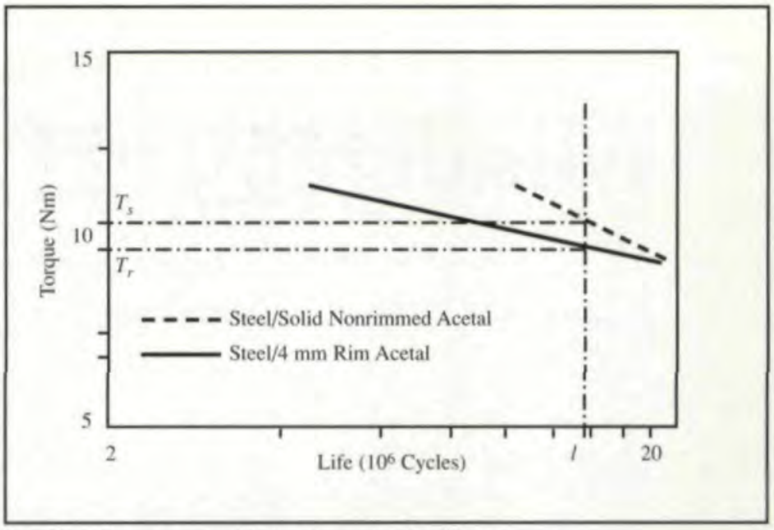


Fig. 12 — Torque versus life for rimmed and solid gears.

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Determining Spline Misalignment Capabilities

Richard T. Friedman

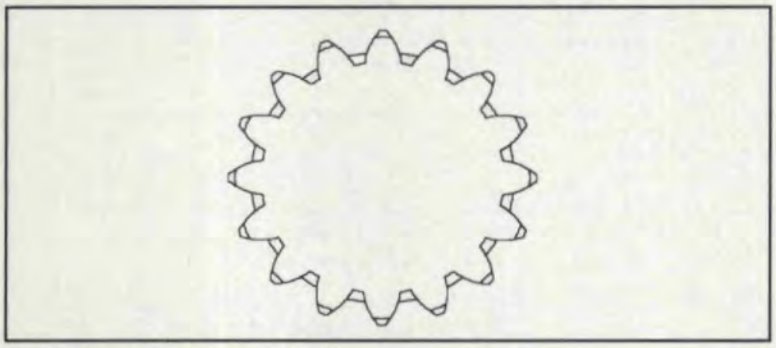

Fig. 1 — Inner and outer tooth profiles.

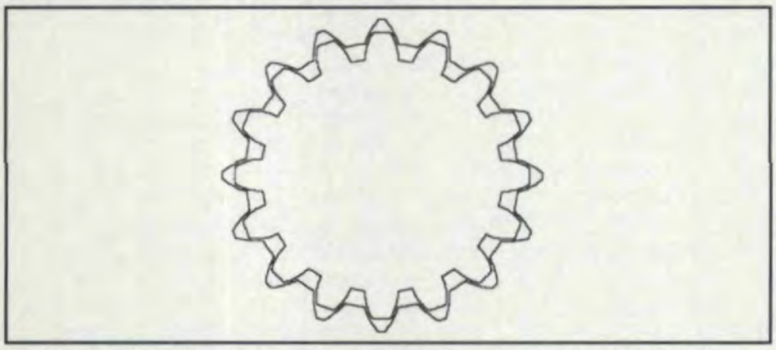

Fig. 2 — Tooth profiles where effective tooth thickness measured at the pitch diameter has been reduced by .015"

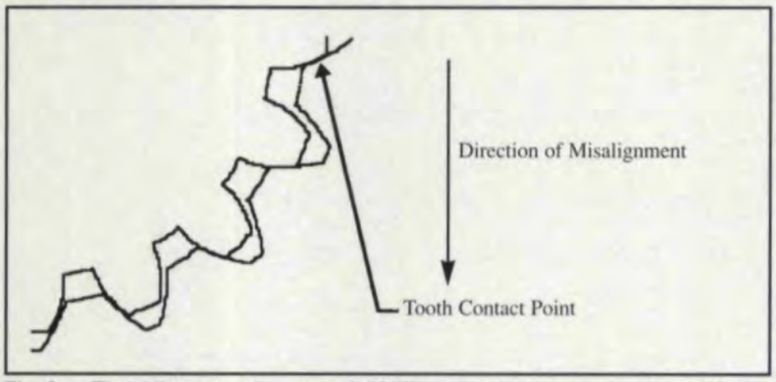

Fig. 3 — The spline center has moved .0065", and contact occurs on the tooth perpendicular to the direction of misalignment.

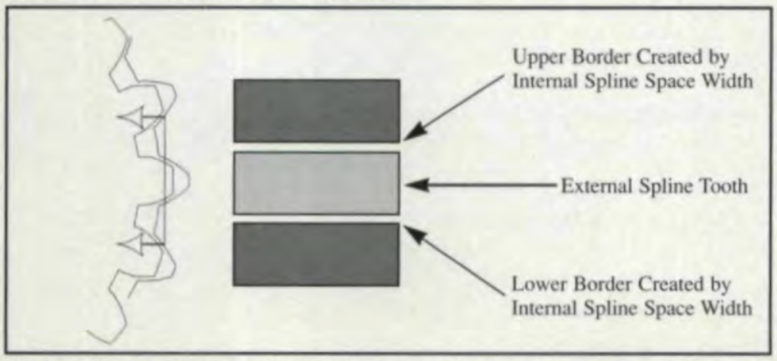

Fig. 4 — Cross section of one tooth on the external spline and one space width on the internal spline.

Introduction

Introducing backlash into spline couplings has been common practice in order to provide for component eccentric and angular misalignment. The method presented here is believed to be exact for splines with even numbers of teeth and approximate for those with odd numbers of teeth. This method is based on the reduction of the maximum effective tooth thickness to achieve the necessary clearance. Other methods, such as tooth crowning, are also effective.

Tooth Thickness and Its Relationship to Misalignment Capability

It is important to understand what feature of the spline provides the misalignment capability. The approach presented here focuses on the spline tooth and space width that is perpendicular to the direction of misalignment. As shown in the following set of figures, this set of teeth is the geometry that controls the misalignment.

Fig. 1 shows the inner and outer tooth profiles of a 16-tooth, 24/48-pitch, 30° pressure angle, fillet root, side-fit spline at maximum material conditions. In this state, no allowance for misalignment exists. The effective tooth thickness of the external spline (inner profile) can be reduced during manufacturing to provide clearance (see Fig. 2).

In Fig. 2, the external spline has been reduced. In shaping or hobbing, this is accomplished by increasing the feed of a standard cutter. In this illustration, the effective tooth thickness measured at the pitch diameter has been reduced by .015".

The resulting clearance allows the spline centerlines to be offset to provide for component misalignment. This appears in Fig. 3, where an enlarged section has been shown for clarity. Note that the amount the spline center moved is .0065" [(Tooth Thickness Reduction/2) • cos30°]. When the spline tooth in Fig. 3 is rotated 30° about the shaft centerline, the normal to the involute profile at the pitch diameter is in the misalignment direction. At that point, the profile of the internal and external splines are colinear. This is the limiting geometry, and it is compensated for by the above trigonometric relationship to the horizontal tooth position.

To calculate the allowable misalignment (angular and eccentric), it is necessary to consider

$$t1 = \frac{-(s - 2 \cdot \cos\beta \cdot HK \cdot \sin\theta + 2 \cdot \cos\beta \cdot \tan\lambda \cdot HK \cdot \cos\theta - 2 \cdot \cos\beta \cdot GZ \cdot \tan\lambda - 2 \cdot \cos\beta \cdot GH)}{(-\cos\beta \cdot \cos\theta - \cos\beta \cdot \tan\lambda \cdot \sin\theta)}$$

$$t2 = \frac{-(s + 2 \cdot \cos\beta \cdot GZ \cdot \tan\lambda + 2 \cdot \cos\beta \cdot GH + 2 \cdot \cos\beta \cdot HK \cdot \sin\theta - 2 \cdot \cos\beta \cdot \sin\theta \cdot Ls - 2 \cdot \cos\beta \cdot \tan\lambda \cdot HK \cdot \cos\theta + 2 \cdot \cos\beta \cdot \tan\lambda \cdot \cos\theta \cdot Ls)}{(-\cos\beta \cdot \cos\theta - \cos\beta \cdot \tan\lambda \cdot \sin\theta)}$$

Fig. 5 — Equations to find the tooth thickness required by tip 1 and tip 2 criteria.

one tooth on the external spline and one space width on the internal spline. The set is perpendicular to the direction of misalignment. Viewing a cross section of this from the side in Fig. 4, one can see the tooth of the external spline as well as the borders of the internal spline space width. The values for the space width and tooth thickness at the pitch diameter are used in the calculations.

Coupling

In the example shown in Fig. 6, we shall consider the external spline on the end of a pump shaft and the internal spline on the end of a motor shaft. The pump pivots around point *H*, while the motor pivots around point Z. Point Z is offset vertically by distance *HG* and horizontally by distance *GZ*. Distance *HK* describes the spline length beyond pivot point *H*, and *Ls* is the spline length. The length of the motor's spline teeth must be sufficient to ensure engagement with the pump's spline. The pump angular misalignment is angle θ, and the motor's angular misalignment is angle β. The intercepts *b1*, *b2* and *b3* for contact at Tip 1 and Tip 2 are calculated, but distances *b1–b2* and *b2–b3* are probably not equal to one another. The formulas using *t*1 as the required tooth thickness to meet the geometric constraints that evolve from tip 1 contact with a space width are as follows:

$\gamma = 180 - \beta$

$\text{tip } 1X = HK \cdot \cos\theta - \frac{t1}{2} \cdot \sin\theta$

$\text{tip } 1Y = HK \cdot \sin\theta + \frac{t1}{2} \cdot \cos\theta$

$b1 = \text{tip } 1Y - \tan\lambda \cdot \text{tip } 1X$

$b2 = -GZ \cdot \tan\lambda - GH$

$s = 2 \cdot (b2 - b1) \cdot \cos\beta$

The additional formulas using *t*2 as the required tooth thickness to meet the geometric constraints that evolve from tip 2 contact with a space width *s* are

$\gamma = 180 - \beta$

$\text{tip } 2X = (HK - Ls) \cdot \cos\theta + \frac{t2}{2} \cdot \sin\theta$

$\text{tip } 2Y = (HK - Ls) \cdot \sin\theta - \frac{t2}{2} \cdot \cos\theta$

$b2 = -GZ \cdot \tan\lambda - GH$

$b3 = \text{tip } 2Y - \tan\lambda \cdot \text{tip } 2X$

$s = 2 \cdot (b2 - b3) \cdot \cos\beta$

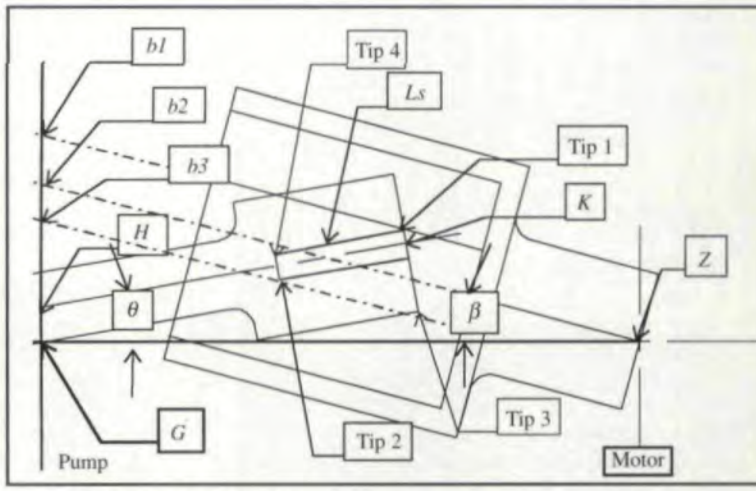

Fig. 6 — Diagram for a direct coupling.

These equations can be rearranged to find the tooth thickness required by the tip 1 and tip 2 criteria. The smaller value for tooth thickness must be chosen (see Fig. 5).

By making the appropriate substitutions, the following expressions are derived for the tooth thickness at tip 1 and tip 2.

$a = 2 \cdot \cos\beta \cdot GH$

$b = 2 \cdot \cos\beta \cdot HK \cdot \sin\theta$

$c = 2 \cdot \cos\beta \cdot \tan\lambda \cdot HK \cdot \cos\theta$

$d = 2 \cdot \cos\beta \cdot GZ \cdot \tan\lambda$

$e = -\cos\beta \cdot \cos\theta - \cos\beta \cdot \tan\lambda \cdot \sin\theta$

$f = 2 \cdot \cos\beta \cdot \sin\theta \cdot Ls$

$g = 2 \cdot \cos\beta \cdot - \tan\lambda \cdot \cos\theta \cdot Ls$

$$t1 = \frac{-(s - b + c - d - a)}{e}$$

$$t2 = \frac{-(s + d + a + b - f - c + g)}{e}$$

The fixed angular displacement of the geometry forces consideration of both *t*1 and *t*2 as independent solutions. The spline tooth thickness that will fit within space width *s* is the smaller of these two values. A second set of equations must be derived in the same manner for contact at tip 3 and tip 4. All permutations of $\pm\beta$ and $\pm\theta$ must be tried to evaluate the smallest tooth thickness.

The final result should be multiplied by the cosine of the pressure angle as shown in Fig. 3 to obtain the required tooth thickness. ○

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Richard T. Friedman

is a principal engineer with Nichols Aircraft Division of Parker Hannifin Corporation, Waltham, MA.

The Industry Now—Who, What & When


Kevin Duffy

New Faces . . . **Daniel B. Hill** has been appointed to the position of district manager of **Falk Corporation**'s Boston, MA, district sales office. . . . **MikroPrecision Instruments** has announced that **Kevin Duffy** has joined the company as its metrology product manager. **David J. Burns** has been named executive vice president of the **Gleason Corporation**, with responsibility for all marketing and manufacturing operations. **Charlie Fischer** has been named as assistant manager of **AGMA**'s Technical Division. . .**Cathy Johnson** is AGMA's new manager of finance, replacing **John R. (Bob) Schultheis**, who has retired.

Corporate Doin's . . . **Gleason Corporation** was one of 16 members of **AMT—The Association For Manufacturing Technology** that participated in a series of technical presentations to overflow audiences of engineers and managers from China's automotive, auto parts and motorcycle industries. The sessions, held last June in Changchun, Shanghai and Chongqing, drew 1,328 people, more than twice as many as were expected, and many more had to be turned away for lack of space . . . **United States Filter Corporation** has acquired **Interlake Water Systems**, a company with 160 employees and 1994 revenues exceeding $21 million. Interlake provides a broad range of water treatment products and services. U. S. Filter is the world's largest manufacturer of water and wastewater treatment systems, specializing in water management and resource recovery services for industrial commercial and municipal customers . . . **ICEM Technologies, Inc.**, a division of **Control Data Systems, Inc.** has announced that it is developing CAD software on the Windows/DOS platform for the first time. The company, best known for its high performance 3-D, UNIX-based CAD/CAM products, plans to introduce the first in a series of PC CAD programs by the end of the year.

In Memoriam . . . The gear industry has lost three important members—**Eugene Shipley**, **William Shippert** and **Bill Daniels**. Shipley, manager of mechanical transmissions for **Mechanical Technology, Inc.**, was a well-known consultant to the industry on gear performance and failure analysis and an active member of AGMA. Shippert was service manager at **Precise Inspection** and served on the Inspection Handbook and Calibration Committees of AGMA. Daniels worked at **AGMA** for many years facilitating standards development and the technical seminars.

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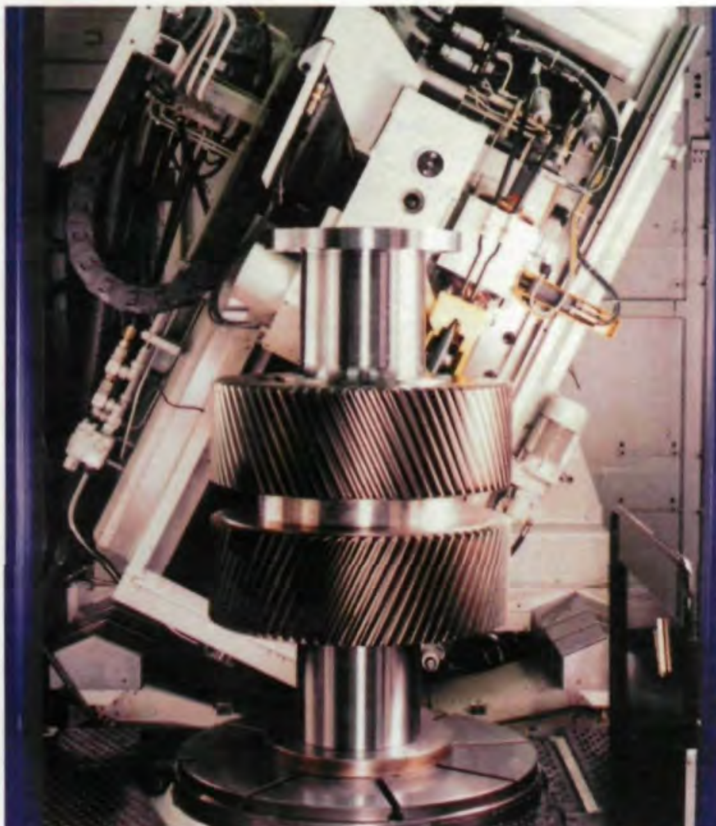

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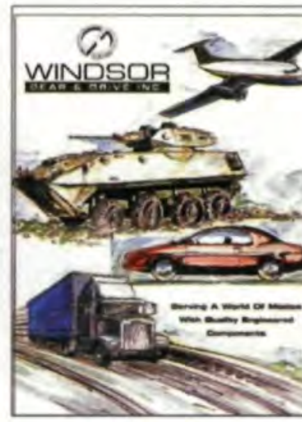

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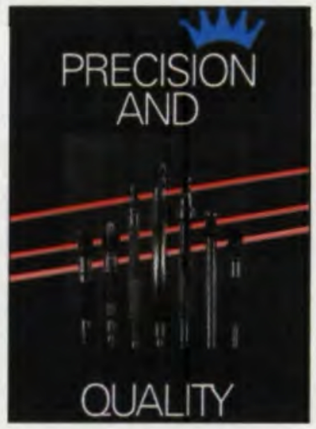

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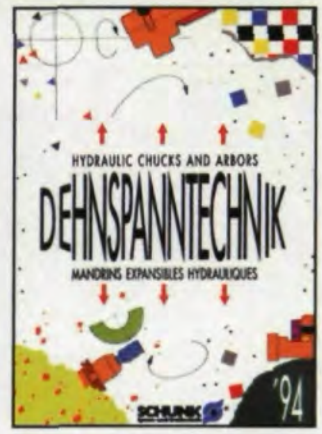

ULTRA Precision Tooling

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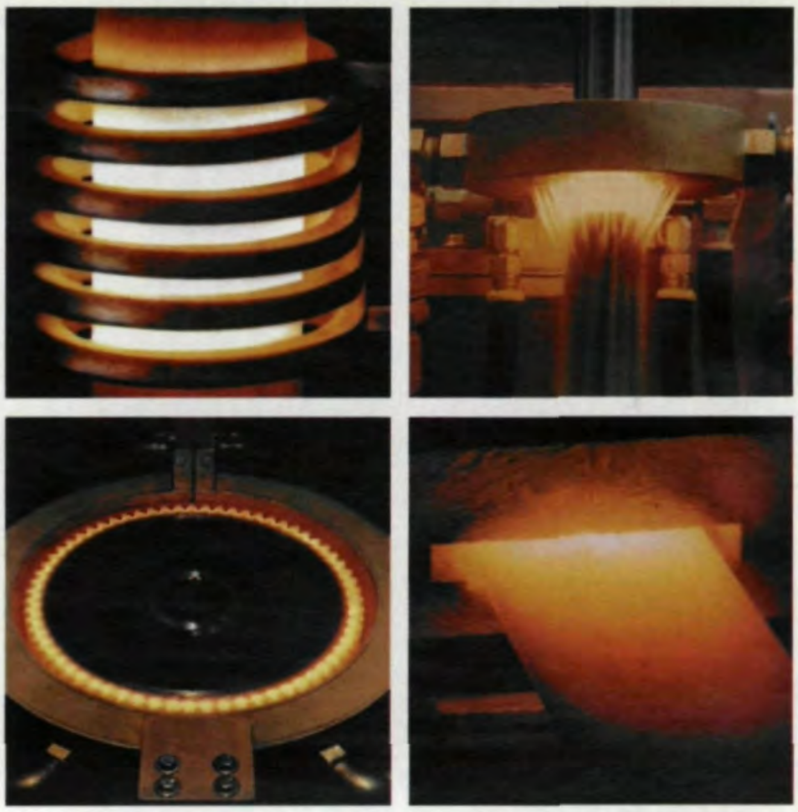
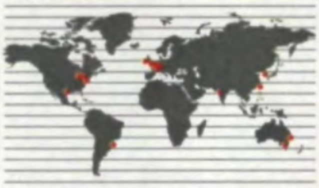




Welcome to our Product News page. Here we feature new products of interest to the gear and gear products markets. To get more information on these items, please circle the Reader Service Number shown.

Carbide Inserts

Madison Cutting Tools, Inc. announces the availability of single-edge, cylindrically ground carbide inserts for Accusize® precision spade drills. The inserts offer high wear resistance in applications requiring close tolerance drilling and uniform surface finishes. They are available uncoated and in a variety of coatings, including TiN and TiCN. They are available in sizes from 1/2" to 1 3/8" and fit the same holders as Madison's Duodex indexable HSS spade drills.

Circle Reader Service No. A-85

Stand-Alone Digital Servo Drives

Emerson Electronic Motion Controls announces that their MX Series of brushless digital servo amplifiers is available with a 50-year limited warranty. The amplifiers accept direct-line power input of 380 VAC to 460 VAC, 3 phase, eliminating the need for an isolation transformer. Available in five models, providing continuous rated current output of 2.8 to 16 amps. They have pulse width modulated design and sinusoidal commutation, ±10 volt analog velocity, and four I/O controllable, user-definable speeds with ramping.

Circle Reader Service No. A-86

Small Shop Coolant Equipment

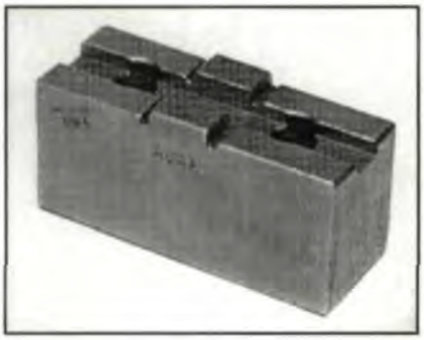
Master Chemical Corporation offers three new pieces of equipment designed for the smaller metalworking shop. The Xybex 300 coolant recycling system has twin 125 gallon coolant holding tanks and an automatic coolant proportioning system and is capable of processing up to 120 gallons of coolant per hour. The Bantam™ Air-65 Yellow Bellied Sump Sucker is a 65-gallon sump cleaner powered by an air-venturi vacuum generator. The ESP™ Ultrafiltration series is a single-step oil/water filtration system that produces clean water from emulsified and non-emulsified oil wastes. Capable of processing up to 50 gallons per day of aqueous and non-aqueous oily waste streams including machining coolants, alkaline cleaners and rinse water from metal parts cleaning.

Circle Reader Service No A-87

Rockwell Hardness Tester

Instron introduces the Wilson 600 Series hardness testers, which incorporate a high stiffness frame and advanced microprocessor design. The series is designed for versatility and ease of use in laboratory and factory floor applications. Four models are available with a throat depth of 6 1/4" and vertical capacities from 7–19". The 600 Series testers meet ASTM E-18 requirements, and models are available for testing on regular Rockwell and/or superficial Rock-well scales. The series comes with a full range of accessories.

Circle Reader Service No. A-88



Chuck Jaws

Ajax Industries offers chuck jaws for Kitagawa, Howa, Matsumoto, Cushman, Buck, Bison and SMW lathe chucks. They are available in serrated, thong & groove and Acme and square master key styles for both metric and English standard style chucks.

Circle Reader Service No. A-89

Compact Rail Rollers

Pacific Bearing Company has announced that the Rollon compact rail linear guideway system's rollers are now available for individual sale. Customers can now buy the rollers individually to create their own linear systems and sliders. The rollers are available in eccentric (adjustable) and centric (centered) styles with either zinc-plated steel or rubber shields. They are life-lubricated and available in four different sizes. They are useful in a variety of applications including machine tool guards, safety panels, sliding doors and drawers and linear table movements.

Circle Reader Service No. A-90

3-D Laser Digitizer

Kreon Industrie (France) offers a contactless 3-D laser digitization system, which scans the surfaces of objects to enter their 3-D geometries into CAD systems for reverse engineering and part replication. Application areas include design of parts, molding and tooling for automotive, aerospace, appliance, business machines and industrial equipment. The system is compatible with all CAD software.

Circle Reader Service No. A-91

NASA Software

NASA's Software Technology Transfer Center offers CARRAC, a tool for combined analysis of reliability, redundancy and cost. CARRAC assists the user in choosing an optimal subsystem that will minimize cost. The program uses associated reliability and cost parameters to calculate and compare a total expected cost for each subsystem. The method of calculation can be selected from five different models, allowing application to a wide variety of cases. Written in Microsoft Quick-Basic for IBM PC-compatible computers.

Circle Reader Service No. A-92

Composite Gear Material

Intech Corp. offers composite gears made of the company's Power-Core™ material. Gears made of Power-Core are constructed with a metal hub that delivers a secure torque transmission and provides positive locking to the shaft. The plastic body imparts vibration dampening and self-lubricating characteristics to give quiet, maintenance-free performance. Available in sizes from 1 to 36" and in ring gears up to 96".

Circle Reader Service No. A-93

3-D Imaging of Gear Tooth Surfaces

Oxford Instruments offers the FACET™ Surface Characterization System, which combines techniques from scanning electron microscopy and X-ray microanalysis to produce 3-D images of engineering surfaces, including gear teeth. It can also generate topographical measurement and precise data on the distribution of the chemical elements in the surface.

Circle Reader Service No. A-94

ISO/QS-9000 Software

Engineered Work Systems, Inc. offers TILLIE™, Windows™-based software for preparing documentation for ISO 9000 or QS-9000 certification. The program purports to make correlation of job descriptions with employee training and proficiency levels easy. It also organizes this information into a relational database and automatically produces required documentation.

Circle Reader Service No. A-95

Multi-Module Aqueous Cleaning Transfer System

SurfTran Cleaning Systems has developed and built an automatic four module in-line transfer cleaning system for tier one suppliers. Each in-line module is separately controlled to precision clean different types and sizes of parts with different cleaning solutions. It is a CNC-programmable, closed-loop system that can process approximately 20 gallons per hour. The modules are individually programmable and contain functions such as rotation, oscillation, turbojet wash and rinsing, patented push-pull ultrasonic devices, hot air drying and patented vacuum shock drying for maximum cleaning.

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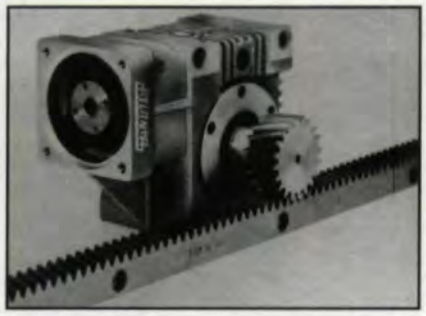

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Andantex USA offers the new ATLANTA servo-worm reducers for a high level of precision and position accuracy in servo applications. The drives encompass newly designed worm and wheel tooth profiles, optimized to achieve angular backlash levels of less than three arc-minutes. Adjustable backlash, precision angular contact bearings to eliminate axial play. High radial and axial loads. Available in four sizes, up to 100 mm center distance. Reduction ratios from 4.75 to 50:1. Input speeds to 5,000 rpm. Output accessories are available.

Circle Reader Service No. A-97

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The Sines of the Fathers

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

Your Addendum team has come across a number of Good Ole Boys in its time; now we bring you something of even more interest—a Good Ole Gear Book. Mr. Robert Price, of Automation • Gears • Machinery, a gear consulting firm in Delanson, NY, shared with us a real find.

A collector of rare books when he's not out solving other people's gear problems, Bob Price showed us his 1806 copy of *A Treatise on the Teeth of Wheels, Pinions, &c*, by Charles Étienne Louis Camus. The book, in remarkably good condition (we should all look so good at 189), is a translation from the French of Books X and XI of Camus' *Cours de Mathématique*, first published in Paris in 1766. It also includes extracts from another important contemporary book, *Imison's Elements of Science and Art*, Vol. 1.

The significance of the book is seen more clearly in its historical context. By 1806 the industrial revolution was beginning to make itself felt in England. Watt had perfected his steam engine and others were developing variations on the theme with nearly the speed of a software revision. New uses for gears (and the need to build them more and more accurately) were growing exponentially. Books like the *Treatise* were invaluable for those early engineers riding the first wave of industrial development.

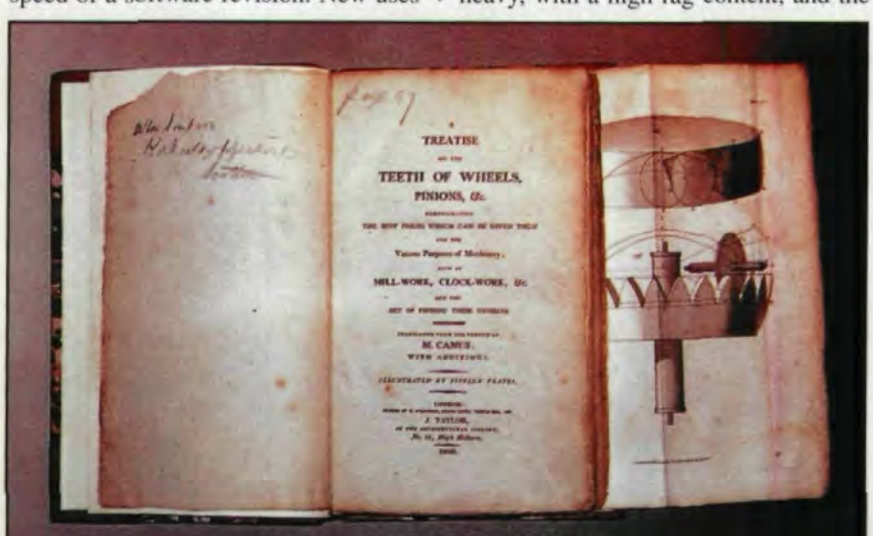
Boy Genius

Camus was one of the Boy Wonders of the 18th century Enlightenment. Born in France in 1699, he was addressing the French Academy on mathematical subjects by the time he was twelve. More than an intellectual oddity, he also had a sense of adventure. In 1736, he was part of an expedition to Lapland co-led by Anders Celsius (yes, *that* Celsius), to measure accurately a degree of latitude.

Camus became a professor of mathematics and engineering at the University of Paris. He was appointed the Royal Architect in 1739 and a Fellow of the Royal Society in 1764. He died in Paris in 1768, but his research into cogs, cogged wheels and pinions remained important for the engineering pioneers of the early 19th century.

Pages of History

The book itself is fascinating and has a certain air of mystery. The paper is heavy, with a high rag content, and the type was hand-set. Bob Price speculates that the book was originally bound in leather, but was rebound, probably sometime in the mid- to late 1800s. The current binding is heavy board covered with marbled paper and trimmed in brown leather with gold lettering on the spine. All the wood-block-print diagrams are bound at the back of the book in an interesting three-part accordion fold with a very wide left margin that allows them to be pulled out and viewed side-by-side with the appropriate text.

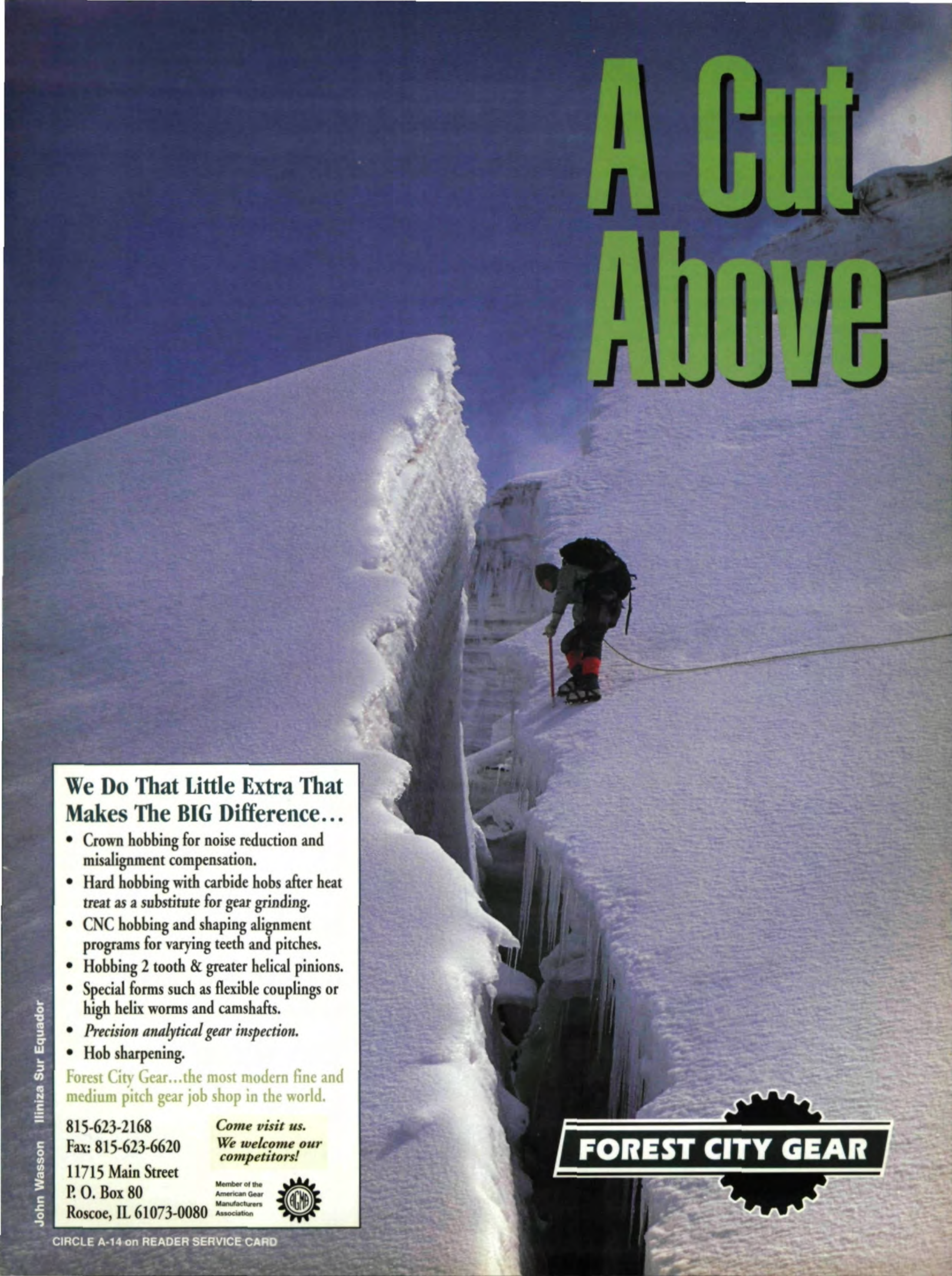


One of the book's previous owners has left his personal mark. On the front flyleaf, Alan Simpson of Kirkcudbrightshire, Scotland, has signed the book. Based on the note he made on the title page, we can assume he found something of interest on page 97, which covers ". . . the Number of the Teeth which the Wheels of a Machine ought to have, that two or more of them may perform in the same Time a given Number of Revolutions."

On the back flyleaf is another intriguing note in the same handwriting: "Presented to Allan Simpson for his kindness to one Janet Sinklar, teacher of Edinburgh." Who was Janet Sinklar, and what kindness did Simpson perform?

Another mystery is how the book got from Alan Simpson's library in Scotland to a used book dealer in Rhode Island, from whom Bob Price purchased it. Any number of possibilities occur.

The Addendum staff has already turned their imaginations to the development of possible plots for a movie or a glitzy t.v. mini-series (with Mel Gibson as Simpson and Jane Seymour as Janet Sinklar). Contributions to this venture, (creative or financial—especially financial) will be appreciated. We'll thank you in our Oscar acceptance speech. Honest.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